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Submission to the Australia's Guarantee of Origin Scheme

Product Expansion & Prioritisation Survey (Part I: Ammonia)

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The Australian Government is currently undertaking consultation to evolve the design and scope of the national Guarantee of Origin (GO) scheme for hydrogen certification. This includes a survey on product prioritization and expansion pathways as part of the GO scheme development. Monash University, as a leader in renewable energy research and advocacy, is pleased to provide input through this submission to help shape an impactful GO framework.

Monash University is the largest University in Australia with a global footprint that includes campuses in India, China, Malaysia, Indonesia, and Italy. Monash has committed to three global challenges: Climate Change, Geopolitical Security, and Thriving Communities. Its flagship Climate strategy, the Net Zero 2030 Initiative, was awarded the UN Momentum for Change Lighthouse award in 2018.

This submission is led by the Monash Energy Institute, the university's primary vehicle for promoting and facilitating Climate Change Mitigation and Energy Transition research. The institute, in addition to coordinating its basic research strengths in novel solar PV and storage materials, green hydrogen and ammonia production and storage, and a full range of AI research strengths, drives impact by bringing deep energy industry expertise to help accelerate the growth of Australia's hydrogen industry. Examples include high-impact initiatives such as the Monash-Geoscience Australia Hydrogen Economic Fairways Tool (awarded the 2023 Eureka Prize for Innovative Research in Sustainability), the Victorian Renewable Liquid Hydrogen Supply Hub, the Monash life-cycle assessment (LCA) tool, leadership of the Electricity Networks Program in the RACE for 2030 Cooperative Research Centre, the industry-funded Monash Grid Innovation Hub, and shortlisted in a consortium bid to establish a Scaling Green Hydrogen CRC. This submission draws upon our extensive research capabilities in hydrogen and energy transition to provide insights and recommendations for Australia's Guarantee of Origin Scheme.

Australia's Guarantee of Origin Scheme: Product Expansion and Prioritisation Survey (Ammonia)

1. **What product/product-specific methodology should the Government prioritise for incorporation into the GO scheme?**

   Our submissions focus on green commodities that add value to Australia's hydrogen exports and maximise hydrogen's potential for decarbonization. This submission serves as Part I of our suggested framework for the Guarantee of Origin (GO) scheme, with a specific emphasis on ammonia. Monash University has also recently completed work with Geoscience Australia which demonstrates that green iron/steel made from renewable hydrogen should also be considered a priority for the GO Scheme. Green steel will be the subject of Part II of our submission.

   The GO scheme represents an important policy lever and lays the framework that enables future government support and incentives towards the most efficient green commodity production solutions. While current GO scheme discussions focus on grid-connected electricity, well-designed certification is also needed for dedicated off-grid renewable systems producing certified green products. Off-grid facilities can benefit from location-optimized incentives that account for factors like resource quality, infrastructure, and seasonal supply-demand. By differentiating certification for elements like hybrid generation, flexible operation, and firming solutions, the GO scheme methodology can stimulate cost-competitive scaling of off-grid green commodity production.

   Monash research [1] suggests the government should prioritize the incorporation of green ammonia into the GO scheme. Ammonia is a promising hydrogen and energy carrier, as well as being an existing internationally-traded commodity. Shipping ammonia is commonplace today [2] as it is one of the world's most widely used chemicals. Ammonia also has significant potential as a clean feedstock chemical that can support decarbonization across multiple sectors. Australia currently manufactures substantial quantities of ammonia (e.g. Yara International plant in the Pilbara, WA) and is also often a net importer of ammonia. This combined with current industry developments (e.g. Asian Renewable Energy Hub) indicates that green ammonia is a front-runner when it comes to potential export markets for renewable hydrogen, makes green ammonia a top priority for inclusion in the GO scheme. Key points regarding products/methodologies that could be prioritized for the GO scheme include:

   - **Green ammonia as an energy carrier for renewable energy trade.** The Monash study [1] discusses the potential for Australia to export green ammonia produced from renewable electricity. Establishing a GO scheme for green ammonia would help enable international renewable energy trade.
   - **Hybrid wind-solar electricity generation.** Combining wind and solar generation reduces costs compared to wind or solar alone. A GO scheme that accounts for hybrid systems (in addition to sole renewable sources) would encourage more cost-effective renewable deployment.
   - **Flexible operation of electrolyzers and Haber-Bosch plants.** The modelling indicates important cost reductions from having partial flexibility in these processes to accommodate variable renewables. Recognizing flexible operation in the GO scheme methodology rewards producers for investing to integrate renewables more efficiently. It also provides incentives for more cost-optimal renewable investments and R&D development in flexible Haber-Bosch plants.
   - **Complementary seasonal supply and demand.** There may be opportunities to link the southern hemisphere solar supply with the northern hemisphere winter energy demand (See Appendix A). GO schemes could be designed to account for seasonal complementarity. By

issuing time-stamped and geographically sourced GOs, the scheme can verify renewable ammonia production during periods of high export value. This provides incentives for Australian producers to supply more seasonal renewable ammonia to meet winter demand peaks overseas. It also creates opportunities for higher export prices during periods of high winter demand, improving project revenue viability. This in turn facilitates growth in optimized renewable energy assets and ammonia production capacity.

- **Renewable firming and dispatchable renewable power.** The GO scheme methodology should clearly differentiate renewable firming solutions for grid electricity firming, onsite battery storage firming, and bioenergy firming. By providing separate lables based on the firming source, the GO scheme recognizes the value of tailored investments in grid imports, storage, or bioenergy. This supports the early adoption of inflexible green ammonia systems in meeting plant operational requirements and contract delivery schedules.
- **Location-specific factors.** The Monash study [1] also emphasizes the importance of local factors like resources, infrastructure, policies, etc. The GO scheme could be location-specific to account for these variables.

2. **What is the emissions reduction potential of this product (immediate-term and future), and how would incorporation into the GO scheme support decarbonisation?**

The current international ammonia market, responsible for 1.3% of global CO2 emissions (450 Mt) [3], has an annual production capacity of around 175 million tonnes and a market value of approximately US$70 billion [4]. IRENA [5] projects global demand for ammonia to increase significantly to around 700 Mt/annum by 2050 in line with the 1.5°C scenario.

Incorporating green ammonia into the GO scheme can provide both immediate and long-term emissions reductions across several different sectors. Produced from renewable electricity, green ammonia eliminates the upstream emissions associated with conventional production methods. GO scheme incentives would support increased green ammonia production and use, enabling economy-wide decarbonization:

- Green ammonia produced from renewable electricity has very low lifecycle emissions compared to conventional fossil-based ammonia production. The study [6] states greenhouse gas emissions are reduced by 17-42% compared to conventional methods.
- To replace the current fossil-fuel ammonia would require 1750 TWh of renewable electricity (assuming 10 MWh per tonne ammonia) - which is around 7 times Australia's current annual electricity generation.
- The GO scheme can accelerate adoption, though cost parity may not occur until around 2030 based on projections [1].
- Once cost-competitive at scale after 2030 or so, very large ammonia emissions reductions become feasible [1].
- Renewable ammonia production and trade displace fossil fuels and lower emissions globally. Seasonal supply-demand complements between Australia and the Northern Hemisphere could facilitate this [1].

3. **How does this product promote Australia's economic prosperity (immediate-term and future) (e.g., potential as an export product, investment, employment creation, industrial development etc)?**

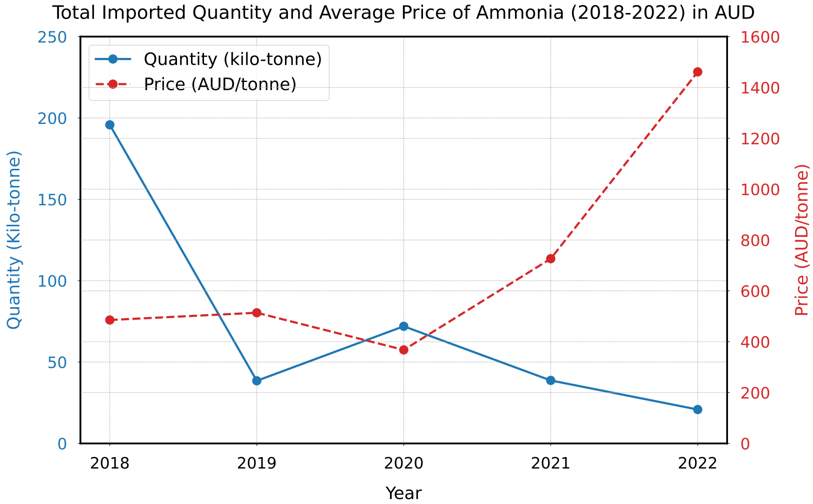

Figure 1: Australia's anhydrous ammonia imports from 2018-2022; data retrieved from World Bank [7]

Green ammonia for domestic use and export has the potential to establish Australia as a renewable energy leader while stimulating economic activity and jobs through new industry growth. Decarbonizing ammonia production offers a major opportunity for near-to-mid-term industrial emissions reductions, given the high global ammonia demand and its potential as a green energy carrier.

Australia's domestic ammonia consumption was around 1.3 million tonnes in 2019 [8], however, the country also depends on imported ammonia produced from fossil fuels. Analysis of World Bank trade data from 2018 to 2022 [7] shows total imported ammonia fluctuating between 20,000 to 200,000 tonnes annually (Figure 1). Over this period, average import prices were volatile, with sharp rises in 2022 reflecting global market dynamics, supply chain issues, and rising international gas prices. According to [1], replacing current fossil fuel ammonia imports with renewable ammonia would require approximately 750 MW of optimally mixed wind and solar PV generation plus 380 MW of electrolysers with onsite battery storage.

As discussed previously, green ammonia creates new export revenue streams while complementing seasonal supply and demand with the Northern Hemisphere. Additionally, constructing large renewable electricity and ammonia facilities generates substantial short-term investment and jobs during the building phase. Longer-term skilled employment opportunities also arise to operate and maintain these assets, especially in regional areas suitable for projects. Early leadership creates knowledge, capabilities and competitive strengths. Australia's political stability and skilled workforce provide additional advantages in developing this emerging sector. Targeted government incentives and policy certainty can further enhance investor confidence and progress.

4. **What is the product's level of technology, production and market readiness?**

The core electrolysis technology for green ammonia production is commercially ready. There are active demonstration and pilot projects underway globally, including in Australia. Yara is collaborating with Engie to build a 10 MW green ammonia plant adjacent to its existing fertiliser plant in the Pilbara, Western Australia. The green ammonia plant received a pre-certification under the Samrt Energy Council's Zero Carbon Certification Scheme. The pre-certification audit was conducted by

Bureau Veritas and concluded that the plant will be capable of producing ammonia and hydrogen with carbon footprints of 0.109 kgCO2-e/kgNH3 and 0.26 kgCO2-e/kgH2, respectively [9].

The market for green ammonia is still emerging but holds significant potential. This is particularly true given recent increases in the price and volatility of natural gas – a key component in conventional ammonia production.

Green ammonia has a medium-term trajectory towards commercial viability during the 2030s based on technical readiness along with progress in markets, policy and strategic partnerships. Continued development is still required to fully realize large-scale production and export capabilities.

Modelling conducted by Monash University estimates that renewable ammonia costs could achieve around A$800/tonne by 2025 and A$700/tonne by 2030 at pre-identified hydrogen hubs with existing infrastructure (Figure 2 and 3) if the system is fully optimised and the chemical plants are partially flexible to reduce battery needs. In that case, by 2030, renewable ammonia is projected to be cost-competitive with fossil ammonia when gas prices exceed A$14/GJ, aligned with current Australian wholesale gas prices of A$15-20/GJ. With fossil fuel prices rising, renewable ammonia is becoming an economically viable and environmentally sustainable alternative. Recent international crises have shone a light on the vulnerability of Australia to supply chain risks (e.g. during Covid) and surges in global prices for fossil fuels (e.g. during the early stages of the Ukraine war). Ammonia, a vital commodity for the world's supply of fertiliser (including being used by Australia's farmers) topped US$1600 a tonne (about A$2240 a tonne) in May 2022 [10]. Prioritising ammonia will help establish the green ammonia industry in Australia which in turn will help build domestic and export markets, as well as reduce supply chain risks for Australia's food and agriculture sectors.

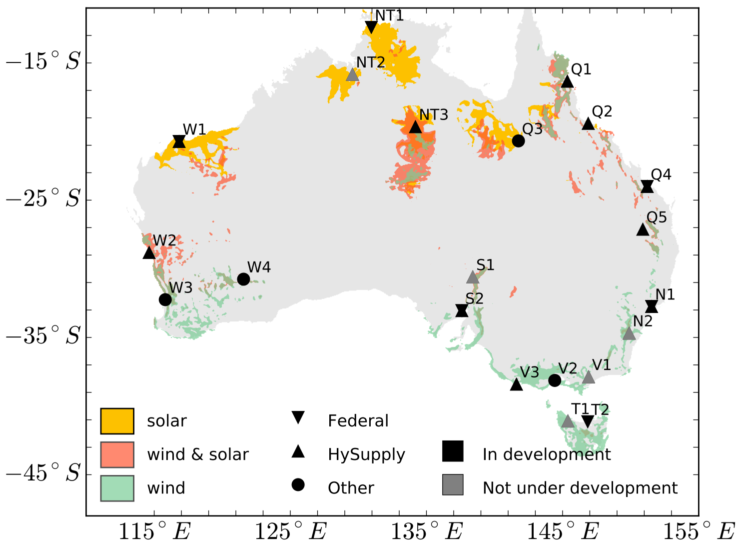

Figure 2: High potential regions (ranked in the 95th percentile) for the production of farm-gate and off-grid hydrogen from solar, wind and hybrid (wind & solar) sources. Locations labeled on the map indicate the position of key hydrogen hubs considered by [1].

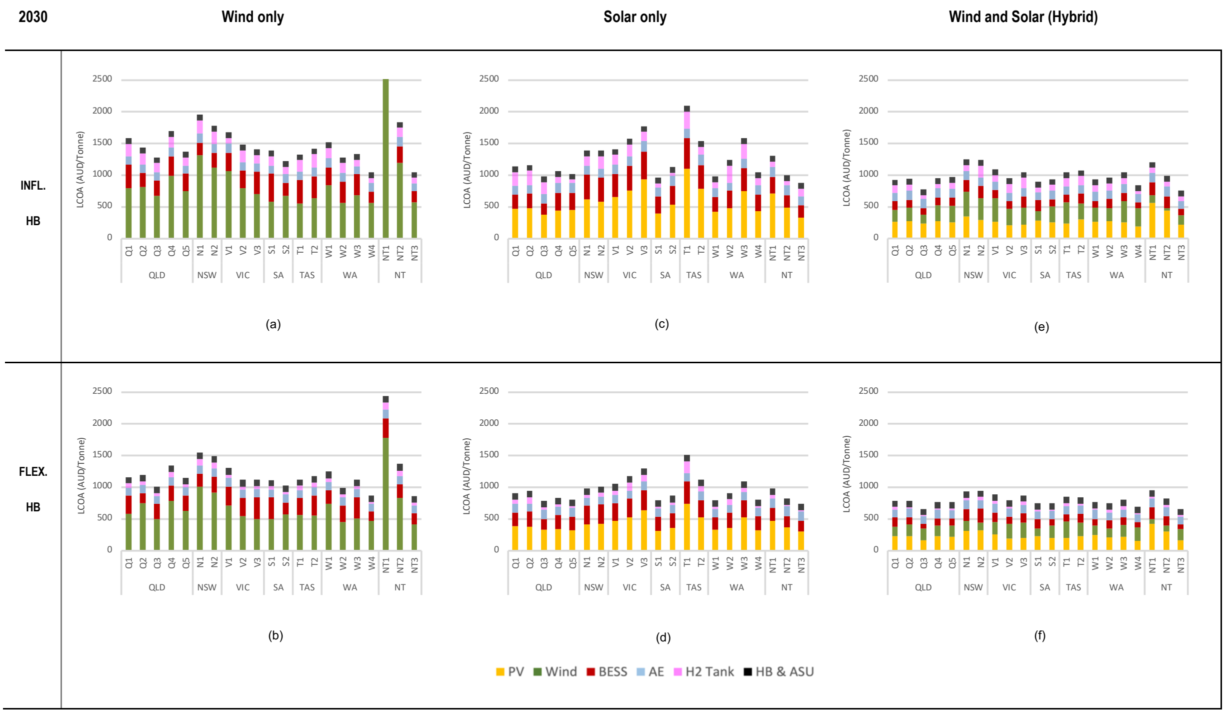

Figure 3: Comparative levelized costs of ammonia (LCOA) based on 2030 capital expenditure (CAPEX) estimates for a range of locations around Australia, showing the breakdown of contributions to the total LCOA. The scenarios are wind-only, solar PV-only, and a hybrid of wind and solar. The upper row depicts results when assuming the Haber-Bosch process is inflexible, while the lower row shows the partially flexible Haber-Bosch process [1].

5. **Are there applicable international or industry-led methodologies that could be amended or adopted?**

Monash University has been developing an online tool for estimation of life cycle emissions for hydrogen and ammonia production. The tool is publicly accessible (requires registration) and expected to be open-source in the future. The tool is specifically designed for electrolysis-based production and addresses gaps in the GO Scheme methodology for hydrogen and ammonia production. A more detailed description is provided in another submission by Monash Energy Institute to 'consultation on scheme design, emissions accounting and renewable electricity certification'. The tool can be accessed at the following URL: https://h2lca.org.

The Smart Energy Council has developed an industry-led Zero Carbon Certification Scheme for renewable hydrogen, renewable ammonia and renewable metals. Three projects, including Yara's green ammonia plant in the Pilbara, have been subject to certification under the scheme. Learnings from this scheme provide valuable input to the design of the GO scheme, including consideration of upstream scope 3 emissions in emissions intensity calculations. The Green Hydrogen Organisation has also developed a standard for green hydrogen. The GH2 standard requires that green hydrogen projects operate at less than 1kgCo-e/kgH2. The GH2 standard also includes additional aspects other than only the emissions intensity of the renewable hydrogen and derived products. For example, the GH2 standard includes consideration of Sustainable Development Goals (SDGs) when assessing green hydrogen projects. The use of thresholds for the generation of GO certificates and consideration of aspects such as SDGs assist build stakeholder and community confidence in the emerging industries, which should be a priority for the GO scheme. The Green Power Renewable Gas Certification Pilot also provides important learning for the GO scheme.

6. **Is this product likely to be an input into another product that could be certified under the GO scheme?**
Yes, green ammonia can be used to produce green fertilizers, explosives, and other chemicals which could also be certified low/zero carbon products under the GO scheme. The scheme could track renewable ammonia into various end-use applications:

   - **Fuel for shipping** - green ammonia is being explored as a bunker fuel for maritime applications. A GO scheme could cover renewable ammonia used in shipping.
   - **Energy storage medium** - ammonia can store and transport renewable energy. Certificates could account for the renewable electricity used to produce ammonia for energy storage.
   - **Agricultural fertilizer** - much ammonia is used for fertilizer. A GO scheme could certify renewable ammonia that displaces conventional fertilizer production.
   - **Fuel for power generation** - co-firing ammonia in Japan. Renewable ammonia could be tracked when used for power generation.
   - **Chemical feedstock** - renewable ammonia may find other industrial uses as a feedstock. A methodology could certify its renewable origins.
   - **Fuel for mining operations** - ammonia may displace diesel for mining equipment. A GO scheme could cover this application.

7. **How will incorporating the product into the GO scheme deliver beneficial outcomes under existing Australian domestic and international policies?**
Certifying green ammonia would support Australia's Technology Investment Roadmap and Low Emissions Technology Statements, which identify hydrogen and clean fuels like ammonia as priority technologies. It would also align with major trading partners' energy transition and decarbonization strategies.

   Incorporating green ammonia into Australia's GO scheme could help deliver beneficial outcomes under existing domestic and international policies in several ways:

   - Aligns with Australia's National Hydrogen Strategy which aims to position Australia as a major renewable hydrogen exporter by 2030. Green ammonia exports support this goal.
   - Implements Australia's commitments under international agreements like the Australia-Japan bilateral hydrogen/ammonia trade agreement and supports additional future agreements.
   - Helps realize Australia's Nationally Determined Contributions (NDCs) under the Paris Agreement by enabling large renewable energy capacity growth.
   - Supports state renewable energy and emissions reduction policies by creating demand for new renewables to produce green ammonia.
   - Aligns with emissions reduction policies in prospective importing countries by displacing fossil ammonia and fuels.
   - Creates a pathway for Australia to contribute to global decarbonization efforts consistent with net zero emissions goals.
   - Gives credibility to claims of Australia's exports being renewable-powered by certifying the ammonia's origins.

   Research conducted at Monash University provides insights into developing Australia's Guarantee of Origin scheme to support sustainable growth in renewable ammonia production and export [1, 11]. Tailoring the GO scheme design to account for technical, temporal, and geographic factors can maximize policy effectiveness. Incorporating location-specific factors, firming solutions, seasonal supply-demand profiles, hybrid generation, and electrolyzer-Haber Bosch flexibility into certification incentivizes optimized systems leveraging Australia's advantages. Recognizing hybrid configurations and renewable firming reduces costs compared to sole wind or solar. Accounting for flexibility rewards integration investments also lowering costs. Factoring seasonal complementarity catalyzes production when export value is high. Formal GO certification strengthens the credentials and policy alignment of this emerging industry. Overall, a tailored GO scheme can drive cost-effective capacity growth, supporting Australia in realizing its renewable export potential and associated economic prosperity through leadership in green ammonia.

Appendix A. Seasonal Complementarity of Australia's Green Ammonia Exports

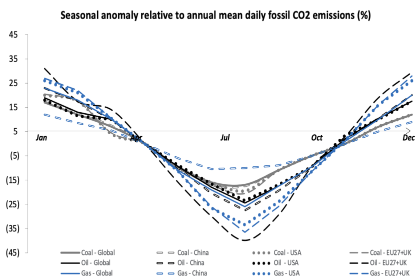

Figure A.4: Seasonal Energy Demand

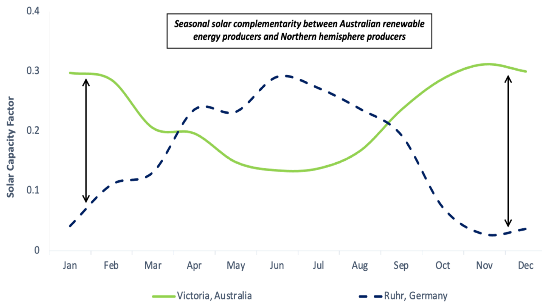

Figure A.5: Seasonal supply from solar PV

Australia should leverage its distinct geological advantage when engaging with trade partners in the Northern Hemisphere.

We have compared the domestic use of coal and fossil gas reserves by major Australia's trade partners in the Northern Hemisphere and their seasonal energy consumption patterns throughout the year. As seen from A.4, global energy demands vary through the year, driven largely by the change in seasons in the northern hemisphere. This has profound implications for the production of green hydrogen and ammonia.

A critical aspect of meeting the world's energy needs in a decarbonised future is the end-use of renewable hydrogen and its temporal value. Figure A.5 shows the seasonal value to Germany of renewable ammonia produced in an area with comparable solar resources – Gippsland, Australia. From both figures, there is a significant demand-supply mismatch in the Northern Hemisphere in winter when local energy demand surges and solar generation plunges. This large gap could be filled by Australian solar-powered ammonia, which peaks during that time. The solar generation shortfall in winter implies a substantial hydrogen supply deficit using regional resources; however, this is when energy demand reaches its highest.

The demand side would need to compete for the limited resources during the Northern Hemisphere's winter, which would likely drive up energy commodity prices, including renewable hydrogen. Prioritising limited resources for social welfare will adversely affect the industrial sector. To meet the enlarged demand-supply gap in winter, domestic producers in the northern hemisphere need to oversize their systems to produce additional hydrogen or ammonia in summer to be stored for winter use, which will significantly drive up overall production costs.

The temporal gap between domestic supply and consumption highlights the economic value of international imports at that time. Rather than investing in additional production capacity and storage, it could be more economical to seasonally boost Australia's solar-made ammonia supply by directly shipping it to the trading partners while their demand peaks and local supply plummets in the boreal winter. In other words, Australia can take advantage of our seasonal competitiveness to export hydrogen to Europe when their demand is high and our generation capacity is also high. Seasonal complementarity will be mutually beneficial to energy and ammonia trading partners on opposite sides of the globe.

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