ANALYSIS

Digging Deeper

Modelling green iron in Western Australia



A companion to the Western Australia Green Iron Roadmap

About The Superpower Institute

Founded in 2023 by economist Ross Garnaut and public policy expert Rod Sims, The Superpower Institute is a not-for-profit organisation dedicated to helping Australia seize the extraordinary economic opportunities of the post-carbon world.

The Institute's focus is on developing the policy settings, market incentives and practical knowledge necessary for Australia to become a major exporter of renewable energy and green industrial products. By leveraging the nation's comparative advantage, the Institute aims to elevate Australia's economic and climate ambition and secure its place as a leader in a decarbonised global economy.

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Further reading

Explore the modelling methodology and inputs underpinning this report, alongside related research from TSI:

Digging Deeper (this report)
superpowerinstitute.com.au/work/digging-deeper

Model methodology and inputs
superpowerinstitute.com.au/model-methodology-digging-deeper

Western Australia Green Iron Roadmap
superpowerinstitute.com.au/work/western-australia-green-iron-roadmap

A Green Iron Plan for Australia
superpowerinstitute.com.au/work/green-iron-plan

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Acknowledgement of Country

This report was authored and edited on the Traditional Lands of the Whadjuk People of the Noongar Nation and the Wurundjeri People of the Kulin Nation. We pay our respects to their Elders past and present, and acknowledge the enduring strength of their cultures, knowledge and custodianship.

As Australia advances toward a new era of clean energy trade, we recognise the vital importance of First Nations voices, rights and leadership. A just transition must ensure that First Nations communities share equitably in the benefits of new industries, and that their deep connections to Country inform how we shape a more sustainable and inclusive future.

AI Statement

This report is the work of its authors. Artificial intelligence (AI) tools were used to support selected research and production tasks. AI-assisted content was subject to human review and verification. The Superpower Institute retains full responsibility for the research, analysis, findings and recommendations presented in this report.

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Executive Summary

Digging Deeper is part of The Superpower Institute's work on the *Western Australia Green Iron Roadmap* (*Roadmap*). It details the modelling that underpins the *Roadmap's* assessment of where green iron projects in WA are most likely to succeed as the green iron industry gets established and as it grows, and what it will take to get them built.

TSI's 2025 report*, A Green Iron Plan for Australia* (*GIPA*) showed that Australian green iron can compete internationally with efficient national policy support, and that location, grid access and technology choice are the major determinants of cost.

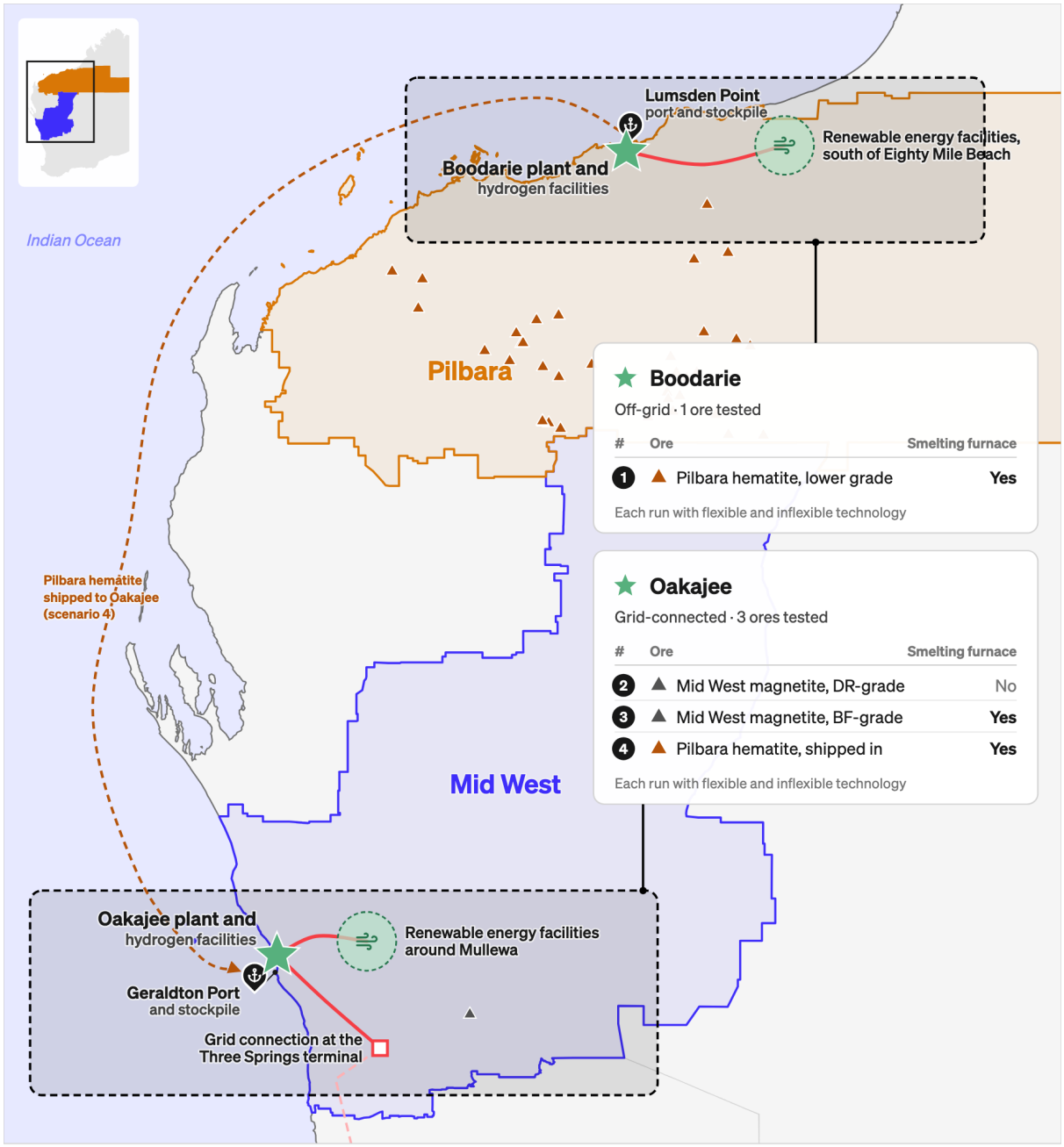
As part of the *Roadmap*, this report takes the next step. It updates and applies that model to the Western Australia's two iron ore regions, the Mid West and the Pilbara, and locates hypothetical plants at real sites: the Oakajee Strategic Industrial Area (SIA) near Geraldton in the Mid-West, and the Boodarie SIA, in the Pilbara near Port Hedland. It identifies and evaluates the factors that will decide project economics in each location: regional construction costs, renewable energy resources, the plant's interaction with the Wholesale Electricity Market (WEM), the ore available locally and its processing requirements, and the infrastructure needed to bring it all together.

Model assumptions have been refined in response to feedback from Western Australian industry and government agencies, and capital costs updated to GenCost 2025-26. All scenarios use a hydrogen-based direct reduction pathway producing hot briquetted iron (HBI) or pig iron suitable for electric arc furnace steelmaking. Policy implications are set out in the *Roadmap*.

The results support the *Roadmap's* central proposition: the Mid West is the most practical place to establish WA's green iron industry, and the Pilbara is where the industry can grow to scale – provided the work to get it ready begins now.

This analysis reaffirms that the Mid West is the lowest-cost location modelled for Western Australia's first green iron projects. It also shows that the cost of green iron is highly sensitive to a small number of location-specific factors, particularly how a plant's energy system is configured and how it connects to the electricity grid.

Figure 1 shows the locations of the WA model's two hypothetical green iron projects.



Plant sites, renewable energy zones and link lengths: Digging Deeper §2.2 and Figure 6 (zones indicative). Planned transmission: Clean Energy Link – North, Western Power.
Ports: Geoscience Australia (CC BY 4.0). Regions: DPIRD (CC BY 4.0).

Figure 1: Green iron and renewable energy facility locations for WA modelling scenarios.

Notes: Pilbara hematite, lower grade refers to Pilbara fines ore assumed to have an average grade of 60 per cent iron (Fe) content. In the model Pilbara hematite is processed via a direct reduction plus electric smelting furnace (DRI-ESF) route to produce green pig iron suitable for use in an electric arc furnace (EAF). Mid West magnetite, DR-grade (direct reduction grade) refers to a magnetite concentrate that meets a quality threshold grade of >66 per cent Fe and <3.5 per cent silica + alumina (SiO_2 + Al_2O_3). DR-grade concentrate can produce a green iron product suitable as feedstock for an EAF. Mid West magnetite, BF-grade (blast furnace grade) refers to a magnetite concentrate assumed to grade <66 per cent Fe and >3.5 per cent SiO_2+Al_2O_3. In the model, BF-grade material is processed via a DRI-EAF route to produce green pig iron suitable for an EAF.

Sources: Plant sites, renewable energy zones and link lengths: Bivios and The Superpower Institute analysis. Planned transmission: Western Power, Clean Energy Link – North. Ports: Geoscience Australia (CC BY 4.0). Regions: Department of Primary Industries and Regional Development (CC BY 4.0).

Scenarios and results

Digging Deeper calculates the levelised cost of iron (LCOI) for four scenarios: processing high-grade magnetite, lower-grade magnetite, and hematite in Oakajee, and processing hematite in Boodarie. Each scenario evaluates outcomes from two technologies: a 'flexible' iron-making technology that can ramp up and down, which does not require a continuous supply of green hydrogen or energy; and an 'inflexible' green iron-making technology that cannot ramp, which requires a continuous supply of hydrogen and energy. The model bases the flexible technology on Calix's ZESTY flash reduction technology and the inflexible technology on a Midrex vertical shaft furnace.

A plant at Oakajee using direct reduction-grade (DR-grade) magnetite concentrate offers the lowest cost of the scenarios analysed: about $839 per tonne for flexible and $1,099 per tonne for inflexible technology. These costs are higher than the comparable Geraldton scenario in TSI's May 2025 analysis (by $69 and $146 respectively). The increase is largely due to the revised treatment of the plant's interaction with the WEM, which captures the effect of electricity exports on wholesale prices. With the plant's exports now depressing the market clearing price, revenue from selling surplus electricity falls sharply.

Where lower-grade magnetite or hematite is used, costs increase for both technology types. The capital and operating costs of an electric smelting furnace (ESF), which is needed to process these ores, drives the difference.

The cost of iron production for each technology type is shown in **Figure 2** for the Mid West.

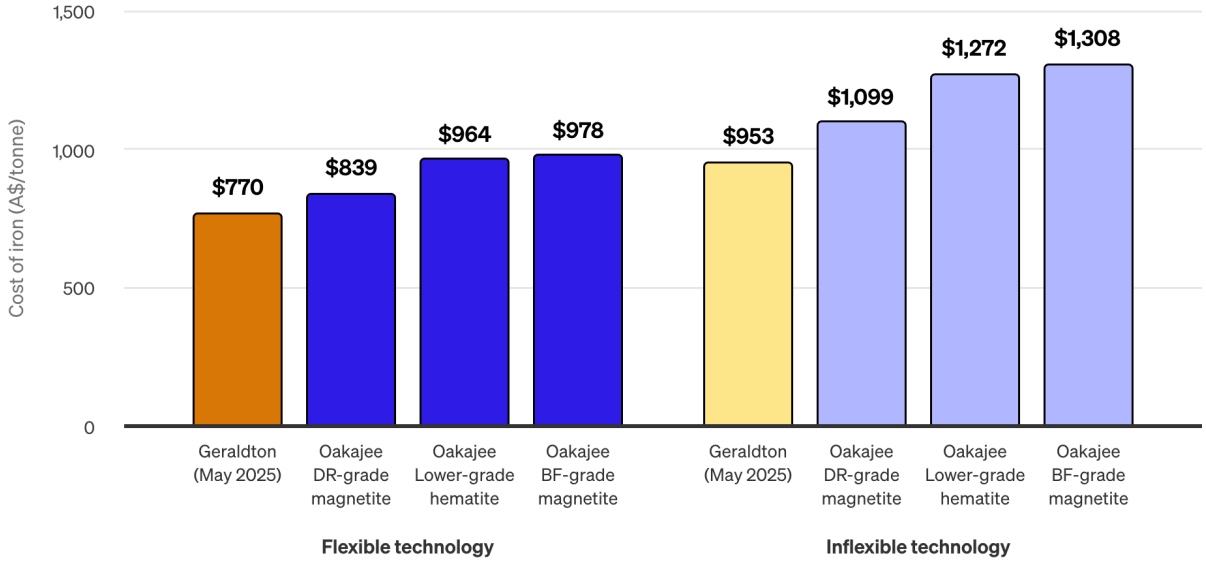


Figure 2: Summary of the levelised cost of iron production for all modelled Mid West scenarios

Notes: DR-grade magnetite refers to magnetite concentrate with a grade >66 per cent Fe and <3.5 per cent SiO_2+Al_2O_3. BF-grade magnetite refers to a concentrate with a grade of <66 per cent Fe and >3.5 per cent

SiO_2+Al_2O_3. Lower-grade hematite refers to Pilbara fines ore with a grade of 60 per cent Fe. Inflexible technology refers to iron-making technology that operates continuously at a steady rate. Flexible technology can vary its output to match variable renewable electricity supply.

Source: Bivios and The Superpower Institute analysis.

In Boodarie, the cost of green iron is substantially higher than all Oakajee scenarios: about $1,324 per tonne for flexible and $2,003 per tonne for inflexible technology. The cost difference between the Boodarie and Oakajee scenarios is driven by the need for more renewable energy capacity in Boodarie, coupled with a higher locations' capital cost factor (the premium paid by capital projects in the Pilbara region) These costs are also higher than the comparable Pilbara scenario examined in *GIPA*. Higher renewable energy capital costs and updated renewable resource assumptions are the main reasons. New capital costs and model re-optimisation also contribute.

The cost of iron production for each technology type is shown in **Figure 3** for the Pilbara.

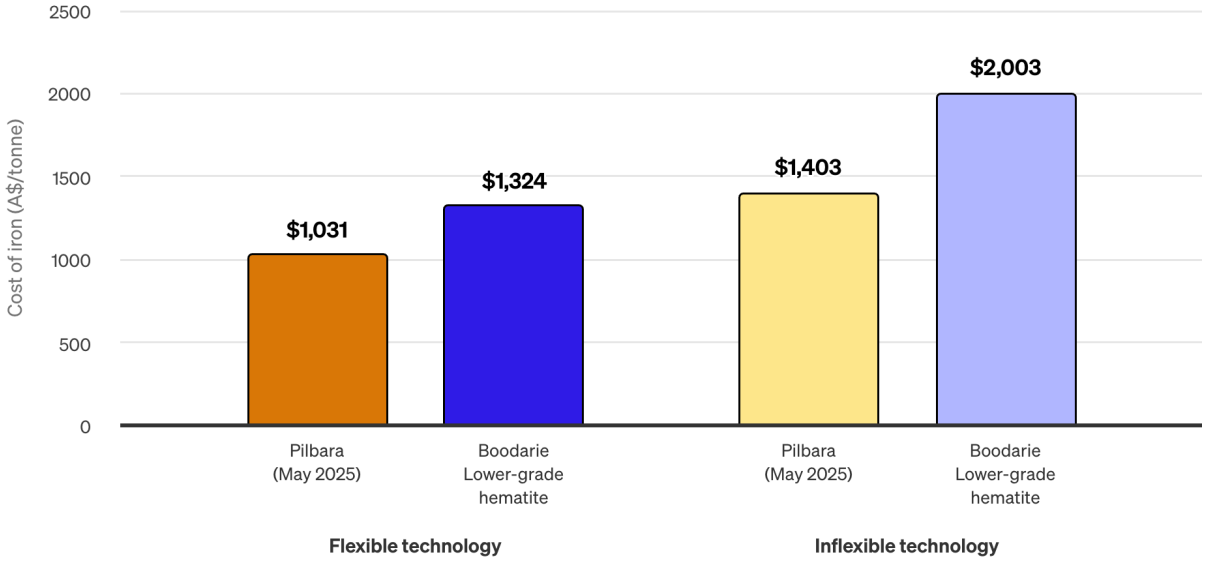


Figure 3: Summary of the levelised cost of iron production for all modelled Pilbara scenarios

Note: Pilbara (May 2025) refers to the *GIPA* scenario which located a green iron plant at the Boodarie Strategic Industrial Area in Port Hedland with off-grid, renewable energy generation located nearby. Boodarie Lower-grade hematite refers to the Digging Deeper scenario which also locates a green iron plant at the Boodarie Strategic Industrial Area, but the location of the renewable energy system has been updated to capture the best available renewable resources using the latest BARRA-2 weather reanalysis model.

Source: Bivios and The Superpower Institute analysis.

Findings and analysis

Five outcomes from the *Digging Deeper* modelling shape the direction of the *Roadmap*.

- **The grid's value in the Mid West is in firming, not trading.** A grid connection lowers costs mainly by supplying firming power to keep production running, rather than by earning revenue from electricity exports. For inflexible technology, a connection of around 300 MW reduces the cost of iron by more than $80 per tonne. The optimal size of connection differs with each project's technology and operating profile, so connections should be planned with proponents rather than assumed.
- **The way the HPTI emissions limit is applied matters.** The model applies the Hydrogen Production Tax Incentive (HPTI) emissions limit using the physical emissions intensity of the grid, which restricts grid imports to a small share of demand. This is a conservative treatment. Arrangements such as renewable power purchase agreements and certificates may allow greater use of the grid, and the *Roadmap* discusses the standards and certification questions this raises.
- **Local ore supply drives costs.** The lowest-cost result depends on a local supply of magnetite that can be upgraded to DR-grade concentrate. Where ore requires an ESF, costs rise for every technology type.
- **The Pilbara is a long-term proposition that needs work now.** The Pilbara's higher cost is driven by larger investments in renewable energy capacity reflecting the off-grid operating environment and ESF requirement. Consultation with energy developers with direct experience in the region also confirms a higher 'Pilbara Premium' locational cost factor than previously assumed. These costs make the Pilbara a challenging location for early investment, although established operators may be able to achieve lower costs than the general estimates used here. Over time, however, energy costs in the Pilbara should fall below those elsewhere and given the volume of low-cost ore available, the region is likely to be central to scaling the industry to 2050. Enabling work in the Pilbara should therefore accelerate alongside early projects in the Mid West.
- **Gas-based iron-making does not offer WA a comparative advantage.** A natural gas to green hydrogen direct reduction pathway is not cheaper in WA than in competing locations overseas. Public support for gas-based production, where no market failure exists, risks locking in emissions and distorting the developing green iron market. Public effort is best directed to near-zero emissions pathways.

Structure of this paper

Chapter 1 summarises the findings of *GIPA* that are relevant to Western Australia and explains why a more detailed regional analysis is needed.

Chapter 2 describes adjustments to TSI's green iron production model for Western Australia. New and updated assumptions about locational capital cost factors, renewable energy capacity factors and electricity market dynamics are detailed, along with new and updated scenarios related to the processing requirements of the state's two distinct iron ore types. High-level

descriptions of the Oakajee and Boodarie Strategic Industrial Areas, in which hypothetical green iron plants are located, provide a real-time look at the existing industrial land and infrastructure options in the Mid West and Pilbara.

Chapter 3 presents results on the levelised cost of iron for the Oakajee and Boodarie scenarios.

Chapter 4 highlights and discusses insights from the results. It identifies the factors that materially influence project economics and the cost of green iron production and identifies issues associated with a natural gas to green hydrogen pathway in Western Australia.

Details of TSI's modelling approach, federal government policy recommendations from *GIPA*, the WA model results and WA model input data and supplementary materials are provided as **Appendices.**

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01.

A Green Iron Plan for Australia – a recap

TSI's *GIPA* was motivated by the findings in TSI's *New Energy Trade*, which demonstrated the remarkable potential of Australia's green iron industry as the world decarbonises.

GIPA did four things. First, it explained how Australia will be able to produce green iron with its abundant iron ore. Second, it modelled the cost of producing green iron in five locations across Australia to better understand the degree and sources of cost variation. Third, it argued that market failures are holding back the market for Australian green iron. Fourth, it showed how efficient national policies that correct market failures would allow Australian green iron to compete in the international market for iron.[1,2]

1.1 The GIPA model

In *GIPA*, TSI partnered with Bivios to develop a model of green iron investment and production to identify the lowest-cost combination of capital investments and technology choices. It examined five locations, selected for their renewable energy resources and proximity to iron ore resources, or – in the case of Gladstone and Kwinana – proximity to a port that could allow iron ore to be transported for processing. It evaluated outcomes when producers use both flexible and inflexible iron-making technology. Each scenario included the production of renewable energy, green hydrogen and green iron. The model outputs were reported as a levelised cost of iron (LCOI) production. More detail on the modelling approach is provided in **Appendix A**.

Table 1 reflects the five scenarios for green iron production across Australia modelled in *GIPA*.

1 Green iron will also need to compete with iron produced from natural gas, or with 'grey' hydrogen produced from natural gas.

2 CSIRO, "Green, Blue, Brown: The Colours of Hydrogen Explained."

Table 1: Summary of characteristics of different iron-making locations used in *GIPA*.

Location	Connected to wholesale electricity market	Locational capital cost factors	Type of iron ore	Processing
Eyre Peninsula (SA)	Yes	1.08	Eyre Peninsula high-grade magnetite	Pelletisation of ore for 'inflexible' technology
Pilbara (WA)	No	1.34	Pilbara lower-grade hematite	Pelletisation of ore for 'inflexible' technology DRI processed in ESF for both 'flexible' and 'inflexible' technologies
Kwinana (WA)	Yes	1.12	Pilbara lower-grade hematite	Pelletisation of ore for 'inflexible' technology DRI processed in ESF for both 'flexible' and 'inflexible' technologies
Geraldton (WA)	Yes	1.24	Central WA high-grade magnetite	Pelletisation of ore for 'inflexible' technology
Gladstone (Qld)	Yes	1.11	Pilbara lower-grade hematite	Pelletisation of ore for 'inflexible' technology DRI processed in ESF for both 'flexible' and 'inflexible' technologies

Source: The Superpower Institute, *A Green Iron Plan for Australia*, appendices 3–8.

1.2 Results from GIPA

The results of the modelling showed that the lowest-cost combination of capital investments varied with location and technology. The resulting LCOI reflects differences in ore types and processing requirements, the locational capital cost factors and renewable energy capacity factors. The Eyre Peninsula and Geraldton returned the lowest LCOIs for both technology types. The Pilbara returned the highest LCOI for both technology types.

The LCOI's for all five locations modelled in *GIPA* are shown in **Figure 4**.

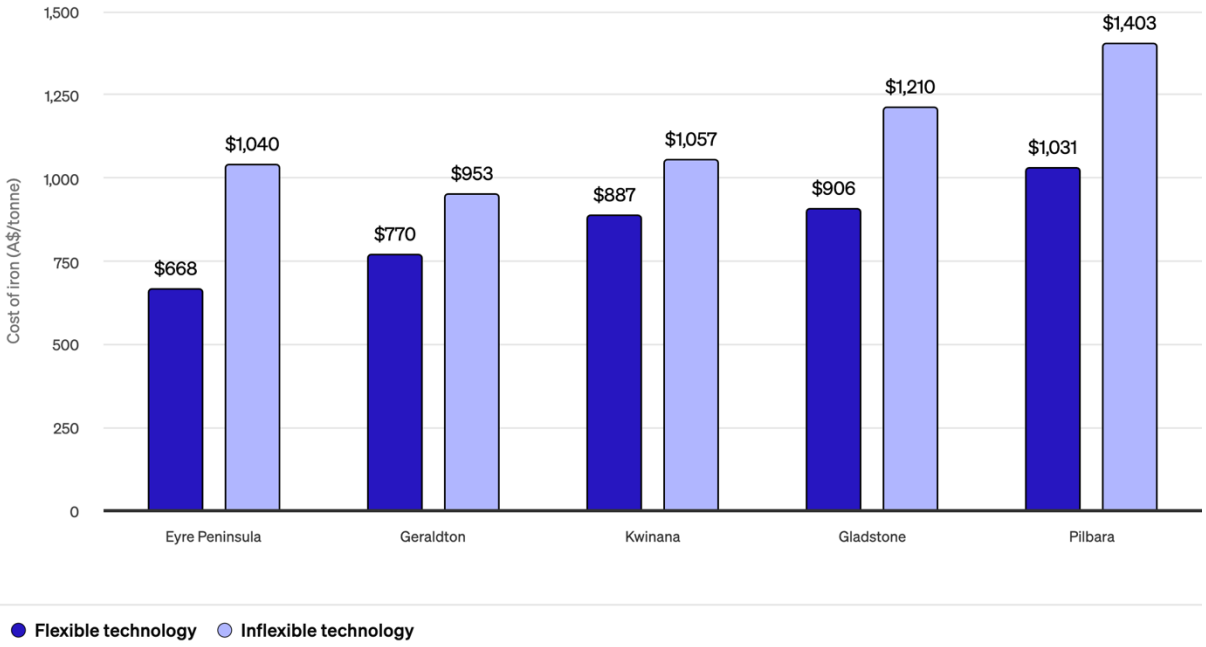


Figure 4: The cost of producing green iron varies across locations and by the type of green iron production technology.

Note: 'Flexible' green iron-making technology can more easily ramp up and down and does not require a continuous supply of green hydrogen or energy. 'Inflexible' green iron-making technology requires a continuous supply of hydrogen and energy.
Source: Bivios and The Superpower Institute, *A Green Iron Plan for Australia*.

1.3 GIPA findings

GIPA identified three core findings that materially influence the cost of green iron production across Australia.

- **Technology flexibility matters:** Flexible green iron technology, with the ability to ramp production up and down, will likely reduce the cost of producing green iron compared to technologies requiring continuous operation. This is particularly beneficial in off-grid locations like the Pilbara. However, flexible technologies are still under development and will require innovation support to be realised at commercial scale.
- **A grid connection can reduce the cost of green iron:** A grid connection has two potential benefits. First, assuming favourable market dynamics and structure, connected projects can sell electricity into the grid when prices are high, and buy electricity when prices are low. *Digging Deeper* finds that this 'trading' benefit is much smaller in the WEM than the National Electricity Market (NEM). Second, a grid connection can reduce costs by firming a producer's electricity supply (sections 4.1 and 4.2).
- **Location is critical:** Despite the geographic advantage of abundant iron ore deposits, the Pilbara is unlikely to be one of Australia's lower-cost locations for producing green iron in the short term. Other locations in Australia possess lower capital costs, have advantages in existing infrastructure, and some regions have superior renewable energy capacity factors.

1.4 Market failures and policy recommendations

Market failures distort the market for iron and steel because green iron does not compete on a level playing field with carbon-intensive iron.

GIPA identified three key market failures that warrant federal government intervention:

1. **Unpriced emissions from fossil-based production**

   Because there is no system of international carbon prices, iron and steel producers do not pay the social cost of their carbon emissions. The lack of carbon price distorts the market and makes it difficult for green iron to compete with carbon-intensive iron in international markets. TSI recommended that to correct for the lack of an international carbon price, the federal government should provide green iron production tax credits.

2. **Under-provision of common-user infrastructure**

   Like other major industries, green iron production requires large-scale, shared infrastructure - roads, transmission lines, pipelines and storage and upgraded ports. These assets have strong spillover benefits that private investors cannot capture, so the private sector will not invest in them at an efficient scale.

3. **Innovation spillovers and early-mover risk**

   In establishing new industries, early producers absorb the costs of technical learning, process optimisation and supply chain development. They confer large benefits on later producers, without reward. Without policy support, this disincentivises early investment. To correct for positive externalities created by early producers, TSI recommended the government should offer capital support worth up to 30 per cent of the investment cost for a green iron project.

With efficient support, Australian green iron can compete in international iron markets. TSI's modelling indicated that a green iron production tax credit of $170 per tonne, including the value of the existing Hydrogen Production Tax Incentive (HPTI), would have a similar effect to an international carbon price.

TSI's proposed production tax credit would address the market distortion created by the missing international carbon price. It would narrow or eliminate cost gaps and expand the number of locations where green iron producers can compete in the international market.

Appendix B outlines *GIPA's* Commonwealth-level recommendations**.**

1.5 Insights for Western Australia from GIPA

GIPA found that the major determinants of LCOI are the location-specific costs of doing business, infrastructure availability *(*particularly access to an electricity grid) and production technology flexibility. All three factors help keep the LCOI low in the Mid West, but locational costs and off-grid production increase costs in the Pilbara.

GIPA compared the cost and emissions-intensity of iron produced in the Pilbara using natural gas as the reductant.[3] TSI proposed an Australian green hydrogen tradeable certificate scheme that could allow iron produced with natural gas to be recognised as 'green' when green hydrogen certificates are purchased and surrendered, with the goal of reducing the cost of green hydrogen.[4] Finally, *GIPA* highlighted how planning and approvals timelines are a barrier to green iron projects.

1.5.1 Locational capital cost factors in WA

GIPA identified three factors that drive the capital costs of green iron production in Western Australia: the local cost of doing business, electricity grid infrastructure availability and renewable energy capacity factors and complementarity.

The local cost of doing business is reflected in capital costs.

The local costs of installing renewable energy systems in the remote north of Western Australia are among the highest in Australia. The colloquially acknowledged 'Pilbara premium' is noteworthy when compared to all other locations in the analysis.

The Mid West capital cost factor in *GIPA* was also high relative to the other locations considered in *GIPA* but was partially offset by the superior renewable energy resource and connection to the SWIS.

On average only the Northern Territory is more expensive than the remote regions of Western Australia.[5]

Access to electricity grid infrastructure is reflected in capital costs.

GIPA showed that access to large electricity grids reduced the LCOI because it reduces the required scale of capital expenditure on renewable energy and potentially allowed projects to generate revenue from electricity sales back to the grid. Western Australia is, however, disadvantaged relative to other Australian locations in this respect. Its Wholesale Electricity Market is shallower and smaller than the much larger and deeper National Electricity Market.

Furthermore, *GIPA* modelling demonstrated that green hydrogen and iron producers could gain significant benefits in regions with high renewable energy penetration in the grid, such as the Eyre Peninsula. South Australia's high renewables grid makes it possible to buy larger quantities of electricity from the market, without exceeding the carbon intensity limits of the HPTI.

In *GIPA's* Geraldton and Kwinana scenarios, purchase of electricity from the WEM was constrained to avoid exceeding the carbon intensity limits of the HPTI.

The Pilbara's electricity network does not have an operating wholesale market, so green iron production relies on 100 per cent off-grid renewable energy generation, firming and storage. For

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[3] Section 4.7 of *A Green Iron Plan for Australia* analyses the use of natural gas for iron production in grid-connected and off-grid scenarios with the application of a forecast EU carbon price.

[4] The Superpower Institute, *A Green Iron Plan for Australia*, Recommendation 4.

[5] GHD, *AEMO Costs and Technical Parameter Review*, table 73, 116.

the Pilbara this meant that flexible technology provided a relatively larger benefit, compared to the grid connected locations.

Renewable energy capacity factors, seasonality and complementarity are reflected in capital costs.

Renewable energy capacity factors for solar and wind energy represent the productivity of solar panels and wind turbines in a given location.

Seasonality refers to seasonal variations in renewable energy resource supply, generally between summer and winter.

Renewable energy complementarity describes the intraday relationship between solar and wind resources, and the extent to which they tend to compensate for periods of low generation in the other. Good complementarity is equivalent to strong and consistent nocturnal wind patterns and consistent solar during the day.

The Pilbara region has relatively high quality solar and wind capacity factors with limited complementarity. However, the Pilbara requires very large investments in renewable energy because there is no access to a grid for firming, and locational capital costs are high. The Pilbara therefore has a high cost of renewable energy capital that currently cannot be overcome by the quality and quantity of its renewable resources.

The Mid West has superior solar and wind capacity factors with some complementarity: the wind is stronger at night, complementing the excellent solar resource during the day.

Typically, Australia benefits from low seasonality, meaning our renewable energy resources can generate relatively consistent year-round energy. This helps lower the cost of renewable energy, through avoided investment in oversized generation and energy storage capacity that is otherwise required to manage seasonal variation.

Figure 5 shows the contribution of each component of the green iron project to the overall cost of production at each location modelled in *GIPA*.

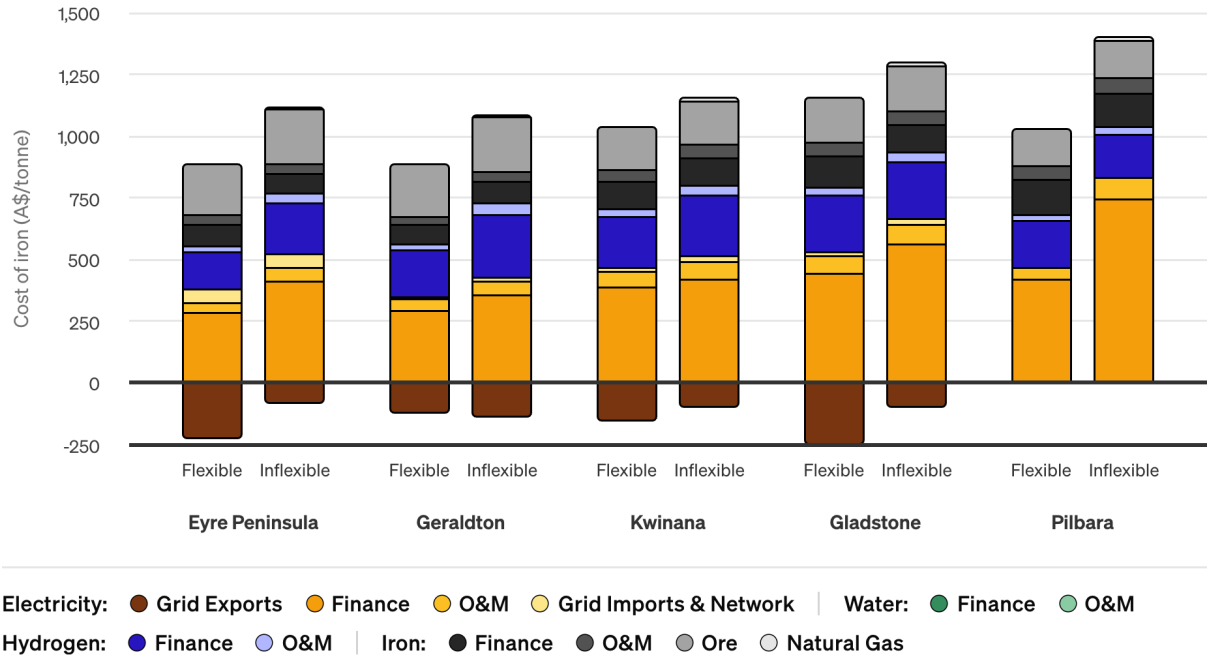


Figure 5: Breakdown of cost components by location and technology type from *GIPA*

Notes: Cost of iron is for green iron produced with green hydrogen with up to 0.6 kg CO_2e per kg of green hydrogen. 'Electricity' refers to renewable energy. 'O&M' refers to operation and maintenance costs. 'Hydrogen' refers to green hydrogen. 'Flexible' technology can be ramped up and down. 'Inflexible technology' needs to produce continuously. Water costs are included but not visible. See Appendix 4 in GIPA for detailed results.
Source: Bivios and The Superpower Institute analysis, in *A Green Iron Plan for Australia*.

1.5.2 Gas-based iron production in WA

Natural gas-based DRI production costs less than green hydrogen-based DRI but increases emissions.

Applying industrial gas cost forecasts for 2030, *GIPA* modelling showed that it is cheaper to produce iron with natural gas than green hydrogen but doing so increases carbon emissions.[6] Natural gas can also be used as a source of power, with gas turbines 'firming' the supply of energy from renewables or from a connected electricity market.

Gas can be used two ways: to firm the power supply to operations, and as the chemical reductant which converts iron ore into iron during the direct reduction process. If gas is used to firm power in a location connected to an electricity grid, there is only a small increase in emissions intensity. The resulting increase in emissions is limited if producers minimise gas use to meet the requirements of the HPTI: 0.6 kg CO2e per kg of hydrogen. When gas is also used as a reductant, displacing green hydrogen, the emissions intensity of iron is much higher.

[6] We modelled natural gas costs based on ACIL Allen industrial gas forecasts for capital cities (Adelaide, Brisbane, Perth), which are also used in AEMO's *2025 Gas Statement of Opportunities*. We adjust for location with transport costs. Delivered prices per gigajoule are $9.15 for the Pilbara, $9.05 for Geraldton and $9.45 for Kwinana. Industrial gas prices in WA are 40 per cent lower than those on the east coast. ACIL Allen, *Gas, Liquid Fuel, Coal and Renewable Gas Projections*; Australian Energy Market Operator, *Gas Statement of Opportunities*.

1.5.3 Approvals and planning in WA

Regulatory and planning delays create large costs for early movers.

While not part of the model, lengthy planning and approval processes was identified in *GIPA* as an expensive barrier to green industry projects. Australia's comparative advantage in green exports justifies state and federal government policies and programs that significantly reduce uncertainty and delays.

1.6 Why dig deeper on WA?

The Western Australian Government has signalled its interest in developing a green iron industry. The 2025 state election *Made in WA* platform outlined the government's commitment to develop a *Green Iron and Steel Action Plan*.[7] In the months after *GIPA* was published, the state budget expanded funding for strategic industries and prioritised activation of strategic industrial areas designated for green iron projects. This was complemented by investments in institutional capacity and restructuring of the public service to improve strategic project delivery. Strengthening the government's economic development agenda, the *State Development Act 2025* has been legislated to empower the newly created Coordinator General to ensure coordination across portfolios to deliver strategic projects, including green iron.

The federal government has introduced a $1 billion Green Iron Investment Fund and allocated $500 million towards the Whyalla Steelworks. They have also signed a Memorandum of Understanding with the Chinese Government, establishing an Australia-China Policy Dialogue on Steel Decarbonisation to support cooperation on green iron market development with China.

Collectively, these actions signal that green iron is a priority for both levels of government.

An increasing number of organisations have published analysis on green iron since *GIPA*. These include the OECD's *Green Iron opportunities in Australia*[8], the First Movers Coalition's *Unlocking Asia-Pacific as a First Mover: Australia's Green Iron Opportunity*[9], the Institute for Energy Economics and Financial Analysis' (IEEFA) briefing notes *How to spend a billion dollars - Lessons from overseas for Australia's green iron ambitions* and *Scale of investment needed for Australia's green iron ambition*[10], Deloitte's report for WWF *Creating the pull – Demand-side levers for green iron and steel*[11], and Climate Energy Finance's *Green Metal Statecraft: Policy, Investment and Technology Trends in the Green Iron Evolution* and *Arc of Ambition: Decarbonising and Safeguarding Australia's Steel Industry.*[12] These add to earlier publications from the Minerals Research Institute of Western Australia, and WWF and Deloitte which both

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7 WA Labor, *Made in WA Plan*.

8 OECD, *Green Iron Opportunities in Australia*.

9 World Economic Forum, *Unlocking Asia-Pacific as a First Mover: Australia's Green Iron Opportunity*.

10 IEEFA, *How to Spend a Billion Dollars*; IEEFA, *Scale of Investment Needed for Australia's Green Iron Ambition*.

11 Deloitte Access Economics, *Creating the Pull*.

12 Climate Energy Finance, *Green Metal Statecraft*; Climate Energy Finance, *Arc of Ambition*.

highlight the feasibility and opportunity for Australia to leverage its renewable energy and iron ore resources to produce green iron.

These publications all point to Western Australia's comparative advantage in green iron production. TSI's intention for *Digging Deeper* is to gain a more granular understanding of what drives green iron project economics and what interventions could have the most material impact on projects in Western Australia's major iron ore regions: the Pilbara and the Mid West.

TSI engaged with green iron project proponents, infrastructure providers and relevant state government agencies to test the findings in *GIPA* and update inputs and assumptions. Common feedback related to our assumptions around grid connection, WEM dynamics and locational capital cost factors.

In *Digging Deeper,* we have refined our assumptions about the interaction between a green iron plant and the WEM and sought advice from government agencies relevant to the operation, planning and construction of the state's energy systems. Additional capital costs have been included in the model, such as grid connection equipment costs, and contemporary locational capital cost factors have been sourced and peer reviewed. We consider additional scenarios for green iron production, which expand on the previous combinations of location, iron ore type and grade.

TSI also compare the cost and emissions intensity of natural gas-based iron production with hydrogen-based production; identify issues with the proposed use of natural gas as a transitional reductant; and highlight that analysis is required to identify and address barriers to investment in green hydrogen production, so that the transition to green hydrogen-based iron production can be accelerated.

Lastly, to anchor this work in Western Australia's unique industrial landscape, we highlight past and present policies related to strategic industrial land and their relevance for developing a green iron industry.

02.

A Green Iron Model for Western Australia

The model developed for *GIPA* identified the lowest-cost combination of capital investments and technology choices for renewable energy, green hydrogen and green iron as part of an integrated green iron production project. Green iron output is fixed at 2.5 million tonnes per annum across all scenarios.

The model captured the relationship between variable renewable energy and fixed capital investments, allowing different locations, different technologies and different scenarios to be compared as a levelised cost of green iron production.

2.1 Assumptions in our WA model

TSI has updated the inputs and the calculation methods for *Digging Deeper*. The changes were made in response to stakeholder feedback and suggestions on how to improve the reliability of the results and to more accurately reflect the specific circumstances in Oakajee and Boodarie.

2.1.1 Updated inputs

The following changes, which are detailed in **Appendix E**, have been made to the inputs used in the WA model:

- **Unit capital costs for renewable energy generation, hydrogen production, and battery storage.** GenCost 2025-26 shows notable increases on GenCost 2024-25 Consultation Draft, which was used in *GIPA*, including an 18 per cent rise in solar costs and a 28 per cent rise in electrolyser costs.[13]
- **Locational cost factors.** Updated following consultation with Horizon Power, Western Power and other stakeholders. Cost stack analysis of publicly available data from the Chichester Hub solar farm, Greenough River solar farm Stage 2, Warradarge wind farm Stage 1 and Yandin wind farm were also considered.
- **Transmission costs.** Following consultation with Western Power, the cost of transmission lines on a levelised m$/km/GW basis more than doubled compared to the input in *GIPA*.

[13] Graham, Hayward and Foster, *GenCost 2025-26: Final Report*. Notable increases compared with the *GenCost 2024-25* Consultation Draft, used in GIPA, include an 18 per cent rise in solar costs and a 28 per cent rise in electrolyser costs.

Significant updates were made to connection costs in terms of both variable and fixed network tariffs[14], as well as capital investments.[15]

- **Iron ore costs.** Iron ore costs are specific to each scenario and come from the same source used in *GIPA*. For the Mid West BF-grade magnetite processed via a DRI-ESF route, the 65 per cent Fe benchmark price is used. For the Mid West DR-grade magnetite scenario, a beneficiation premium of around $20 per tonne iron ore is applied to the 65 per cent Fe benchmark. The 62 per cent Fe benchmark is applied to the Pilbara hematite scenario.
- **Transport costs.** Sea and road freight costs for HBI from the plant to on board for export were defined as export costs and specifically relate to the Oakajee and Boodarie scenarios.
- **Natural gas costs.** The pelletising process to make the iron ores suitable for feeding the inflexible DRI relies on natural gas. Our WA model sources gas unit costs from the ACIL Allen industrial forecast with relevant pipeline tariffs included.[16]
- **Historic hourly solar and wind data.** Updated to reflect revised locations of renewable generation sources and most recent Bureau of Meteorology atmospheric reanalysis model.[17]

More information on all the updated inputs is available in the Inputs and Supplementary Material pack available for download from TSI's website.

2.1.2 New inputs

The following new inputs have been added to the model:

- **Electricity grid connection capital costs:** Added to incorporate the capital equipment costs for connecting to the electricity grid. Based on indicative Western Power data and their TRT1 network tariff from the Three Springs Terminal.[18]
- **Port export costs** (per tonne of iron): Added to incorporate the cost of shipping via existing ports at Geraldton and Port Hedland, following consultation with the Mid West Ports Authority. The cost of iron is assumed to be the cost onboard the export vessel (Free on Board).

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[14] As they relate to Reference Tariff TRT1 at Three Springs Terminal exit point. Western Power, *2025/26 Price List for the Western Power Network*.

[15] Consists of a 330kV terminal to be installed at the plant end of the Three Springs Terminal transmission line. This is a conservative (i.e. upper bound) estimate with a comprehensive network analysis needed to determine actual plant-end infrastructure. Additional scaled costs associated with existing terminal upgrades, communications, all line and site location work.

[16] See note 6.

[17] Solar capacity factors are from Renewables.ninja (MERRA foundation) for a single-axis tracking solar panel. Wind traces are from the BARRA-C2 reanalysis model, with capacity factor calculations based on a Vestas V162-7.2MW wind-to-power conversion curve at a hub height of 100 metres and assuming an air density of 1.2250kg/m^3. BARRA-C2 is on average superior to MERRA, ERA5 and BARRA as per a validation study. This has been confirmed by TSI's own analysis of sodar instrument readings in central Queensland. Renewables.ninja, "About"; Bureau of Meteorology, BARRA-C2 reanalysis; Vestas, *Performance Specification: EnVentus V162-7.2 MW*; Palmer et al., "Validation of BARRA2 and Comparison with MERRA-2 and ERA5 Using Historical Wind Power Generation."

[18] Western Power, *2025/26 Price List for the Western Power Network*, 27ff.

- **Road export costs** (per tonne of iron): Added to incorporate the cost of road freight between the iron-making plant and relevant port.[19]
- **Historic wholesale electricity market bid data:** Dispatch interval supply curves from AEMO's WEM case files (section 2.5 details how this was applied).[20]
- **Natural gas pipeline costs:** Added capital cost for a small gas lateral pipe (i.e. 3-7 TJ/day depending on ore type) is included for the pelletising process.[21]

Figure 6 shows the design of the Oakajee and Boodarie green iron projects in relation to their energy sources and required project infrastructure.

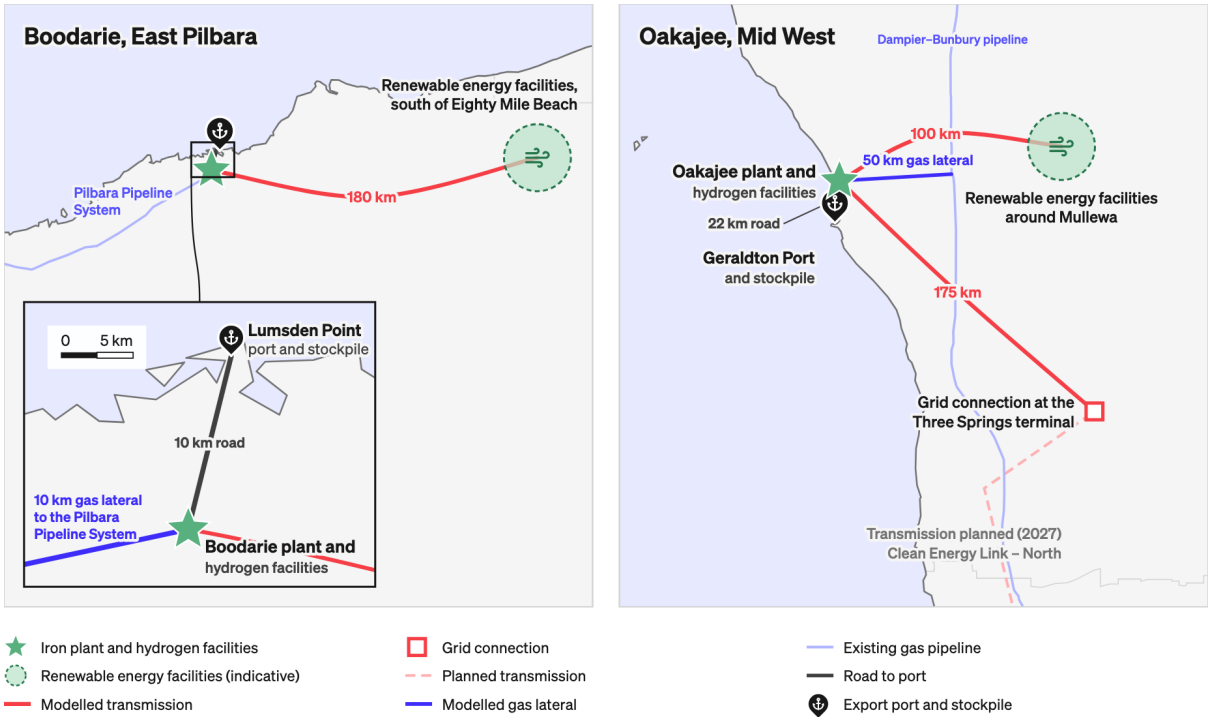


Figure 6. Location of capital items and export facilities.

Note: 'Plant facilities' refer to system control, water treatment, pelletiser, reduction, ESF and briquetting facilities that vary in size and application by scenario. 'Hydrogen facilities' include electrolysers, tank storage and 5km of pipeline. 'Renewable energy facilities' include solar panels, wind turbines and batteries. Installation sizes are not reported in the diagram but vary by scenario and are reported in Appendix D.

Source: The Superpower Institute analysis.

A complete listing of the inputs for the WA model is available for download from TSI's website.

[19] Department of Infrastructure, Transport, Regional Development, Communications, Sport and the Arts, "Supply Chain Transport and Logistics Dashboard."

[20] Australian Energy Market Operator, "Market Data WA," case files.

[21] GHD, *Gas Infrastructure Cost: Building Block Costs for Gas Infrastructure*.

2.2 Western Australian Green Iron Scenarios

Three of the five locations considered in *GIPA* were in Western Australia - the Pilbara, Geraldton and Kwinana.

The *GIPA* Pilbara scenario situated the green iron plant at the Boodarie Strategic Industrial Area in Port Hedland using local hematite ore. Renewable energy generation was off-grid and located nearby. The Kwinana scenario refers to the Strategic Industrial Area south of Perth and assumed lower-grade hematite ore was shipped in from Port Hedland. Renewable energy generation was located near Narrogin and connected to the SWIS. The Geraldton scenario assumed a green iron facility in the vicinity of the Geraldton Port. Renewable energy generation was located around Mullewa and assumed a connection to the SWIS.

The updated scenarios for *Digging Deeper* again locate green iron production in the Pilbara within the Boodarie Strategic Industrial Area, with off-grid renewable energy generation. The location of the renewable energy system has been updated to around 80 kilometres due south of Eighty Mile Beach to capture the best available renewable resources as informed by the Bureau of Meteorology's latest BARRA-2 weather reanalysis model. The Mid West green iron project is now located within the Oakajee Strategic Industrial Area, 20km north of Geraldton. The facility is grid connected with behind-the-meter renewable energy generation located around Mullewa.[22] Facilities located in SA and QLD were not modelled.

Scenarios in our WA model now differentiate two Mid West WA magnetite concentrate grades: high-grade concentrate, also known as DRI-EAF-grade (DR-grade) and lower-grade concentrate, referred to as blast furnace grade (BF-grade).

DR-grade magnetite concentrate has a high iron and low gangue content and is of suitable quality that the resulting DRI product can be directly fed into an electric arc furnace. This was modelled in *GIPA* for the Eyre Peninsula and Geraldton scenarios and remains in our WA model at Oakajee.

BF-grade magnetite concentrate is named for its conventional use in blast furnaces to improve plant productivity and offset the impacts of increasing phosphorus content in hematite fines. As it is not of suitable quality to produce DRI suitable for an electric arc furnace, it was not included in *GIPA*.

The BF-grade magnetite has been added to the WA analysis for two purposes. First, to represent the current production grade of concentrate from Western Australian magnetite operations. This is the most likely local supply of magnetite available to early green iron projects. Secondly, to compare the relative cost of using the available BF-grade concentrate to a DR-grade concentrate. Similar to hematite ores, removal of sufficient gangue from magnetite ore is not always possible through beneficiation, so an ESF is required to remove the gangue, by melting the DRI produced from BF-grade magnetite. With the gangue removed by the ESF,

[22] Kwinana is not included in this analysis, reflecting new government prioritisation for the estate. However, we acknowledge that there are proposals for Kwinana to host two green iron pilots - Calix's Zesty plant and the NeoSmelt plant sponsored by BHP, Rio Tinto, BlueScope, Mitsui Iron Ore Development and Woodside.

the resulting pig iron can then meet the specifications of an EAF.[23] Simply, **Figure 7** shows that the grade of direct reduced iron depends on the grade of the iron ore feedstock.

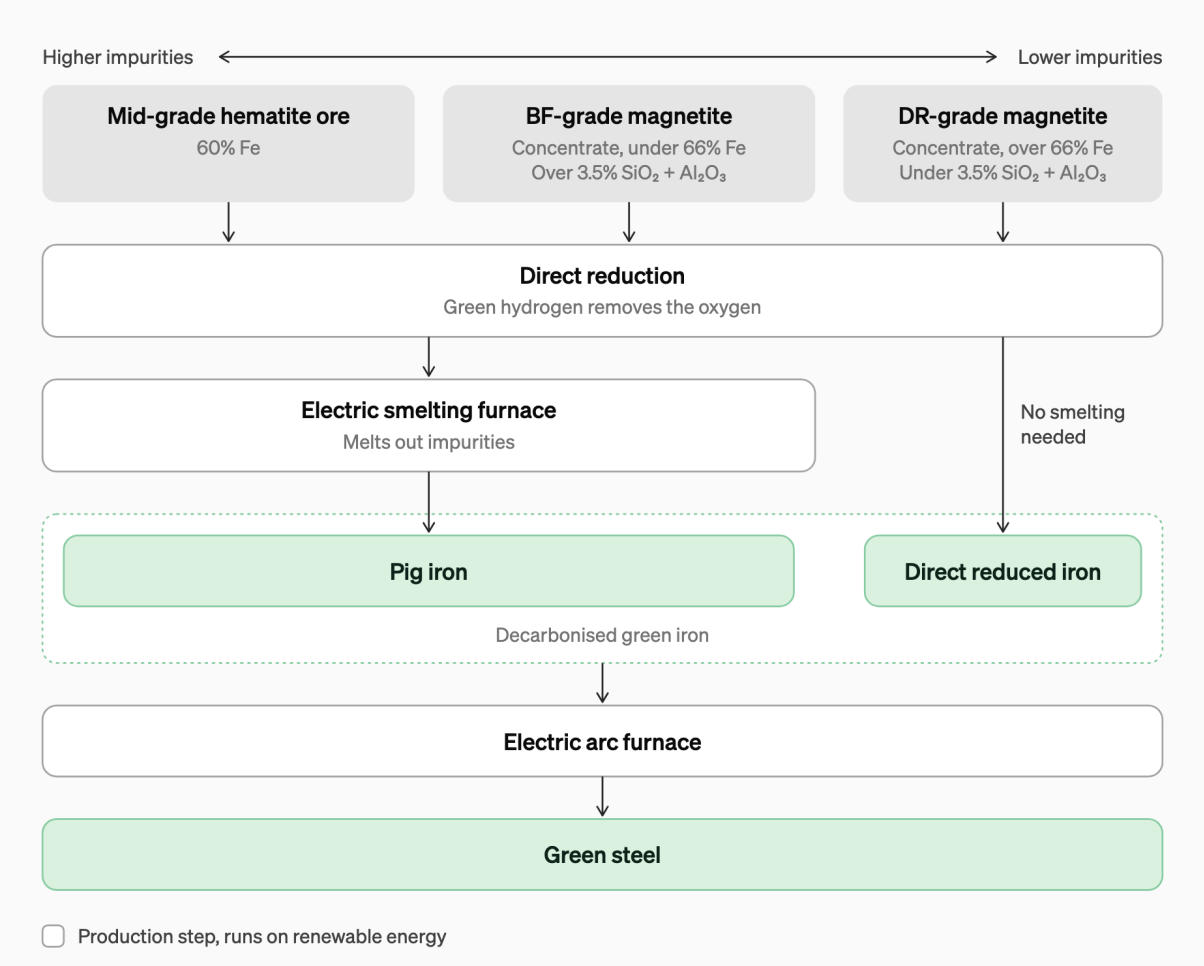


Figure 7. WA green iron model production pathways for different ore grades

Notes: This is a simplified depiction of iron and steel-making processes designed to capture dominant and most likely processes. Direct-reduced iron can be used in a Basic Oxygen Furnace.

Source: The Superpower Institute analysis.

Lastly, *GIPA* found that the lowest cost sites for renewable energy and green hydrogen production may be far away from iron ore deposits. To test this, an additional scenario shipping hematite ore from the Pilbara to Oakajee was added to test the LCOI using hematite in the less capital-intensive environment of the Mid West.

[23] Pig iron is produced when DRI is melted in an ESF, to separate metallic iron from non-ferrous gangue. Pig iron has an iron content of at least 92 per cent iron with low gangue and is stable for transport in its cast ingot form. DRI, also known as sponge iron, is reduced without melting the ore. DRI generally contains between 86 and 94 per cent iron with 3.9 to 8.4 per cent gangue. It is porous and highly reactive which is why it is converted to hot briquetted iron (HBI) for transport.

Box 1: Magnetite mining in WA

Two of the three operating magnetite mines in Western Australia produce a blast furnace grade concentrate for consumption in the owners' Chinese integrated steel plants.

Citic Pacific operates the Sino Iron project at Cape Preston, 100km southwest of Karratha. Karara Mining Limited operates the Karara mine on behalf of Ansteel Group, 200km east of Geraldton. The third magnetite operation, Iron Bridge, is an unincorporated joint venture between Fortescue Metals Group (69 per cent) and Formosa Steel (31 per cent), operated by Fortescue, 145km south of Port Hedland. The Iron Bridge product is supplied to the Formosa Steel integrated steel works in Vietnam and also sold by Fortescue to integrated steel works in Japan, Korea, Taiwan, China and Southeast Asia.

All three magnetite operations produce blast furnace grade concentrate, with silica content well in excess of the requirements of DRI-EAF (maximum 3 per cent). It is understood that all three operations are capable of producing a DRI-EAF suitable product, with investment in further processing and beneficiation.

While the majority of magnetite production is currently located in the Pilbara, a scenario processing magnetite ore in the Pilbara was not modelled because A Green Iron Plan for Australia showed that processing magnetite concentrate (of any grade) in the Pilbara would not be competitive relative to the Mid West. The Pilbara requires a solution for hematite.

All scenarios are based on publicly available renewable energy, mineral reserve and capital cost data. They are not based on private commercial data or designed to reflect particular project proposals. Any similarity to proposed or planned projects is unintentional.

We model a total of eight scenarios, including flexible and inflexible technologies for a single ore type in Boodarie, and for three different ore types in Oakajee.

Table 2: Updated characteristics of different iron-making locations based on refined assumptions and additional scenarios

Location	Connected to wholesale electricity market	Locational capital cost factor	Type of iron ore	Inflexible technology processing	Flexible technology processing
Boodarie (Pilbara)	No	1.55	Pilbara lower-grade hematite	Pelletisation + vertical shaft furnace DRI + ESF	Flash smelting DRI + ESF
Oakajee (Mid West)	Yes	1.15	Pilbara lower-grade hematite	Pelletisation + vertical shaft furnace DRI + ESF	Flash smelting DRI + ESF
Oakajee (Mid West)	Yes	1.15	Mid West DR-grade magnetite	Pelletisation + vertical shaft furnace DRI	Flash smelting DRI
Oakajee (Mid West)	Yes	1.15	Mid West BF-grade magnetite	Pelletisation + vertical shaft furnace DRI + ESF	Flash smelting DRI + ESF

2.3 Locational capital cost factors

Capital expenditure varies across scenarios partly because of differences in the optimal scale and pattern of investments, and partly because the cost of capital varies with location. The locational cost of capital affects the cost of delivered equipment, construction, labour and materials. *GIPA* drew on the latest national study of locational capital cost factors that provided detail across all these components, which dates to 2018.[24]

In *Digging Deeper,* stakeholders such as Horizon Power, Chamber of Minerals and Energy WA and Western Power were engaged to gauge how more contemporary projects are treating locational cost variation in the Mid West and Pilbara. This engagement saw the 'Pilbara premium' increase from 1.34 to 1.55, while the Mid West moderated from 1.24 to 1.15.

These factors and the GenCost data to which they are applied, reflect the costs generally available to a new project in each region. Some established operators in the Pilbara have indicated they can build renewable energy assets at materially lower cost, drawing on existing infrastructure, scale, supply chain relationships and access to finance. These advantages are unlikely to be available to every proponent, particularly new entrants. If lower costs prove achievable more widely, the cost of green iron in the Pilbara would fall, strengthening the case for accelerating enabling work in the region. Similar reductions would also be likely to lower costs in the Mid West, where grid access and stronger renewable resources would continue to give it a relative advantage. TSI welcomes continued engagement with industry to test these assumptions.

For a detailed breakdown of data points used to inform locational capital cost changes, download the Input and Supplementary Materials Pack from the TSI website.[25]

2.4 Local conditions in WA

GIPA identified the under-provision of common-user infrastructure as a market failure. To address it, TSI recommended that the federal and state governments support new natural-monopoly infrastructure essential to green exports in locations that could support multiple green iron projects.

In the Pilbara and Mid West, the Boodarie and Oakajee Strategic Industrial Areas (SIAs) have been selected for our WA model based on their proximity to existing iron ore supply chains, planned common-user infrastructure and proposed connections to large-scale renewable energy developments. Both the Boodarie and Oakajee SIAs could support multiple green iron projects.

There are thirteen SIAs in Western Australia. Their purpose is to attract industrial investment through the provision of pre-planned, infrastructure-ready precincts in strategic locations to reduce costs and facilitate material efficiencies for industry. However, without incentives for foundation tenants to fund common-user infrastructure at an efficient scale, including

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[24] GHD, *AEMO Costs and Technical Parameter Review*, 116 and appendix A.

[25] Note that not all consultation information could be publicly disclosed.

connections to power, water, and gas[26], most SIAs remain undeveloped.[27] In contrast, the successful early development of the Kwinana SIA was driven by the combination of State Agreements which provided advantageous long-term conditions, and turnkey and enabling infrastructure to the foundation tenants.[28]

Recognising the market failure to attract private investment in common-user infrastructure at an efficient scale, the Western Australian Government's allocation of $1 billion to the Strategic Industries Fund aims to activate SIAs through public funding for planning studies and development of business cases for common-user and enabling infrastructure investment. Boodarie and Oakajee are two of the SIAs identified by the government for priority investment in activation activities.

2.4.1 Boodarie

The Boodarie Strategic Industrial Area, situated around ten kilometres southwest of Port Hedland in the Pilbara, is emerging as the epicentre for the Pilbara's transition to value-added, low-emissions industry. Designed to accommodate strategic downstream gas and mineral processing, the precinct already benefits from proximity to enabling infrastructure: gas, water and transmission networks traverse the site, and a 210-megawatt gas-fired power station supplies industrial customers through the North West Interconnected System (NWIS).

An infrastructure corridor links Boodarie directly to the Port of Port Hedland[29] and a priority common-user transmission corridor has been designated from the Great Sandy Desert to Boodarie, to provide energy supply options for emerging green industries in the SIA.[30] Land within the estate has been allocated to green iron, green ammonia, renewable hydrogen and carbon capture and storage projects, signalling the shift to clean downstream production for export.

2.4.2 Oakajee

The Oakajee Strategic Industrial Area, located 23 kilometres north of Geraldton in the Mid West, is conceived as a base for export-oriented industry and has been identified by government as the proposed location for the Mid West Hydrogen Hub. Its extensive buffer zone provides scope for solar and wind generation, underpinning the region's renewable energy potential.

Land allocations have been made to projects in renewable hydrogen, green ammonia and associated processing industries. A deepwater port adjacent to the industrial area is proposed

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[26] The Strategic Industrial Area framework was introduced in the mid-1980s as an alternative pathway to State Agreements for attracting industrial investment.

[27] Chamber of Minerals and Energy of Western Australia, *Activating WA's Strategic Industrial Areas*.

[28] Under the *Oil Refinery (Kwinana) Agreement Act 1952* the government agreed to provide turnkey infrastructure at a cost that halted all other public works spending at the time. Horsley, "The Role of the State and Capital in the Development of Western Australia"; Western Australia, *Parliamentary Debates*, Legislative Assembly, 6 March 1952, 1894–99.

[29] The Lumsden Point development will expand the Port of Port Hedland's export and import capabilities. Imports through Lumsden Point are expected to begin in mid-2026.

[30] The Great Sandy Desert corridor will link Boodarie with the proposed Australian Renewable Energy Hub, which intends to supply renewable electricity and pipe renewable hydrogen via the corridor. Energy Policy WA, "The Great Sandy Desert Corridor"; Australian Renewable Energy Hub, "About AREH."

to meet the future export needs of the region, but in the short term, Geraldton Port has some capacity for green iron exports through its dedicated iron ore facilities.

While Boodarie and Oakajee are logical locations for green iron production, they require common-user infrastructure to unlock private investment. These infrastructure requirements are substantial and are not in scope; this modelling exercise is confined to project-specific costs. Common-user infrastructure and SIA activation and investment for green iron is considered in the *Roadmap*.

2.5 Interaction between green iron producers and the Wholesale Electricity Market

This section describes how the interaction between a Mid West green iron facility and the Wholesale Electricity Market (WEM) is modelled, for both importing and exporting electricity, and as a participant in the Reserve Capacity Mechanism (RCM). This is applicable to the model for Oakajee only.

This model is an update on the modelling used in *GIPA*. It more accurately approximates both the cost of importing electricity and value in exporting electricity for the green iron facility. However, it remains an approximation of a much more complex commercial reality.

A summary of how we have modelled the interaction with the WEM is provided below. Further details are provided in **Appendix C.**

2.5.1 The WEM

The WEM operates as a merit order dispatch system where:

1. **Supply offers** are ranked by price (lowest to highest)
2. Offers are **dispatched** in order until demand is met
3. The **clearing price** is set by the most expensive offer dispatched (marginal pricing)
4. All dispatched participants receive the clearing price

The WA green iron model **imports** electricity when there is insufficient electricity generated from the renewable assets directly connected to the green iron plant. The plant's total demand for electricity includes the needs of water, hydrogen and iron production. The import of electricity is limited by the emissions constraint of the HPTI (0.6 kg CO2e per kg of hydrogen) over the course of the simulated year.

In applying this constraint, the model uses the physical emissions intensity of electricity drawn from the grid. In practice, this limits grid imports to around 2 to 3 per cent of the plant's annual electricity demand. This is a conservative treatment of potential import volumes. Clean Energy Regulator guidance indicates that grid electricity matched by surrendered renewable energy certificates may be counted as renewable, and large WA electricity users, including desalination plants, already buy renewable electricity through power purchase agreements. Arrangements like these could allow a green iron plant to make greater use of the grid for firming and lower its costs, particularly for inflexible technologies. The rules are still evolving, however, and some

export markets apply stricter tests when calculating the carbon content of products: the European Union, for example, will require hourly matching of renewable energy from 2030. A proponent targeting those markets may face constraints closer to those modelled here. We have not modelled these alternatives. The *Roadmap* discusses the standards and certification questions they raise.

The model will **export** electricity when all the plant's requirements for electricity have been met, and there is still additional electricity available from the directly connected renewables (i.e. electricity which would otherwise be curtailed). If electricity prices are high enough that the value of exporting electricity is greater than the value of green iron, electricity demand from hydrogen production may also be reduced by the system.

The model uses historic market data in each hour to recreate the electricity dispatch of all facilities in the WEM, based on the prices and volumes they offered. For the import case, the total system demand is increased by the demand from the green iron facility, which may increase the clearing price. For the export case, an export volume is offered into the market. This may reduce the clearing price.

2.5.2 The Reserve Capacity Mechanism

An important aspect of the WEM is the Reserve Capacity Mechanism (RCM). The RCM is designed to ensure that there is sufficient generation capacity available to meet demand during peak periods in a year. Typically, these are hot days with a high air conditioning load across the SWIS.

The RCM imposes costs on loads which operate during peak periods and provides revenue to generators which are available to provide capacity during peak periods. Revenue can also be generated by loads which are able to guarantee a certain level of turn down during peak periods.

For the WA model, we assume that the flexible technology would not incur RCM costs because it reduces its demand for grid electricity during peak periods. To approximate this, we include as inputs into the model a flag for the peak periods for the year of historic weather and market data. During these periods grid imports are prohibited to avoid incurring an RCM liability.

For the inflexible iron plant, we assume that it is not possible to reduce production to avoid the RCM liability.

03.

Results from the Western Australian Green Iron model

The cost of iron for each of the *Digging Deeper* and comparable *GIPA* scenarios and technology types is shown in **Figure 8** for the Mid West and **Figure 9** for the Pilbara. Detailed results are tabulated in **Appendix D**.

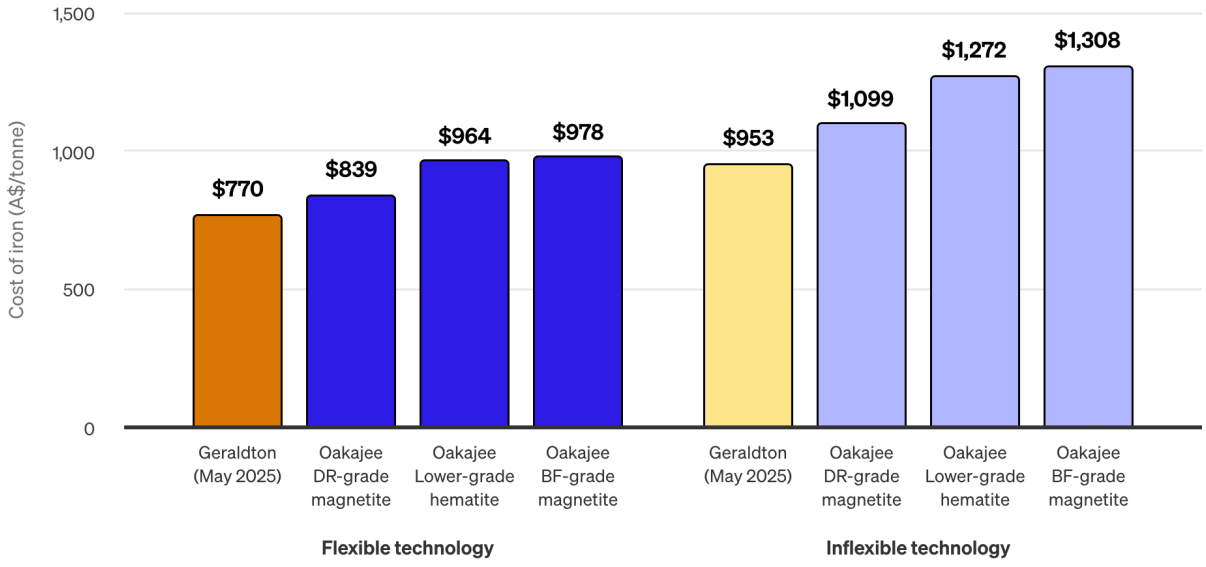


Figure 8: Summary of the levelised cost of iron for all modelled Mid West scenarios

Notes: Includes results from *GIPA* and the Western Australia Green Iron Model. DR-grade magnetite refers to magnetite concentrate with a grade >66 per cent Fe and <3.5 per cent SiO_2+Al_2O_3. BF-grade magnetite refers to a concentrate with a grade of <66 per cent Fe and >3.5 per cent SiO_2+Al_2O_3. Lower-grade hematite refers to Pilbara fines ore with a grade of 60 per cent Fe. Inflexible technology refers to iron-making technology that operates continuously at a steady rate. Flexible technology can vary its output to match variable renewable electricity supply.

Source: Bivios and The Superpower Institute analysis.

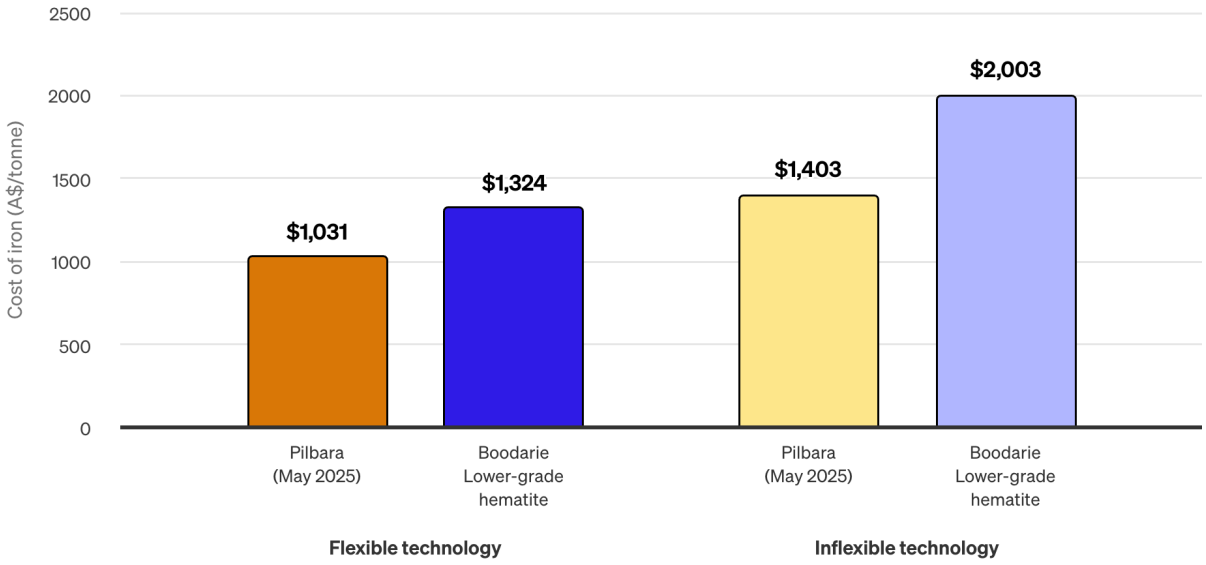


Figure 9: Summary of the levelised cost of iron for all modelled Pilbara scenarios

Notes: Includes results from *GIPA* and the Western Australia Green Iron Model. Lower-grade hematite refers to Pilbara fines ore with a grade of 60 per cent Fe. Inflexible technology refers to iron-making technology that operates continuously at a steady rate. Flexible technology can vary its output to match variable renewable electricity supply.

Source: Bivios and The Superpower Institute analysis.

One driver of differences in the cost of iron between the scenarios is the difference in energy use between the scenarios. Energy use for each scenario is shown in **Figure 10**.

The flexible technology uses less energy than the inflexible technology, because it does not require energy to process iron ore into pellets before the reduction process.

Energy use is also increased for the cases which require treatment after the direct reduction process in an ESF. The inflexible technology, using lower-grade ores, uses the most energy.

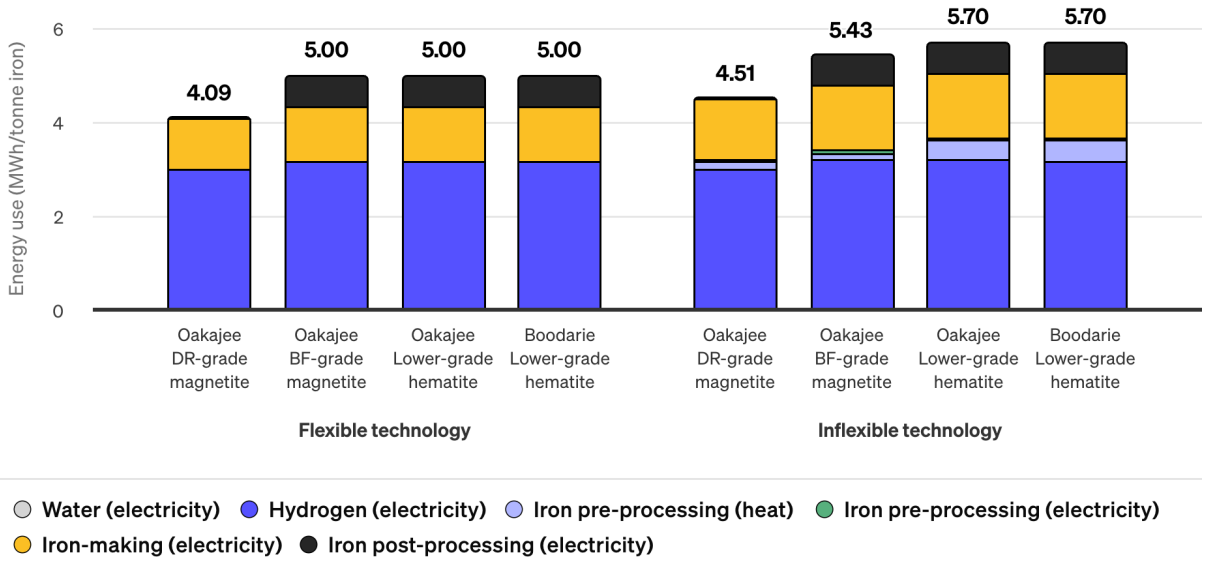


Figure 10: Breakdown of energy use for the updated scenarios.

Notes: Water refers to desalination electricity requirements; hydrogen is the electrolysis electricity requirement; iron pre-processing is the electricity and natural gas MWh-equivalent heating required for pelletisation; iron-making is the electricity for respective direct reduction processes, including heating ore and reducing gas; iron post-processing captures briquetting and ESF operations. See the model inputs data pack for more information. Source: Bivios and The Superpower Institute analysis.

Figure 11 provides a breakdown of contributions to the cost of iron for each scenario and technology type.

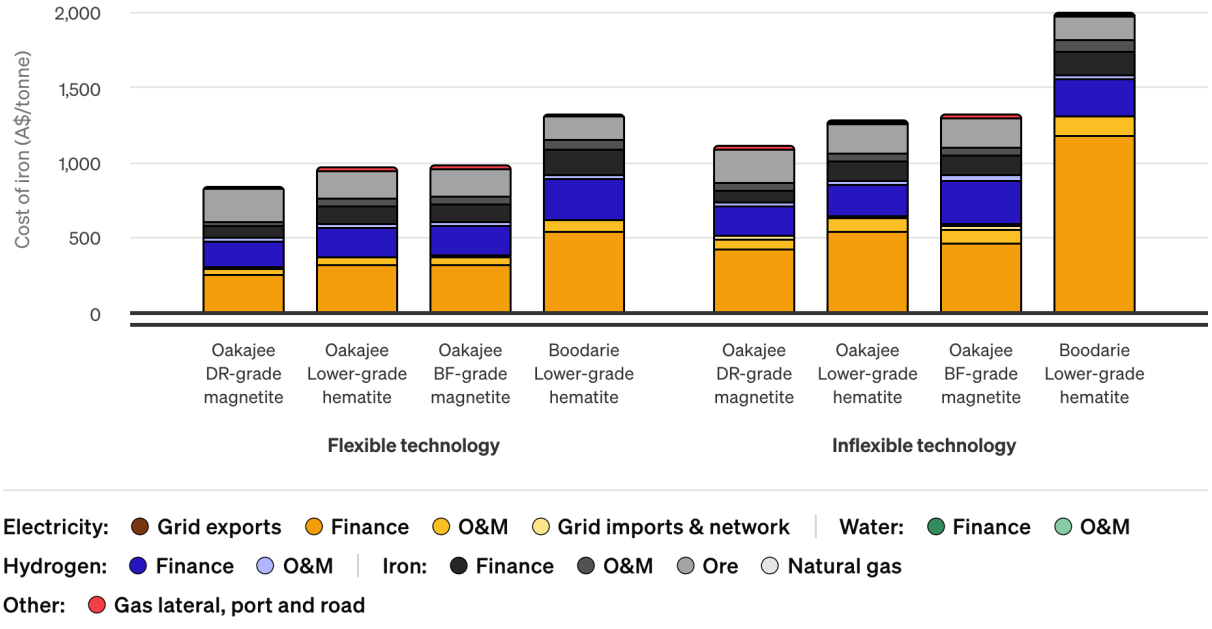


Figure 11: Breakdown of cost of iron for the updated scenarios

Note: "Finance" refers to annualised capital costs, including capital recovery and the modelled return on capital. "O&M" refers to operating and maintenance costs. "Electricity" includes solar, wind, batteries, transmission, electrical distribution and grid-connection infrastructure. "Grid exports" are electricity-sale revenues; "grid imports and network charges" are purchased electricity costs, grid connection and capacity charges. Water covers desalination, storage and distribution infrastructure. "Hydrogen" includes electrolyser, hydrogen storage

and distribution infrastructure. “Iron” covers all relevant iron-making plant costs from pre- to post-processing. “Ore” is the cost of purchased iron-ore feedstock, including relevant transport and handling. “Natural gas” is the fuel consumed in processing, principally for pelletisation in the inflexible cases. “Gas lateral, port and road” combines the capital and operating costs of the local gas connection and transport infrastructure, including port-use fees and road-haulage charges.

Source: Bivios and The Superpower Institute analysis.

3.1 The Mid West

The updated WEM interaction significantly reduces revenue from grid exports relative to the comparable *GIPA* May 2025 scenario. This increases the costs of production and is represented as an increase in ‘Electricity - Grid Exports cost’ component of LCOI. For the inflexible technology in particular there is a large reduction in capital costs for hydrogen generation and storage relative to the May 2025 scenario.

For the inflexible technology, annual revenue from grid exports falls from $331 million to $31 million, adding around $120 per tonne to the cost of iron. This accounts for most of the increase in the LCOI. Total capital costs are almost unchanged. Higher unit costs for solar and electrolysers in GenCost 2025-26 are offset by the lower locational cost factor for the Mid West (1.15, down from 1.24) and by the re-optimised system. That system uses smaller electrolysers and less hydrogen storage, a smaller grid connection (around 300 MW, down from 826 MW) and much more battery storage (around 8,100 MWh, up from 1,100 MWh). For the flexible technology, export revenue falls to zero, adding around $115 per tonne, which outweighs lower capital costs.

Figures 12 and **13** provide a breakdown of the change in contributions to the cost of iron from the comparable Geraldton (May 2025) to Oakajee scenario by technology type.

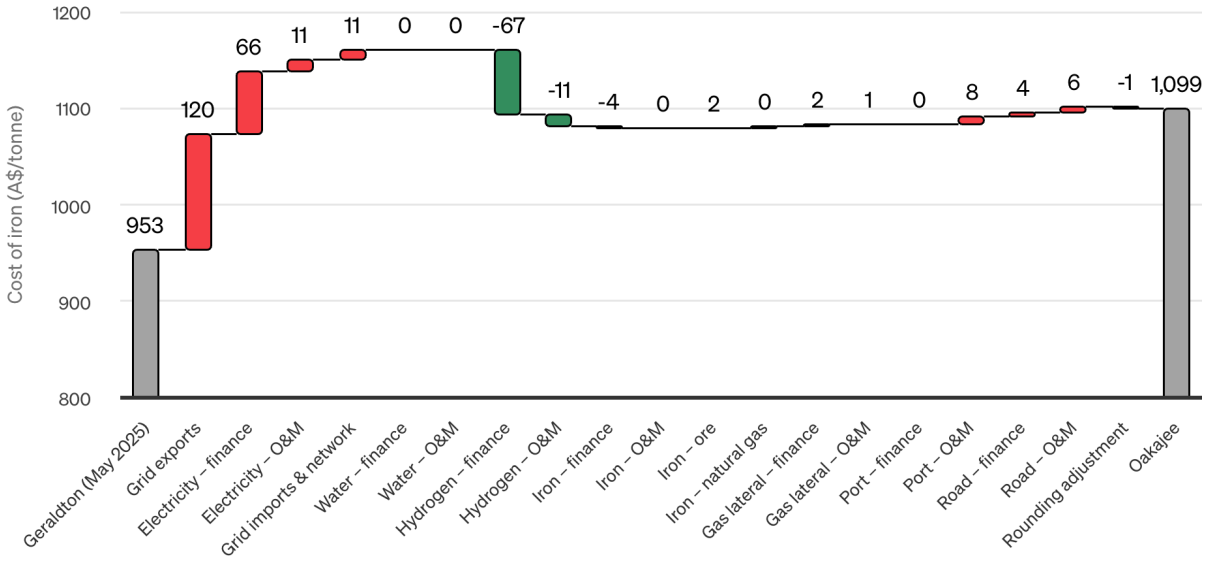


Figure 12: Breakdown of differences in cost of iron between Geraldton case (May 2025) and Oakajee, DR-grade magnetite case, for inflexible technology.

Note: “Finance” refers to the annualised cost of recovering capital investments. “O&M” refers to operating and maintenance costs. Cost categories include electricity (solar, wind, batteries, electrical distribution, and grid-connection infrastructure), water (desalination facility and storage), hydrogen (electrolysers, hydrogen storage, and distribution infrastructure), iron (pelletisation, DRI, briquetting and ESF assets), natural gas (cost of natural

gas consumed in processes), gas lateral (local pipeline connection to the plant), port (O&M to reflect port-use charges such as vessel, berth, and wharfage fees), and road (road infrastructure connecting plant to port and haulage charges).

Source: Bivios and The Superpower Institute analysis.

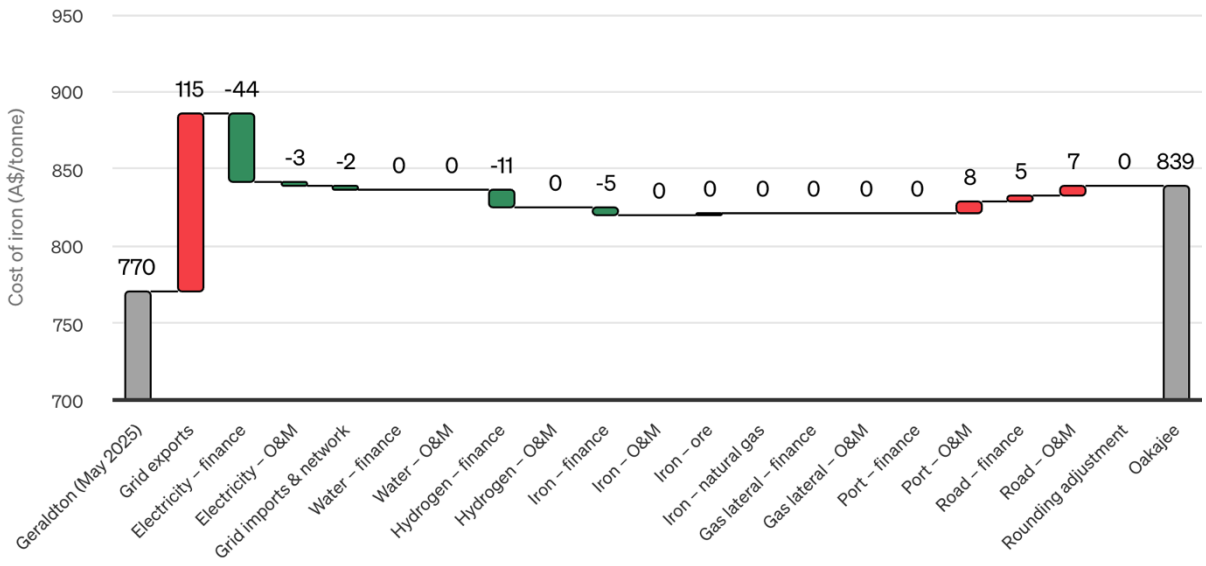


Figure 13: Breakdown of differences in cost of iron between Geraldton case (May 2025) and Oakajee, DR-grade magnetite case, for flexible technology.

Note: "Finance" refers to the annualised cost of recovering capital investments. "O&M" refers to operating and maintenance costs. Cost categories include electricity (solar, wind, batteries, electrical distribution, and grid-connection infrastructure), water (desalination facility and storage), hydrogen (electrolysers, hydrogen storage, and distribution infrastructure), iron (pelletisation, DRI, briquetting and ESF assets), natural gas (cost of natural gas consumed in processes), gas lateral (local pipeline connection to the plant), port (O&M to reflect port-use charges such as vessel, berth, and wharfage fees), and road (road infrastructure connecting plant to port and haulage charges).

Source: Bivios and The Superpower Institute analysis.

3.2 The Pilbara

The updated locational capital cost factor drives the increase in electricity financing. This is the largest contribution to the Boodarie cost increases relative to the comparable Pilbara scenario in *GIPA*. It adds approximately $436 per tonne for inflexible production and $116 per tonne for flexible production, equivalent to 73 per cent and 40 per cent of the respective net LCOI increases.

Figures 14 and **15** provide a breakdown of the change in contributions to the cost of iron from the Pilbara (May 2025) to the Boodarie scenario by technology type.

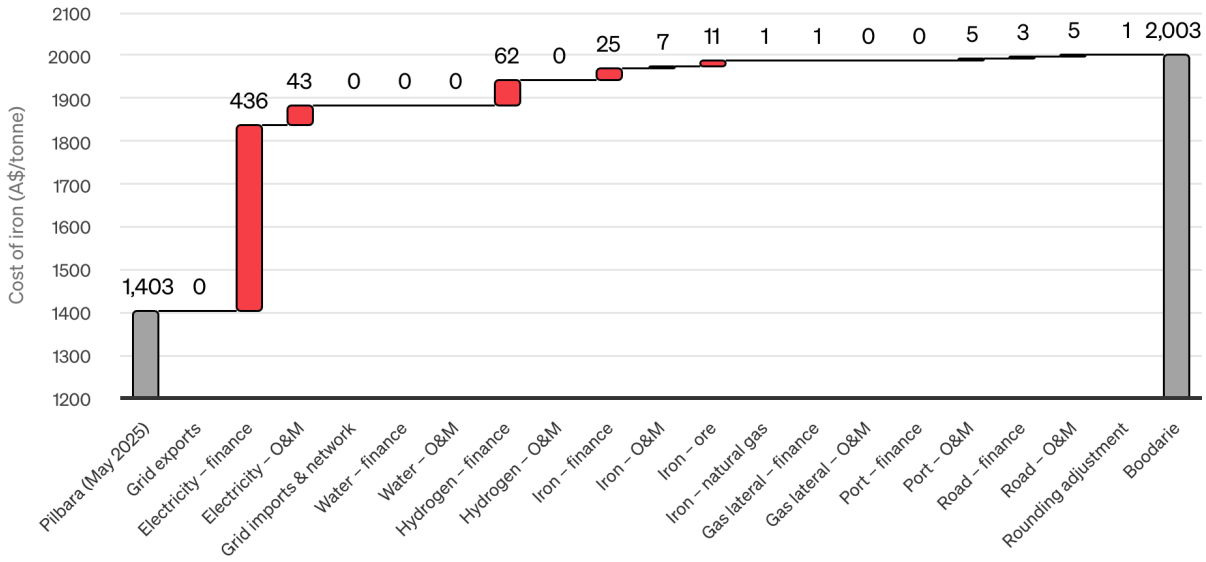


Figure 14: Breakdown of differences in cost of iron between Pilbara case (May 2025) and Boodarie, lower-grade hematite case, for inflexible technology.

Note: "Finance" refers to the annualised cost of recovering capital investments. "O&M" refers to operating and maintenance costs. Cost categories include electricity (solar, wind, batteries, electrical distribution, and grid-connection infrastructure), water (desalination facility and storage), hydrogen (electrolysers, hydrogen storage, and distribution infrastructure), iron (pelletisation, DRI, briquetting and ESF assets), natural gas (cost of natural gas consumed in processes), gas lateral (local pipeline connection to the plant), port (O&M to reflect port-use charges such as vessel, berth, and wharfage fees), and road (road infrastructure connecting plant to port and haulage charges).

Source: Bivios and The Superpower Institute analysis.

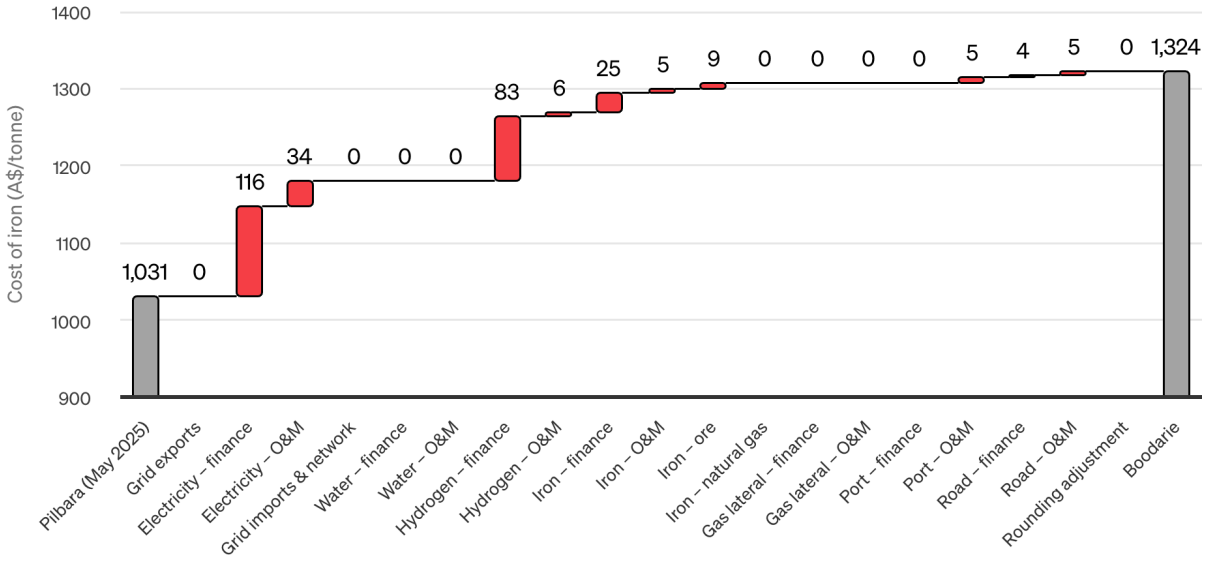


Figure 15: Breakdown of differences in cost of iron between Pilbara case (May 2025) and Boodarie, lower-grade hematite case, for flexible technology.

Note: "Finance" refers to the annualised cost of recovering capital investments. "O&M" refers to operating and maintenance costs. Cost categories include electricity (solar, wind, batteries, electrical distribution, and grid-connection infrastructure), water (desalination facility and storage), hydrogen (electrolysers, hydrogen storage, and distribution infrastructure), iron (pelletisation, DRI, briquetting and ESF assets), natural gas (cost of natural gas consumed in processes), gas lateral (local pipeline connection to the plant), port (O&M to reflect port-use

charges such as vessel, berth, and wharfage fees), and road (road infrastructure connecting plant to port and haulage charges).

Source: Bivios and The Superpower Institute analysis.

Tables of results for each scenario are provided in **Appendix D**.

04.

Conclusions

With updated inputs the WA model shows important determinants of green iron costs in the Mid West and the Pilbara. Six conclusions follow. They concern how a plant interacts with the electricity market, the value of grid and transport infrastructure, the processing needs of WA's ores, the relative costs of the two regions and the role of natural gas. Together, they inform the *Roadmap's* assessment of where early projects are most likely to succeed and where public support can most effectively crowd-in private investment**.**

4.1 A more realistic model of the interaction with the WEM reduces electricity export revenue significantly

Compared to *GIPA,* the most significant change to the results for the Mid West is a reduction in the revenue generated through the sale of unused renewable energy back to the market, either because electricity would have otherwise been curtailed, or because the model reduces hydrogen production when electricity prices are high.

The benefits from turning down electrolysers in response to high WEM prices are small, partly driven by the price cap in the WEM and partly due to the suppressing impact of large exports on the clearing price , which is now captured under our revised modelling approach.

Export revenue may still provide benefit for a small plant in the Mid West, but for the 2.5 million tonnes per annum plant modelled, the results do not demonstrate a benefit for either flexible or inflexible plants from exports to the grid because of the impact of this size of plant on the WEM Real-Time Market, as shown in **Figure 16**. The value of a grid connection therefore lies mainly in firming supply rather than in trading electricity.

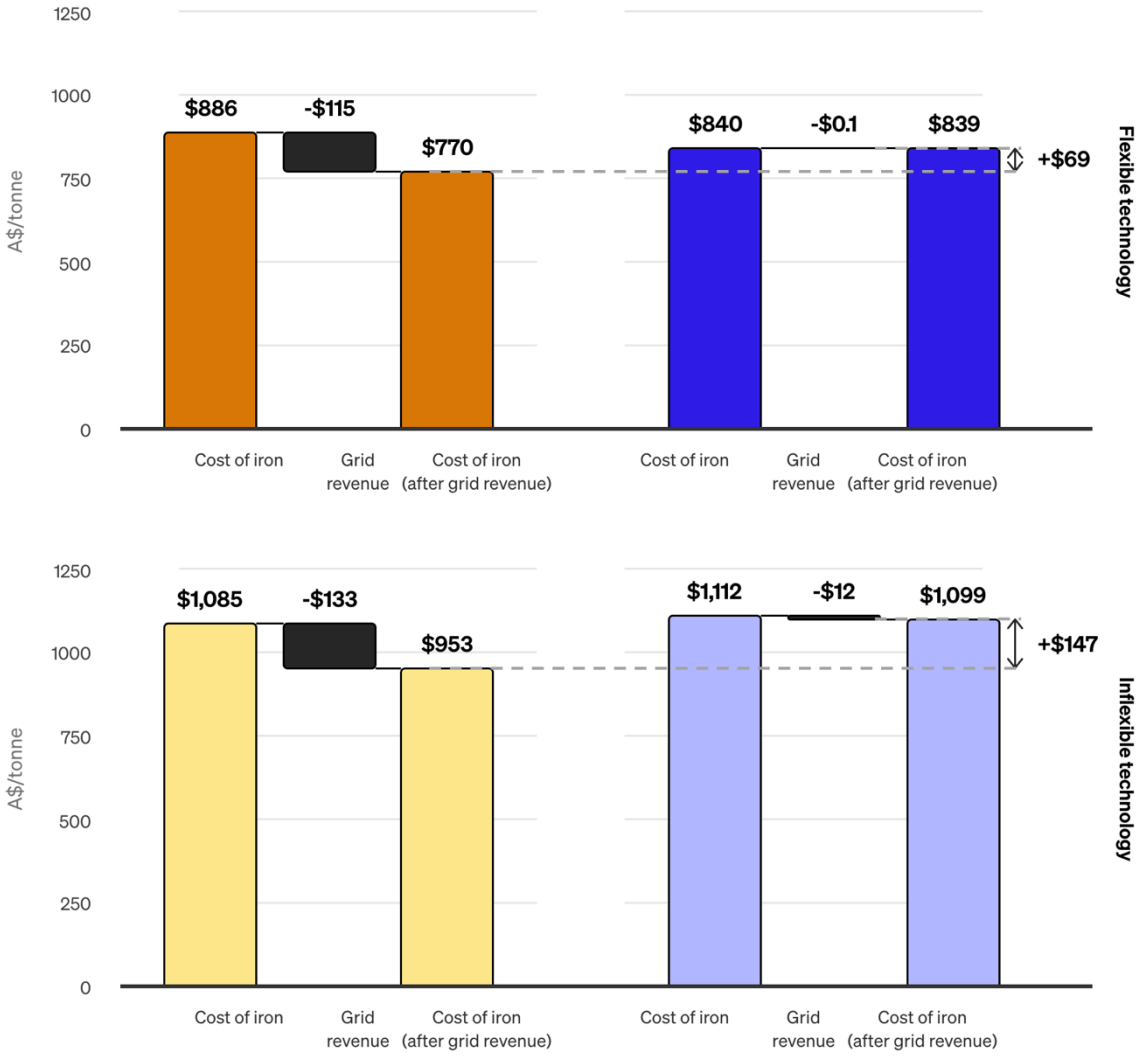


Figure 16: Updates to the interaction between the green iron plant and the WEM results in substantial reductions in grid revenue at the production scale modelled.

Note: Our updated WA model models the impact of exporting electricity into the RTM on the market clearing price. The additional supply tends to suppress the market price, reducing the revenue available from exporting electricity; see Appendix C for further detail.

Source: Bivios and The Superpower Institute analysis.

4.2 Investment in electricity grid connection will lower the cost of iron

In *GIPA,* a key finding was that an electricity grid connection, up to a certain size, will tend to reduce the cost of iron. This is because of the ability to firm the supply of electricity for iron-making. The impact was most pronounced for the inflexible technology.

Figure 17 illustrates the relationship between different sizes of grid connection and the cost of producing iron with inflexible technology and DR-grade magnetite at Oakajee. There are benefits from a grid connection for both flexible and inflexible technologies, reflected in a lower LCOI. The lowest tested LCOI occurs at 300MW for inflexible production and 28MW for flexible production. These results include the additional costs of a larger grid connection and the

transmission infrastructure required to connect the iron-making system to the electricity grid. For the inflexible technology, the benefit of a grid connection is more than $80 per tonne.

For a flexible green iron production system, the costs of a grid connection outweigh the benefits above 28MW. For an inflexible technology, production costs are minimised with a connection of about 300MW. Smaller connections provide less firming benefit, and larger connections cost more than they save.

Flexible technologies are at demonstration stage and unlikely to be commercially deployed in the near-term. First-of-a-kind projects are likely to use a lower-risk, inflexible technology. Frequent and ongoing consultation with green iron proponents is critical to any grid infrastructure planning for the Mid West, because the size of a grid connection affects the LCOI.

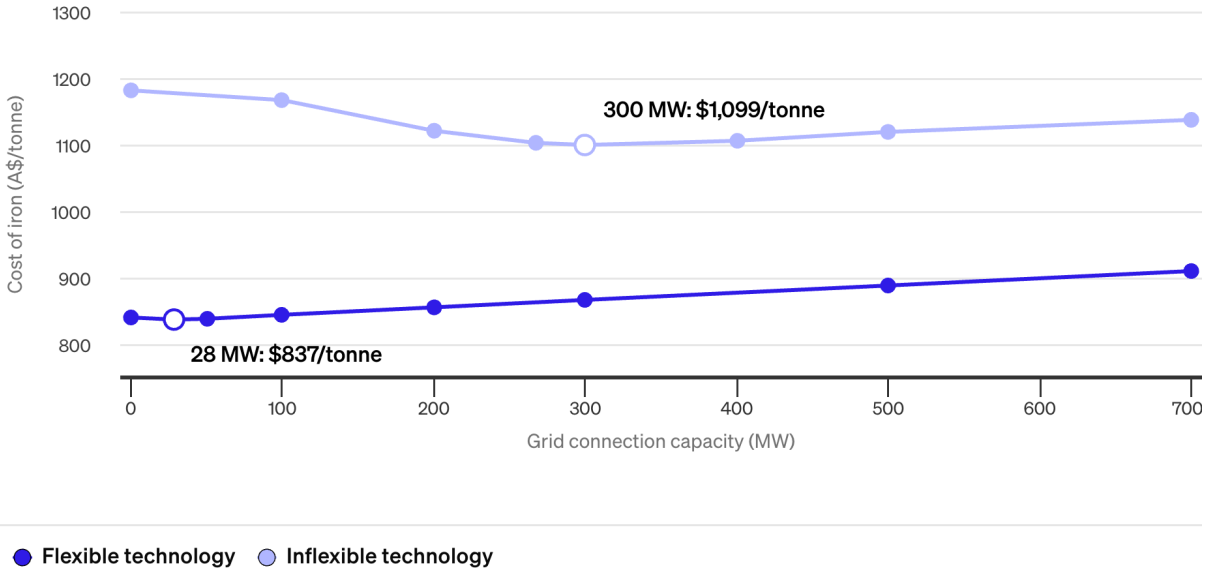


Figure 17: Grid connection size impacts the levelised cost of iron production. This example shows the lowest-cost grid connection size for the Oakajee DR-grade magnetite scenarios.

Note: circles mark the lowest tested LCOI with grid connection size.

Source: Bivios and The Superpower Institute analysis.

The higher electricity requirements for the ESF for the lower-grade ore cases will tend to increase the optimal size slightly but the trend will be similar.

The optimal size of a grid connection, at the point where its benefits outweigh costs, will depend on location-specific connection and energy costs. This result is sensitive to how grid electricity is accounted for under the HPTI (section 2.5.1) and illustrates how strongly the right energy infrastructure depends on each project's technology and location.

4.3 Relatively small investments in transport infrastructure can support the initial development of a WA green iron industry

For *Digging Deeper,* site-specific transport upgrade and use costs were added into the model. This included capital and operating expenses for building new roads, and shipping charges for importing iron ore (if applicable) and exporting HBI via Geraldton and Port Hedland.

The additional annualised infrastructure costs were small for all cases, as illustrated in **Figure 11.** These costs may be necessary to enable a project but do not change the fundamental project economics. Road upgrades account for around 1 per cent of total capital costs in the Oakajee scenarios. Both regions have existing transport networks and ports, including Geraldton Port and Port Hedland, where the Lumsden Point development is expanding capacity. Transport infrastructure may be needed to enable a project, but projects are unlikely to succeed or fail on these costs.

4.4 It is cheaper to beneficiate magnetite ore than to use an ESF to achieve DRI-EAF grade iron

Beneficiation of Mid West magnetite to DRI-EAF specification is lower cost than using an ESF to treat lower-grade ore to achieve DRI-EAF quality. Using an ESF to process BF-grade magnetite adds around $209 per tonne for the inflexible technology and $139 per tonne for the flexible technology, compared with DR-grade magnetite, as shown in **Figure 18**.

Use of an ESF introduces capital costs for both the ESF itself and the increased renewable energy required to meet the ESF's electrical demand.

This conclusion assumes that the market premium for DR-grade iron ore includes a cost for beneficiation. We further assume that beneficiation to DR-grade is possible with the magnetite resources. This assumption can only be tested on a project-by-project basis because it relies on resource specific data which is not available in the public domain.

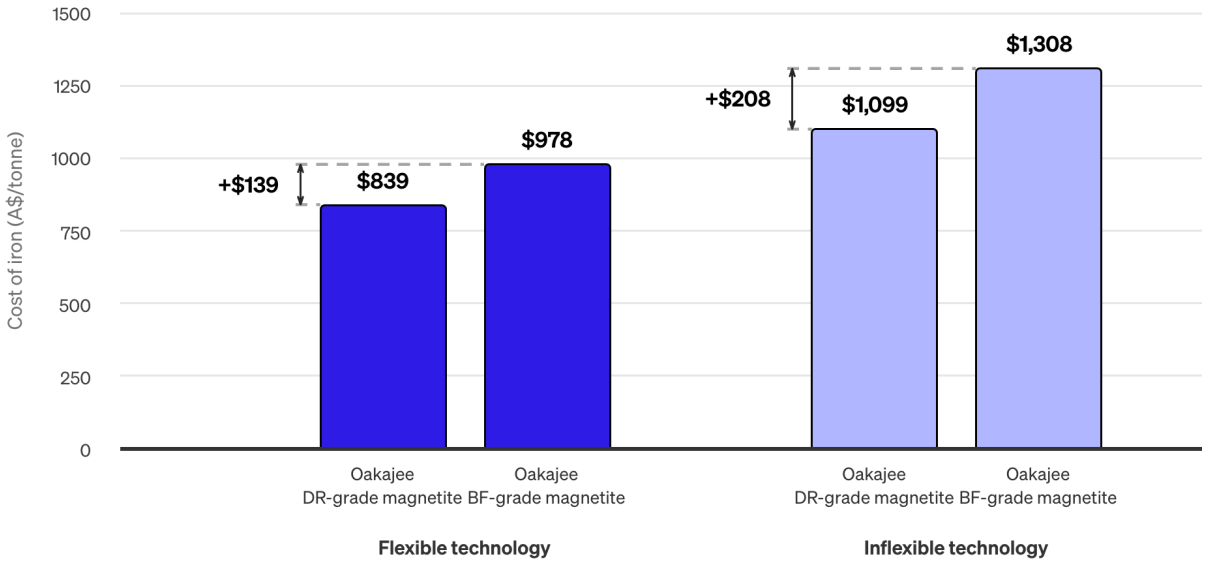


Figure 18: Beneficiation is cheaper than using an ESF to achieve DRI-EAF quality iron.

Note: DR-grade concentrate does not require an ESF downstream while BF-grade concentrate does.
Source: Bivios and The Superpower Institute analysis.

4.5 The Mid West is a lower cost location for WA's first green iron projects than the Pilbara

The Mid West and the Pilbara are the two main regions where project developers have proposed green iron projects in WA.

GIPA identified the Pilbara as relatively expensive compared to the four other locations studied. *Digging Deeper* has confirmed this finding. Costs have increased for the Boodarie case compared to the comparable Pilbara case from *GIPA*. As described in **Section 2.1,** updated renewable energy capital costs and locational cost factor drive much of the change in reported LCOIs. The former was adjusted following the release of the latest GenCost report, and the latter was adjusted upwards after discussions with companies and organisations with recent commercial experience building infrastructure in the Pilbara.

Digging Deeper has also reaffirmed *GIPA's* conclusion that flexibility in iron-making can significantly reduce costs for off-grid locations. **Figure 19** illustrates the amount of electricity that must be generated from renewable sources for the inflexible and flexible cases in Boodarie. The inflexible case requires much more generation capacity – and hence more capital expenditure on renewables– than the flexible technology, despite the final use of energy in hydrogen and iron production being similar. This is because much more energy is generated most of the time than is needed, to maintain operations 98 per cent of the time (TSI's definition of inflexible operation).

In practice, there would likely be some flexibility from an 'inflexible' technology. For example, maintenance periods could be planned during forecast periods of low renewable energy production. This would reduce the need for some of the additional renewable capacity. It may

also be possible to connect the renewable energy generation to other more flexible loads, to return some value from electricity which is assumed as curtailed without value in the current model.

Digging Deeper includes a scenario that ships Pilbara hematite to Oakajee for processing. Under our assumptions, this costs around $731 per tonne less than processing at Boodarie for the inflexible technology, and around $360 per tonne less for the flexible technology. These savings reflect the off-grid configuration and higher locational cost factor modelled for the Pilbara.

These results are based on publicly available cost data. Some proponents privately report lower costs for the Pilbara. If such costs prove achievable more widely, the cost of iron in the Pilbara would fall, strengthening the case for the enabling work already under way in the region. Where cost reductions are not specific to the Pilbara, they would lower costs in the Mid West too.

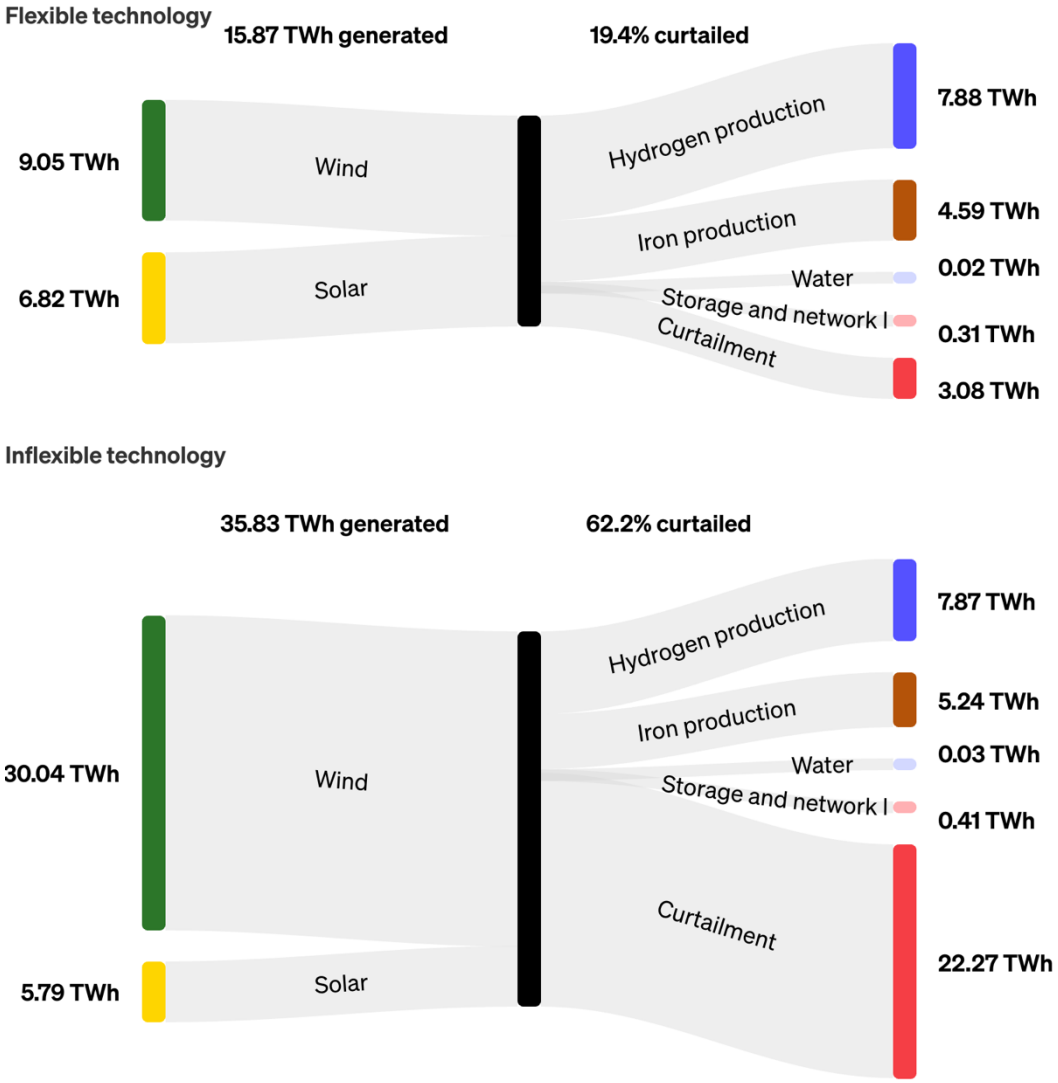


Figure 19: Annual energy flows for the Boodarie 2.5 million tonnes per annum scenarios. Off-grid, inflexible systems curtail over 60 per cent of the electricity generated to ensure sufficient year-round supply of hydrogen and electricity to the iron plant.

Note: Generation is from solar PV and wind installations. Hydrogen production covers electricity used for electrolysis. Iron production covers all iron-making processes (pelletisation, direct reduction, electric smelting furnace (ESF) and briquetting where required). Water covers electricity used for desalination. Storage and network losses include battery and transmission losses. Curtailment is available renewable electricity that is not used, stored or exported.

Source: Bivios and The Superpower Institute analysis.

4.6 Natural gas lowers the cost of iron, but substantially increases emissions intensity

There are different degrees of international commitment to green iron made with green hydrogen. Some projects integrate green hydrogen production on-site with green iron production, others intend to start with natural gas but are ‘green hydrogen ready’ and intend to purchase green hydrogen when it becomes available. Several Western Australian-based green iron proposals reflect this global trend.

In *Digging Deeper,* we have analysed the cost and emissions intensity of natural gas-based DRI at Oakajee based on different blending ratios for hydrogen and natural gas to illustrate the impact of using natural gas as a reductant on the cost of production and emissions intensity of the green iron product.

Figure 20 shows the relationship between the emissions intensity of each reductant and its impact on the cost of production.

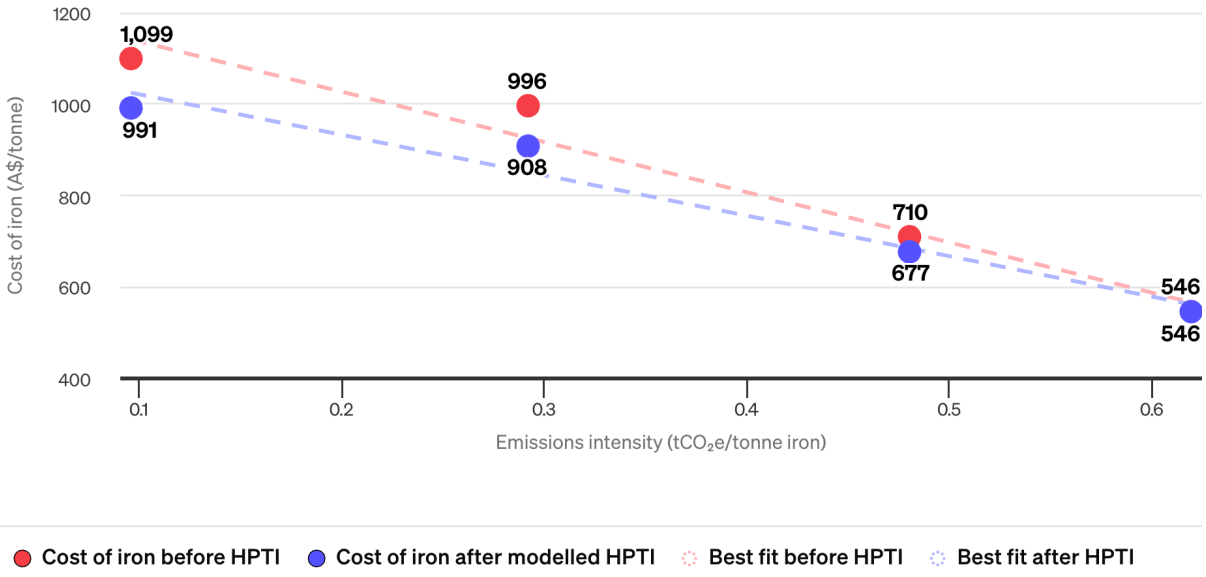


Figure 20: Increasing the use of natural gas in iron-making reduces costs but increases emissions intensity (Oakajee, DR-grade magnetite, inflexible technology shown).

Note: HTPI refers to Hydrogen Production Tax Incentive.

Source: Bivios and The Superpower Institute analysis.

Our model shows that using natural gas as the reductant in place of green hydrogen offers a lower LCOI, but that reducing iron ore with natural gas results in substantial emissions compared to using green hydrogen.[31] Where progressive blending of green hydrogen occurs to substitute for natural gas, the HPTI is apportioned to the volume of green hydrogen used.

The policy implications of gas-based production are discussed in section 5.6 of the *Roadmap*.

4.7 Implications for Western Australia

Taken together, these results support a particular location for establishing Western Australia's green iron industry. Of the options modelled, the Mid West offers the lowest-cost location for early projects, with grid access, high-quality renewable resources, existing infrastructure and local magnetite that can be upgraded to DR-grade. The infrastructure needed to support those

[31] Our modelling estimates the direct emissions of the iron-making process. It does not include upstream emissions from mining, transport or gas production. Including upstream emissions would increase the intensity of both pathways, and the increase is likely to be larger for gas-based DRI because of emissions from gas production and transport. Gas-based DRI is more commonly reported in the literature at around 1 tCO_2e per tonne of iron because those figures include upstream emissions.

projects is small relative to total project costs. It does need to be planned with proponents, however, because the right scale of grid connection depends on each project's technology and operating profile.

The Pilbara is a different proposition. Its costs are higher today, but the scale of its ore resources makes it central to the industry's long-term growth. Lower costs, whether through flexible iron-making technologies, more efficient construction or new approaches to processing Pilbara ores, would strengthen the case for accelerating work in the region. That work needs to begin alongside early projects in the Mid West.

The modelling is indicative. It relies on publicly available cost data, a single plant scale and assumptions about how the HPTI applies to grid electricity. These estimates may prove conservative. Individual projects will face different costs and make different choices. The results nonetheless suggest where and when public support is most likely to make a difference: enabling infrastructure, coordination, and support directed to near-zero emissions pathways. The *Roadmap* sets out how Western Australia can seize the opportunity.

Glossary of Terms

AEMO	Australian Energy Market Operator
Beneficiation	Processing ore to increase its iron content and remove gangue, for example by crushing, grinding and magnetic separation.
BF-BOF (Blast Furnace-Basic Oxygen Furnace)	The dominant global method for producing primary steel. A two-step process whereby iron ore is reduced to molten iron in a blast furnace (BF) using metallurgical coal as both a fuel and a chemical reductant. The molten iron is then refined into steel in a basic oxygen furnace (BOF). The BF-BOF is highly carbon-intensive, generating over 2 tonnes of CO_2 per tonne of steel.
BF-grade (Blast furnace-grade)	Refers to iron ore with an iron content less than 66 per cent or more than 3.5 per cent combined silica and alumina as gangue. Because of the high gangue content these iron ores are conventionally treated in a blast furnace to separate the gangue from the molten iron.
Carbon Price	A cost imposed on emitting carbon to incentivise lower emissions. A price on carbon helps shift the burden for the damage from emissions back to those who are responsible for it.
CBAM (Carbon Border Adjustment Mechanism)	The European Union's mechanism that applies a carbon price to certain imports, including iron and steel, from 2026.
Common-User Infrastructure	Shared infrastructure where capacity is shared between multiple users under a defined set of terms.
Comparative Advantage	A country with comparative advantage can produce a good or service relatively more cheaply than others (more precisely, at lower opportunity cost), such that specialising in and exporting that product generates gains for all. Australia has a comparative advantage in renewable energy production in a decarbonised world.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DR-grade (Direct reduction grade)	Iron ore with an iron content above 66 per cent and less than 3.5 per cent combined silica and alumina, also referred to as DRI-EAF-grade. The low gangue content makes the ore suitable for producing direct reduced iron (DRI) that meets the quality specifications of an EAF.
DRI (Direct Reduced Iron)	A form of iron produced by reducing iron ore into iron at lower temperatures than in traditional blast furnaces, typically using hydrogen or natural gas. The process creates a porous, solid material known as 'sponge iron,' which can be melted in electric furnaces to make steel. DRI generally contains between 86

	and 94 per cent iron with 3.9 to 8.4 per cent gangue. DRI is most commonly used in electric arc furnaces and often blended with scrap.
DRI-EAF	The direct reduction-electric arc furnace route, in which iron ore is reduced to DRI and then melted with scrap in an EAF to make steel.
EAF (Electric Arc Furnace)	A furnace that melts scrap steel or direct reduced iron (DRI) using electrical energy. EAFs typically use high-grade DRI, as they cannot efficiently remove impurities (gangue) from lower-grade iron.
ESF (Electric Smelting Furnace)	A high-temperature, continuous-operation furnace that melts direct reduced iron (DRI) using electricity, enabling the removal of impurities (gangue) from lower and mid-grade iron ores. Unlike electric arc furnaces, ESFs can process ores with higher impurity levels and operate more like blast furnaces, with molten metal and slag removed without interrupting the process.
Externalities (Positive/Negative)	The unintended side effects of an economic activity that affect others and are not reflected in market prices. Positive externalities (e.g. innovation spillovers) provide value to others, while negative externalities (e.g. pollution) impose costs on others.
Flexible and inflexible technology	Inflexible iron-making technology operates continuously at a steady rate. Flexible technology can vary its output to match variable renewable electricity supply.
First-of-a-kind	A project or facility deploying a technology at commercial scale for the first time. First-of-a-kind projects often face higher capital costs, technical risks and financing challenges compared to later, proven deployments.
Gangue	The non-iron material in iron ore, such as silica and alumina, which must be removed during iron-making to produce high-quality metal. Ores with high gangue content are considered lower grade and require more processing energy to extract usable iron.
Green Hydrogen	Hydrogen produced with renewable energy, generally powered by renewable electricity. To qualify for the Australian Government's HPTI, hydrogen must be produced with emissions of no more than 0.6 kg CO_2e per kilogram of hydrogen.
Green Iron	Iron produced using renewable energy and/or green hydrogen, with near-zero emissions
GIPA (A Green Iron Plan for Australia)	TSI's 2025 publication, *A Green Iron Plan for Australia,* which modelled green iron production in various locations around Australia, estimated the levelised costs of production, analysed global markets and identified the policy settings needed to allow Australia to produce green iron and play a major role in global decarbonisation.

Green Steel	Steel made using green iron and electric arc furnaces powered by renewable energy.
Guarantee of Origin (GO)	The Australian Government certification scheme that tracks and verifies the emissions associated with producing hydrogen and renewable electricity.
HBI (Hot Briquetted Iron)	Refers to direct reduced iron (DRI) which has been pressed into a briquette, while still hot exiting the reduction process. Pressing the hot DRI into briquettes increases the density of the iron product from around 3.5 t/m3 to the required 5.0 t/m3 to meet shipping regulations. The stabilised HBI is suitable for storage and transportation over extended times and distances. The principal market for HBI is electric arc furnace steelmaking.
Hematite	An iron oxide ore mineral (Fe_2O_3); pure hematite has an iron content of nearly 70 per cent. Most of Australia's iron ore exports are hematite. Hematite is less amenable to magnetic beneficiation than magnetite but can still be used in a variety of iron-making technologies depending on grade.
HPTI (Hydrogen Production Tax Incentive)	An Australian Government refundable tax offset of $2 per kilogram for eligible hydrogen produced from 2027 to 2040, with emissions intensity of no more than 0.6 $kgCO_2e$ per kilogram.
LCOI (Levelised Cost of Iron)	The average cost to produce a tonne of green iron across a project's life, accounting for capital, operating and energy costs. It enables comparison of cost competitiveness across technologies and locations.
Lighthouse (project)	An early commercial-scale project that demonstrates the operational and commercial viability of green iron production in a new location or supply chain, building confidence for later investment.
Locational Capital Cost Factor	Capital costs vary by location because of differences in equipment, installation, fuel connection, land and development, and operations and maintenance costs. Locational capital cost factors are applied to capital costs to reflect the comparative cost of building and operating in distinct locations. For example, Australian capital cities have lower cost factors than regional towns because they have better access to materials, skilled workforce, and established supply chains.
Market Failure	When markets fail to allocate resources efficiently, due to incomplete property rights, misaligned incentives, and/or asymmetries in information. The non-pricing of harmful CO_2 emissions is a classic example.
Magnetite	An iron oxide ore mineral Fe_3O_4; pure magnetite has an iron content over 72 per cent. Australian magnetite ore typically contains 20-30 per cent iron in its natural state and must be beneficiated (crushed, ground, magnetically separated) to increase the iron content for use as a feedstock for iron-making. It is well-suited to direct reduction due to consistent composition and amenability to pelletisation.

Magnetite Concentrate	Magnetite concentrate is the beneficiated export product. Traditionally, steelmakers pelletise the concentrate themselves to the specification required by their furnaces. Conventional magnetite beneficiation involves large volumes of water to create a slurry, and the concentrate is normally exported as a wet product with volumes reported as wet metric tonnes.
NEM (National Electricity Market)	The interconnected electricity grid and wholesale electricity market covering Queensland, New South Wales, the Australian Capital Territory, Victoria, South Australia and Tasmania. It is operated by the Australian Energy Market Operator (AEMO). Western Australia and the Northern Territory are not connected to the NEM.
NWIS (North-West Interconnected System)	A separate electricity grid located in the Pilbara region of Western Australia. It connects major mining and industrial operations but is not linked to the National Electricity Market or the SWIS.
OECD	Organisation for Economic Co-operation and Development
Pig Iron	The resulting iron product from melting DRI in an electric smelting furnace (ESF) to separate metallic iron from non-ferrous gangue. Pig Iron has an iron content of at least 92 per cent iron with low gangue. It can be used for producing high-quality steel products in a range of furnaces.
Primary Steel	Steel made from iron ore, rather than recycled scrap. It accounts for around 70 per cent of global steel production, with 90 per cent of that made using the carbon-intensive BF-BOF process. Steelmaking overall is responsible for more than 8 per cent of total greenhouse gas emissions.
Production Tax Credit (PTC)	A proposed government support mechanism that would provide a per-tonne subsidy for green iron production. The PTC will help to address key market failures - such as the absence of a global carbon price - closing the cost gap with carbon-intensive alternatives and stimulating early investment in low-emissions technologies.
Reductant	A substance used in iron-making to chemically remove oxygen from iron ore (iron oxide), producing metallic iron. Common reductants include carbon (from coal or fossil gas) and hydrogen. The choice of reductant determines the emissions profile of the process.
Reserve Capacity Mechanism (RCM)	Administered by the Australian Energy Market Operator (AEMO) under rules overseen by Energy Policy WA, the Reserve Capacity Mechanism ensures there is always enough electricity generation and storage available to meet peak demand on WA's main power grid (the South West Interconnected System).
SIA (Strategic Industrial Area)	A designated industrial precinct planned and managed by the Western Australian Government for heavy and strategic industries.

Superpower Trade	The trade in clean energy embedded in energy-intensive goods, that relies on Australia's comparative advantage in clean energy production.
SWIS (South West Interconnected System)	The main electricity network in Western Australia, serving Perth and the south-west of the State, from Kalbarri in the north to Albany in the south and Kalgoorlie in the east. Western Power owns and operates the transmission and distribution network. The SWIS is not connected to the NEM.
Technology Readiness Level (TRL)	Technology Readiness Levels assess the maturity level of a technology as it progresses through the research, development and deployment (RD&D) phases to a commercially mature technology. TRLs are based on a scale from 1 to 9, with 1-3 indicating the research phase from desktop studies to laboratory experiments, 4-6 indicating development phase as laboratory prototypes progress to real world pilot facilities, and 7-9 being the deployment phase as demonstration facilities reach commercial scale deployment.
WEM (Wholesale Electricity Market)	The wholesale electricity market operating on the SWIS, run by AEMO. It includes a real-time energy market, markets for essential system services that keep the grid stable, and a capacity mechanism that pays providers to make capacity available when needed.

Appendix A

GIPA – modelling approach

In *GIPA,* TSI partnered with Bivios to develop a model of green iron investment and production to identify the lowest-cost combination of capital investments, technology choices and production volumes. We assumed a green iron plant production rate of 2.5 million tonnes per year as a likely 'lighthouse' project scale based on commercially available plant sizes.

The original approach examined five locations for production modelled with two types of iron-making technology - inflexible and flexible. Inflexible iron-making technology needs to operate continuously, or near-continuously, while flexible green iron-making technology can ramp up and down.

Each green iron 'project' included the production of renewable energy, green hydrogen and green iron. We modelled production volumes, costs, financial outcomes, and emissions using forecast capital costs for 2030 reported in 2025 dollars. Production costs reflect the costs for producers in an established green iron industry, rather than 'first-of-a-kind' producers who face higher borrowing costs due to their risk profile.

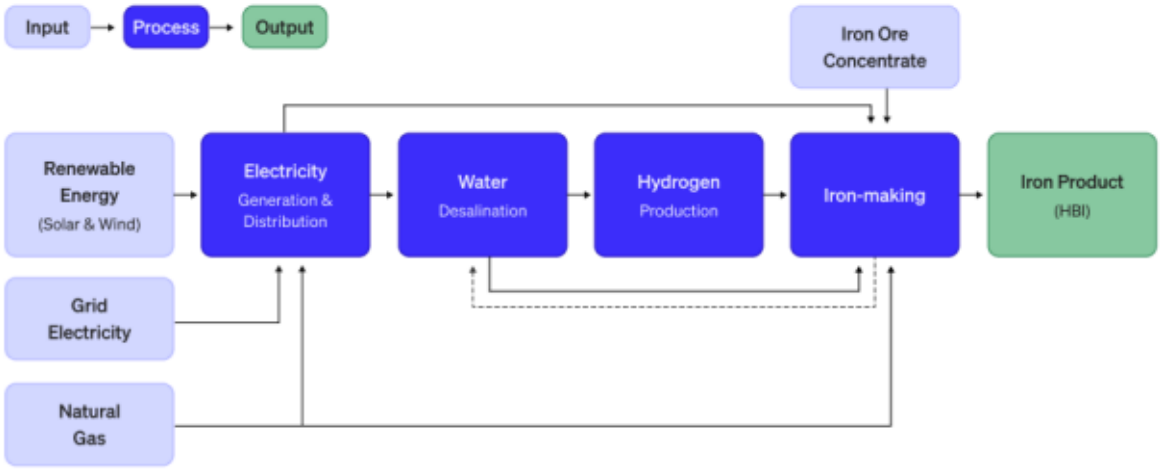


Figure A.1: Summary of the green iron production model

Notes: Use of each input varies by location, technology, and ore type.

Source: Bivios and The Superpower Institute analysis.

Location considerations.

Capital cost factors were applied to each location to capture local construction and operating costs. To compare like for like, these factors were derived from national AEMO cost data.[32]

[32] GHD, *AEMO Costs and Technical Parameter Review*, table 73, 116.

Factors vary significantly between the five locations and particularly between the east coast and Western Australia.

All locations proximal to an electricity network were modelled as grid-connected. Revenue from exporting renewable energy into the grid was calculated based on a consistent assumption across all locations of unconstrained access into a wholesale market. *Digging Deeper* revises this approach for the WEM (section 2.5 and Appendix C).

Iron ore feedstock for each green iron plant was based on the most accessible ore type for each location. Where iron ore required long-distance transport, coastal shipping was modelled as the lowest-cost freight service.

Technology considerations.

'Inflexible' technology is required to maintain high operating temperatures to protect equipment and ensure optimum asset life. Therefore, the inflexible iron-making technology requires a continuous supply of hydrogen or natural gas and will require larger investments in renewable energy and hydrogen storage than flexible technology. These technologies are well-developed and commercially established.

'Flexible' technology can ramp production levels up and down frequently without causing damage to equipment, and therefore lends itself to more variable, intermittent sources of energy and reductants. Flexible technology is not as technologically developed as existing, inflexible technologies.[33]

Ore type considerations.

To make green steel, the iron and steelmaking processes both need to be near-zero emissions. Our model assumes a direct reduction iron (DRI) is supplied to an electric arc furnace (EAF) powered by renewable energy.

Lower-grade 'hematite' ores are typically cheaper, but if they are used to make DRI, they will require an extra processing step (ESF), to remove excess gangue, to be suitable for 'green' steelmaking in an EAF. This extra processing step adds to both capital and operating costs. The model assumed lower-grade Pilbara 'hematite' iron ore is processed via a two-step DRI-ESF pathway.

High-grade 'magnetite' ore is more expensive but contains less gangue so does not require investment in ESF technology to produce a DRI product suitable for an EAF. The scenarios assumed that local high-grade 'magnetite' ore supplied to the Eyre Peninsula and to Geraldton did not require an ESF step.

For all ore types, pelletisation of the iron ore for feeding into the 'inflexible' DRI plant is required. Any beneficiation costs were assumed to be reflected in the price of the iron ore.

[33] More detail about emerging flexible technologies and the particular technology modelled can be found in The Superpower Institute, *A Green Iron Plan for Australia*, 43.

Appendix B

GIPA – Federal policy recommendations

Correcting for the missing international carbon price

1. Introduce a $170 green iron Production Tax Credit

In addition to its $2 per kilogram support for green hydrogen, the federal government should provide support for green iron production to simulate the effects of a carbon price. We estimate total support, including the HPTI, should be worth at least $170 per tonne of green iron in 2030. This could be achieved with a 'stackable' production tax credit for green iron. The production credit should rise to maintain equivalence to the EU carbon price.

2. Extend the $170 green iron Production Tax Credit

Some nascent green iron production technologies do not use hydrogen but may use significant amounts of renewable energy dedicated to iron-making. Here, the HPTI does not help close the cost gap between green iron and carbon-intensive iron. The federal government should provide support that simulates the effect of a carbon price for non-hydrogen-based green iron technologies. This could take the form of an expanded production credit for green iron, worth at least $170 per tonne of green iron in 2030.

Supporting positive spillovers from common-user technology

3. Support shared infrastructure

In locations that are most promising for multiple green iron projects, the federal government and state governments should support new natural-monopoly infrastructure that is essential for green iron, steel, and other green exports: electricity transmission, hydrogen pipelines and storage, ports, and desalination and water supply in areas with no local water supply. This can be direct government investment or support to private investors. The state government's role in supporting infrastructure will solve the coordination problem that will otherwise delay or prevent investments in green iron production.

Infrastructure use should be priced efficiently, so the cost of using infrastructure is not a barrier to early private investment in green iron.

Support green production in low-cost locations

4. Create an Australian green hydrogen certification scheme

We propose an Australian green hydrogen certificate scheme, with green hydrogen producers earning tradable certificates. Certificates could be purchased and surrendered by green iron producers anywhere in Australia. Iron produced with natural

gas could be recognised as ‘green’ iron production when equivalent green hydrogen certificates are purchased and surrendered.

Producers of other green hydrogen-based products would also be included in the scheme.

Supporting positive spillovers from early producers

5. Provide capital support for early producers

The federal government should provide capital support for early commercial producers of green iron, with a planned output of at least 0.5 million tonnes per annum. This could build on or draw from the already announced $1 billion Green Iron Investment Fund. Two levels of support should be available:

- Early investors in green iron projects, using any kind of green iron technology, should receive capital grants, or equivalent tax benefits, representing 15 per cent of capital costs. We propose that this support should be available for up to three green iron projects.
- Grants worth an additional 15 per cent of capital costs should be made available for the first few uses of a particular kind of green iron technology deployed in Australia.

Support should be capped at $500 million per project.

Policies to support international trade dynamics

6. Align Australia’s Guarantee of Origin scheme with the EU’s CBAM requirements

The government should shape its Guarantee of Origin (GO) certificates to be compatible with the EU Carbon Border Adjustment Mechanism. This should be done at the earliest possible date after the EU legislates its requirements.

7. Strengthen support for research into trade opportunities in a decarbonising world

The federal government should strengthen support on countries’ economic challenges and trade opportunities as the world decarbonises.

8. Work with trade partners to get financial support for green iron projects in Australia

The federal government should work with trade partners to secure financial support for green iron production. This may come in the form of contributions by trade partner governments toward the supports described in Recommendations 1 and 2. Such contributions would recognise the shared benefits of successful Australian green iron production, to both Australia and our trade partners.

9. Champion international carbon pricing through global forums

The federal government should use international platforms to advocate for a system of international carbon prices. It should demonstrate Australia's commitment to the Paris Agreement with policies that impose or simulate the effects of a carbon price consistent with net-zero carbon emissions by 2050.

Appendix C

Modelling the interaction with the Wholesale Electricity Market

The WEM

For the import case, the forecast total WEM demand requirement (from the historic data) is increased by the green iron facilities demand. The market clearing price is then calculated as the price offered by the facility which is the last one dispatched (dispatching in order from lowest price to highest). This is illustrated in **Figure C.1**.

In the previous model, the market price of electricity was taken as the historic clearing price. This did not account for the impact of the green iron facilities demand on the price, which will tend to increase it. The new approach does incorporate this impact.

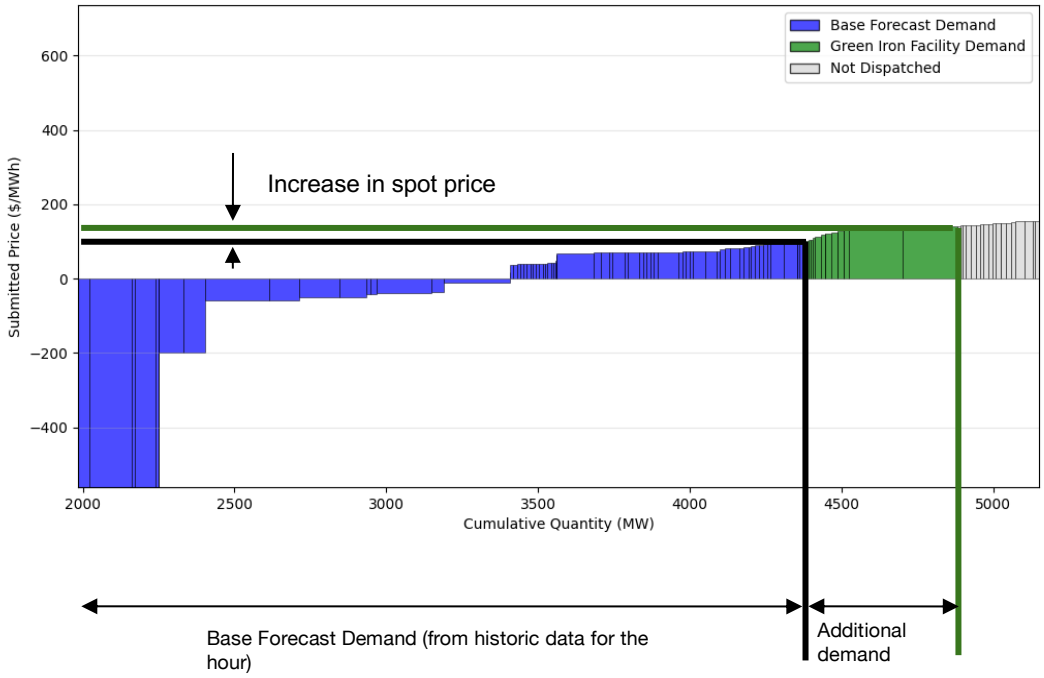


Figure C.1: Demand from green iron facilities will increase the WEM clearing price.

Note: Each bar represents a historical quantity, price bid into the real-time market. The Green Iron Facility Demand represents the hypothetical introduction of additional demand, and how it would fit into the historical bid stack to change clearing prices.

Source: Bivios and The Superpower Institute analysis.

For the export case, the forecast total WEM demand requirement remains unaltered. However, the green iron facility now adds its target export volume to the supply in the bid stack. The new supply is offered in two separate bids. The first bid, which is offered at $0/ MWh, is the electricity that would be otherwise curtailed (i.e. go unused to the iron plant). As long as the

market clears above $0/ MWh, this will generate additional revenue for the green iron system if dispatched.

The second bid is the quantity of electricity that is used to run the electrolysers. This is bid at an estimate of the 'breakeven' cost of electricity for the green iron system. This is the price of electricity at which it is more valuable to sell the electricity back to the market than to use it to produce green iron. This bid will only be dispatched if the clearing price is at or above the breakeven price. **Figure C.2** illustrates a bid stack where the first bid clears and is dispatched but the second bid does not.

Both bids will increase the volume of supply in the market, so will tend to drive clearing prices down, relative to the actual historic clearing price.

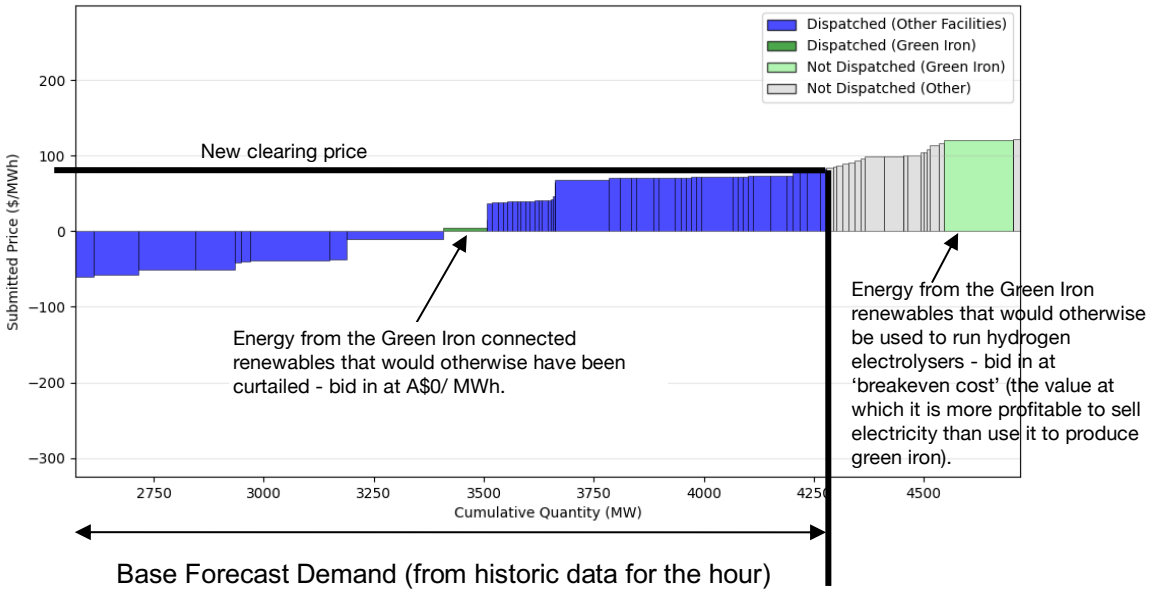


Figure C.2: The green iron system offers exports of energy back to the electricity market as bids at different prices, depending on the utility of the energy to the green iron system

Note: Each bar represents a historical quantity, price bid into the real-time market. The Green Iron facility dispatch represents how the introduction of additional supply, above and below the clearing price, would fit into the historical bid stack to change clearing prices.

Source: Bivios and The Superpower Institute analysis.

The Reserve Capacity Mechanism

To approximate the RCM in our model, we have included a new flag in the input hourly historic data which identifies if an hour was a peak period. For example, in the 2023-24 summer period, all 12 peak periods occurred in the month of February.[34]

The model treats peak periods differently depending on whether the case is a flexible or inflexible case.

Consultation with AEMO suggests that flexible loads are typically able to optimise around peak periods. This means that for flexible cases, grid interaction is prohibited during peak periods. As

[34] Australian Energy Market Operator, "Peak SWIS Trading Intervals."

a result, there is no RCM cost incurred by the flexible facility. Neither does the flexible facility generate revenue under the demand side response component of the RCM because we cannot guarantee that the iron production system will be drawing from the grid in any given hour.

To explore this assumption, the base forecast energy requirement from Case files was used to successfully identify the 12 peak periods.[35]

For the inflexible cases, the iron plant must continue to operate at full capacity, even during peak periods.[36] Under the RCM we conservatively assume the inflexible plant to be classified as a Temperature Dependent Load.[37] This implies slightly higher reserve capacity costs with regard to median consumption in the 12 peak periods.[38]

The maximum demand over the peak periods is used to estimate the RCM liability. For the inflexible facility, the latest RCP cost - $360,700 per MW for Capacity Year 2027-28 - is applied to the 2023-2024 peak periods as it is the most representative cost for a 'lighthouse' green iron plant looking to come online in 2030.

The maximum demand over the peak periods is used to estimate the RCM liability of the system using the following equation:

$$\mathbf{IRCRC(f,m) = TDL(f,m) * TDL_R(m) * TOTAL_R(m) * RCP_C(m)}$$[39]

Where TDL(f,m) is the median contribution of the Facility *f* to load during the 12 peak periods (note that this varies by Trading Month *m*, but not in terms of contribution to the peak periods), TDL_R(m) is the TDL ratio for Trading Month m, TOTAL_R(m) is the Total Ratio for Trading Month *m*, and RCP_C(m) is the Reserve Capacity Price for Trading Month *m*.

[35] Australian Energy Market Operator, "API Details."

[36] If there is sufficient hydrogen stored, the electrolysers can reduce their output as much as possible to reduce the peak period electricity demand.

[37] Government of Western Australia, *Electricity System and Market Rules*, 855.

[38] Australian Energy Market Operator, "Individual Reserve Capacity Requirements (IRCR) Ratios."

[39] Australian Energy Market Operator, *WEM Individual Reserve Capacity Requirement (IRCR) Calculations*, 16–18.

Appendix D

Model results by location and technology type

Table D.1: Modelled capacities, costs, and levelised costs of renewable electricity, green hydrogen, and green iron for Oakajee (DR-grade magnetite case). May 2025 results for Geraldton also shown, for comparison.

Category	Item	Units	Geraldton, inflexible (May 2025)	Geraldton, flexible (May 2025)	Oakajee, DR-grade magnetite, inflexible	Oakajee, DR-grade magnetite, flexible
Facility capacities	Solar PV	MW	2,668	2,317	3,073	2,059
	Wind Turbines	MW	2,587	2,177	2,254	1,745
	BTM Transmission	MW	2,432	1,961	1,811	1,596
	Electricity Grid	MW	826	1,402	306	37
	Battery	MWh	1,106	129	8,068	127
	Hydrogen Production	tph	29	25	20	20
	Hydrogen Storage	tonnes	760	22	308	17
	Iron Production	tph	285	368	291	372
Utilisation	H2 Production	per cent	53 per cent	60 per cent	76 per cent	76 per cent
	Iron Production	per cent	100 per cent	77 per cent	98 per cent	77 per cent
	Elect used from grid	per cent	2 per cent	2 per cent	3 per cent	2 per cent
	Elect generated exported	per cent	26 per cent	20 per cent	5 per cent	0 per cent
	Total electricity (exc. exports)	TWh	11.1	10.4	11.1	10.3
Emissions	Iron emissions intensity	tCO2e/ t	0.11	0.06	0.10	0.04
	Annual total emissions	ktCO2e/ yr	283	144	240	101
Capital costs	Solar PV	mA$	3,914	3,399	4,920	3,297
	Wind Turbines	mA$	8,126	6,839	6,862	5,310
	BTM Transmission	mA$	830	669	833	734
	Grid Transmission	mA$	0	0	246	29
	Grid Connection	mA$	0	0	164	20
	Battery	mA$	361	42	2,310	36
	Natural Gas Lateral	mA$	0	0	110	0
	Roads	mA$	0	0	164	210
	Hydrogen Production	mA$	4,137	3,601	3,397	3,385
	Hydrogen Storage	mA$	2,064	60	776	43
	Iron Production	mA$	3,217	3,013	3,079	2,824
	Other balance of plant	mA$	697	622	491	485
	Total capital costs	mA$	23,345	18,244	23,352	16,374
Annual costs	Financing costs	mA$	1,759	1,404	1,758	1,263
	Operations and maintenance	mA$	344	258	380	288
	Iron ore	mA$	567	532	570	533
	Natural gas	mA$	13	0	13	0
	Wholesale electricity	mA$	22	14	22	9
	Network charges - grid	mA$	5	4	31	4
	Network charges - renewables	mA$	0	0	0	0
	Grid revenue	mA$	-331	-288	-31	0
	Total annual costs	mA$	2,379	1,923	2,745	2,096
Levelised costs	Electricity (after grid revenue)	A$/ MWh	66	56	113	73
	Hydrogen	A$/ kg	9.46	7.57	10.25	7.69
	Iron	A$/ tonne	953	770	1,099	839

Note: The iron production tonnes per hour (tph) is different for the different scenarios. The tph represents the plant nameplate capacity and because the flexible plants have a lower capacity factor, they need a higher maximum output when they do operate to deliver the same tonnes per annum.

Source: Bivios and The Superpower Institute analysis.

Table D.2: Modelled capacities, costs, and levelised costs of renewable electricity, green hydrogen, and green iron for Oakajee (BF-grade magnetite case). May 2025 results for Geraldton also shown, for comparison.

Category	Item	Units	Geraldton, inflexible (May 2025)	Geraldton, flexible (May 2025)	Oakajee, BF-grade magnetite, inflexible	Oakajee, BF-grade magnetite, flexible
Facility capacities	Solar PV	MW	2,668	2,317	4,380	2,369
	Wind Turbines	MW	2,587	2,177	2,408	2,170
	BTM Transmission	MW	2,432	1,961	2,264	2,204
	Electricity Grid	MW	826	1,402	501	54
	Battery	MWh	1,106	129	4,212	847
	Hydrogen Production	tph	29	25	32	23
	Hydrogen Storage	tonnes	760	22	383	55
	Iron Production	tph	285	368	291	350
Utilisation	H2 Production	per cent	53 per cent	60 per cent	52 per cent	73 per cent
	Iron Production	per cent	100 per cent	77 per cent	98 per cent	81 per cent
	Elect used from grid	per cent	2 per cent	2 per cent	3 per cent	2 per cent
	Elect generated exported	per cent	26 per cent	20 per cent	6 per cent	0 per cent
	Total electricity (exc. exports)	TWh	11.1	10.4	13.4	12.6
Emissions	Iron emissions intensity	tCO2e/ t	0.11	0.06	0.14	0.05
	Annual total emissions	ktCO2e/ yr	283	144	351	130
Capital costs	Solar PV	mA$	3,914	3,399	7,012	3,792
	Wind Turbines	mA$	8,126	6,839	7,331	6,604
	BTM Transmission	mA$	830	669	1,042	1,014
	Grid Transmission	mA$	0	0	403	43
	Grid Connection	mA$	0	0	268	29
	Battery	mA$	361	42	1,206	243
	Natural Gas Lateral	mA$	0	0	110	0
	Roads	mA$	0	0	164	198
	Hydrogen Production	mA$	4,137	3,601	5,331	3,788
	Hydrogen Storage	mA$	2,064	60	963	139
	Iron Production	mA$	3,217	3,013	4,433	4,320
	Other balance of plant	mA$	697	622	758	595
	Total capital costs	mA$	23,345	18,244	29,020	20,765
Annual costs	Financing costs	mA$	1,759	1,404	2,205	1,577
	Operations and maintenance	mA$	344	258	495	370
	Iron ore	mA$	567	532	491	483
	Natural gas	mA$	13	0	13	0
	Wholesale electricity	mA$	22	14	42	11
	Network charges - grid	mA$	5	4	51	6
	Network charges - renewables	mA$	0	0	0	0
	Grid revenue	mA$	-331	-288	-31	-4
	Total annual costs	mA$	2,379	1,923	3,265	2,443
Levelised costs	Electricity (after grid revenue)	A$/ MWh	66	56	107	74
	Hydrogen	A$/ kg	9.46	7.57	11.60	8.01
	Iron	A$/ tonne	953	770	1,308	978

Source: Bivios and The Superpower Institute analysis.

Table D.3: Modelled capacities, costs, and levelised costs of renewable electricity, green hydrogen, and green iron for Oakajee (lower-grade hematite case). May 2025 results for Geraldton also shown, for comparison.

Category	Item	Units	Geraldton, inflexible (May 2025)	Geraldton, flexible (May 2025)	Oakajee, lower-grade hematite, inflexible	Oakajee, lower-grade hematite, flexible
Facility capacities	Solar PV	MW	2,668	2,317	4,518	2,452
	Wind Turbines	MW	2,587	2,177	2,815	2,192
	BTM Transmission	MW	2,432	1,961	2,331	2,122
	Electricity Grid	MW	826	1,402	311	58
	Battery	MWh	1,106	129	8,526	217
	Hydrogen Production	tph	29	25	22	22
	Hydrogen Storage	tonnes	760	22	324	44
	Iron Production	tph	285	368	291	358
Utilisation	H2 Production	per cent	53 per cent	60 per cent	76 per cent	76 per cent
	Iron Production	per cent	100 per cent	77 per cent	98 per cent	80 per cent
	Elect used from grid	per cent	2 per cent	2 per cent	2 per cent	2 per cent
	Elect generated exported	per cent	26 per cent	20 per cent	5 per cent	0 per cent
	Total electricity (exc. exports)	TWh	11.1	10.4	13.4	12.6
Emissions	Iron emissions intensity	tCO2e/ t	0.11	0.06	0.16	0.05
	Annual total emissions	ktCO2e/ yr	283	144	395	132
Capital costs	Solar PV	mA$	3,914	3,399	7,232	3,925
	Wind Turbines	mA$	8,126	6,839	8,570	6,673
	BTM Transmission	mA$	830	669	1,072	976
	Grid Transmission	mA$	0	0	250	47
	Grid Connection	mA$	0	0	166	31
	Battery	mA$	361	42	2,441	62
	Natural Gas Lateral	mA$	0	0	110	0
	Roads	mA$	0	0	164	202
	Hydrogen Production	mA$	4,137	3,601	3,615	3,637
	Hydrogen Storage	mA$	2,064	60	817	111
	Iron Production	mA$	3,217	3,013	4,492	4,419
	Other balance of plant	mA$	697	622	579	584
	Total capital costs	mA$	23,345	18,244	29,510	20,668
Annual costs	Financing costs	mA$	1,759	1,404	2,170	1,558
	Operations and maintenance	mA$	344	258	473	369
	Iron ore	mA$	567	532	473	466
	Natural gas	mA$	13	0	35	0
	Wholesale electricity	mA$	22	14	26	12
	Network charges - grid	mA$	5	4	32	6
	Network charges - renewables	mA$	0	0	0	0
	Grid revenue	mA$	-331	-288	-34	-3
	Total annual costs	mA$	2,379	1,923	3,175	2,406
Levelised costs	Electricity (after grid revenue)	A$/ MWh	66	56	118	74
	Hydrogen	A$/ kg	9.46	7.57	10.51	7.82
	Iron	A$/ tonne	953	770	1,272	964

Source: Bivios and The Superpower Institute analysis.

Table D.4: Modelled capacities, costs, and levelised costs of renewable electricity, green hydrogen, and green iron for Boodarie (lower-grade hematite case). May 2025 results for the Pilbara also shown, for comparison.

Category	Item	Units	Pilbara, inflexible	Pilbara, flexible	Boodarie, lower-grade hematite, inflexible	Boodarie, lower-grade hematite, flexible
Facility capacities	Solar PV	MW	5,106	3,299	2,758	3,251
	Wind Turbines	MW	4,226	2,209	7,649	2,303
	BTM Transmission	MW	6,143	2,262	1,855	2,491
	Electricity Grid	MW	0	0	0	0
	Battery	MWh	9,420	4,772	9,232	2,332
	Hydrogen Production	tph	18	23	20	23
	Hydrogen Storage	tonnes	537	40	173	102
	Iron Production	tph	291	368	291	372
Utilisation	H2 Production	per cent	87 per cent	67 per cent	83 per cent	72 per cent
	Iron Production	per cent	98 per cent	77 per cent	98 per cent	77 per cent
	Elect used from grid	per cent	0 per cent	0 per cent	0 per cent	0 per cent
	Elect generated exported	per cent	0 per cent	0 per cent	0 per cent	0 per cent
	Total electricity (exc. exports)	TWh	12.8	12.2	13.6	12.8
Emissions	Iron emissions intensity	tCO2e/ t	0.08	0.00	0.08	0.00
	Annual total emissions	ktCO2e/ yr	188	0	198	0
Capital costs	Solar PV	mA$	8,215	5,308	5,951	7,015
	Wind Turbines	mA$	14,558	7,611	31,381	9,451
	BTM Transmission	mA$	681	251	2,070	2,780
	Grid Transmission	mA$	0	0	0	0
	Grid Connection	mA$	0	0	0	0
	Battery	mA$	3,369	1,707	3,563	900
	Natural Gas Lateral	mA$	0	0	30	0
	Roads	mA$	0	0	151	193
	Hydrogen Production	mA$	2,786	3,626	4,460	5,157
	Hydrogen Storage	mA$	1,598	119	589	345
	Iron Production	mA$	5,129	5,253	6,057	6,181
	Other balance of plant	mA$	604	728	738	825
	Total capital costs	mA$	36,940	24,603	54,989	32,846
Annual costs	Financing costs	mA$	2,646	1,864	3,963	2,435
	Operations and maintenance	mA$	439	326	591	465
	Iron ore	mA$	383	382	411	405
	Natural gas	mA$	34	0	36	0
	Wholesale electricity	mA$	0	0	0	0
	Network charges - grid	mA$	0	0	0	0
	Network charges - renewables	mA$	0	0	0	0
	Grid revenue	mA$	0	0	0	0
	Total annual costs	mA$	3,502	2,573	5,001	3,305
Levelised costs	Electricity (after grid revenue)	A$/ MWh	162	96	241	121
	Hydrogen	A$/ kg	12.79	9.13	18.33	12.02
	Iron	A$/ tonne	1,403	1,031	2,003	1,324

Source: Bivios and The Superpower Institute analysis.

Appendix E

Inputs and Supplementary Materials

Download model inputs and input supplementary material from the TSI website.

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