NSW Carbon Values

Final report

26 April 2024

NSW Government

Deloitte.

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Please note this report is prepared solely for the internal use of the NSW Government.

This report is not intended to and should not be used or relied upon by anyone else and we accept no-duty of care to any other person or entity. The report has been prepared for the purpose set out in the engagement letter dated 23 May 2023. You should not refer to or use our name or the advice for any other purpose.

Key definitions

Term	Definition
NSW Carbon Values	NSW Carbon Values refer to annual values ($/tCO2-e) that are required to incentivise the deployment of the modelled decarbonisation technologies to achieve the NSW's currently legislated FY30, FY35 and FY50 decarbonisation targets. Three sets of NSW Carbon Values (High, Central, Low) have been considered against differing volumes of abatement, speed of deployment and cost-effectiveness of decarbonisation solutions.
Marginal abatement cost or MAC	Marginal abatement cost (MAC) refers to the cost associated with reducing one additional unit of carbon emissions ($/tCO2-e).
Decarbonisation solution or solution	Technologies or non-technological solutions that will achieve reduction of carbon emissions. For example, light-duty battery electric vehicle or carbon forestry/soil carbon management.
Deployment constraint	Deployment constraint is the annual upper limit of deployment feasible for each solution, noting that it could change overtime. For example, deployment of light-duty BEV is constrained by charging infrastructure roll-out; however, the annual deployment upper limit will increase as early adopters move into early majority etc. Deployment constraint could materialise in the form of supply chain, workforce, investment or time constraints.
Accelerated deployment scenario	This scenario is based on future government decarbonisation policies and industry decarbonisation programs (i.e., introduced from now until FY50) that will incentivise NSW citizens and businesses to transition early, i.e., before end of asset life, for select commercially available and cost-effective solutions. This is the target-aligned scenario and used to inform the NSW Carbon Values. In other words, this assumed scenario achieves NSW's currently legislated FY30, FY35 and FY50 decarbonisation targets.
Natural deployment scenario	This scenario is based on future government decarbonisation policies and industry decarbonisation programs (i.e., introduced from now until FY50) that will incentivise NSW citizens and businesses to transition gradually to all solutions, i.e., waiting till end of asset life. This scenario falls short of NSW's currently legislated FY30 decarbonisation targets and is only used as a comparison to the accelerated deployment scenario.

Executive summary (1/2)

Background and project scope

Under the Climate Change (Net Zero Future) Act 2023, the NSW Government has set objectives to achieve net zero emissions by 2050 and make NSW more resilient to a changing climate. This includes interim Scope 1 emission targets including 50% reduction by 2030, 70% reduction by 2035 (compared to NSW's 2005 emissions) and Net Zero by 2050.

The NSW Government is seeking to develop a set of robust and consistent carbon values applicable in the NSW context that can be used to assess the costs or benefits of projects or policies that impact carbon emissions.

The Department of Climate Change, Energy, the Environment and Water (DCCEEW) engaged Deloitte to undertake this project, building upon previous decarbonisation reports and informed by frequent consultation and collaboration with select decarbonisation experts within NSW Government, including the NSW Net Zero Modelling team.

Approach and output

We undertook a three-phase approach:

1. Shortlisted the decarbonisation solutions that could have the highest impact on reducing NSW's Scope 1 emissions, working collaboratively with the DCCEEW project team and decarbonisation experts across NSW Government
2. For each shortlisted decarbonisation solution, we developed each solution's marginal abatement cost (MAC) and maximum allowable deployment trajectories, based on scientific, industry reports and targeted engagement with select decarbonisation experts. To inform the MAC and deployment trajectories. We:

Reviewed and referenced scientific or industry articles/reports	140+	Ran workshops or sessions with 22 decarbonisation experts	20+

3. Developed the NSW Carbon Values based on decarbonisation solutions' relative MAC, deployment trajectories and the State's emission reduction targets, applying a common sense overlay.

Using this approach, we developed three sets of NSW Carbon Values from FY25 to FY50, in real, AUD, FY24 dollars. This report outlines the methodology, application and interpretation of the NSW Carbon Values.

Additional Deliverables

In addition to this report, Deloitte has also developed a corresponding MAC Tool including the Source Files and Tool Guidance (in video format).

- The Source Files summarise the description, inputs, assumptions and references (i.e., scientific reports) that underpin the MAC and assumed deployment trajectory for each decarbonisation solution. The assumed deployment trajectory considers the maximum allowable deployment for each year.
- The MAC Tool – utilising more than 45 tabs, 15,000 data points and 150,000 formulas across Source Files – calculates the MAC based on 5% discount rate in alignment with NSW Business Case guidelines. The user guide is also embedded in the Tool.
- In addition to the embedded user guide, the Tool Guidance video is intended to support future updates to the Source Files and the MAC Tool.

These assets will enable the DCCEEW to independently update the Tool going forward, ensuring the NSW Carbon Values continue to account for NSW's evolving decarbonisation context.

Carbon Value Considerations

When applying and updating the NSW Carbon Values (the Carbon Values), DCCEEW should note the following takeaways:

- The MAC output from the Tool is highly sensitive to assumed baseline emission projections, the deployment potential of cost-effective solutions (e.g. renewable electricity generation) and interdependency with solutions in other years. Hence the MAC outputs could change materially with future updates.
- Translation of the MAC output to Carbon Values is required given direct outputs are inherently uneven.

Executive summary (2/2)

When applying the NSW Carbon Values (the Carbon Values), the broader public should note the following caveats:

- The NSW Carbon Values (FY24 version) reflect the latest publicly available scientific research and market information as of September 2023. As such, the NSW Carbon Values should be updated regularly as living numbers and incorporate best-available information at time of publication.
- Given the methodology, these NSW Carbon Values will assist with the impact assessment of projects in NSW. This methodology examines the cost of meeting NSW's emission reduction targets in the current NSW economy and climate context. This differs from alternate carbon value methodologies that quantify the damage caused by emissions.

Structure of the report

This report has six sections. The body of the report – the first two sections – are intended to guide NSW Government users to apply the NSW Carbon Values in business cases, while the appendices – the latter four sections – outline the methodology FAQs and approach used to develop the NSW Carbon Value.

Body of the report:

1. Methodology: outlines the high-level methodology used to develop the NSW Carbon Values.
2. Interpretation and application of NSW Carbon Values: includes the three sets of NSW Carbon Values FY25 to FY50 at low, central and high, and conditions that need to be considered when applying these carbon values.

Appendices:

3. Appendix 1: NSW Carbon Value Methodology FAQs: includes answers to common (22) methodological questions. These FAQs were discussed and co-developed with the DCCEEW project team and decarbonisation experts.
4. Appendix 2: Shortlisted decarbonisation solutions' marginal abatement cost and deployment: includes the description, overview of the marginal abatement cost calculation approach, summary of the FY24 MAC outputs, and overview of the assumed deployment approach for the shortlisted decarbonisation solutions that informed the NSW Carbon Values.
5. Appendix 3: Approach to selecting decarbonisation solutions: outlines the rigorous approach used to prioritise a longlist of more than 230 decarbonisation solutions to a prioritised longlist of 82 decarbonisation solutions, and finally to a shortlist of 25 decarbonisation solutions across 14 high-emitting NSW subsectors.
6. Appendix 4: Decarbonisation solution longlist and shortlist: includes all decarbonisation solutions in the longlist and shortlist, including the assessment scoring and rationale for inclusion or exclusion based on the approach outlined in the previous appendix.

Methodology and interpretation and application of NSW Carbon Values

Methodology for NSW Carbon Values (1/2)

The Carbon Values for NSW are determined by calculating the marginal abatement cost (MAC) across the set of decarbonisation solutions which will most materially reduce emissions within the State (shortlisted solutions), and then identifying the MAC of the 'last solution' to abate emissions within a given year.

This methodology builds on the traditional marginal abatement cost curve (MACC) by incorporating a time dimension. While a traditional MACC implies that the state could realise all emission benefits of more cost-efficient solutions before moving on to the next most expensive solution, the methodology for NSW Carbon Value considers the time required to achieve full deployment by considering deployment constraints for any given year. See Appendix 1: NSW Carbon Value Methodology FAQs for more detail on the methodology.

Using FY30 as a sample year

1 Calculate MAC for each decarbonisation solution

Calculate the **net present value** for each solution (in FY30)

Calculate the **lifetime emissions reduced** for each solution (starting from FY30 to end of useful life)

Divide to determine **the marginal cost of abatement** for each solution (in FY30)

2 Select solutions available and required to be deployed in FY30

Calculate **the emissions abatement gap** by subtracting the whole-of-economy target emissions from the baseline emissions (in FY30)

Select the solutions available to be deployed in FY30. Deploy solutions by:

- Starting with the solution with the lowest MAC value
- Deploy this solution until maximum additional deployment in NSW (in FY30) is met. In other words, up to the FY30 deployment constraint
- Move on to next lowest MAC solution until the whole of economy abatement gap is met

Availability is based on 1) commercial-availability and 2) deployment potential. In other words, solutions that are not commercially available or are already fully deployed are considered not available.

3 Determine FY30 maximum MAC

Determine the FY30 last solution's MAC (i.e., the maximum*)

*Selecting the maximum, rather than the weighted average reflects the cost to abate the last tonne of emissions. Using the weighted average would result in the State's target being unmet.

The maximum MACs are translated into Carbon Values, so the final set of numbers are simple and intuitive in their application.

See Appendix 1 for more details.

This applicable for all years up to FY50

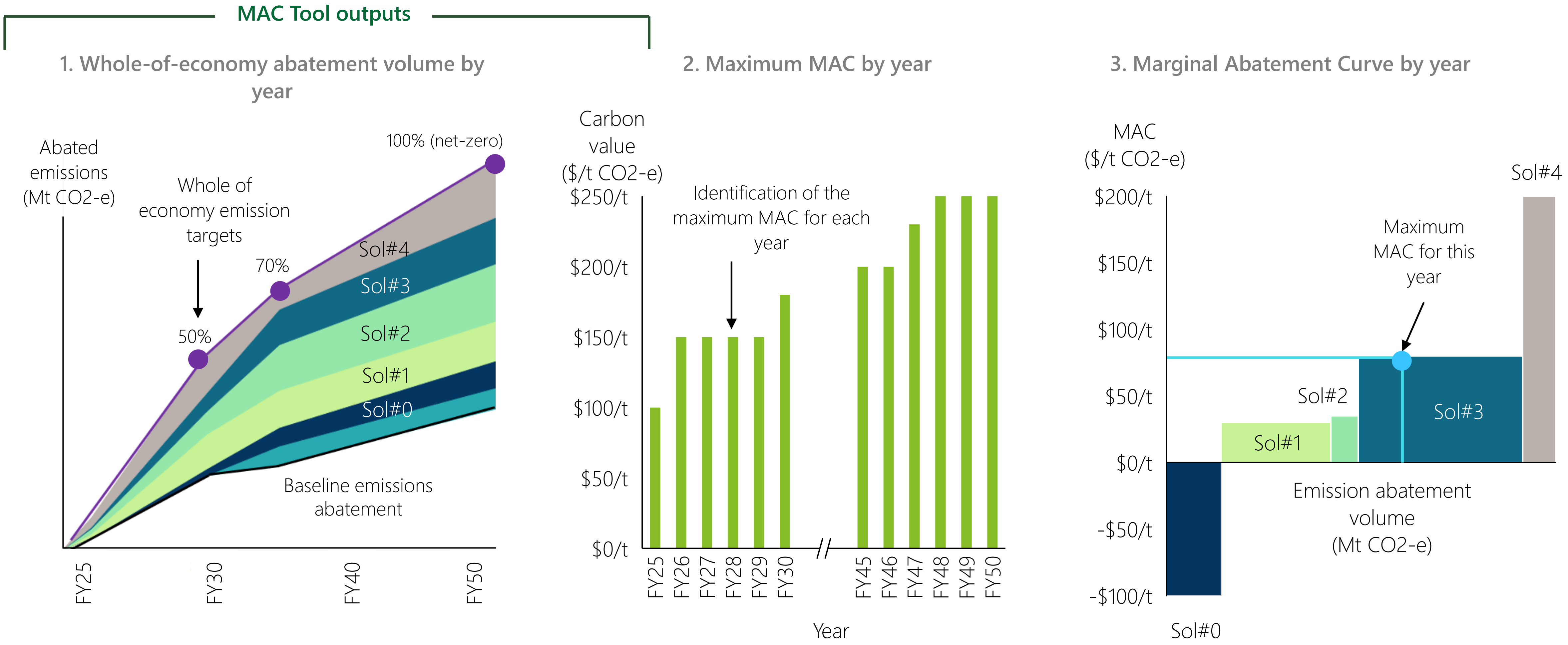
Repeat this approach to determine NSW's Carbon Value for each financial year, adjusting for each shortlisted solution's:

- **Maximum additional deployment**, above assumed deployment under baseline emissions[1] and consistent with deployment constraints
- **MAC,** adjusted for learning rates and electricity grid emission intensity – where relevant

Note: 1. The baseline emissions are aligned to the "Base Case" greenhouse gas emission projections for NSW by year and by Intergovernmental Panel on Climate Change (IPCC) sector out to 2050. "Base Case" considers the impact of proposed government policies/ industry strategies. For more detail, see https://datasets.seed.nsw.gov.au/dataset/nsw-projected-greenhouse-gas-emissions-from-2021-to-2050.

Methodology for NSW Carbon Values (2/2)

This methodology translates into three key outputs in the MAC Tool: 1. Whole-of-economy emission abatement by financial year from the deployment of shortlisted decarbonisation solutions, 2. The maximum MAC by financial year, and 3. The Marginal Abatement Curve by year.



Interpretation and application of NSW Carbon Values (1/2)

Three sets of Carbon Values FY25 to FY50 are developed in alignment with NSW Government Guide to CBA (TPG23-08) with a 5% central discount rate.

The interpretation, application and numeric values of the three sets of NSW Carbon Values are as outlined below.

Scenario	Interpretation of Carbon Values
High Carbon Values	Reflects lower volume of abatement, speed of deployment or cost-effectiveness of decarbonisation solutions, for example, due to supply chain/ workforce/ approval constraints.
Central Carbon Values	Fulfills NSW emission reduction targets with orderly deployment of decarbonisation solutions. Central carbon values are the best translation of the optimised marginal abatement costs of NSW's decarbonisation solutions.
Low Carbon Values	Reflects higher volume of abatement, speed of deployment or cost-effectiveness of decarbonisation solutions, for example, due to the state shifting away from high-emission industries.

The NSW Carbon Values outlined below are presented in AUD, real, FY24 currency and visualised on the next page. These values will need to be inflated accordingly before being applied in NSW business cases. These values reflect the latest publicly available scientific research and market information as of September 2023. As such, the NSW Carbon Values should be updated regularly as living numbers and incorporate best-available information at time of publication.

NSW Carbon Values (AUD per tonne CO2-e)
FY24 version

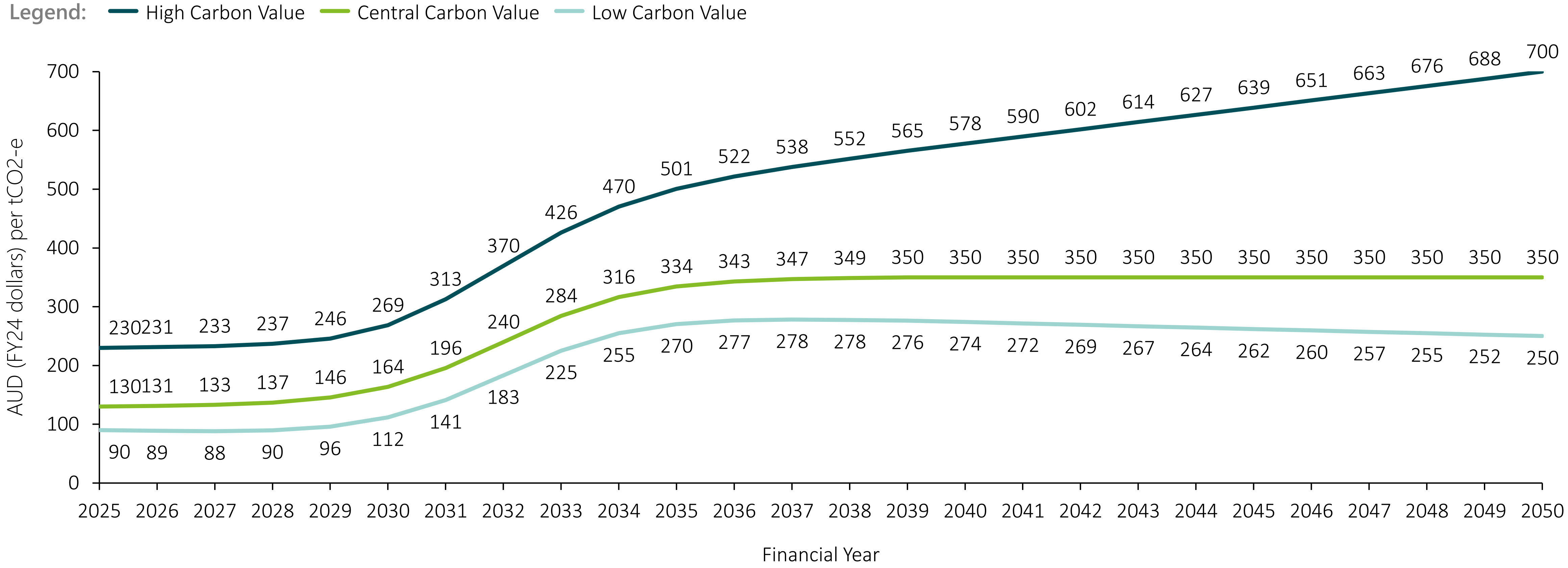
Scenario	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38	FY39	FY40	FY41	FY42	FY43	FY44	FY45	FY46	FY47	FY48	FY49	FY50
High Carbon Values	230	231	233	237	246	269	313	370	426	470	501	522	538	552	565	578	590	602	614	627	639	651	663	676	688	700
Central Carbon Values	130	131	133	137	146	164	196	240	284	316	334	343	347	349	350	350	350	350	350	350	350	350	350	350	350	350
Low Carbon Values	90	89	88	90	96	112	141	183	225	255	270	277	278	278	276	274	272	269	267	264	262	260	257	255	252	250

Interpretation and application of NSW Carbon Values (2/2)

Three sets of Carbon Values FY25 to FY50 are developed in alignment with NSW Government Guide to CBA (TPG23-08) with a 5% central discount rate.

The three sets of Carbon Values reflect greater certainty in the decarbonisation solutions available to and required by NSW in the near term and greater uncertainty into the future.

Low, Central, High Carbon Values (FY25 to FY50)



Appendix 1: NSW Carbon Value Methodology FAQs

Frequently asked questions, answers and key insights

NSW Carbon Value Methodology FAQs

This Appendix includes answers to common (22) methodological questions. These FAQs were discussed and co-developed with the DCCEEW project team and decarbonisation experts.

Category of question	Methodological question
Boundaries	1. What are the NSW Carbon Value analysis boundaries?
Shortlisted solutions	2. What are the shortlisted NSW decarbonisation solutions and how do they map against the key sectors? 3. How are whole-of economy decarbonisation solutions considered? 4. Has the Carbon Values analysis considered emerging decarbonisation solutions?
Scope of emissions	5. What is NSW's emission reduction trajectory under baseline (i.e., "Base Case" greenhouse gas emission projections)? What are the remaining emissions the shortlisted decarbonisation solutions would help abate? 6. Given the NSW Business Case Guideline also outlines requirements for embodied carbon, how is embodied carbon considered in the Carbon Values? 7. How has consideration of embodied carbon impact the shortlisting of decarbonisation solutions? 8. Why would the maximum MAC be used to inform the Carbon Values instead of the weighted average MAC? 9. Should the Carbon Values consider the emissions abated under baseline? 10. How are decarbonisation solutions filtered in or out as part of the MAC curve?
Inputs, assumptions and outputs	11. What is the difference between the sensitivities (i.e., "natural" deployment and "accelerated" deployment of shortlisted decarbonisation solutions)? Which sensitivity is used to inform the Carbon Values? 12. How is the pace of decarbonisation (i.e., deployment trajectory or deployment constraint of decarbonisation solutions) determined? 13. Which decarbonisation solutions are assumed to be accelerated? 14. When are these solutions accelerated? 15. How is the impact of acceleration incorporated in the Carbon Value calculation? 16. How does the maximum MACs translate to Carbon Values? 17. How are deployment sensitivities considered? 18. What is the role of DACCS in the Carbon Values? 19. What are the scientific and industry reports and articles used in the calculation of the Carbon Values? Who provided input to the Carbon Values? 20. How have the Carbon Values considered the cost of replacement? 21. How have the Carbon Values considered the interdependencies of different solutions?
Comparison	22. How do the NSW Carbon Values compare with other carbon values from climate models or used by other governments or institutions?

NSW Carbon Value analysis boundaries

1. What are the Carbon Value analysis boundaries?

Analysis boundary	Rationale
The "baseline" emissions abatement will be aligned to the "Base Case" of NSW emission projects (FY22 version, which uses the 2021 Greenhouse Gas Inventory data) as provided by the NSW Net Zero Modelling Team for this project. The FY22 baseline emission projection was originally provided on 16 June 2024; however, the FY24 to FY50 emission projections for electricity generation was updated separately based direction from and information provided by NSW Government (on 29 February 2024 and 22 March 2024).	Based on discussion with the NSW Net Zero Modelling Team, the "Current Policy" includes prospective initiatives that are yet to be confirmed.
The emission abatement targets will be based on whole-of-economy targets. Sector specific targets will not be incorporated.	Since NSW's legislated targets are all-GHG, whole-of-economy targets.
Only Scope 1 emissions are included.	Aligns with the approach taken for the "Base Case" by the NSW Net Zero Modelling Team.
General methodological boundaries: 1. Reporting jurisdiction is NSW, 2. Reporting years are financial years, 3. Time-period of 26 years (FY25 to FY50), 4. All dollar estimates are presented in real FY24 Australian dollars, 5. Baseline and target emissions are sourced from the Net Zero Modelling team, 6. Timing of cashflows are assumed to be at the end of the financial year, 7. Abatement potential considers the change in projected user base by aligning with baseline emissions trajectory.	Broadly aligns with the NSW Net Zero Modelling team and the NSW CBA approach.
UNFCCC sector classifications will be leveraged to delineate between sectors, rather than those of ANZSIC.	Aligns with the NSW Net Zero Modelling team's sector classification.
A global learning rate, or an Australia-specific learning rate where applicable, will be applied to account for changes in solution's incurred CAPEX over time.	Appropriately considers solution innovation/ impact of economies of scale over time.
The remaining life of existing solutions (e.g., internal combustion engine vehicles) will be considered by netting the CAPEX and/ or OPEX. However, the cost of stranded supporting infrastructure (e.g., gas infrastructure or diesel recharging stations) are not considered.	Appropriately considers the remaining life of existing assets. Simplifying assumption on the cost of stranded assets for this version of the Carbon Values.
Enabling solutions such as transmission upgrades or electrolysers (used to produce green hydrogen) is not considered as separate decarbonisation solutions, but are incorporated in the costings of relevant end-use solutions (e.g., ammonia produced using green hydrogen)	Ensure consistency across decarbonisation solutions and no double counting.
The impacts of climate change on the abatement potential and costs of each solution will not be considered in this analysis (e.g., reducing agricultural production due to increasing temperature/ more extreme weather events), but may have already been incorporated in the NSW emissions modelling.	Simplifying assumption as climate scenarios are frequently updated.

Shortlisted NSW decarbonisation solutions

2. What are the shortlisted NSW decarbonisation solutions and how do they map against the key sectors?
3. How are whole-of economy decarbonisation solutions considered?
4. Has the Carbon Values analysis considered emerging decarbonisation solutions?

Sector	Key subsectors	Shortlisted solutions
Electricity generation	Electricity generation	• Utility solar • Rooftop solar • Wind • Firming
Transport	Light vehicles (cars, LCVs, MCs)	• Light-Duty – Battery EVs
	Heavy-Duty vehicles (trucks, buses, rail)	• Heavy-Duty – Battery EVs • Heavy-Duty – Hydrogen fuel cell • Rail – Hydrogen/bio feedstock/ammonia
Agriculture	Animals	• Dietary manipulation • Herd management
Stationary energy	Energy	• Mining – Vehicle electrification
	Manufacturing	• Industrial electric heating equipment • Cement produced with alternative raw materials
	Residential and other	• Household heat pumps • Household appliance electrification and efficiency • Building efficiency improvements
IPPU	Metals sector	• Aluminium primary smelting – Inert anode • Iron and steel – Direct reduced iron produced using green H2 • CCUS across multiple applications
	Chemicals sector	• Green ammonia produced using green H2
Fugitive emissions	Coal mining	• Drainage – Power generation • Air Methane Oxidation
Waste	Solid waste disposal	• Drainage – Waste power generation
Whole-of-economy		• GHG Removal – DACCS • GHG Removal – Nature-based solutions

For more detail on the longlist of decarbonisation solutions considered and how the longlist was filtered down to the shortlist, refer to Appendix 3: Approach to selecting decarbonisation solutions and Appendix 4: Decarbonisation solution longlist and shortlist.

Consideration of whole-of-economy decarbonisation solutions

Whole-of-economy decarbonisation solutions are considered as a "last resort" after other viable, cost-effective solutions are deployed. We have also applied a cap on nature-based solutions that takes the realities of competing land interests and climate impact on plants'/ soil's sequestration potential into consideration.

Consideration of emerging decarbonisation solutions

Emerging decarbonisation solutions that could have a high impact on NSW's decarbonisation were considered during the shortlisting process, for example:

- Direct Air Capture and Carbon Storage (DACCS) is only expected to commercialise in the 2030s.
- Iron and steel – Direct reduced iron (DRI) produced with green hydrogen is only expected to commercialise in the 2040s.

Several of these solutions have already undergone decades of scientific research and on-the-ground trials. Hence, the likelihood of additional high-impact decarbonisation solutions emerging in the coming decades is relatively low.

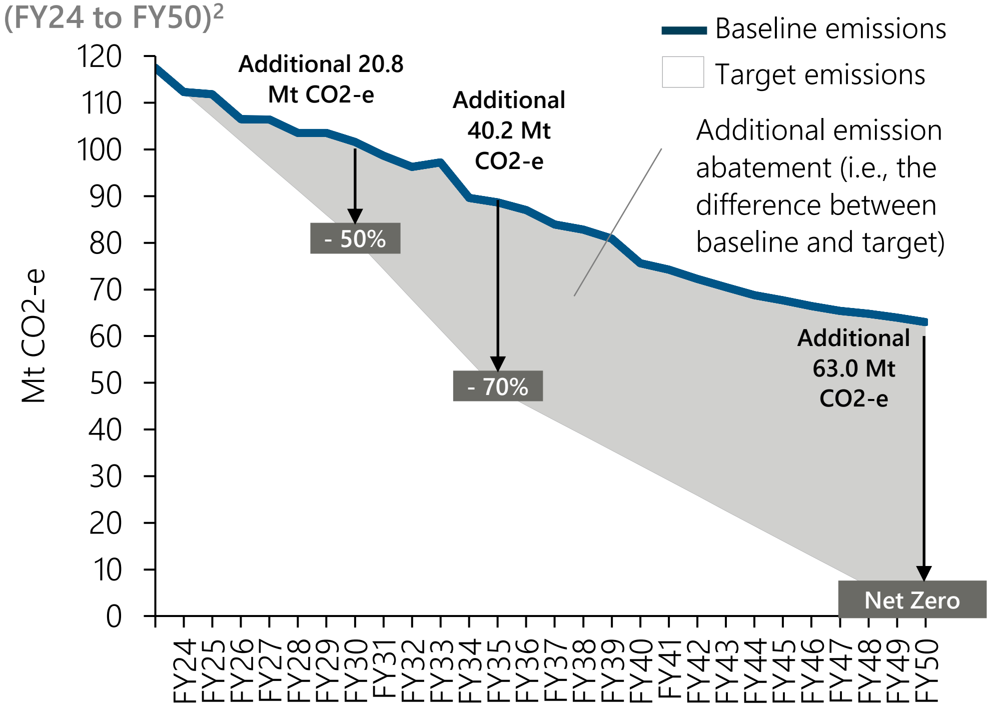
However, there are placeholders for additional solutions in the MAC Tool. Should more decarbonisation solutions that would have a high impact on NSW's decarbonisation emerge in the coming decades, the Carbon Values should be updated to appropriately reflect the evolving decarbonisation landscape.

NSW's baseline and target emissions

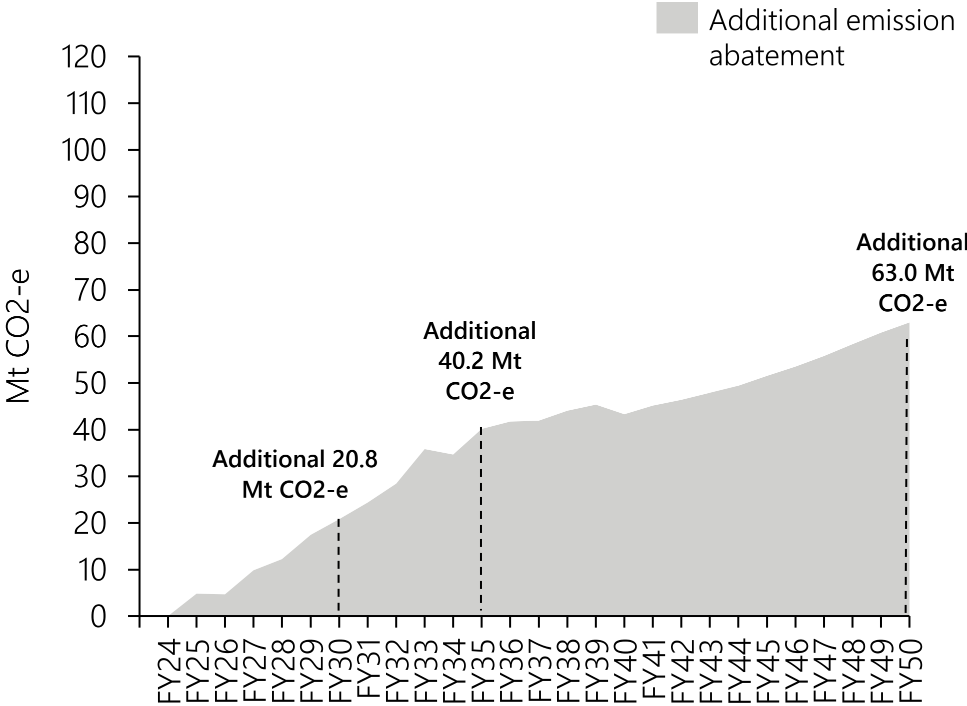
5. What is NSW's emission reduction trajectory under baseline (i.e., "Base Case" greenhouse gas emission projections)? What are the remaining emissions the shortlisted decarbonisation solutions would help abate?

The figures below show a comparison of baseline, target and additional emission abatement required between FY24 to FY50. The additional emissions abatement is driven by interim Scope 1 emission targets including 50% reduction by 2030, 70% reduction by 2035 (compared to NSW's 2005 emissions) and Net Zero by 2050. The assumed decarbonisation solution deployment (as outlined in the following slides) is not forced to meet the "inferred" straight-line emission abatement between the target years (i.e., pre-2030, between 2030 and 2035 or between 2035 and 2050). This means: 1) Decarbonisation solutions' deployment assumptions are driven by the target years (e.g. identification of at-scale, commercially available solutions that can be deployed before 2030), 2) for solutions that require lead-time for deployment, this is also considered prior to the target years; hence 3) there may be "shortfalls" in between the target years.

Comparison of Baseline, Target and Additional emissions (FY24 to FY50)[2]



Additional emission abatement (FY24 to FY50)



Note: 1. Emissions forecast data sourced from the NSW Net Zero Modelling team. Majority of emissions (67%) reduced under Baseline are driven by the Renewable Electricity sector – emissions from this sector are assumed to reduce from 36.5 Mt CO_2-e in 2024 to 0.2 Mt CO_2-e by FY43 and stabilise until FY50.
2. Assumes straight line reduction. All reductions are against NSW's baseline year of 2005 (161.2 Mt CO_2-e).

Consideration of embodied carbon

6. Given the NSW Business Case Guideline also outlines requirements for embodied carbon, how is embodied carbon considered in the Carbon Values?
7. How has consideration of embodied carbon impact the shortlisting of decarbonisation solutions?

Consideration of embodied carbon

Implications of embodied carbon: The transport sector, as a major consumer of cement, steel, bitumen and gravel, has significant embodied carbon. Currently, the majority of materials appear to be sourced locally (see cement[1] and steel[2]). As such, the solutions proposed in the Transport/IPPU/Stationary Energy sectors within the NSW boundaries will help reduce embodied carbon.

Application of NSW Carbon Values to address embodied carbon: the NSW CBA guidelines currently state: "All CBAs are… required to make a technical assumption to include emissions arising from the use of construction materials (known as embodied emissions) regardless of where the materials are produced."[3] Despite not considering embodied carbon in the MAC calculations, the NSW Carbon Values will ultimately address the cost of embodied carbon in future business cases. Per the equations below, materials' comparative emission intensity will be considered and costed, hence influencing decarbonisation of material consumption as part of government decision making.

Embodied carbon (Mt) = estimated emission intensity of materials x volume of materials

Embodied carbon ($ cost) = estimated embodied carbon (Mt) x carbon value

Consideration of embodied carbon impact on shortlisting of decarbonisation solutions

One example of how the exclusion of embodied carbon (i.e., focusing on Scope 1 emissions) impacted the shortlisting of decarbonisation solutions is sustainable aviation fuel (SAF).

SAF has similar tailpipe emissions to traditional jet fuel.[4] Tailpipe emissions are defined as emissions calculated based on emission factors for specific fuel types (per the Net Zero Modelling team's methodology report). Acknowledging that SAF has lower lifecycle emissions – up to 80% reduction,[5] and growing interest from the Federal Government (ARENA SAF grant)[6] and industry (Qantas and Airbus)[7].

Given NSW currently does not produce jet fuel, the production of SAF does not displace lifecycle emissions within NSW boundaries. Hence SAF has been filtered out according to analysis methodology.

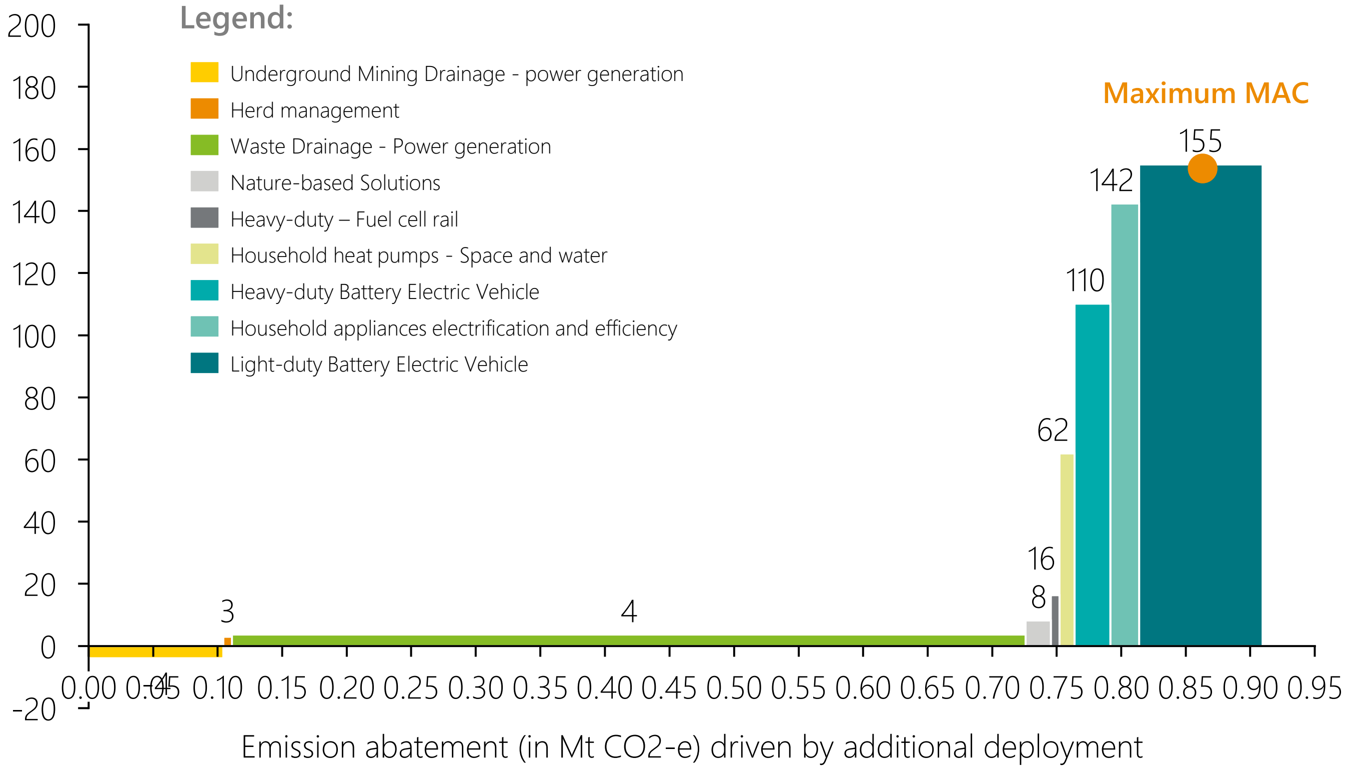
Notes: 1. Australian Clinker and Cement Production, 2024, https://cement.org.au/australias-cement-industry/about-cement/australias-cement-industry/
2. World steel statistical wordbook 2022, https://worldsteel.org/steel-by-topic/statistics/steel-statistical-yearbook/
3. NSW Government Guide to Cost-Benefit Analysis, 2024, https://www.treasury.nsw.gov.au/sites/default/files/2024-04/tpg23-08_nsw-government-guide-to-cost-benefit-analysis_202404.pdf
4. Sustainable Aviation Fuel – An Introduction, n.d., https://www.4air.aero/whitepapers/sustainable-aviation-fuel-an-introduction
5. What is SAF?, n.d., https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/saf-what-is-saf.pdf
6. Sustainable Aviation Fuel Funding Initiative, 2024, https://arena.gov.au/funding/sustainable-aviation-fuel-funding-initiative/
7. Queensland biofuel refinery to turn agricultural by-products into sustainable aviation fuel, 2024, https://www.airbus.com/en/newsroom/news/2024-03-queensland-biofuel-refinery-to-turn-agricultural-by-products-into-sustainable

Maximum MAC is used to inform the Carbon Values

8. Why would the maximum MAC be used to inform the Carbon Values instead of the weighted average MAC?

In FY25, nine out of ten[1] decarbonisation solutions are assumed to be deployed, which could abate 0.91 Mt CO2-e (in total) from the baseline (118 Mt CO2-e). The last solution, light-duty BEV, is the maximum MAC.

Marginal abatement cost curve in FY25
for "accelerated" deployment scenario with 5% discount rate



Notes: 1. Based on assumed deployment trajectory (see page 19 and 20 for more detail).

WORKED EXAMPLE OF CARBON VALUE

The weighted average MAC in FY25 is 24 while the maximum MAC is 155.

If the weighted average MAC (before translating it to Carbon Values) is applied to a Light-duty BEV business case, this results in a negative NPV, which would result in the State not proceeding with Light-duty BEV.

Using the maximum MAC as the Carbon Value input will incentivise timely investment into the decarbonisation solutions necessary for NSW to reach Net Zero. We note that the Carbon Values are different from and should not be used to quantify government subsidy. In this instance, Light-duty BEV would require significantly less subsidy than Heavy-Duty BEV, as a comparatively more costly decarbonisation solution. Please refer to the NSW Government Business Case Guidelines for more details.

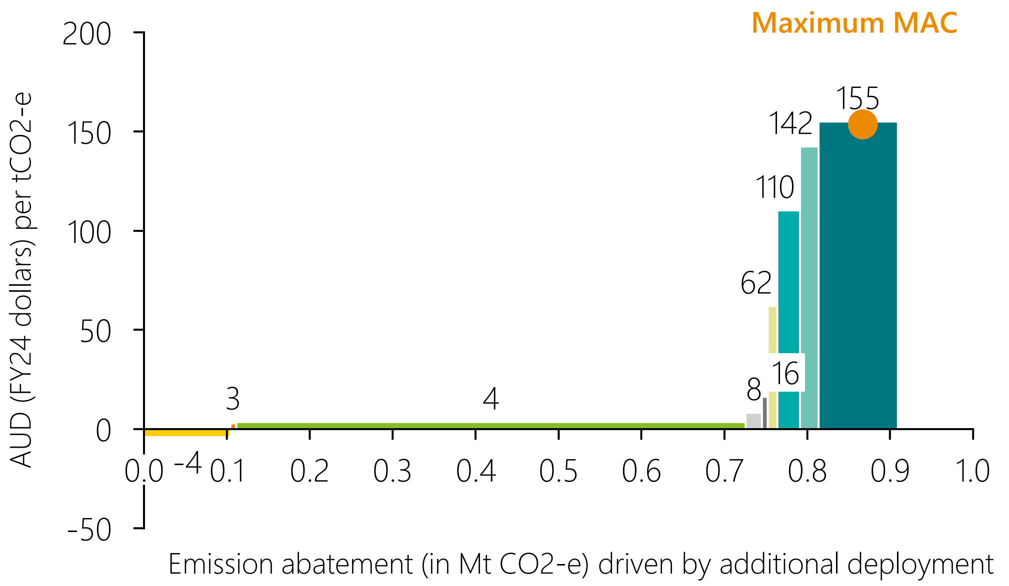
NPV of Light-duty BEV:
Benefit = avoided emissions * carbon value
= avg. 2.7 tonne per yr * 10 yrs * $24 per tonne
= $641
CAPEX = EV price premium + public charger+ private charger
= $17,340
OPEX = avoided maintenance cost + lower energy cost
= - $13,372 (over ten years)
NPV = Benefit - (CAPEX + OPEX) = - $3,327

Inclusion of baseline emissions in the Carbon Values calculations

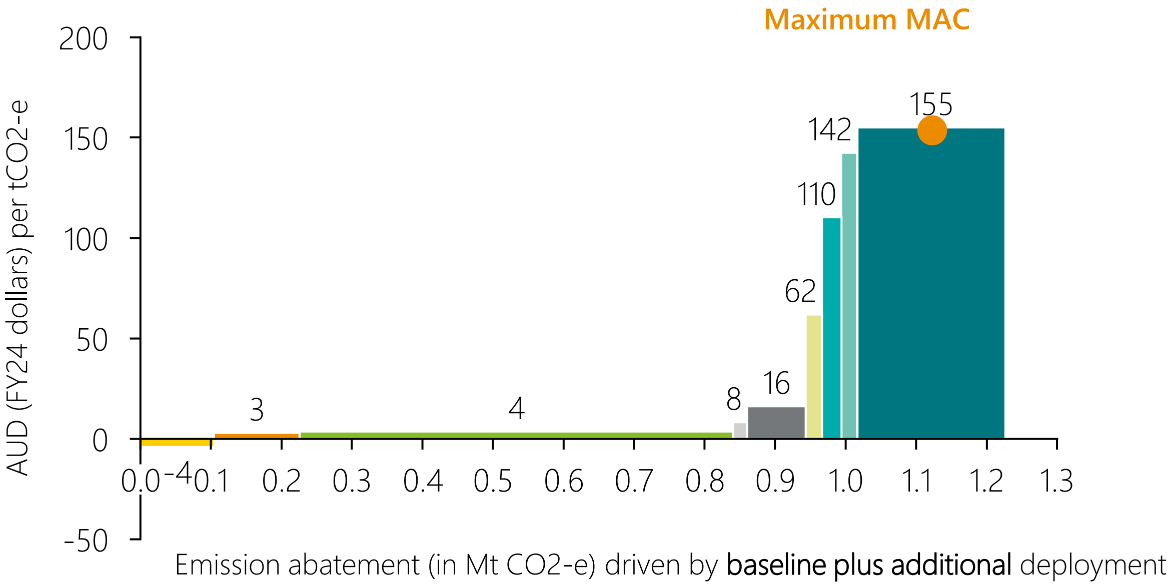
9. Should the Carbon Values consider the emissions abated under baseline?

As illustrated in the two MACCs below, inclusion of emissions abated under baseline deployment (est. 0.3 Mt CO2-e)[1] does not change the marginal abatement cost of the most expensive solution. The MACC that considers baseline emissions (left figure) is assumed to deploy the same set of decarbonisation solutions as the MACC that excludes baseline emissions (right figure). Intuitively, cost-effective decarbonisation solutions are more likely to be already deployed under baseline. See Appendix 2: Shortlisted decarbonisation solutions' marginal abatement cost and deployment for more detail on the inputs and assumptions that underpin the shortlisted decarbonisation solutions' MAC.

Marginal abatement cost curve for "accelerated" deployment in FY25 (as a sample year)



Marginal abatement cost curve for "accelerated" deployment in FY25 (as a sample year)



Legend:
- Underground Mining Drainage - power generation
- Herd management
- Waste Drainage - Power generation
- Nature-based Solutions
- Heavy-duty – Fuel cell rail
- Household heat pumps - Space and water
- Heavy-duty Battery Electric Vehicle
- Household appliances electrification and efficiency
- Light-duty Battery Electric Vehicle

Note 1. This excludes emission reduction not attributable to the shortlisted solutions (e.g., fertilisers or lime and urea).

Impact of solution filtering in determining the maximum MAC

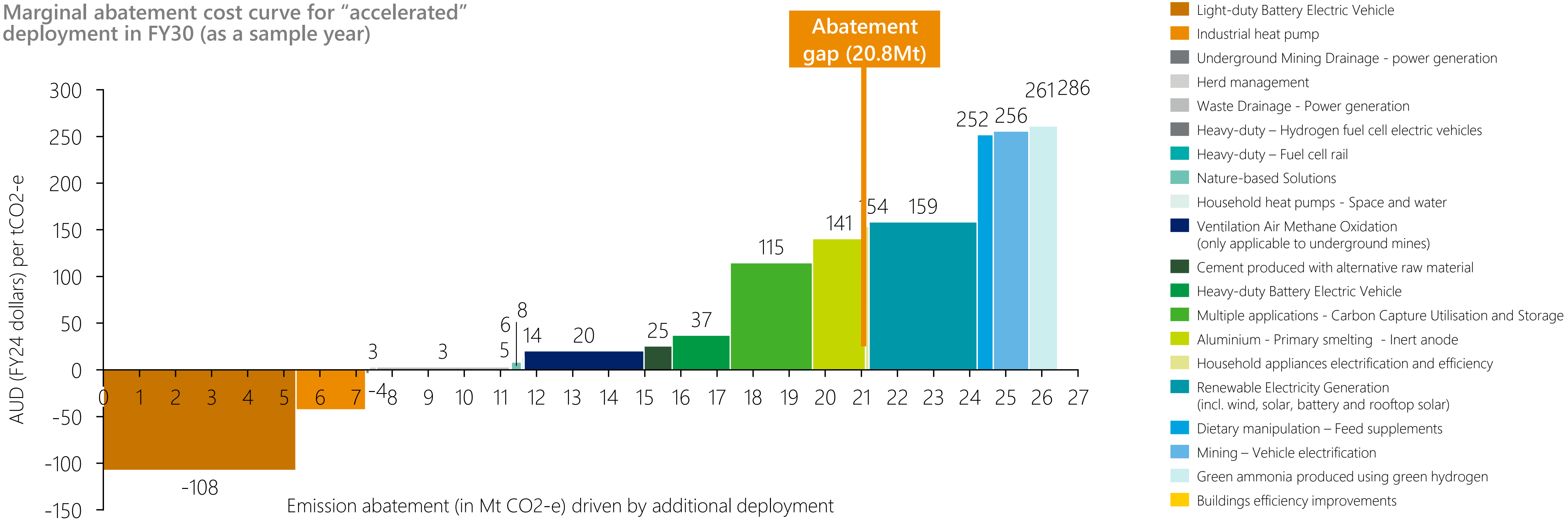
10. How are decarbonisation solutions filtered in or out as part of the MAC curve?

As outlined in page 7, solutions are selected by:

- Starting with solutions with the lowest MAC value
- Deploy this solution until maximum additional deployment in NSW (in FY30) is met. In other words, up to the deployment constraint for FY30
- Move on to next lowest MAC solution until the whole of economy abatement gap is met at 20.8 Mt
- More expensive solutions (including renewable electricity generation, dietary manipulation – feed supplements and mining EV) have been filtered out as they are not required to meet NSW's FY30 abatement target

This is illustrated in the MACC below for FY30 for "accelerated" deployment.

Marginal abatement cost curve for "accelerated" deployment in FY30 (as a sample year)



Two decarb. scenarios were considered, but only one informs Carbon Values

11. What is the difference between the sensitivities (i.e., "natural" deployment and "accelerated" deployment of shortlisted decarbonisation solutions)? Which sensitivity is used to inform the Carbon Values?

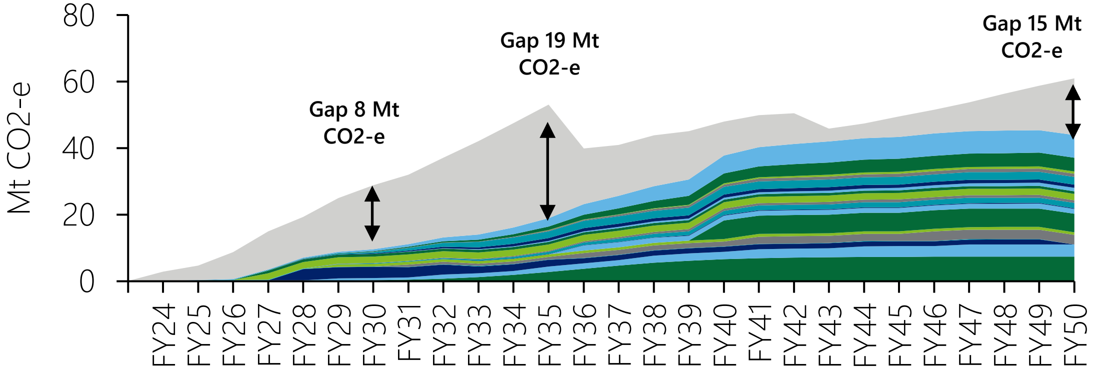
The different deployment, and hence decarbonisation, scenarios reflect the likelihood of different future government decarbonisation policies and industry decarbonisation programs. As more information emerges in the coming years, both the cost and assumed deployment trajectory should be reviewed and updated for future publications of the Carbon Values. The accelerated deployment scenario is considered as inputs in the Carbon Values given it is target-aligned. Within the accelerated deployment scenario, multiple acceleration timing sensitivities were tested (e.g. starting light-duty BEV in FY25 vs. FY28).

"NATURAL" DEPLOYMENT OF SHORTLISTED DECARBONISATION SOLUTIONS

Assumes future government decarbonisation policies and industry decarbonisation programs (i.e., introduced from now until FY50) will incentivise NSW citizens and businesses to transition gradually to all solutions, i.e., waiting till end of asset life. This means NSW could abate ~12% of residual emissions by FY30 and ~24% by FY35 before considering DACCS. This results in a cumulative emission reduction of approximately 115 Mt reduction prior to FY35 and 790 Mt reduction post-FY35[1, 2].

Gap between additional emissions abated (from shortlisted solutions, excluding DACCS) and target emission abatement (FY24 to FY50)

Baseline emission abatement is already excluded

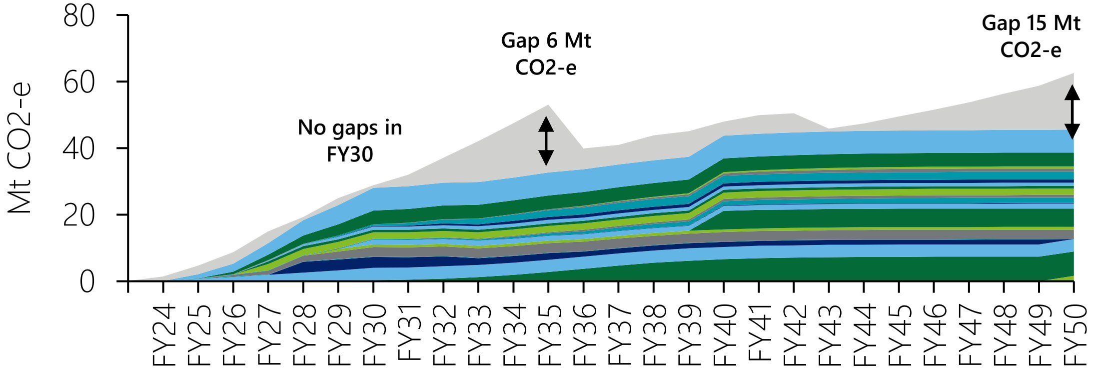


"ACCELERATED" DEPLOYMENT OF SHORTLISTED DECARBONISATION SOLUTIONS

Assumes future government decarbonisation policies and industry decarbonisation programs (i.e., introduced from now until FY50) will incentivise NSW citizens and businesses to transition early, i.e., before end of asset life, for select commercially available and cost-effective solutions. This means the State could abate ~21% of residual emissions by FY30 and ~39% by FY35 before considering DACCS. This results in a cumulative emission reduction of approximately 175 Mt reduction prior to FY35 and 790 to 845 Mt reduction post-FY35.

Gap between additional emissions abated (from shortlisted solutions, excluding DACCS) and target emission abatement (FY24 to FY50)

Baseline emission abatement is already excluded



Note: 1. Rounded to the nearest 5 Mt CO2-e. 2. The 15 Mt Gap excludes the 1.5 Mt reduction from expected mine closures. Minor shortfalls in the target year (up to 0.3 Mt) is rounded.

Deployment trajectory of decarbonisation solutions

12. How is the pace of decarbonisation (i.e., deployment trajectory or deployment constraint of decarbonisation solutions) determined?

Deployment constraints were incorporated to better reflect the lead time required to fully deploy any decarbonisation solution. Deployment constraints could materialise in the form of supply chain, workforce, investment or time constraints. The following rationale is applied to inform the assumed "natural" deployment scenario. See the next page for more detail on the "accelerated" deployment scenario. See Appendix 2: Shortlisted decarbonisation solutions' marginal abatement cost and deployment for more detail on the specific deployment rationale for each solution.

Table of solution category by deployment type and rationale

Solution Category	Deployment Type	Rationale
Renewable Electricity	Deployment based on detailed electricity market forecasts (provided by DCCEEW)	Additional deployment is calculated based on the net emissions difference between Baseline and Current Policy (as advised by the DCCEEW and NZM team as of 29 February 2024). As mentioned previously, the Carbon Values will be updated regularly to account for changes in electricity market forecasts.
Consumer / Business-facing Solutions	S-curve deployment	An S-curve deployment is assumed for economy-wide decarbonisation solutions because it encapsulates the typical solution adoption lifecycle: slow initial uptake due to barriers, rapid growth as those barriers are overcome, and eventual saturation as the solution reaches its market potential. This nonlinear approach more realistically accounts for the technological, economic, and societal factors influencing solution penetration over time.
Mining	Site-specific deployment based on NGER data	Mining site-specific constraints are assumed to drive each site's ability to deploy the respective solution. For mining solutions, the primary constraints are life-of-mine and methane emissions profile (the quantity of pre-drainage and ventilated methane).
Industrials	Site-specific deployment based on assumed asset life	Each industrial site's assumed asset life is assumed to drive each site's adoption of the respective solutions (e.g., Tomago Smelter's asset life is considered when considering the likely decarbonisation).
Whole of Economy – Nature-based Solutions	S-curve deployment	Similar to the consumer / business-facing solutions, an s-curve deployment is assumed to consider nature-based solution's lifecycle. As mentioned previously, we have also applied a cap on nature-based solutions that takes the realities of competing land interests and climate impact on plants'/ soil's sequestration potential into consideration.
Whole of Economy – DACCS	Deployment after FY35 to bridge the gap between NSW's emission reduction targets and emissions abated (baseline plus other decarbonisation solutions).	DACCS is a relatively immature solution from a commercialisation perspective. Hence it is considered as a "last resort" after other viable, cost-effective decarbonisation solutions are deployed to bridge the gap to NSW's interim and net zero targets (in their respective years).

Note: 1. Additionally, within the Tool, if the deployment of a solution is not required to meet the FY30 target, it is not assumed to be deployed prior to FY30. However, in reality this solution may still be deployed.

Accelerated deployment trajectory of select decarbonisation solutions

13. Which decarbonisation solutions are assumed to be accelerated?
14. When are these solutions accelerated?

Six decarbonisation solutions are assumed to be accelerated (as listed in the table). Given these solutions are already fully or partially commercialised, assume Government and industry could accelerate these solutions to meet NSW's first decarbonisation target in FY30. The impact of acceleration selection and assumed timing is considered further in page 23.

Accelerated solutions by sector and rationale

Sector	Key subsectors	Accelerated	Shortlisted solutions	Rationale for assumption
Electricity generation	Electricity generation	× × × ×	Utility Solar Rooftop solar Wind Firming	The additional deployment renewable electricity generation is already assumed to follow Current Policy (which is a more ambitious scenario). Hence further acceleration is considered unlikely.
Transport	Light vehicles (cars, LCVs, MCs)	✓	Light-Duty – Battery EVs	1. Light-duty BEV is mature and commercialised, so assumed acceleration could start from FY25. The tool currently assumes acceleration from FY28 to FY31.
	Heavy-Duty vehicles (Trucks, Buses, Rail)	✓ × ×	Heavy-Duty – Battery EVs Heavy-Duty – Hydrogen fuel cell Rail – Hydrogen/bio feedstock/ammonia	2. Heavy-Duty BEV is rapidly becoming commercially available and heavy-duty charging infrastructure is being scaled up, so assumed acceleration could start from FY26. The tool currently assumes acceleration from FY28 to FY35. Heavy-Duty – Hydrogen fuel cell and Rail – Hydrogen/bio feedstock/ammonia require lead-time for further R&D.
Agriculture	Animals	× ×	Dietary manipulation Herd mgt.	Conservatively assumed fully deployment by FY40 given the lead-time required to scale up dietary manipulation and R&D required for confirming/rolling out herd mgt.
Stationary energy	Energy	✓	Mining – Vehicle electrification	3. Mining EV is rapidly becoming commercially available, so assumed acceleration could start from FY27.
	Manufacturing	× ×	Industrial electric heating equipment Cement produced with alternative raw materials	Industrial electric heating solution is already assumed to be fully deployed in FY27. Cement produced with alternative raw materials is already assumed to be fully deployed in FY27.
	Residential and other	× × × ×	Household heat pumps Household appliances electrification and efficiency Building efficiency improvements	Household heat pumps, household appliances electrification and efficiency and building efficiency improvements are commercially available solutions. However, conservatively assumed it is supply constrained given reliance on imports/ construction workforce constraints.
IPPU	Metals sector	✓ × ✓	Aluminium primary smelting – Inert anode Iron and steel – DRI produced using green H2 CCUS across multiple applications	4. Aluminium primary smelting – inert anode is a mature solution, so assumed one-off deployment (at NSW Tomago) could occur in FY30. 5. CCUS is a mature solution that is already deployed in NSW (i.e., Leilac), so assumed acceleration could start from FY26.
	Chemicals sector	×	Green ammonia produced using green H2	Green ammonia is not accelerated given dependencies on green hydrogen.
Fugitive emissions	Coal mining	×	Drainage – Power gen. Air Methane Oxidation	Drainage power generation and air methane oxidation are not accelerated given assumptions are specific to the mine sites (as advised by the Net Zero Modelling team).
Waste	Solid waste disposal	✓	Drainage – Waste power gen.	6. Drainage power generation is mature and commercialised, so assumed acceleration could start from FY25.
Whole-of-economy		× ×	GHG Removal – DACCS GHG Removal – Nature-based solutions	DACCS and nature-based solutions are not accelerated given the lead-time required for further R&D on DACCS and the need to gradually ramp up nature-based solutions (i.e. sequestration lead-time).

Accelerated deployment trajectory of select decarbonisation solutions

15. How is the impact of acceleration incorporated in the Carbon Value calculation?

Accelerated solutions include early retirement costs by discounting CAPEX avoided commensurate to the acceleration period. The impact on carbon values is calculated by: CAPEX avoided * adjusted replaced solution life / replaced solution life.

For single-site industrial solutions:

- Adjusted replaced solution life = Replaced solution life – (new deployment year – previously assumed deployment year)

For all other solutions:

- Acceleration period = Acceleration end year – acceleration start year + 1
- Adjusted replaced solution life = (Replaced solution life + Acceleration period) / 2

  only applicable during the acceleration period

This is a relatively pessimistic/simplistic approach, given this approach assumes:

- Straight-line depreciation
- The same volume of replacement each year (i.e. not accounting for growth due to population/ reduction as residents move to less emission-intensive solutions in the later years)
- Increased avoided cost as all countries (including countries producing these solutions) progress to net zero and ramps down production.

See diagram on the right for a theoretical worked example of Light-duty BEV deployment over three years, with a starting acceleration year of FY28. This is not actually applied in the model.

Worked Example – Light-Duty ICE vehicles to Light-Duty BEV

Original ICE car purchased year	Car age as of 2024	Assumed % of total car stock
1999	25	4%
2000	24	4%
2001	23	4%
2002	22	4%
2003	21	4%
2004	20	4%
2005	19	4%
2006	18	4%
2007	17	4%
2008	16	4%
2009	15	4%
2010	14	4%
2011	13	4%
2012	12	4%
2013	11	4%
2014	10	4%
2015	9	4%
2016	8	4%
2017	7	4%
2018	6	4%
2019	5	4%
2020	4	4%
2021	3	4%
2022	2	4%
2024	1	4%
Total		100%

The replaced solution life for ICE vehicles is 25 years.

The acceleration years are 2028 to 2030, hence the acceleration period is 3 years.

For the first tranche, assume deployment of the first 33% of stock (between car ages of 25 to 17 as of 2024), at an average weighted age of 21.32

For the second tranche, assume deployment of the second 33% of stock (between car ages of 17 to 9 as of 2024). Given this deployment occurs in 2025, all car ages increase by 1, hence the average weighted age becomes 14.00

For the last tranche, assume deployment of the final 33% of stock (between car ages of 9 to 1 as of 2024). Given this deployment occurs in 2026, all car ages increase by 2, hence the average weighted age becomes 6.68.

Average = 14.00 economic life of asset during the acceleration period. The calculation can be simplified to (25 + 3) / 2

Interpretation of the MACs

16. How does the maximum MACs translate to Carbon Values?

As outlined in the table below, the relative order of shortlisted decarbonisation solutions change by year (four specific solutions are colour coded for ease of interpretation). The maximum MACs follow an upward trajectory from FY25 and capped from FY35 onwards with the introduction of DACCS[1]. Note that solutions that have reached full deployment in a prior year would not be ranked, as they are no longer available (see methodology on page 7).

MACs ordered by lowest to highest for every year

	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38	FY39	FY40	FY41	FY42	FY43	FY44	FY45	FY46	FY47	FY48	FY49	FY50
1	(4)	(7)	(146)	3	(11)	(108)	(107)	(53)	(79)	(103)	(126)	(147)	(166)	(185)	(202)	(218)	(220)	(221)	(222)	(223)	(224)	(224)	(225)	(225)	(225)	(225)
2	3	3	(18)	3	3	3	(25)	(25)	(52)	(76)	(99)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
3	4	3	3	8	3	3	3	3	3	3	3	3	3	3	3	8	8	8	8	8	8	8	8	8	8	233
4	8	8	3	8	7	5	5	4	4	4	3	8	8	8	8	13	13	13	13	13	13	13	13	13	13	346
5	16	13	3	21	8	6	5	8	8	8	8	13	13	13	13	55	162	162	162	162	162	162	162	162	162	n/a
6	62	50	8	31	22	8	8	13	13	13	13	160	160	161	161	162	293	293	293	233	233	233	233	233	233	n/a
7	110	51	10	99	73	14	14	156	157	159	159	252	252	252	252	n/a	346	346	346	293	293	293	293	293	293	n/a
8	155	120	25	114	116	37	155	208	233	252	252	291	292	292	292	n/a	n/a	n/a	n/a	346	346	346	346	346	346	n/a
9	n/a	146	40	n/a	152	115	183	n/a	252	258	282	307	332	347	347	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
10	n/a	n/a	119	n/a	n/a	141	n/a	n/a	289	290	291	349	348	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
11	n/a	n/a	148	n/a	n/a	154	n/a	n/a	n/a	n/a	350	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
12	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
13	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
15	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
16	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
17	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
18	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
19	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
20	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
21	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

In FY25, light-duty BEV sets the max MAC

In FY26, household appliance elec and efficiency sets the max MAC. Due to lowering grid emission intensity, this MAC increases over time (i.e. less emissions are abated for the same electric appliance)

Light-duty BEV was assumed to be accelerated in FY28 but filtered out due to the availability of more cost-effective solutions.

Note the increase of light-duty BEV MAC between FY27 and FY29 is driven by the effect of acceleration lowering avoided CAPEX cost (see slide 23 for more detail). After FY32, light-duty EV is filtered out as it is fully deployed.

Introduction of DACCS in FY35. The DACCS MAC appears in all years (except FY40) due to the assumed gradual deployment of DACCS.

Assumed deployment of DACCS is possible from 2035 onwards. This is based on the assumption that DAC could overcome technological and geological constraints, while carbon storage could be scaled up effectively. IEA report here estimates DACCS could become commercially viable around the 2030s, which means this solution could be operational in NSW from 2035 onwards, given the 2 to 6 years lead time to construct.

DACCS is filtered out in FY40 due to the availability of more cost-effective solutions (i.e. DRI produced using green hydrogen is assumed to become available in FY40, broadly in line with BlueScope Steel's public announcement.

Legend:

- Light-duty Battery Electric Vehicle
- Household appliances electrification and efficiency
- GHG Removal - Direct Air Capture and Carbon Storage
- Direct reduced iron produced using green hydrogen

Translation of maximum MACs into Carbon Values (1/2)

16. How does the maximum MACs translate to Carbon Values?
17. How are deployment sensitivities considered?

The selection of the yearly maximum MAC is driven by solutions' assumed deployment rate. To account for deployment uncertainty, we compared the MACs of the last three necessary solutions as well as that of solutions that have been filtered out. Given NSW has targets in FY30, FY35 and FY50, we have focused on identifying Central Carbon Value inputs for these years in addition to FY25 as the starting year. We also identified Low and High Carbon Value inputs for FY25 and FY50.

- In FY25, the last three MACs range from 110 to 155, with (155) being Light-duty BEV; hence 155 is used as the Central input. Given Household appliances electrification and efficiency (142) is already established in NSW's decarbonisation policy, 142 is used as the Low input. Similarly, Building Efficiency Improvements 273 is used as the High input.
- In FY30, the last three MACs range from 115 to 154, with (154) being Household appliances electricity and efficiency; hence 154 is used as the Central input.
- In FY35, the last three MACs range from 282 to 350, with (350) being DACCS; hence 350 is used as the Central input.
- In FY50, the last three MACs range from 3 to 346, with (346) being DACCS; hence 350 is used as the Central input. Given Renewable Electricity Generation (233) is also critical to NSW's decarbonisation policy, 233 is used as the Low input. Post-FY35, NSW may need to rely on other decarbonisation solutions (either considered within this project or new emerging solutions) should DACCS's deployment becomes capped, hence 700 is assumed as the High input. Noting that this value is assumed given long-term uncertainties associated with the design and cost of decarbonisation solutions.

Comparison of the MACs (last three necessary solutions and solutions that have been filtered out)

	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38	FY39	FY40	FY41	FY42	FY43	FY44	FY45	FY46	FY47	FY48	FY49	FY50
3rd	HBEV	HBEV	HH-HP	HH-HP	HBEV	CCUS	HH-HP	HH-HP	D	D	D	B	B	D	D	DRI	HH	HH	HH	D	D	D	D	D	D	FCR
2nd	HH	CCUS	CCUS	LBEV	CCUS	ALUM	HH	HH	D	D	B	D	D	B	B	HH	B	B	B	B	B	B	B	B	B	D
Max	LBEV	HH	HH	HBEV	HH	HH	D	D	B	B	DACCS	DACCS	DACCS	DACCS	DACCS	B	DACCS	DACCS	DACCS	DACCS	DACCS	DACCS	DACCS	DACCS	DACCS	DACCS
1st Out	D	D	D	CCUS	D	D	NH	NH								DACCS										
2nd Out	B	B	B	HH	MBEV	D	D	D																		
3rd Out			MBEV	D	NH	MBEV	B	B																		
3rd	110	51	40	31	73	115	14	13	233	252	282	291	292	252	252	55	162	162	162	233	233	233	233	233	233	3
2nd	142	120	119	99	116	141	155	156	252	258	291	307	332	292	292	162	293	293	293	293	293	293	293	293	293	233
Max	155	146	148	114	152	154	183	208	289	290	350	349	348	347	347	293	346	346	346	346	346	346	346	346	346	346
1st Out	252	252	252	117	252	159	246	232								346										
2nd Out	273	277	279	150	276	252	252	252																		
3rd Out			336	252	277	256	287	288																		

Legend:
D: Dietary manipulation – Feed supplements
HBEV: Heavy-duty Battery EV
HH: Household appliances elec and efficiency
FCR: Heavy-duty – Fuel cell rail
RE: Renewable Electricity Generation
CCUS: Multiple applications – CCUS
B: Buildings efficiency improvements
HH-HP: Household heat pumps – Space and water
H2: Direct reduced iron produced using green hydrogen
LBEV: Light-Duty Battery EV
DACCS: GHG Removal – DACCS
ALUM: Aluminium – Smelting with Inert Anode

Note: 1. Upper contingency based on Class 5 expected accuracy range of engineering projects for process industries per AACE International Recommended Practices. https://web.aacei.org/resources/recommended-practices

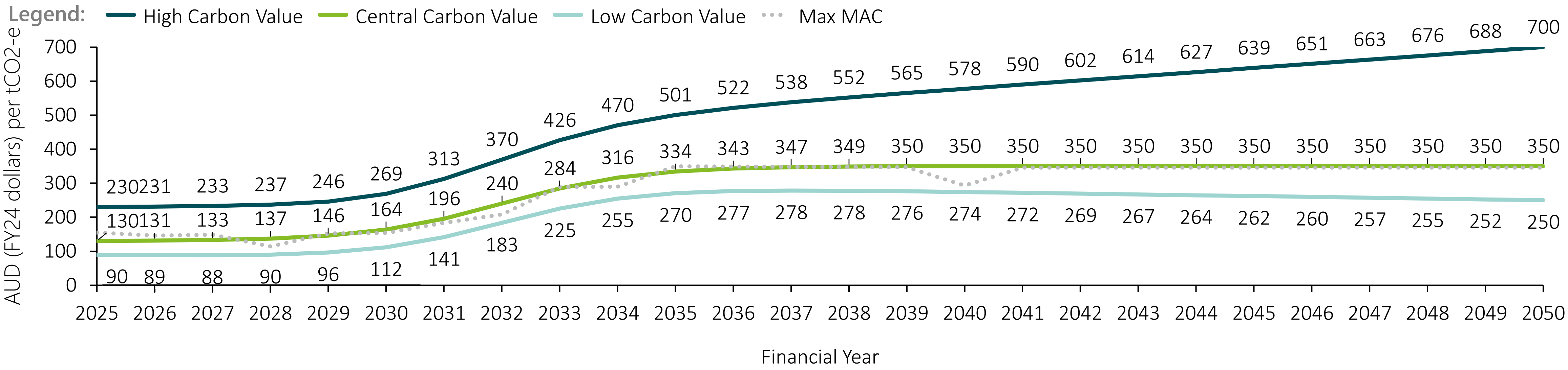
Translation of maximum MACs into Carbon Values (2/2)

16. How does the maximum MACs translate to Carbon Values?

A smoothing approach (sigmoid function) was applied to translate the modelled central inputs (as outlined in Page 25) to the Central Carbon Values, and adjusted by the High/Low inputs accordingly for the High/Low Carbon Values. The sigmoid function reflects a line of best fit approach with greater emphasis placed on the target emission reduction years of 2030, 2035 and 2050. The three sets of Carbon Values reflect greater certainty in the decarbonisation solutions available to and required by NSW in the near term and greater uncertainty into the future. For comparison, the maximum MAC is also included in the figure below.

Scenario	Interpretation of Carbon Values
High Carbon Values	Reflects lower volume of abatement, speed of deployment or cost-effectiveness of decarbonisation solutions, for example, due to supply chain/ workforce/ approval constraints.
Central Carbon Values	Fulfills NSW emission reduction targets with orderly deployment of decarbonisation solutions. Central carbon values are the best translation of the optimised marginal abatement costs of NSW's decarbonisation solutions.
Low Carbon Values	Reflects higher volume of abatement, speed of deployment or cost-effectiveness of decarbonisation solutions, for example, due to the state shifting away from high-emission industries.

Low, Central, High Carbon Values and the underlying maximum MAC (FY25 to FY50)



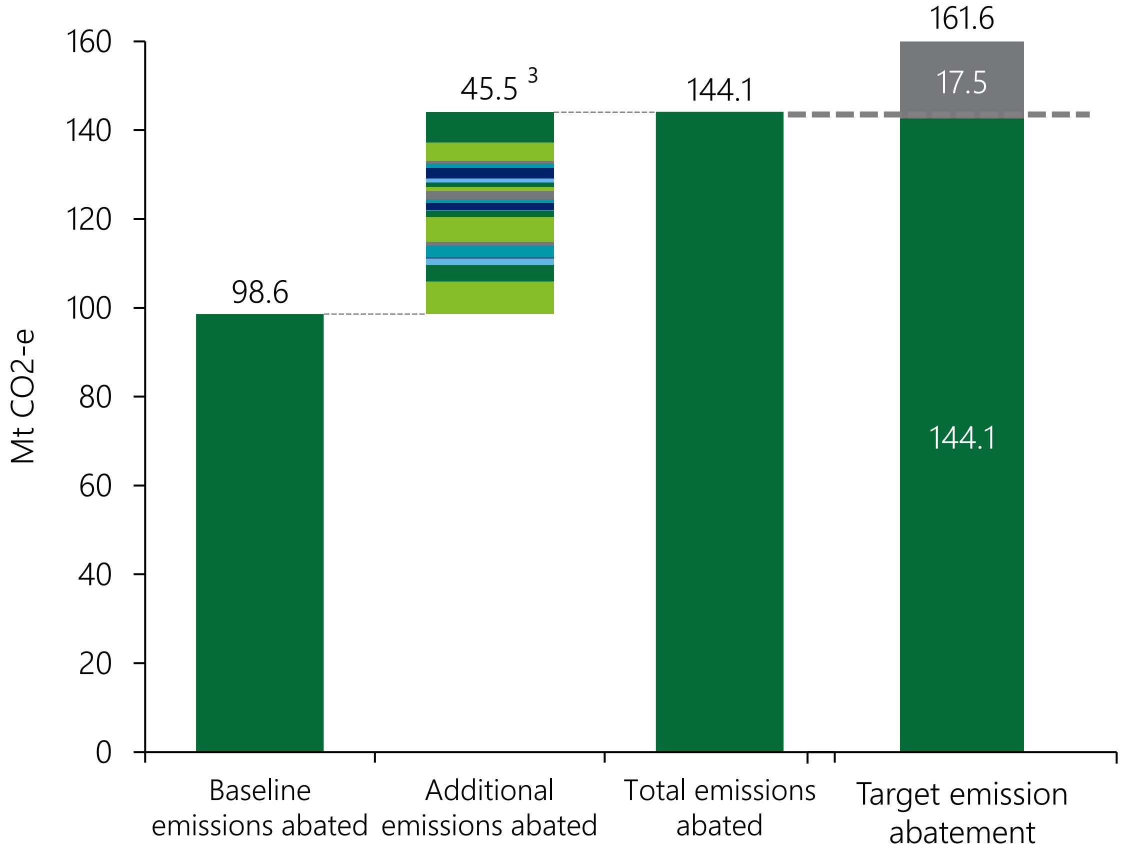
Note: 1. Use of the low carbon value risks underinvestment in high-impact decarbonisation solutions and could result in NSW falling short of its interim decarbonisation targets. Hence recommend limiting the application of the low carbon values.

Role of DACCS in the NSW Carbon Values

18. What is the role of DACCS in the Carbon Values?

Deployment of DACCS is already considered as a "last resort" solution. DACCS is likely to play an integral role in NSW's decarbonisation and hence its MAC drives the Carbon Values in the latter years.

Abatement potential of all shortlisted decarbonisation solutions by FY50 (except for DACCS)
This emissions stack totals 161.6 Mt, which is NSW's 2005 emissions, used to set NSW's emission targets.



DACCS (with additional high-impact decarbonisation solutions not currently included in our shortlisted solutions that emerge over the coming decades) are required to close **the gap of 17.5 Mt CO2-e** [3].

This is also driven by the assumed constraint on nature-based solutions, which was discussed and agreed with the relevant NSW Government decarbonisation experts. It is assumed[1] that nature-based solutions could abate **7.4 Mt CO2-e** by FY50, based on an estimated ~16% of available land area (specifically cultivated terrestrial vegetated: Herbaceous & Natural terrestrial vegetated: Herbaceous in NSW), totalling 7.7 million hectares.

Legend:

- Baseline emission abatement
- Renewable Electricity Generation
- Heavy-duty – Hydrogen fuel cell electric vehicles
- Heavy-duty Battery Electric Vehicle
- Heavy-duty – Fuel cell rail
- Dietary manipulation – feed supplements
- Herd management
- Mining – Vehicle electrification
- Cement produced with alternative raw material
- Industrial heat pump
- Household heat pumps - space and water
- Household appliances electrification and efficiency
- Buildings efficiency improvements
- Primary smelting - aluminium and minerals - Inert anode
- Iron and steel - DRI produced from green hydrogen
- Green ammonia produced using green hydrogen
- Multiple applications - CCUS
- Power gen (UG mines)
- VAM (UG mines)
- Power gen (Waste)
- Nature-based Solutions

Note 1. Informed by the 2020 Department of Primary Industries report "Abatement opportunities from the agriculture sector in New South Wales". This is calculated based on: 1) The NSW land suitable for mixed species planting or soil carbon management (per DPI report). 2) Assumed a percentage of suitable NSW land is used to deploy these solutions - this is assumed to be 1% and 10% respectively. 3) Apply the sequestration rates (adjusted for climate impact per the CSIRO Land and Water report) to arrive on the total emission abatement potential for NSW. 3. Exclusive of mine closures, which could reduce emissions by ~1.6 Mt CO2-e.

Underpinning experts, scientific and industry information

19. What are the scientific and industry reports and articles used in the calculation of the Carbon Values? Who provided input to the Carbon Values?

The NSW Carbon Values were informed by more than 140 scientific and industry reports/articles, a sample of which is included below (non-exhaustive). 23 decarbonisation experts within NSW Government across numerous Departments contributed to this project and helped inform the inputs and assumptions that underpin the NSW Carbon Values.

SAMPLE of the scientific and industry reports/articles used on this project

Report name
Abatement opportunities from the agricultural sector in New South Wales
AEMO 2020 Costs and Technical Parameter Review
AEMO 2021 Transmission Cost Report
AEMO ISP 2020 - Central (DP1)
Australian and Transport Statistics Yearbook 2022
Australian National Greenhouse Accounts Factors
CSIRO Australia's carbon sequestration potential - A stocktake and analysis of sequestration technologies
CSIRO Electric vehicle projections 2022
CSIRO GenCost2022-23
CSIRO National Hydrogen Roadmap
CSIRO Technical review of physical risks to carbon sequestration under the Emissions Reduction Fund (ERF)
Dairy Greenhouse Accounting Framework
DPIE Commissioned Report: Opportunities of fugitive emissions abatement
Hydrogen for Australia's future
Low-Carbon Production of Iron & Steel: Technology Options, Economic Assessment, and Policy
National Land Account, Experimental Estimates, 2016
NGER Emission Data
NREL Perspectives on Charging Medium- and Heavy-Duty Electric Vehicles
NSW Hydrogen Strategy
NSW Net Zero Modelling Scope 1 emissions data

List of decarbonisation experts who contributed to this project

No.	Involvement	Stakeholder	Stakeholder Department
1	Project team member and decarbonisation experts	Kaspar Sollberger	NSW DCCEEW
2		Chelsea Judy	
3		Christopher Royal	Transport for NSW
4		Andrew Mattes	
5		Sophie Clark	NSW Treasury
6		Yisheng Ho	
7		Angus Wood	
8		Rob Hynes	NSW Net Zero Modelling DCCEEW
9		Ronan Kellaghan	
10	Decarbonisation expert	Kaydy Pinetown	
11		Andy Jiang	
12		Lexie Lu	
13		Annette Cowie	Department of Primary Industries
14		Michele Weight	NSW Environment Protection Authority
15		Bronwyn Isaac	NSW DCCEEW
16		Emily Christiansen	
17		Paulo Pinto	
18		Jennifer Hearn	
19		Simon Holloway	
20		Nav Brah	
21		Kazi Kazi	
22		Patrick Riakos	
23		Alexandra Lachsz	

Consideration of the cost of replacement and interdependencies of shortlisted decarbonisation solutions

20. How have the Carbon Values considered the cost of replacement?
21. How have the Carbon Values considered the interdependencies of different solutions?

Consideration of the cost of replacement

When determining the Carbon Value, the analysis focused on the marginal abatement costs – essentially, the costs to eliminate an additional unit of emissions. Replacement costs, or the costs to replace the decarbonisation solutions at the end of their useful life, weren't directly included in this analysis.

This exclusion can be justified by considering the expected lifespan of these solutions. We have outlined two examples below – vehicle-related decarbonisation solutions have the shortest useful life and hence would require replacement within the analysis period, and industrial decarbonisation solutions which drive the Carbon Values in later years.

- For most vehicle-related decarbonisation solutions (e.g., Light-duty BEV) the useful life – as informed by the battery or fuel cell life – is anticipated to be 10 years. Replacement of these solutions will incur a lower MAC than the initial purchase, given supporting costs (e.g., vehicle charging stations) would have already been incurred. However, given the NSW Carbon Value is informed by the maximum MAC for any given year, the lower replacement MAC would not influence the Carbon Value.
- For most industrial decarbonisation solutions, including DACCS – the useful life is 25 years. Most of these solutions are deployed from FY30 or mid-FY30s. Therefore, within the timeframe of this analysis (up to FY50), these solutions will not reach the end of their asset life and require replacement. As a result, their replacement costs are not pertinent to the NSW Carbon Values.

Consideration of interdependencies of different solutions

Emission or energy interdependencies

- Projected electricity grid emissions intensity (FY25 to FY50) is built into the analysis, with inputs provided from the Net Zero Modelling team (sourced from AEMO).

The impact of additional renewable electricity deployment has not been considered for the assumed electricity grid emission intensity for this version of the Tool. However, this should be considered for the next iteration.

Cost interdependencies

Projected green hydrogen cost (FY25 to FY50) is built into the Carbon Value analysis, with inputs and assumptions sourced from the CSIRO National Hydrogen Roadmap. The cost of green hydrogen is incorporated into the OPEX of relevant decarbonisation solutions, such as Heavy-duty fuel cell vehicles and ammonia produced using green hydrogen.

However, the cost of other solutions (e.g., green steel used in the construction of DACCS facilities) has not been incorporated into analysis given the methodology is limited to Scope 1 emissions.

Cross-subsector deployment potential

Cross-sector deployment potential has been considered when calculating the additional emission abatement potential (e.g., CCUS' application across multiple subsectors).

Comparison of NSW Carbon Values with other carbon values

22. How do the NSW Carbon Values compare with other carbon values from climate models or used by other governments or institutions?

The NSW Carbon Values are generally comparable or lower than carbon values from climate models, least-cost and MAC methods. Many climate models utilise a carbon price as either an exogenous (input) or semi-endogenous (partially modelled) variable. For some of these climate models, a carbon price is used as a policy tool to assess the impacts of various climate and energy policies within these climate models. They can give an indication as to the magnitude of the policy response required to meet an economy-wide emissions reduction trajectory. Some governments and institutions use the environmental cost of operations or climate damages (instead of investment required) to inform their carbon values. Given this fundamental difference in methodology, the trajectory of NSW Carbon Values are not comparable to other carbon values used by the US Environmental Protection Agency, the UK or other relevant institutions.

Comparison of carbon values

Organisation (Region)	Model type	Scenario	2030 Average	2050 Average
NGFS Phase 3 (Australia-specific Regions)	Climate model	Divergent Net Zero	$986 (in AUD 2022)	$2,958 (in AUD 2022)
	Climate model	Net Zero 2050	$436 (in AUD 2022)	$1,550 (in AUD 2022)
Dept for Energy Security & NZ (UK)[3]	MAC	Central	$639 (in AUD 2024)	$864 (in AUD 2024)
IEA (Advanced Economies)	Climate model	Net Zero Emissions 2050	$223 (in AUD 2022)	$429 (in AUD 2022)
IPCC (Global)	Climate model	Limit warming to 1.5C	$378 (in AUD 2023)	$1,110 (in AUD 2022)
	Climate model	Limit warming to below 2C	$152 (in AUD 2023)	$342 (in AUD 2022)
AEMC (Aus)	Informed by IPCC	n/a	$105 (in AUD 2023)	$420 (in AUD 2022)
IA (Aus)[4]	Least-cost approach	Central estimate	$148 (in AUD 2023)	$377 (in AUD 2023)
Output from this report	**MAC**	**Central Carbon Values**	$164 (in AUD 2024)	$350 (in AUD 2024)

Other carbon values

The US Environmental Protection Agency (EPA)[1] and other federal agencies adopted a Social Cost of Carbon (SCC) for cost benefit analysis of federal climate-related policies in 2010.

The SCC was calculated by a US Government Interagency Working Group (IWG) drawing on the average outcomes across three separate Integrated Assessment Models (IAM):

- DICE (Dynamic Integrated Climate-Economy model)
- FUND (Framework for Uncertainty, Negotiation and Distribution model)
- PAGE (Policy Analysis of the Greenhouse Effect model)

All three models are built with **damages and discounting** as one of its core pillars.

Similarly, in 2009, the UK moved away from using an SCC approach and now uses a "shadow price" of carbon for policy evaluation.[2]

Whereas the SCC reflects the costs of damages for a given emissions pathway, the shadow price is based on economic model estimates accounting for **the environmental costs of operations** – indicating the cost to achieve a set emissions target.

The UK applies separate shadow prices for its emissions-traded and non-traded sectors, although these converge over time.

Shadow pricing is also used by a number of reputable global institutions, including:

- The World Bank
- International Finance Corporation (IFC)
- European Bank for Reconstruction and Development (EBRD).

Notes: 1. Technical Update of the Social Cost of Carbon for Regulatory Impact of Analysis, 2016, https://www.epa.gov/sites/default/files/2016-12/documents/sc_co2_tsd_august_2016.pdf
2. Valuation of energy use and greenhouse gas (GHG) emissions, 2024, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1129242/valuation-of-energy-use-greenhouse-gas-emissions-for-appraisal.pdf 3. Converted from 2020 Pounds to 2024 AUD, after considering inflation and exchange rates https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal/valuation-of-greenhouse-gas-emissions-for-policy-appraisal-and-evaluation#annex-1-carbon-values-in-2020-prices-per-tonne-of-co2 4. See https://www.infrastructureaustralia.gov.au/sites/default/files/2024-03/Modelling%20report%20-%20%20Estimating%20an%20emissions%20value%20for%20economic%20appraisal_0.pdf

Appendix 2: Shortlisted decarbonisation solutions’ marginal abatement cost and deployment

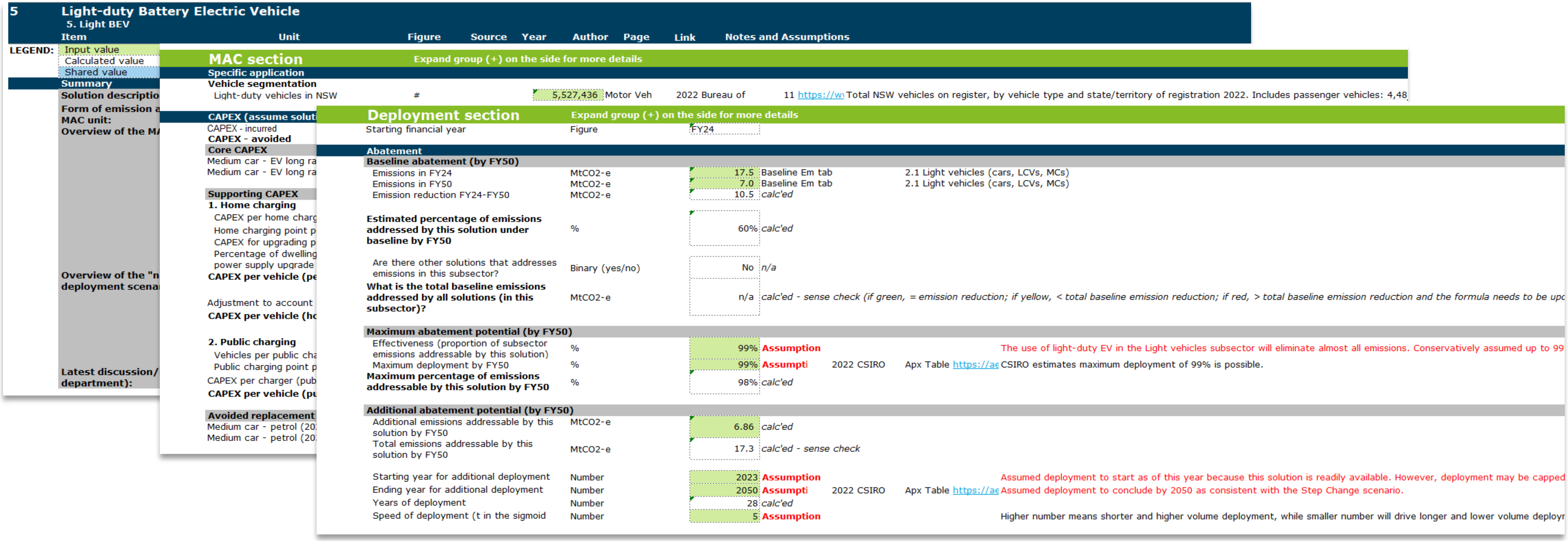
Approach and summary inputs

Shortlisted decarbonisation solutions’ marginal abatement cost and deployment

This Appendix includes the description, overview of the marginal abatement cost calculation approach, summary of the FY24 MAC outputs, and overview of the assumed deployment approach for the 25 shortlisted decarbonisation solutions that informed the NSW Carbon Values.

Refer to the MAC Tool Source Files for more details on the marginal abatement cost inputs and detailed assumptions. The MAC Tool – which utilises more than 45 tabs, 15,000 data points and 150,000 formulas – draws from the Source Files and calculates the Carbon Values based on different discount rates in alignment with NSW Business Case guidelines. The user guide is also embedded in the Tool. See below for sample screenshots of the Tool Source Files.

Screenshots from the MAC Tool Source Files (FY24 version)



Notes: 1. Estimated as 10% of the cells with data (170,000) as part of Workbook Statistics.

Renewable Electricity Generation (1/2)

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

1. Power – Generation – Rooftop solar: Rooftop solar photovoltaic (PV) panels convert surface solar irradiance into zero emissions electricity, for installation on residential and commercial rooftops.
2. Power – Generation – Utility Solar: Utility–scale solar solutions utilise solar PV panels to provide clean and renewable energy to the grid on a large scale.
3. Power – Generation – Wind: Wind generation involves harnessing the power of wind to generate electricity using wind turbines. The kinetic energy of the wind is converted into electrical energy, contributing to the renewable energy mix.
4. Power – Generation – Firming: A firming solution ensures a reliable and consistent energy supply by combining solar or wind generation with energy storage systems such as batteries, pumped hydro, natural gas or hydrogen/natural gas blend. This integration enhances the capacity of intermittent renewable sources to provide a stable power output.

Form of emission abatement: fuel-switch (from fossil-fuel powered generation to renewable generation)

Overview of the MAC approach (continued on next slide)

MAC unit: N/A

Given this solution considers system dynamics, the MAC is calculated differently from other solutions. The yearly MAC is calculated in this tab (instead of the MAC inputs for other solutions).

The net change in solutions is calculated based on the net capacity (by category) difference between Baseline and Current Policy. Two capacity mix trajectories were provided for roadmap scenario and no roadmap scenario, corresponding to Current Policy and Baseline respectively (per email from DCCEEW as of 29 February 2024). Based on another email on 1 March from Kev Yang (DPIE), unified FY24 emissions and capacity mix to the "roadmap scenario" (i.e. Current Policy). The specific approach to inform the change in capacity by year is calculated as:
1) Determined the difference between the capacity for Current Policy and Baseline (i.e. the active capacity every year). This is used to inform OPEX and system costs (i.e. transmission upgrades).
2) Determined the yoy capacity change for Current Policy and Baseline, respectively (i.e. the new capacity investment required, or the existing capacity exiting the system).
3) The difference between the yoy capacity change for Current Policy and the yoy capacity change for Baseline is used to inform CAPEX (i.e. the additional investment required to operationalise new capacity).
Key observations are:
1) Black Coal, Distributed Storage, Distributed PV, and Existing Dispatchable Capacity appears to be the same under the two scenarios.
2) The data provided goes up to 2043. Conservatively assumed no change post-FY43.
3) Wind, Solar, Firming Infrastructure (<8hour BESS and OCGT), Large-scale storage (<8hour BESS), and Long-duration storage infrastructure (greater of equal to 8hour BESS and greater or equal to 8hour Pumped Hydro) is different between the two scenarios. As expected, achieving Current Policy requires higher capacity for variable renewables and firming/storage. Note the specific technologies in the "()" in the previous sentence is based on another email on 28 February from Blake Kirby (DPIE).

The MAC cost components included are: Core: 1) CAPEX for new capacity, and 2) OPEX for operating capacity. Support: 3) System costs (incl. of net transmission and fuel costs). There is no avoided costs, per the key observations listed above. Six technologies have been considered: Battery storage (4 hours), Battery storage (8 hours), Gas open cycle (small), Gas open cycle (large), Pumped hydro (8 hours), Wind and Solar, and mapped against the categories (as provided by DCCEEW/NZM).
1) The CAPEX unit cost by technology has been sourced from CSIRO GenCost (2024). Assumed ratio of technologies against each category given this information was not provided by DCCEEW. When CAPEX is negative, assume there is no reduction in capacity (i.e. there will just be idle capacity for a short period).

Renewable Electricity Generation (2/2)

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Overview of the MAC approach (continued from last slide)

2) The OPEX unit cost is calculated by applying a percentage on CAPEX unit cost. The percentage was informed by the Aurecon Cost and Technical Parameter Review (2022) and AEMO ISP2024 Inputs and Assumptions Workbook (2024). This is a slight undercalculation given the variable O&M cost is not calculatable without generation data.
3) The system cost is sourced from AEMO ISP2024 Outputs Workbook (2024). System costs are only provided for whole-of-NEM, so it is adjusted for NSW and re-adjusted to account for the net differential system investment required to progress from Baseline to Current Policy.

The MAC by year is calculated based on the annual inputs. Since the data concludes in FY43, conservatively assume no new capacity from FY43 onwards. So the MAC post-FY43 only includes the OPEX differential between Baseline and Current Policy. Furthermore, given the MAC is driven by annual capacity changes inferred from two separate models - it is highly uneven. After discussion with DCCEEW, applied smoothing by assuming linear growth between FY25 to FY43 before remaining flat from FY43 onwards. The smoothed MAC by year is used to inform the MAC ranking.

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX – incurred	AUD	n/a
CAPEX – avoided	AUD	n/a
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	n/a
Solution Life	Years	n/a
Replaced solution life	Years	n/a
Learning rate (on CAPEX)	% per annum	n/a
Learning rate (on CAPEX) applicable year	Year	n/a
Net missions Abatement (exc. Impact of grid electricity)	t Co2-e	n/a
Net Grid Electricity	MWh per annum	n/a
Net Hydrogen or Biofuel	Kg per annum	n/a
Deployment year (if single-site industrial solution)	Year	n/a

Overview of the assumed deployment approach

Additional deployment is calculated based on the net emissions difference between Baseline and Current Policy, per emails and discussions with the DCCEEW and NZM team (Kaspar Sollberger, Catherine Allen, Ronan Kellaghan, Cristien Hickey etc. since 14 December 2024). The baseline and current policy emissions included below are from the email provided by Kaspar Sollberger, Blake Kirby, Ronan Kellaghan and Kev Yang as of 29 February 2024. Two emission trajectories were provided for roadmap scenario and no roadmap scenario, corresponding to Current Policy and Baseline respectively. Based on another email on 1 March from Kev Yang (DPIE), unified FY24 emissions and capacity mix to the "roadmap scenario" (i.e. Current Policy).

Light-Duty Battery Electric Vehicle (BEV)

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Electricity–powered passenger cars and light commercial vehicles. These vehicles rely on battery solution to store and utilise electrical energy for propulsion.

Form of emission abatement: fuel-switch (from fossil-fuel petrol to grid electricity)

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	n/a
CAPEX - avoided	AUD	n/a
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	n/a
Solution Life	Years	n/a
Learning rate (on CAPEX)	Per annum	n/a
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	n/a
Net Grid Electricity	MWh per annum	n/a
Net Hydrogen or biofuel	Kg per annum	n/a
Net Diesel	Litres per annum	n/a
Net Petrol	Litres per annum	n/a
Net Natural Gas	GJ per annum	n/a

Overview of the MAC approach

MAC unit: per vehicle

The MAC costs components included are: Core: 1) vehicle cost (i.e., ICE vs. EV), Support: 2) public and private charging infrastructure, and Avoided: 3) difference in fuel and maintenance.

The specific approaches to the corresponding to the cost components are:

1) The price for a medium car (per CSIRO) has been considered as a proxy for ICE and EV passenger and commercial Light-Duty vehicles. For simplicity, applied battery life of 10 years as the solution life for Light-duty BEV and ICE vehicle life of 25 years as the replaced solution life (the latter is used to adjust the incurred CAPEX when deployment is accelerated).

2) Light vehicles will use a public charger (when out on the roads) and private charger (when parked at the primary residence). The household power supply upgrade for private chargers has been considered:

a) Assuming only 55% of NSW dwellings would require power upgrades, and

b) An assumed adjustment factor of 90% have been included to account for the economies of scale that can be achieved in apartment chargers.

As recognised in a CSIRO report, while not a hard constraint, home ownership increases the ability of occupants to modify their house to include EV chargers; however, assume NSW may consider mandating charger installation in the future so renters are not prohibited from owning/operating an EV.

2 and 3) The cost of power asset upgrades are not considered as part of public/private charging infrastructure. As charging price (i.e., the retail electricity price) already incorporates the requisite power asset costs (incl. transmission/distribution upgrades). This assumption is consistently applied to all relevant solutions.

3) Fuel intensity per vehicle (adjusted according to km) is specific to NSW.

3) Assumed EV will charge at retail electricity price, instead of the current flat tariff structure.

Overview of the assumed deployment approach

"Natural" deployment is assumed to be gradual, based on the assumption that individuals will wait until existing ICE vehicles reach the end of asset life before transitioning to Light-Duty BEV.

Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 6.86 Mt CO2-e, reaching a total abatement potential of 17.4 Mt CO2-e (once baseline emission abatement is included) by 2050. This solution is already assumed to be deployed under baseline, but not to its full potential (per CSIRO's projections). Given this solution is readily available, assumed additional deployment can start from 2024 and continue until 2050, based on a general S-curve deployment. Assumed all NSW Light-duty BEV will be electric by FY50 (i.e., fuel cell Light-duty BEV was not considered).

Heavy-Duty Battery Electric Vehicle

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Battery electric vehicles in the heavy–duty category include buses and medium haulage vehicles (rigid and articulated trucks). These vehicles rely on electricity as their power source for transportation.

Form of emission abatement: fuel-switch (from diesel to grid electricity)

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	221,741
CAPEX - avoided	AUD	(105,581)
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	(10,305)
Solution Life	Years	10
Learning rate (on CAPEX)	Per annum	5%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(29.77)
Net Grid Electricity	MWh per annum	43
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	(10,959)
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Overview of the MAC approach

MAC unit: per vehicle

Costs components included are: Core: 1) vehicle cost, Support: 2) charging infrastructure, and Avoided: 3) difference in fuel and maintenance.

The specific approaches to the corresponding to the cost components are:

1) Three vehicle types are considered: rigid trucks, articulated trucks and buses. Assumed the ratio of vehicles will remain the same into the future; and applied a weighted average approach (instead of straight average) to calculate the CAPEX –incurred, CAPEX - avoided, net OPEX and net emissions per vehicle. For simplicity, applied battery life of 10 years as the solution life for Light-duty BEV and ICE vehicle life of 25 years as the replaced solution life (the latter is used to adjust the incurred CAPEX when deployment is accelerated).
2) Given these vehicles will be used by businesses/the public, assume only one primary charging infrastructure is required (as compared with Light-Duty BEV).

2 and 3) The cost of power asset upgrades are not considered as part of the primary charging infrastructure. As charging price (i.e., the retail electricity price) already incorporates the requisite power asset costs (incl. transmission/distribution upgrades). This assumption is consistently applied to all relevant solutions.

3) Fuel intensity per vehicle (adjusted according to km) is specific to NSW.

3) Assumed EV will charge at retail electricity price, instead of the current flat tariff structure.

Overview of the assumed deployment approach

"Natural" deployment is assumed to be gradual, based on the assumption that government/businesses will wait until existing ICE vehicles reach the end of asset life before transitioning to heavy-duty BEV. Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 4.1 Mt CO2-e, reaching a total abatement potential of 4.9 Mt CO2-e (once baseline emission abatement is included) by 2050. This solution is already assumed to be deployed under baseline (per the TfNSW provided VKT projections for light and heavy-duty vehicles, which was used by NZM team's projections). The split of heavy-duty BEV/HFCEV baseline emissions is assumed based on data/methodology supplied by the NZM team. Heavy-duty BEV is assumed to contribute to 86% of emission reduction in the heavy-duty segment. This is calculated based on the relative contribution of heavy-duty BEV and HFCEV to total ZEV uptake, based on emission reduction (i.e., takes into account emission intensity per vehicle, fleet size and portion of BEV or HFCEV to the total fleet. This is a simplistic approach and should be updated in the next iteration. Assumed additional deployment can start from 2025 and continue until 2050, based on a general S-curve deployment. The two years lead time (to 2025) was assumed to allow for (partial) operationalisation of heavy-duty vehicle charging infrastructure and power asset build (i.e., transmission upgrades).

Heavy-Duty Hydrogen Fuel Cell Electric Vehicle

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Hydrogen fuel cell technology

Form of emission abatement: fuel-switch (from petrol/diesel to hydrogen)

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	172,942
CAPEX - avoided	AUD	(105,581)
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	(15,563)
Solution Life	Years	10
Learning rate (on CAPEX)	Per annum	7%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(29.77)
Net Grid Electricity	MWh per annum	-
Net Hydrogen or biofuel	Kg per annum	2,203
Net Diesel	Litres per annum	(10,959)
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Overview of the MAC approach

MAC unit: per vehicle

Costs components included are: Core: 1) vehicle cost, Support: 2) hydrogen refuelling infrastructure, and Avoided: 3) difference in fuel and maintenance.

The specific approaches to the corresponding to the cost components are:

1) The heavy-duty vehicle types (per CSIRO) has been considered as a proxy for ICE and HFCEV heavy-duty vehicles. A similar proportion of heavy-duty types are assumed for HFCEVs as per their ICE equivalents. For simplicity, applied battery life of 10 years as the solution life for Light-duty BEV and ICE vehicle life of 25 years as the replaced solution life (the latter is used to adjust the incurred CAPEX when deployment is accelerated).
2) A 2021 U.S. Department of Energy report was used to inform the costings of hydrogen refuelling infrastructure. The capital cost and capacity of gaseous tube trailers is used to inform the costings for the refuelling stations instead of the liquid hydrogen tankers. This is consistent with the type of hydrogen assumed in the MAC tab (PEM Gas On-grid). Assumed a high refuelling station utilisation rate of 83% (i.e., the station will be refuelling vehicles for 20 hours of the day), noting the average daily utilisation of an individual hydrogen station as of 2019 is ~35%.
2) The amount of hydrogen used per heavy-Duty vehicle per day is estimated based on the distance travelled for each of the different types and their fuel efficiencies.
3) Fuel intensity per vehicle (in terms of km) is specific to NSW.
3) Informed by CSIRO projections, the learning rate of hydrogen (as AUD per kg H_2) is considered separately. The cost of hydrogen (OPEX) is added separately.

Overview of the assumed deployment approach

"Natural" deployment is assumed to be gradual, based on the assumption that government/businesses will wait until existing ICE vehicles reach the end of asset life before transitioning to heavy-duty HCFEV. Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 0.7 Mt CO2-e, reaching a total abatement potential of 0.8 Mt CO2-e (once baseline emission abatement is included) by 2050. This solution is already assumed to be deployed under baseline (per the TfNSW provided VKT projections for light and heavy-duty vehicles, which was used by NZM team's projections). The split of heavy-duty BEV/HFCEV baseline emissions is assumed based on data/methodology supplied by the NZM team. Heavy-duty HFCEV is assumed to contribute to 14% of emission reduction in the heavy-duty segment. This is calculated based on the relative contribution of heavy-duty BEV and HFCEV to total ZEV uptake, based on emission reduction (i.e., takes into account emission intensity per vehicle, fleet size and portion of BEV or HFCEV to the total fleet. This is a simplistic approach and should be updated in the next iteration. Assumed additional deployment can start from 2030 and continue until 2050, based on a general S-curve deployment. The lead time was assumed to allow for (partial) operationalisation of heavy-duty vehicle charging infrastructure and power asset build (i.e., transmission upgrades).

Heavy-Duty Fuel Cell Rail

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Rail systems that are powered by fuel cells utilising green hydrogen, combustion of ammonia, or biofuel. Given hydrogen fuel cell rail is still an emerging technology, biofuel fuel cell rail is considered as a proxy for fuel cell rail.

Form of emission abatement: fuel-switch (from diesel to biofuel)

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	172,942
CAPEX - avoided	AUD	(105,581)
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	(15,563)
Solution Life	Years	10
Learning rate (on CAPEX)	Per annum	7%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(29.77)
Net Grid Electricity	MWh per annum	-
Net Hydrogen or biofuel	Kg per annum	2,203
Net Diesel	Litres per annum	(10,959)
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Overview of the MAC approach

MAC unit: Whole of NSW rail system

Costs components included are: Core: 1) biofuel fuel cell vs. diesel rail cost, 2) biofuel cost, and Avoided: 3) diesel cost

The specific approaches to the corresponding to the cost components are:

1) An EMD-710 was used to inform the capital cost of diesel rail. Assumed a 10% cost premium for biofuel retrofit, specifically for 100% biodiesel blend (B100) and the same solution/ replaced solution life of 25 years.
2) Considered the difference between B100 and diesel energy content factor when estimating the volume of biodiesel required. Assumed the price premium for biodiesel will reduce over time to reach price parity with diesel.
3) Avoided diesel cost is not estimated separately, given the price premium for biodiesel is used (i.e., the diesel cost is already deducted in the calculations).

Overview of the assumed deployment approach

"Natural" deployment is assumed to be gradual, based on the assumption that the availability of biofuel will increase over time. Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 1 Mt CO2-e, reaching a total abatement potential of 1 Mt CO2-e (once baseline emission abatement is included) by 2050. This solution is not assumed to be deployed under baseline. Assumed additional deployment can start from 2025 and continue until 2050, based on a general S-curve deployment. The two years lead time (to 2025) was assumed to allow for (partial) operationalisation of heavy-duty vehicle charging infrastructure and power asset build (i.e., transmission upgrades).

Feed Supplements (1/2)

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Dietary manipulation, such as feedstock supplements – based on seaweed or microbes or insects or botanical compounds – for ruminants to address enteric fermentation emissions. Different feedstock supplements are considered including biochar, tannins, antibiotic rumen modifiers, etc. Asparagopsis (red algae) and 3-NOP are selected as proxies for feed supplements given 1) they are estimated to be the most effective feedstock supplement and have routinely delivered over 20% mitigation of enteric methane, and 2) applicable for dairy cattle, beef cattle and sheep. The cumulative impact of feed supplements with herd management is not considered given the current lack of research and trials in this space.

Form of emission abatement: reduced enteric emissions of cattle and sheep

Overview of the MAC approach

MAC unit: per head

Overall: Three categories of livestock were considered: dairy cattle, beef cattle and sheep. The compounding impact of applying multiple feed supplements (e.g., Asparagopsis with oils) is not considered due to (currently) a lack of information. The feed intake calculations are based on the methodology outlined in the Dairy Greenhouse Accounting Framework and Sheep and Beef GHG Accounting Framework. Calving emissions are not considered.

Costs components included are: Asparagopsis and 3-NOP supplement.

The specific approaches to the corresponding to the cost components are:

- A Department of Primary Industries' report (Waters, C., Cattleie, A., Wang, B., Simpson, M., Gray, J., Simmons, A. and Stephens, S.) was used as the primary report to inform the efficacy and deployment assumptions.
- The efficacy of Asparagopsis and 3-NOP supplement varies significantly depending on the dosage (i.e., percentage included in dry matter), duration of feeding, and emission capturing/calculation approach. The industry acknowledges additional longer-term and at-scale research is required. Compared seven data points for asparagopsis and three data points for 3-NOP to inform the assumed efficacy for dairy cattle, beef cattle and sheep. Assumed the following methane reduction: dairy (75% reduction), beef cattle (80% reduction), and sheep (2% reduction); which is aligned with the overall methane reduction assumed by DPI (50% reduction).
- There is limited public information about the cost of supplements by dosage (i.e., methane reduction efficacy), likely because this information is still commercial-in-confidence. The market price, dosage and efficacy are informed by general research and industry discussions (as discussed and agreed with the reviewers). Also assumed the cost of supplement based on the relative ratio of asparagopsis or 3-NOP to dry matter (i.e., dosage), adjusted to the assumed methane reduction percentage for each category of livestock. As more information emerges, the inputs below should be updated to reflect the latest commercial information.
- Regarding the application of feed supplements, majority of research and trials have been limited to feedlots, and it still needs to be determined whether the same efficacy can be achieved through slow-release forms/grazing (there are trials currently underway). For simplicity, assumed that the same efficacy is achievable (by 2050) regardless of the method of feeding.
- Assumed no additional capital investment is required to distribute either asparagopsis or 3-NOP supplement.
- Assumed a market share of 50:50 between asparagopsis and 3-NOP.
- Assumed no impact on livestock weight, given studies yielded inconsistent results (some reported up to 42% increase in weight, while others reported a reduction in weight).

Feed Supplements (2/2)

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Overview of the assumed deployment approach

“Natural” deployment is assumed to be gradual, based on the assumption that farmers will gradually introduce feed supplements. Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 2.3 Mt CO2-e, reaching a total abatement potential of 4.1 Mt CO2-e (once baseline emission abatement is included) by 2050. This solution is already assumed to be deployed under baseline (NZM team applied an overall 30% reduction by 2050 based on commitments from Meat and Livestock Australia, National Farmers Federation and Dairy Australia, both organisations recognise feed supplements as a key decarbonisation enabler). Assumed 80% of the baseline reduction (i.e., 80% of the 30% reduction) is attributable to feed supplementation; and the remaining 20% of baseline reduction (i.e., 20% of the 30% reduction) is attributable to herd management. During the discussion with the reviewers, another report was identified as a referable source (Meat and Livestock Australia, link). However, this report - when compared to the primary report (by DPI) - was overly optimistic about the effectiveness of herd management: “1) sheep emissions can reduce 59.8% from herd management and 39.5% from feed additives; 2) pasture beef cattle can reduce 72.5% from herd management and 19.9% from feed additives". As such, did not use this source to inform the baseline deployment assumption. Assumed effectiveness of 49% and maximum deployment of 39% (based on weighted average effectiveness and deployment by dairy cattle, beef cattle and sheep per the primary report). Assumed additional deployment can start from 2025 (to allow lead time for 1) additional R&D (in grazing), 2) to implement industrial-scale Asparagopsis to supplement production) and continue until 2040, based on a general S-curve deployment.

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	-
CAPEX - avoided	AUD	-
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	56
Solution Life	Years	Varied
Learning rate (on CAPEX)	Per annum	0%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(0.22)
Net Grid Electricity	MWh per annum	-
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Herd Management (1/2)

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Herd management practices to reduce emissions intensity of livestock (e.g., early breeding, culling poor performers, enhancing fertility, improving animal health, and breeding for low methane production). The compounding impact of feed supplement and herd management is not considered due to (currently) a lack of information.

Form of emission abatement: reduced enteric emissions of livestock

Overview of the MAC approach

Overall: Three categories of livestock was considered: dairy cattle, beef cattle and sheep. The compounding impact of applying multiple non-dietary measures (e.g., herd management with pasture management) is not considered due to (currently) a lack of information.

Costs components included are: Core: 1) Development of herd management practices, and 2) Implementation of herd management practices.

The specific approaches to the corresponding to the cost components are:

1) A Department of Primary Industries' report (Waters, C., Cattleie, A., Wang, B., Simpson, M., Gray, J., Simmons, A. and Stephens, S.) was used as the primary report to inform herd management approaches. It mentions "[as of 2020] Herd management has had limited uptake nationally. Eligible activities under this method include installing fences, planting improved pastures, improving herd genetics and increased density of water points. Low adoption is considered to have resulted from a lack of awareness and a perception of onerous monitoring, reporting and verification requirements, but the primary factor is considered to be the size of a herd required to develop a viable project." This report is also used to inform the efficacy and deployment assumptions.

1) The Meat and Livestock Australia's Carbon Neutral Roadmap was used to inform the costings for the development of herd management practices. The R&D funding specified by Meat and Livestock Australia is only applicable to red meat, but assume the same investment is required for sheep. Conservatively assumed ongoing investment so herd management takes into account 1) the latest agriculture trends and 2) climate impact, etc.

2) Conservatively assumed implementation of herd management practices will have a net cost of zero to the farms. While there is an upfront cost, assume it would be offset by increased profitability from greater productivity. Per the Department of Primary Industry report: "Herd management practices are all consistent with good management and increased profitability, so should be readily adopted." As more information emerges, the inputs below should be updated to reflect actual market information.

Herd Management (2/2)

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Overview of the assumed deployment approach

"Natural" deployment is assumed to be gradual, based on the assumption that farmers will gradually adopt better herd management practices. Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 1 Mt CO2-e, reaching a total abatement potential of 1.4 Mt CO2-e (once baseline emission abatement is included) by 2050. This solution is already assumed to be deployed under baseline (NZM team applied an overall 30% reduction by 2050 based on commitments from Meat and Livestock Australia, National Farmers Federation and Dairy Australia, both organisations recognise herd management as a key decarbonisation enabler). Assumed 80% of the baseline reduction (i.e., 80% of the 30% reduction) is attributable to feed supplementation; and the remaining 20% of baseline reduction (i.e., 20% of the 30% reduction) is attributable to herd management. During the discussion with the reviewers, another report was identified as a referable source (Meat and Livestock Australia, link). However, this report - when compared to the primary report (by DPI) - was overly optimistic about the effectiveness of herd management: "1) sheep emissions can reduce 59.8% from herd management and 39.5% from feed additives; 2) pasture beef cattle can reduce 72.5% from herd management and 19.9% from feed additives". As such, did not use this source to inform the baseline deployment assumption. Assumed effectiveness of 12% and maximum deployment of 69% (based on weighted average effectiveness and deployment by dairy cattle, beef cattle and sheep per the primary report). Assumed additional deployment can start from 2025 (to allow lead time for 1) additional R&D (to determine the practices required to implement herd management effectively)) and continue until 2040, based on a general S-curve deployment.

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	-
CAPEX - avoided	AUD	-
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	0.16
Solution Life	Years	Varied
Learning rate (on CAPEX)	Per annum	0%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(0.05)
Net Grid Electricity	MWh per annum	-
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Mining Vehicle Electrification

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Vehicle electrification technology in mining involves replacing diesel–fuelled mining vehicles with battery–electric ones, utilising battery power instead of combustion engines.

Form of emission abatement: fuel-switch (from diesel to electric)

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	187,538,937
CAPEX - avoided	AUD	(81,954,887)
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	(2,118,792)
Solution Life	Years	10
Learning rate (on CAPEX)	Per annum	2%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(49,994.2)
Net Grid Electricity	MWh per annum	99,740
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	1,287,827,495
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Overview of the MAC approach

MAC unit: per mine site

Costs components included are: Core: 1) Vehicle cost, Support: 2) Charging infrastructure for vehicles and mine site electricity infrastructure upgrades, and Avoided: 3) Difference in energy costs (i.e., increased electricity costs and reduced diesel costs).

The specific approaches to the corresponding to the cost components are:

1) Three vehicle types are considered: haul trucks, loaders and excavators. Assume the ratio of vehicles will remain the same into the future; and applied a weighted average approach (instead of straight average) to calculate the CAPEX - incurred, CAPEX - avoided, net OPEX and net emissions per vehicle. For simplicity, applied battery life of 10 years as the solution life for Light-duty BEV and ICE vehicle life of 25 years as the replaced solution life (the latter is used to adjust the incurred CAPEX when deployment is accelerated).
2) Supporting CAPEX is split into two categories: a) per vehicle and b) per mine site. Per vehicle CAPEX is calculated on the amount of charging points required on a mine site based on the number of vehicles. Per mine site is calculated based on the electricity network transmission and distribution installation and per or upgrades required.
3) Considered avoided diesel costs, taking into consideration the relative energy efficiency of electric to ICE mining vehicles.

Overview of the assumed deployment approach

"Natural" deployment is assumed to be gradual, based on the assumption that the availability of biofuel will increase over time. Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 1 Mt CO2-e, reaching a total abatement potential of 1 Mt CO2-e (once baseline emission abatement is included) by 2050. This solution is not assumed to be deployed under baseline. Assumed additional deployment can start from 2031 and continue until 2050, based on gradual deployment. The eight years lead time (to 2031) was assumed to enable learning rates to reduce the CAPEX costs and lead-time required for charging infrastructure and power asset build (i.e., transmission upgrades).

Cement Produced with Alternative Raw Material

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Cement produced with 1) low emissions geopolymer cement and 2) novel cement formulations that combine geopolymer and Portland cements / fly ash as alternatives to traditional Portland cement.

Form of emission abatement: better emission efficiency (through use of alternative inputs)

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	159,965,000
CAPEX - avoided	AUD	(139,100,000)
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	35,817,555
Solution Life	Years	20
Learning rate (on CAPEX)	Per annum	0%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(962,000)
Net Grid Electricity	MWh per annum	-
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Overview of the MAC approach

MAC unit: per site

Costs components included are: **Core**: 1) Facility for geopolymer cement and high-blend and magnesium cement and **Avoided**: 2) Facility for ordinary Portland cement.

The specific approaches to the corresponding cost components are:

1) Two green cement types were considered: geopolymer cement and high-blend and magnesium cement. Assumed 100% of cement production in NSW will transition to geopolymer cement, given there is only one cement plant in NSW.
2) Currently, there is limited information about the capital cost of geopolymer cement facility; hence assumed a relative capital cost based on an EPA report. This should be updated once more market information emerges.
2) Boral Berrima production (specifically from Kiln 6) is used to inform inputs for ordinary Portland cement.

Overview of the assumed deployment approach

"Natural" deployment is assumed to be once-off, given NSW only has one cement plant (Boral Berrima). Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 0.76 Mt CO2-e, reaching a total abatement potential of 0.76 Mt CO2-e (once baseline emission abatement is included) by 2050. Assumed all Scope 1 emissions from non-metallic minerals is from cement production in NSW, where 76% of emissions could be abated with geopolymer cement. This solution is not assumed to be deployed under baseline. Assumed Boral could look to upgrade its facilities to Geopolymer Cement in 2027. Given the last significant upgrade to Boral Berrima occurred in 2007 (commissioning of Mill No 7) and based on Portland Cement Plant's natural end of useful life of 20 years (2007 + 20).

Industrial Heat Pump

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Industrial electric heating solution in manufacturing involves the use of industrial heating equipment that operates at low, medium, and high temperatures, utilising renewable electricity instead of fossil fuels.

Form of emission abatement: fuel-switch (from diesel to grid electricity)

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	159,965,000
CAPEX - avoided	AUD	(139,100,000)
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	35,817,555
Solution Life	Years	20
Learning rate (on CAPEX)	Per annum	0%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(962,000)
Net Grid Electricity	MWh per annum	-
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Overview of the MAC approach

MAC unit: per site

Costs components included are: Core: 1) industrial heat pump system cost, and 2) differential in energy costs, Avoided: 3) conventional heating system.

The specific approaches to the corresponding cost components are:

1) Industrial heat pump systems are selected as a proxy for industrial electric heating. Industrial heat pump system for heating up to 95°C are readily available, and systems that can heat up to 110°C are becoming more common. The maximum heat output from industrial heat pumps achieved to date is 165°C in some Japanese systems in demonstration projects. In comparison, Australia's uptake of industrial heat pumps is relatively low, and application needs to be bespoke. As such, the primary report is based on a report from IEA Japan Commission, which compared 17 case studies of industrial heat pumps, ranging from food and agriculture to chemicals use. The CAPEX, OPEX and energy inputs used are specific to a heat pump that is used to maintain a temperature of 60°C for washing and cutting.

1 and 3) The primary report assumes the boiler will switch from diesel-fuelled boiler to industrial heat pump. However, Australia primarily rely on natural gas to fuel boilers - hence have estimated the avoided natural gas separately.

2) When considering the net electricity and net natural gas consumption, the coefficient of performance has been considered. Assumed the same coefficient of performance as household heat pump (4 for water heating) per the IEA.

As more information emerges, the inputs above should be updated to reflect high-temperature industrial heat pumps (up to 250°C) deployed in the Australian context.

Overview of the assumed deployment approach

Additional "Natural" deployment is assumed to be gradual, given several NSW plants use industrial heating in their manufacturing processes. Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 1.9 Mt CO2-e, reaching a total abatement potential of 2.9 Mt CO2-e (once baseline emission abatement is included) by 2050. Assumed 53% of Scope 1 emissions from manufacturing (excluding non-metallic minerals) could be attributed to industrial heating and can be abated using this solution. This solution is not assumed to be deployed under baseline.

Household Heat Pumps – Space and Water

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Heat pumps utilise vapour compression refrigeration cycle solution to provide heating or heating and cooling capabilities in residential, commercial and institutional buildings. Heat pumps can heat water or air and function in reverse cycle units. They are designed to replace gas–powered heaters and/or electricity–powered air conditioning systems. Heat pumps that use emission-generating coolants are not considered part of this solution and are assumed to be gradually phased out.

Form of emission abatement: fuel-switch (from natural gas to grid electricity)

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	6,952
CAPEX - avoided	AUD	(6,008)
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	82
Solution Life	Years	12
Learning rate (on CAPEX)	Per annum	4%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(2)
Net Grid Electricity	MWh per annum	2
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	(45)

Overview of the MAC approach

MAC unit: per dwelling

Costs components included are: Core: 1) appliance cost Support: 2) installation cost, and Avoided: 3) difference in gas/electricity cost.

The specific approaches to the corresponding cost components are:

1) Both water and space heating has been considered. Hence each household is assumed to require two heat pumps. Costings for water and space heat pumps is sourced from IEA. An assumed adjustment factor of 80% have been included to account for the economies of scale that can be achieved in apartment water and space heat pumps.
2) The cost of installation is already included in the water and space heat pump costs, and hence has not been included separately.
3) Assumed 30% of dwellings will power heat pumps with rooftop solar (as discussed and agreed with stakeholders), which is broadly consistent with rooftop solar uptake in NSW. As such, the remaining 70% of dwellings is assumed to be powered with grid electricity. Also conservatively assumed wholesale electricity prices (AUD per MWh) as a proxy for rooftop solar prices.
3) When considering the net electricity and net natural gas consumption, the coefficient of performance has been considered (4 for water heating and 7 for space heating).

Overview of the assumed deployment approach

"Natural" deployment is assumed to be gradual, based on the assumption that households will gradually switch to heat pumps as their existing water/space heating appliances reach the end of their asset lives. Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 0.8 Mt CO2-e, reaching a total abatement potential of 0.8 Mt CO2-e (once baseline emission abatement is included) by 2050. This solution is not assumed to be deployed under baseline as Sustainable Building SEPP (one of the primary policies identified in the baseline scenario) does not list heat pumps as one of the solutions. While there is an avg. 9% NSW households with two heat pumps, the emissions reduced from heat pumps should already be already incorporated in the FY23 emissions. The following emissions sources are considered: stationary energy - residential, stationary energy- commercial/institutional and IPPU - product uses as ODS substitutes. The latter has been added based on advice from stakeholders (NZM team). Assumed household heat pumps could abate 53% residential emissions and 20% commercial/industrial emissions, household appliances electrification could abate 23% residential emissions and 80% commercial/industrial emissions, and building efficiency improvement could abate 24% residential emissions and 0% commercial/industrial emissions. Assumed an additional uptake of 90% is feasible (reaching a total of 99% uptake, including current uptake of 9%) given heat pumps are readily available. Given this solution is readily available, assumed additional deployment can start from 2024 and continue until 2050, based on a general S-curve deployment.

Household Appliances Electrification and Efficiency

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

A selection of electric, high efficiency household appliances, including 1) electric instead of gas–powered cooktops and ovens, and 2) five-star efficient clothes washer/dryer, etc. These appliances are applicable to residential, commercial and institutional buildings.

Form of emission abatement: fuel-switch (from natural gas to grid electricity) and more efficient energy use

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	7,186
CAPEX - avoided	AUD	(2,299)
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	(405)
Solution Life	Years	10
Learning rate (on CAPEX)	Per annum	-
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(0.98)
Net Grid Electricity	MWh per annum	(0.60)
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	(0)

Overview of the MAC approach

MAC unit: per dwelling

Costs components included are: Core: 1) appliance cost Support: 2) retrofitting cost, Avoided: 3) difference in gas/electricity cost.

The specific approaches to the corresponding cost components are:

1) Only cooking appliances will undergo electrification. Cooking electrification is limited to induction cooktop with oven, given deep fryers, griddle and chargrill are not common across all households in NSW. Assumed solution/ replaced solution life of 10 years based on average appliance life.
1) Other electrical appliances (except for heating and lighting, which are covered under heat pumps and building efficiency respectively) will become more efficient. Assumed each dwelling would - on average – purchase five more efficient electrical appliances, including washer, fridge, dryer, TV and other monitors, and dishwashers. The price differential of less/more efficient washer is used as a proxy for all household appliances.
2) The cost of installation, removal, rectification, and power supply upgrade have been considered. Assuming that it would consist of 10% of the total cost to electrify a dwelling.
3) The energy saving of changing from gas to induction cooktop and oven have been considered when estimating the energy required.

Overview of the assumed deployment approach

"Natural" deployment is assumed to be gradual, based on the assumption that households will gradually electrify their stovetop/oven and switch to more efficient appliances as their existing appliances reach end of asset life. Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 1.4 Mt CO2-e, reaching a total abatement potential of 3.1 Mt CO2-e (once baseline emission abatement is included) by 2050. This solution is already assumed to be deployed under baseline. The Sustainable Building SEPP considers household appliances electrification and efficiency and building efficiency. The emissions sources are considered: stationary energy - residential, stationary energy- commercial/institutional and IPPU - product uses as ODS substitutes. The latter has been added based on advice from stakeholders (NZM team). Assumed household heat pumps could abate 53% residential emissions and 20% commercial/industrial emissions, household appliances electrification could abate 23% residential emissions and 80% commercial/industrial emissions and building efficiency improvement could abate 24% residential emissions and 0% commercial/industrial emissions. Assumed eventual full deployment (of 99%), assuming government will support low-income households to transition. Given this solution is readily available, assumed additional deployment can start from 2024 and continue until 2050, based on a general S-curve deployment.

Building Efficiency Improvements

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Building efficiency improvements involve the implementation of efficient lighting and thermal building components installed as design enhancements for new and existing buildings. This includes considerations such as building orientation, envelope materials and daylight capturing solutions. These improvements are applicable to residential, commercial and institutional buildings.

Form of emission abatement: energy efficiency

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	11,990
CAPEX - avoided	AUD	(384)
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	(416)
Solution Life	Years	20
Learning rate (on CAPEX)	Per annum	0%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(1.04)
Net Grid Electricity	MWh per annum	(0.59)
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	20

Overview of the MAC approach

MAC unit: per dwelling

Costs components included are: **Core**: More efficient 1) Lighting and 2) HVAC, **Supporting**: 3) change in natural gas and electricity consumption.

The specific approaches to the corresponding to the cost components are:

2) HVAC includes measures such as draught sealing, wall and floor insulation (double glazing has been excluded due to significant costs, upwards of $12k per dwelling). For HVAC costings, the primary report used (Comprehensive Energy Efficiency Retrofits to Existing Victorian Houses) is specific to retrofitting.

Assumed 20 years of solution/ replaced solution life based on typical insulation life.

Overview of the assumed deployment approach

"Natural" deployment is assumed to be gradual, based on the assumption that households will improve building efficiency over time (constrained by changes in home ownership / availability and price of labour). Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 0.2 Mt CO2-e, reaching a total abatement potential of 0.3 Mt CO2-e (once baseline emission abatement is included) by 2050. This solution is already assumed to be deployed under baseline. The Sustainable Building SEPP considers household appliances electrification and efficiency and building efficiency. The emissions sources are considered: stationary energy - residential, stationary energy- commercial/institutional and IPPU - product uses as ODS substitutes. The latter has been added based on advice from stakeholders (NZM team). Assumed household heat pumps could abate 53% residential emissions and 20% commercial/industrial emissions, household appliances electrification could abate 23% residential emissions and 80% commercial/industrial emissions, and building efficiency improvement could abate 24% residential emissions and 0% commercial/industrial emissions. Assumed 80% maximum deployment, given the high upfront cost of building retrofits may deter some low-income households or landlords that will not benefit from the cost savings. Given this solution is readily available, assumed additional deployment can start from 2024 and continue until 2050, based on a general S-curve deployment.

Primary Smelting – Aluminium and Minerals – Inert Anode

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Inert anode cells can replace the carbon anodes consumed during mineral smelting. Greenhouse gas, in the form of sulphur dioxide (SO_2) is produced during smelting when oxygen in the air reacts with sulphur in the carbon anodes. This reaction does not occur when using inert anodes; hence removing SO_2 emissions from the smelting process.

Form of emission abatement: process efficiency

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	5,282,519,605
CAPEX - avoided	AUD	(2,235,993,618)
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	(11,743,421)
Solution Life	Years	20
Learning rate (on CAPEX)	Per annum	0.5%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(1,207,850)
Net Grid Electricity	MWh per annum	-
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Overview of the MAC approach

MAC unit: per site

Costs components included are: Core: 1) Aluminium smelter that is configured to inert anodes, Avoided: 2) Aluminium smelter that is configured to carbon anodes, and 3) change in electricity consumption.
The specific approaches to the corresponding cost components are:

1 and 2) One primary report (Making net-zero aluminium possible, Mission Possible Partnership) was used to inform the CAPEX and OPEX for the inert anode smelter, while a Tomago report was used to inform the CAPEX of the carbon anode smelter.

3) Conservatively assumed equal electricity consumption for the two types of facilities.

Overview of the assumed deployment approach

'"Natural" deployment is assumed to be once-off, given NSW only has one aluminium smelter (Tomago Aluminium). Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 1.5 Mt CO2-e, reaching a total abatement potential of 1.5 Mt CO2-e (once baseline emission abatement is included) by 2050. Calculated Tomago Smelter's current Scope 1 emissions (adjusted for growth in emissions in this subsector), where 100% of emissions could be abated with inert anode. This solution is not assumed to be deployed under baseline. Assumed Tomago Aluminium will upgrade to inert anode smelter in 2036. The last significant upgrade occurred in 2016 (approval to increase capacity to 600,000 tonnes of saleable metal) and based on natural end of useful life of 20 years, assumed the upgrade could occur in 2036.

Iron and Steel – Direct Reduced Iron produced using Green Hydrogen

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Direct reduced iron produced using green hydrogen instead of natural gas and coal.

While Scrap EAF iron was also considered, it was not included given it was not identified as part of BlueScope's decarbonisation strategy.

Form of emission abatement: fuel-switch (from natural gas and coal to green hydrogen and grid electricity)

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	5,282,519,605
CAPEX - avoided	AUD	(2,235,993,618)
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	(11,743,421)
Solution Life	Years	20
Learning rate (on CAPEX)	Per annum	0.5%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(1,207,850)
Net Grid Electricity	MWh per annum	-
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Overview of the MAC approach

MAC unit: per site

Costs components included are: Core: 1) Hydrogen-fuelled direct reduce iron electric arc furnace (H_2-DRI-EAF) Supporting: 2) transmission upgrade, 3) site upgrades, 4) difference in fuel, Avoided: 5) Blast Furnace - Basic Oxygen Furnace (BF-BOF).

The specific approaches to the corresponding cost components are:

1 and 4) The H_2-DRI-EAF production pathway will completely replace the existing BF-BOF production pathway

2 and 3) As discussed and agreed with stakeholders, assumed the electric arc furnace will be powered by electricity from the grid and offsite hydrogen (instead of behind-the-meter electricity and/or on-site hydrogen production). Consistent with current agreements, assumed wholesale electricity prices (instead of retail electricity prices) given the plant would be a significant industrial electricity user.

2 and 3) Included transmission and site upgrades - based on the capacity of the H_2-DRI-EAF (exclusive of electrolyser capacity - given the electric arc furnace would be powered by grid electricity.

4) Informed by CSIRO projections, the learning rate of hydrogen (as AUD per kg H_2) is considered separately. The cost of hydrogen (OPEX) is added separately.

Overview of the assumed deployment approach

"Natural" deployment is assumed to be once-off, given NSW only has one steel plant (Port Kembla). Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 4.9 Mt CO2-e, reaching a total abatement potential of 4.9 Mt CO2-e (once baseline emission abatement is included) by 2050. Calculated Port Kembla's current Scope 1 emissions (adjusted for growth in emissions in this subsector), where 86% of emissions could be abated with H_2-DRI-EAF. This solution is not assumed to be deployed under baseline. Assumed BlueScope (Port Kembla Steelworks) could look to upgrade its facilities to H_2-DRI-EAF in 2040. Given (by their estimate) green steel solutions are unlikely to be viable until the 2040s.

Green Ammonia Produced using Green Hydrogen

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Green ammonia produced with green hydrogen, replacing traditional production method of steam methane reformer.

Form of emission abatement: fuel-switch (from grey hydrogen/grid electricity to green hydrogen/ behind the meter renewable electricity)

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	4,679,388,946
CAPEX - avoided	AUD	(392,206,715)
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	112,203,229
Solution Life	Years	25
Learning rate (on CAPEX)	Per annum	9%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(619,195)
Net Grid Electricity	MWh per annum	-
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	(12,016,214)

Overview of the MAC approach

MAC unit: per site

Costs components included are: Core: 1) hydrogen electrolyser, Support: 2) behind-the-meter solar and battery storage and Avoided: 3) steam methane reformer.

The specific approaches to the corresponding cost components are:

1) Assume the hydrogen electrolyser and ammonia production are co-located.

1 and 3) Hydrogen electrolyser will replace steam methane reformer. Given the hydrogen will continue to undergo the Haber Bosch process for ammonia production (i.e., no changes will be made), the Haber Bosch component is not included in the costings. Green ammonia production is assumed to release no GHGs (i.e., no hydrogen leakage, renewably powered Haber Bosch).

2) The hydrogen electrolyser will be supplied by behind the meter electricity instead of grid electricity (consistent with current direction of industrial hydrogen production). Hence the cost of transmission upgrades are not incorporated in the costings.

2) For behind the meter electricity generation, assumed a ratio of 0.4 kW of battery for 1 kW of solar to ensure stable electricity source for the hydrogen electrolyser. This is consistent with CSIRO's latest modelling.

2) The learning rate of hydrogen is considered as part of this solution given hydrogen is produced on-site.

Overview of the assumed deployment approach

"Natural" deployment is assumed to be once-off, given NSW only has one ammonia plant (Orica Kooragang Island). Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 0.8 Mt CO2-e, reaching a total abatement potential of 0.8 Mt CO2-e (once baseline emission abatement is included) by 2050. Calculated Orica Kooragang Island ammonia plant's current Scope 1 emissions (adjusted for growth in emissions in this subsector), where 100% of emissions could be abated with green ammonia produced using green hydrogen. This solution is not assumed to be deployed under baseline. Assumed Orica could look to upgrade its facilities to green hydrogen/ammonia facilities in 2029. The last significant upgrade of the Kooragang Island ammonia plant occurred in 2004 (third nitric acid plant) and based on natural end of useful life of 25 years, assumed the upgrade could occur in 2029.

Multiple Applications – Carbon Capture, Utilisation and Storage

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

CCUS can be deployed broadly across subsectors, particularly in IPPU and stationary energy to capture flue gas from industrial production. Key applications considered for NSW are CCUS deployment in production processes for iron and steel, ammonia and cement. The amine-based CO_2-e absorption and desorption process is considered as a proxy for this solution given it is currently the most mature technology for carbon capture. It can be built together with a new process plant or as a retrofit to an existing process plant.

Form of emission abatement: emission capturing

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	418,631,549
CAPEX - avoided	AUD	-
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	140,480,621
Solution Life	Years	25
Learning rate (on CAPEX)	Per annum	6%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(839,104)
Net Grid Electricity	MWh per annum	243,716
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Overview of the MAC approach

MAC unit: per site

Costs components included are: Core: 1) Amine-based carbon capture facility, Supporting: 2) Transport and storage.
The specific approaches to the corresponding cost components are:

1) The cost of carbon capture facility varies greatly depending on industrial application, methodology and location. One primary report (Solomon Aforkoghene Aromada, Nils Henrik Eldrup, Lars Erik Øi) was used to inform the CAPEX, OPEX and emission captured, given it aggregated seven different studies (for seven different carbon capture facilities across the globe).
1) A site capturing 955,000 tonnes of carbon is considered based on the primary report.
1) The net electricity use of the carbon capture facility was also considered. At the time of writing, there was a lack of reputable, publicly-available research reports, hence information from a current project - an amine based carbon capture technology for Cleco's Madison Unit 3 (a US-based power plant) - was considered. The Madison Unit 3 is one of the three power-generating units for Cleco's Brame Energy Centre. The carbon capture facility was reported to require more than 30% of Madison Unit 3's electricity generation to capture up to 95% of its emissions.
1) The amine-based carbon capture facility is assumed to be powered by grid electricity; however, it is not costed separately since it is already included in the OPEX/tonne sourced from the primary report.
2) Carbon transport and storage is considered separately since it is not covered by the primary report. Transport and storage costs also vary greatly based on the volume of carbon stored and distance travelled. The current estimate is based on upper (conservative) end of best case (short transport distances to storage formations with good characteristics) in the Australian context.
2) The downstream emissions from transport, storage or utilisation have not been considered.

Overview of the assumed deployment approach

"Natural" deployment is assumed to be gradual (modifications to fit one CCUS for a site every five years), for NSW's manufacturing, metals, chemicals and minerals industries. Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 3.3 Mt CO2-e, reaching a total abatement potential of 3.3 Mt CO2-e (once baseline emission abatement is included) by 2050. Calculated IPPU and Stationary Energy's residual emissions, after considering the emissions abated through 1) cement produced through alternative raw material, 2) industrial heat pump, 3) household heat pumps - space and water, 4) household appliances electrification and efficiency, 5) buildings efficiency improvements, 6) aluminium - primary smelting-inert anode, 7) H_2-DRI, EAF, and 8) Green ammonia produced using green hydrogen. Assume 88% (carbon capture rate of CCUS) of residual emissions could be abated with CCUS, and a maximum deployment rate of 80% by FY50. This solution is not assumed to be deployed under baseline. Based on the assumption that deployment will be rolled out across five deployments, the NSW state is assumed to fit ~5 CCUS on five sites in total.

Underground Mining Drainage – Power Generation

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Utilisation of fugitive methane emissions from underground mines for power generation. The combustion of methane avoids direct release of methane into the atmosphere, which has a much higher global warming potential while providing a source of energy.

After discussion with key stakeholders, adjusted the solution to focus on underground mines (instead of underground and open cut).

Form of emission abatement: fugitive emissions combustion

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	13,633,657
CAPEX - avoided	AUD	-
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	(2,203,514)
Solution Life	Years	10
Learning rate (on CAPEX)	Per annum	0%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(104,274)
Net Grid Electricity	MWh per annum	(7,470)
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Overview of the MAC approach

MAC unit: NSW state-wide

Cost components included are: Core: 1) power generation and Avoided: 2) change in electricity consumption.
The specific approaches to the corresponding cost components are:
1) A Palaris report (Preliminary Analysis of Coal Emissions Abatement) provided for this project was used as the primary report to inform the cost components and assumptions. Only included power generation in the core cost component, given most NSW underground mines sites already have pre-drainage systems in place. Assumed a capacity factor of 40% for the power generation.
2) Assumed mine sites would have paid retail electricity costs (which is partially avoided through the use of power generation)

Overview of the assumed deployment approach

"Natural" deployment, across three NSW underground mine sites, is assumed to occur in 2025 (as discussed and agreed with key stakeholders). Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 0.1 Mt CO2-e by 2049. Based on discussion with stakeholders, and informed by NGER emissions data, confirmed that three NSW underground mine sites (Appin Mine, Ashton Mine and Narrabri Mine) could implement this decarbonisation solution. Of which, each mine site could capture and generate power from either 7% of 100% of fugitive emissions (i.e., assumed pre-drainage capture efficiency). Assumed all power generation assets will be retired at 2050 given the three applicable NSW underground mine sites are scheduled to close in 2050. For underground coal mines that don't report drainage and ventilation of fugitive methane emissions separately, a default split of 93% ventilation and 7% drainage has been used (source - only including drained gas and ventilation air methane). This decarbonisation solution is already deployed under baseline for some mine sites, which have been excluded from the selection and calculation respectively.

Ventilation Air Methane Oxidation (only applicable to underground mines)

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Ventilation air methane oxidation captures fugitive methane emissions from underground mines and converts it to CO_2 and water vapour. Avoids the direct release of methane into the atmosphere, which has a much higher global warming potential. Regenerative Thermal Oxidiser (RTO) technology is used as a proxy for this solution.

Form of emission abatement: fugitive emissions combustion

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	19,579,577,188
CAPEX - avoided	AUD	-
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	1,823,807,063
Solution Life	Years	17
Learning rate (on CAPEX)	Per annum	2%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(113,104,595)
Net Grid Electricity	MWh per annum	-
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Overview of the MAC approach

MAC unit: NSW state-wide

Cost components included are: Core: 1) Costs related to Regenerative Thermal Oxidiser (RTO) technology (installation & operation).
1) A Palaris report (DPIE Commissioned Report: Opportunities of fugitive emissions abatement) provided for a previous DCCEEW project was used as the primary report to inform the cost components and assumptions. Only included RTO technology costs, assuming that Maxwell and Myuna costings as outlined in the Palaris report are representative of typical underground mines.

Overview of the assumed deployment approach

"Natural" deployment, across three NSW underground mine sites, is assumed to occur in 2025 (as discussed and agreed with key stakeholders). Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 1.5 Mt CO2-e by 2049. Based on discussion with stakeholders, and informed by NGER emissions' data, confirmed that seven NSW underground mine sites (Appin Mine, Ashton Mine. Mandalong Mine, Myuna Mine, Narrabri Mine, Tahmoor Mine and Wambo Mine) could implement this decarbonisation solution. Of which, each mine site could capture 93% to 100% of methane (the 93% sites correspond to the sites that will deploy power generation with drainage) and oxidates 97%. Assumed all VAM oxidation assets will gradually retire over the 2040s. By 2050, the additional VAM assets will all retire given the seven applicable NSW underground mine sites are scheduled to close. For underground coal mines that don't report drainage and ventilation fugitive methane emissions separately, a default split of 93% ventilation and 7% drainage has been used (source - only including drained gas and ventilation air methane). This decarbonisation solution is already deployed under baseline for some mine sites, which have been excluded from the selection and calculation respectively.

Waste Drainage – Power Generation

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Utilisation of methane emissions from organics in landfill for power generation.

Form of emission abatement: fugitive emissions combustion

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	429,002,525
CAPEX - avoided	AUD	-
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	(37,543,075)
Solution Life	Years	10
Learning rate (on CAPEX)	Per annum	1%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(3,368,158)
Net Grid Electricity	MWh per annum	(202,068)
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Overview of the MAC approach

MAC unit: NSW state-wide

Cost components included are: Core: 1) power generation, Supporting: 2) capture and flaring infrastructure and Avoided: 3) change in electricity consumption.
The specific approaches to the corresponding cost components are:
1) A USA EPA document (Landfill Gas Energy Cost Model: Version 3.5) was used as the primary report to inform the cost components and assumptions. Considered power generation costs, including cost of gas compression/treatment, microturbine/generator, site work, housings, and electrical interconnect equipment.
2) Methane capturing and flaring infrastructure has been included as supporting infrastructure, given not all NSW landfill sites have this supporting infrastructure.
3) Assumed landfill sites would have paid retail electricity costs (which is partially avoided through the use of power generation)

Overview of the assumed deployment approach

"Natural" deployment, across NSW landfill sites is assumed to occur gradually.
Additional deployment considers the additional emission abatement potential above what is forecasted by the NZM team (under their Base Case scenario, i.e., baseline). This approach is consistent across all (except whole-of-economy) solutions. Assumed this solution could abate an additional 3.9 Mt CO2-e by 2049, reaching a total abatement potential of 3.9 Mt CO2-e (once baseline emission abatement is included) by 2050. This solution is not assumed to be deployed under baseline. Assumed 98% of emissions could be abated with this solution. Assumed additional deployment can start from 2025 and continue until 2050, based on gradual deployment. This deployment trajectory allows orderly transition of all landfill sites.

Nature-based Solutions (1/2)

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Nature-based solutions conserve, restore and expand on natural ecosystems to sequestrate carbon emissions.

There are many nature-based solutions - projects currently registered with Verified Carbon Standard utilise approximately 36 different methodologies (e.g., mangrove, kelp/seagrass plantations, savanna fire management) related to agriculture, forestry and other land use. Of all possible solutions, two prominent, broader-based solutions were selected: 1) reforestation and afforestation (specifically mixed-species environmental plantings - block) and 2) soil carbon management (assumed to be applied in agriculture) as proxies for all nature-based solutions.

Form of emission abatement: emissions sequestration

Overview of the MAC approach

MAC unit: per hectare

Cost components included are: Core: 1) cost of reforestation and afforestation, and 2) cost of soil carbon management.

1 and 2) Four reports (one Department of Primary Industries' report, two CSIRO reports and one jointly funded by Australia Government and Meat and Livestock Australia) was used to inform the CAPEX, OPEX, sequestration rate and potential of reforestation, afforestation and the cost of soil carbon management. Assumed the authors considered best-practices for the respective solutions (e.g., incorporation of native forests/shrublands in mixed-species environmental plantings).

1 and 2) Reforestation and afforestation has an assumed sequestration rate of 50.2 tCO2-e per hectare per annum, while soil carbon management has an assumed sequestration rate of 0.05 tCO2-e per hectare per annum. These estimates are calculated based on the Department of Primary Industries' report (Waters, C., Cattleie, A., Wang, B., Simpson, M., Gray, J., Simmons, A. and Stephens, S.) and adjusted by 75% to incorporate the possible climate impact on abatement potential.

1 and 2) The primary reports did not consider land costs. Land cost is optimistically set to $0, based on the assumption that landowners will choose to undergo reforestation and afforestation or soil carbon management (per the report - Technical review of physical risks to carbon sequestration under the Emissions Reduction Fund, CSIRO Land and Water).

1 and 2) As discussed with stakeholders, ERF participation cost is not incorporated into the costings. This approach is consistently applied for other solutions.

1) Reforestation and afforestation CAPEX per hectare ($4,264 per hectare) is the midpoint cost between direct seeding and tube stock planting for mixed species planting. OPEX per hectare ($103 per hectare per annum) is assumed to include components such as monitoring, weed control and bushfire mitigation, etc to improve permeance of the stored carbon.

2) Soil carbon management CAPEX per hectare ($94 per hectare) includes baseline and activity capital; while OPEX per hectare is assumed to be zero.

1 and 2) The overall per hectare CAPEX, OPEX, and net emissions abatement is based on the relative ratio of the two solutions - as informed by the deployment assumptions.

Nature-based Solutions (2/2)

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Overview of the assumed deployment approach

Deployment will be gradual (given lead-time required to establish and expand the ecosystem). Additional deployment considers the sequestration potential of 1) reforestation and afforestation and 2) soil carbon management in NSW. This is calculated based on:

1) The NSW land suitable for mixed species planting or soil carbon management (per DPI report).

2) Assumed a percentage of suitable NSW land is used to deploy these solutions - this is assumed to be 1% and 10% respectively.

3) Apply the sequestration rates (adjusted for climate impact per the CSIRO Land and Water report) to arrive on the total emission abatement potential for NSW.

Based on this approach, this solution could abate an additional 7.4 Mt CO2-e by 2050 (given there is no baseline emission abatement). Overall, the assumed land used for this solution is est. ~16% of available land area (specifically cultivated terrestrial vegetated: Herbaceous & Natural terrestrial vegetated: Herbaceous in NSW), totalling 7.7 million hectares.

The following considerations have not been assessed separately through this project/ as part of CSIRO's report but are assumed to addressed by assuming smaller deployment percentages.

1) Impact of competing land-use of the different decarbonisation solutions (of green hydrogen facilities, renewable energy generation, herd management etc.)

2) Exclusion of land that is already marked for reforestation

3) Exclusion of land that already have a significant volume of carbon stored in the plants/soil (i.e., in the vegetative cover)

The report caveats that each abatement method is treated independently, and the implications of displacement of (or trade-offs with) current land use are not considered. Assumed additional deployment can start from 2024 and continue until 2050, based on a general S-curve deployment.

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	168
CAPEX - avoided	AUD	
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	2
Solution Life	Years	25
Learning rate (on CAPEX)	Per annum	0%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(0.95)
Net Grid Electricity	MWh per annum	-
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

GHG Removal – Direct Air Capture and Carbon Storage (1/2)

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

Direct Air Capture and Carbon Storage (DACCS) captures and stores CO_2-e directly from the atmosphere. The CO_2-e emissions can then be used for various applications (such as enhancing oil recovery) or be injected into geological formations and stored permanently. Capturing CO_2-e from the air is the most expensive application of carbon capture. The CO_2-e in the atmosphere is much more dilute than in, for example, flue gas from a power station or a cement plant. This contributes to DAC's higher energy needs and costs relative to these applications.

Two DAC approaches were considered - chemical liquid solvent DAC and solid sorbent DAC. Chemical liquid solvent DAC would require high-quality heat at 900°C - which is not available in industrial power generation waste streams. However, solid sorbent DAC would require lower quality heat at 100°C. the use of waste heat sources with solid sorbent DAC has the potential to offset 80% of the process energy requirements. As such, solid sorbent DAC paired with waste heat sources was considered for this solution.

Form of emission abatement: emission capturing

Summary of the FY24 MAC outputs

MAC section	Unit	Value
CAPEX - incurred	AUD	9,619,675
CAPEX - avoided	AUD	-
Net OPEX (exc. cost of hydrogen or biofuel)	AUD per annum	650,261
Solution Life	Years	10
Learning rate (on CAPEX)	Per annum	3%
Net Emissions Abatement (exc. impact of grid electricity)	tCO_2-e per annum	(4,000)
Net Grid Electricity	MWh per annum	1,667
Net Hydrogen or biofuel	Kg per annum	-
Net Diesel	Litres per annum	-
Net Petrol	Litres per annum	-
Net Natural Gas	GJ per annum	-

Overview of the MAC approach

MAC unit: per site

Costs components included are: Core: 1) Solid sorbent DAC facility, transport and storage, 2) land costs.
The specific approaches to the corresponding cost components are:

1) A small-scale site capturing 4000 tonnes of carbon is considered, which is based on the current biggest Climeworks solid sorbent DAC (direct air capture) facility located in Iceland. Given DAC is still at the early stage of technology development - the cost estimates used for this solution have a significant uncertainty range. To date, DAC plants have been successfully operated in a range of climatic conditions in Europe and North America, but further testing is still needed in locations characterised, for instance, by extremely dry or humid climates, or polluted air. As DAC matures and overcomes its technological and geological constraints, these cost estimates will naturally evolve and should be updated accordingly.
1) One primary scientific report (Noah McQueen, Peter Psarras, Hélène Pilorgé, Simona Liguori, Jiajun He, Mengyao Yuan, Caleb M. Woodall, Kourosh Kian, Lara Pierpoint, Jacob Jurewicz, J. Matthew Lucas, Rory Jacobson, Noah Deich, and Jennifer Wilcox) was used to inform the CAPEX and OPEX. This report compares the costs of three deployed sites.
1) The solid sorbent DAC is assumed to be powered by waste heat from geothermal energy, and its average energy requirement is approximately 80% thermal and 20% electrical.
2) Land costs for DAC has been included as this solution is expected to require additional land (contrasted with other solutions). Used the equivalent land inputs from the Climeworks solid sorbent DAC (direct air capture)facility located in Iceland to inform land costs.

Overview of the assumed deployment approach

Based on currently available information, assumed DACCS can be deployed from 2035 onwards. This is based on the assumption that DAC could overcome technological and geological constraints, while carbon storage could be scaled up effectively. IEA estimates DACCS could become commercially viable around the 2030s (source) which means this solution could be operational in NSW from 2035 onwards, given the 2 to 6 years lead time to construct.

GHG Removal – Direct Air Capture and Carbon Storage (2/2)

The solution description, MAC approach, the FY24 MAC inputs, and the assumed deployment approach is outlined below.

Solution Description

1) Per the IEA, the availability and cost of carbon storage is also highly uncertain. Limited availability of storage could constrain the possibility of both CCUS and DACCS (source). The downstream emissions from transport, storage or utilisation have not been considered. As more information emerges, the inputs below should be updated to reflect updated DACCS technology that is deployed in the Australian context.
3) Conservatively included cost of transmission and site upgrades (per AEMO and NREL), assuming that it has not been incorporated in the facility CAPEX.

The resulting MAC is comparable with this NSW report "*Scaling atmospheric carbon dioxide removal in New South Wales*" source for high cost, high-tech sorbent ($133 to $411 per t CO2-e for 22Mt of deployment). This report also identified that NSW has strong potential to deploy DACCS at large scales due to the NSW resource profile and industrial capability.

Appendix 3: Approach to selecting decarbonisation solutions

Approach and key insights

Decarbonisation solution shortlisting approach

This section outlines the rigorous approach used to prioritise the list of decarbonisation solutions to be included in the MAC analysis to determine NSW Carbon Values. The application of this approach is outlined in Appendix 4: Decarbonisation solution longlist and shortlist.

1 Review key sectors within NSW

Reviewed NSW's emissions as categorised by the United Nations Framework Convention on Climate Change (UNFCCC) sectors and subsectors[1]:

1. Electricity generation
2. Transport
3. Agriculture
4. Stationary energy[2]
5. Industrial Processes and Product Use (IPPU)
6. Fugitive emissions
7. Waste
8. Land Use, Land–Use Change and Forestry (LULUCF)

2 Develop longlist and prioritised longlist

Leveraged Deloitte's proprietary Greenspace Navigator tool, the IEA technology list and a review of NSW Gov documents we have

- Identified 230+ decarbonisation solutions across the eight sectors
- Prioritised the longlist based on IEA's classification of 'Importance to reach Net Zero', and/or relevance to NSW

A total of 82 unique solutions constitute the prioritised solution longlist.

3 Develop and rate against the criteria

Four criteria have been agreed to assess the prioritised solution longlist. Each criteria is rated relatively as high, medium or low and weighted.

Criteria	Weighting	Rating
Strategic Alignment (S)	10%	High (3)
Desirability (D)	40%	Medium (2)
Viability (V)	25%	Low (1)
Feasibility (F)	25%	

See next page for more detail on the assessment criteria.

4 Develop a solution shortlist

Based on the outcomes from the assessment **we developed a shortlist of 25 solutions that have undergone MAC analysis**. Shortlisting criteria were:

a. All 'High' Desirability solutions,
b. Weighted scoring of 8 and above on the SDFV assessment criteria (i.e. score Medium on average), and
c. if the above criteria were not satisfied within a Top 10 sub–sector, at least one solution has been included on the shortlist for that sub–sector.

Note: 1. NSW GHG Projections are prepared at a sectoral level consistent with international guidelines adopted by the United Nations Framework Convention on Climate Change (UNFCCC).
Note: 2. Stationary energy (excluding electricity generation) includes on–site fuel combustion in manufacturing, energy and primary sectors and the commercial and residential sectors.
Note: 3. Weightings have been adjusted based on feedback from the DCCEEW project working group on 29 June 2024.

Solution assessment considerations

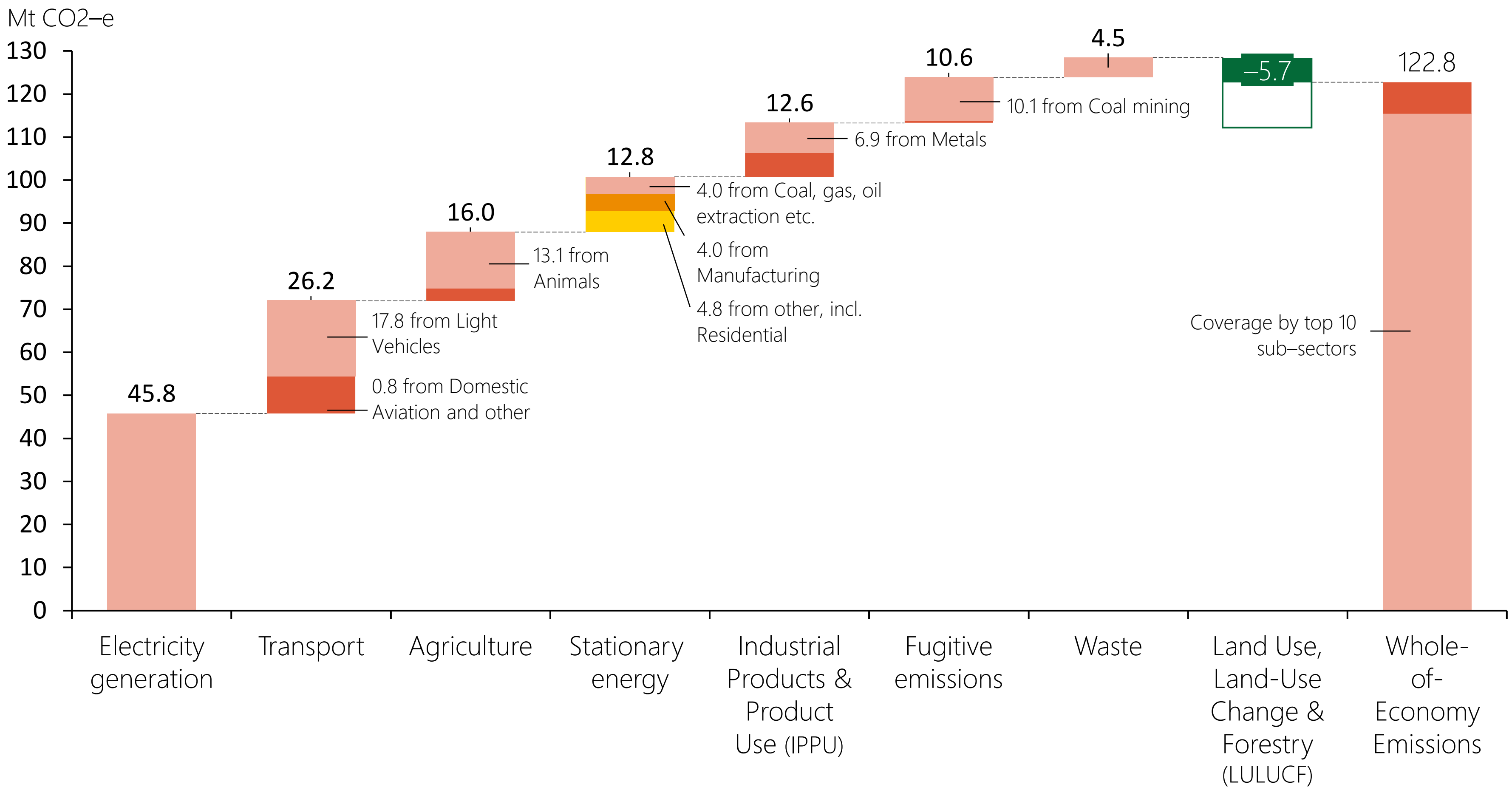
The prioritised solution longlist has been assessed and scored against four weighted assessment criteria, each of which are underpinned by key considerations.

CRITERIA & WEIGHTING	HOW SOLUTIONS HAVE BEEN ASSESSED (& SCORED)		
	High (3)	**Medium (2)**	**Low (1)**
	A particular decarbonisation solution is…		
Strategic alignment 10%	Mandated or recommended within a **NSW/ Fed Gov. strategy/policy/program**	Recognised in **sector publications** applicable to NSW	**Not clearly relevant** and/or a strategic choice was made to not deploy in NSW
	Considers 1. Solution's abatement potential: efficiency (incremental change) or fuel switch (substantial change) 2. How broadly the solution can be deployed within the subsector, and 3. Contribution of emissions of the sub–sector to overall NSW emissions (Top 10 or not):		
Desirability 40%	The solution has **high abatement potential**, can be **deployed broadly**, and is **relevant to a Top 10 sub–sector** in terms of emissions contribution within NSW	The solution is **relevant to a Top 10 sub–sector** within NSW and has either: • **broad use** but is efficiency–related, or • has limited use but entails a **fuel switch**	All other solutions, i.e. the solution is **not related to a Top 10 sub–sector** within NSW and/or has limited deployment potential or only entails efficiency gains
	Considers the solution's deployment readiness from now to the next 10–15 years:		
Viability 25%	The solution is **already being deployed** and **commercially viable at scale today**	The solution is expected to be **ready for commercial deployment on a cost–effective basis** in the next 10–15 years	The solution is **not expected to be ready for commercial deployment** in the next 10–15 years
	Considers 1. Enabling infrastructure and capabilities for the solution to be deployed successfully (e.g., supply chain/workforce/social license are/would be in place) and 2. Negative externalities (e.g., emissions/ pollutants/ safety concerns influences deployment of the solution):		
Feasibility 25%	**Enabling infrastructure and capabilities are largely already available**, and **no negative externalities are expected**	The requisite supply chain/workforce/social license **can feasibly be implemented** and **no/limited negative externalities**	There will be **considerable constraints to successfully implement the sol**, and/or **considerable negative externalities**

NSW emissions profile by sector and key subsectors

The longlist of decarbonisation solutions have been aligned to the NSW Net Zero Modelling team's categorisation of sectors. This categorisation of emissions highlights that 10/17 subsectors are responsible for ~94% of emissions in the State.

NSW's FY21 emissions[1] by sector and sub–sector:



The following top 10 sub–sectors are responsible for ~94% of emissions in the State:

1. (37%) Electricity generation
2. (15%) Light vehicles
3. (11%) Agriculture – Animals
4. (8%) Fugitives from coal mining
5. (6%) IPPU Metals
6. (5%) Heavy-Duty vehicles (trucks, buses)
7. (3%) Stationary energy – Coal, oil and gas extraction
8. (3%) Stationary energy – Manufacturing, incl. chemicals, iron and steel
9. (3%) Solid Waste Disposal
10. (3%) IPPU Chemicals, incl. ozone depleting substance substitutes

Source: 1. FY21 NSW emissions profile, provided by the Net Zero Modelling team. Some subsectors have been grouped (e.g., Cattle, Pigs and other animals are grouped under "Animals").

Solution coverage by sector and sub–sector

A longlist of 235 solutions were compiled across the 17 NSW subsectors. A two–step selection process was applied to prioritise the longlist based on abatement Importance to Net Zero, and to develop a shortlist of 25 solutions based on the assessment criteria (SDVF).

Sector	Key subsectors	Emissions Contribution[1]	Longlist	Prioritised longlist	Shortlist
Electricity generation	Electricity generation	37%	11	4	4
Transport	Light vehicles (cars, LCVs, MCs)	15%	9	2	1
	Heavy-Duty vehicles (Trucks, Buses, Rail)	5%	17	10	3
	Domestic aviation, navigation and other	2%	30	7	0
Agriculture	Animals	11%	7	3	2
	Fertilisers, urea and lime, and crops	2%	5	2	*covered*[3]
Stationary energy	Manufacturing	3%	27	6	2
	Energy	3%	2	2	1
	Residential and other	4%	29	8	3
IPPU	Metals sector	6%	42	15	3
	Chemicals sector incl. ozone depleting substance substitutes	3%	20	1	1
	Minerals and other product manufacturing/use	1%	16	5	*covered*
Fugitive emissions	Coal mining	8%	5	5	2
	Oil and gas	0.4%	n/a	0	0
Waste	Solid waste disposal	3%	4	4	1
	Other waste	1%	0	0	0
LULUCF	Forest land	–14%	n/a	n/a	n/a
	Other, incl. cropland	10%[2]	n/a	n/a	n/a
Whole-of-economy		–	11	8	2
TOTAL		**100%**	**235**	**82**	**25**

Longlist → Prioritised longlist: *Filter based on **Importance to reach Net Zero (Y/N).** This assessment is based on IEA's classification of solutions in terms of importance to the Net Zero transition, as well as an overlay of Deloitte Assessment to ensure coverage of NSW sub–sectors.*

Prioritised longlist → Shortlist: *Filter based on scoring across **four criteria**: Strategic alignment, Desirability (within sub–sector), Viability, and Feasibility*

Key take–aways:

- All top ten emitting subsectors have been covered in the shortlist
- Supporting infrastructure is considered within each solution instead of separately (e.g., charging infrastructure is considered within Battery EVs)
- Select solutions could be used across multiple sectors (*more detail on next slide*)
- Two groups of solutions – GHG removal through Nature-based solutions and DACCs – will abate any hard-to-abate emissions (post–deployment of other solutions) across sectors / at the Whole-of-economy level.

Note: 1. The breakdown of emissions by subsector will vary across the analysis period of FY24–FY50, but an FY21 view is valuable to determine relative emissions contribution towards overall NSW State emissions.
2. Other emissions from LULUCF from cropland, grassland, wetland etc. have been excluded from the top ten emitting subsectors. This relates to the change in carbon stock caused by land cover changes (e.g., bushfire and land management activities). IPCC notes that reducing deforestation has the largest potential to reduce anthropogenic GHG emissions, followed by carbon sequestration in agriculture and ecosystem restoration including afforestation and reforestation (source), which is considered under whole-of-economy in this framework.
3. Covered by a cross–sector solution that is counted in another subsector.

Decarbonisation solution shortlist that progressed to MAC analysis

25 solutions were shortlisted for MAC analysis based on the selection process. The table below lists the shortlisted solutions by sub–sector, as well as the shortlisting criteria that each decarbonisation solution met.

Shortlist criteria legend:
- a All 'High' Desirability solutions
- b Weighted scoring of 8 and above on the SDFV assessment criteria
- c (If the above criteria are not satisfied within a Top 10 sub–sector), at least one solution will be included on the shortlist for that sub–sector.

SHORTLISTED SOLUTIONS + RATIONALE

Sector	Key subsectors	Emissions Contribution	Solution 1		Solution 2		Solution 3		Solution 4	
Electricity generation	Electricity generation	37%	Utility Solar	a	Rooftop solar	a	Wind	a	Firming	a
Transport	Light vehicles (cars, LCVs, MCs)	15%	Light-Duty – Battery EVs	a						
	Heavy-Duty vehicles (Trucks, Buses, Rail)	5%	Heavy-Duty – Battery EVs	a	Heavy-Duty – Hydrogen fuel cell	a	Rail – Hydrogen/bio feedstock/ammonia	a		
	Domestic aviation, navigation and other[1]	2%								
Agriculture	Animals	11%	Dietary manipulation	a	Herd mgt.	b				
	Fertilisers, urea and lime, and crops	2%	Covered by green ammonia (in IPPU | Chemicals sector)							
Stationary energy	Energy	3%	Mining – Vehicle electrification	a						
	Manufacturing	3%	Industrial electric heating equipment	a	Cement produced with alternative raw materials	b				
	Residential and other	4%	Household heat pumps	a	Household appliances electrification and efficiency	b	Building efficiency improvements	b		
IPPU	Metals sector	6%	Aluminium primary smelting – Inert anode	a	Iron and steel – DRI produced using green H2	a	CCUS across multiple applications	a		
	Chemicals sector incl. ozone depleting substance substitutes	3%	Green ammonia produced using green H2	a						
	Minerals and other product manufacturing/use	1%	Covered by Inert anode (under IPPU | Metals) and industrial electric heating (under Stationary energy | Manufacturing)							
Fugitive emissions	Coal mining	8%	Drainage – Power gen.	b	Air Methane Oxidation	b				
	Oil and gas extraction	0.4%								
Waste	Solid waste disposal	3%	Drainage – Power gen.	b						
	Wastewater disposal	1%								
Whole-of-economy		–	GHG Removal – DACCS	a	GHG Removal – Nature-based solutions	b				

Note: 1. See this page for further consideration of aviation biogenic SAF and consideration of embodied carbon.

Appendix 4: Decarbonisation solution longlist and shortlist

Scoring and rationale

1. Electricity Generation

Electricity generation – 11 solutions (1/1)

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | × ; Grouped solutions

Electricity generation is currently the most significant contributor (37%) to NSW emissions. Within this sector, 11 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z*	S	D	V	F
Electricity generation 37% of total NSW emissions	Electricity generation	1. Power – Generation – Rooftop solar	✓	H	H	H	M
		2. Power – Generation – Utility solar	✓	H	H	H	H
		3. Power – Generation – Wind	✓	H	H	H	H
		4. Power – Generation – Firming, including concentrated solar, pumped hydro, battery storage (utility–scale and behind–the–meter) , hydrogen/natural gas blend, etc.	✓	H	H	M	H
		5. Power – Generation – Biomass	×				
		6. Power – Generation – Geothermal	×				
		7. Power – Generation – Ammonia	×				
		8. Power – Generation – Hydropower	×1				
		9. Power – Generation – Nuclear	×1				
		10. Power – Generation – Ocean and Tidal	×1				
		11. Systems integration – Hybrid flexible demand and battery network	×				

* INZ = Importance to Net Zero. This assessment is based on IEA's classification of solutions in terms of importance to the Net Zero transition, as well as an overlay of Deloitte Assessment to ensure coverage of NSW sub-sectors.
Note: 1. Hydropower, nuclear and ocean and tidal are solutions identified as important to Net Zero by IEA. However, Deloitte's view that they are less important in the Australian/NSW context.

Electricity generation – 4 solutions (1/2)

4 decarbonisation solutions have been identified in the Electricity Generation prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

	No	Subsector	Solution	Description	Assessment and rationale				
					S	D	V	F	Rationale
●	1	Electricity Generation	Power – Generation – Rooftop solar	Rooftop solar PV panel converts surface solar irradiance into zero emissions electricity, for installation on residential and commercial rooftops.	H	H	H	H	Rooftop solar PV panels align strategically with the NSW Electricity Infrastructure Roadmap and NSW Energy Security Safeguard, indicating their importance in the state's energy plans. They exhibit high desirability due to broad deployment potential. Their viability and feasibility are proven by successful commercial implementation across NSW and incentivisation through rebate programs. Additionally, rooftop solar benefits from a well–established supply chain, ensuring availability, has positive social acceptance, contributing to its high feasibility.
●	2	Electricity Generation	Power – Generation – Utility Solar	Utility–scale solar solutions utilise solar photovoltaic (PV) panels to provide clean and renewable energy to the grid on a large scale.	H	H	H	H	Utility–scale solar generation is strategically aligned with the NSW Electricity Strategy, highlighting its importance in the state's renewable energy plans. Its high desirability stems from the ability to be deployed broadly across NSW's designated renewable energy zones, contributing to the expansion of clean energy generation. The solution exhibits high viability, as it is already successfully deployed in NSW, demonstrating its proven track record and commercial viability. Utility–scale solar generation has high feasibility due to the presence of enabling infrastructure and capabilities. The necessary components, such as solar panels and grid integration systems, are already available, facilitating seamless implementation.

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Electricity generation – 4 solutions (2/2)

4 decarbonisation solutions have been identified in the Electricity Generation prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

	No	Subsector	Solution	Description	Assessment and rationale				
					S	D	V	F	Rationale
●	3	Electricity Generation	Power – Generation – Wind	Wind generation involves harnessing the power of wind to generate electricity using wind turbines. The kinetic energy of the wind is converted into electrical energy, contributing to the renewable energy mix.	H	H	H	H	Wind generation aligns strategically with the NSW Electricity Strategy, serving as a vital component of the state's renewable energy objectives. Its high desirability stems from its potential for broad deployment across NSW's designated renewable energy zones, supporting the expansion of clean energy production. The solution exhibits high viability, as it is already successfully deployed in NSW, demonstrating its proven effectiveness and commercial feasibility. High feasibility, as the necessary infrastructure, (incl. wind turbines and transmission systems), are largely available, facilitating the efficient implementation of wind farms. Additionally, the solution is expected to have no significant negative externalities, further enhancing its feasibility.
●	4	Electricity Generation	Power – Generation – Firming	Firming solution ensures a reliable and consistent energy supply by combining solar or wind generation with energy storage systems such as batteries, pumped hydro, natural gas or hydrogen/natural gas blend. This integration enhances the capacity of intermittent renewable sources to provide a stable power output.	H	H	M	H	Firming solution strategically aligns with the NSW Electricity Strategy, playing a crucial role in ensuring a reliable and resilient energy supply. High desirability, given its potential for broad deployment across NSW's renewable energy zones. The combination of renewables with energy storage enhances the stability and availability of clean energy. Medium viability due to certain technical limitations of energy storage, particularly for long–duration storage, and the relatively higher implementation cost. However, ongoing advancements in storage tech are expected to improve viability over time. High feasibility, as existing grid infrastructure can be integrated with energy storage systems, allowing for seamless implementation. Additionally, the solution is expected to have no significant negative externalities, further enhancing its feasibility.

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2. Transport

Transport – 56 solutions (1/2)

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | × ; Grouped solutions

Transport is currently the second most significant contributor to NSW emissions (22%), with light vehicles being the most significant subsector (68% of sector, 15% of total NSW). Within this sector, 56 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z	S	D	V	F
Transport 22% of total NSW emissions	Road Transport – Light-Duty Vehicles – Battery EVs	1. Light vehicles – Charging	✓	H	H	H	H
		2. Light vehicles – Battery electric vehicle					
	Light vehicles incl. Cars, LCVs, MCs (68% of the Transport sector)	3. Light vehicles – Hydrogen Refuelling Station	×				
		4. Light vehicles – Automated and connected vehicles (level 4+)	×				
		5. Light vehicles – Hydrogen fuel cell electric vehicle	×				
		6. Light vehicles – Hydrogen–fuelled engine	×				
		7. Light vehicles – Methanol–fuelled engine	×				
		8. Light vehicles – Bioethanol and biodiesel fuelled engine	×				
		9. Light vehicles – Gas–fuelled engine	×				
	Heavy-Duty vehicles incl. Trucks (medium and heavy road haulage), Buses and Rail (23% of the Transport sector)	10. Buses, Medium & Heavy Haulage – Bioethanol and biodiesel fuelled engine	×				
	Road Transport – Heavy-Duty Vehicles – Battery EVs	11. Buses & Medium haulage – Charging	✓	H	H	M	M
		12. Buses – Battery electric vehicle					
		13. Medium haulage – Battery electric vehicle					
		14. Heavy haulage – Battery electric vehicle	×				
	Road Transport – Heavy-Duty Vehicles – Hydrogen Fuel Cell	15. Buses & Heavy haulage – Hydrogen refuelling station	✓	H	H	M	M
		16. Buses – Hydrogen fuel cell electric vehicle					
		17. Heavy haulage – Hydrogen fuel–cell electric vehicle					
		18. Medium haulage – Hydrogen fuel–cell electric vehicle	×				
		19. Medium haulage – Conversion of ICE to EV or CNG	×				
		20. Heavy haulage – Conversion of ICE to EV or CNG	×				
		21. Rail – Hyperloop	×				
		22. Rail – Magnetic levitation	×				
		23. Rail – Battery electric locomotives	×				
		24. Rail – Diesel–electric hybrid (internal combustion engine and overhead power)	✓	H	L	H	M
	Rail – Hydrogen Fuel Cell	25. Rail – Hydrogen fuel cell electric vehicle	✓	H	H	M	M
		26. Rail – Ammonia–fuelled engine					

Transport – 56 solutions (2/2)

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | × ; Grouped solutions

Transport is currently the second most significant contributor to NSW emissions (22%), with light vehicles being the most significant subsector (68% of sector, 15% of total NSW). Within this sector, 56 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z.	S	D	V	F
Transport 22% of total NSW emissions	Domestic Aviation, Navigation and other incl. Recreational vehicles, Pipelines (9% of the Transport sector)	27. Aircraft – Electric vertical take–off and landing jets	×				
		28. Aircraft – Electric taxiing and ground operations	×				
		29. Aircraft – Hybrid vehicle	×				
		30. Aircraft – Green ammonia powered aircraft	×2				
		31. Aircraft – Biogenic SAF engine	✓	M	L	M	M
		32. Aircraft – Short–distance electric aircraft	✓	L	M	L	M
		33. Aircraft – Hydrogen fuel cell electric vehicle	✓	L	H	L	L
		34. Aircraft – Hydrogen–fuelled engine					
		35. Aircraft – Solar powered aircraft	×				
		36. Aircraft – Long–distance electric vehicle	×				
		37. Aircraft – Blended Wing Body Design	×				
		38. Aircraft – Ultra–High Bypass Ratio engine	×				
		39. Aircraft – Components – Open Rotor	×				
		40. Aircraft – Components – Propulsion–Airframe Integration	×				

Grouped solutions (33, 34): Aircraft – Hydrogen Fuel Cell

Note: 1. Battery electric vessel is considered given the number of ferries and short travel distances within Sydney and other part of NSW.
2. Even though ammonia–fuelled engine has ranked high in IEA for international shipping and aviation it still has been dropped out considering NSW state boundary and emissions scope of domestic shipping and aviation.

Transport – 56 solutions (2/2)

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | × — Grouped solutions

Transport is currently the second most significant contributor to NSW emissions (22%), with light vehicles being the most significant subsector (68% of sector, 15% of total NSW). Within this sector, 56 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z.	S	D	V	F
Transport 22% of total NSW emissions	Domestic Aviation, Navigation and other incl. Recreational vehicles, Pipelines (9% of the Transport sector)	41. Marine – Charging and refuelling – Bunkering	×				
		42. Marine – Charging and refuelling – Fast charging	×				
		43. Marine – Operations – Automated and connected ship	×				
		44. Marine – Operations – Cold Ironing or shore connection	×				
		45. Marine – Ammonia Solid Oxide fuel cell electric vehicle	×				
		46. Marine – Battery electric vehicle	✓[1] (Deloitte)	M	L	M	M
		47. Marine – Biogas–fuelled engine	×				
		48. Marine – Foul Release Hull Coating	×				
		49. Marine – Ammonia–fuelled engine	×[2]				
		50. Marine – Hydrogen fuel cell electric vehicle (grouped: Marine – Hydrogen Fuel Cell)	✓ (IEA)	M	L	M	M
		51. Marine – Hydrogen–fuelled engine (grouped: Marine – Hydrogen Fuel Cell)					
		52. Marine – Components – Kite	×				
		53. Marine – Methanol fuel cell electric vehicle	×				
		54. Marine – Ammonia or Methanol–fuelled engine	×				
		55. Marine – Components – Rotor Sail	×				
		56. Marine – Components – Rudder Bulb	×				

Marine – Hydrogen Fuel Cell

Note: 1. Battery electric vessel is considered given the number of ferries and short travel distances within Sydney and other part of NSW.
2. Even though ammonia–fuelled engine has ranked high in IEA for international shipping and aviation it still has been dropped out considering NSW state boundary and emissions scope of domestic shipping and aviation.

Transport – 10 solutions (1/4)

10 decarbonisation solutions have been identified in the Transport prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

	No	Subsector	Solution	Description	Assessment and rationale				
					S	D	V	F	Rationale
●	1	Light vehicles (68% emissions of the Transport sector)	Road Transport – Light-Duty Vehicles – Battery EVs	Battery electric vehicles (EVs) refer to electricity–powered passenger cars and light commercial vehicles. They rely on battery solution to store and utilise electrical energy for propulsion.	H	H	H	H	Strategically aligned as per the NSW EV Strategy and NSW Future Transport Strategy, promoting sustainable transportation. High desirability due to broad use and significant fuel–switch potential. High viability demonstrated by successful deployment and proven market acceptance of EVs in NSW. High feasibility given the ongoing charging infrastructure rollout, ensuring EV ownership and operation is practical.
●	2	Heavy-Duty vehicles incl. trucks, buses and rail (23% emissions of the Transport sector)	Road Transport – Heavy-Duty Vehicles – Battery EVs	Battery electric vehicles (EVs) in the heavy–duty category include buses and medium haulage vehicles. These vehicles rely on electricity as their power source for transportation.	H	H	M	M	Strategically aligned as per the NSW EV Strategy and Zero emissions Bus Transition Strategy. High desirability stems from their broad–use nature and the significant potential for fuel–switching. Ongoing advancements in battery solution will enhance the economic viability of these vehicles in the coming decades. Medium feasibility due to the need for a robust charging network to support the charging needs of heavy–duty EVs.
●	3	Heavy-Duty vehicles incl. trucks, buses and rail (23% emissions of the Transport sector)	Road Transport – Heavy-Duty Vehicles – Hydrogen Fuel Cell	Hydrogen fuel cell solution is utilised in heavy–duty vehicles such as buses and medium haulage, enabling them to operate using hydrogen gas and producing only water vapor as emissions.	H	H	M	M	Strategically aligned as per the Hume Hydrogen Highway initiative under the NSW Hydrogen refuelling network funding and Zero emissions Bus Transition Strategy. High desirability, given this is a broad–use, fuel–switch solution. Medium viability and feasibility given these vehicles are expected to only become commercially viable in the coming decades, and a comprehensive and accessible refuelling network is yet to be implemented across NSW.

Transport – 10 solutions (2/4)

10 decarbonisation solutions have been identified in the Transport prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

Shortlist	No	Subsector	Solution	Description	S	D	V	F	Rationale
	4	Heavy-Duty vehicles incl. trucks, buses and rail (23% emissions of the Transport sector)	Rail – Diesel–electric hybrid (internal combustion engine and overhead power)	Rail solution that combines the use of overhead power and diesel engines. These trains utilise overhead power when operating on electrified train networks, while relying on on–board diesel engines to generate power when outside of the electrified network.	H	L	H	M	Strategically aligned as per the NSW Transport Strategy and backed by investments from the NSW Government. Although it exhibits a relatively low abatement potential, it demonstrates high viability due to its successful implementation in the regional trains network in NSW . Medium feasibility given it still partially relies on diesel engines and will generate emissions and pollutants as by–products.
●	5	Heavy-Duty vehicles incl. trucks, buses and rail (23% emissions of the Transport sector)	Rail – Fuel switch – Hydrogen/ammonia /biofuel	Rail systems that are powered by fuel cells utilising green hydrogen, combustion of ammonia, or biofuel.	H	H	M	M	Strategically aligned with the NSW Hydrogen Strategy and Future Transport Strategy, the fuel switch solution for rail demonstrates its importance in the state's sustainable transportation plans. High desirability as a broad–use, fuel–switch solution. However, medium viability as further feasibility studies, trials, and proof–of–concept testing are required in NSW. Commercial viability of this solution is expected to be achieved within the next 10–15 years. Medium feasibility as refuelling stations and distribution networks are yet to be fully implemented.
	6	Domestic Aviation, Navigation and other (9% of the Transport sector)	Aircraft – Short–distance electric aircraft	Battery–electric aircraft powered by renewable electricity. These aircraft are typically intended for regional short–haul domestic flights.	L	M	L	M	As NSW has not publicly stated its position on battery–electric aircraft, the solution is deemed as one with low strategic alignment. Medium desirability since this is a fuel–switch solution limited to small short–distance flights (i.e. 30-passanger regional flights like Sydney to Newcastle). Low viability since the solution faces significant thermal and energy density constraints and hence is not expected to become commercially deployable within the next 10–15 years. Moderate feasibility given the need for the implementation of charging infrastructure, and regulatory frameworks to support adoption of electric aircraft.

Transport – 10 solutions (3/4)

10 decarbonisation solutions have been identified in the Transport prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) Solutions in the proposed shortlist

No	Subsector	Solution	Description	Assessment and rationale				
				S	D	V	F	Rationale
7	Domestic Aviation, Navigation and other (9% of the Transport sector)	Aircraft – Biogenic SAF engine	Aircrafts which utilise renewable and low–carbon alternatives, known as biogenic sustainable aviation fuel (SAF), instead of traditional jet fuel. Biogenic SAF is typically derived from sources such as municipal waste, used cooking oil, and agricultural residues.	M	L	M	M	Medium strategic focus, given NSW has not publicly stated its position on aviation fuel switching. It is; however, aligned to Australia's Bioenergy Roadmap, which includes sustainable aviation fuels as a key opportunity to reduce emissions. Low desirability given SAF has similar tailpipe emissions to traditional jet fuel. While the solution is not yet commercially deployable, ongoing investments from government and industry are expected to enhance viability over the next 10–15 years. Medium feasibility given NSW currently does not produce jet fuel, and the enabling infrastructure needs to be setup. See page 11 for consideration of embodied carbon.

Transport – 10 solutions (4/4)

10 decarbonisation solutions have been identified in the Transport prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) Solutions in the proposed shortlist

No	Subsector	Solution	Description	Assessment and rationale: S	D	V	F	Rationale
8	Domestic Aviation, Navigation and other (9% of the Transport sector)	Aircraft – Hydrogen Fuel Cell	Aircraft use hydrogen either through: • Fuel cells to generate electricity, or • Fuel in an internal combustion engine.	L	H	L	L	Low strategic focus, given NSW has not publicly stated its position on hydrogen in domestic aviation sector. High desirability since this is a fuel–switch solution applicable to short–distance and long–distance flights. Low viability since the solution not expected to become commercially deployable within the next 10–15 years. Medium feasibility given the requisite enabling refuelling infrastructure is yet to be implemented.
9	Domestic Aviation, Navigation and other (9% of the Transport sector)	Marine – Battery EVs	Battery–electric vessels powered by renewable electricity. Typically expected to be implemented for short–haul ferries, pleasurecraft and recreational boating.	M	L	M	M	Broadly strategically aligned with NSW Future Transport Strategy. Low desirability since marine is not a top ten emissions contributing subsector. Low desirability since the solution is limited to ferries, pleasurecraft and recreational boating. Medium viability given this solution is expected to become more broadly commercially viable in the next 10–15 years. Medium feasibility given the requisite enabling charging infrastructure is yet to be implemented.
10	Domestic Aviation, Navigation and other (9% of the Transport sector)	Marine – Hydrogen Fuel Cell	Vessels that use hydrogen either through: • Fuel cells to generate electricity, or • Fuel in an internal combustion engine.	M	L	L	M	Strategically aligned with NSW Hydrogen Strategy. Low desirability since marine is not a top ten emissions contributing subsector. Low viability since the solution is still undergoing trials (hydrogen–powered small size experimental vessels in UK and Canada) and is not expected to become technically and commercially viable in the short term. Medium feasibility given the requisite enabling refuelling infrastructure is yet to be implemented.

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3. Agriculture

Agriculture – 12 solutions

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | × ; Grouped solutions

Agriculture is currently the third most significant contributor (13%) to NSW emissions, with animals being the most significant subsector (~83% of sector, 11% of total NSW). Within this sector, 12 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z	S	D	V	F
Agriculture 13% of total NSW emissions	Animals incl. Grazing Beef, Grain Fed Beef, Sheep, Dairy, Pigs and other (83% of the Agriculture sector)	1. Agri–genomics	×				
		2. Dietary manipulation – Feed supplements	✓[1]	H	H	L	M
		3. Dietary manipulation – Additives – asparagopsis, 3–NOP, nitrate	✓[1]				
		4. Dietary manipulation – Other (e.g., oils and phytochemicals)	×				
		5. System-level approaches – Herd management	✓[1]	H	M	H	H
		6. Manure / animal effluent management	×				
		7. Alternative proteins[2]	×				
	Fertilisers, urea and lime, and crops (16% of the Agriculture sector)	8. Carbon stabilisation through use of biochar as a soil amendment	✓[1]	H	L	M	M
		9. Fertiliser management	✓[1]	M	M	L	M
		10. Low GHG farm inputs (fertilisers and pesticides)	✓[1]	n/a – already shortlisted			
		11. Vertical/controlled environment farming	×				
		12. Precision agriculture	×				

Grouped solutions (2 and 3): **Dietary manipulation – feed supplements**

Note: 1. These decarbonisation solutions specific to the agriculture sector have been included as referenced in the NSW Department of Primary Industries Report 'Abatement opportunities from the agricultural sector in NSW' released in Oct 2020.
2. Alternative proteins is a demand reduction option and would only incrementally reduce emissions assuming current production processes.

Agriculture – 5 solutions (1/2)

5 decarbonisation solutions have been identified in the Agriculture prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

	No	Subsector	Solution	Description	S	D	V	F	Rationale
					Assessment and rationale				
●	1	Animals (83% emissions of Agriculture sector)	Dietary manipulation – feed supplements	Dietary manipulation, such as feedstock supplements – based on seaweed or microbes or insects or botanical compounds – for ruminants to address enteric fermentation emissions.	H	H	L	M	Strategically aligned with NSW Primary Industries Productivity and Abatement program which is a key element of the NSW Net Zero Plan Stage 1: 2020–2030. High desirability, given its large abatement potential in the agricultural sector, but viability is low as it is yet to be proven commercially. Locally emerging feed supplements, such as FutureFeed, could increase viability over time supported by NSW Government's funding. Medium feasibility given the requisite workforce and supply chains are yet to be implemented.
●	2	Animals (83% emissions of Agriculture sector)	System-level approaches – herd management	Herd management practices to reduce emissions intensity of livestock (e.g., reduction of average age of herd, reduction of stocking levels, early breeding, culling poor performers, enhancing fertility, improving animal health, and breeding for low methane production)	H	M	H	H	Strategically aligned with NSW Primary Industries Productivity and Abatement program. Medium desirability, given herd management solutions will have broad applications as an efficiency solution. High viability given these solutions does not require significant commercial investment . High feasibility given most herd management measures, incl. breeding low-methane traits, are readily adoptable.
	3	Fertilisers, urea and lime, and crops (16% emissions of the Agriculture sector)	Carbon stabilisation through use of biochar as a soil amendment	Biochar is the carbon–rich materials (charcoal) produced from the slow pyrolysis (heating in the absence of oxygen) of biomass. Soil applications of biochar as either a controlled–release fertilizer or an immobilization agent is shown to suppress CO2, CH4 and N2O emissions.	H	L	M	M	Strategically aligned with NSW Primary Industries Productivity and Abatement program and there is a . Low desirability given the effectiveness of biochar in suppressing emissions can vary depending on several factors, including soil type, biochar properties, application rate, and environmental conditions. Medium viability given the current cost of pyrolysis facilities and biochar limits commercial deployment. Medium feasibility - despite a lack of enabling regulatory approvals for production and application of biochar, there is significant gov./sector investment interest.

Agriculture – 5 solutions (2/2)

5 decarbonisation solutions have been identified in the Agriculture prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

No	Subsector	Solution	Description	S	D	V	F	Rationale
4	Fertilisers, urea and lime, and crops (16% emissions of the Agriculture sector)	Fertilisation management	Fertilisation management include: • nitrification inhibitors (e.g., enhanced efficiency nitrogen fertilisers) • slow-release fertilisers (e.g., polymer coated urea) • Better plant/fertiliser matching (i.e. at greatest plant demand instead of during seeding)	M	M	L	M	Strategically aligned with the National Soil Strategy and Dairy Australia Fert$mart. Medium desirability given this is an efficiency solution that could be widely applied. Low viability given 1) testing for soil nitrogen is lengthy, expensive and not commonly available, and 2) different sub-solutions also show varying degrees of efficiency (e.g., enhanced efficiency nitrogen fertiliser or polymer-coated urea perform inconsistently, especially in warmer or wetter environments). Medium feasibility given some of the enabling infrastructure (e.g., drip irrigation) is already implemented, however uptake of these fertiliser solutions may be impeded by higher costs/inconsistent performance.
● 5	Fertilisers, urea and lime, and crops (16% emissions of the Agriculture sector)	Low GHG farm inputs (fertilisers and pesticides)	Green ammonia, commonly used as a fertiliser, produced using green hydrogen.					Green ammonia produced using green hydrogen is already captured in the shortlist in the IPPU sector (#14).

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4. Stationary energy

Stationary energy – 58 solutions (1/3)

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | × — Grouped solutions

Stationary energy is currently the fourth contributor (10%) to NSW emissions. Within this sector, 58 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z.	S	D	V	F
Stationary energy 10% of total NSW emissions	Energy incl. Coal, coke and oil and gas extraction (32% of the Stationary energy sector)	1. Mining – Electrification – In pit crushing and conveying (IPCC)	✓[1]	M	L	H	L
		2. Mining – Electrification – Vehicle Electrification	✓[2]	M	H	M	M
	Manufacturing incl. Chemicals, Iron and steel, Non–Metallic Minerals, Pulp, Paper and print (31% of the Stationary energy sector) Grouped: Manufacturing – Cement produced with alternative raw materials	3. Cement and concrete – Raw materials – Ordinary Portland Cement from non–carbonate calcium sources 4. Cement and concrete – Raw materials – Supplementary cementious materials/alternative cement constituents	✓	M	M	M	M
		5. Cement and concrete – Bio–cement	×				
		6. Cement and concrete – Production – Cement kiln – Direct heat from variable renewables	×				
		7. Cement and concrete – Production – Cement kiln – Electrification (direct)	×				
		8. Cement and concrete – Production – Cement kiln – Electrolyser–based process for decarbonating calcium carbonate prior to clinker production in the kiln	×				
		9. Cement and concrete – Production – Cement kiln – Partial use of hydrogen	×				
		10. Cement and concrete – Alkali–activated binders (geopolymers)	×				
		11. Cement and concrete – CO2 curing in concrete (carbon sequestration)	×				
		12. Cement and concrete – recycled bricks from construction waste	×				
		13. Cement and concrete – Magnesium oxide binders	×				
		14. Multi–sector – Production – CO2 sequestration in inert carbonate materials	×				
	Grouped: Manufacturing – Industrial Electric Heating – Multi–sector	15. Multi–sector – Production – High temperature heating – Electric boiler 16. Multi–sector – Production – High temperature heating – Industrial electric	✓	H	H	M	M
		17. Paper – Production – Paper dewatering and drying – Compression refining	×				
		18. Paper – Production – Paper dewatering and drying – Mechanical dewatering	×				
	Grouped: Manufacturing – Paper dewatering and drying	19. Paper – Production – Paper dewatering and drying – Paper making without water 20. Paper – Production – Paper dewatering and drying – Superheated steam	✓	L	M	L	M
		21. Paper – Production – Paper dewatering and drying – Water reduction in size press	×				
		22. Paper – Production – Paper dewatering and drying – Supercritical CO2 drying	×				

Notes: 1. Although NSW has not publicly stated its preference for PICC, the tech is broadly aligned with NZIIP (DPIE 2021c) and NSW EPA Climate Change Policy and Action Plan. High viability given it is already relatively mature and cost–effective (SRK).2. Vehicle electrification in Mining is broadly aligned with the NSW EV Strategy (2021). High desirability and feasibility given electric mining trucks are more energy–efficient and – in the long run – will result in lower operating costs.

Stationary energy – 58 solutions (2/3)

Legend: Importance to Net Zero: IEA ✓ | Deluxe ✓ | × ; Grouped solutions

Stationary energy is currently the fourth contributor (10%) to NSW emissions. Within this sector, 58 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z.	S	D	V	F
Stationary energy 10% of total NSW emissions	Manufacturing incl. Chemicals, Iron and steel, Non–Metallic Minerals, Pulp, Paper and print (31% of the Stationary energy sector) – *continued*	23. Paper – Production – Paper dewatering and drying – without evaporation	×				
		24. Pulp and paper – Production – Pulping – Deep eutectic solvent	×				
		25. Pulp and paper – Production – Pulping – Mild repulping solutions	×				
		26. Pulp and paper – End–of–life – Waste product conversion to chemicals and bioenergy – Black liquor gasification	×				
		27. Pulp and paper – End–of–life – Waste product conversion to chemicals and bioenergy – Lignin extraction–Organic solvent	×				
		28. Pulp and paper – End–of–life – Waste product conversion to chemicals and bioenergy – Lignin extraction–Precipitation and acidification	×				
		29. Pulp and paper – End–of–life – Waste product conversion to chemicals and bioenergy – Pyrolysis of by–product streams	×				
	Other – Building efficiency improvements	30. Buildings efficiency improvement – Electrical performance	✓[1] (Deloitte)	H	M	H	M
		31. Buildings efficiency improvement – Lighting performance – Building orientation	✓ (IEA)				
		32. Buildings efficiency improvement – Lighting performance – Fibre–optic daylighting					
		33. Buildings efficiency improvement – Thermal performance – Building envelope					
		34. Buildings efficiency improvement – Thermal performance – Building orientation					
	Other sectors, incl. Residential and Commercial/Institutional (37% of the Stationary energy sector)	35. Buildings construction and renovation – Thermal performance – Ventilation	×				
		36. Cooking – Appliances – Electrification	✓[2] (Deloitte)	H	M	H	H
		37. Cooking – Appliances – Biofuels	×				
		38. Cooking – Appliances – LPG stove	×				
		39. Cooking – Appliances – Solar cooking	×				
		40. Heating and cooling – Control systems – Active control systems	×				
		41. Heating and cooling – Control systems – Programmable thermostat	×				
		42. Heating and cooling – Distribution – Heat exchanger	×				
		43. Heating and cooling – Distribution – Proportional hydraulic control	×				
		44. Heating and cooling – Distribution – Water heating heat pump booster	×				

Notes: 1. Optimizing electrical performance in Building efficiency improvements is crucial in NSW, Australia, as an emissions decarbonisation solution, supported by the NSW Government's Energy Efficiency Action Plan.
2. Electrification of cooktops in kitchens is significant for reducing emissions and promoting sustainable practices, supported by the NSW Government's initiatives for clean energy transition

Stationary energy – 58 solutions (3/3)

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | × ; Grouped solutions

Stationary energy is currently the fourth contributor (10%) to NSW emissions. Within this sector, 58 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z.	S	D	V	F
Stationary energy 10% of total NSW emissions	Other sectors, incl. Residential and Commercial/Institutional (37% of the Stationary energy sector) – *continued*	45. Heating and cooling – Generation – Electric Heater	×				
		46. Heating and cooling – Generation – Electric and Hydrogen Boilers etc.	×				
		47. Heating and cooling – Generation – Cogeneration	×				
		48. Heating and cooling – Generation – Trigeneration	×				
		49. Heating and cooling – Generation – Heat pumps	✓	H	H	H	M
		50. Heating and cooling – Generation – Evaporative Cooling	×				
		51. Heating and cooling – Generation – Quad–generation	×				
		52. Heating and cooling – Generation – Solid–state equipment cooling	×				
		53. Heating and cooling – Generation – Standalone liquid or solid desiccant cooling	×				
		54. Heating and cooling – Storage – Thermal storage	×				
		55. Heating and cooling – Storage – Thermo–chemical storage	×				
		56. Systems integration – Grid interaction – Direct current buildings system	×				
		57. Systems integration – Grid interaction – Double smart grid	×				
		58. Zero emissions farm equipment	✓[1]	M	L	M	M

Stationary energy – 9 solutions (1/3)

9 decarbonisation solutions have been identified in the Stationary energy prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

Shortlist	No	Subsector	Solution	Description	S	D	V	F	Rationale
	1	Energy incl. Coal, coke and oil and gas extraction (32% emissions of Stationary energy)	Mining – Electrification – In pit crushing and conveying (IPCC)	IPCC solution minimises the reliance on diesel–fuelled haul trucks by locating the primary crusher in the pit area close to active mining zones. This setup enables the transportation of mined material through an electricity–powered conveyor system.	M	L	H	L	While NSW has not publicly stated its position on IPCC, the solution is broadly aligned with the NZIIP and the NSW EPA Climate Change Policy and Action Plan. This indicates a moderate strategic focus on implementing IPCC in mining operations. Low desirability given its applicability is restricted to specific mining contexts despite offering benefits in terms of reducing reliance on diesel–fuelled haul trucks. High viability given it is already a relatively mature and cost–effective tech. Low feasibility as implementation is contingent on meeting requirements of specific mining operations/ conditions.
●	2	Energy incl. Coal, coke and oil and gas extraction (32% emissions of Stationary energy)	Mining – Electrification – Vehicle Electrification	Vehicle Electrification solution in mining involves replacing diesel-fuelled mining vehicles with battery-electric ones, utilising battery power instead of combustion engines.	M	H	M	M	Medium rating for Strategic Alignment, given that NSW Gov. has not publicly stated its position on electrification of mining vehicles; this approach is however broadly aligned with the NZIIP (DPIE 2021c) and NSW Electric Vehicle Strategy. High desirability, given battery–electric mining vehicles offer a significant benefit as a fuel–switch solution with broad applicability in the sector. Medium viability given the solution is still maturing (DCCEEW), although continued advancements and refinement are expected to improve their cost effectiveness. Medium feasibility given successful implementation of vehicle electrification in mining requires the installation of heavy–duty charging infrastructure across mine sites.
●	3	Manufacturing (31% emissions of Stationary energy)	Manufacturing – Cement produced with alternative raw materials	Cement produced with alternative raw materials involves the use of low emissions geopolymer cement as an alternative to traditional Portland cement or novel cement formulations which combine geopolymer and Portland cements / fly ash.	M	M	M	M	Medium strategic focus, broad alignment with the NZIIP (DPIE 2021c). Medium desirability, given this is an efficiency solution with broad use; although its impact on emissions reduction may vary depending on the specific application and market demand. Medium viability given this solution is only expected to be commercially viable within the next 10–15 years. Medium feasibility given the need to mitigate negative externalities associated with residual emissions.

Stationary energy – 9 solutions (2/3)

9 decarbonisation solutions have been identified in the Stationary energy prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

Shortlist	No	Subsector	Solution	Description	S	D	V	F	Rationale
●	4	Manufacturing (31% emissions of Stationary energy)	Manufacturing – Industrial Electric Heating Equipment	Industrial Electric Heating solution in manufacturing involves the use of industrial heating equipment that operates at low, medium, and high temperatures, utilising renewable electricity instead of fossil fuels.	H	H	M	M	Strategically aligned as per the NSW Net Zero Plan Implementation Update 2022 and Stage 1 Plan: 2020–2030. High desirability, given electrification of industrial heating involves fuel switching and has broad use within the Manufacturing sector. While electric heating equipment may have higher upfront costs compared to traditional fuel–based systems, the long–term operational and maintenance costs can be lower, especially if electricity prices are competitive or if manufacturing sites have access to renewable energy sources. This solution is therefore rated as Medium for Viability (CSIRO). Medium feasibility as additional backup infrastructure is necessary to maintain high energy density and temperature requirements.
	5	Manufacturing (31% emissions of Stationary energy)	Manufacturing – Paper dewatering and drying	Production of pulp and paper using less or no water, such as stone paper (uses no water) and superheated steam in the drying process.	L	M	L	M	Low strategic focus, given NSW has not publicly stated its position on this solution. Medium desirability, given paper dewatering and drying will have broad applications but is an efficiency solution unlikely to achieve significant emissions reductions. Low viability as it is an emerging solution with a low readiness level. Medium feasibility given the requisite workforce and supply chains are yet to be implemented.
●	6	Other sectors, incl. Residential (37% emissions of Stationary energy)	Other – Building efficiency improvements	Building efficiency improvements involve the implementation of efficient electrical, lighting, and thermal building components installed as design enhancements for new and existing buildings. This includes considerations such as building orientation, envelope materials and daylight capturing solutions.	H	M	H	M	Strategically aligned as per with the NSW Net Zero Building program. Medium desirability as these solutions have broad applications but would only incrementally reduce energy use. While they can contribute to incremental energy savings and improve overall efficiency, their impact on reducing energy use may vary depending on specific factors such as building design, size, and usage patterns. High viability given most of these solutions are already deployed today. The feasibility of implementing these solutions may vary, especially for pre–existing buildings that may require significant retrofitting to improve thermal efficiency.

Stationary energy – 9 solutions (3/3)

9 decarbonisation solutions have been identified in the Stationary energy prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

Shortlist	No	Subsector	Solution	Description	S	D	V	F	Rationale
●	7	Other sectors, incl. Residential (37% emissions of Stationary energy)	Cooking – Appliances – Electrification	Electric instead of gas–powered cooktops and ovens.	M	M	H	H	Broadly aligned to the NSW Net Zero Building program and Sustainable Buildings SEPP; NSW is yet to ban/remove mandatory gas connections (consistent with ACT or Vic). Medium desirability as cooktops and ovens have narrow application as a fuel–switch solution. High viability given electric cooktops and ovens are already widely deployed today and have proven their effectiveness and reliability. While the electrification of cooking appliances is technically feasible, retrofitting of appliances into pre–existing buildings need to be considered.
●	8	Other sectors, incl. Residential (37% emissions of Stationary energy)	Heating and cooling – Generation – Heat pumps	Heat pumps utilise vapour compression refrigeration cycle solution to provide heating or heating and cooling capabilities. Heat pumps can heat water or air and can also function in reverse cycle units. They are designed to replace gas–powered heaters and/or electricity–powered air conditioning systems.	H	H	H	M	Strategically aligned as per the NSW's Net Zero Plan Implementation Update 2022, the Energy Savings Scheme and Sustainable Buildings SEPP. High desirability as heat pumps have broad applications as a fuel–switch solution. High viability, despite current preference for "classic" hot water systems, availability of newer models with higher efficiency and lower costs compared to traditional gas–powered heaters is likely to drive uptake. Medium feasibility given there're some supply chain constraints (e.g., small number of installers), and heat pumps are not expected to generate any negative externalities.
	9	Other sectors, incl. Residential (37% emissions of Stationary energy)	Zero emissions farm equipment	Electrification of diesel–powered equipment such as farming tractors and irrigation pumps.	M	L	M	M	Limited strategic focus as NSW has yet to publicly announce its commitment to this solution, but DPE is clear in its intent to decarbonise the Agricultural sector (NSW Primary Industries Productivity and Abatement program). Low desirability since fertiliser and crop is not a top ten emissions contributing subsector. Medium viability given this solution is only expected to be commercially viable within the next 10–15 years. Medium feasibility given the requisite workforce and supply chains are yet to be implemented.

5. IPPU

IPPU – 78 solutions (1/4)

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | × ; Grouped solutions

IPPU is currently the third last contributor (10%) to NSW emissions, with metals sector being the most significant subsector (55% of sector, 6% of total NSW). Within this sector, 78 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z.	S	D	V	F
IPPU 10% of total NSW emissions	Metals Industry (55% of the IPPU sector)	1. Iron and steel – Production – Blast furnace – CCUS	✓ (IEA)	**n/a – already shortlisted**			
		2. Iron and steel – Blast furnace – CCUS via chemical absorption	✓ (IEA)	**n/a – already shortlisted**			
		3. Iron and steel – Direct reduced iron – CCUS	✓ (IEA)	**n/a – already shortlisted**			
		4. Iron and steel – Direct reduced iron – produced from green/blue hydrogen	✓ (IEA)	H	H	L	M
		5. Iron and steel – Direct reduced iron – produced from natural gas and green hydrogen blend	✓ (IEA)	L	L	M	M
		6. Iron and steel – Blast furnace – Electrolytic hydrogen partially replacing injected coal	×				
		7. Iron and steel – Blast furnace – Torrefied biomass partially replacing injected coal	×				
		8. Iron and steel – Direct reduced iron – Based on biogenic reduction gas	×				
		9. Iron and steel – Direct reduced iron – Improved ore refining methods	×				
		10. Iron and steel – Hydrogen for high–temperature heat for ancillary steelmaking processes	×				
		11. Iron and steel – Ore electrolysis – High temperature molten oxide electrolysis	×				
		12. Iron and steel – Ore electrolysis – Low temperature alkaline electrolysis (110°C)	×				
		13. Iron and steel – Reduction via alkali metal looping	×	**n/a – already shortlisted**			
		14. Iron and steel – Smelting reduction – CCUS	✓ (IEA)				
	Iron and Steel – Efficiency equipment	15. Iron and Steel – Dual lance tuyeres	✓[1, 2, 3] (Deloitte)	H	L	M	H
		16. Iron and Steel – Top gas recovery turbines					
		17. Iron and Steel – Hot blast waste gas heat recovery					
	Iron and Steel – Low emissions fuels	18. Iron and Steel – Coal replacement with biomass (charcoal)	✓ (IEA)	L	M	M	M
		19. Iron and Steel – Coal replacement with torrefied biomass (bio–coal)	✓[4] (Deloitte)				
		20. Iron and Steel – Direct reduced iron steel with attached carbon capture	×				
		21. Iron and Steel – Direct reduced iron steel with blended hydrogen	×				
		22. Iron and Steel – Direct reduction of iron oxide to pig iron using natural gas	×				
		23. Iron and Steel – Plasma reduction	×				

Notes: 1. Dual lance tuyeres is strategically aligned with NSW NZIIP and could be viable in the short–medium term (10–15 years). 2. Top gas recovery turbines are supported by NSW Gov's initiatives/programs such as the Industrial Energy Efficiency Program and aligned with the NSW NZIIP. 3. Implementing hot blast waste gas heat recovery solutions within the steel sector in NSW allows for the utilization of waste heat and significantly reduces carbon emissions. 4. An increase in regulatory frameworks, financial penalties and shareholder activism is putting pressure on the metal sector to reduce their dependence on coal and coke (CSIRO).

IPPU – 78 solutions (2/4)

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | × | Grouped solutions

IPPU is currently the third last contributor (10%) to NSW emissions, with metals sector being the most significant subsector (55% of sector, 6% of total NSW). Within this sector, 78 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z.	S	D	V	F
IPPU 10% of total NSW emissions	Metals Industry (55% of the IPPU sector) – *continued*	24. Iron and Steel – Blast furnace steel using off–gas hydrogen enrichment	×				
		25. Iron and Steel – Molten oxide electrolysis	×				
		26. Iron and steel – Smelting reduction – Smelting reduction – hydrogen plasma	×				
		27. Iron and steel – electric arc furnace for steel making	✓[1]	L	M	M	M
		28. Iron and Steel – Advanced analytics (AI/ML) in iron and steel production for process optimisation	×				
		29. Iron and Steel – Blast furnace – converting off gases into chemicals	×				
		30. Iron and Steel – Blast furnace – converting off gases into fuels	×				
		31. Iron and Steel – Blast furnace – hydrogen fuel injection (blending)	×				
		32. Iron and Steel – Coke dry quenching in BF–BOF steel for waste heat recovery	×				
		33. Iron and Steel – Top–pressure recovery turbines (TRTs) in blast furnaces	×				
		34. Aluminium – Hydrogen for high–temperature heat for ancillary processes	×				
		35. Aluminium – Mechanical vapour recompression during alumina refining	×				
		36. Aluminium – Alumina refining through the use of biomass, electricity or hydrogen in the Bayer process	×[2]				
		37. Aluminium – Integration of heat exchangers to vary energy consumption and production levels	✓[1]	H	L	M	H
		38. Aluminium – Primary smelting – CCUS	✓[1]				
		39. Aluminium – Primary smelting – Inert anode	✓	H	H	M	H
		40. Aluminium – Primary smelting – Chloride electrolysis	×				
		41. Aluminium – Primary smelting – Multipolar cell	×				
		42. Aluminium – Reducing metal forming losses and light weighting through additive manufacturing	×				
	Chemicals Industry, Non–energy products and ODS substitutes (34% of the IPPU sector)	43. Ammonia – Production – Biomass gasification	×				
		44. Ammonia – Production – CCUS	✓	n/a – see above			
		45. Ammonia – Production – Green hydrogen	✓	H	H	M	M
		46. Ammonia – Production – Methane pyrolysis	×				

Multi-application – CCUS (grouping solutions 38 and 44)

Note: 1. Strategically aligned with NSW NZIIP (DPIE 2021c). Medium viability since different solutions are in varied maturity level. These solutions are expected to be developed further and more cost effective in near future
2. Although alumina refining is a priority solution for the IEA, this solution is excluded from the prioritised longlist since there is no alumina refining in NSW. More information on Australia's alumina refining sector and prioritised solutions at each refinery can be found in the Roadmap for Decarbonising Australian Alumina Refining.

IPPU – 78 solutions (3/4)

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | × ; Grouped solutions

IPPU is currently the third last contributor (10%) to NSW emissions, with metal sector being the most significant subsector (55% of sector, 6% of total NSW). Within this sector, 78 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z.	S	D	V	F
IPPU 10% of total NSW emissions	Chemicals Industry, Non–energy products and ODS substitutes (34% of the IPPU sector) – *continued*	47. Nitric acid – Production – Nitrous oxide capturing, utilisation and storage	×[1]				
		48. Benzene, toluene and xylenes – Production – Methanol–based	×				
		49. Ethylene – Production – Bioethanol route	×				
		50. High value chemicals – Production – CCUS	×				
		51. High value chemicals – Production – Naptha catalytic cracking	×				
		52. High value chemicals – Production – Steam cracker electrification	×				
		53. High value chemicals – Production – Synthetic hydrogen–based fuels in a conventional steam cracker	×				
		54. Methanol – Production – Biomass and waste gasification	×				
		55. Methanol – Production – CCUS	×				
		56. Methanol – Production – Methane pyrolysis	×				
		57. Bio–based polymers	×				
		58. Low–carbon – Ammonia	×				
		59. Low–carbon – Benzene, toluene and xylenes: methanol based production	×				
		60. Low–carbon – Ethylene & propylene	×				
		61. Low–carbon – Methanol	×				
		62. Low–carbon – Syngas	×				
	Minerals and other product manufacturing/use (11% of the IPPU sector)	63. Minerals – Electric calcination during alumina refining	×				
		64. Minerals – Hydrogen calcination during alumina refining	×				
		65. Minerals – Smelting – Inert anode	✓[2] (Deloitte)	**n/a – already assessed with #39 on previous slide**			
		66. Minerals – Calcined clay	×				
		67. Multi–sector – High temperature heating – Bio–coal–based large–scale heating	×				
		68. Multi–sector – High temperature heating – Biomethane–based large–scale heating	×				
		69. Multi–sector – High temperature heating – Direct heat from variable renewables	✓ (IEA)	**n/a – already shortlisted**			
		70. Multi–sector – High temperature heating – Electric arc and plasma arc furnaces	✓ (IEA)	**n/a – already shortlisted**			

Note: 1. Already implemented by the only nitric acid operation in NSW (Orica). 2. Strategically aligned with NZIIP (DPIE 2021c). High desirability, given it has the potential to curve out the last 10% of the energy consumption in smelting process leaving the up front 90% to renewable energy sources to address (DISER – AUS Government). Also high feasibility considering recent development in inert anode cell solution.

IPPU – 78 solutions (4/4)

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | × ; Grouped solutions

IPPU is currently the third last contributor (10%) to NSW emissions, with metal sector being the most significant subsector (55% of sector, 6% of total NSW). Within this sector, 78 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z.	S	D	V	F
IPPU 10% of total NSW emissions	Minerals and other product manufacturing/use (11% of the IPPU sector) – *continued*	71. Multi–sector – High temperature heating – Electromagnetic large–scale heating	✓	**n/a – already shortlisted**			
		72. Multi–sector – High temperature heating – Fluidized–bed boiler fuelled with biomass	×				
		73. Multi–sector – Low to medium temperature heating – Bio–coal–based heating for large–scale industrial processes	×				
		74. Multi–sector – Low to medium temperature heating – Biomethane–based large–scale heating for industrial processes	×				
		75. Multi–sector – Low to medium temperature heating – Electromagnetic heating for large–scale industrial processes	×				
		76. Multi–sector – Low to medium temperature heating – Fluidized–bed boiler fuelled with biomass	×				
		78. Multi–sector – Hydrogen blend for heat	×				
		78. Multi–sector – Low to Medium temperature heating – Industrial electric	✓	**n/a – already shortlisted**			

IPPU – 15 unique solutions (1/5)

15 unique decarbonisation solutions have been identified in the IPPU prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

Shortlist	No	Subsector	Solution	Description	S	D	V	F	Rationale
●	1	Multi-application across key sub-sectors within IPPU & Stationary Energy	Carbon Capture, Utilisation and Storage (CCUS)	CCUS can be deployed broadly across subsectors, particularly in IPPU and stationary energy to capture hard-to-abate emissions. Key applications considered for NSW are CCUS deployment in production processes for iron and steel, ammonia and cement.	M	H	L	M	Limited strategic focus as NSW has yet to publicly announce its commitment, but it is generally aligned with Net Zero Industry and Innovation Program. High desirability, given CCUS could be deployed broadly and capture hard-to-abate emissions released in the production of iron and steel, ammonia and cement. Low viability, given CCUS is yet to be proven to be deployable on a cost effective basis. Medium feasibility given challenges with initial CCUS projects such as Gorgon. Furthermore, CCUS projects often face public scrutiny and opposition due to concerns related to the safety and environmental impacts of CO2 storage, including potential leakage or seismic activity.
●	2	Metals Industry (55% of emissions within the IPPU sector)	Iron and steel – Direct reduced iron – produced from green/blue hydrogen	Direct reduced iron produced using green/blue hydrogen instead of natural gas and coal.	H	H	L	M	Strategically aligned with the Federal State of Hydrogen report. High desirability as this is a broad–use, fuel–switch solution. Low viability given the solution is yet to be commercially and technically viable, given existing direct reduction processes need to be modified to accommodate hydrogen as a reducing agent (IEA). Medium feasibility given blue/green hydrogen supply chains are yet to be implemented.
	3	Metals Industry (55% of emissions within the IPPU sector)	Iron and steel – Direct reduced iron – produced from natural gas and green hydrogen blend	Direct reduced iron produced using gas–powered furnace using natural gas and green hydrogen blend instead of natural gas	L	L	M	M	Low strategic alignment because NSW has not publicly stated its alignment with this solution. Low desirability, given low abatement potential, with the continued use of (reduced) fossil fuel. Medium viability given hydrogen blending solution is not yet ready for commercial deployment. Medium feasibility given blue/green hydrogen supply chains are yet to be implemented.

IPPU – 15 unique solutions (2/5)

15 unique decarbonisation solutions have been identified in the IPPU prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) Solutions in the proposed shortlist

No	Subsector	Solution	Description	Assessment and rationale				
				S	D	V	F	Rationale
4	Metals Industry (55% of emissions within the IPPU sector)	Iron and Steel – Efficiency equipment	An increase in energy efficiency in the iron and steel smelting process using solutions such dual lances tuyeres, top gas recovery turbines and gas heat recovery	H	L	M	H	Strategically aligned with NSW NZIIP (DPIE 2021c). Low desirability, given these efficiency solutions has limited deployment potential and only entails efficiency gains. Medium viability since different solutions vary in commercial viability. High feasibility given existing solutions can be easily replaced with energy efficient equipment, and limited additional infrastructure is required.
5	Metals Industry (55% of emissions within the IPPU sector)	Iron and Steel – Low emissions fuels	Use of low emissions fuels, such as charcoal, to replace (a portion of) coal or coke in the production of iron and steel. Wood waste and forest residues can be used to produce charcoal	L	M	M	M	Low strategic alignment as NSW has yet to publicly announce its commitment to this solution. Medium desirability as this is a partial fuel–switch solution with broad applicability. Medium viability because charcoal is more expensive fuel source; however, this solution is already used in some countries with limited coal resources. Medium feasibility because adjustments to existing infrastructure, including the feeding systems, combustion processes, and gas cleaning systems are required.
6	Metals Industry (55% of emissions within the IPPU sector)	Iron and steel – electric arc furnace for steel making	Electric arc furnace (EAF) uses scrap metal and electricity instead of iron ore and coke to produce steel.	L	M	M	M	Low strategic alignment as NSW has yet to publicly announce its commitment. Medium desirability, being a fuel–switch solution with limited application. Medium viability, because although the solution is commercially available, it is harder to produce clean steel, and the availability of scrap metal constrained. Medium feasibility, EAF require adjustments to accommodate different operating characteristics, including the availability and quality of scrap metal.

IPPU – 15 unique solutions (3/5)

15 unique decarbonisation solutions have been identified in the IPPU prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

Shortlist	No	Subsector	Solution	Description	Assessment and rationale				
					S	D	V	F	Rationale
	7	Metals Industry (55% of emissions within the IPPU sector)	Aluminium – Integration of heat exchangers to vary energy consumption and production levels	Adjustable heat exchangers which dynamically adjust energy use and optimise energy usage in the aluminium smelting process.	H	L	M	H	Strategically aligned with NSW NZIIP (DPIE 2021c). Low desirability, given this has limited deployment potential and only entails efficiency gains. Medium viability since the solution is still limited to specific temperature range, corrosion resistance, fouling and scaling etc., and expected to become more broadly commercially viable in the next 10–15 years (IEA). High feasibility as the existing infrastructure, incl. piping, fluid circulation and control systems, are already in place for traditional heat exchangers.
●	8	Metals Industry (55% of emissions within the IPPU sector)	Aluminium – Primary smelting – inert anode	Inert anode cells can replace the carbon anodes consumed during mineral smelting. Greenhouse gas, in the form of sulphur dioxide (SO2) is produced during smelting when oxygen in the air reacts with sulphur in the carbon anodes. This reaction does not occur when using inert anodes; hence removing SO2 emissions from the smelting process.	H	H	M	H	Strategically aligned with NZIIP (DPIE 2021c). High desirability as inert anode cells have broad applications (for aluminium and minerals smelting) as a fuel–switch solution that will abate CO2 and potentially avoid fluorocarbon releases (CFA and C2F6). Medium viability given this solution is only expected to be commercially viable within the next 10–15 years (IEA), despite recent developments. High feasibility as the existing infrastructure, incl. smelting furnace, anode handling facilities, and ventilation systems, are already in place for traditional carbon anode smelting.
●	9	Chemicals Industry, Non–energy products and ODS substitutes (34% of the IPPU sector)	Ammonia – Production – Green hydrogen	Green ammonia produced with green hydrogen, replacing traditional production methods.	H	H	M	M	Strategically aligned with NSW Hydrogen Strategy (DPIE 2021f) and Net Zero Industry and Innovation Program (NZIIP) (DPIE 2021c). High desirability , given this is a fuel–switch solution with broad use in IPPU and Agriculture sectors. Medium viability given this solution is only expected to be commercially viable within the next 10–15 years (IEA). Medium feasibility given the regulation and safety standards and green hydrogen supply chains are yet to be implemented. Also applicable as a fertiliser in the Agriculture sector (#5)

IPPU – 15 unique solutions (4/5)

15 unique decarbonisation solutions have been identified in the IPPU prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

Shortlist	No	Subsector	Solution	Description	S	D	V	F	Rationale
●	10	Minerals and other product manufacturing/use (11% of the IPPU sector)	Minerals – Smelting – Inert anode	Inert anode cells can replace the carbon anodes consumed during mineral smelting. Greenhouse gas, in the form of sulfur dioxide (SO2) is produced during smelting when oxygen in the air reacts with sulfur in the carbon anodes. This reaction does not occur when using inert anodes; hence removing SO2 emissions from the smelting process.					Inert anode for smelting is already captured in the shortlist in the IPPU sector/aluminium (#12).
●	11	Minerals and other product manufacturing/use (11% of the IPPU sector)	Multi–sector – High temperature heating – Direct heat from variable renewables	Industrial heating (low, medium and high temperature) equipment that uses renewable electricity instead of fossil fuels.					Electrification of industrial heating is already captured in the shortlist in the Stationary Energy sector (#4).
●	12	Minerals and other product manufacturing/use (11% of the IPPU sector)	Multi–sector – High temperature heating – Electric arc and plasma arc furnaces	Industrial heating equipment, including electric arc and plasma arc furnaces, that uses renewable electricity instead of fossil fuels.					Electrification of industrial heating is already captured in the shortlist in the Stationary Energy sector (#4).

IPPU – 15 unique solutions (5/5)

15 unique decarbonisation solutions have been identified in the IPPU prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

Shortlist	No	Subsector	Solution	Description	S	D	V	F	Rationale
●	13	Minerals and other product manufacturing/use (11% of the IPPU sector)	Multi–sector – High temperature heating – Electromagnetic large–scale heating	Industrial heating equipment, including electromagnetic large–scale heating equipment, that uses renewable electricity instead of fossil fuels.					Electrification of industrial heating is already captured in the shortlist in the Stationary Energy sector (#4).
	14	Minerals and other product manufacturing/use (11% of the IPPU sector)	Multi–sector – Hydrogen blend for heat	Heating equipment that blends hydrogen with conventional fossil fuels.	H	M	M	L	Strategically aligned with NSW Hydrogen Strategy (DPIE 2021f) and Net Zero Industry and Innovation Program (NZIIP) (DPIE 2021c). Medium desirability given this is a partial fuel–switch solution with broad application across metals and minerals production. Medium viability given this solution is only expected to be commercially viable within the next 10–15 years after green/blue hydrogen could be produced at scale. Low feasibility given supporting infrastructure is likely to need upgrading to support high penetrations of hydrogen (e.g., supply pipelines or new on–site storage) and residual emissions/pollutants as a by–product.
●	15	Minerals and other product manufacturing/use (11% of the IPPU sector)	Multi–sector – Low to Medium temperature heating – Industrial electric	Industrial heating equipment, including electromagnetic large–scale heating equipment, that uses renewable electricity instead of fossil fuels.					Electrification of industrial heating is already captured in the shortlist in the Stationary Energy sector (#4).

6. Fugitive emissions

Fugitive emissions – 5 solutions

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | ✗ | Grouped solutions

Fugitive emissions is currently the second last contributor (9%) to NSW emissions, with coal mining being the most significant subsector (95% of sector, 8% of total NSW). Within this sector, 5 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z.	S	D	V	F
Fugitive emissions 9% of total NSW emissions	Coal mining (95% of the Fugitive emissions sector)	1. Mining – Ventilation Air Methane Oxidation (**underground**)	✓[1]	M	M	M	M
	Mining – Drainage – Flaring (**underground and open cut**)	2. Mining – Gas destruction – Goaf drainage with flaring 3. Mining – Gas destruction – Pre–drainage with flaring	✓[2]	M	L	H	M
	Mining – Drainage – Power generation (**underground and open cut**)	4. Mining – Goaf drainage with power generation 5. Mining – Pre–drainage with power generation	✓[2]	M	M	H	M

Note: 1. Moderate strategic focus, given NSW has not publicly stated its position, but generally aligned with NZIIP (DPIE 2021c) and NSW EPA Climate Change Policy and Action Plan. Medium Desirability as it is one of the few solutions available to treat methane emissions from ventilation air, demonstrated in pilots (CSIRO).
2. Moderate strategic focus, given NSW has not publicly stated its position, but generally aligned with NZIIP (DPIE 2021c) and NSW EPA Climate Change Policy and Action Plan. Medium desirability and feasibility given the potential for emissions reduction is contingent on technical requirements of the specific mining operation and local conditions. Solution readiness is in a considerate level as well.

Fugitive emissions – 3 solutions

3 decarbonisation solutions have been identified in the Fugitive emissions prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

Shortlist	No	Subsector	Solution	Description	S	D	V	F	Rationale
					Assessment and rationale				
●	1	Coal mining (95% of Fugitive emissions)	Mining – Ventilation Air Methane (VAM) Oxidation	VAM oxidation captures fugitive methane emissions from **underground mines** and converts it to CO2 and water vapor. Avoids the direct release of methane into the atmosphere, which has a much higher global warming potential.	M	M	M	M	Medium strategic focus, given NSW has not publicly stated its position, but generally aligned with NZIIP (DPIE 2021c) and NSW EPA Climate Change Policy and Action Plan. Medium desirability as VAM has broad use as an efficiency solution, noting that application could vary depending on the specific mining operation and local conditions. Medium viability given VAM is only at the pilot phase and (CSIRO) would only be ready for commercial deployment in the coming decades. Medium feasibility given additional infrastructure such as adapted air extraction and oxidation units needs to be implemented on mine sites.
	2	Coal mining (95% of Fugitive emissions)	Mining – Drainage – Flaring	Flaring (controlled combustion) of fugitive methane emissions from **underground and open cut mines.** Avoids the direct release of methane into the atmosphere, which has a much higher global warming potential.	M	L	H	M	Medium strategic focus, given NSW has not publicly stated its position, but generally aligned with NZIIP (DPIE 2021c) and NSW EPA Climate Change Policy and Action Plan. Low desirability as flaring is an efficiency solution commonly used for underground coal mines. High viability given it is already ready for commercial deployment. Medium feasibility given the flaring requires infrastructure including gas collection wells, pipelines and gas processing equipment, noting that implementation may be limited by geological conditions, mine designs and operational characteristics.
●	3	Coal mining (95% of Fugitive emissions)	Mining – Drainage – Power generation	Utilisation of fugitive methane emissions from **underground and open cut mines** for power generation. The combustion of methane avoids direct release of methane into the atmosphere, which has a much higher global warming potential while providing a source of energy.	M	M	H	M	Medium strategic focus, given NSW has not publicly stated its position, but generally aligned with NZIIP (DPIE 2021c) and NSW EPA Climate Change Policy and Action Plan. Medium desirability as drainage power generation is an efficiency solution that can be used across different mine sites. High viability given it is ready for commercial deployment. Medium feasibility given the requisite infrastructure, including methane capture and treatment, and gas engines/turbines can be implemented; however, residual emissions (produced during combustion) is a negative by product.

7. Waste

Waste – 4 solutions

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | × — Grouped solutions

Waste is currently the last contributor (4%) to NSW emissions, with solid waste disposal being the most significant subsector (76% of sector, 3% of total NSW). Within this sector, 4 decarbonisation solutions have been identified in the longlist

Sector	Subsector	Solution	I.N.Z.	S	D	V	F
Waste 4% of total NSW emissions	Solid waste disposal (76% of the Waste sector)	1. Organic waste processing (anaerobic digestion) 2 Organic waste processing (composting)	✓[1]	M	M	M	L
		3. Drainage – Power generation	✓	H	M	H	M
		4. Incineration for energy recovery	✓[2]	M	L	M	L

Grouped solution (1 and 2): Organic waste processing

Note: 1. Strategically aligned with NSW Waste and Sustainable Materials Strategy 2041 and EPA Go FOGO grants which are already rolled out across the state, indicating high viability. Medium desirability as it is one of the few options available for emissions reduction from landfill gasses. Medium feasibility given it still requires government subsidy in the short–term.
Note: 2. Medium strategic alignment given it is a transitionary solution despite the current NSW Thermal Energy from waste Planning Policy. Medium viability as the solution is deployed overseas but not locally.

Waste – 3 solutions

3 decarbonisation solutions have been identified in the Waste prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

No	Subsector	Solution	Description	Assessment and rationale				
				S	D	V	F	Rationale
1	Solid waste disposal (76% of emissions within the Waste sector)	Organic waste processing[1]	Waste management system that involves separating and collecting organic materials, such as food and yard waste, from municipal, commercial and industrial, and construction and demolition waste streams. These organic materials are then processed through composting or anaerobic digestion methods to convert them into nutrient–rich compost or biogas, avoiding decomposition in landfill.	M	M	M	L	Medium strategic alignment given it is a transitional solution despite the current NSW Thermal Energy from waste Planning Policy. Medium viability as the solution is deployed overseas but not locally, furthermore the organic feedstocks are more likely to be used for sustainable aviation fuel production rather than be processed by anaerobic digestion. Medium desirability, given organic composting have broad application as an efficiency solution. Low feasibility given emission, odours and pollutants are negative by–products during the composting process.
● 2	Solid waste disposal (76% of emissions within the Waste sector)	Drainage – Power generation	Utilisation of methane emissions from organics in landfill for power generation.	H	M	H	M	Strategic alignment with NSW's Waste and Sustainable Materials Strategy. Medium desirability as drainage power generation is an efficiency solution that can be used across different waste plants. High viability given it is ready for commercial deployment. Medium feasibility given the requisite infrastructure, including methane capture and treatment, and gas engines/turbines can be implemented; however, residual emissions (produced during combustion) is a negative by product.
3	Solid waste disposal (76% of emissions within the Waste sector)	Incineration for energy recovery	Combusts solid waste at high temperatures to generate energy. This solution reduces the volume of waste, while simultaneously generating energy, but it also generates emissions and potentially releases pollutants.	M	L	M	L	Medium strategic alignment given it is a transitional solution despite the current NSW Thermal Energy from waste Planning Policy. Medium viability as the solution is deployed overseas but not locally. However, low desirability, given this has limited deployment potential and only entails efficiency gains, and low feasibility given emissions, odours and pollutants are negative by–products.

8. Whole-of-economy

Whole-of-economy – 11 solutions

Legend: Importance to Net Zero: IEA ✓ | Deloitte ✓ | × — Grouped solutions

For the remaining hard-to-abate emissions, 11 decarbonisation solutions have been captured in the longlist.

Sector	Subsector	Solution	I.N.Z.	S	D	V	F
Whole of economy	GHG Removal – Direct Air Capture and Carbon Storage (DACCS)	1. Carbon capture	✓[1] (Deloitte)	M	H	L	M
		2. Carbon sequestration	✓[1] (Deloitte)				
		3. CO2 storage – Depleted oil and gas reservoir	✓ (IEA)				
		4. CO2 storage – Saline formation	✓ (IEA)				
		5. Direct air capture – Liquid DAC (L–DAC)	✓ (Deloitte)				
		6. Direct air capture – Solid DAC (S–DAC)	✓ (Deloitte)				
		7. Cement and concrete – Cement kiln – CCUS	✓ (IEA)				
		8. Multi–sector – Production – High temperature heating – Boilers with CCUS	✓ (IEA)				
		9. Carbon utilisation	×				
		10. CO2 storage – CO2–enhanced oil recovery	×				
		11. Nature-based solutions	✓[1] (Deloitte)	H	M	H	M

Note: 1. Carbon capture, sequestration and Nature-based solutions are all part of carbon management solutions that has the abatement potential across multiple sectors. EIA has 'Moderate' importance ranking for net–zero of these solutions. These can play an important role for the hard-to-abate portion of total abatement.

Whole-of-economy – 2 solutions

2 decarbonisation solutions have been identified in the Fugitive emissions prioritised longlist. Each solution has been assessed against the agreed solution selection criteria

Legend: Strategic Alignment (S) Desirability (D) Viability (V) Feasibility (F) ● Solutions in the proposed shortlist

	No	Subsector	Solution	Description	Assessment and rationale				
					S	D	V	F	Rationale
●	1	Whole of economy	GHG Removal – Technological – Direct Air Capture and Carbon Storage (DACCS)	DACCS captures and stores CO_2 directly from the atmosphere. The CO_2 emissions can then be used for various applications (such as enhancing oil recovery) or be injected into geological formations and stored permanently.	M	H	L	M	Limited strategic focus as NSW has yet to publicly announce its commitment, but it is generally aligned with Net Zero Industry and Innovation Program. High desirability, given DACCS could be deployed to capture residual emissions from hard-to-abate sectors. Low viability, given DACCS is yet to be proven to be deployable on a cost-effective basis. The high upfront capital costs associated with building and operating DACCS infrastructure, including capture facilities and transportation networks, can be a barrier to widespread adoption. Additionally, the cost of carbon capture solutions and the energy required to capture and compress CO_2 can be substantial. The technical feasibility of DACCS depends on the availability of suitable storage sites, the efficiency of capture solutions, and the transportation infrastructure. Medium feasibility given DACCS projects require significant lead time and often face public scrutiny and opposition due to concerns related to the safety and environmental impacts of CO_2 storage, including potential leakage or seismic activity.
●	2	Whole of economy	GHG Removal – Nature-based solutions	Nature-based solutions such as reforestation within the boundaries of NSW. Full scope of nature-based solutions (e.g., consideration of soil management) to be finalised in the MAC analysis.	H	M	H	M	Strategically aligned with NSW Gov's recognition of the role of natural capital in attracting international capital investment and enabling participation in carbon, biodiversity and natural capital markets, as per the NSW Natural Capital Statement of Intent. High viability given Nature based solutions are already being deployed locally and globally. Medium desirability, given deployment potential will be capped by NSW's land size and competing land–use from the LULUCF and agriculture sectors. Medium feasibility given need for social license, landowner participation, and endorsement of First Nations.

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