Australia's National Science Agency

CO_2 Utilisation in Australia: State of Play

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Citation and authorship

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Disclosure statement

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Contents

This report

Carbon dioxide (CO_2) utilisation technologies convert CO_2 captured from industrial emissions and the atmosphere into useful products – like fuels, chemicals and materials. If successfully commercialised, they could help mitigate hard-to-abate emissions and enable a transition to low emission manufacturing in Australia.

With a historic economic reliance on emissions-intensive fossil fuel and mining exports, and abundant renewable resources, Australia has both a strong driver and an opportunity to be at the forefront of CO_2 utilisation development. Recognising this, CSIRO's CO_2 Utilisation Roadmap (2021)[1] explored the opportunities and challenges associated with the use of CO_2 in Australia.

Since the Roadmap's release, domestic and global carbon emissions have continued to grow, increasing the need for decarbonisation solutions, including carbon management technologies, and the transition towards the use of low-emission products.

Against this backdrop, this report:

- Reviews the **state of play** (Section 2) in the CO_2 utilisation ecosystem with a focus on Australia's industrial activity, policy and regulatory changes, and progress against the themes identified in the CSIRO CO_2 Utilisation Roadmap since its release in 2021.
- Delivers **market analysis** (Section 3) that explores the industry development status and potential domestic market demand for a selection of CO_2-derived products in 2050: methanol, aviation fuel, urea, mineral aggregates, and supplementary cementitious materials.

This report seeks to provide an overview of the current state of play of industry activity in CO_2 utilisation globally and in Australia, and to assess the domestic opportunity and enabling factors that may be required to support further engagement and activity.

CO_2 sources and utilisation pathways in scope of this report

CO_2 SOURCE	CO_2 UTILISATION PATHWAYS IN SCOPE
Point Source Capture (PSC) and flue gas CO_2 from industry **Direct Air Capture (DAC) CO_2** from the atmosphere	**CO_2-derived products** using CO_2 captured from a point source (PSC) or the atmosphere (DAC) are the primary focus of this report. Production costs for these products are estimated using updated CSIRO levelised cost of production (LCOP) models.
Biologically captured CO_2 from the atmosphere	**Bio-products** produced from the carbon contained in biomass or organic waste. Production costs for these products are estimated from literature.

1 Srinivasan V, Temminghoff M, Charnock S, Moisi A, Palfreyman D, Patel J, Hornung C, Hortle A (2021) CO_2 Utilisation Roadmap. CSIRO.

Executive summary

This report explores the state of play in Australia's emerging CO_2 utilisation industry and assesses the domestic market potential of several CO_2-derived products in 2050.

CO_2 utilisation provides an opportunity to utilise CO_2 captured from industrial processes and the atmosphere to produce CO_2-derived chemicals, fuels, and materials. Utilising captured CO_2 can reduce the emissions intensity of these products compared to conventional production methods. Along with carbon capture and storage (CCS) and carbon dioxide removal (CDR), CO_2 utilisation (also referred to as carbon capture and utilisation, or CCU) contributes to a holistic approach to carbon management.

State of play: Australia's emerging CO_2 utilisation industry

Australia's CO_2 utilisation industry has continued to develop with mineral carbonation projects operating at pilot and demonstration scale, and multiple e-methanol and bio-e-methanol projects under development.

While no Australian CO_2 utilisation projects have achieved full commercial-scale operations yet, there are important signs of progress. MCi Carbon's Myrtle Demonstration Plant commenced operations in 2025, and HIF Global completed a pre-FEED study for an e-methanol plant in 2024. Bio-e-methanol projects planning to utilise biological sources of carbon and renewable hydrogen inputs are also in various stages of development in Tasmania and Victoria. Although many domestic projects are at early stage, this is relatively consistent with global developments, providing Australia with the opportunity to capture competitive-advantage and capture demand.

Australian federal and state governments continue to support the development of CO_2 utilisation technologies and projects through targeted funding mechanisms and investment in feasibility studies and pilots.

To accelerate the development of new carbon management technologies, the Australian Government continues to invest in CO_2 utilisation projects through the Carbon Capture Technologies Program. The first round of this program invested approximately $41 million in CO_2 utilisation projects, supporting three mineral carbonation projects and one methanol project. A further $52 million has been allocated for a second funding round, opening in 2026.

At the state-level, CO_2 utilisation policy and funding approaches are linked to each state and territory's respective industrial strategy. Due to the high costs and risks associated with first-of-a-kind projects, government support has been a critical enabler of the CO_2 utilisation projects under development in Australia.

Despite steady industry progress and government support, the deployment of commercial scale CO_2 utilisation faces significant economic, technical, and system challenges.

The cost of carbon capture technologies – especially direct air capture (DAC) – continues to limit their deployment. Similarly, the high cost and limited availability of renewable hydrogen is limiting the cost competitiveness of CO_2 utilisation pathways where hydrogen is a primary feedstock (e.g. methanol, aviation fuel, and urea). Due to these high costs, bio-production pathways for methanol and sustainable aviation fuel (SAF) show much greater potential for cost effectiveness. Some stakeholders also identified the lack of price signals that value CO_2 emissions intensity reductions associated with recycling industrial CO_2 into short-term stores of CO_2 (e.g. fuels, fertilisers) as a constraint for CO_2 utilisation industry development.

Other products such as construction aggregates and supplementary cementitious materials (SCMs) show strong potential for cost-effectiveness. However, they may face technical challenges such as validating their technical performance for use in regulated and standardised construction industry applications.

Scaling up CO_2 utilisation to meet demand for bulk commodities requires alignment of many factors including CO_2 sources and other feedstocks, logistics, and supply chains to create commercially viable projects. For example, urea produced from industrial emissions shows strong potential for cost effectiveness by 2050 but will require a nearby and consistent CO_2 source, affordable and scalable low-carbon hydrogen and ammonia production. Similarly, the opportunity for construction aggregate and SCM production is strengthened if supply chains are optimised through co-located feedstock sources and end-users. Upstream and downstream partnerships – including bilateral partnerships with key trading partners – will likely be required to coordinate this and reduce risks for urea and mineral carbonate developers.

Market analysis: opportunities and enabling conditions for CO_2 utilisation

CO_2 utilisation is a nascent industry opportunity that has potential to support decarbonisation of some of the hardest-to-abate sectors in Australia in the long-term. This report estimates the potential domestic market demand for a selection of PSC and DAC CO_2-derived and bio-products in the year 2050 by assessing their cost-competitiveness against incumbent products in five markets: methanol, aviation fuel, urea, mineral aggregates, and SCMs.

This analysis uses low and high decarbonisation ambition scenarios to explore the evolving carbon and industrial policy landscape and model a limited number of CO_2-derived products and production pathways in future domestic markets (see Appendix A.2 for scenario details). It is conservative in its scope and assumptions and does not evaluate the potential impact of exports. As such, it may overestimate the potential costs and underestimate the addressable markets for CO_2-derived products as the world transitions towards net-zero in 2050.

The overall market assessment results, and the cost-competitiveness results are summarised in Table ES1 and Table ES2, respectively. CO_2-derived products have the potential to cut emissions significantly by displacing conventional products at scale. As such, carbon abatement potential is assessed over the full life cycle by comparing their carbon intensity with incumbent products across projected market demand (see Appendix A.3–A.7 for calculation details).

Table ES1: Annual domestic demand, economic impacts, and CO_2 abatement results for the cost-competitive CO_2-derived and bio-products in 2050

CARBON SOURCE	PRODUCT	DOMESTIC DEMAND (Mtpa)	REVENUE (AUD, billion)	JOBS (FTE, ROUNDED)	CO_2 ABATEMENT* (Mtpa CO_2)
Industry (PSC)	Urea	2.7	$1.6	1000	2.1
Industry (Flue gas)	Carbonated fine aggregate	2.1	$0.13	200	0.15
	Carbonated (steel slag) SCM	0.15	$0.012	10	0.04
Biological	Bio-methanol	8.7	$6.9	5000	18.5
	Bio-SAF (FT and HEFA⁺)	3.2–3.4	$5.2–5.6	3800–4000	10.8–11.3

* CO_2 abatement is based on substitution of an incumbent product.

⁺ Bio-SAF (HEFA) is only cost-competitive with conventional jet fuel in the high ambition scenario, as such the total demand for bio-SAF products is presented as a range representing the low and high ambition scenario results.

Note: The economic impact and CO_2 abatement potential were not calculated for products that did not capture demand.

Table ES2: 2050 cost competitiveness of CO_2-derived and bio-products under low and high ambition scenarios

MARKET	PRODUCT	COST COMPETITIVENESS	
		Low ambition	High ambition
Methanol	e-Methanol (PSC)	Cost-competitive	Cost-competitive
	e-Methanol (DAC)	Not cost-competitive	Cost-competitive
	Bio-methanol	Most cost-competitive	Most cost-competitive
Aviation Fuel	e-SAF (PSC)	Not cost-competitive	Not cost-competitive
	e-SAF (DAC)	Not cost-competitive	Not cost-competitive
	Bio-SAF (HEFA)	Not cost-competitive	Cost-competitive
	Bio-SAF (FT)	Most cost-competitive	Most cost-competitive
Urea	Urea (PSC)	Most cost-competitive	Most cost-competitive
	Urea (DAC)	Not cost-competitive	Cost-competitive
Mineral aggregates	Concrete blend with **carbonated fine aggregate**	Most cost-competitive	Most cost-competitive
SCMs	Cement blend with **carbonated SCM**	Most cost-competitive	Most cost-competitive

LEGEND

PSC or DAC CO_2-derived product (levelised cost of production modelled).

Bio-product (production cost estimated from literature).

Most cost-competitive product in market.

Cost-competitive compared to the incumbent product.

Not cost-competitive compared to the incumbent product.

Note: Direct Air Capture (DAC); Fischer–Tropsch (FT); Hydroprocessed Esters and Fatty Acids (HEFA); Point Source Capture (PSC); Supplementary Cementitious Material (SCM).

Urea produced from recycled industrial CO_2 presents a strong $1.6 billion market opportunity in 2050.

The viability of producing urea from industrial emissions is dependent on the successful deployment of green ammonia projects, the establishment of CO_2 PSC and distribution infrastructure, and the development of relevant carbon accounting methodologies. Hybrid urea production (incorporating green ammonia feedstocks into conventional urea production to reduce overall emissions intensity) may offer a transitional pathway to the use of industrial emissions and potentially DAC CO_2.

Carbonated fine aggregate and carbonated SCMs may present a near-term opportunity with potential for $142 million revenue in 2050.

These products have potential to support emissions reduction in the construction sector and recycle industrial waste streams. Modelling suggests that mineral carbonation-based products will approach cost competitiveness more quickly than other modelled products as they are not reliant on expected cost reductions in hydrogen inputs. These results suggest that carbonated waste products can compete in the market, however they are limited by the assumed supply of the modelled feedstocks (steelmaking slag and recycled concrete) in 2050. The size of this opportunity could be larger if scalable supplies of suitable feedstocks can be identified. Other feedstocks suitable for mineral carbonation, including serpentinite, are not considered in this report.

Bio-methanol and bio-SAF products could generate $12 billion revenue and up to 9000 jobs in 2050.

CO_2-derived e-methanol and e-SAF remain relatively expensive in 2050 and capture no domestic market demand. However, e-methanol achieves cost competitiveness with conventional methanol and could be expected to capture demand if the supply of bio-methanol is constrained by feedstock availability, or the demand for low-emissions methanol increases further – due to green shipping demand, for example. In the aviation fuel market, the potential demand for bio-SAF products in 2050 exceeds assumed supply constraints. As such, conventional jet fuel paired with high-quality emissions offsets may continue to meet most of the aviation sector's fuel demand in 2050 unless policy or regulatory mandates drive uptake of e-SAF. A more rigorous analysis of future bio-feedstock availability and demand will be essential to understanding the potential role of both bio-fuels and CO_2-derived fuels in the future.

The modelled CO_2-derived products and bio-products have potential to abate over 31.6 Mtpa of CO_2 emissions in 2050.

This analysis estimates that the production and use of CO_2-derived urea, mineral aggregate, and SCMs could abate almost 2.3 Mtpa of CO_2 in 2050. The abatement potential of bio-methanol and bio-SAF products was estimated at be 29.3 Mtpa (in the low ambition scenario).

The high decarbonisation ambition scenario had a small impact on the relative cost-competitiveness and demand for the modelled products and, as such, the potential CO_2 abatement. This subdued impact – an additional 0.5 Mtpa CO_2 abatement associated with the supply of bio-SAF (HEFA) – is due to market saturation in the urea and methanol markets occurring under the low ambition scenario, and supply constraints on the cost-competitive products in the other markets.

The economic and emissions abatement impact of CO_2 utilisation technologies could be improved through low-cost feedstocks and technical process innovations.

The overall emissions abatement impact and market viability of CO_2-derived products could be increased by securing supplies of low-cost CO_2 feedstocks, increasing the supply of low-cost renewable hydrogen, developing more efficient CO_2 utilisation processes, and implementing policy and regulatory support or drivers.

Improving the cost-competitiveness of DAC and the uptake of DAC capture carbon can enhance the abatement impact of CO_2 derived products in the long-term. Even under the high decarbonisation ambition scenario, products derived from DAC CO_2 feedstocks remain significantly more expensive than PSC CO_2-derived and bioproduct alternatives. Further reductions in the cost of DAC could be enabled by driving down associated capital costs, improving operational efficiency and increasing the supply and affordability of renewable energy.

Glossary

Term/acronym

ACCU	Australian Carbon Credit Unit: tradable units representing one tonne of carbon dioxide equivalent (CO_2-e) stored or avoided.
ATJ	Alcohol-to-Jet: a process for producing sustainable aviation fuel from alcohols.
bio-	(prefix) Denotes a product (e.g. bio-methanol, bio-SAF) produced from biological/organic feedstocks like biomass or waste.
Carbonated fine aggregate	A mineral aggregate product designed as a substitute for sand in concrete production produced from waste materials such as steel slag or concrete and CO_2 in flue gas.
Carbonated SCM	A carbonated Supplementary Cementitious Material made from steel slag waste and CO_2 in flue gas.
CAGR	Compound Annual Growth Rate
CCS	Carbon Capture and Storage: capturing CO_2 from point sources and storing it underground.
CCU	Carbon Capture and Utilisation: capturing CO_2 and using it to produce products.
CCUS	Carbon Capture, Utilisation and Storage: an umbrella term for CCS and CCU technologies.
CDR	Carbon Dioxide Removal: technologies that remove CO_2 from the atmosphere and store it permanently.
CJF	Conventional Jet Fuel: standard petroleum-based aviation fuel.
CO_2	Carbon Dioxide
CO_2 Utilisation	The use of captured carbon dioxide to create products. Also referred to as CCU.
DAC	Direct Air Capture: technology that captures CO_2 directly from the atmosphere.
ETS	Emissions Trading Scheme
e-	(prefix) denotes a product that is produced using captured CO_2 and renewable hydrogen feedstock produced using renewable electricity (e.g. e-fuels).
FEED	Front End Engineering and Design
FID	Final Investment Decision
FT	Fischer–Tropsch: a series of chemical reactions used to convert syngas (a mixture of carbon monoxide and hydrogen) into liquid hydrocarbons.
FTE	Full Time Equivalent (jobs)
GGBFS	Ground Granulated Blast Furnace Slag: a by-product of steelmaking used as a supplementary cementitious material.
HEFA	Hydroprocessed Esters and Fatty Acids – a processing pathway used to produce sustainable aviation fuel by hydrogenating biological feedstocks (e.g. cooking oils, vegetable oils, and animal fats).
IMO	International Maritime Organisation – UN agency responsible for regulating shipping.
IRA	Inflation Reduction Act
LCA	Life Cycle Assessment – analysis of environmental impacts associated with all stages of a product's life.
LCOP	Levelised Cost of Production – the average cost of producing a product over its lifetime.
e-methanol	e-methanol is a CO_2-derived product, produced from captured CO_2 (PSC or DAC) and renewable hydrogen.
Bio-methanol	bio-methanol relies on the gasification or combustion of biomass to generate a syngas intermediate.
Bio-e-methanol	bio-e-methanol is a hybrid approach, where biomass-derived syngas is supplemented with renewable H_2 to improve the conversion efficiency and yield.
MoU	Memorandum of Understanding
$MtCO_2$	Million tonnes of carbon dioxide.
$MtCO_2$-e	Million tonnes of carbon dioxide equivalent – includes other greenhouse gases.
NO_x	Nitrogen oxides
OPC	Ordinary Portland Cement
pre-FEED	pre-Front End Engineering and Design
PSC	Point Source Capture of CO_2 from industrial processes.
PtL	Power-to-liquids
SAF	Sustainable aviation fuel – low-carbon alternatives to conventional jet fuel.
SCM	Supplementary Cementitious Material – materials used to partially replace cement in concrete.
SO_x	Sulphur oxides
Urea	Urea is a nitrogen-based fertiliser produced through the reaction of ammonia (NH_3) with CO_2 at high pressure. Conventionally, both the ammonia and CO_2 are derived from natural gas feedstocks. This report models the production of low-carbon urea using PSC and DAC sources of CO_2 combined with renewable ammonia.
Well-to-wheel	Well-to-wheel (or well-to-wake) – refers to the emissions produced through the entire lifecycle of a product, including its production, transport and use.

1 Introduction

CO_2 utilisation technologies convert CO_2 captured from the atmosphere or industrial emissions into useful products – like fuels, chemicals and materials. If successfully commercialised, they could help mitigate hard-to-abate emissions and enable a transition to low emission manufacturing in Australia.

There are a range of industries that are difficult to decarbonise with renewable energy and electrification alone. These industries often rely on fossil fuel feedstocks to produce carbon-based products, like fuels and plastics. Others have emissions inherent in their processes, like steel and concrete production, or are reliant on energy dense fuels, like heavy transportation.

CO_2 utilisation provides an opportunity to utilise CO_2 from industry and the atmosphere to produce chemicals, fuels, and materials with reduced emissions intensities compared to conventional products. Along with carbon capture and storage (CCS) and carbon dioxide removal removal (CDR), CO_2 utilisation (commonly referred to as carbon capture and utilisation, or CCU) can support a holistic approach to carbon management and support decarbonisation of hard-to-abate industries (See Box 1).

As both a major fossil fuel exporter and a country with abundant renewable energy resources, Australia has both a strong driver and an opportunity to be at the forefront of CO_2 utilisation development. Recognising this, CSIRO's CO_2 Utilisation Roadmap (2021)[2] explored the opportunities and challenges associated with manufacturing CO_2-derived products in Australia.

Since the Roadmap's release, domestic and global carbon emissions have continued to grow, which is driving the acceleration of the deployment of decarbonisation solutions, including carbon management technologies, and the transition towards the use of low-emission products. Against this backdrop, it is timely to provide an update on Australia's progress in this space to support decision makers in industry, government and research. This report:

- Reviews the **state of play** (Chapter 2) in the CO_2 utilisation ecosystem with a focus on Australia's industrial activity, policy and regulatory changes, and progress against the themes identified in the CSIRO CO_2 Utilisation Roadmap since its release in 2021.
- Delivers new **economic analysis** (Chapter 3) assessing the potential market demand for a selection of CO_2-derived products in 2050, including: methanol, aviation fuels, urea, cement and concrete.

Box 1: Carbon Management[3]

Carbon management includes the following approaches to managing hard-to-abate emissions:

- **Carbon Capture and Utilisation (CCU):** CO_2 captured from a point source or the atmosphere and used either directly or indirectly to form CO_2-derived products.
- **Carbon Capture and Storage (CCS):** CO_2 captured from a point source and permanently stored.
- **Carbon Dioxide Removal (CDR):** CO_2 captured from the atmosphere and stored permanently.

Figure 1: CO_2 sources and utilisation pathways in scope of this report

CO_2 SOURCE	CO_2 UTILISATION PATHWAYS
Point Source Capture (PSC) and flue gas CO_2 from industry	**CO_2-derived products** using CO_2 captured from a point source (PSC) or the atmosphere (DAC) are the primary focus of this report.
Direct Air Capture (DAC) CO_2 from the atmosphere	
Biologically captured CO_2 from the atmosphere	**Bio-products** produced from the carbon contained in biomass or organic waste.

2 Srinivasan V, Temminghoff M, Charnock S, Moisi A, Palfreyman D, Patel J, Hornung C, Hortle A (2021) CO_2 Utilisation Roadmap. CSIRO.

3 Department of Climate Change, Energy, the Environment and Water (DCCEEW) (2025) Carbon Management for Tough Emissions. <https://www.dcceew.gov.au/climate-change/emissions-reduction/carbon-management-technologies> (accessed 8 October 2025); European Commission (2024) Towards an ambitious Industrial Carbon Management for the EU. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2024:62:FIN> (accessed 8 October 2025).

2 State of play

Australia's CO_2 utilisation industry has been developing slowly between 2021 to 2025, interspersed by important signals of momentum.

This section provides an overview of Australian industry activity since 2021 (Section 2.1), relevant policy and regulatory changes (Section 2.2), Australia's progress against industry development themes identified in CSIRO's CO_2 Utilisation Roadmap (Section 2.3), and a high-level overview of relevant global activity (Section 2.4).

2.1 Industry

Major Australian CO_2 utilisation industry projects are mapped in Figure 2. While the environment has continued to develop, only two industry projects (MCi Carbon's Myrtle Demonstration Plant, and Novalith's Pilot Plant) are currently operational.

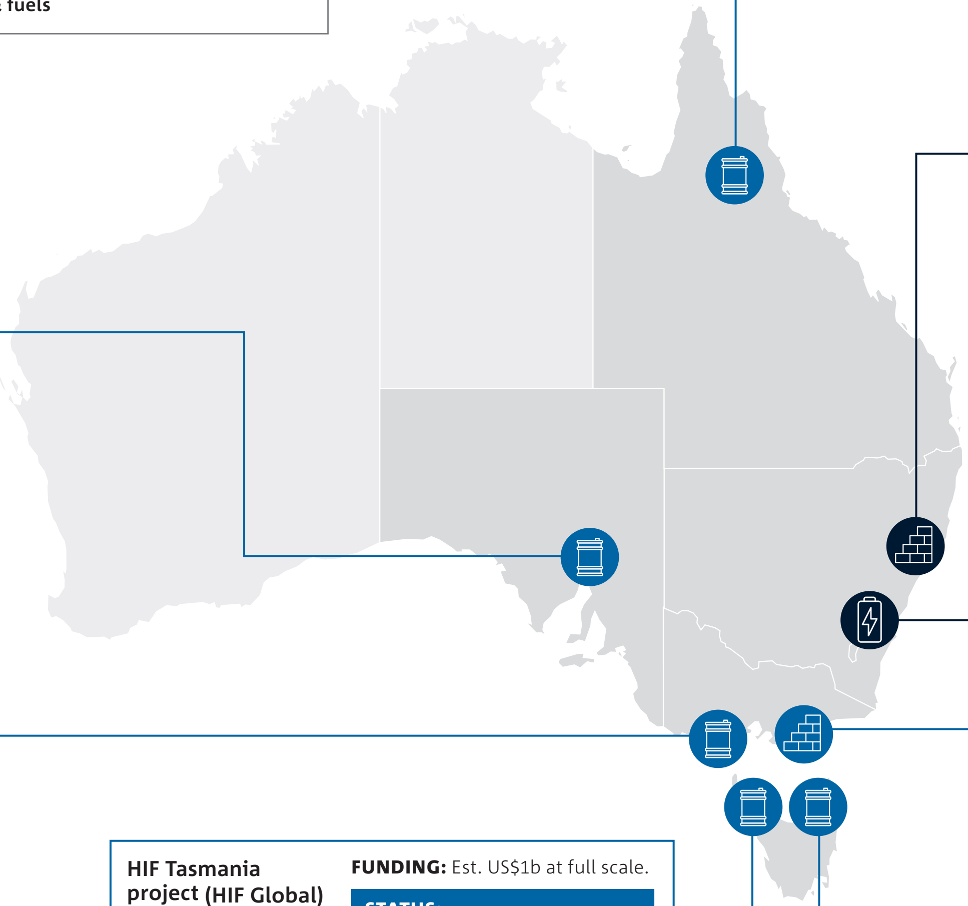
Six other projects are conducting or have recently completed pre-Front End Engineering and Design (pre-FEED) studies, with some progressing to FEED studies in 2025. Three of the eight identified projects relate to mineral carbonation, three relate to methanol production, and one relates to sustainable aviation fuel (SAF) production, which aligns with the relative cost competitiveness and projected market value of these products identified in the 2021 CO_2 Utilisation Roadmap and the market viability results in Section 3.

Figure 2: Snapshot of CO_2 utilisation industry activity in Australia

Industrial projects

STATUS
- IN DEVELOPMENT
- OPERATIONAL

PRODUCT
- Synthetic hydrocarbon chemicals & fuels
- Building materials
- Battery materials



South Australia Solar Fuels (Vast Renewables)
e-methanol production facility

FUNDING: Est. $90m total. $32m has been awarded under the under the German-Australian HyGATE initiative, and $700k via the Singapore-Australia ASLET initiative.

STATUS: Pre-FEED study complete. Vast Renewables entered voluntary administration in November 2025.

Portland Renewable Fuels Project (HAMR Energy)
Bio-e-methanol production facility

FUNDING: $500k state funding via the Portland Diversification Fund for feasibility study support.

STATUS: Commenced FEED study. Targeting operation in 2027.

HIF Tasmania project (HIF Global)
e-methanol production facility

FUNDING: Est. US$1b at full scale.

STATUS: Pre-FEED study complete. Targeting operation in 2030.

Project Ulysses (Jet Zero Australia)
Bio-SAF production facility

FUNDING: The $36.8m FEED study has received ARENA support and state funding, as well as private industry investment.

STATUS: Commenced FEED study.

Myrtle Demonstration Plant (MCi Carbon)
Mineral carbonate production facility

FUNDING: Received $14.6m and $14.5m in federal grants in 2021 and 2024 respectively, as well as global private investment in Japan and Europe.

STATUS: Commenced operation in 2025.

Novalith Pilot Plant
Lithium extraction and processing using CO_2

FUNDING: $23m Series A funding raised to build Novalith's pilot facility in NSW (2023), alongside a further $16m (2024) to accelerate commercialisation through scale up. ~$10m secured through the federal CCTP. $1.5m received from NSW Government in 2025.

STATUS: Scaling process to commercial scale.

O.C.O Accelerated Carbonation Technology Facility at Maryvale Energy From Waste Plant (O.C.O Technology)
Mineral carbonate production facility using particulate matter and CO_2

FUNDING: Private investment. $16.3m facility.

STATUS: Early development work underway. Targeting operation in 2029.

Bell Bay Powerfuels Project (ABEL Energy)
Bio-e-methanol production facility

FUNDING: The methanol production facility is estimated to cost $2b.

STATUS: FEED study contracted. Targeting operation in 2029.

Note: Project list is non exhaustive. Only major projects at the pre-FEED stage (or further) have been noted. Feasibility studies are excluded for this reason.

Stakeholder consultations and desktop research identified the following industry trends:

- **Government support remains a critical enabler of first-of-a-kind CO_2 utilisation projects in Australia.** Progressing projects have seen funding models combine state and federal support with private capital and international partnerships. Grants and competitive loans through government programs (such as the Clean Energy Finance Corporation, Future Made in Australia, and Northern Australia Infrastructure Fund) continue to play a pivotal role in risk-management for novel projects.
- **Bilateral collaboration with key trading partners can strengthen strategic partnerships and reduce project risk.** International funding (public and private) plays a critical role in enabling Australia's CO_2 utilisation sector, aligning export ambitions with the decarbonisation strategies of major trading partners. For example, international partners continue to express interest in importing renewable hydrogen and its derivatives. Japanese gas companies (Osaka Gas, Toho Gas, and Tokyo Gas) are collaborating with Santos on e-methane;[4] Japanese firms, such as ENEOS, have invested in Australia-based hydrogen production;[5] and the German-Australia HyGATE initiative demonstrates the value of bilateral public funding. Japan and Australia also cooperate through the Joint Partnership on Decarbonisation through Technology, providing a foundation for collaborative public and private ventures.[6] Export positioning is further reinforced by maritime CO_2 trade pilots, which are progressing globally.[7]
- **Most CO_2-derived products remain significantly more expensive than conventional products.** For hydrogen-derived products, such as e-methanol and e-SAF, this is primarily driven by the high cost and limited availability of renewable hydrogen (and other low-emission hydrogen sources). The cost of carbon capture technologies – especially DAC – also contributes to overall costs and potentially limits deployment. Stakeholders indicated that most customers are not yet willing to pay a significant green premium for CO_2-derived products, and the reduced emissions intensity that can be enabled through utilisation of industrial CO_2 emissions in chemicals and fuels is not currently accounted for in government policy. This underscores the importance of accelerating cost reductions and exploring opportunities to reduce the green premium, enabling wider market adoption of CO_2-derived products.
- **Scaling up utilisation is capital-intensive and requires integration of many upstream and downstream factors.** Securing and integrating cost-effective energy supply, CO_2 capture infrastructure, other feedstocks, and downstream customers will be critical to the success of commercially viable CCU pathways. These challenges create risks for developers, especially in the absence of long-term policy certainty and pricing signals

2.2 Government

Figure 3 provides a non-exhaustive timeline of major CO_2 utilisation related policy developments in Australia since 2021.

4 AusTrade (2024) Japanese utility giants to explore e-methane production in Australia. <https://international.austrade.gov.au/en/news-and-analysis/news/japanese-utility-giants-to-explore-e-methane-production-in-australia> (accessed 8 October 2025).

5 AusTrade (2025) ENEOS invests A$200 million in Australian green hydrogen demonstration plant. <https://international.austrade.gov.au/en/news-and-analysis/news/eneos-invests-200-million-in-Australian-green-hydrogen-demonstration-plant> (accessed 8 October 2025).

6 Department of Industry, Science and Resources (DISR) (2021) Japan-Australia partnership on decarbonisation through technology. <https://www.minister.industry.gov.au/ministers/taylor/media-releases/japan-australia-partnership-decarbonisation-through-technology> (accessed 8 October 2025).

7 Hakirevic Prevljak N (2025) K Line: New research project eyes development of onboard CCS. Offshore Energy. <https://www.offshore-energy.biz/k-line-new-research-project-eyes-development-of-onboard-ccs/> (accessed 8 October 2025); Kawasaki Kisen Kaisha (2024) 'K' LINE enters into charter contracts with Northern Lights for third liquefied CO2 vessels. <https://www.kline.co.jp/en/news/liquefied_gas/liquefied_gas-20240206.html>; Petronas (2023) PETRONAS, MOL, and SDARI Acquire Four AiPs for LCO_2 Transportation. <https://www.petronas.com/media/media-releases/petronas-mol-and-sdari-acquire-four-aips-lco2-transportation> (accessed 8 October 2025); TOKYO-Mitsui O.S.K. Lines (2024) MOL to Study Vessel Transport of Liquefied CO2 as Part of JOGMEC Call for 'Engineering Design Work for Advanced CCS Projects'. <https://www.mol.co.jp/en/pr/2024/24112.html> (accessed 8 October 2025).

Figure 3: Major Australian CO_2 utilisation policy developments (2021–2025)

FEDERAL

STATE AND TERRITORY

2021

CCUS Hubs and Technologies Program (est. 2021, *discontinued*)
A two-stream program to support multi-user CCS hubs ($100m) and CCUS technologies ($150m).
Discontinued in 2022–23, with budget refocussed towards broader decarbonisation objectives.

CCUS Development fund (2021)
A $50m fund providing business grants up to $25m for pilot or pre-commercial emissions reduction projects. Of the 6 projects awarded, 3 explicitly contained a utilisation aspect.

NT CCUS Middle Arm Precinct (2021)
The proposed CCUS Hub at the Middle Arm Precinct was announced and is currently under development. Two storage projects are at engineering stages, and an MoU for Australia's first CO_2 import terminal was signed in 2024 (Royal Vopak).

CSIRO CO_2 Utilisation Roadmap (2021)
The roadmap explores the risks and opportunities associated with the scale-up of carbon capture and utilisation (CCU) in Australia.

2022

NSW Net Zero Industry and Innovation Investment Plan (2022)
A $360m initiative to support industrial emissions reduction, including via CCUS opportunities.

2023

Australian Carbon Credit Unit (ACCU) Scheme reforms (2023–2028)
The ACCU system underwent review by an independent panel (2022) and by the CCA (2023). $66m is allocated to execute the reforms over 5 years. This includes the Safeguard Mechanism amendment (2023).

NT Opportunities for CO_2 Utilisation in the NT (2023) CSIRO
CSIRO collaborates with industry and government to support business case development for the low emissions NT CCUS hub. This report was released as part of this work.

Diversify WA (2023)
CCUS identified as one of the pillars of the Diversify WA framework.

Safeguard Mechanism reform (2023)
The reforms apply a decline rate to facility baseline emissions so that they reduce gradually in line with Australia's emissions reduction targets.

Carbon Capture Technologies Program, CCTP (2023)
A $65m fund targeting emerging technologies to capture and utilise CO_2. Funded projects were announced in July 2024.

NSW Net Zero Future Act (2023)
The Act, passed Nov 2023, establishes a framework within which CCUS could be considered in sectoral pathways.

WA CCUS Hubs Study (2023)
The study, undertaken by the Global CCS Institute and CSIRO, for the WA LNG Jobs Taskforce was released Nov 2023.

2024

WA Petroleum Legislation Amendment Act (2024)
The Act, assented in May 2024, provides a regulatory foundation for utilisation projects by enabling the transport and permanent storage of greenhouse gases.

QLD Great Artesian Basin GHG ban (2024)
QLD permanently bans GHG storage projects within the Great Artesian Basin in June 2024, which may promote regional utilisation projects.

QLD funding for utilisation projects (2024)
QLD announced new investments in SAF projects including a multi-seed crushing and processing facility at Yamala and funding for feasibility studies for Wagner and Liquid Power.

WA CCUS Action Plan (2024)
The plan, launched Nov 2024, outlines a vision to establish a CCUS industry in WA. $26m currently earmarked for CCS projects, funded through the Investment Attraction Fund (IAF).

WA Mineral Carbonation Roadmap released (2024)
The roadmap, delivered by the MRIWA, was launched in December 2024.

2025

Net Zero Plan and CCTP Round 2 (2025)
Australian Government announced updated 2035 emissions target, a Net Zero Plan, and $52m CCTP funding to accelerate the development of new carbon management technologies.

Federal Government

The Australian Government provides targeted support for CO_2 utilisation and other carbon management technologies through the Carbon Capture Technologies Program which invested approximately $41 million in CO_2 utilisation projects in its first round in 2024, including:[8]

- $15 million to **Calix Ltd** to support the construction of a renewably powered CCU demonstration plant that will supply CO_2 for methanol production.
- $14.5 million to **MCi Carbon** to fund plant upgrades to the Myrtle facility to process a greater range of feedstocks to produce carbon embodied building and construction materials.
- $9.9 million to **Novalith Technologies** to demonstrate the production of battery-grade lithium carbonate from atmospheric CO_2.
- $1.6 million to the **University of Melbourne's** Carbon Trap Lab to trial the conversion of CO_2 from DAC into travertine – a carbonated mineral suitable for use in building materials.

In 2025, $52 million was announced for a second funding round of the Carbon Capture Technologies Program to accelerate the development of new carbon management technologies.[9]

Previous support for CO_2 utilisation was focused on hub-building. In 2021, the CCUS Development Fund was established to accelerate early-stage or pre-commercial Carbon Capture, Utilisation and Storage (CCUS) projects; six projects received one-off funding grants, three of which explicitly contained a utilisation component.[10] In the same year, the $250m CCUS Hubs and Technologies Program was announced but was subsequently discontinued in the 2022–23 Budget. The Australian Government announced a refocus of its CCUS strategy towards more targeted innovation programs, formally launching the Carbon Capture Technologies Program in 2023.[11] This saw a pivot from multi-user hubs connected to CO_2 storage sites, towards a redesigned program aimed at accelerating the integration of novel CO_2 capture and utilisation technologies.

No formal carbon crediting pathways for CO_2 utilisation processes have been established in Australia.[12] The lack of price signals that value the potential CO_2 emissions intensity reductions associated with CO_2 utilisation was identified by several stakeholders as a constraint on Australia's CO_2 utilisation industry development. However, there is a growing acknowledgement of the role of carbon management (CCU, CDR and CCS), including in the Australian Government's Resources Sector Plan, Net Zero Plan and sectoral emissions plans,[13] in addition to investment in CSIRO's Carbon Dioxide Removal Roadmap.[14]

The Safeguard Mechanism, which sets legislated limits on emissions from Australia's largest industrial facilities, was amended in 2023 to ensure facilities reduce emissions on a trajectory consistent with Australia's emissions reduction targets.[15] This included baseline limits declining by 4.9% annually to 2029–30. The National Greenhouse and Energy Reporting (NGER) Scheme is used to determine which facilities are covered by the Safeguard Mechanism. In the future, CO_2 utilisation applications that store carbon in long lived products could potentially be deployed at relevant facilities to reduce emissions below the Safeguard Mechanism baseline and generate tradeable Safeguard Mechanism Credits. However, this would depend on how the captured and utilised CO_2 emissions are treated under the NGER Scheme, and would require the development of new reporting methodologies for emerging utilisation technologies.

Australian Carbon Credit Unit (ACCU) demand is expected to rise as facilities prepare to meet their future obligations under the Safeguard Mechanism. There are no approved ACCU methodologies for CO_2 utilisation processes.[16] If CO_2 utilisation methodologies are approved in the future, this may help improve revenue streams for relevant projects. In this scenario, facilities with co-located CCU projects registered under the ACCU scheme (pending methodology approval) can generate ACCUs and sell credits. Alternatively, Safeguard facilities that exceed their baselines could purchase ACCUs from external CCU projects registered with the ACCU scheme (pending methodology approval) to achieve compliance.

8 Department of Climate Change, Energy, the Environment and Water (2024) Carbon Capture Technologies Program grant recipients announced. Media release. <https://www.dcceew.gov.au/about/news/carbon-capture-technologies-program-grant-recipients-announced#:~:text=Through%20the%20Carbon%20Capture%20Technologies,carbon%20dioxide%20from%20the%20atmosphere> (accessed 8 October 2025).

9 Department of Climate Change, Energy, the Environment and Water (2025) Carbon management for hard-to-abate emissions. <https://www.dcceew.gov.au/climate-change/emissions-reduction/carbon-management-technologies>.

10 Department of Industry, Science and Resources (DISR) (2021) $412 million of new investment in carbon capture projects. <https://www.minister.industry.gov.au/ministers/taylor/media-releases/412-million-new-investment-carbon-capture-projects> (accessed 8 October 2025).

11 DCCEEW (2022) Meeting: APPEA CEO Samantha McCulloch. Meeting. <https://www.dcceew.gov.au/sites/default/files/documents/73531.pdf>

12 DCCEEW (2025) Net Zero. <https://www.dcceew.gov.au/climate-change/emissions-reduction/net-zero> (accessed 8 October 2025).

13 DISR and DCCEEW (2025) Resources Sector Plan. <https://www.industry.gov.au/sites/default/files/2025-09/disr-resources-sector-plan.pdf>; DCCEEW (2025) Setting our 2035 target and path to net zero. <https://www.dcceew.gov.au/about/news/setting-2035-target-path-net-zero>.

14 CSIRO (2025) Australian Carbon Dioxide Removal Roadmap. CSIRO, Canberra.

15 Department of Climate Change, Energy, the Environment and Water (2025) Safeguard Mechanism. <https://www.dcceew.gov.au/climate-change/emissions-reporting/national-greenhouse-energy-reporting-scheme/safeguard-mechanism>.

16 Department of Climate Change, Energy, the Environment and Water (2025) Method Development Tracker. <https://www.dcceew.gov.au/climate-change/emissions-reduction/accu-scheme/assurance-committee/method-development-tracker> (accessed 8 October 2025).

Federal Government programs that support hydrogen production, green and advanced manufacturing, and industrial decarbonisation can also support CO_2 utilisation. For example, a ten-year, $1.1 billion Cleaner Fuels Program was announced in September 2025. This program will support the development of low-carbon liquid fuels including SAFs and renewable diesel, where CO_2 utilisation projects may be eligible.[17] The Future Made in Australia program announced in the 2024–25 Budget also supports industries that can intersect with CO_2 utilisation including renewable hydrogen, critical minerals processing, low carbon liquid fuels and clean energy manufacturing.[18] Meanwhile, the Guarantee of Origin scheme, which seeks to measure and certify the emissions intensity of various commodities, was established initially to monitor renewable electricity and hydrogen claims, and intends to expand to include low carbon liquid fuels and green metals.[19] Hydrogen Headstart (2023) supports scaling renewable hydrogen projects, which could directly intersect with e-fuels and synthetic products reliant on captured CO_2. Although not targeted funding, the Australian Renewable Energy Agency (ARENA) can provide funding for CO_2 utilisation projects as part of relevant bioenergy, waste recovery and renewable energy projects.

State and Territory governments

State and Territory governments have implemented policies and regulations to support the deployment of CCU. At the state level, the WA *Petroleum Legislation Amendment Act 2024* represents a regulatory blueprint enabling the transport and permanent storage of captured CO_2, providing a regulatory framework for utilisation by enabling the movement of CO_2 feedstocks. WA Department of Mines, Petroleum and Exploration is also drafting regulations under the *Petroleum Legislation Amendment Act 2024*, designed to support the growth of a carbon service industry including CO_2 utilisation technologies.[20]

State-level CO_2 utilisation policy is linked to each state's respective economic agenda. WA's Diversify WA (2023) strategy explicitly specifies CCUS technology as a key opportunity of the state's economic diversification framework linked to areas with global growth potential, with WA's CCUS Action Plan (2024) outlining a vision and action areas to establish a CCUS industry in WA.[21] Similarly, NSW's Industry and Innovation Investment Plan (2022),[22] while broader, has created a $360 million industry package in which CCU is recognised as a relevant pathway. Queensland has announced partnerships linked to SAF projects, aligning with broader low emissions strategies[23] that seek to create regional jobs, stimulate innovation and reduce transport emissions, with major commitments from both the Commonwealth and Queensland governments.[24] NT developments, including a Memorandum of Understanding (MoU) for a CO_2 import terminal at Middle Arm Precinct signed in 2024, highlight opportunities tied to international CO_2 trade and infrastructure.

States also vary in their funding approaches to achieving these industrial ambitions. WA and the NT are actively building enabling environments, as seen through the establishment of CCUS-related legislation, action plans and hub precincts. NSW is positioning CCU as part of a wider net zero agenda but without standalone CCU policy. While Queensland is adopting a more restricted approach, selectively funding utilisation projects in which the state is competitively advantaged.

Beyond broad state-level action plans, several states have commissioned location and/or product specific roadmaps and studies. This includes WA's Mineral Carbonation Roadmap (2024) which sets a structured pathway for scaling mineral carbonation, and WA's CCUS Hubs Study (2023) which analyses the potential opportunity for CCUS hubs in the context of WA's Liquid Natural Gas and manufacturing industries. The NT Opportunities for CO_2 Utilisation study (2023) was prepared as one input into a broader investment case for a low emissions industry hub in the NT.

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17 King M (2025) Fuelling the future: $1.1 billion to power cleaner Aussie fuel production. Media Release. <https://minister.infrastructure.gov.au/c-king/media-release/fuelling-future-11-billion-power-cleaner-aussie-fuel-production> (accessed 8 October 2025).

18 Australian Government (2024) A Future Made In Australia. <https://archive.budget.gov.au/2024-25/factsheets/download/factsheet-fmia.pdf> (accessed 8 October 2025).

19 Department of Climate Change, Energy, the Environment and Water (2024) New Guarantee of Origin scheme to support low-emission industries. <https://www.dcceew.gov.au/about/news/new-guarantee-origin-scheme-support-low-emission-industries> (accessed 8 October 2025).

20 Western Australia Department of Mines, Petroleum and Exploration (DMPE) (2025) Draft Petroleum, Geothermal Energy and Greenhouse Gas Storage (Greenhouse Gas Injection and Storage) Regulations 2025. Fact Sheet. <https://www.wa.gov.au/government/publications/draft-petroleum-geothermal-energy-and-greenhouse-gas-storage-greenhouse-gas-injection-and-storage-regulations-2025>.

21 Western Australia Department of Energy and Economic Diversification (2024) Carbon capture utilisation and storage: Action Plan. <https://www.wa.gov.au/government/publications/carbon-capture-utilisation-and-storage-action-plan>; Western Australia Department of Energy and Economic Diversification (2023) Future State: Accelerating Diversify WA. <https://www.wa.gov.au/government/document-collections/diversify-wa-resources-and-publications>.

22 New South Wales Office of Energy and Climate Change (2022) Investing in a low carbon future for NSW industry. <https://www.energy.nsw.gov.au/nsw-plans-and-progress/government-strategies-and-frameworks/net-zero-industry-and-innovation-investment-plan>.

23 Queensland Government (2016) Biofutures 10-Year Roadmap and Action Plan <https://www.statedevelopment.qld.gov.au/__data/assets/pdf_file/0017/13337/biofutures-10yr-roadmap-actionplan.pdf> (accessed 8 October 2025); Queensland Government (2023) Queensland New Industry Development Strategy. <https://statements.qld.gov.au/statements/97757> (accessed 8 October 2025); Queensland Government (n.d.) Industry Partnership Program. <https://www.statedevelopment.qld.gov.au/queensland-jobs-fund/industry-partnership-program> (accessed 8 October 2025).

24 State Development, Infrastructure and Planning (2024) Fuelling the future – Queensland's sustainable aviation revolution. Queensland Government. <https://www.statedevelopment.qld.gov.au/news-and-events/fuelling-the-future-queenslands-sustainable-aviation-revolution> (accessed 8 October 2025); Department of Infrastructure, Transport, Regional Development, Communications, Sport and the Arts (2024) Albanese Government supports cleaner aviation with new emissions-reducing fuel projects. Media release. <https://minister.infrastructure.gov.au/c-king/media-release/albanese-government-supports-cleaner-aviation-new-emissions-reducing-fuel-projects> (accessed 8 October 2025).

2.3 Progress on CO_2 Utilisation Roadmap themes

Table 1 describes progress on the four themes identified in CSIRO's CO_2 Utilisation Roadmap that could support the development and scale-up of CO_2 utilisation in Australia. Progress on each theme has been given a qualitative ranking (limited, emerging, or strong) based on the amount of relevant activity identified. While there are some strong examples of progress identified in Section 2.1 and 2.2, the progress on these enabling themes emphasises the relative nascency of CO_2 utilisation in Australia.

Table 1: Australian progress aligned with the CO_2 Utilisation Roadmap (2021) themes

THEME	PROGRESS	DETAILS
Diversify and engage across the value chain and multiple CCU applications	Emerging progress	• Demonstration activities in Australia have expanded into new sectors (i.e., construction materials and e-fuels), and progress and scale up is being tied to a diversity of end use markets. • State-based strategies are tailored towards diverse regional innovation and industrial agendas, supported by targeted roadmaps and studies. • The continuation of product-agnostic funding mechanisms like the Carbon Capture Technologies Program will support diverse CO_2 utilisation projects.
Use CCU as part of a portfolio of decarbonisation solutions	Limited progress	• There is growing recognition of CO_2 utilisation in climate policy and strategies for emissions reduction, with increased traction of portfolio-based carbon management approaches in federal and state strategies. • Deployment of CO_2 utilisation in Australia is still nascent. CO_2 utilisation projects remain at demonstration, pilot and project development stages, with no commercial scale projects reaching final investment decision at the time of writing.
Explore incentives and minimise barriers to entry	Emerging progress	• Federal funding mechanisms have been established, with targeted support from the Carbon Capture Technologies Program. Some state and territory government programs also support CO_2 utilisation activities. • Bilateral funding partnerships demonstrate a growing appetite for government-led strategic cooperation that leverages diverse partner strengths. • No carbon credit methodologies have been approved for CO_2 utilisation. • Scale-up is limited by a range of technical, economic, and system integration challenges, as well as progress delays in the scale-up of necessary precursors. • Standardisation/regulatory frameworks are progressing, but further testing and demonstrations will be required for more novel products like carbonated SCMs.
Use CCU to support or de-risk investment in existing and planned infrastructure	Limited progress	• The NT and WA have undertaken targeted CCUS hub exploration activities. However, the potential role of CO_2 utilisation in the proposed hubs is still being explored. • Federal support for CO_2 utilisation has seen a shift from hub-building to targeted technology innovation programs, most notably the Carbon Capture Technologies Program, which may have implications for the development of integrated infrastructure developments.

2.4 Global context

The global CCU industry has continued to develop since 2021,[25] with commercial and demonstration scale facilities operating, under construction or proposed for many CO_2-derived products (see Figure 4).

Regional CCU approaches largely align with local industrial strengths and strategic priorities. Europe has emerged as an early leader, leveraging established industrial clusters and climate frameworks to incentivise demonstration and early commercial deployment. Across Asia, engagement is growing, often anchored in manufacturing and energy markets, while North American activity shows strong technological innovation despite policy uncertainty in the United States. Standards and mandates are increasingly shaping the adoption of CCU, highlighting the interplay between regional capabilities, policy ambitions and the influence of international regulatory frameworks.

Globally, demand-side signals for CO_2 utilisation have strengthened since 2021, with maritime, aviation, and construction sectors emerging as likely markets for CO_2-derived products:

- **Maritime fuel:** In April 2025, the International Maritime Organisation (IMO) introduced draft measures, comprising a global fuel standard for ships and a pricing mechanism for maritime emissions, with formal adoption expected in October 2026 and entry into force in 2028.[26] This marks the first step toward a global price signal for green shipping fuels, likely to accelerate uptake of low-carbon liquid fuels such as e-methanol.[27]
- **Aviation fuel:** Aviation policy has been most ambitious in Europe, embodied by the ReFuelEU Aviation regulation mandates (discussed below). These measures are complemented by the International Civil Aviation Organization (ICAO) global offsetting regime (Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)), which continues to create incremental demand for verifiable low-carbon fuels; and through tax credit provisions for SAF production and CO_2 utilisation that were extended and modified in 2025.
- **Construction materials:** In the construction sector, demand drivers are emerging more gradually. In the US, Federal Buy Clean initiatives have begun to establish embodied-carbon requirements for concrete procurement, while in Europe, the Carbon Border Adjustment Mechanism, moving to full implementation in 2026, will place pressure on carbon-intensive materials such as cement and steel. Policy drivers within Europe include the RE2020 environmental regulations in France, which will take into account carbon emissions;[28] Denmark's national carbon limits for new buildings, with its most recent limit taken effect from July 2025;[29] and mandatory life-cycle assessments to obtain building permit clearance in Sweden.[30]

Figure 5 provides a non-exhaustive timeline of major global CCU-related policy developments since 2021.

25 World Economic Forum (2025) Defossilizing Industry: Considerations for Scaling-up Carbon Capture and Utilization Pathways. <https://reports.weforum.org/docs/WEF_Defossilizing_Industry_Scaling-up_CCU_2025.pdf>.

26 Environmental Defense Fund (2025) IMO postpones adoption of Net Zero Framework, delaying global action to decarbonize shipping. <https://www.edf.org/media/imo-postpones-adoption-net-zero-framework-delaying-global-action-decarbonize-shipping>.

27 International Maritime Organization (IMO) (2025) IMO approves net-zero regulations for global shipping. <https://www.imo.org/en/mediacentre/pressbriefings/pages/imo-approves-netzero-regulations.aspx>.

28 Ministère de la Transition Écologique (2025) Réglementation environnementale RE2020. <https://www.ecologie.gouv.fr/politiques-publiques/reglementation-environnementale-re2020>.

29 Buro Happold (2023) How Denmark leads the way in decarbonising the construction industry. <https://www.burohappold.com/news/how-denmark-leads-the-way-in-decarbonising-the-construction-industry/>.

30 Nordic Council of Ministers (2023) Appendix: Building LCA and BIM Practices in Sweden. <https://pub.norden.org/us2023-463/appendix-building-lca-and-bim-practices-in-sweden.html>.

Figure 4: Non-exhaustive overview of prominent commercial or near-commercial scale CO_2 utilisation projects, globally

North America

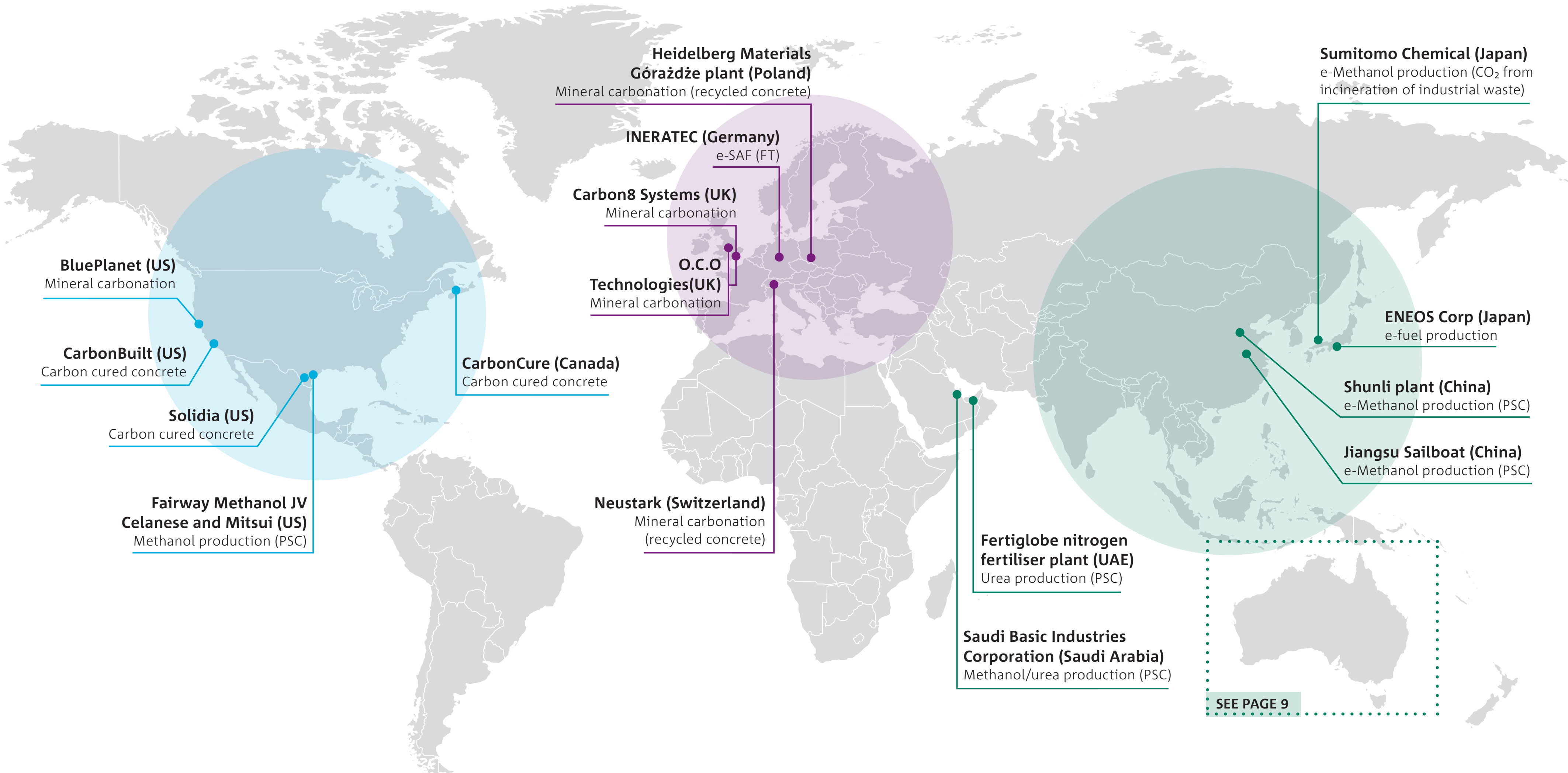
9 major CCU projects announced from 2021 (up from 1 pre-2021)*

Europe

28 major CCU projects announced from 2021 (up from 9 pre-2021)*

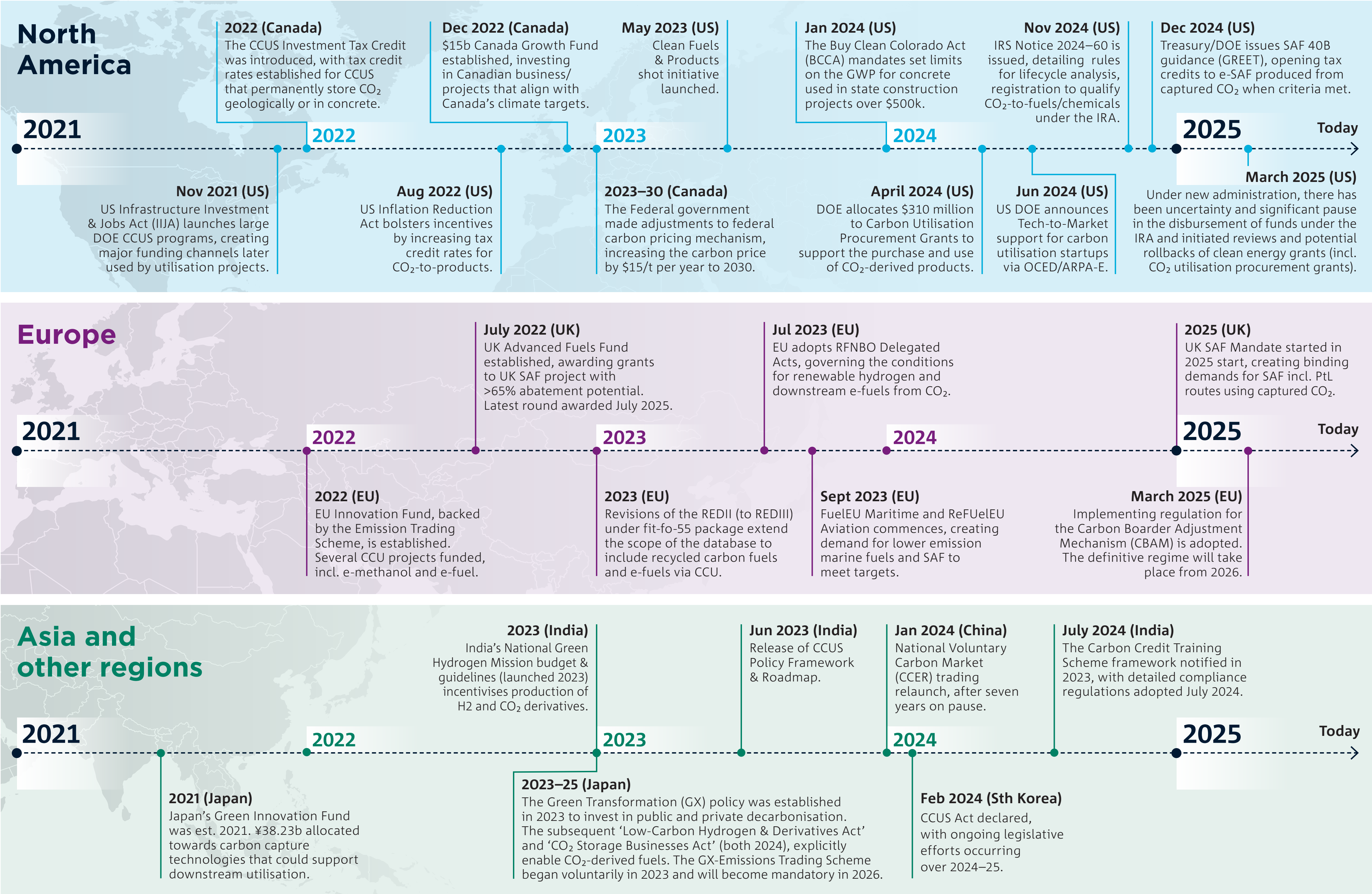
Asia and other regions

6 major CCU projects announced from 2021 (up from 2 pre-2021)*



*References carbon capture projects with a clearly identified source for the CO_2 as per the IEA CCUS project database (2025). This does not include end-use utilisation projects, including some captured in this diagram.

Figure 5: Major CO_2 utilisation policy developments, by global region



North America

In North America, the trajectory of CCU policy has been defined by strong incentives, and more recently, political uncertainty from the United States.

In the United States, the Infrastructure Investment and Jobs Act 2021 opened major funding streams for large-scale CCUS programs, including those later applied to utilisation projects.[31] The IRA added technology-specific credits, covering: CO_2 capture and CO_2 utilisation; SAF production; and clean fuel production.[32] These provisions, alongside the introduction of a clean hydrogen credit, have directly and indirectly improved the economics of CO_2-derived fuels such as e-methanol and e-SAF. Pauses and reviews of IRA funding and Department of Energy grants[33] through the enactment of the One Big Beautiful Bill Act in early 2025 created some uncertainty for project proponents. However, the Section 45Q Tax Credit that provides tax credits for carbon management projects was retained and the credit values for CO_2 captured and utilised from industry and power sources were increased.[34]

In Canada, the CCUS Investment Tax Credit (introduced 2022) provides offsets for capture, transport and storage infrastructure, including utilisation in concrete.[35] In 2023, the Canadian government also announced adjustments to its carbon pricing mechanism, increasing the carbon price by \$15/tCO_2 per year to 2030.[36] This marks an increase from CAD\$80/tCO_2 (April 2024) to CAD\$170/tCO_2 in 2030. This combined with provincial clean fuel standards in Canada may create a supportive environment for CCU.

Europe

Progress in Europe since 2021 has been shaped by binding demand mandates, reforms to carbon pricing and explicit recognition of CCU in long-term climate planning, with the European Commission's proposed 2040 climate target (released July 2025), explicitly identifying CCU as a potential contributor.

The European Union (EU) has put in place several demand-side policies, enabling CCU markets:

- The **ReFuelEU Aviation regulation**, implemented from 2024, mandates an increase in SAF share from 2% in 2025 to 70% by 2050, including a sub-target for synthetic fuels (1.2% of aviation fuel content by 2030, increasing to 35% by 2050).[37]
- The **FuelEU Maritime regulation** requires progressive reductions in the emissions intensity of marine fuels, decreasing by 2% in 2025 to 80% in 2050 from a 2020 baseline.[38]
- The updated **Renewable Energy Directive (RED III)** introduces mandatory use of renewable fuels of non-biological origin, creating a binding market for e-fuels.

At the same time, reforms to the EU Emissions Trading Scheme (ETS) have extended recognition to 'permanent CCU,' with emissions bound into durable products such as carbonated aggregates and concrete exempted from ETS. However, certification processes for such products are not yet formalised at the EU-level. Together, these measures offer both supply- and demand-side support for CCU deployment in fuels and materials.

In the United Kingdom (UK), by contrast, policies have primarily focused on carbon capture and storage projects, rather than utilisation.[39] However, a SAF mandate was introduced at the start of 2025, and the existence of landfill taxes has seen the advent of several start-ups pursuing the development of novel construction materials such as aggregates. The UK has also established a Green Building Council that has articulated a target to achieve a net-zero-carbon built environment by 2050. This could increase demand for low-emission construction materials, such as CO_2-derived products.[40]

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31 U.S. Department of Energy (2021) FECM Infrastructure Factsheet. <https://www.energy.gov/sites/default/files/2021-12/FECM%20Infrastructure%20Factsheet.pdf>.

32 Internal Revenue Service (2025) Inflation Reduction Act of 2022. United States Department of the Treasury, Washington, DC. <https://www.irs.gov/inflation-reduction-act-of-2022>.

33 The White House (2025) Unleashing American Energy. <https://www.whitehouse.gov/presidential-actions/2025/01/unleashing-american-energy/>.

34 Carbon Capture Coalition (2025) Senate Finance Committee preserves 45Q, but value of credit will continue to erode until 2028. <https://carboncapturecoalition.org/senate-finance-committee-preserves-45q-but-value-of-credit-will-continue-to-erode-until-2028/>.

35 Natural Resources Canada (2023) Canada's Carbon Management Strategy. Government of Canada, Ottawa. <https://natural-resources.canada.ca/energy-sources/carbon-management/canada-s-carbon-management-strategy>.

36 Department of Finance Canada (2025) Removing the consumer carbon price, effective April 1, 2025. Government of Canada, Ottawa. <https://www.canada.ca/en/department-finance/news/2025/03/removing-the-consumer-carbon-price-effective-april-1-2025.html>.

37 European Commission (2025) ReFuelEU Aviation. Directorate-General for Mobility and Transport, Brussels. <https://transport.ec.europa.eu/transport-modes/air/environment/refueleu-aviation_en>.

38 European Commission (2025) Decarbonising maritime transport – FuelEU Maritime. <https://transport.ec.europa.eu/transport-modes/maritime/decarbonising-maritime-transport-fueleu-maritime_en>.

39 Oil and Gas Climate Initiative (OGCI) (2024) Carbon capture and utilization as a decarbonization lever. <https://www.ogci.com/wp-content/uploads/2024/05/CCU-Report-vf.pdf>.

40 UK Green Building Council (2021) Whole Life Carbon Roadmap: A Pathway to Net Zero. <https://ukgbc.org/wp-content/uploads/2021/11/UKGBC-Whole-Life-Carbon-Roadmap-A-Pathway-to-Net-Zero.pdf>.

Asia and other regions

Across Oceania, Asia and the Middle East, policy approaches are at various stages of development. Even where explicit policy may be limited, CCU developments appear where conditions are favourable, such as access to renewable energy zones and/or proximity to industrial point source emissions. Across these regions, industry development is primarily concentrated in chemicals and fuels manufacturing.

In China, the national voluntary carbon market relaunched in January 2024 after a seven-year pause, reinstating an avenue for crediting CCU projects. China remains the world's dominant methanol producer. Though most production is fossil-based, the world's two largest commercial-scale CO_2-derived e-methanol plants are both located in China (Shunli & Sailboat) using carbon recycled from co-located industrial processes. In October 2024, Carbon Recycling International announced plans for a third plant (Tianying) in Liaoyuan.[41]

In Japan, the Green Transformation-Emissions Trading System, began as a voluntary scheme in 2023–24, and will become a mandatory compliance-based system for 300–400 major firms from mid-2026. Japan also passed legislation in 2023–24 enabling CO_2 storage and low-carbon hydrogen derivatives, supported by a national CCS roadmap. As Japan has limited geological CCS capacity, it is expected that export or utilisation of CO_2 will feature in Japan's carbon management strategies.[42]

In India, the release of a CCUS policy framework in June 2023 and subsequent launch of the Carbon Credit Trading Scheme in July 2024 established foundations for a domestic carbon market. At the same time, India's National Green Hydrogen Mission is incentivising hydrogen and derivative production, which could indirectly enable CO_2-based fuels and chemicals production.

Across some Middle Eastern and South American countries, industries are pursuing e-fuels and CCU chemicals projects to leverage abundant low-cost renewables and co-located industrial emissions, often in an export-oriented context. Potential for growth in renewable hydrogen production could also position some countries to produce CO_2-derived chemicals and fuels products.[43] The HIF Global Haru Oni e-fuel plant in Chile was completed in 2022 and has achieved production of 130,000 litres/year e-Gasoline in 2023.[44] This plant uses CO_2 captured from a brewery to produce e-methanol which is converted to e-gasoline for export to Europe. HIF is currently developing an e-methanol project in Tasmania (see Section 3.1). Across these regions, CCU activity is concentrated in fuels and chemicals, reflecting both comparative advantages and the global demand pull emerging from shipping and aviation.

41 Carbon Recycling International (2025) Projects. <https://carbonrecycling.com/projects>.

42 James W (2025) Japan is betting big on exporting carbon emissions. Climate and Capital Media, 1 August. <https://www.climateandcapitalmedia.com/japan-is-betting-big-on-exporting-carbon-emissions/>.

43 OGCI (Oil and Gas Climate Initiative) (2024) Carbon capture and utilization as a decarbonization lever. OGCI, London, UK. <https://www.ogci.com/wp-content/uploads/2024/05/CCU-Report-vf.pdf>.

44 HIF Global (n.d.) HIF Haru Oni. <https://hifglobal.com/locations/hif-haru-oni>.

3 Market analysis

This report estimates the potential market demand for a range of CO_2-derived products and bio-products (e.g. bio-fuels) in the year 2050 by assessing their cost competitiveness against incumbent products.

This analysis uses low and high decarbonisation ambition scenarios to explore the evolving carbon and industrial policy landscape and the role of low-emissions technologies in future markets. This section presents the industry status and domestic market assessment results for five product markets: methanol (Section 3.1), aviation fuel (Section 3.2), urea (Section 3.3), mineral aggregates (Section 3.4), and SCMs (Section 3.5).

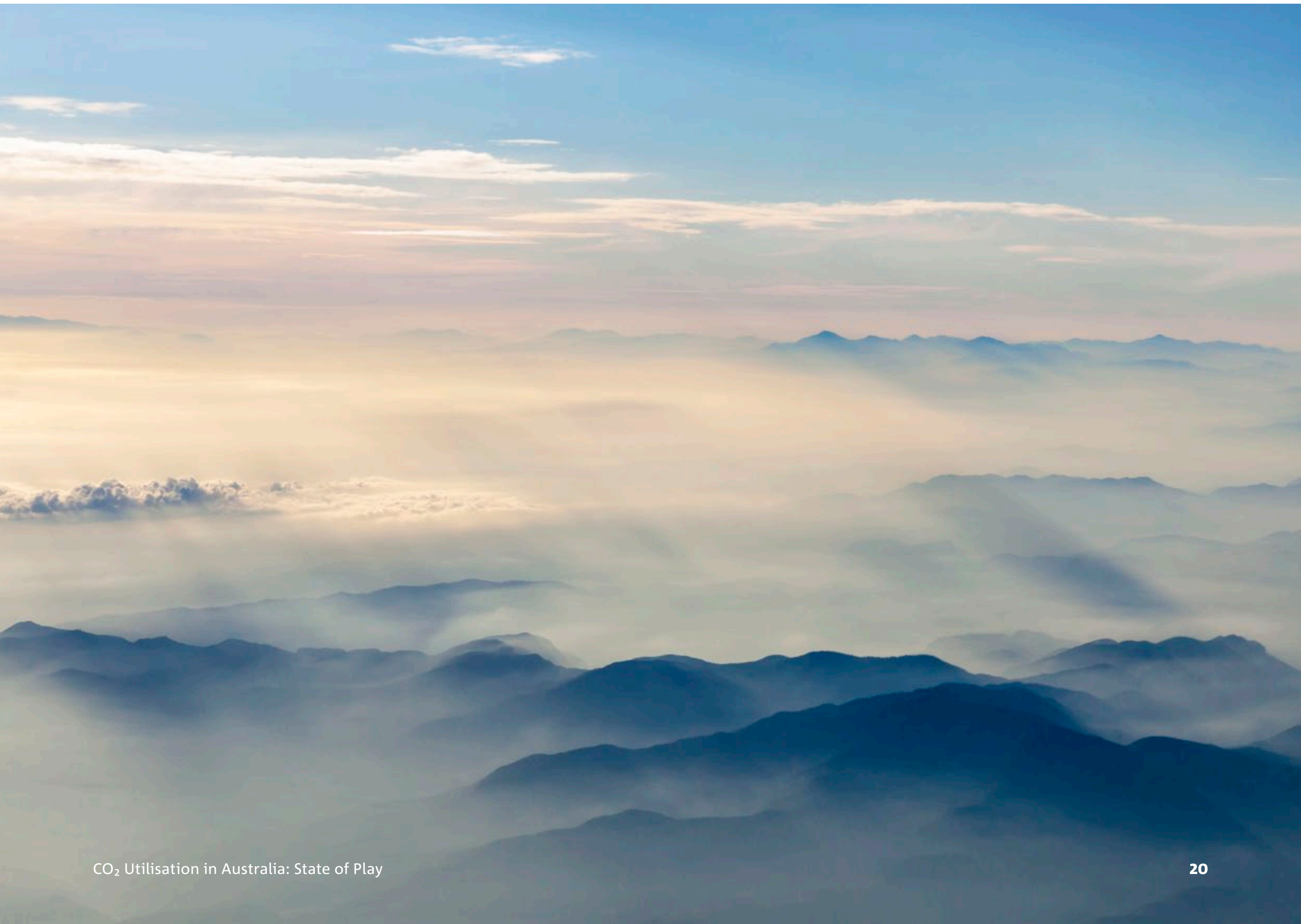


Table 2 shows the cost competitiveness of CO_2-derived products and bio-products against the incumbent (or conventional) products. In the high ambition scenario, six CO_2-derived products and three bio-products become competitive with the incumbent product. In the low ambition scenario, only four CO_2-derived products and two bio-products are cost competitive with the incumbent product. When considering only production cost with no decarbonisation ambition at all, the results still show potential for three CO_2-derived products and one bio-product to reach cost competitiveness by 2050.

Table 2: 2050 cost competitiveness results for CO_2-derived products and bio-products under low and high ambition scenarios

MARKET	PRODUCT	2050 COST COMPETITIVENESS (Relative to incumbent product)		
		LCOP	LOW AMBITION	HIGH AMBITION
Methanol	e-methanol (PSC)	16%	-5%	-29%
	e-methanol (DAC)	74%	27%	-23%
	Bio-methanol	-5%	-29%	-54%
Aviation Fuel	e-SAF (PSC)	125%	80%	32%
	e-SAF (DAC)	240%	149%	51%
	Bio-SAF (HEFA)	45%	15%	-18%
	Bio-SAF (FT)	24%	-8%	-43%
Urea	Urea (PSC)	-1%	-15%	-33%
	Urea (DAC)	48%	17%	-22%
Concrete (Mineral aggregate/sand)	Concrete blend with **carbonated fine aggregate**	-11%	-10%	-9%
Cement (SCMs)	Cement blend with **carbonated (steel slag) SCM**	-13%	-14%	-15%

LEGEND

COST DISADVANTAGE ←				→ COST ADVANTAGE		
> 25%	10–25%	< 10%		< 10%	10–25%	> 25%

Note: Direct Air Capture (DAC); Fischer–Tropsch (FT); Hydroprocessed Esters and Fatty Acids (HEFA); Point Source Capture (PSC); Supplementary Cementitious Material (SCM)

Table 3: Annual domestic demand, economic impacts, and CO_2 abatement results for CO_2-derived products and bio-products in 2050

CARBON SOURCE	PRODUCT	DOMESTIC DEMAND (Mtpa)	REVENUE (AUD, billion)	JOBS (FTE, ROUNDED)	CO_2 ABATEMENT* (Mtpa CO_2)
Industry (PSC)	Urea	2.7	$1.6	1000	2.1
Industry (Flue gas)	Carbonated fine aggregate	2.1	$0.13	200	0.15
	Carbonated (steel slag) SCM	0.15	$0.012	10	0.04
Biological	Bio-methanol	8.7	$6.9	5000	18.5
	Bio-SAF (FT and HEFA+)	3.2–3.4	$5.2–5.6	3800–4100	10.8–11.3

* CO_2 abatement is based on substitution of an incumbent product.

+ Bio-SAF (HEFA) is only cost-competitive with conventional jet fuel in the high ambition scenario, as such the total demand for bio-SAF products is presented as a range representing the low and high ambition scenario results.

Table 3 shows the modelled demand, economic impacts, and CO_2 utilisation for the three CO_2-derived products and two bio-products that capture demand in 2050 – urea (PSC), carbonated fine aggregate, carbonated SCM, bio-methanol and bio-SAF (FT and HEFA). E-methanol products do not capture demand (despite being cost competitive with conventional methanol under at least one scenario) as bio-methanol is the most competitive product in the 2050 market for methanol.

Despite having a significant impact on the cost competitiveness of some CO_2-derived products, the low and high ambition scenarios returned identical demand results for the CO_2-derived products found to be viable. For urea, this is because urea (PSC) is the most cost competitive product in both scenarios. For the mineral aggregates and SCMs, this is because the modelled demand for the product exceeds supply side constraints in both scenarios.

This report analyses a limited selection of products chosen in discussion with the project partners. As these represent only a small selection of CO_2 utilisation applications, this report does not describe the full potential of CO_2 utilisation. The emerging CO_2-derived products described in Section 3.6 could increase the economic and environmental benefits of CO_2 utilisation for Australia.

Analysis approach

At a high-level, this methodology consisted of 3 stages (Figure 6). While each of these stages presented a series of detailed calculations and economic approaches (described in more detail in Appendices A.2–A.7), for each CO_2-derived product the approach involved:

Figure 6: High-level overview of market assessment approach

1 Estimate production and CO_2 emission costs in 2050

- Calculate **levelised cost of production** for each CO_2-derived product.
- Estimate **production costs** for bio-products and conventional products from market research and literature.
- Estimate **CO_2 emission costs** under low and high decarbonisation ambition scenarios.

2 Model domestic demand and market share in 2050

- Estimate **total domestic market** using market research data.
- Allocate **market share** using a market clearing assessment and relevant supply constraints.

3 Estimate potential economic benefits, CO_2 utilisation and abatement

- Estimate **domestic revenue** and **job potential** using industry benchmarks for CO_2-derived and bio-products with market share.
- Calculate **CO_2 utilisation** volume (feedstock requirement) for CO_2-derived products with market share.
- Calculate **CO_2 abatement** potential for CO_2-derived and bio-products with market share.

1. Estimate production and CO_2 emissions costs in 2050

Production costs are estimated for the CO_2-derived products and benchmarked against conventional counterparts in each product category, with biomass-derived alternatives included where relevant. These production costs are projected to 2050, incorporating a baseline scenario and two carbon price pathways (one low and one high). To apply these carbon prices, well-to-wheel carbon intensities are estimated for each product.[45] Assumptions are derived from existing CSIRO analysis, literature, and industry insights. For bio-products and conventional products, production cost estimates are derived from literature or market price data. Where necessary, profit margins are removed from market prices to estimate production costs.

To explore different decarbonisation ambition scenarios, two distinct CO_2 emission cost assumptions are modelled for 2050. In each scenario, a CO_2 emission cost is assigned for each tonne of CO_2 emitted during the production and use of each product. Well-to-wheel carbon intensities are estimated for each product and multiplied by the shadow carbon price to calculate the emissions cost component of production. This cost is added to the levelised cost of production (LCOP), improving the relative competitiveness of products that emit less CO_2, and reducing the competitiveness of products that emit more CO_2.

The scenarios and their CO_2 emission costs are defined as follows:

- The **low ambition** scenario assumes CO_2 emission costs rise gradually to $125/t in 2050[46], reflecting limited uptake of abatement technologies and fragmented climate action.
- The **high ambition scenario** assumes CO_2 emission costs rise more sharply (to $425/t in 2050[47]), reflecting emissions reductions and accelerating demand for low-emissions products. This scenario is broadly consistent with the level of ambition required to achieve net zero by 2050.

The CO_2 emission costs applied in this scenario-based approach are shadow carbon prices, which reflect the combined effect of all policies, regulations, and incentives that affect relative product costs of CO_2 emitting products. This is a standard method for assessing low-emissions technologies and does not imply the adoption of a carbon pricing policy. Rather, it provides a structured framework to explore how different policy and market signals may shape future demand for CO_2-derived products.

General assumptions, including input costs for the LCOP models for the CO_2-deriverd products, can be found in Appendix A.2. Broadly these assumptions align with previous CSIRO analysis and modelling.

2. Model domestic demand and market share in 2050

Given the commodity nature and price inelasticity of the products modelled in this report, the market demand is allocated using a market clearing assessment which assumes that demand is captured by the lowest-cost product. The total market size is estimated by projecting current demand volumes out to 2050. Where relevant, constraints on production capacity and feedstock availability are applied to the lowest cost products, with excess demand redistributed to the next cheapest products. These constraints, where relevant, are aligned with existing CSIRO assumptions, including the SAF roadmap.

3. Estimate potential economic benefits, CO_2 utilisation requirements, and abatement potential

Assuming that all domestic demand is met from domestic supply, revenue estimates for all CO_2-derived products and bio-products that capture market share, are calculated by multiplying each product's volume by its estimated price in 2050. Profit margin assumptions are added to the estimated production costs when estimating revenue. The associated job potential is also estimated using revenue-to-job ratios for comparable industries in Australia.

For the CO_2-derived products (utilising either DAC, PSC or flue gas CO_2 feedstocks) that capture market share, the volume of CO_2 feedstock required to manufacture the product is calculated.

For both CO_2-derived products and bio-products that capture market share, the model calculates an estimate of the CO_2 emissions abatement potential that can be achieved via replacement of the incumbent product.

45 Well-to-wheel carbon intensities refer to the measure of greenhouse gas emissions produced through the entire lifecycle of a fuel or energy source.

46 Derived by applying Compound Annual Growth Rate (CAGR) of 2% to the Safeguard Guard Mechanism price of $75/t out to 2050. See: Clean Energy Regulator (2025) Cost Containment Measure: FY2023–24 (rounded). <https://cer.gov.au/schemes/safeguard-mechanism/managing-excess-emissions/cost-containment-measure>.

47 Derived by adapting estimates from the International Energy Agency (IEA) to align with CSIRO modelling specifications. This estimate reflects the value of the shadow carbon price required to achieve net zero for advanced economies. Shadow carbon prices are proxies for the combined economic effect of direct carbon pricing and complementary policies. See: Carbon price under Net Zero Emissions by 2050 (NZE) scenario, IEA (International Energy Agency) (2024) World Energy Outlook 2024. IEA, Paris, France. <https://www.iea.org/reports/world-energy-outlook-2024>.

3.1 Methanol

VALUE IN 2050

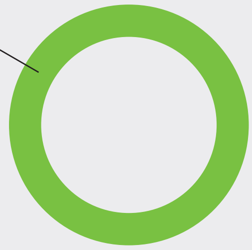
By 2050, the production of bio-methanol could create an estimated:

$7 billion revenue

5000 jobs

Abating **18.5 Mtpa** CO_2 emissions

DOMESTIC DEMAND IN 2050



CURRENT ACTIVITY

e-methanol

2 Projects
Pre-FEED

bio-e-methanol

2 Projects
FEED study

Note: These results are based on analysis of conventional methanol and a non-exhaustive selection of CO_2 utilisation pathways and feedstocks for methanol production: e-methanol (PSC), e-methanol (DAC), bio-methanol.

Background

Methanol (CH_3OH) is an alcohol and platform chemical used in the production of a wide array of chemicals and materials such as plastics, textiles, pharmaceuticals, insulation, and paints. It is also used directly as a fuel and as a fuel additive.[48] The domestic market for methanol is modest with Australian demand for methanol estimated to be 3.1 Mt per year in 2023.[49] There has not been any industrial-scale methanol production in Australia since 2016, when Australia's only operating methanol plant (Coogee, Victoria) was placed into care and maintenance.

Methanol is conventionally produced from natural gas or coal and was responsible for 261 $MtCO_2$ emissions globally in 2022 – equivalent to 28% of emissions from the global chemical sector.[50] Today, the vast majority of conventional methanol production occurs through the reforming of fossil fuels to generate syngas (a mix of CO, CO_2, and H_2).[51] This process occurs at high temperatures (900°C) and pressures (16–30 bar) and is the most energy intensive and expensive step of the synthesis pathway.[52] The resulting syngas is processed in a synthesis loop to yield methanol, in the presence of a catalyst.[53]

48 Srinivasan V, Temminghoff M, Charnock S, Moisi A, Palfreyman D, Patel J, Hornung C, Hortle A (2021) CO_2 Utilisation Roadmap. CSIRO, Canberra, ACT. <https://www.csiro.au/-/media/Science-Connect/Futures/21-00285_SER-FUT_REPORT_CO2UtilisationRoadmap_WEB_210810.pdf>.

49 Chemanalyst (2024) Australian Methanol Market Analysis. <https://www.chemanalyst.com/industry-report/australia-methanol-market-201>.

50 IEA (2023) Chemicals. <https://www.iea.org/energy-system/industry/chemicals>.

51 Steam methane reforming (SMR) of natural gas accounts for ~65% of global syngas production, and steam gasification of coal ~35%; Sollai S, Porcu A, Tola V, Ferrara F, Pettinau A (2023) Renewable methanol production from green hydrogen and captured CO2: A techno-economic assessment. Journal of CO2 Utilization. 68, 102345. <https://www.sciencedirect.com/science/article/pii/S2212982022004644>.

52 Azhari NJ, Erika D, Mardiana S, Ilmi T, Gunawan ML, Makertihartha I.G.B.N, Kadja TM (2022) Methanol synthesis from CO2: A mechanistic overview. Results in Engineering. 16, 100711. <https://www.sciencedirect.com/science/article/pii/S2590123022003814>.

53 Dalena F, Senatore A, Marino A, Gordano A, Basile M, Basile A (2018) Chapter a – Methanol Production and Applications: An Overview. Science and Engineering. 3-28. <https://doi.org/10.1016/B978-0-444-63903-5.00001-7>.

To decouple methanol synthesis from fossil fuels, low-emission methanol can be generated the following ways[54]:

- **e-methanol** is produced from captured CO_2 (PSC or DAC) and renewable hydrogen.
- **bio-methanol** relies on the gasification of biomass to generate syngas.
- **bio-e-methanol** is a hybrid approach, where biomass-derived syngas is supplemented with renewable hydrogen to improve yield. Bio-e-methanol is not modelled in the market assessment of this report due to limited data availability.

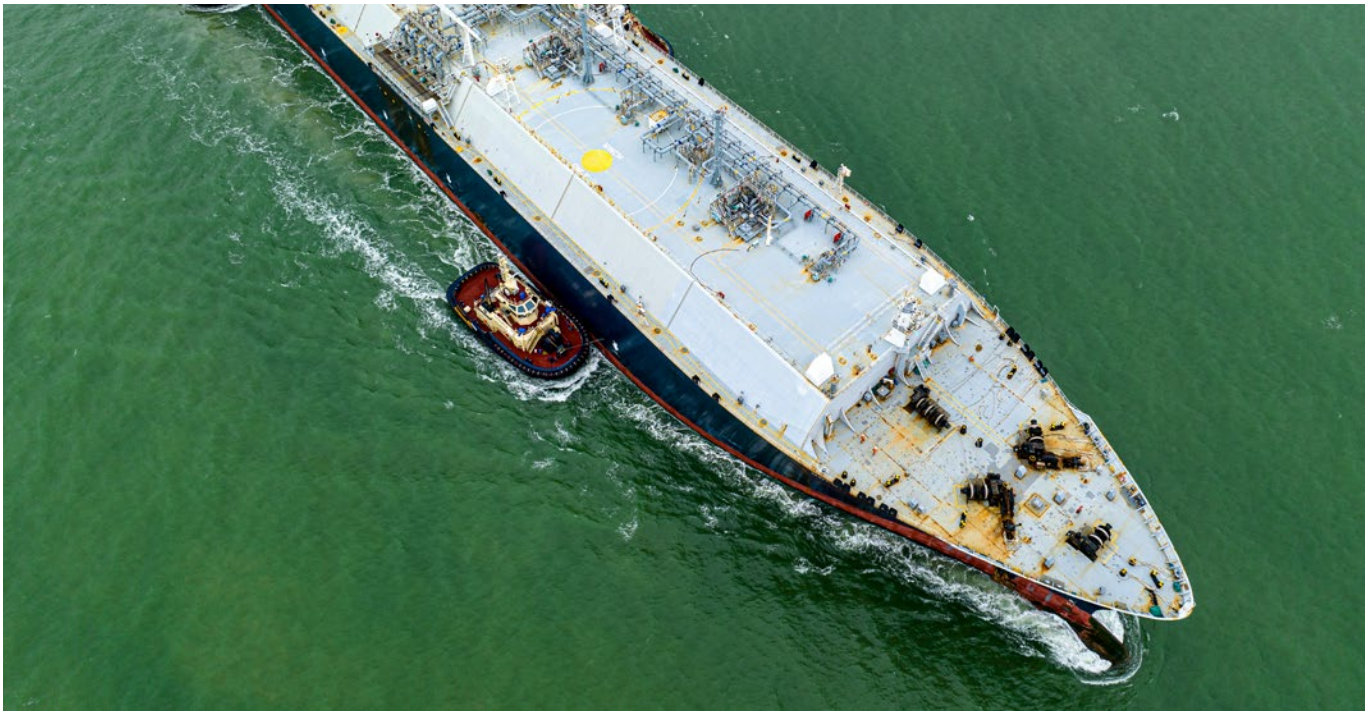
Methanol can serve as an energy carrier or as an intermediate in the production of other hydrocarbon fuels. This is enabled by its chemical properties, with a relatively high energy density and liquid state under ambient conditions, offering ease of handling compared to hydrogen or liquefied natural gas. These characteristics position low-emission methanol as a flexible option for transport applications and industrial decarbonisation.

Demand for low-emission methanol is expected to increase, especially given its potential use as an alternative marine fuel. Methanol offers a pathway to reduce emissions from shipping. In addition to reducing CO_2 emissions it also generates significantly lower levels of sulphur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter relative to conventional marine fuels. Several methanol-compatible, dual-fuel marine engines have been commercialised for medium to large vessels, including container ships and bulk carriers.[55]

Industry status

There are currently multiple low-emission methanol projects in Australia that are advancing towards FEED. These projects aim to service growing demand for low-carbon fuels in the maritime sector. HIF Global's Tasmania eFuels Facility[56] completed a pre-FEED study for a 210 ktpa e-methanol plant in 2024.[57] In 2025, Vast Renewables completed a pre-FEED study for a 7.5 kt e-methanol project in Port Augusta. However, the future of the project is currently uncertain, as the Vast Renewables entered voluntary administration in November 2025.

In addition, there are multiple bio-e-methanol projects under development, including HAMR Energy's Portland Renewable Fuels[58] project (FEED underway), and ABEL Energy's Bell Bay Powerfuels project in Tasmania[59] (FEED contractor announced).



54 For additional details on methanol synthesis, see the 2021 CO_2 Utilisation Roadmap (CSIRO).

55 DNV (2024) Alternative Fuels Insight – Methanol use in shipping. DNV, Oslo, Norway. <https://www.dnv.com/services/alternative-fuels-insights-afi--128171/>.

56 HIF Global (n.d.) HIF Tasmania. <https://hifglobal.com/locations/tasmania>.

57 South Australia Solar Fuels (2025) Vast Secures AUD 700,000 Grant from Australia-Singapore Initiative for Decarbonising Shipping to Progress World-First South Australia Solar Fuels Project. <https://www.sasolarfuels.com/news-and-media/vast-secures-aud-700-000-grant-from-australia-singapore-initiative-for-decarbonising-shipping-to-progress-world-first-south-australia-solar-fuels-project>.

58 HAMR Energy (n.d.) Project pipeline. <https://www.hamrenergy.com/project-pipeline>.

59 CSIRO (2025) HyResource: Abel Energy Bell Bay Powerfuels Project. <https://research.csiro.au/hyresource/abel-energy-bell-bay-powerfuels-project/>.

Table 4: Announced e-methanol and bio-e-methanol projects in Australia

PROJECT	ANNOUNCEMENT DATE	EXPECTED YEAR OF OPERATION	FUNDING	DESCRIPTION
South Australia Solar Fuels (Vast Renewables), South Australia *e-methanol*	2024	2029[60]	**Est. $90 million** *including $32m via the Australia-Germany HyGATE initiative.*[61]	This e-methanol project is to be co-located with the 30 MW Vast Solar 1 (VS1) concentrated solar thermal power project, and includes a 10 MW electrolyser producing hydrogen and CO_2 capture from a co-located Calix lime plant to synthesise up to 7.5 ktpa of methanol.[62] Funding agreements were announced in early 2024 under the German-Australian Hydrogen Innovation and Technology Incubator (HyGATE) initiative. The project, (formerly Solar Methanol 1) has since been awarded additional funding for a supply chain feasibility study through the Australia-Singapore Low Emissions Technologies (ASLET) initiative for maritime and port operations (March 2025).[63] **STATUS: Pre-FEED completed in 2025.[64] Vast Renewables entered voluntary administration in November 2025.[65]**
HIF Tasmania project (HIF Global), Tasmania *e-methanol*	2022	2030	**Est. US$1 billion** at full scale.[66]	This project aims to use up to 280 MW of electrolysers and CO_2 captured from a biomass boiler to produce up to 210 ktpa of e-methanol. **STATUS: Pre-FEED study completed in 2024.[67]**
Bell Bay Powerfuels Project (ABEL Energy), Tasmania *bio-e-methanol*	2022	2029	**Est. $2 billion** at full scale.[68]	This project aims to deploy biomass gasification and water electrolysis (300 MW plant) to produce up to 360 ktpa of bio-e-methanol. Bell Bay Powerfuels was announced as the provisional proponent for the Tasmanian Green Hydrogen Hub in May 2025.[69] **STATUS: FEED study contractor announced in January 2024.**
Portland Renewable Fuels Project (HAMR Energy), Victoria *bio-e-methanol*	2023	2027	**Est. $500 thousand** *including state funding via the Portland Diversification Fund for feasibility study support.*	This project aims to leverage local residual forestry biomass to produce syngas and onshore wind resources with a target capacity of 300 ktpa of bio-e-methanol.[70] **STATUS: FEED underway in 2025.**

60 Australian Renewable Energy Agency (ARENA) (2025) Port Augusta Solar Methanol Project. <https://arena.gov.au/projects/port-augusta-solar-methanol-project/>.

61 ARENA-administered Australian funding of AUD$19.48 million awarded to Vast and German funding of €13.2 million received by Fichtner as project co-developer; ARENA (2023) Recipients announced for Australia-Germany HyGATE Initiative. <https://arena.gov.au/news/recipients-announced-for-australia-germany-hygate-initiative/>.

62 CSIRO (2025) HyResource: SM1 – Solar Methanol 1 Project. <https://research.csiro.au/hyresource/sm1/>.

63 Vast Renewables Ltd (2025) Vast secures AUD 700,000 grant from Australia-Singapore Initiative for decarbonising shipping to progress world-first South Australia Solar Fuels Project. <https://www.vast.energy/news/vast-secures-aud-700-000-grant-from-australia-singapore-initiative-for-decarbonising-shipping-to-progress-world-first-south-australia-solar-fuels-project>.

64 Vast (2025) Vast Secures AUD 700,000 Grant from Australia-Singapore Initiative for Decarbonising Shipping to Progress World-First South Australia Solar Fuels Project. <https://www.vast.energy/news/vast-secures-aud-700-000-grant-from-australia-singapore-initiative-for-decarbonising-shipping-to-progress-world-first-south-australia-solar-fuels-project>

65 KPMG (2025) Vast Renewables Limited. <https://kpmg.com/au/en/creditors/vast-renewables.html>.

66 HIF Global (n.d.) HIF Tasmania. <https://hifglobal.com/locations/tasmania>.

67 CSIRO (2025) HyResource: HIF Tasmania eFuels Facility. <https://research.csiro.au/hyresource/hif-tasmania-efuels-facility/>.

68 Infrastructure Partnerships Australia (n.d.) Bell Bay Powerfuels Project. <https://infrastructurepipeline.org/project/bell-bay-powerfuel-project>.

69 CSIRO (2025) HyResource: Abel Energy Bell Bay Powerfuels Project. <https://research.csiro.au/hyresource/abel-energy-bell-bay-powerfuels-project/>.

70 HAMR Energy (n.d.) Portland Renewable Fuels. <https://www.hamrenergy.com/portland-renewable-fuels>.

Globally, e-methanol production has advanced to an early commercial stage. Significant projects and proposals include:

- **Carbon Recycling International technology** has been deployed at an industrial scale in a range of locations globally. The largest of which, the 110 ktpa Shunli plant in China, completed construction in 2022 – marking the world's first commercial-scale emissions-to-liquids facility.[71] The Jiangsu Sailboat project became operational in 2023 (100 ktpa capacity), cited to be the most efficient CO_2-to-methanol plant.[72] The technology is also deployed at pilot scale in Germany and at an industrial-scale in Iceland with integrated electrolyser capacity.[73]
- The **Fairway Methanol project (US)** is a joint venture between Mitsui & Co. and Celanese Corporation, which commenced production of e-methanol from CO_2 sourced from Celanese's chemical production site in Texas. The facility has capacity to produce 130 ktpa of e-methanol, from the capture of 180 ktpa of CO_2.[74]
- **HIF Global's Matagorda eFuels Facility (US)** has completed Front End Engineering and Design (FEED) and is permitted to commence construction. When fully constructed, it would produce up to 1.4 Mtpa e-methanol.[75]

Industry insights

Stakeholder consultations and desktop research identified the following industry insights:

- **The viability of e-methanol projects is still limited by market willingness to pay for sustainable methanol alternatives**. Even with emerging regulations and an increasing CO_2 emission cost, many customers are not yet able to absorb the green premium, which makes it difficult to secure bankable projects and slows deployment. This is compounded by slower than expected development of renewable hydrogen projects and the resulting uncertainty in input costs and availability. Parallel challenges in scaling CO_2 capture and ensuring reliable supply chains may further constrain the pace of industry deployment.
- **Early offtake agreements are critical for signalling market demands and securing investment in production supply chains, with early interest indicated by maritime and aviation sectors.** Though offtake agreements remain difficult to secure given the immaturity of supply chains and price uncertainty for renewable products, there are signs of early-stage coordination across supply chains.[76] For example, the Port of Melbourne has signed an MoU with several entities to examine a potential project involving the transportation of methanol from production sites in Bell Bay, Tasmania (ABEL Energy) and Portland, Victoria (HAMR Energy) for storage and bunkering services in Melbourne.[77] National frameworks, such as Australia's forthcoming Maritime Emissions Reduction National Action Plan, are also expected to drive demand for low-emission methanol in the maritime sector. While activity is centred on the maritime sector, some proponents, such as HAMR Energy, are also pursuing aviation markets (see also Section 3.2).

71 Carbon Recycling International (2023) CRI and Jiangsu Sailboat start up world's most efficient CO_2-to-methanol plant. <https://carbonrecycling.com/about/news/carbon-recycling-international-cri-and-jiangsu-sailboat-start-up-worlds-most-efficient-co2-to-methanol-plant>.

72 Carbon Recycling International (n.d.) Carbon Recycling International and Jiangsu Sailboat start up world's most efficient CO_2-to-methanol plant. <https://carbonrecycling.com/projects/sailboat>.

73 Carbon Recycling International (n.d.) ETL technology. <https://carbonrecycling.com/etl-technology>.

74 Mitsui & Co. Ltd. (2024) US Methanol JV commences production of methanol derived from CO_2. <https://www.mitsui.com/jp/en/topics/2024/1248163_14380.html>.

75 HIF Global (n.d.) HIF Matagorda. <https://hifglobal.com/locations/matagorda>.

76 Australian Renewable Energy Agency (ARENA) (2025) Vast – Port Augusta Solar Methanol Project – Lessons Learnt Report. <https://arena.gov.au/assets/2025/06/Vast-Port-Augusta-Solar-Methanol-Project-Lessons-Learnt-Report.pdf>.

77 Port of Melbourne (2023) Green methanol MoU signed with Melbourne port. <https://www.portofmelbourne.com/wp-content/uploads/Joint-Media-Release-Green-methanol-MoU-signed-with-Melbourne-port.pdf>.

- **The success of low-emission methanol projects is linked to the accessibility of low-cost renewable energy.**[78] Proponents often seek integration with co-located renewable generation to reduce the cost of electricity supply. However, other proponents may favour grid connections and Renewable Energy Certificates to avoid exposure to the high capital costs and extended development times associated with new-build renewable energy projects, and ensure access to a continuous supply of energy for large-scale low carbon liquid fuels projects.
- **Projects demonstrate diversity in prospective carbon feedstocks**, ranging from biological sources (ABEL and HAMR) to captured industrial process CO_2 (South Australia Solar Fuels). Utilisation of CO_2 from fermentation processes (e.g. ethanol production from sugarcane) may also have potential as a near-term CO_2 feedstock.[79] While this suggests that the industry is still exploring multiple utilisation pathways, bio-derived projects appear to be early leaders. In the longer term, supply-side limitations on sustainable biological carbon sources may create increasing demand for CO_2-derived methanol.

78 Australian Renewable Energy Agency (ARENA) (2025) Vast – Port Augusta Solar Methanol Project – Lessons Learnt Report. <https://arena.gov.au/assets/2025/06/Vast-Port-Augusta-Solar-Methanol-Project-Lessons-Learnt-Report.pdf>.

79 Blaine M, Webley P and Honnery D (2025) CO_2e emissions of renewable methanol from forestry residues and conventional natural gas-based methanol: a comparative analysis. Energy Environmental Science. 18, 6325.

2050 market assessment

Scope of analysis

This analysis assesses the potential demand for e-methanol products derived using PSC and DAC CO_2 sources in a simplified 2050 domestic methanol market. The two e-methanol products are compared against conventional methanol and bio-methanol reference products. Bio-e-methanol was not modelled in this report but should be considered in further work.

The methodology, assumptions and results of this analysis are described in detail in Appendices A.2 and A.3.

Cost competitiveness

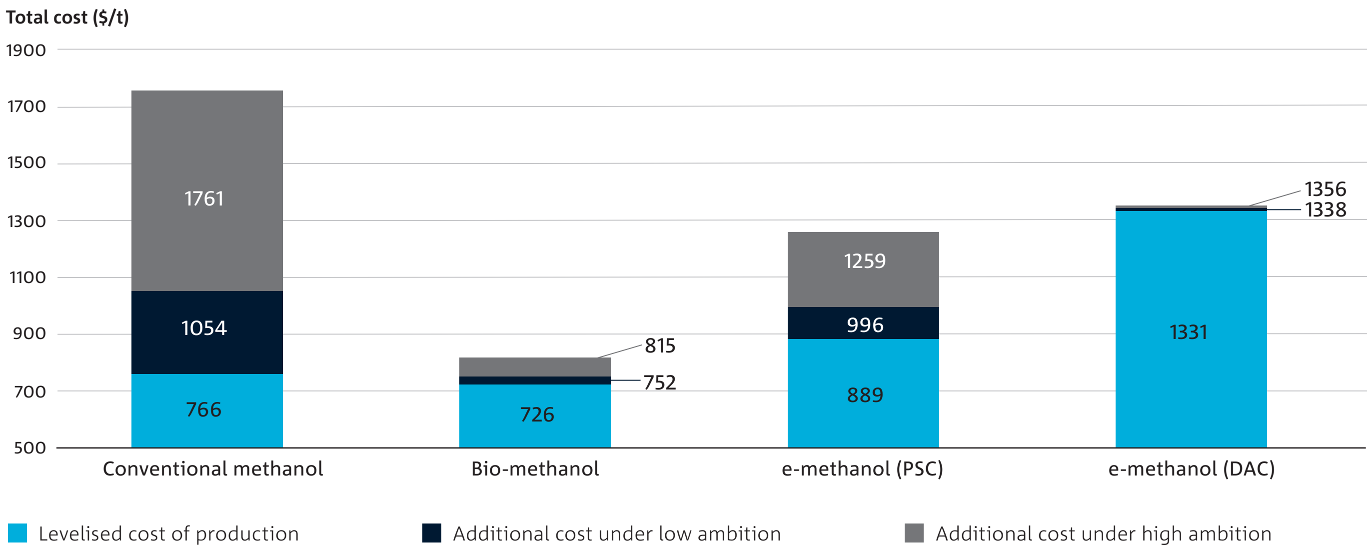
The modelled LCOP and CO_2 emissions cost for methanol products in each scenario is shown in Figure 7. Under the modelled scenarios, e-methanol production from PSC is found to be more cost-competitive compared to conventional methanol, largely driven by the high emissions intensity associated with incumbent production processes. E-methanol produced using DAC also becomes cost competitive under the high ambition scenario. Of the two CO_2-derived products, point sourced e-methanol proves to be the least expensive, with lower carbon feedstock costs relative to DAC.

Overall, bio-methanol is found to be the most cost competitive product in 2050. This is driven by lower production costs, and lower emission intensity compared to both conventional and point source e-methanol production.

Table 5: Assessed and reference methanol product descriptions

	PRODUCT	DESCRIPTION
ASSESSED PRODUCTS	e-methanol (PSC)	Methanol produced from electrolytic hydrogen and CO_2 from industrial point sources.
	e-methanol (DAC)	Methanol produced from electrolytic hydrogen and CO_2 from direct air capture.
REFERENCE PRODUCTS	Conventional methanol	Methanol produced from fossil fuels (natural gas or coal). This assessment assumes a weighted average of both routes, assuming 65% of global production is via steam methane reforming, and 35% via coal gasification.
	Bio-methanol	Methanol produced from biomass feedstocks such as forestry residues or municipal solid wastes.

Figure 7: LCOP and CO_2 emission costs for methanol products in 2050



Note: Cumulative data labels indicated.

Demand

The modelled domestic demand for methanol in each scenario is shown in Figure 8. The demand for each methanol product has been projected for each ambition scenario based on its cost and estimated production limit (see Appendix A.3 for more details). Given its cost competitiveness, bio-methanol is projected to capture the entire market share under the modelled conditions. Feedstock supply is not expected to constrain production, as total methanol demand does not exceed assumed production limit of 9.1 Mtpa.[80]

Some analysts suggest that low-carbon methanol could become the dominant maritime fuel in the future. If this occurs, global demand for methanol products could approach 540 Mtpa in 2050.[81] This suggests that Australian demand for low-carbon methanol for international maritime transport could reach up to 76 Mtpa by 2050.[82] This demand would significantly exceed the domestic supply limit assumption for bio-methanol. The cost competitiveness results suggest that this could create significant demand for e-methanol (PSC). Under the high ambition scenario, e-methanol (DAC) is also cost competitive, making it likely to capture a share of the demand if PSC CO_2 sources are exhausted.[83]

Economic benefits and CO_2 abatement potential

If Australian industry supplies the forecast domestic demand for bio-methanol, the modelling estimates domestic revenue of $7 billion and employment potential of 5000 jobs in 2050, approximated using the employee-to-revenue benchmark for the basic organic chemical manufacturing industry in Australia.

If methanol production continues to rely on conventional fossil-based pathways, meeting the projected 2050 demand of 8.7 Mt could result in an estimated 20.3 Mt of CO_2 emissions.[84] If this demand is replaced by bio-methanol, the associated CO_2 emissions would be reduced by 18.5 Mt CO_2 per annum (a reduction of 91%).

Figure 8: Modelled demand for methanol products in 2050

80 Municipal solid waste, agricultural and sawmill residues, and sorghum are considered as bio-feedstocks in this modelling. While other biomass sources are also suitable for bio-methanol production, a detailed assessment is beyond the scope of this report. See Appendix A.3 for more details.

81 Green methanol production would have to reach over 540 million metric tons per year to fully replace all marine fuel by 2050. Figure 3: Cumulative green methanol capacity planned and needed. Burga B (2023) Green methanol makes a splash in quest for net-zero shipping. BloombergNEF. <https://about.bnef.com/insights/clean-transport/green-methanol-makes-a-splash-in-quest-for-net-zero-shipping/>.

82 Australia's share of global sea freight is around 14%, contributing to 76 Mt of methanol demand as maritime fuel. Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA), BloombergNEF (2024) MERNAP Issues Paper 4: Green shipping corridors and partnerships. <https://www.infrastructure.gov.au/sites/default/files/documents/mernap-issues-paper-4-green-shipping-corridors-and-partnerships-march2024.pdf>.

83 Based on Treasury's Baseline Scenario, emissions from Australia's industrial and waste sectors are projected to decline from 61 $MtCO_2$-e in 2025 to 32 $MtCO_2$-e by 2050. This correlates to an optimistic maximum e-methanol (PSC) supply of 23.3 Mt if all of these emissions were capture and converted to e-methanol. This is an overestimate of the potential supply as not all these greenhouse gas emissions will be CO_2 and amenable to capture and utilisation. See: Department of Industry, Science and Resources (2025) Industry Sector Plan. <https://www.industry.gov.au/sites/default/files/2025-09/disr-industry-sector-plan.pdf>.

84 The well-to-wake emissions for conventional methanol are estimated at 2.34 t CO_2 per tonne of product. Emissions estimates for both methanol and bio-methanol assume that all CO_2 embodied in the product is released during use. See Appendix A3 for further details.

3.2 Aviation fuel

VALUE IN 2050

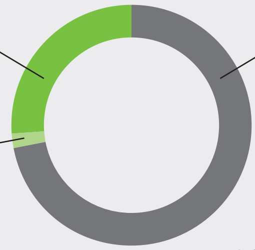
By 2050, the production of bio-SAF could create an estimated:

$5 billion
revenue

4100
jobs

Abating
11.3 Mtpa
CO_2 emissions

DOMESTIC DEMAND IN 2050



CURRENT ACTIVITY

e-SAF
1 Project
Feasibility study

bio-SAF
1 Project
FEED study

Note: These results are based on analysis of conventional jet fuel and a non-exhaustive selection of pathways and feedstocks for SAF production: e-SAF (PSC), e-SAF (DAC), bio-SAF (HEFA), bio-SAF (FT).

Background

Conventional jet fuels used in aviation (Jet A and Jet A-1) are refined from crude oil via distillation and hydro-processing. Their combustion contributes significantly to global emissions, making aviation one of the more difficult sectors to decarbonise due to long asset lifetimes, high energy density requirements, a lack of readily available technology substitutes, and global infrastructure lock-ins. Australia's aviation subsector emitted 12 $MtCO_2$-e in 2023–24, accounting for 9% of Australia's total transport emissions[85] and as hard-to-abate industry, absolute emissions are expected to grow.[86]

SAFs are a drop-in liquid hydrocarbon alternatives to conventional jet fuels that offer a pathway to reduce life-cycle emissions from aviation. SAFs are designed to be compatible with existing jet engines and fuelling systems, enabling near-term emissions reductions without requiring substantial changes to the aircraft or airport infrastructure.

SAFs can be produced from a range of feedstocks. Synthetic fuels derived from captured CO_2 and renewable hydrogen, commonly referred to as e-SAFs or Power-to-Liquids (PtL), are a promising subcategory due to their potential for large scale production if large quantities of renewable energy and CO_2 capture are scaled, avoiding land-based and biomass related constraints. The potential for these pathways in the Australian context is explored further in the CSIRO-Boeing SAF Roadmap released in 2023.[87]

85 Climate Change Authority (2024) Sector Pathways Review: Transport. <https://www.climatechangeauthority.gov.au/sites/default/files/documents/2024-09/2024SectorPathwaysReviewTransport.pdf> (accessed 21 March 2025).

86 Ritchie H (2020) Climate change and flying: what share of global CO_2 emissions come from aviation? <https://ourworldindata.org/co2-emissions-from-aviation> (accessed 17 January 2023).

87 CSIRO (2023) Sustainable Aviation Fuel Roadmap. <https://www.csiro.au/-/media/Energy/Sustainable-Aviation-Fuel/Sustainable-Aviation-Fuel-Roadmap.pdf>.

Within international policy frameworks, SAFs are considered a core decarbonisation lever for aviation. The International Civil Aviation Organization (ICAO) recognises SAFs under its Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) scheme and has developed a methodology to evaluate SAF life-cycle emissions, sustainability criteria, and eligibility for emissions crediting. Concurrently, industry groups such as the International Air Transport Association (IATA) and Airports Council International (ACI) are standing by commitments to achieve net-zero emissions by 2050.[88] Several SAF production pathways have been approved by Advancing Standards Transforming Markets (ASTM) International for blending with conventional jet fuel at specified ratios.[89]

Industry status

Demand for SAF is driven largely by commitments from airlines to decarbonise operations and by customers looking to reduce their Scope 3 emissions, alongside interest from energy companies and state governments in positioning Australia as a renewable fuel exporter. A number of industry and government partnerships and initiatives have been announced. In 2025, Wagner Sustainable Fuels commenced operations of Australia's first SAF-blending facility at Toowoomba Wellcamp Airport, in partnership with Boeing and FlyORO.[90] This facility could in principle accommodate e-SAF products if they were to be produced domestically. Qantas' SAF Coalition (established 2023) has now reached 14 partners and members which contribute to the incremental cost of sustainable aviation fuel purchased by Qantas.[91] The Queensland Government and Qantas formalised a strategic partnership in 2023 to establish a green jet fuel industry in Queensland leveraging sugarcane and agricultural by-products. The Australian Jet Zero Council was announced (2023) to provide coordinated advice and lead efforts for aviation decarbonisation.

Domestic e-SAF activity is limited in Australia. The only e-SAF project identified in Australia is a Zero Petroleum feasibility study announced in 2024, evaluating the viability of a 10 ML (~8000 t) facility in Whyalla, South Australia (see Table 6).[92]

Most activity to date in Australia has focused on bio-based SAF pathways, drawing on residues, energy crops, and waste oils. The most mature SAF project in development is Project Ulysses (LanzaJet and Jet Zero, currently completing FEED). Several other pre-FEED project assessments remain ongoing.[93] For example, HAMR Energy has also completed feasibility work for a bio-methanol-to-jet facility with Melbourne or Adelaide shortlisted as host locations.

At least two projects that were previously under development have not proceeded. These include the Oceania Biofuels biorefinery proposed for Gladstone, Queensland, which was announced in 2022 and discontinued in 2024[94] and BP's proposed Kwinana Renewable Fuels project that has paused its development in 2025.[95]

88 International Air Transport Association (IATA) (2021) Net-zero carbon emissions by 2050. <https://www.iata.org/en/pressroom/pressroom-archive/2021-releases/2021-10-04-03/> (accessed 17 January 2023); Airports Council International (2021) Net zero by 2050: ACI sets global long term carbon goal for airports. <https://aci.aero/2021/06/08/net-zero-by-2050-aci-sets-global-long-term-carbon-goal-for-airports/> (accessed 17 January 2023).

89 Currently, ten SAF production pathways have been approved by ASTM, eight under ASTM D7566 and two co-processing pathways under D1655. ASTM International (2022) ASTM D7566-22: Standard specification for aviation turbine fuel containing synthesized hydrocarbons. <https://www.astm.org/d7566-22.html>; ASTM International (2022) ASTM D1655-22a: Standard specification for aviation turbine fuels. <https://store.astm.org/d1655-22a.html>.

90 Boeing Australia (2025) Wagner delivers Australia's first dedicated Sustainable Aviation Fuel Blending Terminal. <https://www.boeing.com.au/news/2025/wagner-delivers-australia-s-first-dedicated-saf-blending-termina>.

91 Qantas (2024) Australia's largest import of sustainable aviation fuel lands in Sydney. <https://www.qantasnewsroom.com.au/media-releases/australias-largest-import-of-sustainable-aviation-fuel-lands-in-sydney/>.

92 Government of South Australia (2024) Whyalla set to take flight with sustainable aviation fuel project. <https://statedevelopment.sa.gov.au/news/whyalla-set-to-take-flight-with-sustainable-aviation-fuel-project>.

93 Australian Renewable Energy Agency (ARENA) (n.d.) Ampol Brisbane Renewable Fuels Pre-FEED Study. <https://arena.gov.au/projects/ampol-brisbane-renewable-fuels-pre-feed-study/>.

94 S&P Global Commodity Insights (2024) Oceania Biofuels scraps A$500 million Australia SAF and R&D project. <https://www.spglobal.com/commodity-insights/en/news-research/latest-news/agriculture/071624-oceania-biofuels-scraps-a500-million-australia-saf-and-rd-project-epbc>.

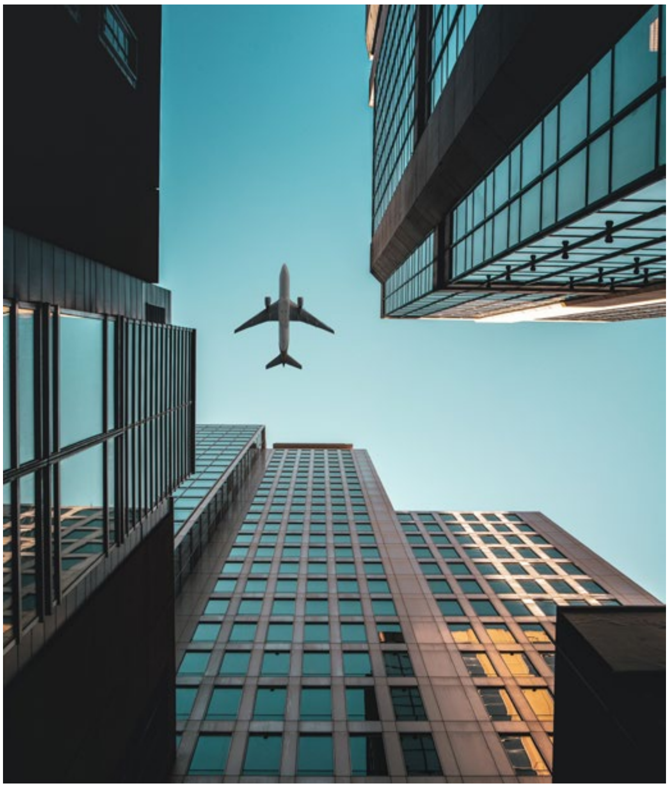
95 S&P Global Commodity Insights (2025) BP puts the brakes on Australia's Kwinana biofuels project. <https://www.spglobal.com/commodity-insights/en/news-research/latest-news/agriculture/020425-bp-puts-the-brakes-on-australias-kwinana-biofuels-project>.

Table 6: Announced e-SAF and bio-SAF projects in Australia

PROJECT	ANNOUNCEMENT DATE	EXPECTED YEAR OF OPERATION	FUNDING	DESCRIPTION
Plant Zero.SA (Zero Petroleum), South Australia *e-SAF*	2024	2026[96]	–	After signing an MoU with the South Australian Government, Zero Petroleum is undertaking a feasibility project to evaluate the viability of a facility in Whyalla capable of producing up to 10 ML (~8000 t) of e-SAF annually.[97] **STATUS: Feasibility study commenced in 2024.[98]**
Project Ulysses (Jet Zero Australia and LanzaJet), Queensland *Bio-SAF*	2024	2027	**Est. $36.8 million** *including $9m ARENA funding and $5m from Queensland New-Industry Development Strategy (QNIDS) funding program.*	Announced in 2024, the project aims to convert 183 ML of agricultural by-product-based ethanol feedstock into 113 ML bio-SAF, balanced with renewable diesel. **STATUS: FEED study commenced in 2024.[99]**

Internationally, SAF production remains dominated by HEFA and Alcohol-to-Jet (ATJ) pathways. However, multiple demonstration and commercial-scale e-SAF facilities are under development, largely driven by supportive policies, particularly in Europe and the US. Notable commercial scale e-SAF projects and proposals include:

- **Infinium's Project Roadrunner (US)** began construction in 2025 and aims to commence commercial operation in 2027. It will produce up to 23 ktpa e-SAF.[100]
- **Arcadia eFuels (US)** has completed FEED and obtained environmental permits for its proposed e-SAF facility in Denmark with an expected capacity of up to 80 ktpa.[101]
- **SkyKraft (Sweden)** is a joint venture between SkyNRG and Skellefteå Kraft that aims to produce up to 100 ktpa e-SAF. The project is currently undertaking technical studies and environmental permitting and aims to reach Final Investment Decision (FID) in 2027.[102]



96 Zero Petroleum (2024) Zero marks a historic move into the Australian market with vintage motorbike. <https://www.zero.co/news-media/zero-marks-a-historic-move-into-the-australian-market-with-vintage-motorbike>.

97 Government of South Australia (2024) Whyalla set to take flight with sustainable aviation fuel project. <https://statedevelopment.sa.gov.au/news/whyalla-set-to-take-flight-with-sustainable-aviation-fuel-project>.

98 Zero Petroleum (2024) Zero marks a historic move into the Australian market with vintage motorbike. <https://www.zero.co/news-media/zero-marks-a-historic-move-into-the-australian-market-with-vintage-motorbike>.

99 Australian Renewable Energy Agency (ARENA) (2024) Jet Zero Australia – FEED Study for Project Ulysses ATJ SAF Plant. <https://arena.gov.au/projects/jet-zero-australia-feed-study-for-project-ulysses/>.

100 Infinium (n.d.) Project Roadrunner. <https://www.infiniumco.com/roadrunner>.

101 Arcadia eFuels (n.d.) News. <https://arcadiaefuels.com/news/>.

102 SkyKraft (n.d.) Large-scale sustainable aviation fuel (eSAF) production in Sweden. <https://skykraft.se/en/home/>.

Industry insights

Note: due to similarities in their feedstocks and production processes, the methanol industry insights in Section 3.1 are also relevant to SAF production.

Stakeholder consultations and desktop research identified the following industry insights:

- **Australia's SAF development will be shaped by both international partnerships and positioning within global markets, though progress could be strengthened further by domestic support.** Australia's aviation sector is highly dependent on long-haul flights, creating a strong imperative for SAF development. In the absence of domestic SAF mandates and policy frameworks, early projects remain exposed to global competition but could also potentially produce fuels for exports to markets with stronger demand incentives. The progress of Project Ulysses underscores the importance of international technology partnerships and export-oriented positioning.
- **Capital intensity and feedstock risk are central challenges for bio-SAF, with technology immaturity and high costs expected to continue to constrain e-SAF development in the medium-term.** e-SAF faces not only high costs but also dependence on large-scale renewable hydrogen and CO_2 utilisation infrastructure, neither of which yet exists in Australia at the scale required. Though structural costs for supporting technologies like hydrogen production are expected to decline over the long-term, the timing of these reductions is and has been uncertain.
- **Establishing sufficient aggregated demand through industry partnerships will be crucial for supporting infrastructure scale-up.** Aggregating demand not only reduces developer risk but also creates the scale economies needed to drive costs down over time.
- **Global industry stakeholders are advocating for collective effort from industry and government to reach commercial e-SAF production.** For example, Project SkyPower in Europe identified five steps to increase the likelihood of getting e-SAF projects to FID in short term: Creating regulatory certainty, securing public funding, establishing offtake contracts, providing low-interest loans and loan guarantees, and developing appropriate risk sharing models.[103]

103 Project SkyPower (2024) Accelerating the take-off for e-SAF in Europe. <https://www.systemiq.earth/wp-content/uploads/2024/10/Project-SkyPower-Insights.pdf>

2050 market assessment

Scope of analysis

This analysis assesses the potential demand for e-SAF products derived using PSC and DAC CO_2 sources in a simplified 2050 domestic aviation fuel market. The two e-SAF products are compared against conventional jet fuel (CJF) and two bio-SAF reference products.

The methodology, assumptions and results of this analysis are described in detail in Appendices A.2 and A.4.

Cost competitiveness

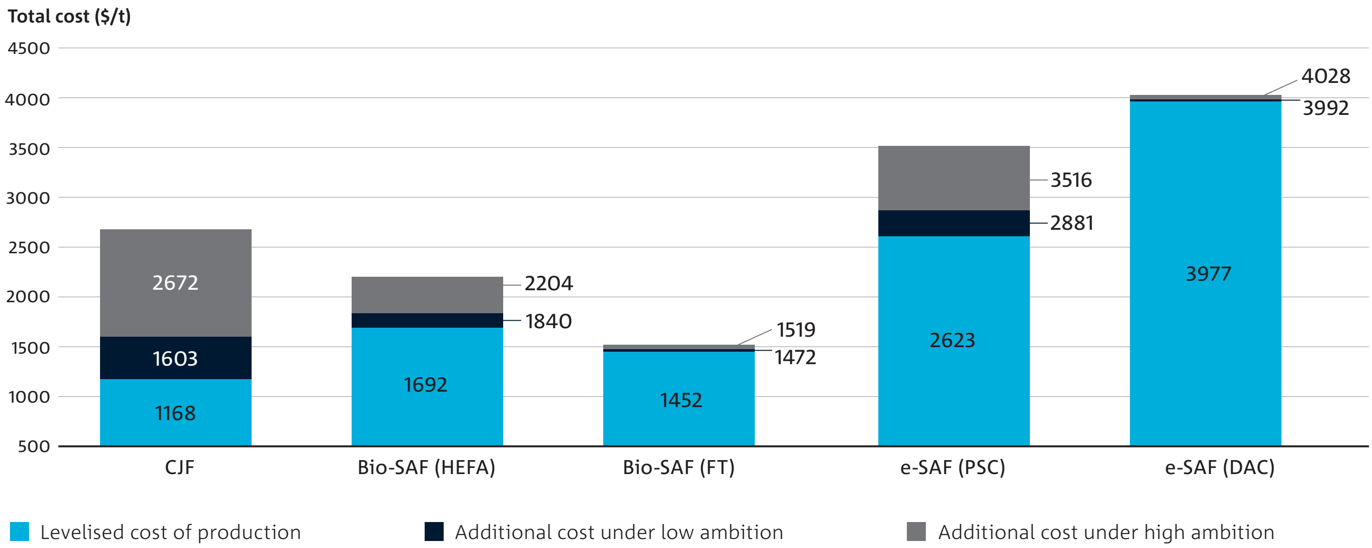
The modelled LCOP and CO_2 emissions cost for aviation fuel products in each scenario is shown in Figure 9. Under all modelled scenarios, CO_2-derived e-SAF products are not competitive with the conventional jet fuel incumbent product or the emerging bio-SAF alternatives. However, demand for e-SAF (PSC) could become competitive with conventional jet fuel in the high ambition scenario if hydrogen prices were to become much lower than currently estimated (approximately $1.8/kg or less).

Under the low ambition scenario, bio-SAF (FT) is cost competitive product with conventional jet fuel. Under the high ambition scenario, both bio-SAF products become cost competitive with conventional jet fuel.

Table 7: Assessed and reference aviation fuel product descriptions

	PRODUCT	DESCRIPTION
ASSESSED PRODUCTS	e-SAF (PSC)	e-SAF produced from electrolytic hydrogen and CO_2 acquired from industrial point source emissions, through an ATJ production pathway.
	e-SAF (DAC)	e-SAF produced from electrolytic hydrogen and CO_2 acquired from Direct Air Capture (DAC), through an ATJ production pathway.
REFERENCE PRODUCTS	Conventional Jet Fuel (CJF)	CJF produced from crude oil through fractal distillation and hydrotreating.
	Bio-SAF (FT)	SAF derived from carbohydrates (eg. Bagasse), municipal solid waste, and agricultural and sawmill residues as feedstocks, to produce biofuels through the Fischer-Tropsch process.
	Bio-SAF (HEFA)	SAF derived from lipid-based feedstocks, to produce Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosine (HEFA-SPK) fuel.

Figure 9: LCOP and CO_2 emission costs for aviation fuel products in 2050



Note: Cumulative data labels indicated.

Demand

The modelled domestic demand for aviation fuel products in each scenario is shown in Figure 10. Due to its high production cost, demand for e-SAF products is negligible in the modelled scenarios.

Feedstock limitations constrain the supply of bio-SAF products (see Appendix A.4 for assumptions), leading to redistribution of unmet demand to more cost-competitive alternatives. As a result, conventional jet fuel (with offset emissions) may continue to hold a substantial market share in both 2050 scenarios, if this shortfall is not met by SAF imports.

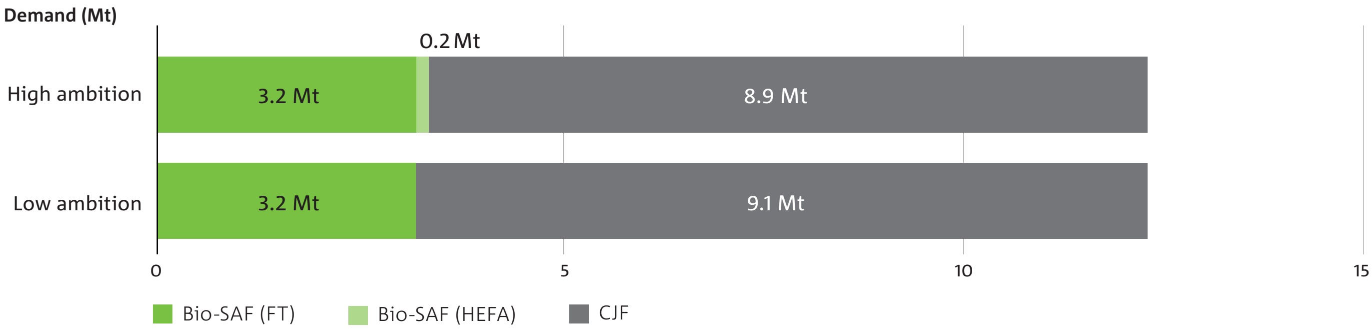
Supply constraints are anticipated at 3.2 Mtpa for bio-SAF (FT) which could supply approximately 26% of the future aviation fuel demand.[104] Under the high ambition scenario, bio-SAF (HEFA) becomes a viable product and supplies 2% of the future aviation fuel demand, as supply constraints are anticipated at 0.2 Mtpa.[105] Policies that discourage or prohibit the use of conventional jet fuel could increase demand for alternative SAFs, including e-SAF products, despite their higher cost.

Economic benefits and CO_2 abatement potential

If Australian industry meets the projected domestic demand for bio-SAF, the low ambition scenario indicates potential domestic revenue of $5 billion and employment of around 3800 jobs by 2050 for bio-SAF (FT). Under the high ambition scenario, where bio-SAF (HEFA) also becomes cost-competitive, the modelling projects an additional $0.4 billion in domestic revenue and 300 additional jobs by 2050. Employment potential is estimated using the employee-to-revenue ratio from Australia's petroleum refining and fuel manufacturing sector.

If aviation fuel production continues to rely on conventional fossil-based pathways, meeting the projected 2050 demand of 12.3 Mtpa could result in an estimated 43.5 Mtpa of CO_2 emissions that would need to be abated with offsets or CDR to achieve net zero emissions.[106] The modelled demand for bio-SAF products could abate between 10.8 and 11.3 Mtpa CO_2 emissions (a 24.8–26% reduction).

Figure 10: Modelled demand for aviation fuel products in 2050



104 Domestic biomass feedstock (including municipal solid waste, agricultural and sawmill residues, and bagasse) are considered for bio-SAF (FT) pathway. See Appendix A.4 for more details.

105 Domestic biomass feedstock (including tallow, cottonseed, and canola) are considered for bio-SAF (HEFA) pathway. See Appendix A.4 for more details.

106 The well-to-wake emissions for conventional jet fuel are estimated at 3.54 tCO_2 per tonne of product. The conventional jet fuel and bio-SAF emissions estimates assume that all CO_2 embodied in the fuel is released during product use. See Appendix A4 for further details.

3.3 Urea

VALUE IN 2050

By 2050, the production of urea (PSC) could create an estimated:

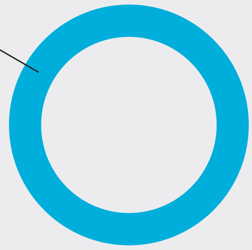
$1.6 billion revenue

1000 jobs

Abating **2.1 Mtpa** CO_2 emissions

DOMESTIC DEMAND IN 2050

Urea (PSC)
2.74 Mt
100%



Under both scenarios

CURRENT ACTIVITY

Green ammonia
2 Projects
FEED and FID

NG ammonia
1 Project
Construction

Note: These results are based on analysis of conventional urea and a non-exhaustive selection of CO_2 utilisation pathways and feedstocks for low-carbon production: urea (PSC) and urea (DAC).

Background

Urea is a nitrogen-based fertiliser produced through the reaction of ammonia (NH_3) with CO_2 at high pressure. It is the most widely used nitrogen fertiliser globally, accounting for around 50% of global consumption and nearly 70% of Australian consumption.[107] In 2023 Australia imported around 3.2 Mt urea to service this demand.[108] Australia has no operational urea production facilities, but Perdaman Chemicals & Fertilisers are constructing a 2.3 Mt plant in WA with an expected completion date in 2027.[109] This would supply over 70% of Australia's 2023 urea demand.

While primarily applied as a straight fertiliser, urea is also used in the production of NPK (nitrogen-phosphorus-potassium) compound fertilisers. It is also used as feedstock in melamine and urea-formaldehyde resin production, as a dietary supplement in ruminant diets, and in AdBlue (a diesel exhaust fluid used in some vehicles to reduce harmful NO_x gases being released into the atmosphere).

107 International Fertilizer Association (IFA) (2018) Statistics: production & international trade. <https://www.ifastat.org/> (accessed 18 January 2023).

108 World Bank (2023) Australia urea imports by country. <https://wits.worldbank.org/trade/comtrade/en/country/AUS/year/2023/tradeflow/Imports/partner/ALL/product/310210>.

109 Perdaman Chemicals and Fertilisers (2025) Project Ceres. <https://perdamanchemicalsandfertilisers.com/project/ceres/>.

Conventionally, urea is synthesised from fossil-derived inputs, where methane (or occasionally, syngas produced from gasified coal), atmospheric nitrogen, and water are reacted at high temperature and pressure to produce ammonia and CO_2.[110] The ammonia and a portion of the CO_2 are then reacted to form urea.[111] The production and use of urea is responsible for around 2% of total CO_2-e emissions and over 10% of agricultural emissions globally, with the main contributors coming from synthesis and field emissions.[112] Global urea production was estimated at 201 Mt in 2024 and nitrogen fertiliser demand is expected to continue growing at 1–2% annually in coming years.[113]

Transitioning to low-carbon urea production hinges on the availability of low-emissions ammonia and sustainable CO_2 sources to replace the conventional methane (or coal) feedstocks. Electrolytic hydrogen (produced via water electrolysis using renewable electricity) could be reacted with atmospheric nitrogen to produce ammonia. This process change can potentially be achieved without major disruption by retrofitting existing ammonia plants.[114]

Because there is excess CO_2 produced in the conventional production of urea, there is also potential for hybrid urea production (incorporating renewable hydrogen feedstock into conventional urea projects). While this has not been modelled in this report, it may offer a nearer term opportunity for emissions intensity reductions in the urea industry.

Industry status

There are no active low-carbon urea projects or proposals in Australia. Australia saw a wave of interest in green ammonia production in 2020–21, reflecting both the strategic importance of domestic fertiliser security and the emerging role of green ammonia (a critical input for urea production using DAC or PSC CO_2) in decarbonisation pathways. Since the closure of Incitec Pivot's natural gas-based Gibson Island urea plant in 2023 Australia is fully reliant on urea imports.[115] In 2024, Fortescue Future Industries and Dyno Nobel (formerly Incitec Pivot) undertook a FEED study for industrial-scale manufacturing of green ammonia production at the Gibson Island site.[116] However, the project has not progressed, with Dyno Nobel divesting from the site and selling their fertiliser distribution business in May 2025.[117]

As there are no low-carbon urea projects announced in Australia, Table 8 summarises announced hybrid and green ammonia projects to give context for the potential development of low-carbon urea projects in the future.

110 Incitec Pivot Fertilisers (2021) Fact sheet – urea. <https://www.incitecpivotfertilisers.com.au/contentassets/5d912d3ebea9460e93c4c608c5277243/32-urea-fact-sheet.pdf> (accessed 18 January 2023); Ghavam S, Vahdati M, Wilson I, Styring P (2021) Sustainable ammonia production processes. Frontiers in Energy Research 9, Article 580808. <https://www.frontiersin.org/journals/energy-research/articles/10.3389/fenrg.2021.580808/full>.

111 Grains Research and Development Corporation (GRDC) (2023) Sustainable fertilisers for Australian growers. <https://grdc.com.au/__data/assets/pdf_file/0029/591536/GRDC-Urea-Report-Factsheet.pdf>.

112 Menegat S, Ledo A, Tirado R (2022) Greenhouse gas emissions from global production and use of nitrogen synthetic fertilisers in agriculture. Scientific Reports 12, Article 18773. <https://www.nature.com/articles/s41598-022-18773-w.pdf>.

113 International Fertilizer Association (IFA) (2025) Public Summary: Medium-Term Fertilizer Outlook 2025–2029. IFA Annual Conference, Monaco, 12–14 May. <https://www.ifastat.org/market-outlooks>.

114 MacFarlane DR, Cherepanov PV, Choi J, Suryanto BHR, Hodgetts RY, Bakker J, Ferrero Vallana FM, Simonov AN (2021) A roadmap to the ammonia economy. ARC Centre of Excellence for Electromaterials Science, School of Chemistry, Monash University, Clayton, Victoria, Australia. <https://researchmgt.monash.edu/ws/portalfiles/portal/310071142/310069820_oa.pdf> (accessed 14 January 2025).

115 The site was used to produce anhydrous ammonia, ammonium sulphate fertiliser and urea for agricultural customers, as well as AdBlue (a liquid additive used to remove harmful exhaust emissions from diesel vehicles) and carbon dioxide for industrial uses. Fortescue Future Industries (2024) Gibson Island Renewable Ammonia Project – Public FEED Summary Report. <https://arena.gov.au/assets/2024/10/Fortescue-Future-Industries_Gibson-Island-Renewable-Ammonia-Project-FEED-Study_Public-FEED-Summary-Report.pdf>.

116 Fortescue Future Industries (2024) Gibson Island Renewable Ammonia Project – Public FEED Summary Report. <https://arena.gov.au/assets/2024/10/Fortescue-Future-Industries_Gibson-Island-Renewable-Ammonia-Project-FEED-Study_Public-FEED-Summary-Report.pdf>.

117 Real Estate Source (2025) Goodman buys Gibson Island. <https://www.realestatesource.com.au/goodman-buys-gibson-island/>.

Table 8: Announced green ammonia projects in Australia

PROJECT	ANNOUNCEMENT DATE	EXPECTED YEAR OF OPERATION	FUNDING	DESCRIPTION
YURI Project (ENGIE), Western Australia[118] *Renewable hydrogen and natural gas-derived ammonia*	2019	2025	**Est. $87 million** *including a $47.5 million grant from the Australian Renewable Energy Agency (ARENA) and an additional $2 million from the Western Australian government.*	A 10 MW electrolyser is being installed to produce renewables-based hydrogen to supplement natural gas use in Yara Fertilisers' existing liquid ammonia plant in north-west Western Australia. **STATUS: Under construction.**
Good Earth Green Hydrogen and Ammonia Project (Hiringa Energy), New South Wales[119] *Green ammonia*	2023	2027	**Est. $71.6 million** *including $35.8 million of funding through the New South Wales Hydrogen Hubs initiative.*	Aims to produce up to 4,500 tonnes of green ammonia annually to supply local and regional farming operations as a low-carbon fertilizer. **STATUS: Under construction.**
Allied Green Ammonia Project (Allied Green), Northern Territory *Green ammonia*	2023	2030	**Est. $10 billion**[120]	Proposed green ammonia facility on the Gove Peninsula producing up to 958,500 tonnes of green ammonia for export.[121] **STATUS: Project feasibility and pre-FEED studies completed in 2024. Preliminary design package finalised in Jan 2025. FEED studies underway.**

Internationally, low-carbon urea production using DAC or PSC CO_2 has not yet been demonstrated at a commercial scale, but there are emerging examples of industrial-scale green ammonia synthesis, for example:

- **Chinese company Envision** commissioned a 320,000 tpa green ammonia plant at Chifeng Net Zero Industrial Park in Inner Mongolia in 2025.
- The EU's first industrial-scale green ammonia and renewable hydrogen plant by **Fertiberia (Spain)** is under development to produce 180,000 tpa of ammonia.[122]
- **Yara's renewable Hydrogen plant in Norway**, established in 2023, can produce up to 20,000 tpa of green ammonia.[123]

118 CSIRO (2025) HyResource: Yuri Renewable Hydrogen to Ammonia Project. <https://research.csiro.au/hyresource/yuri-renewable-hydrogen-to-ammonia-project/>.

119 CSIRO (2025) HyResource: Good Earth Green Hydrogen and Ammonia Project. <https://research.csiro.au/hyresource/good-earth-green-hydrogen-and-ammonia-project/>.

120 Allied Green Ammonia (2025) Affinity Capital appointed for flagship green ammonia project. <https://renewablesnow.com/news/aga-seeks-to-raise-usd-6-5bn-for-major-aussie-green-ammonia-project-868587/>.

121 Allied Green Ammonia (2025) ABB and Allied Green Ammonia sign MOU to accelerate the energy transition. <https://new.abb.com/news/detail/124309/abb-and-allied-green-ammonia-sign-mou-to-accelerate-the-energy-transition-with-green-hydrogen-and-ammonia>.

122 Fertiberia (n.d.) GAIA: Green Ammonia in Asturias. <https://www.fertiberia.com/en/greenammonia/gaia-green-ammonia-in-asturias/>.

123 Yara (n.d.) Renewable hydrogen plant at Herøya (Press Kit). <https://www.yara.com/news-and-media/media-library/press-kits/renewable-hydrogen-plant-heroya-norway/>.

Industry insights

Stakeholder consultations and desktop research identified the following industry insights:

- **Urea is a globally traded commodity and Australian urea projects must compete with low-cost gas imports from the Middle East and East Asia**. The closure of Dyno Nobel's Gibson Island Plant due to high gas prices and ageing infrastructure, the discontinuation of Strike Energy's Project Haber proposal due to gas resource limitations, and the delays to NeuRizer's Urea proposal due to the loss of a strategic partner and a requirement to prepare an Environmental Impact Statement highlight diverse challenges associated with conventional urea production in Australia. In this already challenging environment for conventional urea production, low-carbon urea is expected to face even greater challenges. In the absence of effective global carbon pricing and carbon leakage mechanisms, Australian low-carbon urea manufacturers will have to compete directly with conventional urea imported from countries with no carbon price. This likely explains why, the conventional urea industry is currently focused on deploying CCS and renewable hydrogen integration (for hybrid production) to reduce the emissions intensity of natural gas derived urea rather than developing urea production facilities using PSC or DAC CO_2 feedstocks.
- **Green ammonia production and secure CO_2 supply are essential precursors to commercial scale low-carbon urea production.** As such, it is unlikely for commercial-scale projects to be seriously pursued by Australian industry until green ammonia projects are successfully deployed. Like all CO_2 utilisation applications, it also requires a secure supply of CO_2, which in the absence of CO_2 capture and distribution infrastructure creates a significant geographic constraint. Aligning both supply chains adds complexity and risk at early commercial stages, which can make it much harder to secure offtake agreements and financing. Hybrid urea production (combining renewable hydrogen feedstock and conventional urea production) may offer a nearer term opportunity for emissions intensity reductions in the urea industry.
- **Capital intensity and financing risk remain central barriers to project realisation**. Perdaman's Project Ceres may suggest important factors for the success of future low-carbon urea projects, including offtake agreements, supportive finance arrangements, and federal government support. Project Ceres is a conventional urea manufacturing plan under development in Karratha, Western Australia. Factors in its success are likely to include a 20-year gas supply agreement with Woodside, an offtake partnership entered with Dyno Nobel (prior to the sale of its fertiliser distribution business to Ridley Corporation), and government loans to support the development of the project ($220m) and related infrastructure ($255m) via the Northern Australia Infrastructure Fund.[124]

124 NAIF (Northern Australia Infrastructure Facility) (2022) Perdaman Urea Project and supporting infrastructure. <https://www.naif.gov.au/our-projects/perdaman-urea-project-and-supporting-infrastructure/>.

2050 market assessment

Scope of analysis

This analysis assesses the potential demand for urea derived using PSC and DAC CO_2 sources in a simplified 2050 domestic fertiliser market. The two low-carbon urea products are compared against conventional urea produced from fossil-based methane via incumbent processes.

The methodology, assumptions and results of this analysis are described in detail in Appendices A.2 and A.5.

Cost competitiveness

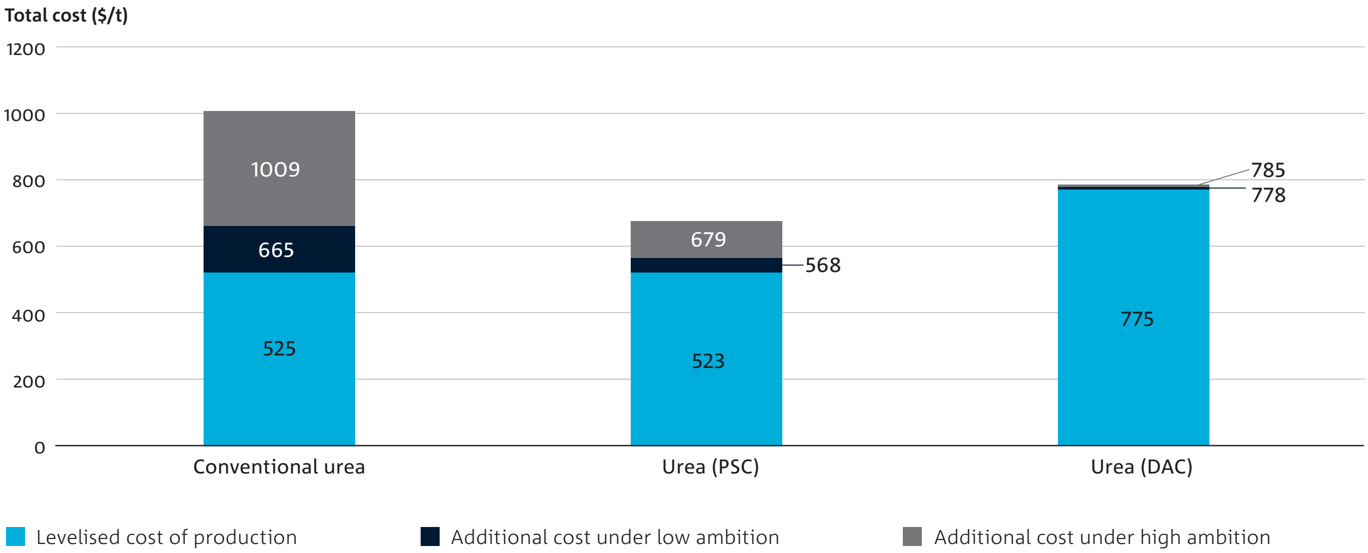
The modelled LCOP and CO_2 emissions cost for urea products in each scenario is shown in Figure 11. Under all modelled scenarios, green urea produced using point source CO_2 is projected to be cost competitive with the conventional urea product. Urea synthesised from DAC was not found to be competitive under either scenario, reflecting substantially higher production costs. These elevated costs are primarily attributable to the expense of the carbon feedstock, which remains a dominant cost driver in DAC-based urea production.

The cost of both PSC and DAC-derived urea, could be further reduced if hydrogen prices were to become much lower than currently estimated (≤$1.8/kg).

Table 9: Assessed and reference urea product descriptions

	PRODUCT	DESCRIPTION
ASSESSED PRODUCTS	Urea (PSC)	Urea produced using green ammonia (synthesised from renewable hydrogen and atmospheric nitrogen) and CO_2 captured from industrial point source emissions.
	Urea (DAC)	Urea produced using green ammonia (as above) and CO_2 captured via Direct Air Capture (DAC).
REFERENCE PRODUCT	Conventional urea	Fossil-based urea produced using hydrogen and CO_2 derived from natural gas reforming, via a conventional ammonia synthesis pathway.

Figure 11: LCOP and CO_2 emission costs for urea products in 2050



Demand

The modelled domestic demand for the urea in each scenario is shown in Figure 12. Forecast demand modelling indicates that urea produced from point source CO_2 captures the entirety of projected domestic demand under both low-and high-ambition scenarios.

This outcome reflects relative cost competitiveness, while neither DAC-based urea nor conventional urea capture any market share. No limiting production constraints were identified for PSC-based urea within the modelling framework, as feedstocks were assumed to be scalable in line with demand. It should be noted, however, that this suggests unconstrained renewable hydrogen and CO_2 availability, which in practice may influence production capacity and market uptake.

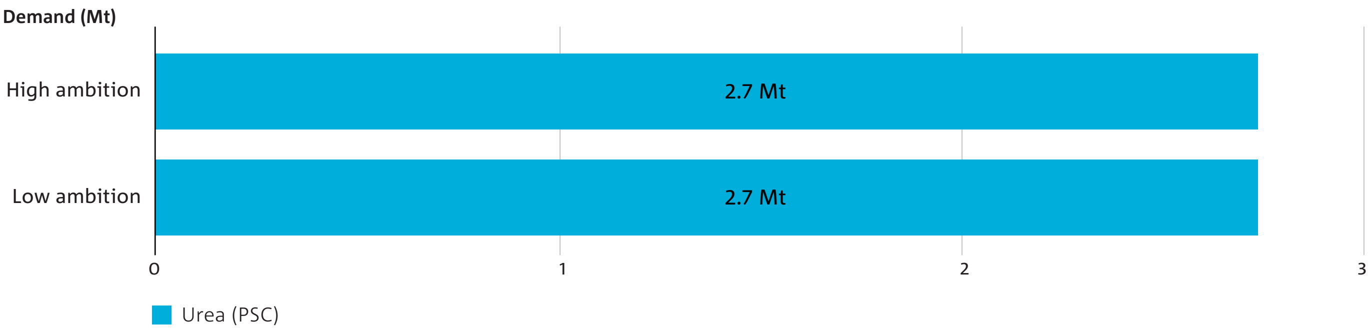
Economic benefits, CO_2 utilisation and abatement potential

Urea (PSC) shows potential for CO_2 utilisation, with 2.1 million tonnes of CO_2 use forecast under both scenarios. If reliable sources and industry uptake of PSC CO_2 cannot be secured, this could limit the supply of urea (PSC). If this is the case, the modelling results suggest that under the low ambition scenario, conventional urea would capture the remaining demand, but in the high ambition scenario, urea (DAC) is found to become competitive.

If Australian industry supplies the forecast domestic demand for urea (PSC), the modelling estimates domestic revenue of $1.6 billion and employment potential of 976 jobs in 2050, approximated using the employee-to-revenue benchmark for the fertiliser manufacturing industry in Australia.

If urea production continues to rely on conventional fossil-based pathways, meeting the projected 2050 demand of 2.7 Mt could result in an estimated 3.1 Mt of CO_2 emissions.[125] If this demand is replaced by urea (PSC), the associated CO_2 emissions would be reduced by 2.1 $MtCO_2$ per annum (a reduction of 68%).

Figure 12: Modelled demand for urea products in 2050



125 The well-to-wake emissions for conventional urea are estimated at 1.14 tCO_2 per tonne of product. See Appendix A5 for further details.

3.4 Mineral aggregates

VALUE IN 2050

By 2050, the production of carbonated fine aggregates for use in concrete could create an estimated:

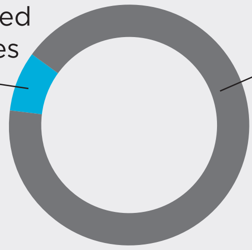
$130 million
revenue

200
jobs

Abating
150 ktpa
CO_2 emissions

DOMESTIC DEMAND IN 2050

Concrete blend with carbonated fine aggregates
8.35 Mt*
8%



Conventional concrete blend
96.8 Mt
92%

*containing 2.1 Mt of carbonated aggregate

Under both scenarios

CURRENT ACTIVITY

Mineral carbonation demonstration plant
1 Project

Carbonated limestone aggregates
1 Project

Note: These results are based on analysis of a non-exhaustive selection of CO_2 utilisation pathways and feedstocks for mineral aggregate production: carbonated fine aggregates produced from steel slag and waste concrete.

Background

Carbonated mineral aggregates are construction-grade materials produced by reacting CO_2 with alkaline minerals or industrial residues.[126] Carbonated aggregate products have the potential to be used as low emission alternatives to quarried rock and sand used in concrete, pre-cast construction products, road bases, and other building materials. Their physical and mechanical properties, such as strength and durability, are expected to be able to meet construction standards when properly engineered.

Carbonated aggregates may assist with decarbonisation efforts in the construction sector, particularly in response to rising scrutiny of embodied scope 3 emissions.[127] In Australia, scope 3 emissions from the built environment were estimated to be 10% of national carbon emissions in 2023.[128] Other analyses suggest concrete alone is responsible for approximately 11 $MtCO_2$ per year.[129]

Carbonated aggregates can be durable stores of carbon, making them a carbon-negative product. This contrasts with CO_2-derived chemicals and fuels, which are typically short-term stores of carbon. Carbonated mineral aggregates support a shift toward low-carbon construction practices, which will be increasingly important as demand for new housing and infrastructure increase, driven by population growth and national infrastructure targets.

Carbonated mineral aggregates (and carbonated SCMs, see Section 3.5) are examples of mineral carbonation products that can be made using CO_2 utilisation. Some other mineral carbonation products are discussed briefly in Section 3.6 and there is a broader discussion in the CSIRO CO_2 Utilisation Roadmap.[130] Because of the potential long-term durability of carbonates, mineral carbonation processes are also being explored for their potential in CCS and CDR applications.

126 Zhang T, Chen M, Wang Y, Zhang M (2023) Roles of carbonated recycled fines and aggregates in hydration, microstructure and mechanical properties of concrete: A critical review. Cement and Concrete Composites 138, 104994. <https://doi.org/10.1016/j.cemconcomp.2023.104994>.

127 Emissions generated throughout the lifecycle of a product from extraction of raw material resources through to extraction, including from manufacture, transport, construction and end-of-life processes.

128 Infrastructure Australia (2024) Embodied carbon projections for Australian infrastructure and buildings. <https://www.infrastructureaustralia.gov.au/reports/embodied-carbon-projections-australian-infrastructure-and-buildings>.

129 Climate Change Authority (2024) Sector pathways review: Built environment. <https://www.climatechangeauthority.gov.au/sites/default/files/documents/2024-09/2024SectorPathwaysReviewBuilt%20Environment.pdf>.

Industry status

The production of carbonated mineral aggregates in Australia is approaching commercial scale. MCi Carbon (Australia) has developed a mineral-carbonation process for industrial residues and quarried materials, and commenced operation of the Myrtle demonstration plant on Kooragang Island, NSW in November 2025. O.C.O Technology (UK) is also developing a mineral carbonation project in Victoria utilising emissions from the proposed Maryvale Energy Waste facility.

Table 10: Active and announced mineral carbonation projects in Australia

PROJECT	ANNOUNCEMENT DATE	EXPECTED YEAR OF OPERATION	FUNDING	DESCRIPTION
Myrtle Demonstration Plant (MCi Carbon), New South Wales	2022	2025	**Est. $29m** *including $14.6m in Australian Government grants.*[131]	MCi Carbon's Myrtle demonstration plant will use up to 1,000–3,000 tCO_2/yr from Orica's Kooragang Island to produce low carbon materials.[132] For slag-based feedstocks (post-upgrades) the system can process up to ~2,500 tCO_2 per year, producing up to ~12,500 t/yr of carbonated products. Myrtle provides a platform for advancing mineral carbonation process engineering and evaluating the integration of different waste feedstocks. **STATUS: Commenced operations in November 2025.**
O.C.O Technology plant at Maryvale Energy from Waste facility, Victoria	2022	2029	**Est. $16.3m (£8m)**	O.C.O Technology (UK) has entered into a partnership to build a purpose-built facility adjacent to the Maryvale Energy from Waste operation being developed by Veolia. This facility will treat Flue Gas Treatment residues from the operation with CO_2 to create carbon negative manufactured limestone aggregate for the construction sector. In 2024, O.C.O technology imported 40 t of its limestone aggregate to Australia to demonstrate its use in the production of concrete blocks. **STATUS: In 2024, O.C.O Technology was granted a Development License and commenced geotechnical work.**[133]

130 Srinivasan V, Temminghoff M, Charnock S, Moisi A, Palfreyman D, Patel J, Hornung C, Hortle A (2021) CO_2 Utilisation Roadmap. CSIRO, Australia.

131 MCi Carbon secured a $14.5M Carbon Capture Technology Grant from DCCEEW in 2024 and a $14.6M CCUS Demonstration Fund Grant from DISR/DCCEEW in 2021: MCi Carbon (2024) Submission to the Productivity Commission: Circular economy. <https://www.pc.gov.au/__data/assets/pdf_file/0005/387545/sub119-circular-economy.pdf>.

132 MCi Carbon (2024) Myrtle foundation for global industrial decarbonisation. <https://mcicarbon.com/mci-carbon-lays-foundation-for-global-industrial-decarbonisation/>.

133 O.C.O Technology (2024) First O.C.O blocks made in Australia. <https://oco.co.uk/first-o-c-o-blocks-made-in-australia/>.

Internationally, carbonated mineral aggregates have been demonstrated in a variety of applications but are yet to transition to commercial-scale projects. There are currently several pilot and demonstration scale projects announced or operating, including:

- **Blue Planet Systems (US)** has demonstrated synthetic limestone aggregate in concrete. It's San Francisco Bay Global Innovation Center is operating and being expanded to a design target of ~5,000 tCO_2/yr and ~11,000 t/yr of aggregate (current operational capacity not disclosed).[134]
- **Carbon8 Systems (UK)** provides a containerised mineral-carbonation unit, with a capture range of ~1,500–4,000 tCO_2/yr (and up to ~24,000 t/yr residues treated per modular system). Deployments include Vicat (France) and a pilot at AVR Duiven (Netherlands).[135]
- **O.C.O Technology (UK)** operates three mineral carbonation facilities in the UK using Accelerated Carbonation Technology to treat thermal residues with CO_2, producing manufactured limestone (M-LS) aggregate (current per-plant CO_2 capture rate not disclosed).[136]
- **Resilco (Italy)** raised €5 million of funding in 2025 to build a mobile mineral carbonation plant in 2026 and develop Italy's first industrial mineral carbonation plant in 2027 (current plant capacity not disclosed).[137]

Industry insights

Stakeholder consultations and desktop research identified the following industry insights:

- **As a volume-driven commodity with highly localised markets, commercial success will be dependent on the scale and integration with both feedstock supply and product distribution chains.** Aggregates are a volume-driven commodity, required in high volumes with a relatively low unit value. Moreover, they are typically supplied through highly localised supply chains, where transport costs dominate. Therefore, achieving large-scale penetration will be dependent on proximity to key markets and integration with existing construction logistics, as well as plant capacity. Vertical integration in the construction sector further complicates adoption of low-carbon alternatives. Already, many downstream concrete manufacturers choose to adopt manufactured sands as aggregates to minimise quarry waste from upstream mining activities and avoid disposal costs. As such, the economic prospects of low carbon carbonated aggregates must also account for the external factors associated with the change of materials, including interplay with existing supply and waste disposal value chains. However, some technologies, including MCi Carbon's, can support full circularity which helps reduce these logistical barriers.
- **Feedstock flexibility is a strength, but supply chains are uncertain.** MCi Carbon has successfully trialled carbonation across a range of alkaline residues, including mine tailings and industrial by-products such as waste concrete and steel slag. Managing supply side risk for feedstock materials will be a critical enabling factor for mineral aggregate products that use waste feedstocks.

134 Blue Planet Systems (2025) Carbon capture & utilization pioneer announces world's first net zero concrete placement using synthetic limestone aggregate. Press Release. <https://www.newswire.com/news/carbon-capture-utilization-pioneer-blue-planet-announces-worlds-first-22518347>.

135 Carbon8 (n.d.) Our Solution. <https://www.carbon8.co.uk/solution>.

136 O.C.O Technology (2025) O.C.O Technology's King's Award for Enterprise milestone celebration. Agg-Net, 16 May. <https://www.agg-net.com/resources/articles/decarbonization/oco-technologys-kings-award-for-enterprise-milestone-celebration>.

137 CDP Venture Capital (2025) Investment announcement. <https://www.cdpventurecapital.it/cdp-venture-capital/en/dettaglio_comunicato.page?contentId=COM3847>.

2050 market assessment

Scope of analysis

Carbonated fine aggregates are a potential substitute for sand in concrete that could help to reduce the emissions intensity of concrete products. To explore the economic viability of carbonated aggregates in this application, this analysis assesses the potential demand for carbonated fine aggregates in a simplified pre-mixed concrete market. It considers two N25[138] concrete blends: a conventional formulation, and one in which sand is replaced with carbonated fine aggregate, produced with flue gas CO_2. This report models mineral aggregates produced from steel slag waste and concrete waste (recycled concrete fines) only. Mineral carbonation products produced using other feedstocks (e.g. serpentinite) are not in scope of this analysis.

For the purposes of this analysis, the modelled carbonated fine aggregate product is assumed to meet the technical performance specifications for concrete aggregates, though this has not yet been fully validated.

The methodology, assumptions and results of this analysis are described in detail in Appendices A.2 and A.6.

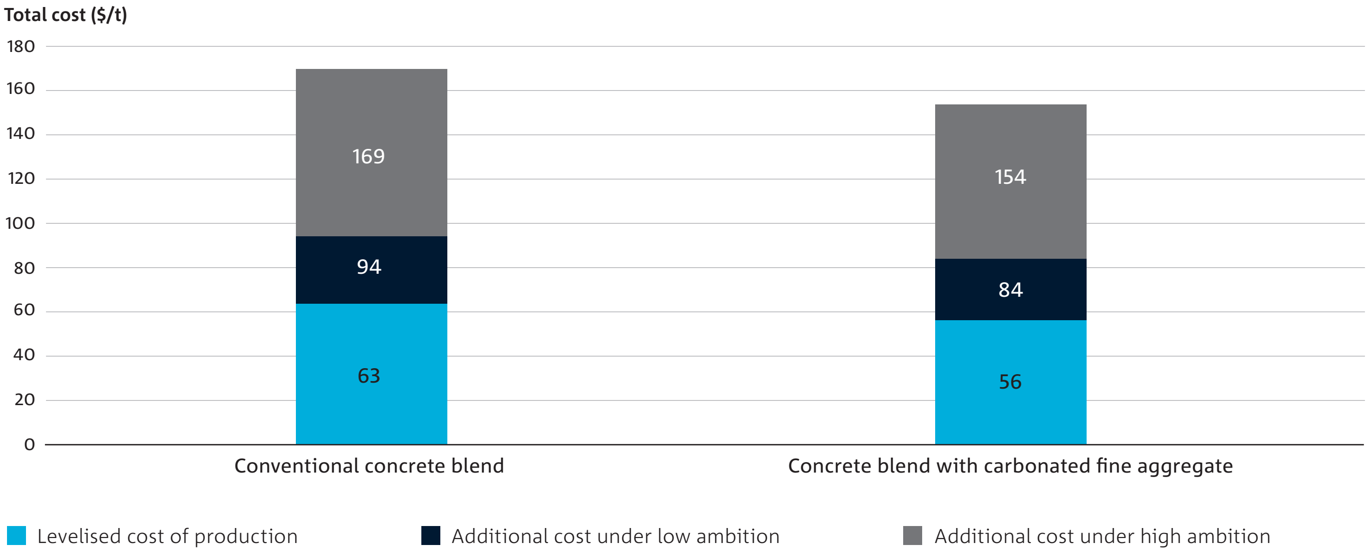
Cost competitiveness

The modelled LCOP and CO_2 emissions cost for concrete blends in each scenario is shown in Figure 13. The blend containing carbonated fine aggregate is projected to be cost competitive with the conventional concrete blend in both low- and high-ambition scenarios. Modelled costs for the carbonated fine aggregate blend assume that steel slag and concrete waste products are obtained at zero cost as industrial by-products. This represents a best-case condition. Limited feedstock availability, competing end uses, and the dispersed geographical distribution of steelmaking and concrete manufacturing operations are all likely to influence costs, and could erode this assumption, particularly where transport or processing requirements are significant.

Table 11: Assessed and reference concrete product descriptions

	PRODUCT	DESCRIPTION
ASSESSED PRODUCT	Concrete blend with carbonated fine aggregate	A concrete blend comprised of Ordinary Portland Cement (OPC) (25%), coarse aggregate (50%) and carbonated fine aggregate (25%). The carbonated fine aggregate product contains manufactured sand and raw limestone and is produced by reacting waste steel slag and/or concrete feedstocks with CO_2 capture from industrial flue gas. The carbonated fine aggregate replaces sand in the conventional concrete blend.
REFERENCE PRODUCT	Conventional concrete blend	A concrete blend comprised of OPC (25%), coarse aggregate (50%) and sand (25%).

Figure 13: LCOP and CO_2 emission costs for concrete blend products in 2050



Note: Cumulative data labels indicated.

138 N25 is a common concrete grade with a compressive strength rating of 25 MPa, it is produced with a ratio of 1:1:2 (i.e. one part cement, one part sand, and two parts coarse aggregate)

Demand

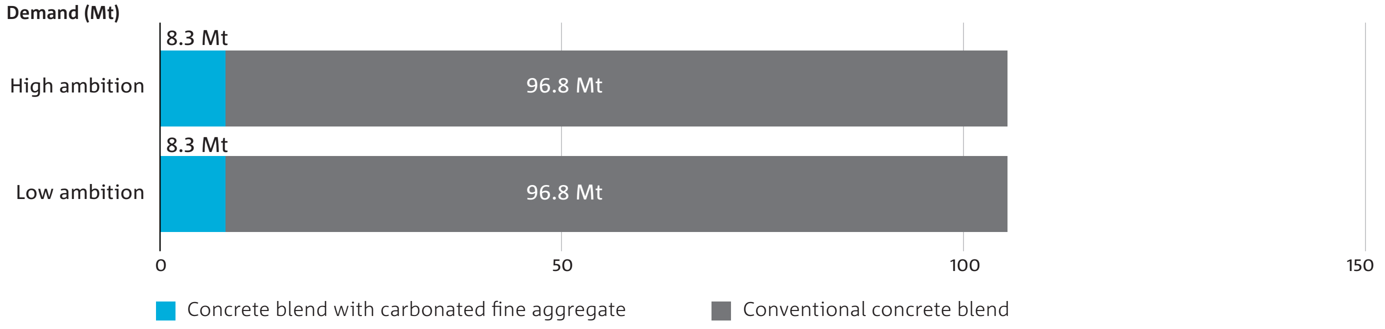
The modelled domestic demand for the concrete blends in each scenario is shown in Figure 14. Concrete blends containing carbonated aggregates are constrained by feedstock availability, limiting their contribution to approximately 8.3 Mtpa of total demand across both scenarios. As shown in Figure 13, the cost modelling indicates concrete blends containing carbonated aggregates are likely to be competitive with the conventional blend. However, their supply is constrained by the availability of steel waste slag and waste concrete. Assuming that 50% of steel slag waste[139] and 20% of concrete waste[140] generated in Australia is allocated to carbonated fine aggregate production, the total production of carbonated fine aggregates is constrained to around 2.1 Mtpa in 2050. This corresponds to a maximum supply limit of 8.3 Mtpa of the concrete blend with carbonated fine aggregate; well under the total demand projected in 2050. The residual demand is met by the conventional concrete blend.

Economic benefits, CO_2 utilisation and abatement potential

If Australian industry supplies the forecast domestic demand for carbonated fine aggregates, the modelling estimates domestic revenue of $131 million and employment potential of 202 jobs in 2050, approximated using the employee-to-revenue benchmark for the rock, limestone and clay mining manufacturing industry in Australia.

Carbonated fine aggregates show potential for total CO_2 utilisation, with 0.16 MtCO_2 use forecast in both scenarios. It is assumed that 90% of the utilised CO_2 remains stored in carbonated fine aggregates. For the projected 8.3 Mt demand of concrete blend with carbonated fine aggregates, this represents an estimated 142,000 tonnes of CO_2 stored. The use of this volume of carbonated aggregate as a sand substitute in concrete has potential to abate an estimated 0.15 Mt of CO_2 per annum.

Figure 14: Modelled demand for concrete blend products in 2050



139 It is assumed that the 26% of steel slag output that is currently sent to landfill could be utilised for mineral carbonation, and 50% of this is allocated to carbonated fine aggregates production. See Appendix A.6 for more details.

140 It is assumed that a 20% of waste concrete in Australia can be recovered and used for carbonated fine aggregate production, considering other competing recycling usage and material utilisation compliance. Further analysis to improve the accuracy of this figure is recommended to validate the scale of this opportunity. See Appendix A.7 for more details.

3.5 Supplementary cementitious materials (SCMs)

VALUE IN 2050

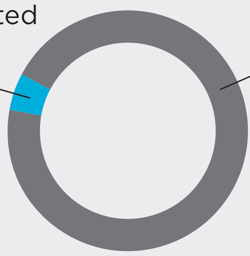
By 2050, the production of carbonated steel slag SCMs for use in cement blends could create an estimated:

$12 million revenue

10 jobs

Abating **40 ktpa** CO_2 emissions

DOMESTIC DEMAND IN 2050



Cement blend with carbonated SCMs **0.75 Mt*** **5%**

Cement blend with conventional SCMs **14.2 Mt** **95%**

*containing 0.15 Mt of carbonated SCM

Under both scenarios

CURRENT ACTIVITY

Carbonated SCM
1 Project
Demonstration plant

Note: These results are based on analysis of a non-exhaustive selection of CO_2 utilisation pathways and feedstocks for SCM production: carbonate SCMs produced from waste steel slag.

Background

Supplementary cementitious materials (SCMs) are reactive inorganic materials used to replace a portion of cement in concrete mixtures, either by partially replacing clinker in cement or by directly substituting cement in the concrete mix. Modern blended cements often contain 20–35% SCMs, although proportions may vary depending on the type of concrete and other factors.[141]

SCMs approved for use in Australia include fly ash (a by-product of coal-fired power generation), ground granulated blast furnace slag (GGBFS, derived from steelmaking), and silica fume (a byproduct of silicon and ferrosilicon alloy production).[142] These materials are largely sourced from industrial waste streams and are blended with cement to produce concretes that can exhibit properties for dedicated applications (i.e., improve durability, strength development, and long-term chemical resistance). Their use can also have environmental benefits including the reduction of the emissions intensity of the cement blends.

Cement production generates around 0.6 tCO_2 per tonne of cement,[143] and contributes approximately 7–8% of global CO_2 emissions.[144] In Australia, the cement industry emitted approximately 4.7 $MtCO_2$ in 2020–21.[145] This primarily arises from the calcination of limestone and fossil fuel combustion during clinker production. Carbonated SCMs, produced via mineral carbonation of alkaline waste, provide a potential pathway to reducing the embodied emissions in concrete. Carbon embodied SCMs are yet to be commercialised for use in the cement and concrete industry, however, these products hold potential for emissions reductions and circular-material innovation if performance and cost targets are met.

141 ASTM International (2025) ASTM C595/C595M – Standard specification for blended hydraulic cements. <https://www.astm.org/c0595_c0595m-21.html>.

142 CCAA (Cement Concrete & Aggregates Australia) (2020) Supplementary cementitious materials – GTCC Part II-2. <https://www.ccaa.com.au/common/Uploaded%20files/CCAA/Publications/Technical%20Publications/PART_II_-2-_SUPPLEMENTARY_CEMENTITIOUS_MATERIALS_GTCC_2020.pdf>.

143 International Energy Agency (2025) Cement industry overview. <https://www.iea.org/energy-system/industry/cement>.

144 Cement Industry Federation (2021) Decarbonisation pathways for the Australian cement and concrete sector. <https://cement.org.au/wp-content/uploads/2021/10/Decarbonisation_Pathways_Australian_Cement_and_Concrete_Sector.pdf>.

145 CSIRO (2023) CCUS roadmap for low emission cement and lime production. <https://www.csiro.au/en/news/All/Articles/2023/November/CCUS-Roadmap>.

Carbonated SCMs are formed via a process of mineral carbonation, involving the reaction of CO_2 with alkaline industrial residues, such as steel slag. This reaction produces stable carbonates which can then be tailored for use in cement blends as a partial clinker replacement, depending on particle size and chemical composition. Products of mineral carbonation processes such as amorphous silica are also being explored for their suitability for use as an SCM. Some other mineral carbonation products are discussed briefly in Section 3.6 and there is a broader discussion in the CSIRO CO_2 Utilisation Roadmap.[146] Because of the potential long-term durability of carbonates, mineral carbonation processes are also being explored for their potential in CCS and CDR applications.

Industry status

In Australia, the use of carbonated SCMs is the subject of ongoing research and testing. MCi Carbon has positioned SCMs as a strategic output of its carbonation activities, alongside carbonated mineral aggregates (see Section 3.4). They are currently investigating the integration of amorphous silica, created as a product of their mineral carbonation process, and carbonated steel slag as potential SCMs, with their Myrtle demonstration plant capable of kiloton-scale SCM production. While in the research trial phase, this work highlights a pathway for diversifying SCM sources beyond traditional industrial by-products.

Table 12: Active carbonated SCM projects in Australia

PROJECT	ANNOUNCEMENT DATE	FUNDING	DESCRIPTION
Myrtle Demonstration Plant (MCi Carbon), New South Wales	2022	**Est $29m** *including $14.6m in Australian Government grants.*[147]	MCi Carbon's Myrtle demonstration plant will use up to 1,000–3,000 tCO_2/yr from Orica's Kooragang Island to produce low carbon materials.[148] For slag-based feedstocks (post-upgrades) the system can process up to ~2,500 tCO_2 per year, producing up to ~12,500 t/yr of carbonated products. Myrtle provides a platform for advancing mineral carbonation process engineering and evaluating the integration of different waste feedstocks. This plant has capability of producing SCM from the amorphous silica product of their mineral carbonation process. **STATUS: Commenced operations in November 2025.**

146 Srinivasan V, Temminghoff M, Charnock S, Moisi A, Palfreyman D, Patel J, Hornung C, Hortle A (2021) CO_2 Utilisation Roadmap. CSIRO, Australia.

147 MCi Carbon secured a $14.5M Carbon Capture Technology Grant from DCCEEW in 2024 and a $14.6M CCUS Demonstration Fund Grant from DISR/DCCEEW in 2021: MCi Carbon (2024) Submission to the Productivity Commission: Circular economy. <https://www.pc.gov.au/__data/assets/pdf_file/0005/387545/sub119-circular-economy.pdf>.

Internationally, research into CO_2-derived SCMs is accelerating but commercial deployments remain limited. Projects in North America, Europe and Asia have demonstrated partial substitution of Portland cement with carbonated SCMs. Identified carbonated SCM research and demonstration projects include:

- **RHI Magnesita (Austria)** is testing the scale-up of MCi Carbon (Australia) mineral carbonation technology in preparation for a planned commercial scale deployment in 2028 at RHI Magnesita's refractory in Austria that would utilise an estimated 50,000 tCO_2 per year to produce SCMs (amorphous silica) and magnesium carbonate.[149]
- **Ash Grove Carbon 1 Mississauga project (Canada)** will use point source CO_2 from Ash Grove's cement plant in Ontario, combined with landfilled coal ash, iron and steel slag, and clays. Once operational (targeting 2026), the facility will have the capacity to produce up to 30,000 t of SCMs annually.[150]
- **TITAN Group (Greece-based)** is advancing SCM sourcing and processing across the United States, United Kingdom, Turkey, Greece (partnership with Ecocem) and India (partnership with JAYCEE). These ventures focus on deploying conventional SCM routes such as calcined clay, pozzolana, ponded fly ash, and slag, tied to local feedstock availability.[151] Separately, Titan's American subsidiary is exploring CO_2 enabled mineral upcycling in collaboration with Carbon Upcycling Technologies, and engaging in discrete carbon capture activities which could supply CO_2 for future carbonated SCM routes.[152]
- **Paebbl (Netherlands)** began operating a continuous demonstration plant using silicate-rich minerals in 2025. The project is intended to become the world's fastest continuous production plant storing up to 500 tCO_2 per year.[153]
- **Solidia (US)** produces a synthetic low-lime carbonated calcium silicate clinker feedstock that is converted into an SCM.[154] In 2023, the company expanded the capacity at their Texas headquarters, reaching around 1000 t per year for pilot-scale production.
- **Asia Cement (Taiwan/South Korea)** is developing the production of carbonated SCMs.[155] In parallel, through its South Korean operations, the company is now developing supplementary cementitious feedstocks with captured CO_2, cement kiln dust and by-pass particles. The company is targeting an initial capture of 30,000 tCO_2 per year, expanding to 180,000 tCO_2 per year through the CCUS project.[156]

148 MCi Carbon (2024) MCi Carbon lays foundation for global industrial decarbonisation. <https://mcicarbon.com/mci-carbon-lays-foundation-for-global-industrial-decarbonisation/>.

149 RHI Magnesita (2025) CCUpScale project: RHI Magnesita and MCi Carbon move closer to world's first CCU plant. <https://www.rhimagnesita.com/en/ccupscale-project-rhim-and-mci-carbon/>.

150 Carbon Upcycling Technologies (2025) Carbon Upcycling and Ash Grove break ground on Canadian first-of-its-kind carbon capture and utilization facility. <https://carbonupcycling.com/2025/07/29/carbon-upcycling-and-ash-grove-break-ground-on-canadian-first-of-its-kind-carbon-capture-and-utilization-facility/>.

151 World Cement (2025) Ecocem signs agreement with TITAN Group to accelerate the deployment of low-carbon cement. <https://www.worldcement.com/europe-cis/03042025/ecocem-signs-agreement-with-titan-group-to-accelerate-the-deployment-of-low-carbon-cement/>; TITAN Group (2025) TITAN Group expands global reach of low-carbon building materials with cementitious venture in India. <https://ir.titanmaterials.com/uploads/announcements/2025/tci_media_release_13022025.pdf>

152 TITAN Group (2025) TITAN and Carbon Upcycling forge strategic partnership to develop low-carbon construction materials. <https://www.titanmaterials.com/wp-content/uploads/2025/06/04062025_TITAN_and_Carbon_Upcycling-forge_strategic_partnership_EN.pdf>.

153 Paebbl (2025) Paebbl starts operating its continuous demo plant, a world-first for CO_2 mineralisation. <https://paebbl.com/news-feed/paebbl-starts-operating-its-continuous-demo-plant-a-world-first-for-co2-mineralisation>.

154 Solidia Technologies (2019) The science behind Solidia. <https://assets.ctfassets.net/jv4d7wct8mc0/5DwEAeEYqsFAYA9UC53EF7/4f8b7566221a8d9cb38f970867003226/Solidia_Science_Backgrounder_11.21.19__5_.pdf>.

155 Asia Cement Corporation (n.d.) Low carbon harbors project. <https://esg.acc.com.tw/en/esg_development/environmental/projects/low_carbon_harbors>.

156 Global Cement (2022) TCRK announces carbon capture project with Asia Cement. <https://www.globalcement.com/news/item/14926-tcrk-announces-carbon-capture-project-with-asia-cement>.

Industry insights

Stakeholder consultations and desktop research identified the following industry insights:

- **Further development of carbonated SCMs will be required prior to commercialisation.** Trial results have indicated positive performance of embodied products in cement and concrete, however, further testing and optimisation is required to validate the materials and enhance performance.
- **Standardisation and regulatory frameworks are a barrier to the use of emerging carbonated SCMs.** Traditional SCMs are well-covered by the AS 3582 series of Australian Standards,[157] and the introduction of the AS 3582.4 in 2022 saw greater expansion of the standards to capture manufactured pozzolans (i.e., silica and/or alumina-based materials which react readily with lime), signalling accommodation of emerging materials.[158] However, concrete supply and performance standards may omit guidance on SCM replacement or prescribe their use only in certain circumstances, which may limit their uptake.[159] Beyond compositional limitations, there is international momentum toward performance-based specifications that focus on end-use functionality over fixed compositions, which in Australia is still nascent.[160]
- **Coordination and integration with Australia's heavy industries may be required to secure suitable feedstocks (i.e., steelmaking slag), but long-term reliance may present supply challenges.** Many SCM pathways depend on access to low-cost industrial by-products and wastes that could be supplied by Australian heavy industries, particularly those already diverting wastes toward the construction industry for use in road bases and concrete production. However, as feedstock volumes decline with the phase out of incumbent technologies (i.e., coal-fired power stations and blast furnaces), downstream utilisation processes will also be impacted. Alternative feedstocks, such as serpentinite, that offer less restricted scale opportunities are being investigated.

157 CCAA (Cement Concrete & Aggregates Australia) (2020) Supplementary cementitious materials – GTCC Part II-2. <https://www.ccaa.com.au/common/Uploaded%20files/CCAA/Publications/Technical%20Publications/PART_II_-2-_SUPPLEMENTARY_CEMENTITIOUS_MATERIALS_GTCC_2020.pdf>.

158 Standards Australia (2022) AS 3582.4:2022 – Supplementary cementitious materials, Part 4: Pozzolans – Manufactured. <https://www.standards-global.com/wp-content/uploads/pdfs/preview/2246260>.

159 NSW Department of Climate Change, Energy, the Environment and Water (2025) Low carbon concrete: Frequently asked questions. <https://www.energy.nsw.gov.au/sites/default/files/2025-04/2025%20NSW%20%20A4%20Factsheet_LCC_Frequently%20Asked%20Questions.pdf>; Cement Industry Federation (2021) Decarbonisation pathways for the Australian cement and concrete sector. <https://cement.org.au/wp-content/uploads/2021/10/Decarbonisation_Pathways_Australian_Cement_and_Concrete_Sector.pdf>.

160 IEAGHG (2023) International standards and testing for novel carbonaceous building materials. <https://ieaghg.org/publications/international-standards-and-testing-for-novel-carbonaceous-building-materials/>.

2050 market assessment

Scope of analysis

To explore the economic viability of carbonated SCMs in cement blends, this analysis assesses the potential demand for carbonated SCMs through their utilisation in cement-based products. It considers the use of carbonated steel slag, produced with flue gas CO_2, as an input to blended cement, and compares its uptake against a conventional cement blend in a simplified 2050 domestic market. This report models only SCMs produced using carbonation of steel slag waste, and does not consider other SCMs that could be produced using other feedstocks.

For the purposes of this analysis the modelled cement blend containing carbonated steel slag is assumed to meet the technical performance specifications required by commercial cement mixes.

The methodology, assumptions and results of this analysis are described in detail in Appendices A.2 and A.7.

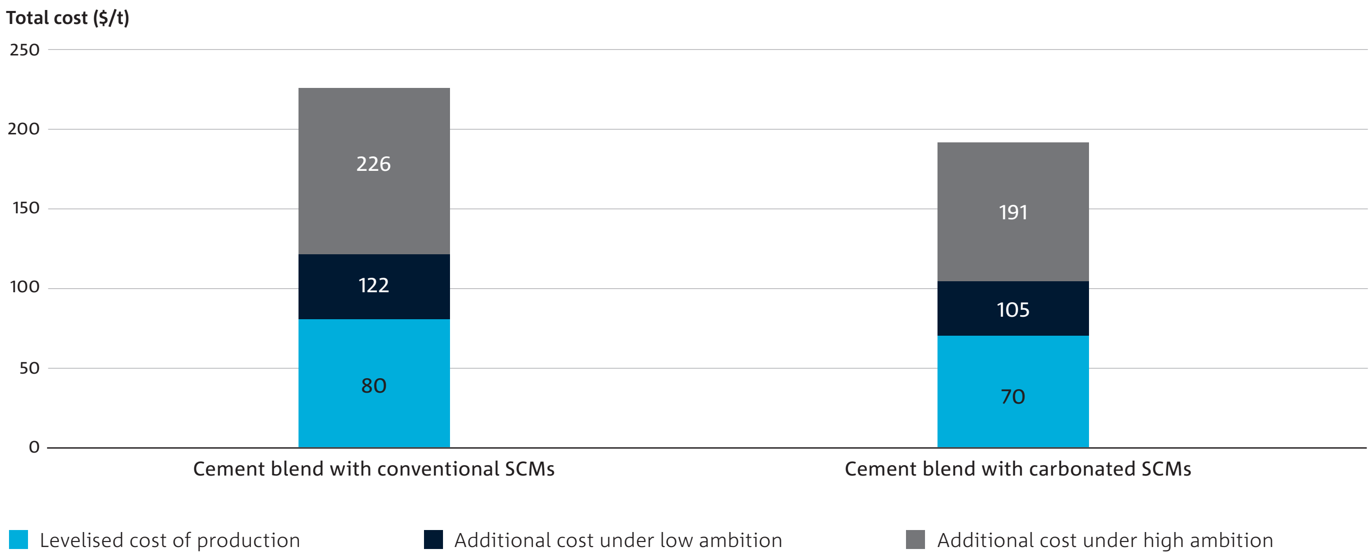
Cost competitiveness

The modelled LCOP and CO_2 emissions cost for cement blends in each scenario is shown in Figure 15. The blend containing carbonated (steel slag) SCMs are projected to be cost competitive compared to the conventional cement blend in both low- and high-ambition scenarios. Production costs for the carbonated-SCM blend assume that steel slag is obtained at zero cost as an industrial by-product. This represents a best-case condition. Limited feedstock availability, competing end uses, and the dispersed geographical distribution of steelmaking operations are all likely to influence costs, and could erode this assumption, particularly where transport requirements are significant.

Table 13: Assessed and reference cement product descriptions

	PRODUCT	DESCRIPTION
ASSESSED PRODUCT	Cement blend with carbonated SCM	Cement mix comprised of OPC (25%), fly ash (15%), Ground Granulated Blast Furnace Slag, GGBFS (40%), and carbonated SCM (20%). The carbonated (steel slag) SCM – produced by reacting waste steel slag with CO_2 captured from industrial flue gases – replaces a portion traditional non-carbonated SCMs in the conventional cement blend.
REFERENCE PRODUCT	Cement blend with traditional SCMs	Cement mix comprised of OPC (25%) and traditional SCMs – fly ash (25%) and GGBFS (50%).

Figure 15: LCOP and CO_2 emission costs for cement products in 2050



Note: Cumulative data labels indicated.

Demand

The modelled domestic demand for the cement blends in each scenario is shown in Figure 16. The modelling results found that cements blend incorporating carbonated SCMs can be cost-competitive with conventional blends and as such they capture market share under both scenarios. However, the supply of carbonated SCM is ultimately constrained by the limited domestic availability of waste steel slag feedstock which is tied to the scale of Australian steel production.

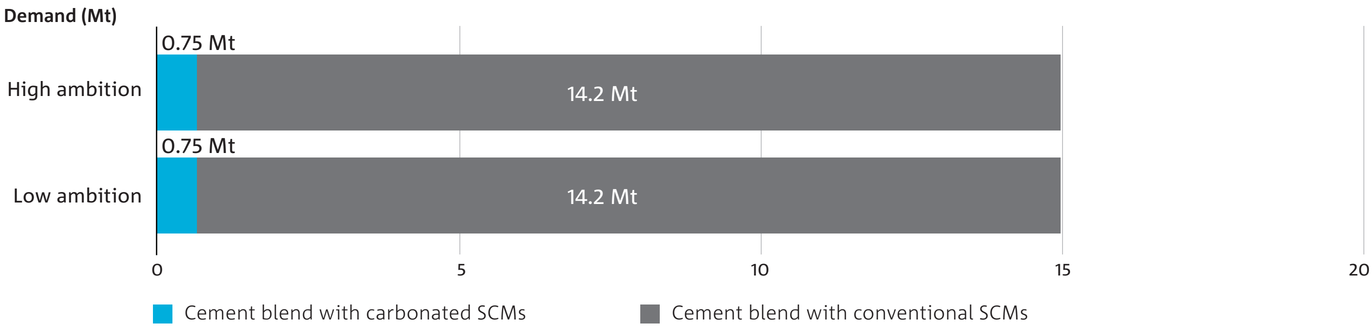
Assuming that 50% of domestic steel slag waste in 2050[161] is allocated to carbonated SCM production, the total production of carbonated fine aggregates is constrained to an estimated 0.15 Mt in 2050. This corresponds to a supply limit of 0.75 Mtpa of the cement blend with carbonated SCMs; well under the total demand of 14.9 Mt cement blends projected for 2050. The residual demand is met by the conventional cement blend.

Economic benefits, CO_2 utilisation and abatement potential

If Australian industry supplies the forecast domestic demand for carbonated SCMs, the modelling estimates domestic revenue of $12 million and employment potential of 9 jobs, approximated using the employee-to-revenue benchmark for the cement and lime manufacturing industry in Australia.

Carbonated SCMs show potential for CO_2 utilisation, with 30,000 tonnes of CO_2 utilisation forecast under both scenarios. It is assumed that 90% of the utilised CO_2 remains stored in carbonated SCMs. For the projected 0.75 Mt demand of the cement blend with carbonated SCMs, this represents around 27,000 tpa of CO_2 stored. Assuming replacement of the cement blend reference product, the use of carbonated SCMs in cement blends could abate an estimated 40,000 tonnes of CO_2 per annum.

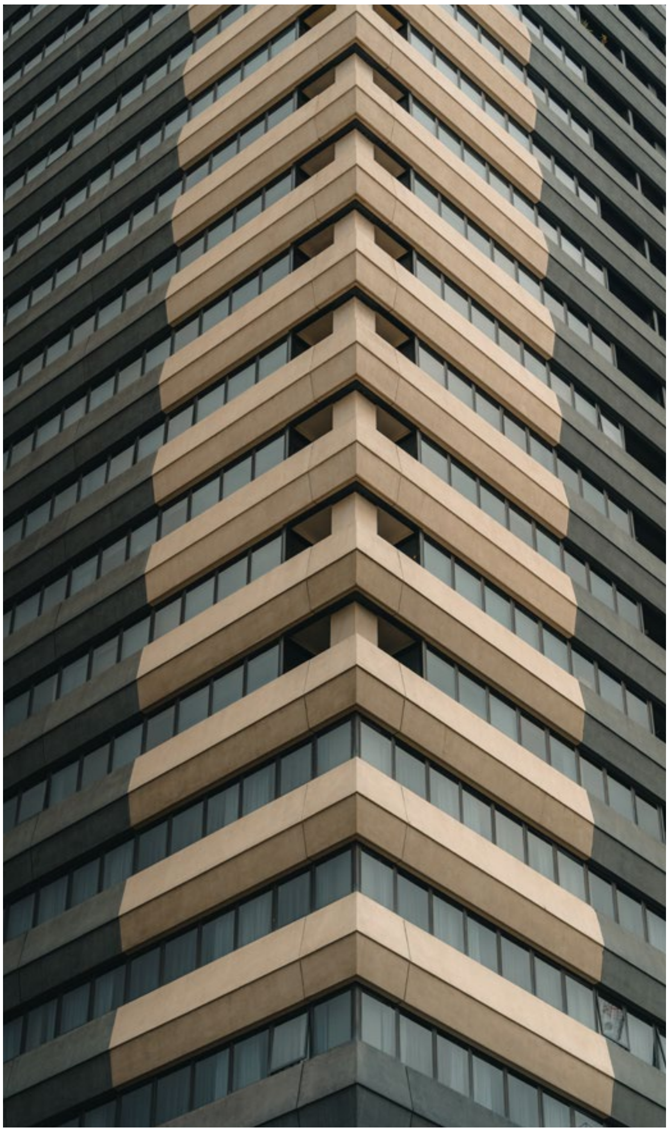
Figure 16: Modelled demand for cement products in 2050



161 It is assumed that the 26% of steel slag output that is currently sent to landfill could be utilised for mineral carbonation and 50% of this is allocated to carbonated SCMs production.

3.6 Other products

In addition to the five CO_2-derived products modelled in this report, several other applications of CO_2 utilisation are under development. These emerging applications illustrate the diversity of potential products and materials that can be derived from CO_2 and could be explored in future analysis.



Construction and building materials

Carbon-cured concrete

In addition to its use as a feedstock for SCMs and aggregates in concrete and cement production, CO_2 can be injected into fresh concrete during mixing and hardening in a process called CO_2 curing.[162] This process enhances the mechanical performance and durability of cement-based products. During curing, CO_2 reacts with calcium-bearing phases in the cement matrix to form calcium carbonate ($CaCO_3$), which fills pore spaces and densifies the microstructure.[163] Two North American companies, CarbonCure (US) and Solidia (US), are leading commercial deployment of carbon curing technologies, with CarbonCure having licensed over 800 systems to concrete producers globally, predominantly in the United States and Canada.[164]

While carbon curing is reaching industrial-scale deployment, ongoing research is investigating the combined effects of SCMs and CO_2 curing on cementitious materials, including the structural and performance impacts of curing on SCMs-blended cement blocks.[165] However, adoption of these products in the near-term is likely to be largely constrained to the precast concrete market which possesses a more controlled environment for curing.[166]

162 International Energy Agency (2020) CCUS in clean energy transitions. <https://www.iea.org/reports/ccus-in-clean-energy-transitions>.

163 CSIRO (2023) CO_2 Utilisation Roadmap. <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/energy/co2-utilisation-roadmap>.

164 CarbonCure Technologies (2024) CarbonCure marks 50 million cubic yards milestone. <https://www.carboncure.com/news/carboncure-marks-50-million-cubic-yards-milestone/>; CarbonCure Technologies (n.d.) Research and testing data. <https://www.carboncure.com/audience/research-testing-data/>.

165 Song Q, Guo M-Z, Gu Y, Ling T-C (2023) CO_2 curing of SCMs blended cement blocks subject to elevated temperatures. Construction and Building Materials 374, 130907. <https://doi.org/10.1016/j.conbuildmat.2023.130907>.

166 RMI (Rocky Mountain Institute) (2021) Concrete solutions guide. <https://rmi.org/wp-content/uploads/2021/08/ConcreteGuide5.pdf>.

Plasterboard, flooring material and paint fillers

Mineral carbonation can be used to produce carbonate fillers for a wide range of construction products beyond cement and concrete, such as plasterboards, wall panels, flooring materials and paints and coatings. These products offer a means of carbon storage alongside performance benefits such as fire resistance, density control and durability, while also reducing reliance on mined materials.

Traditionally, plasterboard production relies on gypsum (calcium sulphate dihydrate) as the base material, sourced either from natural deposits or as an industrial by-product. Magnesium carbonate and its hydrated forms are being increasingly investigated as alternative fillers, particularly due to their fire resistance and thermal stability.[167] These materials can be produced through the carbonation of serpentinite or other magnesium-rich feedstocks with the potential to reduce reliance on mined materials as well as store CO_2. However, the gypsum-based plasterboard market is well established, with the global market share of magnesium-based boards being substantially smaller.[168] Further work is also required to understand how mineral carbonates affect the microstructure, strength and blend ratios of their plaster products.[169]

Similarly, flooring materials such as vinyl, linoleum and polymer-based composite flooring typically incorporate finely ground calcium carbonate to control mechanical strength, density and wear resistance.[170] Paints and coatings often incorporate finely ground mineral fillers, such as calcium carbonate, to improve opacity, durability, viscosity, and weather resistance.[171] CO_2-derived alternatives could serve as a direct substitute for quarried limestone in these applications and reduce overall carbon intensity. MCi Carbon is investigating the technical and commercial feasibility of many of these applications.

Across these applications, the low cost of traditional quarried materials poses challenges to the adoption of CO_2-derived fillers,[172] as does manufacturer uncertainty driven by a lack of large-scale demonstrations to validate performance and feasibility in practice.[173]

Carbonate minerals are also widely used in glassmaking and refractory materials. In these applications the CO_2 is generally re-released during processing and therefore these pathways do not represent permanent CO_2 utilisation. However, there is an opportunity for integration of circular processes that can restrict the re-release of CO_2 and create a permanent release and recapture loop.

167 Shahid K, Nguyen H, Unluer C, Kinnunen P (2024) Development of alternative for gypsum-based plaster using magnesium carbonates from carbon capture and utilization process. Construction and Building Materials 447, 137999. <https://doi.org/10.1016/j.conbuildmat.2024.137999>.

168 Estimates suggest the global gypsum board market reached USD $13.73b in 2024, compared to USD $1.72m for the magnesium oxide board market. See Fortune Business Insights (2025) Gypsum board market size, share & industry analysis, 2025–2032. <https://www.fortunebusinessinsights.com/gypsum-board-market-102718> and Fortune Business Insights (2025) Magnesium oxide boards market size, share & regional forecast, 2023–2030. <https://www.fortunebusinessinsights.com/magnesium-oxide-boards-market-103006>.

169 Shahid K, Nguyen H, Unluer C, Kinnunen P (2024) Development of alternative for gypsum-based plaster using magnesium carbonates from carbon capture and utilization process. Construction and Building Materials 447, 137999. <https://doi.org/10.1016/j.conbuildmat.2024.137999>.

170 OECD (Organisation for Economic Co-operation and Development) (2021) OECD Guidelines for Multinational Enterprises: Responsible business conduct for climate. <https://one.oecd.org/document/ENV/CBC/MONO(2021)33/en/pdf>.

171 ACCM (n.d.) Introduction: The importance of calcium carbonate in the paint industry for quality and cost efficiency. <https://accm.com.eg/introduction-the-importance-of-calcium-carbonate-in-the-paint-industry-for-quality-and-cost-efficiency/>

172 Olfe-Kräutlein B, Strunge T, Chanin A (2021) Push or pull? Policy barriers and incentives to the development and deployment of CO_2 utilization, in particular CO_2 mineralization. Frontiers in Energy Research 9, 742709. <https://www.frontiersin.org/journals/energy-research/articles/10.3389/fenrg.2021.742709/full>.

173 National Academies of Sciences, Engineering, and Medicine (2019) Gaseous carbon waste streams utilization: Status and research needs. The National Academies Press, Washington, DC. <https://nap.nationalacademies.org/read/25232/chapter/5#48>; Olfe-Kräutlein B, Strunge T, Chanin A (2021) Push or pull? Policy barriers and incentives to the development and deployment of CO_2 utilization, in particular CO_2 mineralization. Frontiers in Energy Research 9, 742709. <https://www.frontiersin.org/journals/energy-research/articles/10.3389/fenrg.2021.742709/full>.

Chemicals, polymers and fuels

Polymers (plastic, foams and resins)

Plastics are synthetic polymers comprised primarily of carbon, hydrogen, and oxygen, with smaller contributions from other elements depending on polymer type. Plastics are pervasive in modern society, used across packaging, construction, transport, electronics, textiles, and medical applications due to their durability, low cost, and versatility in form and function.[174] The global plastics industry currently relies almost entirely on petroleum-derived hydrocarbon monomers, which are produced through cracking of fossil feedstocks.[175]

Global production of plastics reached 413.8 Mt in 2023.[176] In Australia, an estimated 3.8 Mt of plastics were consumed in 2020–21.[177] Global plastics production is expected to continue growing, and the IEA projects that the use of oil by the petrochemicals sector will increase by more than 50% by 2050 under current policies, with plastics accounting for much of this demand growth.[178]

Polymers can be grouped by distinct properties, end-use applications, and production processes, but all can be derived from a variety of platform chemicals. For example, olefins such as ethylene and propylene can be synthesised from CO_2 and hydrogen via a methanol intermediate;[179] compounds such as benzene, toluene, and xylene are key precursors for high-performance plastics like polyesters and polyamides; and polyols and polycarbonates serve as building blocks for polyurethane foams, insulation materials, cushioning, and adhesives.[180] These mechanisms are discussed further in the CO_2 Utilisation Roadmap.[181]

CO_2 utilisation presents an opportunity to produce polymers from captured CO_2, reducing reliance on fossil feedstocks and enabling lower-emissions plastics. However, the cost-competitiveness of CO_2 derived polymer production relies on the reduction of green hydrogen levelised cost of production.[182]

Lithium chemicals

Captured CO_2 can also play a novel role in lithium chemical production, offering lower-carbon pathways for battery-grade materials. Conventional hard-rock refining extracts lithium (Li) as lithium sulphate which is then converted to lithium carbonate (Li_2CO_3) or hydroxide (LiOH) using sodium carbonate (Na_2CO_3) or sodium hydroxide (NaOH). However, Na_2CO_3 can also be replaced by CO_2.[183] As an alternative, Novalith Technologies (Australia) is commercialising a process that uses captured CO_2 to produce lithium carbonate from spodumene and related materials, eliminating the need for strong acids and simplifying downstream conversion to battery-grade lithium carbonate.

Methanol-based chemicals and fuels

Beyond its role as a feedstock for olefins, methanol can be converted into a wide range of other products including formic acid and dimethyl ether (DME). DME is a clean burning fuel, which leaves little contamination and produces minimal smoke and harmful pollutants, similar to liquified petroleum gas (LPG). DME can act as propane supplement in cooking gas, aerosol spray-can propellant, solvent and chemical feedstock. There is interest in exploring DME as a transportation fuel, as well as potential in electric power generation, though large-scale deployment faces infrastructure and cost challenges.[184] Meanwhile, formic acid is used across agriculture, leather, textiles and food manufacturing industries.

174 Geyer R, Jambeck JR, Law KL (2017) Production, use, and fate of all plastics ever made. Science Advances 3(7), e1700782. <https://doi.org/10.1126/sciadv.1700782>.

175 International Energy Agency (2018) The future of petrochemicals. <https://www.iea.org/reports/the-future-of-petrochemicals>.

176 Plastics Europe (2024) Plastics – the fast facts 2024. <https://plasticseurope.org/knowledge-hub/plastics-the-fast-facts-2024/>.

177 Department of Climate Change, Energy, the Environment and Water (2022) Australian plastics flows and fates study 2020–21 – National report. <https://www.dcceew.gov.au/sites/default/files/documents/apff-national-report-2020-21.pdf>.

178 International Energy Agency (2018) The future of petrochemicals. <https://www.iea.org/reports/the-future-of-petrochemicals>.

179 Han, Z., Tang, C., & Wang, J. (2021). Catalytic conversion of CO_2 to methanol and subsequently to olefins: Current status and future perspectives. Journal of CO_2 Utilization, 49, 101536

180 Kätelhön, A., Meys, R., Deutz, S., Suh, S., & Bardow, A. (2019). Climate change mitigation potential of carbon capture and utilization in the chemical industry. Proceedings of the National Academy of Sciences, 116(23), 11187–11194.

181 Srinivasan V, Temminghoff M, Charnock S, Moisi A, Palfreyman D, Patel J, Hornung C, Hortle A (2021) CO2 Utilisation Roadmap. CSIRO. <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/energy/co2-utilisation-roadmap>.

182 Srinivasan V, Temminghoff M, Charnock S, Moisi A, Palfreyman D, Patel J, Hornung C, Hortle A (2021) CO2 Utilisation Roadmap. CSIRO. <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/energy/co2-utilisation-roadmap>.

183 Kim S, Yoon H, Min T, Han B, Lim S, Park J (2024) Carbon dioxide utilization in lithium carbonate precipitation: a short review. Environmental Engineering Research 29(3), 230553.

184 Methanol Institute (2016) DME: an emerging global fuel. <https://www.methanol.org/wp-content/uploads/2016/06/DME-An-Emerging-Global-Guel-FS.pdf>.

Speciality and niche materials

Carbon nanomaterials

Carbon nanomaterials such as carbon nanotubes, graphene, and carbon nanofibers can be synthesised from CO_2 through electrochemical or catalytic processes. Some of these production processes combine the CO_2 with industrial byproducts such as fly ash.[185] These materials possess properties, such as high electrical and thermal conductivity and good mechanical strength, that position them well for uses in electronics, advanced composites, and energy storage.[186] RMIT University is conducting research on carbon nanotubes and their use across a variety of applications including energy storage and conversion systems. At the same time, researchers have developed a technology that captures CO_2 and converts it into solid carbon through the use of liquid metal catalysts. A provisional patent has been filed, and commercial partnership formed with ABR.[187] These products, though in early commercialisation,[188] offer a pathway to embed CO_2 into important high-performance materials with higher unit value compared to other pathways.

Synthetic proteins and food ingredients

Synthetic proteins and food ingredients are an emerging application, where CO_2 is used as a carbon source for microbial or algal fermentation. Combined with renewable hydrogen or electricity, CO_2 can be converted into amino acids, protein, and nutrient-rich supplements.

LanzaTech is in the process of completing trials and testing in animal feed and pet food, and is underway with completing the U.S. Food and Drug Administration's Generally Recognized as Safe ('GRAS') certification process for LanzaTech Nutritional Protein (LNP) in human nutrition formulations.[189] The Center for Aquaculture Technologies has successfully tested LNP for fish feed applications, and human food and beverage innovation firm Mattson completed thorough protein characterisation and food prototyping for dish concepts such as smoothies, dairy-free cheese, and bread. These technologies are early-stage, but offer the potential to decouple protein production from traditional agriculture, reducing land, water, and emissions footprints.

185 Dlamini N, Mukaya HE, Nkazi D (2022) Carbon-based nanomaterials production from environmental pollutant byproducts: a review. Journal of CO_2 Utilization 60, 101953.

186 Dlamini N, Mukaya HE, Nkazi D (2022) Carbon-based nanomaterials production from environmental pollutant byproducts: a review. Journal of CO_2 Utilization 60, 101953; Hofstetter K, Licht G, Licht S (2025) New scalable electrosynthesis of distinct high purity graphene nanoallotropes from CO_2 enabled by transition metal nucleation. Crystals 15, 680. <https://doi.org/10.3390/cryst15080680>.

187 RMIT University (2022) Decarbonisation tech instantly converts CO_2 to solid carbon. <https://www.rmit.edu.au/news/media-releases-and-expert-comments/2022/jan/decarbonisation-tech>.

188 See, for example, CarbonCorp (n.d.) Transforming CO_2 into valuable carbon nanomaterials. <https://carboncorp.org/>.

189 LanzaTech (2024) LanzaTech Nutritional Protein investor presentation. <https://lanzatech.com/wp-content/uploads/2024/11/LNZA-LNP-Investor-Presentation-Nov-2024.pdf>.

4 Appendices

A.1 Contributing organisations

The authors would like to thank the following organisations that contributed to the development of this report through participation in consultations, calls for input, or reviews of draft content. Many CSIRO researchers also contributed their expertise. This report has not been endorsed by these organisations or their representatives.

- ABEL Energy
- Australian Government Department of Climate Change, Energy, the Environment and Water
- CarbonNet
- Climate Change Authority
- Cement Concrete & Aggregates Australia
- CO_2 Value Australia
- CO_2 Value Europe
- CSR
- Dyno Nobel
- HAMR Energy
- HIF Global
- MCi Carbon
- New South Wales Department of Climate Change, Energy, the Environment and Water
- Northern Territory Department of Mining and Energy
- Orica
- RECARB Hub
- Western Australia Department of Energy and Economic Diversification
- Xodus Group

A.2 Modelling methodology and general assumptions

This appendix outlines the modelling methodology and assumptions used to assess the market viability of CO_2-derived products across multiple sectors. While the specific cost components vary by product (reflecting differences in production pathways, feedstocks and end uses), all CO_2-derived products are assessed using a consistent framework that estimates levelised cost of production (LCOP), incorporating capital costs, input costs, and other operating costs. Carbon intensity values are used to estimate CO_2 emission costs under low and high ambition scenarios, which are added to production costs to compare their cost competitiveness. Market share is allocated using a market clearing approach, in order of increasing production cost. This approach makes the simplifying assumptions that price is the sole factor influencing consumer choice among competing options, that total demand is inelastic (e.g. does not change in response to price), and that feedstock and/or production capacity constraints apply. Where a CO_2-derived product is forecast to be cost competitive and capture market share, CO_2 utilisation, domestic revenue, and employment potential have also been estimated.

Model Overview

1 Estimate production and CO_2 emission costs in 2050

- Calculate **levelised cost of production** for each CO_2-derived product.
- Estimate **production costs** for bio-products and conventional products from market research and literature.
- Estimate **CO_2 emission costs** under low and high decarbonisation ambition scenarios.

2 Model domestic demand and market share in 2050

- Estimate **total domestic market** using market research data.
- Allocate **market share** using a market clearing assessment and relevant supply constraints.

3 Estimate potential economic benefits, CO_2 utilisation and abatement

- Estimate **domestic revenue** and **job potential** using industry benchmarks for CO_2-derived and bio-products with market share.
- Calculate **CO_2 utilisation** volume (feedstock requirement) for CO_2-derived products with market share.
- Calculate **CO_2 abatement** potential for CO_2-derived and bio-products with market share.

1. Estimate production and CO_2 emission cost in 2050

Each CO_2-derived product is assessed using a LCOP model that reflects its specific production pathway, feedstock requirements, and operational characteristics. While the structure varies by product, all models include capital investment and key input costs and produce estimates of the total production cost per tonne of output in 2050. All electricity inputs and prices are assumed to be renewable. Assumptions are derived from existing CSIRO analysis, literature, and industry insights. For bio-products and conventional products, production cost estimates are derived from literature or market price data. Where necessary, profit margins are removed from market prices to estimate production costs.

To explore different decarbonisation ambition scenarios, two distinct CO_2 emission cost assumptions are modelled for 2050. Well-to-wheel[190] carbon intensities are estimated for each product and are multiplied by the CO_2 emission cost applied to each tonne of CO_2 emitted during the production and use of each product to determine the emissions cost component of production. This cost is added to the LCOP, improving the relative competitiveness of products that emit less CO_2, and reducing the competitiveness of products that emit more CO_2.

- **Low ambition scenario**: **CO_2 emission costs rise gradually (from $75/t in 2025 to $125/t in 2050[191])**, reflecting limited uptake of abatement technologies and fragmented climate action.
- **High ambition scenario: CO_2 emission costs rise more sharply (to $425/t in 2050[192])**, reflecting emissions reductions and accelerating demand for low-emissions products. This scenario is broadly consistent with the level of ambition required to achieve net zero by 2050.

The CO_2 emission costs applied in this scenario-based approach are shadow carbon prices, which reflect the combined effect of all policies, regulations, and incentives that affect relative product costs of CO_2 emitting products. This is a standard method for assessing low-emissions technologies and does not imply the adoption of a carbon pricing policy. Rather, it provides a structured framework to explore how different policy and market signals may shape future demand for CO_2-derived products.

2. Model domestic demand and market share in 2050

Demand and market share is determined using a market clearing methodology:

1. Estimating the total market size for each product, regardless of production pathway
2. Ranking production pathways by cost (including CO_2 emission cost adjustments)
3. Applying feedstock or production capacity limits where relevant
4. Allocating demand to the cheapest available product until feedstock/production capacity limits or the overall market size are reached (a market clearing approach)

The analysis analyses demand projections for the Australian market, without attributing supply sources between local production and imports. It assumes a commodity market context, where incumbent prices reflect global commodity prices paid by domestic consumers. In doing so, it accounts for the competitiveness of cheaper incumbent imports. However, the CO_2-derived production costs are based on Australia-specific assumptions as provided in Table 14. As such, this analysis does not assess potential competition from imported low-carbon products.

3. Estimate potential economic benefits, CO_2 utilisation requirements, and abatement

For CO_2-derived products and bio-products that are forecast to capture some market share, the following are estimated:

- Domestic revenue potential.
- Employment potential.
- Carbon utilisation potential.
- Carbon abatement potential.

190 Well-to-wheel (or well-to-wake) refers to the emissions produced through the entire lifecycle of a product, including its production, transport and use.

191 Derived by applying CAGR of 2% to the Safeguard Guard Mechanism price of $75/t out to 2050. Clean Energy Regulator (2025) Cost containment measure. <https://cer.gov.au/schemes/safeguard-mechanism/managing-excess-emissions/cost-containment-measure>.

192 Derived by adapting estimates from the International Energy Agency (IEA) to align with CSIRO modelling specifications. This estimate reflects the value of the shadow carbon price required to achieve net zero for advanced economies. Shadow carbon prices are proxies for the combined economic effect of direct carbon pricing and complementary policies. See International Energy Agency (2024) World energy outlook 2024. <https://www.iea.org/reports/world-energy-outlook-2024>.

General assumptions

Table 14: Common inputs and assumptions across modelled products

INPUT	UNIT	2050 LOW AMBITION	2050 HIGH AMBITION	SOURCE
CO_2 emission cost	$/tCO_2$	125	425	The low CO_2 emission cost assumption was estimated by applying Compound Annual Growth Rate (CAGR) of 2% to the Safeguard Guard Mechanism price of $75/t.[193] The high CO_2 emission cost assumption was adapted from the International Energy Agency's forecasts.[194]
Hydrogen production cost	$/kg H_2	3.4		CSIRO Levelised Cost of Production modelling (unpublished) for 2050. Optimised production costs calculated using partially firmed renewable electricity.
Assumed electricity cost for hydrogen production	c/kWh	7.0 (60% firmed, renewable)		CSIRO Levelised Cost of Production modelling (unpublished) for 2050.
Industrial captured CO_2	$/tCO_2$	62		The assumed cost of industrial CO_2 capture was derived from the best case (2050) levelised cost of capture modelling under medium partial pressure of 12–14 kPa.[195]
DAC CO_2	$/tCO_2$	408		CSIRO Levelised Cost of Capture Modelling of Nth-of-a-Kind (2050) DAC facilities.[196]
Assumed electricity cost for DAC	c/kWh	9.7 (firmed, renewable)		CSIRO Levelised Cost of Production Modelling for 2050. Optimised production costs calculated using firmed renewable electricity.[197]
USD:AUD Exchange rate	AUD	1.5266		Three-year average. Reserve Bank of Australia.
Jet fuel specific volume	L/t	1263		CSIRO Sustainable Aviation Fuel Roadmap

193 Clean Energy Regulator (2025) Cost containment measure. <https://cer.gov.au/schemes/safeguard-mechanism/managing-excess-emissions/cost-containment-measure>.

194 This estimate reflects the value of the CO_2 emission cost required to achieve net zero for advanced economies. They are assumed to rise on average to USD 130 per tonne (tCO_2) by 2030 and to USD 250/tCO_2 by 2050. International Energy Agency (2021) Net zero by 2050: a roadmap for the global energy sector. International Energy Agency, Paris. <https://www.iea.org/reports/world-energy-outlook-2024>.

195 Srinivasan V, Temminghoff M, Charnock S, Moisi A, Palfreyman D, Patel J, Hornung C, Hortle A (2021) CO2 Utilisation Roadmap. CSIRO. <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/energy/co2-utilisation-roadmap>.

196 CSIRO (2025) Australian Carbon Dioxide Removal Roadmap. CSIRO.

197 CSIRO (2025) Australian Carbon Dioxide Removal Roadmap. CSIRO.

A.3 Methanol assumptions and results

To assess the potential demand for e-methanol in Australia, we model the demand for e-methanol produced using point source (PSC) and direct air capture (DAC) CO_2 feedstocks in a simplified domestic market with conventional methanol and bio-methanol[198] alternatives.

Production and CO_2 emission costs

Levelised production cost components for e-methanol are estimated by applying updated cost assumptions (see Appendix A.2) to the LCOP model developed by CSIRO for the 2021 CO_2 Utilisation Roadmap. These costs are summed together to estimate the total LCOP in Table 15.

Table 15: Cost components that contribute to the 2050 LCOP of e-methanol using PSC or DAC CO_2

COST COMPONENT	UNIT	2050 LEVELISED COST
Capital cost	$/t methanol	94
Hydrogen	$/t methanol	586
CO_2 capture cost (PSC)	$/t methanol	79.4
CO_2 capture cost (DAC)	$/t methanol	522
Other variables	$/t methanol	130

Comparative costs for each reference product derived from literature are described in Table 16. For conventional methanol, the 2050 cost is estimated by extrapolating current market values forward using long-run natural gas and coal price trends and removing average industry profit margins.

Table 16: Production cost assumptions for reference methanol products

PRODUCT	UNIT	2025	2050	SOURCE
Conventional methanol	$/t	546[199]	766	The production cost of conventional methanol in 2050 is calculated assuming a weighted average compound annual growth rate of 1.4% assuming 65% is produced from natural gas (0.7% CAGR) and 35% is produced from coal (2.5% CAGR).[200,201]
Bio-methanol	$/t	1143	726	Average bio-methanol production costs (USD/t) for 2025 and 2050 are estimated from biomass and municipal solid waste feedstocks, incorporating low/high CAPEX, feedstock, and OPEX scenarios. The 2025 cost is inflated to reflect current price levels.[202]

CO_2 emission intensity values are estimated for all products (Table 17).

Table 17: Well-to-wheel life-cycle carbon intensity values of different methanol products[203]

PRODUCT	UNIT	TOTAL WELL-TO-WHEEL
e-methanol (PSC)	tCO_2/t	0.870
e-methanol (DAC)	tCO_2/t	0.0574
Conventional methanol	tCO_2/t	2.34
Bio-methanol	tCO_2/t	0.210

Note: The carbon intensities are calculated assuming end-of-cycle release of captured carbon to the atmosphere.

198 Bio-e-methanol (produced from both biomass and renewable hydrogen feedstocks) is being pursued by some project developers in Australia, however this product is not included in our market modelling due to limited data availability.

199 Fossil fuel-based methanol production costs range from USD 100–250 per tonne and have been adjusted to reflect current-year estimates. IRENA And Methanol Institute (2021) Innovation Outlook: Renewable Methanol, International Renewable Energy Agency, Abu Dhabi.

200 The growth rate is calculated using weighted average rate of coal. <U.S. Energy Information Administration (2025) Annual Energy Outlook 2025. Table: Table 1. Total Energy Supply, Disposition, and Price Summary. <https://www.eia.gov/outlooks/aeo/data/browser/#/?id=1-AEO2025&region=0-0&cases=ref2025&start=2023&end=2050&f=Q&linechart=ref2025-d032025a.3-1-AEO2025>.> The growth rate of natural gas is adapted from internal CSIRO modelling (unpublished).

201 Conventional methanol is obtained from fossil fuels. 55–65% of global methanol production uses natural gas feedstock, about 30–35% uses coal. National Energy Techology Laboaraty (n.d.) 10.3. Syngas Conversion to Methanol. <https://www.netl.doe.gov/research/carbon-management/energy-systems/gasification/gasifipedia/methanol>.

202 Production cost estimated adapted from Figure 35 in: IRENA And Methanol Institute (2021) Innovation outlook: Renewable Methanol, International Renewable Energy Agency, Abu Dhabi.

203 Hawkins TR, Masum F, Beck A, Young B (2022) GREET marine module introduction and instructions. Argonne National Laboratory, Lemont, Illinois. <https://greet.anl.gov/files/greet_marine_manual_2022>.

These carbon intensity estimates are then multiplied by the low and high CO_2 emission cost assumptions and added to the estimated LCOP to calculate total costs for each product under the low and high ambition scenarios in 2050 (Table 18).

Table 18: Estimated LCOP and total cost of methanol products with CO_2 emission cost in 2050

PRODUCT	UNIT	LCOP	LOW AMBITION	HIGH AMBITION
e-methanol (PSC)	$/t	889	996	1259
e-methanol (DAC)	$/t	1331	1338	1356
Conventional methanol	$/t	766	1054	1761
Bio-methanol	$/t	726	752	815

Forecast domestic demand

To estimate the modelled demand for each methanol product, the total domestic demand for methanol in 2050 (Table 19) is estimated to reach 8.7 Mt. This demand is assumed to be inelastic.

Table 19: Total domestic market size for methanol in 2025 and 2050

	UNIT	2025	2050	SOURCE
Total domestic methanol demand	Mt	3.3	8.7	Methanol demand of 3.1 MT estimated in 2023 with CAGR 3.89%.[204]

This modelled demand is allocated to the cheapest products available, in consideration of relevant supply limits described in Table 20. Supply limits are aligned with the feedstock allocation estimated in the Sustainable Aviation Fuel Roadmap (2023) under the *Low Allocation scenario*, which considers SAF and other alterative competing uses for feedstocks.[205] An estimated 19.5 Mt of suitable feedstocks – comprising municipal solid waste and biomass sources such as agricultural and sawmill residues, and sorghum[206] – is assumed to be available for bio-methanol production. Based on conversion yields of 20%[207] from municipal solid waste, 55%[208] from agricultural and sawmill residues, and 42%[209] from sorghum; the effective production capacity is estimated at 9.1 Mt of bio-methanol. Supply limits for products that do not capture any demand were not estimated.

Table 20: Supply limit assumptions for methanol products

PRODUCT	UNIT	2050	SOURCE
Bio-methanol	Mt	9.1	SAF Roadmap

204 Australia methanol demand was estimated to be 3.1 Mt in 2023 and was forecast to grow at CAGR of 3.89% until 2035. ChemAnalyst (2024) Australia methanol market analysis: industry market size, plant capacity, production, operating efficiency, demand & supply, end-user industries, sales channel, foreign trade, regional demand, company share, manufacturing process, 2015–2034. <https://www.chemanalyst.com/industry-report/australia-methanol-market-201>.

205 Only municipal solid waste, residues, and sorghum are considered as bio-feedstocks in this modelling. While other biomass sources are also suitable for bio-methanol production, a detailed assessment is beyond the scope of this report.

206 Feedstock limit is adapted from Temminghoff M, Kuen M, Cohen J, Duong P, Deverell J, Palfreyman D, Livitsanis A, Clark J, Patel J, Moore A (2023) Sustainable aviation fuel roadmap. CSIRO, Canberra. Biomass feedstock (including municipal solid waste, sorghum, agricultural and sawmill residues) available for biomethanol production adapted under high yield, high growth, and high allocation scenario.

207 The energy conversion of municipal solid waste is around 50%. At 8MJ/kg energy content for municipal solid waste, after conversion, this leaves 4MJ of MeOH, which is 0.20kg, so a mass conversion efficiency of 20%. IRENA and Methanol Institute (2021) Innovation outlook: renewable methanol. International Renewable Energy Agency, Abu Dhabi.

208 Kasmuri NH, Kamarudin SK, Abdullah SRS, Hasan HA, Som AM (2016) Potential of biomass for biomethanol production. International Journal of Applied Engineering Research 11(19), 10016–10019. Comparison of biomethanol yield in table 2.

209 Nakagawa H, Harada T, Ichinose T, Takeno K, Matsumoto S, Kobayashi M, Sakai M (2007) Biomethanol production and CO_2 emission reduction from forage grasses, trees, and crop residues. Japan Agricultural Research Quarterly (JARQ) 41(2), 173–180.

Table 21 shows the forecast demand for methanol products under the different scenarios with the feedstock limits applied. In both scenarios the modelled demand for bio-methanol products is lower than the feedstock limit in Table 20. As such, the total modelled demand can be met by bio-methanol.

Table 21: Forecast demand for methanol products in 2050 under low and high ambition scenarios with the feedstock limits applied

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
e-methanol (PSC)	Mt	0	0
e-methanol (DAC)	Mt	0	0
Conventional methanol	Mt	0	0
Bio-methanol	Mt	8.7	8.7

CO_2 abatement potential

For products modelled to capture market share, CO_2 abatement is quantified relative to the carbon intensity of the incumbent product and applied to its estimated market demand. Table 22 shows the forecast CO_2 abatement potential for methanol products under the different scenarios.

Table 22: Carbon abatement potential for bio-methanol in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Bio-methanol	$MtCO_2$	18.5	18.5

Domestic revenue and employment potential

The profit margin from the basic organic chemical manufacturing industry is applied to estimate the revenue associated with methanol demand in 2050. Revenue data from this industry is also used to estimate potential employment figures associated with this revenue (Table 23).

Table 23: Profit margin and revenue per employee industry benchmark[210]

VARIABLES	VALUE	BENCHMARK INDUSTRY
Profit margin applied to estimate revenue	9.2%	Basic organic chemical manufacturing industry.
Revenue/employee	$1.4m	

Table 24 shows the forecast domestic revenue and Table 25 shows the employment potential for bio-methanol products under the different scenarios.

Table 24: Domestic revenue potential for bio-methanol products in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Bio-methanol	$b	7	7

Table 25: Employment potential for bio-methanol products in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Bio-methanol	FTE	5000	5000

210 IBISWorld (2025) Basic Organic Chemical Manufacturing in Australia. <https://my.ibisworld.com/au/en/industry/c1812/at-a-glance>.

A.4 Aviation fuel assumptions and results

To assess the potential demand for e-SAF in Australia, we model the demand for e-SAF products derived from point source (PSC) and direct air capture (DAC) CO_2 feedstocks in a simplified domestic market with conventional jet fuel (CJF) and two bio-SAF alternatives: bio-SAF (HEFA) derived from lipid-based feedstocks and bio-SAF (FT) derived from carbohydrates, municipal solid waste, and residues.

Production and CO_2 emission costs

Levelised production cost components for e-SAF are estimated by applying updated cost assumptions (see Appendix A.2) to the LCOP model developed by CSIRO for the 2021 CO_2 Utilisation Roadmap. The relevant cost components are summed together to estimate the total LCOP for each e-SAF product in Table 26.

Table 26: Cost components that contribute to the 2050 LCOP for e-SAF produced using PSC or DAC CO_2 via an ATJ pathway with methanol as an intermediate

COST COMPONENT	UNIT	2050 LEVELISED COST
Capital cost	$/t SAF	23.6
Methanol production (excluding H_2 and CO_2)	$/t SAF	553
Hydrogen	$/t SAF	1780
CO_2 capture cost (PSC)	$/t SAF	243
CO_2 capture cost (DAC)	$/t SAF	1600
Other variables	$/t SAF	9.45
Fixed O&M	$/t SAF	9.45

Comparative costs for each reference product derived from literature are described in Table 27. For CJF, the 2050 cost is estimated by extrapolating current market values forward using long-term oil price trends and removing average industry profit margins. For bio-SAF products, levelised production costs are based on previous technoeconomic assessment in the CSIRO Sustainable Aviation Fuel Roadmap (2021).

Table 27: Production cost assumptions for reference aviation fuel products

PRODUCT	UNIT	2025	2050	SOURCE
CJF	$/t	921	1170[211]	IATA (2025) Jet Fuel Price Monitor. Weekly average jet fuel price of USD 678.03/t. 12.5% profit margin was removed to estimate production cost of CJF.
Bio-SAF (HEFA)	$/t	1910	1690	Sustainable Aviation Fuel Roadmap.[212]
Bio-SAF (FT)	$/t	2360	1450	Sustainable Aviation Fuel Roadmap.[213]

211 U.S. Energy Information Administration (2025) Annual energy outlook 2025. U.S. Department of Energy, Washington, DC. <https://www.eia.gov/outlooks/aeo/>. According to the EIA, the spot price of conventional jet fuel is projected to grow at 0.96% CAGR between 2025 and 2050.

212 SAF produced by the Hydroprocessed Esters and Fatty Acids (HEFA) pathway using oilseeds and tallow waste as feedstocks. Converted from average levelised cost of production (LCOP) of SAF (HEFA) is estimated as 1.51 $/L and 1.34 $/L for 2025 and 2050 respectively. Profit margin not included in LCOP. Temminghoff M, Kuen M, Cohen J, Duong P, Deverell J, Palfreyman D, Livitsanis A, Clark J, Patel J, Moore A (2023) Sustainable aviation fuel roadmap. CSIRO, Canberra.

213 SAF produced by the Fischer-Tropsch (FT) pathways using bagasse, municipal solid waste, or residues as feedstocks. Converted from average levelised cost of production (LCOP) of SAF (FT) is estimated as 1.87 $/L and 1.15 $/L for 2025 and 2050 respectively. Profit margin not included in LCOP. Temminghoff M, Kuen M, Cohen J, Duong P, Deverell J, Palfreyman D, Livitsanis A, Clark J, Patel J, Moore A (2023) Sustainable aviation fuel roadmap. CSIRO, Canberra.

CO_2 emission intensity values are estimated for all products (Table 28).

Table 28: Well-to-wheel life-cycle carbon intensity values of different jet fuel products[214]

PRODUCT	UNIT	TOTAL WELL-TO-WHEEL
e-SAF (PSC)	tCO_2/t	2.10
e-SAF (DAC)	tCO_2/t	0.120
CJF	tCO_2/t	3.54
Bio-SAF (HEFA)	tCO_2/t	1.20
Bio-SAF (FT)	tCO_2/t	0.157

These carbon intensity estimates are then multiplied by the low and high CO_2 emission cost assumptions and added to the estimated LCOP to calculate total costs for each product under the low and high ambition scenarios in 2050 (Table 29).

Table 29: Estimated LCOP and total cost of aviation fuel products with CO_2 emission cost in 2050

PRODUCT	UNIT	LCOP	LOW AMBITION	HIGH AMBITION
e-SAF (PSC)	$/t	2623	2881	3516
e-SAF (DAC)	$/t	3977	3992	4028
CJF	$/t	1168	1603	2672
Bio-SAF (HEFA)	$/t	1692	1840	2204
Bio-SAF (FT)	$/t	1452	1472	1519

Forecast domestic demand

To estimate the demand for each aviation fuel product, the total domestic demand for aviation fuel in 2050 (Table 30) is estimated by extrapolating data from the CSIRO Sustainable Aviation Fuel Roadmap (2023). This demand is assumed to be inelastic.

Table 30: Total domestic market size for jet fuel in 2025 and 2050

	UNIT	2025	2050	SOURCE
Domestic jet fuel demand	Mt	7.33	12.3	CSIRO SAF Roadmap

This demand is allocated to the cheapest products available, in consideration of relevant production capacity limits described in Table 31. Supply limits are aligned with the feedstock allocation estimated in the Sustainable Aviation Fuel Roadmap (2023) under the *Low Allocation scenario*, which considers bio-methanol and other alterative competing uses for bio-feedstocks. Supply limits for products that do not capture any demand were not estimated.

Table 31: Supply limit assumptions for sustainable aviation fuel products in 2050

PRODUCT	UNIT	ESTIMATED ANNUAL SUPPLY LIMIT	SOURCE
Bio-SAF (HEFA) [215]	Mt	0.2	CSIRO SAF Roadmap
Bio-SAF (FT) [216]	Mt	3.2	CSIRO SAF Roadmap

214 Argonne National Laboratory (n.d.) GREET model: greenhouse gases, regulated emissions, and energy use in transportation. <https://greet.anl.gov/greet_marine> and Argonne National Laboratory (2025) R&D GREET marine module introduction and instructions. <https://greet.anl.gov/files/ttt_2025-marine_fuel_vessels-intro>.

215 Equivalent to high growth, high yield, high allocation scenario of suitable domestic biomass feedstock (including tallow, cottonseed, and canola) in 2050. Temminghoff M, Kuen M, Cohen J, Duong P, Deverell J, Palfreyman D, Livitsanis A, Clark J, Patel J, Moore A (2023) Sustainable aviation fuel roadmap. CSIRO, Canberra.

216 Equivalent to high growth, high yield, high allocation scenario of suitable domestic biomass feedstock (including municipal solid waste, agricultural and sawmill residues, and bagasse) in 2050. Temminghoff M, Kuen M, Cohen J, Duong P, Deverell J, Palfreyman D, Livitsanis A, Clark J, Patel J, Moore A (2023) Sustainable aviation fuel roadmap. CSIRO, Canberra.

Table 32 shows the forecast demand for jet fuel products under the different scenarios with the production limits applied. In both scenarios the demand for one or more bio-SAF products exceeds the production limits in Table 31. As such, the remaining demand is distributed to the next cheapest product.

Table 32: Forecast demand for jet fuel products in 2050 under low and high ambition scenarios with the capacity limits applied

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
e-SAF (PSC)	Mt	0	0
e-SAF (DAC)	Mt	0	0
CJF	Mt	9.1	8.9
Bio-SAF (HEFA)	Mt	0	0.2
Bio-SAF (FT)	Mt	3.2	3.2

CO_2 abatement potential

For products modelled to capture market share, CO_2 abatement is quantified relative to the carbon intensity of the incumbent product and applied to its estimated market demand. Table 33 shows the forecast CO_2 abatement potential for bio-SAF products under the different scenarios.

Table 33: Carbon abatement potential for bio-SAF products in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Bio-SAF (HEFA)	$MtCO_2$	0	0.5
Bio-SAF (FT)	$MtCO_2$	10.8	10.8

Domestic revenue and employment potential

The profit margin from the basic organic chemical manufacturing industry is applied to estimate the revenue associated with aviation fuel demand in 2050. Revenue data from this industry is also used to estimate potential employment figures associated with this revenue (Table 34).

Table 34: Profit margin and revenue per employee industry benchmark[217]

VARIABLES	VALUE	BENCHMARK INDUSTRY
Profit margin applied to estimate revenue	9.2%	Basic organic chemical manufacturing industry.
Revenue/employee	$1.4m	

Table 35 shows the forecast domestic revenue and Table 36 shows the employment potential for bio-SAF products under the different scenarios.

Table 35: Domestic revenue potential for bio-SAF products in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Bio-SAF (HEFA)	$b	0	0.4
Bio-SAF (FT)	$b	5	5

Table 36: Employment potential for bio-SAF products in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Bio-SAF (HEFA)	FTE	0	300
Bio-SAF (FT)	FTE	3800	3800

217 IBISWorld (2025) Basic Organic Chemical Manufacturing in Australia. <https://my.ibisworld.com/au/en/industry/c1812/at-a-glance>.

A.5 Urea assumptions and results

To assess the potential demand for low-carbon urea in Australia, we model the demand for urea produced using renewable hydrogen and atmospheric nitrogen (with ammonia as intermediate) with point source (PSC) or direct air capture (DAC) CO_2 feedstocks in a simplified domestic market with conventional urea.

Production and CO_2 emission costs

Levelised production cost components for urea produced from PSC and DAC CO_2 feedstocks are estimated by applying updated cost assumptions (see Appendix A.2) to the LCOP model developed by CSIRO for the 2023 CO_2 Utilisation in the Northern Territory report. The relevant cost components are summed together to estimate the total LCOP for each urea product in Table 37.

Table 37: Cost components that contribute to the 2050 LCOP of urea produced using PSC or DAC CO_2 and renewable hydrogen with green ammonia as an intermediate

COST COMPONENT	UNIT	2050 LEVELISED COST
Capital cost	$/t urea	1.87
Ammonia production cost (excluding H_2)	$/t urea	95.9
Hydrogen	$/t urea	347
CO_2 capture cost (PSC)	$/t urea	45.3
CO_2 capture cost (DAC)	$/t urea	297
Other variables	$/t urea	30.1
Fixed O&M	$/t urea	2

Comparative costs derived from literature for the conventional urea reference product are described in Table 38. For conventional urea, the 2050 cost is estimated by extrapolating current market values forward using long-run natural gas price trends and removing average industry profit margins.

Table 38: Production cost assumptions for reference urea product

PRODUCT	UNIT	2025	2050	SOURCE
Conventional urea	$/t	437[218]	525	10 year average urea price is estimated at 477.8 $/t; calculated over 2015–2025. The 2025 production cost is reported exclusive of profit margin. Domestic natural gas price projections used as proxy for urea price growth (0.74% CAGR[219]).

CO_2 emission intensity values are estimated for all products (Table 39).

Table 39: Well-to-wheel life-cycle carbon intensity values of different urea products[220]

PRODUCT	UNIT	TOTAL WELL-TO-WHEEL
Urea (PSC)	tCO_2/t	0.369
Urea (DAC)	tCO_2/t	0.0247
Conventional urea	tCO_2/t	1.14

218 IndexMundi (n.d.) Urea – monthly price (Australian Dollar per metric ton). <https://www.indexmundi.com/commodities/?commodity=urea&currency=aud>.

219 CSIRO Levelised Cost of Production Modelling (unpublished) for 2025 and 2050.

220 CSIRO internal modelling.

These carbon intensity estimates are then multiplied by the low and high CO_2 emission cost assumptions and added to the estimated LCOP to calculate total costs for each product under the low and high ambition scenarios in 2050 (Table 40).

Table 40: Estimated LCOP and total cost of urea products with CO_2 emission cost in 2050

PRODUCT	UNIT	LCOP	LOW AMBITION	HIGH AMBITION
Urea (PSC)	$/t	523	568	679
Urea (DAC)	$/t	775	778	785
Conventional urea	$/t	525	665	1009

Forecast domestic demand

To estimate the demand for each urea product, the total domestic demand for urea in 2050 (Table 41) is estimated by extrapolating current domestic demand (assumed to be the average of Australia's urea imports between 2014–2024) based on a global growth rate calculated from the IEA modelling.[221] This demand is assumed to be inelastic.

Table 41: Total domestic market size for urea in 2025 and 2050

	UNIT	2025	2050
Total domestic urea demand	Mt	2.32[222]	2.74

This demand is allocated to the cheapest product available. No supply limits were applied to low-carbon urea production, but the availability of renewable H_2 and suitable CO_2 sources could limit its availability. Table 42 shows the forecast demand for urea products under the different scenarios. Under both scenarios, urea (PSC) captures all demand.

Table 42: Forecast demand for urea products in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Urea (PSC)	Mt	2.74	2.74
Urea (DAC)	Mt	0	0
Conventional urea	Mt	0	0

221 The Stated Policies scenario predicts that global demand for urea-based fertilisers will increase from 84 Mt in 2030 to 96 Mt in 2050, equivalent to CAGR for urea demand of 0.67% between 2030-2050. International Energy Agency (2021) Nitrogen demand by end use and scenario, 2020–2050. IEA, Paris. <https://www.iea.org/data-and-statistics/charts/nitrogen-demand-by-end-use-and-scenario-2020-2050>.

222 10-year average of urea imports to Australia. World Bank (2014) Australia urea imports. World Integrated Trade Solution (WITS). <https://wits.worldbank.org/CountryProfile/en/AUS>.

CO_2 utilisation and abatement potential

CO_2 utilisation for modelled products capturing market share is determined from the stoichiometric CO_2 requirement per tonne of product, multiplied by the estimated market demand. Table 43 shows the forecast CO_2 utilisation for urea (PSC) products under the different scenarios.

Table 43: Carbon utilisation potential for urea (PSC) products in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Urea (PSC)	$MtCO_2$	2.01	2.01

For products modelled to capture market share, CO_2 abatement is quantified relative to the carbon intensity of the incumbent product and applied to its estimated market demand. Table 44 shows the forecast CO_2 abatement potential for green urea products under the different scenarios.

Table 44: Carbon abatement potential for urea (PSC) products in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Urea (PSC)	$MtCO_2$	2.1	2.1

Domestic revenue and employment potential

The profit margin from the fertiliser manufacturing industry is applied to estimate the revenue associated with urea demand in 2050. Revenue data from this industry is also used to estimate potential employment figures associated with this revenue (Table 45).

Table 45: Profit margin and revenue per employee industry benchmark[223]

VARIABLES	VALUE	BENCHMARK INDUSTRY
Profit margin applied to estimate revenue	9.4%	Fertiliser manufacturing industry.
Revenue/employee	$1.6m	

Table 46 shows the forecast domestic revenue and Table 47 shows the employment potential for urea (PSC) products under the different scenarios.

Table 46: Domestic revenue potential for urea (PSC) products in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Urea (PSC)	$b	1.6	1.6

Table 47: Employment potential for urea (PSC) products in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Urea (PSC)	FTE	1000	1000

223 IBISWorld (2025) Fertiliser manufacturing industry. <https://my.ibisworld.com/au/en/industry/c1831/at-a-glance>.

A.6 Mineral aggregate assumptions and results

To assess the potential demand for carbonated mineral aggregates in Australia, we estimate the demand for a carbonated fine aggregate product (produced from concrete and steel waste, and industrial flue gas containing CO_2) by modelling a simplified pre-mixed concrete market that considers two concrete blends: one conventional and one carbonated fine aggregate as substitute for sand. The techno-economic model and input data was partially informed by data provided by MCi Carbon.

Production and CO_2 emission costs

The LCOP for carbonated fine mineral aggregates (Table 49) was estimated by applying updated cost assumptions (see Appendix A.2, and Table 48) and updated data provided by MCi Carbon to a levelised cost of production model developed by CSIRO for the 2021 CO_2 Utilisation Roadmap. As some of the data provided by MCi Carbon is confidential, a full break down of the levelised cost components is not available for this model.

Table 48: Carbonated fine mineral aggregate input cost assumptions

INPUT COST ASSUMPTION	UNIT	2050	SOURCE
Steel slag waste	$/t	0	Steel slag waste is assumed to be procured at zero cost.
Concrete waste	$/t	0	Concrete waste is assumed to be procured at zero cost.
Concrete waste pretreatment	$/t	0	It is assumed that concrete waste incurs no pretreatment cost.
Logistics and transport	$/t	0	It is assumed that there are no logistics and transport costs associated with the transportation of feedstocks to the production facility.
Flue Gas (containing CO_2)	$/t	0	Assumed zero cost waste feedstock.

Table 49: LCOP cost for carbonated mineral aggregates

PRODUCT	UNIT	2050
Carbonated fine aggregate	$/t	15.4

Cost estimates for concrete blend inputs derived from literature are described in Table 50. The costs of Ordinary Portland Cement (OPC), sand, and coarse aggregates are estimated by removing average industry profit margins from recent market prices. It is assumed that these costs do not increase in real terms between 2025 and 2050.

Table 50: Input cost assumptions for concrete blends

PRODUCT	UNIT	COST		SOURCE
		2025	2050	
Ordinary Portland Cement (OPC)	$/t	99	99	The 2025 cost of producing OPC is estimated by removing an assumed 15.7% profit[224] from an average OPC price of $115 per tonne.[225]
Sand	$/t	45	45	The 2025 cost of producing sand is estimated by removing a 12.4%[226] profit from average sand price of $50 per tonne.[227]
Coarse aggregate	$/t	55	55	The 2025 cost of producing coarse aggregate is estimated by removing an assumed 12.4% profit[228] from average aggregate price of $61.50 per tonne.[229]

224 IBISWorld (2025) Cement and lime Manufacturing in Australia. <https://my.ibisworld.com/au/en/industry/c2031/at-a-glance>.

225 IMARC Group. (2025). Cement Prices, Trend, Chart, Demand, Market Analysis, News, Historical and Forecast Data Report 2025 Edition. IMARC Group. <https://www.imarcgroup.com/cement-pricing-report>.

226 IBISWorld (2025) Rock, limestone, and clay mining in Australia. <https://my.ibisworld.com/au/en/industry/b0919/at-a-glance>.

227 IMARC Group. (2025). Silica Sand Prices, Trend, Chart, Demand, Market Analysis, News, Historical and Forecast Data Report 2025 Edition. IMARC Group. <https://www.imarcgroup.com/silica-sand-price-trend>.

228 IBISWorld (2025) Rock, limestone, and clay mining in Australia. <https://my.ibisworld.com/au/en/industry/b0919/at-a-glance>

229 Price data sourced from MJ Rowles Building Products. Building Products – Aggregates. Available at: https://mjrowles.com.au/building-products/ (accessed 24 October 2025).

An N25[230] concrete blend was used to model the competitiveness and potential demand for carbonated fine aggregate in this application. The mix specifications for both blends are described in Table 51. These specifications are used to estimate the LCOP of both concrete blends in Table 53.

Table 51: Input specifications for the modelled concrete blends

CONCRETE BLEND	MIX
Concrete blend with carbonated fine aggregate	25% cement. 25% carbonated fine aggregate. 50% coarse aggregate.
Conventional concrete blend	25% cement. 25% sand. 50% coarse aggregate.

CO_2 emission intensity values are estimated for both concrete blends (Table 52).

Table 52: Well-to-wheel life-cycle carbon intensity values of different concrete blends[231]

PRODUCT	UNIT	TOTAL WELL-TO-WHEEL
Concrete blend with carbonated fine aggregate	tCO_2e/t	0.229
Conventional concrete blend	tCO_2e/t	0.248

These carbon intensity estimates are then multiplied by the low and high CO_2 emission cost assumptions and added to the estimated LCOP to calculate total costs for each product under the low and high ambition scenarios in 2050 (Table 53).

Table 53: Estimated LCOP and total cost of concrete blends with CO_2 emission cost in 2050

PRODUCT	UNIT	LCOP	LOW AMBITION	HIGH AMBITION
Concrete blend with carbonated fine aggregate	$/t	56.0	84.3	153.7
Conventional concrete blend	$/t	63.3	93.8	168.7

Forecast domestic demand

To estimate the demand for each concrete product, the total domestic demand for concrete in 2050 (Table 54) is estimated by extrapolating current domestic demand based on projected population growth. This demand is assumed to be inelastic. In 2018, around 29 million cubic metres (69.6 Mt[232]) of pre-mixed concrete was produced in Australia. This was scaled in proportion to Australia's population growth to estimate 2025 and 2050 demand.[233] Concrete was employed as the parent market for aggregate demand, but carbonated aggregates could have applications in other building products.

Table 54: Total domestic market size for concrete in 2025 and 2050

PRODUCT	UNIT	2025	2050	SOURCE
Concrete	Mt	76.4	105	CCAA[234]

230 N25 is a common concrete grade with a compressive strength rating of 25 MPa, it is produced with a ratio of 1:1:2 (i.e. one part cement, one part sand, and two parts coarse aggregate)

231 Department of Climate Change, Energy, the Environment and Water (2024) How to calculate embodied carbon of a concrete mix: Fact sheet Rev 01. Department of Climate Change, Energy, the Environment and Water, NSW. <https://mecla.org.au/wp-content/uploads/2024/09/DCCEEW-Fact-sheet-Concrete-emissions-calculation_Rev01.pdf>.

232 Concrete has a typical density of 2400 kg/m^3.

233 Australia's population was 25137059 people at the end of 2018. This is estimated to be reach 27594464 in 2025 and 37973865 in 2050. ABS (2025) Population clock and pyramid <https://www.abs.gov.au/statistics/people/population/population-clock-pyramid>.

234 Cement Concrete & Aggregates Australia (2018) Concrete infographic. <https://www.ccaa.com.au/images/CCAA/Concrete/InfographicThumbnail.PNG?version=3C753F33>.

This demand is allocated to the cheapest product available, in consideration of relevant feedstock limits described in Table 55.

Table 55: Supply limit assumptions for key feedstocks, carbonated fine aggregate, and concrete containing carbonated fine aggregate in 2050

FEEDSTOCK/PRODUCT	UNIT	SUPPLY LIMIT	SOURCES AND ASSUMPTIONS
Steel slag	Mt	0.96	Australia produced around 4.8 Mt of crude steel in 2024–2025.[235] The 2050 production volume was calculated assuming zero growth to 2050.[236] Steel slag supply is estimated to be 20% of crude steel output.[237]
Steel slag waste	Mt	0.25	Assumes that the 26% of steel slag output that is currently sent to landfill could be utilised for mineral carbonation instead.[238]
Steel slag waste allocation for carbonated fine aggregate	Mt	0.125	Assumes that 50% of the steel slag waste available could be utilised for carbonated fine aggregate production.
Waste concrete	Mt	8.8	Australia generated 26.8 Mt of building and demolition waste in 2022–23,[239] containing approximately 22.9% concrete[240]. This was scaled to 2050 in proportion with population growth from 26.3 million in 2022 to 37.9 million in 2050. [241]
Allocated waste concrete	Mt	1.77	Assumes that a maximum of 20% of waste concrete in Australia could be recovered and utilised for carbonated fine aggregate production.
Carbonated fine aggregate	Mt	2.09	Total mass of carbonated fine aggregate that could be produced from the steel slag and concrete waste feedstocks. Feedstock input to output ratio provided by MCi Carbon.
Concrete blend with carbonated fine aggregate	Mt	8.3	Concrete mix blend contains 25% carbonated fine aggregate.

Table 56 shows the forecast demand for concrete products under the different scenarios with the feedstock limits applied. The blend with carbonated fine aggregate is the most cost competitive product. However, the potential demand for concrete exceeds supply of carbonated mineral aggregate products exceeds the feedstock limits in Table 55. As such, the remaining demand is distributed to the conventional concrete blend.

Table 56: Forecast demand for both concrete blends and the related demand for carbonated fine aggregate in 2050 with the feedstock limits applied

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Concrete blend with carbonated fine aggregate	Mt	8.3	8.3
Conventional concrete blend	Mt	96.8	96.8
Carbonated fine aggregate	Mt	2.09	2.09

235 Department of Industry, Science and Resources (2025) Resources and energy quarterly: June 2025. Office of the Chief Economist, Canberra. <https://www.industry.gov.au/sites/default/files/2025-06/resources-and-energy-quarterly-june-2025.pdf>.

236 Assumptions informed by industry feedback.

237 Gao W, Zhou W, Lyu X, Liu X, Su H, Li C, Wang H (2023) Comprehensive utilization of steel slag: A review. Powder Technology 422, 118449. <https://doi.org/10.1016/j.powtec.2023.118449>. 15–20% of crude steel output is considered steel slag.

238 According to IEA, 28% of basic oxygen steel slag goes to the sinter plant, 46% is sold and the remaining 26% goes to landfill. IEAGHG (n.d.) Iron and steel CCS study: Techno-economics of integrated steel mill. IEA Greenhouse Gas R&D Programme, Cheltenham, UK. <https://ieaghg.org/publications/iron-and-steel-ccs-study-techno-economics-integrated-steel-mill/>.

239 Pickin J, Macklin J (2024) National waste and resource recovery report 2024. Department of Climate Change, Energy, the Environment and Water, Canberra. <https://www.dcceew.gov.au/sites/default/files/documents/national-waste-resource-recovery-report-2024.pdf>.

240 DCCEEW (2024) Waste minimisation. YourHome. <https://www.yourhome.gov.au/materials/waste-minimisation>.

241 ABS (Australian Bureau of Statistics) (2025) Population clock and pyramid. <https://www.abs.gov.au/statistics/people/population/population-clock-pyramid>.

CO_2 utilisation and abatement potential

CO_2 utilisation for modelled products capturing market share is calculated by multiplying the blend percentage by the product's carbon intensity and the projected market demand. It is assumed that 90% of the utilised CO_2 remains stored in carbonated fine aggregates. For the projected 8.3 Mt demand of concrete blend with carbonated fine aggregates, this represents around 142,000 tonnes of CO_2 stored. Table 57 shows the total forecast CO_2 utilisation for carbonated fine aggregate under the different scenarios.

Table 57: CO_2 utilisation potential for carbonated fine aggregate products in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Carbonated fine aggregate	Mt	0.16	0.16

For products modelled to capture market share, CO_2 abatement is quantified for the blend relative to the carbon intensity of the incumbent product and applied to its estimated market demand. Table 58 shows the forecast CO_2 abatement potential for carbonated fine aggregates under the different scenarios.

Table 58: Carbon abatement potential for carbonated fine aggregate products in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Carbonated fine aggregate	Mt	0.15	0.15

Domestic revenue and employment potential

The profit margin of the rock, limestone, and clay mining industry is applied to estimate the revenue associated with carbonated fine aggregate demand in 2050. Revenue data from this industry is also used to estimate potential employment figures associated with this revenue (Table 59).

Table 59: Profit margin and revenue per employee industry benchmark[242]

<table>
<tr><th>VARIABLES</th><th>VALUE</th><th>BENCHMARK INDUSTRY</th></tr>
<tr><td>Profit margin applied to estimate revenue</td><td>12.4%</td><td rowspan="2">Rock, limestone, and clay mining in Australia</td></tr>
<tr><td>Revenue/employee</td><td>$0.64m</td></tr>
</table>

Table 60 shows the forecast domestic revenue and Table 61 show the employment potential for carbonated fine aggregate under the different scenarios.

Table 60: Domestic revenue potential for carbonated fine in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Carbonated fine aggregate	$b	0.131	0.131

Table 61: Employment potential for carbonated mineral aggregates in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Carbonated mineral aggregates	FTE	200	200

242 IBISWorld (2025) Rock, limestone, and clay mining in Australia. <https://my.ibisworld.com/au/en/industry/b0919/at-a-glance>

A.7 SCMs assumptions and results

To assess the potential demand for carbonated supplementary cementitious materials (SCMs) in Australia, we model the demand for a carbonated SCM (produced from steel waste slag and industrial flue gas containing CO_2) by modelling a modelling a simplified cement market that considers two cement blends: a reference blend containing only conventional SCMs like fly ash and ground granulated blast furnace slag (GGBFS), and a concrete blend also containing a carbonated steel slag SCM product. The techno-economic model and input data was partially informed by data provided by MCi Carbon.

Production and CO_2 emission costs

The LCOP for carbonated SCM (Table 63) was estimated by applying updated cost assumptions (see Appendix A.2, and Table 62) and updated data provided by MCi Carbon to a LCOP model developed by CSIRO for the 2021 CO_2 Utilisation Roadmap. As some of the data provided by MCi Carbon is confidential, full break down of the cost components is not available for this model.

Table 62: Carbonated SCM input cost assumptions

INPUT COST ASSUMPTION	UNIT	2050	SOURCE
Steel slag waste	$/t	0	Steel slag waste is assumed to be procured at zero cost.
Logistics and transport	$/t	0	It is assumed that there are no logistics and transport costs associated with the transportation of feedstocks to the production facility.
Flue Gas (containing CO_2)	$/t	0	Assumed zero cost waste feedstock.

Table 63: LCOP cost for carbonated SCM

PRODUCT	UNIT	2050
Carbonated SCM	$/t	28.75

Cost estimates for cement blend inputs derived from literature are described in Table 64. The costs of OPC, fly ash, and GGBFS are estimated by removing average industry profit margins from recent market prices. It is assumed that these costs do not increase in real terms between 2025 and 2050.

Table 64: Input cost assumptions for cement blends

		COST		
PRODUCT	UNIT	2025	2050	SOURCE
Ordinary Portland Cement (OPC)	$/t	99	99	The 2025 cost of producing OPC is estimated by removing an assumed 15.7% profit[243] from an average OPC price of $115 per tonne. [244]
Fly ash	$/t	97.6	97.6	The 2025 cost of producing flyash is estimated by removing an assumed 15.7%[245] profit from average fly ash price of $113 per tonne.[246]
GGBFS	$/t	61.6	61.6	The 2025 cost of producing GGBFS is estimated by removing an assumed 15.7%[247] profit from average GGBFS price of $72 per tonne.[248]

243 IBISWorld (2025) Cement and lime Manufacturing in Australia. <https://my.ibisworld.com/au/en/industry/c2031/at-a-glance>.

244 IMARC Group. (2025). Cement Prices, Trend, Chart, Demand, Market Analysis, News, Historical and Forecast Data Report 2025 Edition. IMARC Group. <https://www.imarcgroup.com/cement-pricing-report>.

245 IBISWorld (2025) Cement and lime Manufacturing in Australia. <https://my.ibisworld.com/au/en/industry/c2031/at-a-glance>.

246 IMARC Group. (2024). Fly Ash Market: Global Industry Trends, Share, Size, Growth, Opportunity and Forecast 2025–2033. <https://www.imarcgroup.com/fly-ash-market>.

247 IBISWorld (2025) Cement and lime Manufacturing in Australia. <https://my.ibisworld.com/au/en/industry/c2031/at-a-glance>.

248 IMARC Group. (2025). Ground Granulated Blast-Furnace Slag (GGBFS) Prices, Trend, Chart, Demand, Market Analysis, News, Historical and Forecast Data Report 2025 Edition. IMARC Group. <https://www.imarcgroup.com/ground-granulated-blast-furnace-slag-pricing-report>.

A reference cement blend containing conventional SCMs like fly ash and GGBFS was used to model the competitiveness and potential demand for a carbonated steel slag product in a cement blend with carbonated steel slag SCM. The mix specifications for both blends are described in Table 65. These specifications are used to estimate the LCOP of both cement blends in Table 67.

Table 65: Input specifications for the modelled cement blends

CEMENT BLEND	MIX
Cement blend with carbonated SCM	20% carbonated steel slag 25% cement 15% flyash 40% GGBFS
Cement blend with conventional SCM	25% cement 25% flyash 50% GGBFS

CO_2 emission intensity values are estimated for both concrete blends (Table 66).

Table 66: Well-to-wheel life-cycle carbon intensity values of different cement blends[249]

PRODUCT	UNIT	TOTAL WELL-TO-WHEEL
Cement blend with carbonated SCM	tCO_2e/t	0.286
Cement blend with conventional SCM	tCO_2e/t	0.343

These carbon intensity estimates are then multiplied by the low and high CO_2 emission cost assumptions and added to the estimated LCOP to calculate total costs for each product under the low and high ambition scenarios in 2050 (Table 67).

Table 67: Estimated LCOP and total cost of cement blends with CO_2 emission cost in 2050

PRODUCT	UNIT	LCOP	LOW AMBITION	HIGH AMBITION
Cement blend with carbonated SCM	$/t	69.8	104.9	191.2
Cement blend with conventional SCM	$/t	80.0	122.1	225.6

249 DCCEEW (2024) How to calculate embodied carbon of a concrete mix: Fact sheet Rev 01. <https://mecla.org.au/wp-content/uploads/2024/09/DCCEEW-Fact-sheet-Concrete-emissions-calculation_Rev01.pdf>.

Forecast domestic demand

To estimate the demand for each product, the total domestic demand for cement in 2050 (Table 68) is estimated by extrapolating domestic demand (10.17Mt in 2021[250]) based on projected population growth.[251] Cement was employed as the parent market for SCMs, as SCM demand is intrinsically tied to cement production volumes. The total demand for cement is assumed to be inelastic.

Table 68: Total domestic market for cement in 2025 and 2050

PRODUCT	UNIT	2025	2050	SOURCE
Cement	Mt	10.9	15	Cement industry federation, Australian Bureau of Statistics (ABS)[252]

This demand is allocated to the cheapest product available, in consideration of relevant feedstock limits described in (Table 69).

Table 69: Supply limit assumptions for steel slag waste feedstock, carbonated (steel slag) SCM, and cement blend with carbonated SCM in 2050

FEEDSTOCK/PRODUCT	UNIT	SUPPLY LIMIT	SOURCES AND ASSUMPTIONS
Steel slag	Mt	0.96	Australia produced around 4.8 Mt of crude steel in 2024-2025.[253] The 2050 production volume was calculated assuming zero growth to 2050.[254] Steel slag supply is estimated to be 20% of crude steel output.[255]
Steel slag waste	Mt	0.25	Assumes that the 26% of steel slag output that is currently sent to landfill could be utilised for mineral carbonation instead.[256]
Steel slag waste allocation for carbonated steel slag	Mt	0.125	Assumes that 50% of the steel slag waste available could be utilised for carbonated steel slag production.
Carbonated steel slag	Mt	0.15	Total mass of carbonated steel slag that could be produced from the steel slag feedstocks. Feedstock input to output ratio provided by MCi Carbon.
Cement blend with carbonated SCM	Mt	0.75	Cement mix blend contains 20% carbonated steel slag.

Table 70 shows the forecast demand for cement products under the different scenarios with the feedstock limits applied. In both scenarios the demand for SCM products is higher than the feedstock limits in Table 69. As such, the remaining demand is distributed to the next cheapest product, the reference cement blend.

Table 70: Forecast demand for both cement blends and the related demand for carbonated SCM in 2050 with the feedstock limits applied

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Cement blend with carbonated SCM	Mt	0.75	0.75
Cement blend with conventional SCM	Mt	14.2	14.2
Carbonated SCM	Mt	0.15	0.15

250 Cement industry federation. Australian clinker and cement production statistics. In 2021, 9.6 Mt cement was produced domestically, and 0.57 Mt cement was imported to meet the population demand. Cement Industry Federation (n.d.) Australia's cement industry. Cement Industry Federation, Australia. <https://cement.org.au/australias-cement-industry/about-cement/australias-cement-industry/>.

251 Australia's population was 25,180,200 people at the end of 2018. This is estimated to be reach 27,613,489 in 2025 and 34,890,378 in 2050. ABS (Australian Bureau of Statistics) (2025) Population clock and pyramid. <https://www.abs.gov.au/statistics/people/population/population-clock-pyramid>.

252 Cement Industry Federation (n.d.) Australia's cement industry. Cement Industry Federation, Australia. <https://cement.org.au/australias-cement-industry/about-cement/australias-cement-industry/>.

253 Department of Industry, Science and Resources (2025) Resources and energy quarterly: June 2025. Table 3.3. Office of the Chief Economist, Canberra. <https://www.industry.gov.au/sites/default/files/2025-06/resources-and-energy-quarterly-june-2025.pdf>.

254 Assumption informed by industry feedback.

255 Gao W, Zhou W, Lyu X, Liu X, Su H, Li C, Wang H (2023) Comprehensive utilization of steel slag: A review. Powder Technology 422, 118449. <https://doi.org/10.1016/j.powtec.2023.118449>. 15–20% of crude steel output is considered steel slag.

256 According to IEA, 28% of basic oxygen steel slag goes to the sinter plant, 46% is sold and the remaining 26% goes to landfill. IEAGHG (2013) Iron and steel CCS study: Techno-economics of integrated steel mill. IEA Greenhouse Gas R&D Programme, Cheltenham, UK. <https://ieaghg.org/publications/iron-and-steel-ccs-study-techno-economics-integrated-steel-mill/>.

CO_2 utilisation and abatement potential

CO_2 utilisation for modelled products capturing market share is calculated by multiplying the blend percentage by the product's carbon intensity and the projected market demand. It is assumed that 90% of the utilised CO_2 remains stored in carbonated SCMs. For the projected 0.7 Mt demand of cement blend with carbonated SCMs, this represents around 27,000 tonnes of CO_2 stored. Table 71 shows the forecast CO_2 utilisation for carbonated SCM under the different scenarios.

Table 71: CO_2 utilisation potential for carbonated SCM in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Carbonated SCM	Mt	0.03	0.03

For products modelled to capture market share, CO_2 abatement is quantified for the blend relative to the carbon intensity of the incumbent product and applied to its estimated market demand. Table 72 shows the forecast CO_2 abatement potential for carbonated SCM under the different scenarios.

Table 72: Carbon abatement potential for carbonated SCM in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Carbonated SCM	Mt	0.04	0.04

Domestic revenue and employment potential

The profit margin from the Cement and Lime Manufacturing industry is applied to estimate the revenue associated with carbonated steel slag demand in 2050. Revenue data from this industry is also used to estimate potential employment figures associated with this revenue (Table 73).

Table 73: Profit margin and revenue per employee industry benchmarks[257]

VARIABLES	VALUE	BENCHMARK INDUSTRY
Profit margin	15.7%	Cement and lime Manufacturing in Australia
Revenue per employee	$1.2m	

Table 74 shows the forecast domestic revenue and Table 75 show the employment potential for carbonated SCM under the different scenarios.

Table 74: Domestic revenue potential for carbonated SCM in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Carbonated SCM	$b	0.01	0.01

Table 75: Employment potential for carbonated (steel slag) SCM in 2050 under low and high ambition scenarios

PRODUCT	UNIT	LOW AMBITION	HIGH AMBITION
Carbonated SCM	FTE	10	10

257 IBISWorld (2025) Cement and lime Manufacturing in Australia. <https://my.ibisworld.com/au/en/industry/c2031/at-a-glance>.

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