MONASH University

MONASH ENERGY INSTITUTE

Submission to the Australia's Guarantee of Origin Scheme

Product Expansion & Prioritisation Survey (Part II: Iron/Steel)

AUTHORS:

DR. CHANGLONG WANG

DR. STUART WALSH

ADJ. ASSOC. PROF. SCOTT HAMILTON

DR. GRAHAM PALMER

ASSOCIATE PROF. ROGER DARGAVILLE

14 NOV. 23

Submission to the Australia's Guarantee of Origin Scheme:
Product Expansion and Prioritisation Survey (Part II: Iron/Steel)

Prepared by:

Dr. Changlong Wang

Dr. Stuart Walsh

Adjunct Associate Professor Scott Hamilton

Dr. Graham Palmer

Associate Professor Roger Dargaville

Institutional Affiliation:

Monash Hydrogen Energy Research Node
Monash University Energy Institute (MuEI)

For Further Inquiries:

Dr. Changlong Wang
Monash University, Clayton Campus
Email: chang.wang@monash.edu

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 (Iron/Steel)

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

   This submission represents Part II of our recommendations for the Guarantee of Origin (GO) scheme, focusing on renewable hydrogen applications in iron and steelmaking. Part I focuses on ammonia as a hydrogen derivative. Green iron/steel and ammonia exemplify potential value-added export products enabled by hydrogen that could be incorporated into the GO scheme.

   Given major international policies like the United States' Inflation Reduction Act (IRA) and the European Union's Green Deal, Australia would benefit by focusing hydrogen exports on value-added carriers and derivatives. This allows Australia to capitalize on its domestic resources and geographic proximity to demand centres in Asia and the Pacific. Prioritizing value-added exports helps mitigate risks from countries subsidizing hydrogen production for domestic use and export. Pursuing this strategy can empower Australia to establish a competitive and resilient hydrogen export industry.

   In addition to ammonia, Monash research [1] suggests the government should also prioritize the incorporation of green iron/steel into the GO scheme. A strategic GO scheme design provides policymakers with an important lever to drive efficient utilization of Australia's comparative advantages in renewable and mineral resources.

   Apart from the recommendations outlined in Part I of our submission, such as accounting for electrolyzer flexibility, hybrid wind-solar generation, and renewable firming solutions, the GO scheme methodology could further prioritize certification related to iron/steelmaking in the following areas:

   - **Differentiate green steel and iron production technologies.** Certifying the steel production technology based on emissions intensity would incentivize uptake of lower-carbon methods that eliminate most process emissions compared to conventional blast furnace routes. Example includes MIDREX fluidized bed technology for utilizing iron ore fines and avoiding the need for pelletization; HYBRIT hydrogen direct reduction designed for using iron ore pellets as feedstock; and melter solutions that enable the use of lower-grade hematite iron ores. This would encourage uptake of technologies suited to local ore grades and drive innovation across the spectrum of green steel production processes using various renewable inputs.
   - **Source of iron ore.** Steel production involves different sources of iron ore that vary in their mineralogy (e.g., hematite vs. magnetite ores), grade and form (eg. lump, sinters, fines or pellets). Factoring in iron ore type would account for additional beneficiation and processing steps like pelletization that may be required for lower-grade ores. This would provide incentives to use abundant iron ore resources available locally in Australia. Tailoring certification based on ore type would lower costs by encouraging the use of optimal local iron feeds while driving innovation in beneficiation and smelting methods suited to the unique composition of Australia's iron ore reserves.
   - **Reducing agent.** The climate impact of steel depends heavily on the reducing agent. Delineating pure renewable hydrogen from natural gas blends would provide transparency on the emissions intensity of the reducing agent used in steel production. This would maximize actual emissions reductions by incentivizing take-up of zero-emissions renewable hydrogen over fossil natural gas. Tailoring certification based on reducing agent sources is important because hydrogen-natural gas blends can still produce significant CO2 emissions. Clearly distinguishing renewables-derived hydrogen would enable authentic emissions cuts when displacing conventional iron and steel production routes.

- **Vertically integrated vs. disaggregated production.** The GO scheme should accommodate both vertically integrated green steel production, where a single entity controls the full supply chain and disaggregated production where separate entities produce inputs like iron ore, renewable electricity, and hydrogen and iron/steel. Vertical integration promotes system optimization by enabling holistic design and control. This differentiation would incentivize optimized supply chain configurations suited to location-specific factors. Vertically integrated production may be favourable where high-quality co-located resources enable single-entity control at a significantly lower cost. Meanwhile, disaggregated approaches can leverage specialized third-party providers in each supply chain segment while avoiding high capital expenditure and diversifying supply chain risks. Consideration should be given such that the GO scheme does not unduly favour one model over the other.
- **Recognize shared infrastructure with mining operations.** Many iron ore deposits in Australia are co-located with excellent renewable resources [2, 1]. Recognizing shared infrastructure with mining operations, such as roads, rails, transmission lines, and ports lowers project risks, minimises hydrogen transportation, storage and conversion losses, and encourages optimal siting adjacent to mining. Co-locating hydrogen production with industrial facilities is an emerging strategy being pursued by some companies and governments in Australia. Fortescue Metals Group, Iron Road, and AMP are exploring large-scale green hydrogen projects, with some initiatives directly integrating electrolyzer operations at iron ore sites. The Queensland government also aims to avoid infrastructure duplication and missed efficiency opportunities similar to earlier LNG industry development in the state. Establishing dedicated industrial zones can catalyze renewable developments and growth in areas ideal for green metals production and export. Coordinated planning and certification to maximize shared mining infrastructure minimizes costs and enables efficient public funding allocation.
- **Accounting for land use.** Green steel production will require significant amounts of land for wind and solar power. The GO scheme methodology could account for the cumulative land use requirements of green steel projects. Assessing land use would encourage sustainable scale-up by guiding site selection and planning. It would also incentivize siting projects in areas with minimal biodiversity and habitat value. Tracking cumulative land impacts would enable policymakers to plan ahead for land needs as the industry grows. Location-optimized certification informed by a spatial assessment of land factors would drive sustainable growth of this emerging export industry.

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

Green iron and green steel have significant potential to reduce emissions from the carbon-intensive steel sector. The GO scheme can provide policy incentives to enable medium and long-term emissions reductions by displacing conventional production. Monash research [1] highlights the following key points on the emissions reduction potential of green steel:

- Scaling green steel could displace existing blast furnace steel production and associated emissions. Global steel production was 1875 million tonnes in 2019 and accounted for 7-8% of global energy-related emissions [3]. Meeting the international net zero goal requires fundamental shifts to low-emission iron and steel production, with IEA's Net Zero by 2050 scenario [4] indicating required global steel emissions reductions of 24% by 2030 and 91% by 2050 to limit warming to 1.5°C.
- Green steel produced via renewable hydrogen direct reduction eliminates most process emissions relative to conventional iron and steelmaking. Conventional blast furnace-basic oxygen furnace

(BF-BOF) production emits over 1800 kg CO2 per tonne of steel, whereas hydrogen direct reduction (H2-DRI) emits only 53 kg CO2 per tonne [5] (i.e., 2.8% of emissions from the BF-BOF route).

- While green steel is not yet cost-competitive compared to conventional production, Monash modelling [1] estimates cost parity by around 2050 as technologies mature. But adoption and emissions reductions can be accelerated even before full parity by policy incentives. Direct government funding, low-cost financing, and partnerships can derisk investments to drive earlier roll-out. Carbon pricing also improves competitiveness of green steel compared to unpriced emissions from conventional production. Border carbon adjustments like the EU's CBAM proposal may be needed to prevent leakage from domestic emissions policies. These complementary measures alongside the GO scheme which tracks origination can enable green steel to start displacing blast furnace production well before 2050. Once cost competitive at scale, very large emissions reductions are possible.

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)?**

Renewable hydrogen-based green steel presents a significant opportunity for export revenue, investment, employment, and industrial development, catalyzing sustainable economic prosperity. As the world's largest iron ore exporter with substantial resources, Australia earned $133 billion from iron ore exports in 2021-2022 ($72 billion from metallurgical coal) [6]. However, this pivotal industry requires urgent decarbonization aligned with global net zero ambitions, necessitating changes to maintain future competitiveness.

Green iron and steel presents solutions to cooperatively counteract the difficulties of decarbonizing global steel and expanding hydrogen exports for Australia. While Australia traditionally exports hematite ores (96% of iron exports), magnetite comprises just 4% despite substantial resources. With green steel demand rising, opportunities exist to expand magnetite mining and find innovative uses for lower-grade ores. This can catalyze a strategic shift in Australia's export mix toward products enabling low-carbon steel manufacturing.

Constructing large-scale renewable and green steel production facilities in suitable mining regions generates substantial investment and near-term employment opportunities. The ongoing operation of these projects provides long-term skilled jobs producing green steel for export. Exporting green steel brings new revenue streams while diversifying iron ore exports, reducing Australia's vulnerability to global decarbonization policies.

Gaining first-mover advantages in this emerging industry also creates valuable knowledge, capabilities, and competitive strengths. Several factors make Australia well-positioned to capitalize on these prospects - its stable investment climate, expertise in mining and exports, and potential for shared infrastructure synergies with existing activities that reduce costs. Government incentives can further stimulate private investment and growth in this nascent sector. With strategic coordination, Australia can benefit across economic, employment, trade, and emissions dimensions by embracing green metals production and exports.

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

Continued development of a competitive renewable hydrogen supply chain will be crucial to realize the green iron/steel potential. While not fully mature today, the production technologies exist at scale and green steel is projected to reach commercial viability by the 2030s-2040s based on current trajectories [7]. On the other hand, H2 Green Steel, a company pioneering new steel manufacturing processes, is hoping to have commercial green steel available by 2025 for European customers, pointing to a near-term potential for commercial viability on a smaller scale [8].

Additionally, the Monash paper [1] provides some insights into the current status of green steel technology and production readiness:

- The hydrogen direct reduction process for green steel is technically proven and already being implemented at a commercial scale, such as the HYBRIT project.
- However, fully commercial-scale export-oriented green steel production facilities have yet to be developed in Australia. The technology is currently pre-commercial.
- Renewable hydrogen production via electrolysis is a commercially available technology but requires further cost reductions.
- Iron ore beneficiation and pelletization are mature, commercially deployed processes in Australia.
- Green steel approaching production cost parity with conventional steel around 2050 as the technology matures. So full commercial viability is a medium-term prospect.
- Pilot facilities like HYBRIT demonstrate the technology is ready to be rolled out at increasing scale when costs become more competitive.
- Australia has existing deep expertise in iron ore mining, processing, and exporting that can be leveraged to support green steel.
- Strategic partnerships, project planning and government support will be key to driving the development of a full-scale export industry as costs decline.

The Monash study [1] also models the projected cost evolution of green steel over time. The analysis indicates significant cost reductions are possible as technologies advance and scale expands. Due to existing infrastructure, iron ore centres like the Pilbara (WA) and Eyre Peninsula (SA) are highly prospective for magnetite mining, renewables, and hydrogen production [1].

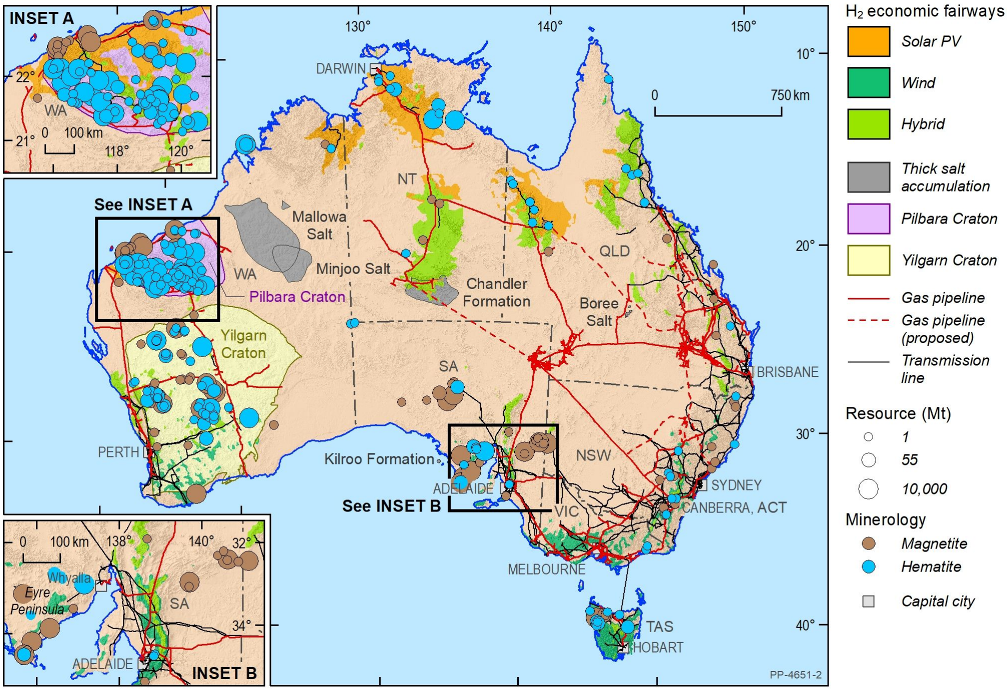

Figure 1: Critical infrastructure map overlain with annual average solar capacity factor for Australia. It illustrates that the resource is broadly distributed, but differences in local infrastructure lead to variations in economic potential. The shaded areas show high potential regions for producing farm-gate and off-grid hydrogen from solar, wind, and hybrid sources and locations of iron ore deposits (the coloured dots) in Australia. Deposit locations are based on [9], and the size of the symbol reflects the deposit size category. INSET A shows expanded views of the Pilbara region of Western Australia, and INSET B shows the Eyre Peninsula in South Australia. Geological formations with thick salt deposits, like those found in Western Australia's Pilbara region, present a promising opportunity for low-cost, large-scale hydrogen storage in underground salt caverns for long durations [10].

Analysis by Monash and Geoscience Australia [1, 11] reveals synergies between potential hydrogen hubs and iron operations (Figure 1). The research [1] identified the Pilbara and Eyre Peninsula as prime locations for co-locating hydrogen and steel facilities. Site-based optimization modelling estimates green steel costs around AU$900/tonne in 2030 and AU$750/tonne in 2050 (Figure 2).

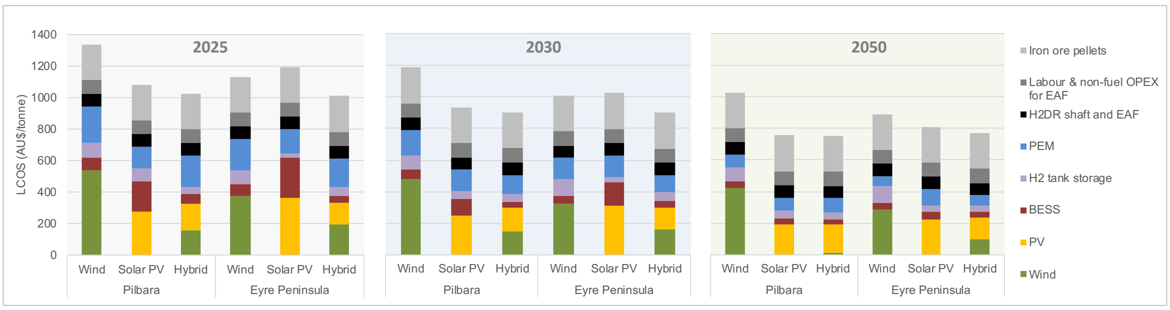

Figure 2: levelized costs of steel production in the Pilbara (Western Australia), and the Eyre Peninsula (South Australia) with 100% Direct Reduced Iron (*i.e.,* no recycled steel).

Initial low-emission steel uptake will likely rely on recycling, with estimated 70-90% end-of-life ferrous recycling rates [12]. However, due to rising demand and long product lifetimes, recycled content will stay below these levels. Estimates suggest 50% of global steel will still use virgin ores in 2050 [13], necessitating urgent efforts to address primary production impacts.

As mentioned, green steel currently costs more than conventional methods with coking coal. However, this gap is expected to narrow as renewable energy prices fall and technologies advance. Higher carbon prices and border taxes will further close the differential. If production costs continue decreasing, Australia may soon face opportunity costs by not producing green steel, given the reliance of its exported hematite ores on emissions-intensive BF-BOF processes [1, 11].

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

   Please refer to Part I of our submission on ammonia.

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

   Embracing green iron, Australia can tackle two challenges simultaneously: decarbonising steel production and exporting green hydrogen. This effort would not only support Australia's long-term economic growth but also strengthen its position in the global transition to a low-carbon economy. In particular, incorporating green iron/steel 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 enable renewable hydrogen exports. Green steel supports this goal as an export product enabled by hydrogen.
   - Complements Australia's partnerships with countries like Japan and South Korea that intend to import green steel in future. The GO scheme would help enable and support two-way green steel trade as these nations implement their own net zero emissions plans.
   - 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 iron/steel.
   - Helps insulate Australia's exports against potential border carbon tariffs applied to conventional steel.
   - Creates a pathway for Australia to contribute to global decarbonization efforts consistent with net zero emissions goals.
   - Gives credibility to claims of Australian steel exports being renewable-powered through certification.

In conclusion, Monash University research provides insights to inform the design of Australia's Guarantee of Origin scheme to catalyze growth of renewable hydrogen exports and value-added products like green ammonia and steel. For green steel specifically, differentiating based on production technologies, iron ore inputs, reducing agents, supply chain integration models, infrastructure sharing, and land use requirements would promote efficient industry development. Recognizing lower-emissions steel manufacturing routes, locally available iron ore grades, pure renewable hydrogen, synergies with mining, and sustainable scale-up would drive innovation across the supply chain. A strategic, tailored GO scheme design can accelerate Australia's leadership in renewable exports. By incentivizing technologies and solutions optimized to Australia's advantages in resources and geography, the scheme methodology becomes an impactful policy lever to aid government resource allocation and realize sustainable growth in new clean energy industries. Our submissions aim to inform effective scheme development that unlocks Australia's potential.

References

[1] C. Wang, S. D. Walsh, Z. Weng, M. W. Haynes, D. Summerfield, and A. Feitz, "Green steel: Synergies between the Australian iron ore industry and the production of green hydrogen," *International Journal of Hydrogen Energy*, may 2023. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0360319923022930

[2] C. Wang, A. Feitz, M. Haynes, S. Walsh, and Z. Weng, "Picture this: Green hydrogen plants next to green steelworks to boost efficiency and kickstart both industries," *The Conversation*, May 2023, [Accessed 11 November 2023]. [Online]. Available: https://theconversation.com/picture-this-green-hydrogen-plants-next-to-green-steelworks-to-boost-efficiency-and-kickstart-both-industries-205845

[3] International Energy Agency, "Iron and steel technology roadmap," IEA, Technical Report, 2020. [Online]. Available: https://www.iea.org/reports/iron-and-steel-technology-roadmap

[4] IEA, *Iron and Steel Technology Roadmap*. OECD, oct 2020. [Online]. Available: https://www.oecd-ilibrary.org/energy/iron-and-steel-technology-roadmap_3dcc2a1b-en

[5] V. Vogl, M. Åhman, and L. J. Nilsson, "Assessment of hydrogen direct reduction for fossil-free steelmaking," *Journal of Cleaner Production*, vol. 203, pp. 736–745, 2018.

[6] Office of the Chief Economist. (2022) Resources and energy quarterly: December 2022. Accessed: 2023-08-18. [Online]. Available: https://www.industry.gov.au/publications/resources-and-energy-quarterly-december-2022

[7] C. Choo, "Green steel – likely later than sooner," https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/metals/030421-green-steel-likely-later-than-sooner, 2021, [Accessed 11 November 2023].

[8] J. MacAlpine, "Two 'green steel' processes close to commercial viability," https://www.engineering.com/story/two-green-steel-processes-close-to-commercial-viability, 2023, [Accessed 14 November 2023].

[9] A. Britt, A. Schofield, M. Sexton, D. C. Champion, A. Hughes, A. P. Hitchman, D. L. Huston, A. Senior, D. Summerfield, E. Bastrakov *et al.*, *Australia's Identified Mineral Resources 2020*. Geoscience Australia, 2021. [Online]. Available: https://www.ga.gov.au/digital-publication/aimr2021

[10] S. D. C. Walsh, L. Easton, C. Wang, and A. J. Feitz, "Evaluating the Economic Potential for Geological Hydrogen Storage in Australia," *Earth Science, Systems and Society*, vol. 3, jul 2023. [Online]. Available: https://www.escubed.org/articles/10.3389/esss.2023.10074/full

[11] C. Wang, S. Walsh, M. Haynes, Z. Weng, A. Feitz, D. Summerfield, and I. Lutalo, "From australian iron ore to green steel: the opportunity for technology-driven decarbonisation," *Geoscience Australia Exploring for the Future: Extended Abstracts*, p. 6, 2022. [Online]. Available: https://ecat.ga.gov.au/geonetwork/srv/api/records/5377741d-ece0-4e01-b87e-6bf49da11c03

[12] United Nations Environment Programme and International Resource Panel, "Recycling rates of metals: A status report," Tech. Rep., 2011, accessed: 18 August 2023. [Online]. Available: https://wedocs.unep.org/20.500.11822/8702

[13] J. Morfeldt, W. Nijs, and S. Silveira, "The impact of climate targets on future steel production – an analysis based on a global energy system model," *Journal of Cleaner Production*, vol. 103, pp. 469–482, sep 2015. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0959652614004004

Further information

Monash University
Wellington Road
Clayton, Victoria 3800
Australia

T: +61 3 9905 9419
E: chang.wang@monash.edu

monash.edu.au