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How mining could ignite Australia's green hydrogen boom

The financial case for shifting to green explosives

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Key Findings

Decarbonising Australia's ammonia production facilities would present a triple win: alleviating domestic gas market pressure; reducing emissions; and catalysing Australia's emerging green hydrogen industry.

Adoption of green hydrogen in ammonia production is currently slow, but a proposed ammonia plant expansion in Western Australia, while currently gas-based, presents a timely opportunity to demonstrate large-scale integration of renewables and green hydrogen.

Miners consume about half of Australia's ammonia through explosives; they could shift to green explosives for a minimal increase in operating costs, with the right incentives.

Government could help accelerate the shift to green explosives through improved data transparency, regulation and targeted support to complement miners' commitments.

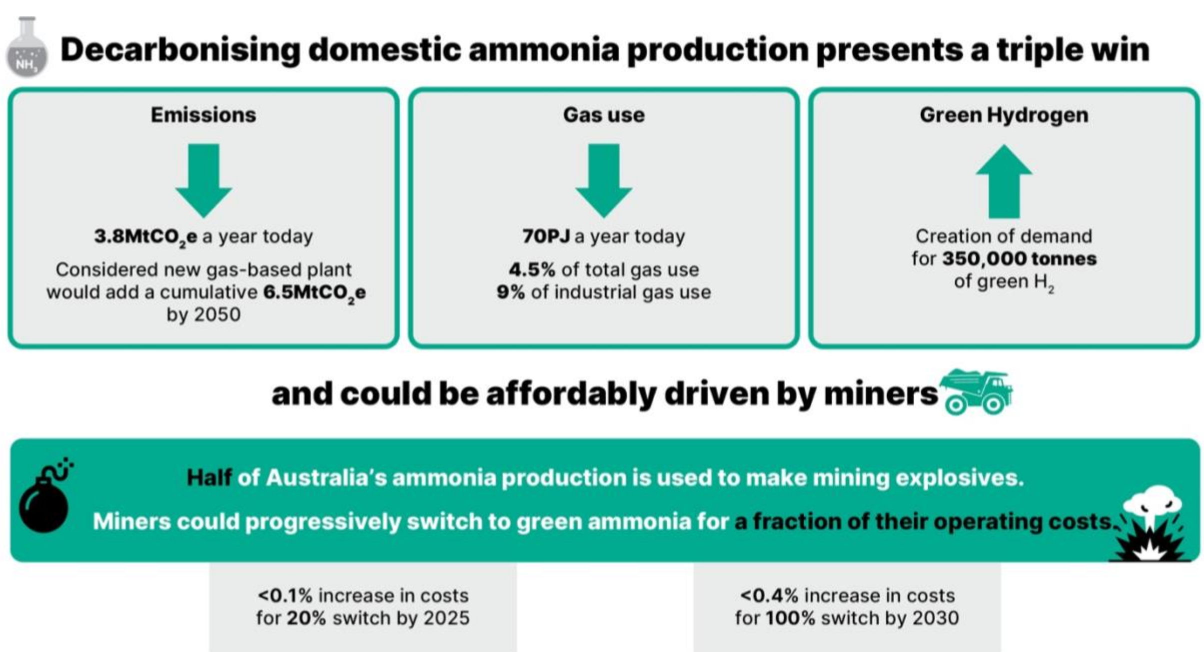
Executive Summary

Australia's ammonia supply chain is currently energy- and emissions-intensive. Ammonia accounted for roughly 5% of Australia's total gas use in 2021, making it the second-highest gas user across Australia's manufacturing sectors. Combined emissions from facilities producing ammonia and its derivatives such as ammonium nitrate are around 4 million tonnes of carbon dioxide equivalent ($MtCO_2e$), or just under 1% of Australia annual emissions.

Most of these emissions are from the use of fossil gas in the production of ammonia, with further emissions from the production of nitric acid. Mature technologies exist to eliminate most of the emissions from these sources, with the largest reductions coming from switching from gas-based hydrogen to green hydrogen.

Ammonia production stands out as a logical early adopter of green hydrogen, which is considered critical to global decarbonisation efforts. Unlike other sectors, ammonia's production process already involves hydrogen as an intermediary product, and no viable alternative low-carbon routes exist. In addition, Australia's existing ammonia plants are in regions with abundant renewable resources. These regions – Pilbara, Kwinana, Hunter and Gladstone – have all been identified as potential hydrogen hubs under Australia's National Hydrogen Strategy and offer the potential of large-scale demand clusters. Switching all of Australia's current ammonia production away from gas would create demand for around 350,000 tonnes of green hydrogen.

Decarbonising ammonia and ammonium nitrate facilities presents the opportunity of a triple win: alleviating domestic gas market pressure; reducing emissions; and catalysing Australia's emerging green hydrogen industry.



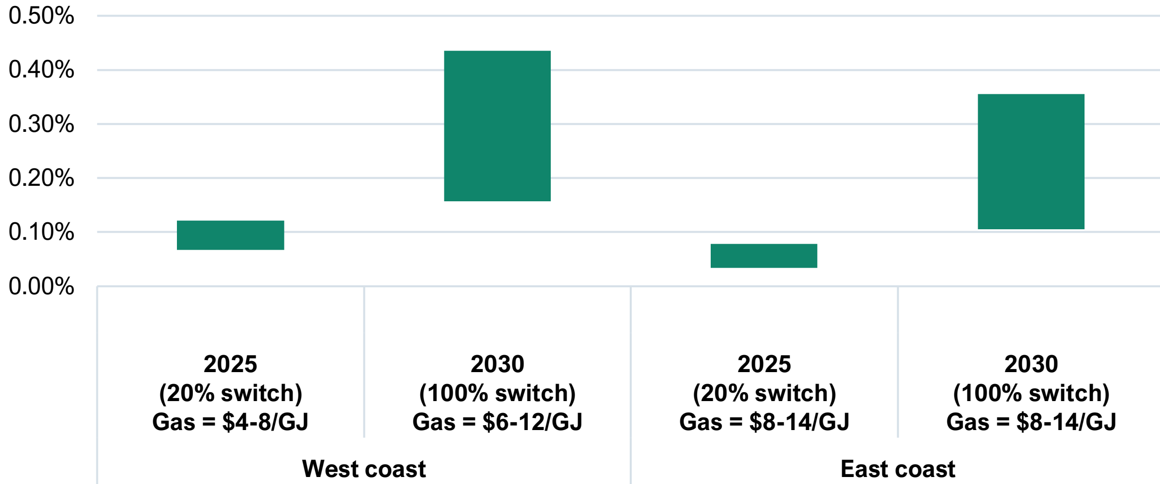
However, progress is slow. Most proposed green ammonia projects remain at an early stage and are focused on exports rather than replacing gas in domestic production. High production costs for green hydrogen (and therefore green ammonia) compared with conventional methods, a lack of demand at premium prices, and insufficient policy drivers are hindering widespread adoption.

Current proposals for a gas-based expansion of CSBP's ammonia plant in Kwinana, Western Australia, would add about 0.5MtCO_2e to Australia's emissions each year. However, instead of proceeding as planned, the expansion offers an opportunity to demonstrate large-scale integration of renewables and green hydrogen in the domestic ammonia supply chain. It could create demand for about 53,000 tonnes of green hydrogen – 18% of the green hydrogen production currently proposed across Australia for domestic use, and more than twice the planned capacity in Western Australia.

Just above half of Australia's ammonia production is used to produce explosives, with the remainder used for exports or to produce fertilisers. As major ammonia consumers through purchased explosives, miners wield significant influence and purchasing power, and can play a pivotal role in accelerating the transition to green hydrogen and ammonia. However, miners currently lack incentives to adopt green explosives due to cost considerations, a lack of policy mechanisms, and limited transparency or scrutiny regarding their contribution to company emissions. By quantifying and setting reduction targets on upstream emissions from explosives products, miners could guarantee offtake and provide the certainty required to shift investment from suppliers.

IEEFA estimates that a complete shift to green explosives would be affordable for miners. We found that switching to 20% green ammonia for explosives production by 2025 would increase mining operating costs by less than 0.1%. This could be done by blending green hydrogen and existing gas-based hydrogen with minimal asset upgrades. A full switch to 100% green ammonia for explosives production by 2030 would increase mining operating costs by up to 0.4%, but this impact could be much lower in particularly favourable regions or if future gas prices increase. This would mean up to a 0.7% reduction in mining profit margins.

Increase in mining operational costs for switching to green ammonia input for producing explosives



Government support will be crucial to drive and complement action by miners, by addressing data transparency challenges and reducing investment risk. Adapting existing schemes such as Renewable Energy Certificates could drive investment in explosives inputs. The creation of a similar market-based mechanism offers the opportunity of recognition for miners' action, and financial incentives and competitive advantages for ammonia producers. Other emerging initiatives such as a hydrogen Guarantee of Origin (GO) scheme could also provide a consistent, accurate approach to tracking emissions from production of hydrogen and derivative products such as ammonia. Investment support can cover shortfalls in miners' commitments, while regulatory measures can mandate full decarbonisation of explosives production. Other measures such as legislating Scope 3 emissions reductions or placing limits on the use of offsets would also accelerate action across the ammonia supply chain.

The convergence of miner influence, market-driven incentives and government support forms a compelling case for accelerating Australia's transition to green ammonia. By embracing this opportunity, miners can not only contribute significantly to global decarbonisation but also position Australia as a leader in green ammonia production. The proposed CSBP plant expansion provides a timely and pivotal moment for miners to catalyse change and drive the adoption of green ammonia in Australian mining and the emergence of a green hydrogen industry.

Decarbonising ammonia offers significant benefits for Australia

The ammonia supply chain is currently energy- and emissions-intensive

Ammonia is an important industry in Australia as a critical input to the agriculture, mining and manufacturing sectors. As shown in Table 1 below, Australia's ammonia supply is relatively concentrated, with four companies operating seven facilities across the country.[1] Production in Australia has remained relatively stable at around 2 million tonnes (Mt) since 2010, slightly lagging global output, which has increased by 17% over this period to around 185Mt.[2,3]

Australia's facilities are often integrated plants that produce ammonia and derivatives such as nitric acid and ammonium nitrate, which in Australia is primarily used to make explosives.[4,5] There is currently 2.65Mt of ammonium nitrate capacity in Australia.[6] Along with manufacturing ammonium nitrate, both Orica and Dyno Nobel also provide blasting services, sell commercial explosives, and provide blast initiating systems. Other companies in the Australian market (CSBP Limited, QNP and Yara Pilbara Nitrates) are primarily manufacturers of ammonium nitrates and do not provide blasting services.[7]

> **Ammonia accounted for roughly 5% of Australia's total gas use in 2021, making it the second-highest gas user across Australia's manufacturing sectors, behind non-ferrous metals production.**

The Haber-Bosch (HB) process to produce ammonia is an energy- and emissions-intensive process. It currently utilises fossil gas to firstly produce hydrogen via steam methane reforming (SMR), then synthesise it with nitrogen, producing on average 1.9 tonnes CO_2 per tonne output.[8] Ammonia accounted for roughly 5% of Australia's total gas use in 2021, making it the second-highest gas user

[1] Queensland Nitrates is a standalone 50/50 joint venture by Dyno Nobel Asia Pacific (a subsidiary of Incitec Pivot) and CSBP (a subsidiary of Wesfarmers Limited).
[2] Department of Climate Change, Energy, the Environment and Water (DCCEEW). Activity Table 1990-2021 - Industrial Processes (Excel). April 2023.
[3] International Fertilizer Association. Production & Trade Tables by Region. January 2023.
[4] For example, Orica's Kooragang Island facilities include an ammonia plant, three nitric acid plants, two ammonium nitrate plants and a product dispatch facility.
[5] Department of Industry, Science and Resources (DISR). Anti-dumping commission preliminary reinvestigation report for the anti-dumping review panel. 1July 2022. Appendix C, Page 88 onwards.
[6] Based on company websites. See footnotes for Figure 1.
[7] DISR. Anti-dumping commission preliminary reinvestigation report for the anti-dumping review panel. 1 July 2022. Appendix C, Page 88 onwards.
[8] Australian Government. National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015 – Schedule 2, Part 6. 7 October 2023. Part 6 – Ammonia production.

across Australia's manufacturing sectors, behind non-ferrous metals production.[9,10] Roughly three-quarters of the gas is used as the hydrogen feedstock while the remainder provides heat for the endothermic reforming reaction and to raise the necessary process steam.[11]

The use of ammonia to manufacture derivative products is another key source of emissions. Nitric acid, a raw material for many critical products such as ammonium nitrate, is manufactured through the Ostwald process, involving the high-temperature catalytic oxidation of ammonia.[12] This produces large amounts of nitrous oxide, which is a potent greenhouse gas.

The latest reported emissions for Australia's producers of ammonia and derivative products are listed in Table 1. Together, these facilities were responsible for 4.6 million tonnes of carbon dioxide equivalent (MtCO2e) in 2021. This translates to about 1% of Australia's annual emissions.

Table 1: Reported capacity and emissions from Australia's producers of ammonia and derivatives

State	Company	Location	Capacity (Mt)		2021 emissions ($MtCO_2e$)
			Ammonia	Ammonium nitrate	
WA	Yara & Orica[13]	Pilbara	0.85	0.35	1.4
WA	CSBP	Kwinana	0.26	0.80	0.6
QLD	Queensland Nitrates[14]	Moura	0.09	0.22	0.2
QLD	Orica	Yarwun	0.22	0.53	0.3
QLD	Incitec Pivot	Moranbah	0.15	0.35	0.6
QLD	Incitec Pivot	Phosphate Hill	0.20	0.00	0.5
NSW	Orica	Kooragang Island	0.36	0.4	1.1
Total operating capacity			**2.13**	**2.65**	**4.6**[15]

Source: Companies reports and websites, IEEFA calculations, Clean Energy Regulator.[16] Note: The Phosphate Hill plant produces 0.98Mt of ammonium phosphate, with production of input ammonia on-site estimated at 195,000 tonnes.[17]

[9] Yara. Ammonia and urea cash cost. 2024. Energy intensity = 36 million British thermal units of gas per tonne of ammonia (NH_3), which is approximately 38 gigajoules per tonne (GJ/t) of NH_3. DECHEMA. Technology Study: Low carbon energy and feedstock for the European chemical industry. June 2017. Page 57. Table 11 gives energy intensity of 35GJ/t NH_3. Midpoint of these two sources is 36.5GJ/t NH_3. For 2Mt of production this amounts to 70 petajoules (PJ), or 4.5% of Australia's gas use.
[10] DCCEEW. Australian Energy Update 2023: Table F. 29 September 2023. Compares 70PJ (above footnote) to gas use within sectors of ANZSIC Div. C Manufacturing.
[11] Royal Society of Chemistry. Current and future role of Haber–Bosch ammonia in a carbon-free energy landscape. 28 December 2019. Smith, C., Hill, A. K. and Torrente-Murciano, L.
[12] DCCEEW. National Inventory Report 2021: The Australian Government Submission to the United Nations Framework Convention on Climate Change. April 2023. Page 165.
[13] Yara. Yara Pilbara Nitrates. Yara Pilbara Nitrates is a joint venture between Yara (50%) and Orica (50%), where a technical ammonium nitrate (TAN) facility was constructed adjacent to Yara Pilbara's existing liquid ammonia plant on the Burrup Peninsula.
[14] Queensland Nitrates is a standalone 50/50 joint venture by Dyno Nobel Asia Pacific (a subsidiary of Incitec Pivot) and CSBP (a subsidiary of Wesfarmers Limited).
[15] There is a discrepancy between emissions reported under the Safeguard Mechanism and bottom-up calculations using 2021 government emissions data for ammonia and nitric acid production and the assumed emissions intensity of 1.87 $tCO_2e/t\ NH_3$. We were unable to find the cause of this variance.
[16] Clean Energy Regulator. Safeguard facility reported emissions 2021-22. 31 March 2023. Totals may not sum due to rounding.
[17] The Mosaic Company. Diammonium Phosphate. 2024. Assumes 0.2 tonnes of ammonia per tonne of diammonium phosphate.

Australian production is considered unlikely to decline in the foreseeable future given the expected sustained demand and the capital-intensive, long-lived nature of ammonia and ammonium nitrate plants, which according to the International Energy Agency (IEA) have a typical lifetime of 20-50 years.[18] This is reflected in the inclusion of existing facilities in company plans for the next 15-20 years, which signals a strategic reluctance towards closure in the foreseeable future. Government projections see emissions from Australia's chemical sector remain broadly flat through to 2035, underscoring the lack of attention on decarbonising existing assets for at least the next decade.[19]

The technologies to decarbonise ammonia and ammonium nitrate are commercially available

As noted earlier, there are two primary sources of emissions from the production of ammonia and its derivatives such as ammonium nitrate: the gas used to produce ammonia via the conventional SMR-HB pathway; and nitrous oxide emissions from the production of nitric acid (an input to ammonium nitrate). There are mature, commercially available technologies to eliminate these emissions sources and achieve near-zero emissions production. The key steps involved are:

- Switching ammonia production from using gas-based hydrogen to using green hydrogen.
- Electrifying compressors and implementing an air separation unit to provide nitrogen to support ammonia synthesis, and powering them with renewable electricity.
- Implementing catalyst abatement technology to break down nitrous oxide into nitrogen and oxygen.

Ammonia is already one of the largest consumers of hydrogen globally.[20] Through the HB process, nitrogen reacts with hydrogen (produced from gas via SMR) under high temperatures and pressures. This gas-based hydrogen could be switched to green hydrogen produced from renewable electricity at zero emissions.

For ammonia production, the integrated nature of the current SMR-HB process[21] introduces barriers to simply injecting a green hydrogen stream into existing plant configurations. Along with a decarbonised hydrogen feedstock, green ammonia requires a renewable energy source to run the compressors needed for ammonia synthesis, which can be achieved with electric compressors (powered by renewables) to replace condensing steam turbine compressors.[22] An electrically driven HB system (with green hydrogen feedstock) would also require an air separation unit to provide the nitrogen required for ammonia synthesis.[23] This means that producing green ammonia at existing

[18] IEA. Ammonia Technology Roadmap. October 2021. Page 56.
[19] DCCEEW. Australia's emissions projections 2023. November 2023. Page 46, Table 14; and Page 65, Table 26.
[20] IEA. Global Hydrogen Review 2023. September 2023. Page 25.
[21] In the current SMR-HB process, gas is used both as hydrogen feedstock and as energy source for the reaction, including recycling of large amounts of waste heat.
[22] Royal Society of Chemistry. Current and future role of Haber-Bosch ammonia in a carbon-free energy landscape. December 2019.
[23] Ibid. In a conventional SMR-HB plant, air is compressed and fed to the reactor to provide heat of reaction, which provides the stoichiometric nitrogen required for the downstream reaction.

facilities will present different challenges to greenfield projects, particularly given the need to maintain thermal optimisation and other balance of plant considerations.

There is limited public information on how much green hydrogen could be integrated into existing facilities without incurring significant costs. One feasibility study suggests that at least 6% and potentially up to 20% of hydrogen feedstock could be switched to green hydrogen with minimal modifications.[24] Moreover, recent research by ClimateWorks Centre for the Australian Industry Energy Transitions Initiative suggests that retrofitting for green hydrogen supply was a minor part of overall transition costs.[25] Orica's plan to displace 7% of the plant's annual gas consumption with green hydrogen notes a requirement for minor modifications, but this does not appear a major hurdle to implementation.[26] IEEFA industry consultation suggests that up to 30% of the hydrogen feedstock could be replaced in brownfield operations before major plant reconfigurations and capital investments are required.[27]

> **IEEFA industry consultation suggests that up to 30% of the hydrogen feedstock could be replaced in brownfield operations before major plant reconfigurations and capital investments are required.**

Further research is needed in this area to better understand the technical and commercial feasibility of integrating green hydrogen into existing HB facilities. However, Fortescue's repurposing of the Gibson Island ammonia plant suggests potentially favourable economics for retrofitting existing facilities rather than developing greenfield projects.[28]

While the current SMR-HB process accounts for most emissions in the ammonia supply chain, nitrous oxide emissions from the production of nitric acid will also need to be eliminated to manufacture green explosives. There are three main abatement options to address nitrous oxide emissions, classified as primary, secondary and tertiary solutions. Primary and secondary technologies are applied during ammonia oxidation, with abatement potential of 40% and 95% respectively. Tertiary technologies reduce nitrous oxide from the tail gas by installing a catalytic or thermal reactor downstream of the absorption stage, typically reducing emissions by over 95%.[29] These technologies can be deployed relatively easily and at low cost depending on plant characteristics, with more than two-thirds of global abatement potential achievable below USD20 per tonne of carbon dioxide equivalent (tCO_2e) and around 80% available at less than USD50/tCO_2e.[30]

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[24] Engie and Yara. ENGIE-YARA Renewable Hydrogen and Ammonia Deployment in Pilbara. October 2020. Page 33.
[25] Australian Industry Energy Transitions Initiative. Pathways to industrial decarbonisation: Positioning Australian industry to prosper in a net zero global economy. February 2023. Page 114.
[26] Orica. Hunter Valley Hydrogen Hub.
[27] Conversation with industry expert Brian Innes, Director at Partners in Performance.
[28] Fortescue. Gibson Island Green Hydrogen and Ammonia Project.
[29] Nitric Acid Climate Action Group. Nitrous oxide emissions from nitric acid production.
[30] United States Environmental Protection Agency. Global Mitigation of Non-CO_2 Greenhouse Gases: Nitric and Adipic Acid Production.

Australia's nitric acid industry has historically been slow to deploy nitrous oxide abatement, though significant progress has been made in recent years. Australia's nitric acid production was responsible for an estimated 1.4MtCO_2e per year in 2021. However, Orica has recently installed tertiary abatement technology to eliminate 0.57MtCO_2e per year, while Incitec Pivot has similar plans to remove 0.2MtCO_2e in 2024. [31,32] Once implemented, these two initiatives will have eliminated roughly half of Australia's nitrous oxide emissions. This will reduce emissions from the ammonia supply chain to at least 3.8MtCO_2e (all else being equal).[33] Overall abatement potential in Australia has been estimated at 80%-90%, with roughly 20% considered easy to achieve in as-yet-unabated plants.[34]

There has, however, been limited progress in implementing a shift to green hydrogen, which is discussed later in this report.

Decarbonising ammonia production can kickstart Australia's green hydrogen industry

Hydrogen has attracted considerable attention in recent years as a potential decarbonisation option in 'harder-to-abate' parts of the economy such as heavy industry and transport. Future demand estimates vary widely, but there is broad consensus that it will play a key role in driving global emissions towards net zero. Across scenarios recently assessed by the Intergovernmental Panel on Climate Change (IPCC), hydrogen makes up as much as 6% of final energy use in 2050, while other modelling efforts by the IEA and the International Renewable Energy Agency (IRENA) see higher shares of 10%-12% by mid-century.[35] In Australia, recent modelling by ClimateWorks Centre estimates that a 'well-below 2°C' transition could see hydrogen account for 10%-14% of total energy demand by 2050.[36]

Green hydrogen, produced through electrolysis powered by renewable electricity, is considered a key economic opportunity to transform Australia into a "renewable energy super power".[37,38] In IEEFA's opinion, alternative decarbonisation routes for hydrogen involving carbon capture, utilisation and storage (CCUS) are not viable.[39]

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[31] Orica. Orica set to eliminate nearly 50 per cent of total greenhouse gas emissions from Hunter site. 13 July 2023.
[32] Incitec Pivot. Incitec Pivot Limited releases 2022 Climate Change Report. 30 November 2022.
[33] This is produced by subtracting expected nitrous oxide abatement from 2021 emissions reported under the Safeguard Mechanism. As noted above, there is a discrepancy between this figure and bottom-up calculations using 2021 government data for nitric acid emissions, ammonia production and ammonia emissions intensity. Using available data, we consider 3.8MtCO_2e to be the minimum emissions associated with ammonia and its value chain, but bottom-up calculations suggest it could be closer to 4.5MtCO_2e. Further transparency is needed on ammonia emissions separately from nitric acid emissions.
[34] Öko-Institut. Mitigation potentials for emissions of nitrous oxide from chemical industry in industrialised countries world-wide. March 2023. Jörß et al.
[35] Joule. On the cost competitiveness of blue and green hydrogen. 17 January 2024. Ueckerdt et al.
[36] ClimateWorks Centre. ClimateWorks Centre decarbonisation scenarios 2023: Australia can still meet the Paris Agreement. November 2023. Page 16.
[37] DCCEEW. Growing Australia's hydrogen industry. November 2023.
[38] CSIRO. Hydrogen projects map. 2023.
[39] IEEFA. Blue hydrogen: Not clean, not low carbon, not a solution. 12 September 2023.

Despite the maturity of the technologies involved, green hydrogen remains economically less competitive than the conventional SMR method.[40] The large scope for cost reductions in green hydrogen production with the scale-up of the industry could make it cost-competitive with the SMR pathway in the coming decades.[41] However, this is contingent on significant capital investment and the ability to secure substantial, robust demand.[42] This is difficult given the current cost disparity, producing a vicious cycle that hinders the rapid development of green hydrogen supply chains.

Australia boasts a considerable pipeline of announced hydrogen projects, totalling AUD127 billion in investment, including more than 15 projects that have passed Final Investment Decision.[43] However, there are concerns that inadequate government support and a lack of concrete offtake agreements could weaken investor confidence, delaying or threatening many large projects.[44]

Despite the enthusiasm surrounding green hydrogen as a decarbonisation solution across numerous sectors, many proposed applications are technologically immature and face competition, particularly from electrification.[45] Ammonia stands out in this context as a unique case. The potential to partially or entirely replace current gas-based hydrogen means that ammonia production offers a ready-made demand source for green hydrogen with far lower technological risk relative to other sectors. Moreover, there are limited alternatives for decarbonising the two primary end products of ammonia – fertilisers and explosives. Switching all of Australia's current ammonia production away from gas would create demand for around 350,000 tonnes per year of green hydrogen.[46]

> **Switching all of Australia's current ammonia production away from gas would create demand for around 350,000 tonnes per year of green hydrogen.**

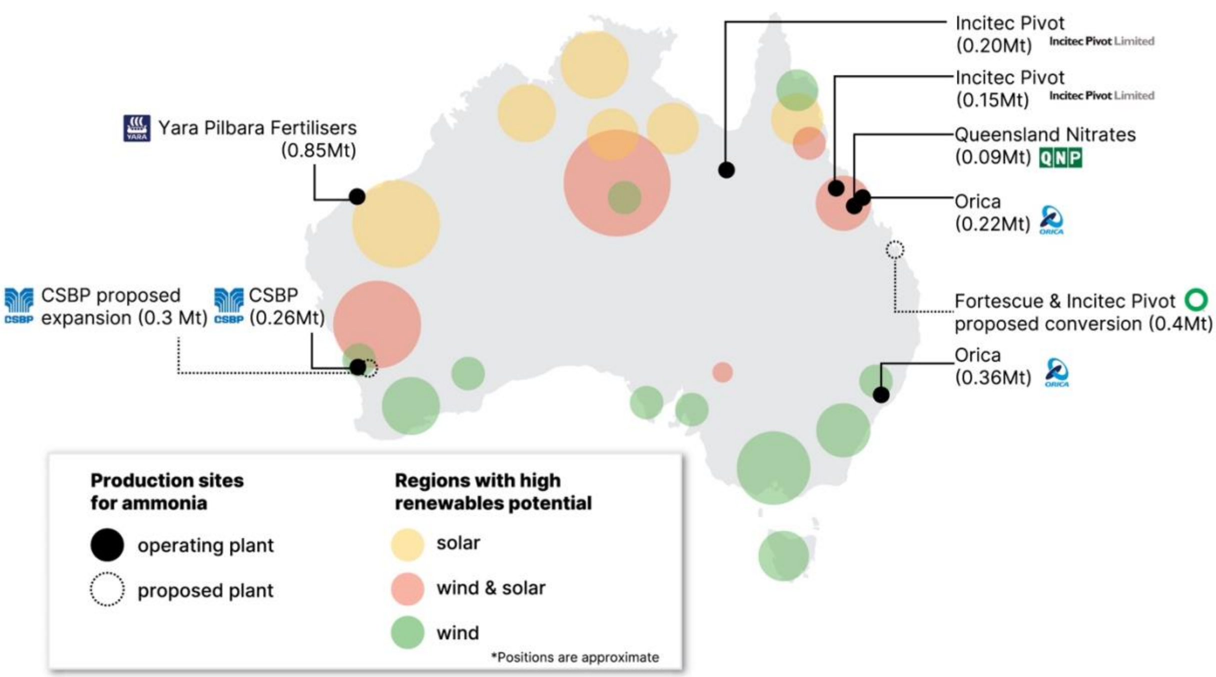
Green ammonia is also touted as a potential decarbonisation solution to displace fossil fuel use in other sectors such as shipping, though the outlook for this demand source is less clear.[47]

Further strengthening the case for ammonia as a key demand source for green hydrogen is the fact that Australia's ammonia plants are located in favourable areas for producing low-cost renewable electricity to power hydrogen electrolysers.[48] These high-potential areas have been identified based on geospatial factors such as availability of local energy resources, access to key infrastructure and

[40] IEA. ETP Clean Energy Technology Guide. 14 September 2023.
[41] Energy Transitions Commission. Making the Hydrogen Economy Possible: Accelerating Clean Hydrogen in an Electrified Economy. April 2021. Page 28.
[42] IEA. Global Hydrogen Review 2023 – Executive summary. September 2023.
[43] DCCEEW. Growing Australia's hydrogen industry. November 2023.
[44] Hydrogen Insight. BNEF: 'Expect delays to Australia's green hydrogen projects – investors don't yet have confidence in H2 import demand'. 25 May 2023.
[45] Liebrich, M. Hydrogen Ladder Version 5.0. October 2023.
[46] WRI India. Emission Reduction Potential of Green Hydrogen in Ammonia Synthesis for Fertilizer Industry. 4 October 2022. Assumes 0.178 tonnes of hydrogen (H_2) per tonne NH_3. It is unclear whether this ratio includes efficiency losses, which could increase the amount of H_2 needed per tonne NH_3 to 0.223 (assuming 80% efficiency).
[47] European Maritime Safety Agency. Potential of ammonia as fuel in shipping. 26 September 2023. Page 39.
[48] Energy Conversion and Management. Optimising renewable generation configurations of off-grid green ammonia production systems considering Haber-Bosch flexibility. 15 March 2023. Figure 2. Changlong et al.

water supplies, and the distance to export ports and energy markets.[49] Part of Australia's National Hydrogen Strategy includes the development of regional hydrogen hubs to cluster large-scale demand, with these regions covering existing ammonia production facilities in the Pilbara and Kwinana in Western Australia (WA); the Hunter Valley in New South Wales (NSW); and Gladstone in Queensland (QLD).[50,51,52]

Figure 1: Comparison of regions with high renewables potential with locations of current ammonia plants



Sources: Yara, CSBP, Orica.[53,54,55,56,57] Note: figures refer to ammonia production capacity, which are based on company websites or IEEFA estimates where information was not available.

Decarbonising existing ammonia facilities therefore presents a win-win-win, by easing pressure on the domestic gas market, reducing emissions, and accelerating development of Australia's hydrogen industry – which has been identified as an economic priority.

[49] International Journal of Hydrogen Energy. Evaluating the economic fairways for hydrogen production in Australia. 22 October 2021. Walsh et al.
[50] Commonwealth of Australia. Australia's National Hydrogen Strategy. 2019. Pages 34-38.
[51] DCCEEW. Building regional hydrogen hubs. October 2023.
[52] Hydrogen Insight. Pilbara hydrogen hub to receive $92m in state funding as Australia signs off on $320m programme. 19 February 2024.
[53] Yara. Yara Pilbara Nitrates 2022 Compliance Assessment Report Ministerial Statement 870 Technical Ammonium Nitrate Production Facility. 7 October 2022. Page 5.
[54] Yara. Yara Pilbara Fertilisers. Accessed February 2024.
[55] CSBP. Ammonium Nitrate. Accessed February 2024.
[56] Orica. Information for the local community. Page 2.
[57] Orica. Operations. Accessed February 2024.

Progress in decarbonising Australia's ammonia production has been limited

Most green ammonia projects focus on exports, rather than replacing gas in existing plants

Overall Australian ammonia production could increase dramatically as the domestic green hydrogen industry develops. CSIRO maintains a database of active hydrogen projects in Australia, with more than 100 proposals totalling nearly 7.3Mt of green hydrogen across the project lifecycle from feasibility studies through to construction.[58] However, 95% of this proposed production focuses on exports rather than domestic use (see Appendix A).

One export-focused green ammonia project plans to use the recently closed Gibson Island ammonia facility, which Fortescue and Incitec Pivot are collaborating on converting to produce up to 400,000 tonnes of ammonia annually for export. This includes the development of green hydrogen produced via electrolysis, which will be fed to Incitec Pivot's upgraded ammonia plant, located adjacent to Fortescue's site, to produce green ammonia.[59] If completed, this would provide a leading example of the large-scale conversion of existing gas-based capacity to green hydrogen. A Final Investment Decision was expected in 2023, but at time of writing had been pushed out to the end of February 2024.[60]

A handful of projects explicitly mention plans to use produced hydrogen or ammonia to decarbonise facilities currently operating in Gladstone, the Hunter Valley and the Pilbara, though it can be difficult to ascertain the quantity of production that is earmarked for export versus domestic use. Where domestic uses are mentioned, information is usually scarce regarding the quantities available for use in ammonia production.

> **Phase one of the Kooragang Island project will use more than 4,000 tonnes of renewable hydrogen at the plant annually and displace 7% of the plant's annual gas consumption.**

Orica provides the most detail with plans to develop the Hunter Valley Hydrogen Hub and pipe renewable hydrogen directly into its existing Kooragang Island operations.[61] Phase one of the Kooragang Island project will use more than 4,000 tonnes of renewable hydrogen at the plant annually and displace 7% of the plant's annual gas consumption. This will provide a critical demonstration of the feasibility of integrating large-scale hydrogen production. The project

[58] CSIRO. HyResource: Projects spreadsheet. January 2024.
[59] Fortescue. Gibson Island Green Hydrogen and Ammonia Project.
[60] The West Australian. Fortescue pushes out FID on Gibson Island project as deadline looms on green energy ambitions. 22 December 2023.
[61] Orica. Hunter Valley Hydrogen Hub. 2024.

incorporates an intention to be scaled up in subsequent phases, but no information is available yet on expected timings and volumes, except for Orica's goal to achieve net zero emissions by 2050.

Yara Fertilisers' project in the Pilbara will produce up to 625 tonnes of renewable hydrogen and 3,700 tonnes of green ammonia per year, which would only provide about 0.4% of the plant's targeted feedstock needs if it was fully utilised.[62] This suggests that projects dedicated to supplying existing ammonia plants would only displace a small share of the gas-based hydrogen used by the production processes.

A gas-based ammonia expansion is planned in Western Australia

In contrast to the bevy of emerging greenfield projects targeting green hydrogen, a major fossil-fuelled expansion of CSBP's ammonia plant in Kwinana has recently been recommended for approval by the Environmental Protection Authority (EPA).[63] The proposed expansion would use fossil gas to produce roughly 300,000 tonnes of ammonia per year to enable debottlenecking of CSBP's chemical facilities and meet an expected increase in long-term offtake from customers. This is equivalent to around 15% of Australia's existing capacity, with annual emissions of 539,000tCO_2e. A Final Investment Decision on the proposed expansion is expected in the second half of 2024, with plans to be operational in 2027-28.

In the proposal's Greenhouse Gas Management Plan, the company states an undefined aim of switching to a green hydrogen feedstock "when it becomes commercially viable", and plans to produce 3.5% of the ammonia with a 10-megawatt electrolyser.[64] Beyond this, there are few major emissions mitigation commitments, with the proposed emissions intensity just 8% lower than existing plants. Moreover, CSBP's limited interim emissions targets (e.g. a 40% reduction by 2040) and its focus on CCUS options does not indicate a meaningful shift to green hydrogen in the short-to-medium term. Assuming the company meets the interim targets as described in the project's Greenhouse Gas Management Plan, this project represents emissions of at least 6.5MtCO_2e through to 2050.

In addition, IEEFA's research has shown that relying on CCUS technologies presents many risks. Our team globally has undertaken significant research on the performance of large CCUS projects worldwide and found that failed/underperforming projects considerably outnumbered successful experiences.[65] A recent IEEFA analysis of Norway's Sleipner and Snøhvit projects, two of the most successful CCUS projects globally, demonstrated that CCUS is not an exact science, and that each project will present unique challenges.[66]

[62] Yara. Yara Pilbara to host renewable hydrogen and ammonia production facility. May 2021. The facility's total ammonia capacity is 850,000 tonnes.
[63] EPA. Ammonia Expansion Project. November 2023.
[64] CSBP. CSBP Ammonia Expansion Project Greenhouse Gas Management Plan. 11 November 2022. Page 17.
[65] IEEFA. The carbon capture crux: Lessons learned. 1 September 2022.
[66] IEEFA. Norway's Sleipner and Snøhvit CCS: Industry models or cautionary tales? 14 June 2023.

Instead of the CSBP plant expansion going ahead using gas as planned, the project provides an opportunity to demonstrate the large-scale integration of renewables and green hydrogen into the domestic ammonia supply chain. Implementing electrolytic technology rather than SMR would create demand for about 53,000 tonnes of green hydrogen to use for ammonia production.[67] This represents 18% of the green hydrogen production currently proposed across Australia for domestic use, and more than twice the planned capacity in Western Australia.[68]

Implementing green ammonia technologies from the start would also avoid locking in fossil fuel technologies and infrastructure – significant capital expenditure that investors will expect to recoup before switching to alternative processes. Moreover, with Australia's national emissions budget fixed in law, any emissions from new facilities mean other parts of the economy must emit less.[69,70] Under current plans, this means that more than 6.5MtCO_2e of emissions reduction would be needed in other sectors just to offset the impact of this expansion.

Ammonia producers have limited incentives to decarbonise their processes

Australia's major explosives manufacturers have all committed to near-term emissions reduction targets ranging from 30%-45% by 2030, while Orica, WESCEF (parent company of CSBP) and Incitec Pivot have also announced an ambition of net zero emissions by 2050 (Table 2). Green hydrogen is included as a key future technology alongside other options such as CCUS. However, there is no firm commitment or timeline on phasing out fossil fuels entirely, with the near-term focus instead on operational efficiencies and deployment of mature abatement technologies.

Table 2: Emissions reduction commitments of Australia's major chemical producers

Companies	Scope 1 and 2
Orica	• 45% reduction by 2030 vs 2019 baseline
WESCEF	• 30% reduction by 2030 vs 2020 baseline • Net zero by 2050
Yara	• 30% reduction by 2030 vs 2019 baseline • No net zero target
Incitec Pivot	• 42% reduction by 2030 • Net zero by 2050

Sources: Orica, WESCEF, Yara, Incitec Pivot.[71,72,73,74]

[67] WRI India. Emission Reduction Potential of Green Hydrogen in Ammonia Synthesis for Fertilizer Industry. 4 October 2022. Assumes 0.178 tonnes of hydrogen (H_2) per tonne NH_3. It is unclear whether this ratio includes efficiency losses, which could increase the amount of H_2 needed per tonne NH_3 to 0.223 (assuming 80% efficiency).
[68] CSIRO. HyResource: Projects spreadsheet. January 2024. Note: these figures exclude proposed hydrogen/ammonia export projects. Total green hydrogen capacity in operation or underway (i.e. either under construction or development) throughout Australia that is not earmarked for export = 299,000 tonnes, 22,000 of which are in Western Australia.
[69] The Parliament of the Commonwealth of Australia. Climate Change Bill 2022. September 2022. Page 5.
[70] Grattan Institute. Safeguard reforms: managing the risks. 2023. Page 6.
[71] Orica. FY2023 Climate Action Report. November 2023. Page 4.
[72] WESCEF. Wesfarmers Chemical, Energy and Fertilisers' Decarbonisation Journey. April 2022. Page 2.
[73] Yara. Climate Action: Yara's road to 2030 and beyond. 24 March 2023.
[74] Incitec Pivot. Climate Change Report 2023. November 2023. Page 7.

The Safeguard Mechanism (SGM) – the Australian Government's main policy for decarbonising Australia's largest industrial facilities – covers all of Australia's current ammonia plants, legislating a 4.9% emissions reduction of facility baselines each year through to 2030.[75] These declining baselines are production-adjusted (i.e. emissions intensity rather than absolute values) and currently site specific, although they will gradually converge to an industry average value by 2030.[76] At the start of the latest SGM reforms (FY2023), the default emissions intensity for ammonia production was set at 1.9tCO_2e per tonne of ammonia.[77] This means that by the end of FY2030, emissions from current ammonia facilities must decline to around 1.2tCO_2e per tonne of ammonia produced. If achieved by a switch to green hydrogen, this would replace about 38% of existing facilities' current gas use.

Facilities failing to comply with their emissions baselines face a penalty of AUD275/tCO_2e, which should incentivise the deployment of all but the most expensive abatement technologies. However, the SGM currently places no limits on the use of carbon credits to offset facility emissions, with a cost containment measure fixing prices at AUD75/tCO_2e (increasing with CPI plus 2% each year).[78]

Our analysis suggests that buying offsets, even at the capped price, will be materially cheaper than switching from gas to green hydrogen in 2025 and 2030 (see Appendix B). This could compromise the mitigation hierarchy by allowing companies to delay genuine efforts to avoid and reduce emissions, while still meeting regulatory requirements by purchasing offsets.[79] Given the significant capital investment and associated risks of establishing a green hydrogen and ammonia supply chain, there is a clear need for stronger incentives to drive investment on both the supply and demand side of the industry.

Australian miners can play a critical role in decarbonising the ammonia value chain

Half of Australia's ammonia is used to produce explosives and could be decarbonised first

Roughly 0.43 tonnes of ammonia are needed per tonne of ammonium nitrate, which suggests that 1.1Mt of ammonia are required to support the manufacture of Australia's 2.65Mt of ammonium nitrate.[80] Given that Australia's ammonium nitrate is almost entirely (more than 95%) used to

[75] DCCEEW. Safeguard Mechanism. December 2023.
[76] DCCEEW. Safeguard Mechanism Reforms. May 2023. Page 2.
[77] Australian Government. National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015 – Schedule 2, Part 6. October 2023. Part 6 – Ammonia production.
[78] DCCEEW. Safeguard Mechanism Reforms. May 2023. Pages 5.
[79] Terrascope. Mitigation Hierarchy: The Key to a Viable Decarbonisation Strategy. 29 March 2023.
[80] Mission Possible Partnership. Making Net-zero 1.5°C-aligned possible: Technical appendix. 2022. Page 14, Exhibit 12. Validated by calculating ammonia supply at Queensland Nitrate's plant (estimated at 100,000 tonnes) compared to ammonium nitrate capacity of 220,000.

manufacture explosives, this means that explosives are responsible for just over half of Australia's ammonia production.[81,82]

Explosives are used in both open-cut (or open-pit) and underground mining, with specific methods and quantities varying based on the mining operation and the nature of the ore deposit. Open-cut mining generally involves larger-scale blasts for removing overburden (the non-valuable material that must be removed to access and extract the underlying ore or mineral resources). Australia's two largest export commodities – iron ore and coal – are primarily produced in open-cut mines, and will therefore heavily influence future ammonia demand in Australia.[83,84]

Explosives present a good opportunity to drive the first wave of ammonia decarbonisation projects, given that their cost has a more limited impact on the cost of living than the cost of fertilisers as they are further removed from consumer products. The cost implications of decarbonising explosives are discussed in more detail in later sections of this report. Moreover, Australia's explosives supply chain is more centralised than fertilisers, which allows for greater influence on suppliers and efficient demand pooling.

The abatement solutions discussed in this report could help achieve near zero emissions explosives. For the purposes of this report, explosives are considered "green" if they are produced using the abatement technologies described in the first section, or alternative technologies with a similar emissions intensity, and residual emissions offset. This amounts to near-zero emissions (>95% abatement) from ammonia production, and >80% abatement of nitrous oxide emissions. This reflects the difficulty in achieving absolute zero emissions with currently available technologies.

Miners currently have no incentive to adopt green explosives

In line with international convention, Australian mining companies include all upstream emissions associated with explosives manufacturing as part of Scope 3 emissions, specifically falling under *Category 1: Purchased Goods and Services*.[85,86] The production of explosives introduces various emissions sources, including those from ammonia and nitric acid production, and from the consumption of fuel oil to produce Ammonium Nitrate Fuel Oil (ANFO), a widely used explosive.[87] Notably, only emissions stemming from the eventual use of ANFO, such as the oxidation of fuel oil

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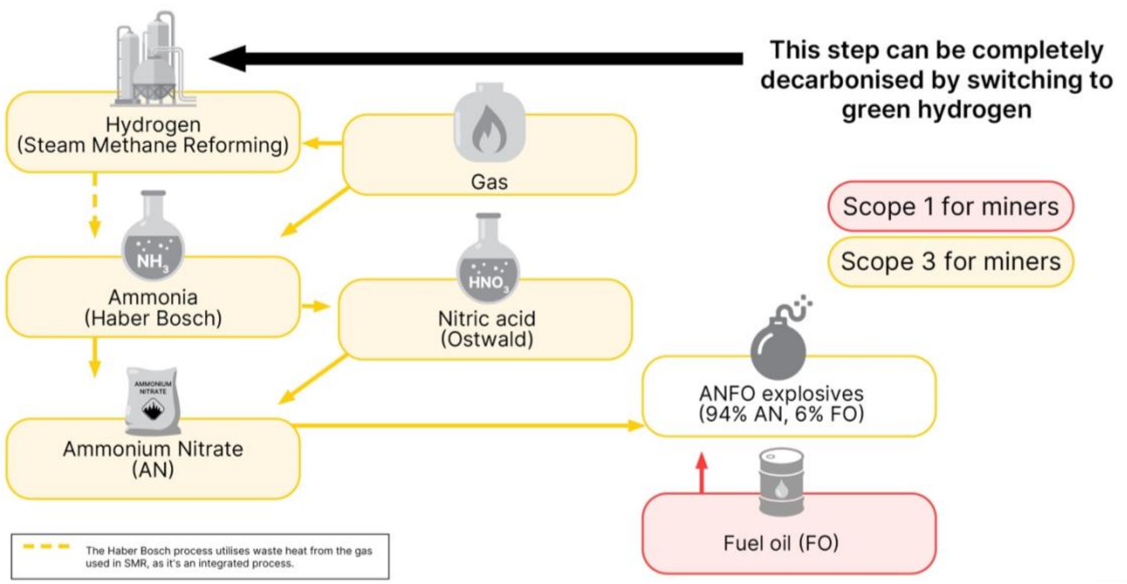
[81] SafeWork SA. Ammonium nitrate licences.
[82] DISER. Australian industry verification report. June 2022. Unlike other countries where ammonium nitrate is widely used for fertiliser production, this is limited in Australia due to its classification as a dangerous good.
[83] Geoscience Australia. Australian mineral facts: Iron. September 2023.
[84] International Trade Administration. Australia - Country Commercial Guide: Mining. July 2022.
[85] Greenhouse Gas Protocol. Technical Guidance for Calculating Scope 3 Emissions (version 1.0). 2013.
[86] Greenhouse Gas Protocol. Category 1: Purchased Goods and Services. This category includes all upstream (i.e. cradle-to-gate) emissions from the production of products purchased or acquired by the reporting company in the reporting year. Products include both goods (tangible products) and services (intangible products).
[87] Materials. Improving ANFO: Effect of Additives and Ammonium Nitrate Morphology on Detonation Parameters. 1 October 2021. Table 1. Fabin, M and Jarosz, T.

upon detonation, are accounted for in a miner's Scope 1 emissions, but these are not material enough to warrant explicit disclosure in most company climate reporting.[88]

Figure 2: Simplified material flows and emissions sources from ammonia to explosives production



Source: IEEFA

Lack of data transparency hinders precise quantification of emissions from explosives. Among Australia's major mining companies – such as BHP, Rio Tinto and Fortescue – Scope 3 emissions constitute 95%-99% of the overall emissions inventory, with the majority originating from the downstream use and processing of sold products such as the burning of coal or the production of iron and steel. Between 1% and 3% of these Scope 3 emissions are associated with *Category 1: Purchased Goods and Services*, of which explosives production constitutes a fraction that is rarely disaggregated from other purchased goods and services. Although *Category 1* emissions may not be particularly material relative to other Scope 3 emissions, they are comparable with operational emissions (Scope 1 and 2) of Australia's mining companies. The lack of detail on Scope 3 emissions arising from explosives manufacture means miners have little incentive to reduce those emissions.[89]

There are also few policy or regulatory mechanisms to drive ambitious action by miners on decarbonising explosives. The SGM exclusively addresses Scope 1 emissions, placing Australian mining companies under no regulatory obligation to reduce Scope 3 emissions, including those from

[88] Newcrest Mining Limited. 2023 Sustainability Report. September 2023. Page 47. Of the mining companies assessed (see Table 2), only Newcrest Mining Limited specifically reported energy use and emissions associated with explosives, which were just 0.1% of Scope 1 emissions.
[89] Greenhouse Gas Protocol. Category 1: Purchased Goods and Services.

the production of purchased explosives.[90] Companies are often reluctant to set Scope 3 targets due to a perceived inability to directly influence the action of suppliers or customers.

However, this is arguably less defensible in the case of explosives products given their niche application, the direct relationship between supplier and purchaser, and the considerable buying power of miners. As evidenced in Table 3: Scope 3 emissions reduction commitments from large Australian miners, there is a notable lack of concrete commitments by Australia's major explosives customers regarding Scope 3 emissions. BHP is an exception, explicitly referencing direct suppliers' operational emissions, though this is contingent on the widespread availability of carbon-neutral solutions to meet company requirements.

Table 3: Scope 3 emissions reduction commitments from large Australian miners

Companies	Scope 3
BHP	• Net zero by 2050 for operational emissions of direct suppliers (e.g. explosives)
Rio Tinto	• Some targets but none relating to explosives
Fortescue	• Some targets but none relating to explosives
Newcrest Mining	• No specified targets

Sources: BHP, Rio Tinto, Fortescue, Newcrest Mining.[91,92,93,94]

With current technologies, producing green hydrogen and its derivatives such as ammonia is more expensive than conventional methods such as SMR. With no incentive to pay a premium for green hydrogen-based explosives, those costs would have to be borne by producers.

In essence, both producers and buyers of mining explosives currently face no substantial pressure to eliminate emissions in the near future. This situation is worsened by the low availability and quality of data, a recognised barrier that impedes the analysis of material flows within chemicals value chains, limiting the capacity of investors and other stakeholders to hold companies accountable.[95]

[90] DCCEEW. Safeguard Mechanism. December 2023.
[91] BHP. Scopes 1, 2 and 3 GHG emissions calculation methodology. 2023. Pages 6-11 for emissions inventories; page 11 for Scope 3 targets.
[92] Rio Tinto. Climate Change Report 2022. February 2023. Page 7 for Scope 3 goals; page 37 for emissions inventory.
[93] Fortescue. FY23 Climate Change Report. August 2023. Page 14 for emissions inventory; page 19 for targets.
[94] Newcrest Mining Limited. 2023 Sustainability Report. September 2023. Pages 47-48 for emissions inventories.
[95] Science Based Targets Initiative. Barriers, Challenges, and Opportunities for Chemical Companies to Set Science-Based Targets. December 2020. Page 18.

Shifting to green explosives would be affordable for miners

The costs of producing green ammonia are expected to decline considerably

The economic viability of green hydrogen – and by extension, green ammonia – is influenced by many factors that will vary by geography and over time. This makes it challenging to draw generalised conclusions on how costs of different technologies currently compare or will shift in the future. Nevertheless, there are compelling grounds for optimism regarding the future of green hydrogen, primarily driven by anticipated reductions in key cost components as the industry scales – namely, renewable energy generation, storage, and electrolyser equipment. Conversely, hydrogen produced through SMR has limited scope for efficiency gains and may be susceptible to downside risks such as gas price volatility, as well as potential penalties or restrictions on emissions.

Table 4: Key factors influencing relative economics of different hydrogen production routes

Steam Methane Reforming	Electrolysis
Capital expenditure • SMR infrastructure • CCUS (for blue hydrogen) **Operational expenditure** • Gas price (input to SMR) • Emissions penalty (e.g. carbon price)	**Capital expenditure** • Renewable generation and storage (for off-grid source) • Hydrogen electrolysers **Operational expenses** • Electricity (for on-grid source) **Other variables** • Capacity factor (renewables, electrolyser) • Electrolyser efficiency

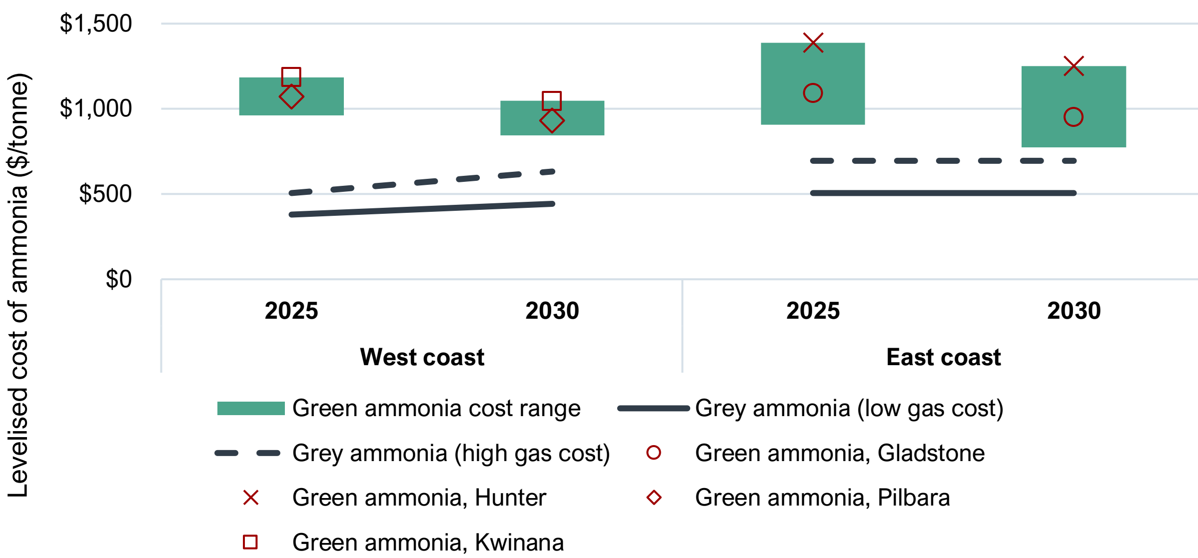
Note: Green text indicates cost driver that is expected to improve (reduce) over time. Red text indicates cost driver that could reasonably be expected to worsen (increase) in a low carbon transition.

Cost estimates for producing green ammonia vary significantly by region and depending on technology and energy cost assumptions. As a relatively immature production method, green ammonia currently attracts a large cost premium compared with "grey" ammonia (made via a conventional, gas-based SMR pathway).[96] However, recent analysis in the Australian context

[96] Sustainability. Ammonia Production from Clean Hydrogen and the Implications for Global Natural Gas Demand. 13 January 2023. Page 10. Saygin et al.

suggests that by 2030, the costs of producing green ammonia in favourable regions could decrease considerably relative to conventional routes, which have limited opportunities for cost reductions.[97,98]

Figure 3: Levelised costs of producing green ammonia in different regions compared with grey ammonia



Source: IEEFA analysis using levelised costs of inflexible green ammonia production from Changlong et al.[99] With the exception of Incitec Pivot's Moranbah Plant, all facilities are covered by one of the 21 potential hydrogen hubs identified in this paper. It is assumed that green ammonia could be produced at Moranbah at a similar cost to the Gladstone hub, given similar renewable energy capacity factors in the Renewable Energy Zones covering these regions (Fitzroy and Isaac).[100]

These costs exclude any additional costs associated with grey ammonia production due to the SGM. For a portion of the hydrogen (up to 38% by 2030 as per the previous section), using gas-based hydrogen would require the purchase of Australian Carbon Credit Units (ACCU) to meet the declining emissions baselines. Appendix C shows how this would likely make the financial case for switching to green hydrogen slightly more attractive, especially by 2030.

The above results represent the cost of a greenfield ammonia project. Further research is needed to better understand the financial case for brownfield versus greenfield decarbonisation, as it may be preferable to modify existing ammonia plants to run on green hydrogen. Recent analysis shows that

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[97] Energy Conversion and Management. Optimising renewable generation configurations of off-grid green ammonia production systems considering Haber-Bosch flexibility. 15 March 2023. Figure 9. Changlong et al.
[98] In addition to regional renewable energy generation potential, other key factors include capital costs of electrolysers, renewable energy generation and battery storage, flexibility of HB technologies, underlying gas price, and the existence/extent of a carbon price or other mechanism.
[99] Energy Conversion and Management. Optimising renewable generation configurations of off-grid green ammonia production systems considering Haber-Bosch flexibility. 15 March 2023. Figure 2. Changlong et al.
[100] Australian Energy Market Operator. 2022 ISP inputs, assumptions and scenarios: 2022 Forecasting Assumptions Workbook. March 2023. Capacity Factors tab.

hydrogen production costs represent most of the investment required to decarbonise the Australian ammonia value chain, which suggests that the results may be similar for modifying existing plants.[101]

Switching to green explosives would increase mining costs by less than 0.4%

The detailed analysis in subsequent sections of this report focuses on the cost of switching to green ammonia production and does not include costs associated with nitrous oxide abatement. Deployment of secondary or tertiary nitrous oxide abatement technologies are considered likely to be deployed due to policies such as the SGM, as reflected in recent company investments, given that a large share of potential abatement is low-cost even relative to purchasing ACCUs.

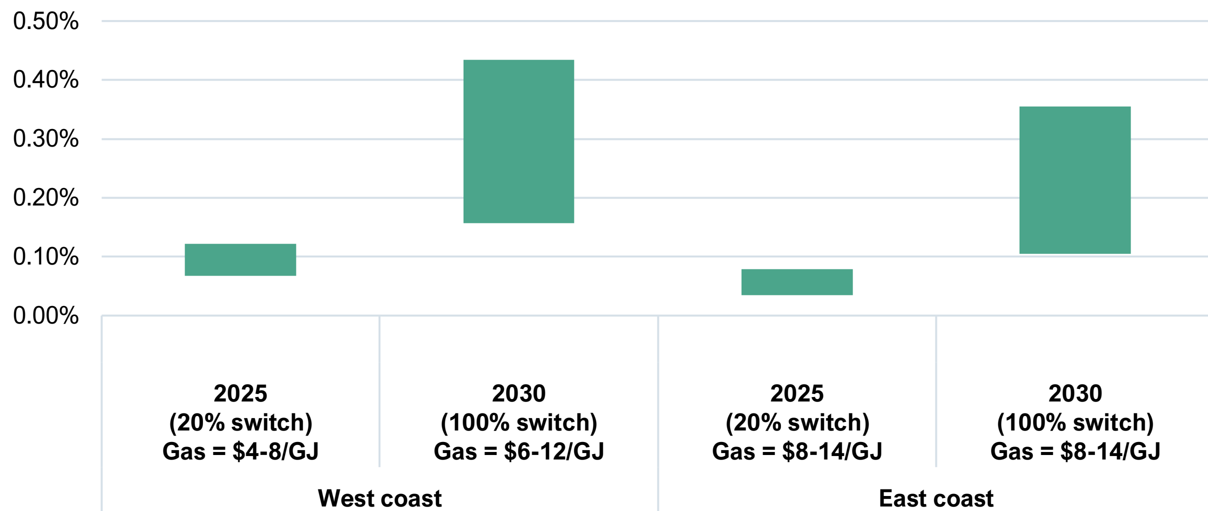
If the potential cost reductions discussed above were to eventuate, IEEFA analysis suggests that a switch to green ammonia-based explosives would be manageable for miners, even if increased production costs (relative to conventional gas-based production) were passed on in full. The cost premium for green ammonia is considerably higher in 2025 than 2030. This could make a complete switch to green ammonia prohibitively expensive in the least favourable conditions (i.e. low gas prices, relatively high production costs for green ammonia). To manage this cost impact, the analysis assumes gradual phasing in of green hydrogen into existing ammonia assets, with a 20% integration in 2025. This only considers the cost of producing hydrogen and does not include any other retrofit costs.

The results suggest that incremental blending could limit operational cost increases to less than 0.1% in 2025 (Figure 4). This implies that even at today's costs, Australia's existing facilities should be able to convert at least 20% of their production to green ammonia, with minimal downstream impact on supply chain costs.

With expected improvements in the relative economics of green ammonia production, a complete switch to 100% green ammonia for explosives production by 2030 would increase mining operating costs by up to 0.4%. This would mean a reduction of up to 0.7% in profit margins.[102] However, this impact could be much lower in particularly favourable regions or if future gas prices increase.

[101] Australian Industry Energy Transitions Initiative. Pathways to industrial decarbonisation. February 2023. Page 114.
[102] Australian Bureau of Statistics. Australian industry by subdivision. May 2023. Based on average of EBITDA over 2019-22 for mining activities.

Figure 4: Increase in mine site operational costs from a given switch to green ammonia input for producing ANFO explosives



Source: IEEFA analysis using levelised costs from Changlong et al, and estimated value chain impact using ABS data.[103,104]

These results are based on several assumptions:

- By 2025, we assume that 20% of ammonia used for explosives is switched from gas-based to green hydrogen-based. The cost implications of integrating green hydrogen into existing plant are calculated using a weighted average of current ammonia production by location.
- By 2030, we assume that 100% of the ammonia used to produce explosives in Australia is based on green hydrogen. This includes an assumption that the proposed CSBP plant expansion is online and fully based on green hydrogen (instead of the current plans to use gas as an input). We have assumed that the percentage of green hydrogen increases progressively, and so the total cost of hydrogen produced by 2030 is a weighted average of the cost of production between 2025 and 2030.
- Analysis uses the levelised cost of producing green ammonia and excludes costs of hydrogen storage or transportation. As such, there is an implicit assumption that green hydrogen is produced on-site or in close proximity and used when delivered. There may be logistical challenges (e.g. land availability, lack of infrastructure) to developing the necessary scale of renewable electricity production and hydrogen electrolysis at brownfield sites; however, potential cost implications were not quantified in this analysis.
- Gas prices (used to compute a cost of producing ammonia from gas-based hydrogen) tested in the analysis range from AUD4-AUD16 per gigajoule (GJ) and vary by time period and

[103] Energy Conversion and Management. Optimising renewable generation configurations of off-grid green ammonia production systems considering Haber-Bosch flexibility. 15 March 2023. Figure 2. Changlong et al.
[104] Australian Bureau of Statistics. Australian industry by subdivision. May 2023.

between the west and east coasts of Australia.[105,106] This is a very wide range that reflects market volatility and uncertainty in the gas price paid by ammonia producers, which would vary by location, exposure to domestic spot market prices, and the prevailing market price at the time gas supply agreements (GSAs) were executed.[107] By assessing publicly available information on ammonia producers' GSAs and market prices, IEEFA analysis estimates that a reasonable range is AUD8-AUD14/GJ for east coast producers, and AUD4-AUD8/GJ in the near term for west coast producers, potentially rising to AUD6-AUD12/GJ by 2030 given predicted shortfalls in gas supply.[108] The analysis in Figure 4 is highly sensitive to these assumptions, with a best-case scenario (i.e. low costs of producing green ammonia coupled with high gas prices) almost eliminating the cost premium of green ammonia and resulting in a negligible impact on mine site costs.

- Computed levelised costs of grey ammonia were then translated into a cost per tonne of ammonium nitrate output, 95% of which was assumed to be used in explosives. This produced a total cost of around AUD600 million, which was compared to expenses over the financial year 2021-22 for Australia's mining sector to produce an approximate contribution of 0.3%.[109] Variances in the levelised costs of green versus grey ammonia are then applied to this value to produce an estimated financial impact of a miner switching to green ammonia-based explosives products. For example, if the cost of producing green ammonia were three times that of grey ammonia, the impact on overall expenses would be 0.6% (200% x 0.3%).

For simplicity, the above analysis assumes that the costs of switching to a green ammonia input for explosives production are borne entirely by a mining customer. In reality, alternative financing arrangements could share these costs across stakeholders in the value chain, with support from government in the form of grants, subsidies or other financial incentives. This kind of coordination would likely be critical to de-risk the scale of capital investment needed for 100% green ammonia facilities.

Miners and government must take action now

Immediate green explosives pledges from miners could shift the supply chain

Australia's major mining companies could play a crucial role in accelerating Australia's net-zero transition by advocating for decarbonised inputs to purchased explosives products. Collectively,

[105] Energy Conversion and Management. Optimising renewable generation configurations of off-grid green ammonia production systems considering Haber-Bosch flexibility. 15 March 2023. Changlong et al. See caption of Figure 9 for LCOA from SMR as a function of gas price = 253.22 + (29.93 * cost of gas). Converted into $/GJ from $/mbtu using a factor of 1.055:1.
[106] Energy Star. Thermal Energy Conversions. August 2015. Gas prices used to compute grey ammonia costs were converted from $/GJ to $/mbtu using a multiplier of 0.9478 (Figure 2 – Quick Reference Multipliers).
[107] Australian Energy Regulator. Gas market prices. 2023.
[108] AEMO. 2023 Western Australia Gas Statement of Opportunities. December 2023. Page 3.
[109] Australian Bureau of Statistics. Australian industry by subdivision. May 2023.

these companies have significant influence and purchasing power to guarantee offtake that could provide the certainty required to shift investment. This would support the development of a broader green hydrogen/ammonia supply chain, potentially benefitting decarbonisation of numerous other sectors domestically.

Mining companies could start by quantifying upstream emissions from explosives production and setting emissions intensity-based reduction targets to guide procurement decisions. To be sufficiently ambitious while reflecting technological viability, these targets should involve a near-total decarbonisation of the upstream ammonia input, and greater than 80% reduction in nitrous oxide emissions by 2030.

The proposed expansion of CSBP's Kwinana facility presents the most obvious and immediate opportunity for miners to influence upstream producers. Construction is scheduled to commence in the second half of 2024 (subject to approvals), so there is not yet the problem of sunk costs facing other ammonia facilities in Australia.[110] This provides a small window for CSBP's current or prospective customers to signal a desire for green ammonia inputs rather than locking in further fossil fuel investment and associated emissions. As discussed earlier, the proposed capacity of this expansion represents 15% of Australia's current production, and proving feasibility at such scale could serve as a catalyst for transitioning the rest of the industry.

Existing government schemes could be leveraged to encourage a shift to green explosives

There are currently limited incentives driving a shift to either production or consumption of green ammonia products in Australia. Poor supply chain transparency and data availability are further challenges to tracing lifecycle emissions relating to products such as explosives.

Over the past decade the Australian Government has successfully implemented schemes such as Renewable Energy Certificates to encourage investment in renewable energy supply.[111] Establishing a similar market-based scheme that would allow the creation and trade of Renewable Ammonia Certificates could enable producers to attract investment, develop competitive advantage and receive financial reward for supplying green ammonia. Under such a system, ammonia producers could switch to green hydrogen or ammonia where it is most cost-effective rather than be limited to regions where they currently produce explosives. Consumers could also benefit from improved supply chain transparency regarding the origin of ammonia and derivatives, allowing them to actively choose lower-emissions products.

The aviation industry serves as a potential model for developing a certification system for green ammonia. As with green ammonia, the sustainable aviation fuel (SAF) industry is currently nascent

[110] CSBP. CSBP Ammonia Expansion Project Greenhouse Gas Management Plan. November 2022. Page 4.
[111] Clean Energy Regulator. About the Renewable Energy Target: How the scheme works. 18 July 2023.

and not yet able to benefit from efficiencies of scale or best practices of other facilities.[112] This led to the development of SAF certificates, which provide a mechanism for corporate customers of airlines to shoulder the increased cost of decarbonised fuels.[113] A similar framework could be developed to assist mining companies that are willing to bear the additional cost of green ammonia inputs into purchased explosives.

The Australian Government is also currently working to develop a hydrogen Guarantee of Origin (GO) scheme to provide a consistent and accurate approach to tracking emissions from production of hydrogen and its derivatives.[114] If such a scheme were extended to include derivative products such as nitric acid and ammonium nitrate, this would provide transparency to consumers and further support the production and uptake of green explosives. Some industry-led schemes already exist, such as the Smart Energy Council's Zero Carbon Certification scheme, which assesses the embedded carbon in participating hydrogen, ammonia and metals produced within Australia.[115]

Government support is vital

As it stands, a large-scale shift to green ammonia is an inherently risky endeavour, involving large capital investment and uncertain future demand. While mining companies could play some role, there is likely to be a near-term shortfall in demand for green ammonia and therefore insufficient impetus for ammonia producers to decarbonise. Government support will be needed to spread this risk, for example by providing investment support to cover any shortfall in miners' commitments before the proposed CSBP plant goes into construction.

The transition would also benefit from the introduction of policies that require companies to address Scope 3 emissions, or specific regulations to fully decarbonise explosives. An obvious first step would be improving data transparency and disclosure relating to Scope 3 emissions from explosives manufacture. Governments could also accelerate action by legislating Scope 3 emissions reductions, limiting the use of offsets under the SGM or introducing and regulating green explosives targets. These measures could be key to encouraging smaller miners that are unlikely to move as fast as larger companies facing greater public and investor pressure.

Finally, while not covered in this report, developing Australia's green ammonia industry is an immense task that requires a transformation of regional electricity systems. This scale of change is beyond the ability of the private sector alone and will require significant investment and central coordination from governments throughout Australia.

[112] World Economic Forum. Powering Sustainable Aviation Through Consumer Demand: The Clean Skies for Tomorrow Sustainable Aviation Fuel Certificate (SAFc) Framework. June 2021.
[113] IBM. SAF certificates explained: sustainable aviation fuel certificates. 2 September 2021.
[114] Department of Industry, Science, Energy and Resources. Hydrogen Guarantee of Origin scheme. June 2021.
[115] Smart Energy Council. Introduction and Overview of the Zero Carbon Certification Scheme.

Appendix A: Currently proposed hydrogen projects in Australia

The CSIRO's HyResource database was used to develop an understanding of the current and emerging hydrogen landscape in Australia. The following information is correct as of 31 January 2024. Most of the projects in the database have not yet reached Final Investment Decision. In many instances, there is limited project information regarding proposed production quantities and end uses, but best efforts have been made based on classification within the database and embedded links to key projects.

The key findings of this process are as follows:

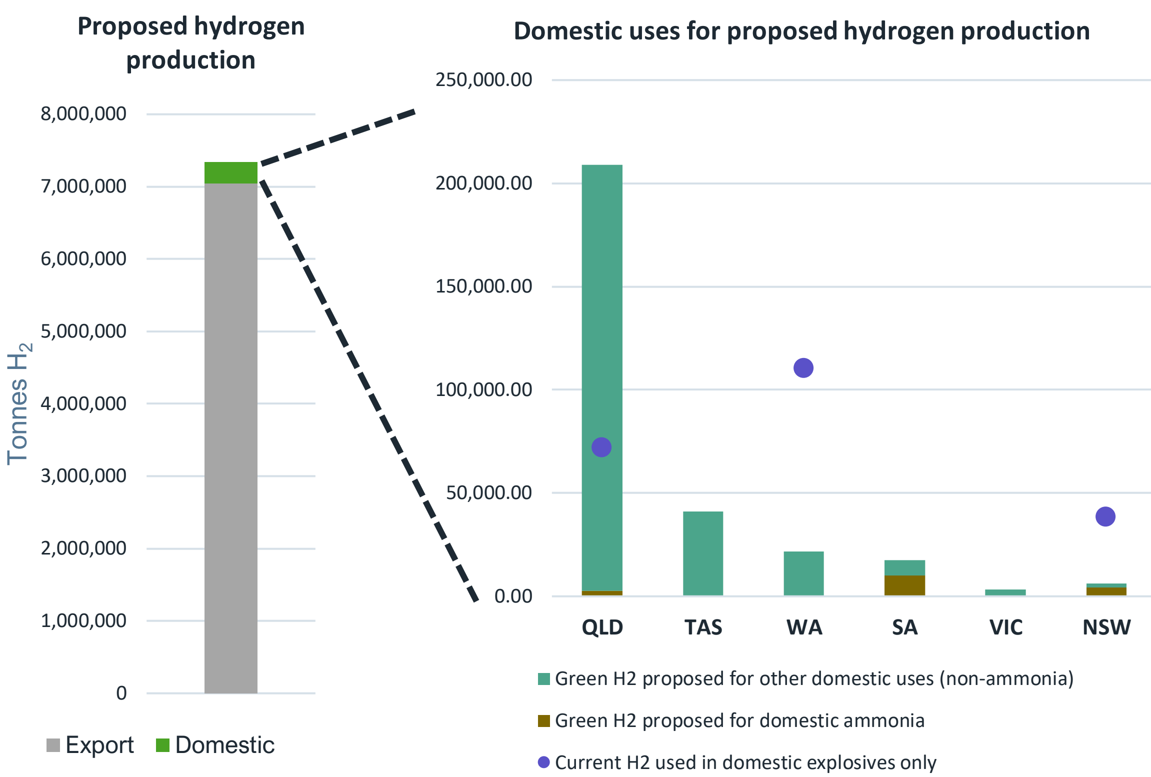
- The vast majority (95%) of the 7.3Mt of proposed green hydrogen production listed in the database targets the export of hydrogen and derivatives rather than domestic use.
- Of the roughly 300,000 tonnes of green hydrogen proposed for domestic use, only 6% (17,000 tonnes) targets ammonia production.
- Assuming this green hydrogen were used exclusively for explosives (i.e. to displace existing grey hydrogen use), this represents 10% of current explosives production.
- At a state level, this equates to 4,300 tonnes in NSW (14% of explosives production), 2,800 tonnes in QLD (5%), and zero in WA.

Notes and additional assumptions are as follows:

- Conversions used in calculations are consistent with those described elsewhere in this report. In particular, 0.178 tonnes of hydrogen per tonne of ammonia, and 0.43 tonnes of ammonia per tonne of ammonium nitrate.
- It has been assumed that all of the proposed hydrogen production that does not explicitly mention export, fertiliser production or other domestic uses is used for producing ammonia that is in turn used for producing explosives.
- It has been assumed that all of the 4,380 tonnes of green hydrogen that Orica plans to use from the Hunter Valley Hydrogen Hub (12 tonnes per day according to company website) is used for explosives rather than fertilisers. It is also assumed that Orica replaces an equivalent share of gas (i.e. 7%) at its Yarwun operations using green hydrogen from the H2-Hub Gladstone project. A Memorandum of Understanding has been announced between Orica and H2U Group stating an intention to displace some gas use in the Yarwun plant, but there is no further detail on proposed quantities or timing.[116]
- The QLD results appear skewed by the proposed Gibson Island green ammonia facility, which aims to produce up to 70,000 tonnes of ammonia annually. This replaces the existing gas-based capacity that was closed in 2022, but this capacity is not included in the 'Current H2 used' figures in Figure 5 as it is not currently operational.

[116] Orica. Hunter Valley Hydrogen Hub. 2024.

Figure 5: Proposed green hydrogen projects and potential end uses



Source: IEEFA analysis based on CSIRO HyResource data.[117]

[117] CSIRO. HyResource.

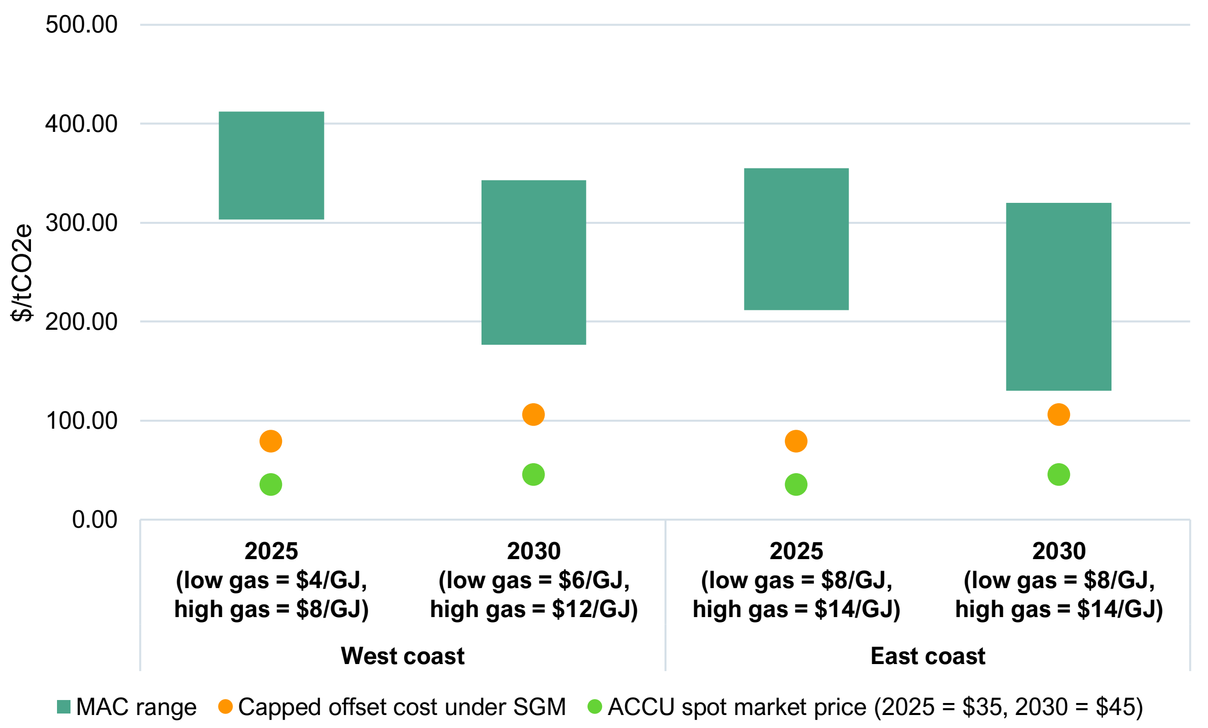
Appendix B: Marginal abatement cost analysis

The cost differentials for producing ammonia presented in this report can be used to compute marginal abatement costs (MAC), which are useful for understanding how producers' investment decisions may change in the face of policies such as the SGM discussed earlier.

As shown in Figure 6, the MAC of green ammonia is materially higher than the maximum possible cost of purchasing offsets in all regions in 2025, even at the upper bound of gas price assumptions – particularly on the west coast given its significantly cheaper gas prices. This implies little incentive for producers to switch to green ammonia.

By 2030, the situation changes with assumed lower costs of producing green ammonia, potentially higher gas prices with a possible supply shortage, and an increase in the offset price cap depending on inflation. This creates a situation where, under the high gas price assumptions, the MAC of producing green ammonia on the east coast approaches the cost of purchasing SGM offsets, but still exceeds the assumed cost of ACCUs by some margin.

Figure 6: MAC of producing green ammonia compared with grey ammonia

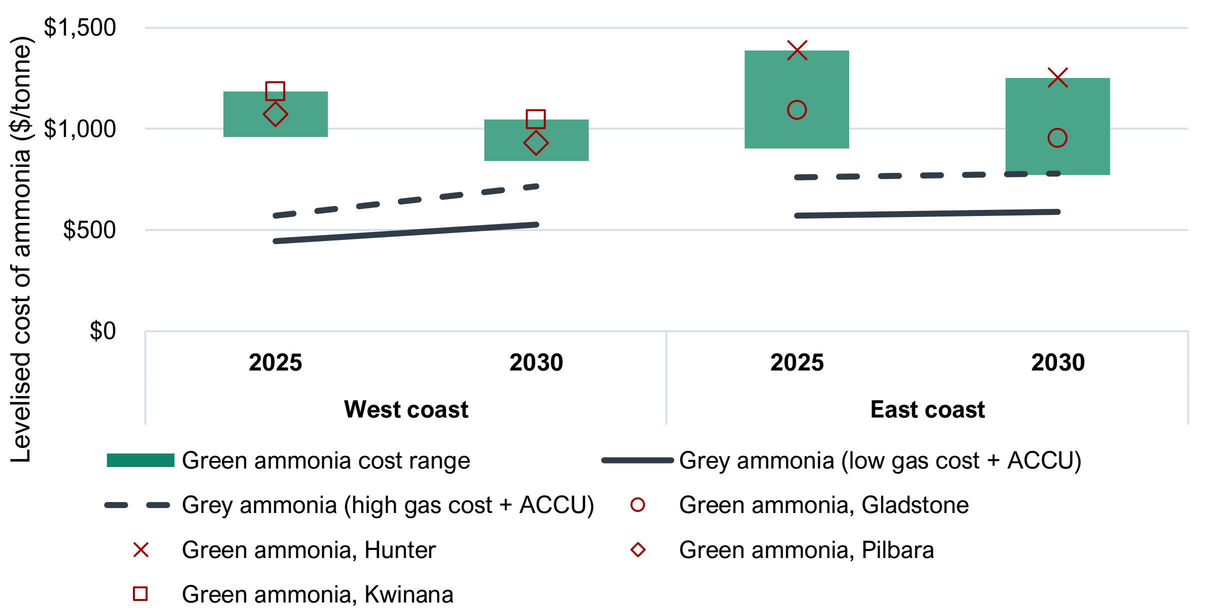


Source: IEEFA Analysis

Appendix C: Levelised costs of ammonia including emissions

Under the SGM, covered facilities will need to reduce emissions in line with declining baselines, or face a financial penalty. This requirement to reduce emissions, either through financing deployment of abatement technologies or the purchase of ACCUs, imposes additional costs on emitting activities. Figure 7 replicates the analysis in Figure 3, with an additional cost to grey ammonia production that reflects this financial pressure. For simplicity, it represents the costs of fully offsetting emissions from grey ammonia production at assumed ACCU prices of AUD35/tCO_2e in 2025 and AUD45/tCO_2e in 2030, so that the emissions footprint is equivalent (in an accounting sense) to green ammonia production. In reality, companies would only have to offset the amount that exceeds their baselines so would face a portion of this cost. Nonetheless, Figure 7 shows that when emissions are fully priced, the cost-competitiveness of green ammonia improves, particularly in the east coast by 2030.

Figure 7: Levelised costs of producing green ammonia in different regions compared with grey ammonia, including cost of purchasing ACCUs



Source: IEEFA analysis using levelised costs of inflexible green ammonia production from Changlong et al.[118] With the exception of Incitec Pivot's Moranbah Plant, all facilities are covered by one of the 21 potential hydrogen hubs identified in this paper. It is assumed that green ammonia could be produced at Moranbah at a similar cost to the Gladstone hub, given similar renewable energy capacity factors in the Renewable Energy Zones covering these regions (Fitzroy and Isaac).[119]

[118] Energy Conversion and Management. Optimising renewable generation configurations of off-grid green ammonia production systems considering Haber-Bosch flexibility. 15 March 2023. Figure 2. Changlong et al.
[119] Australian Energy Market Operator. 2022 ISP inputs, assumptions and scenarios: 2022 Forecasting Assumptions Workbook. March 2023. Capacity Factors tab.

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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