Heavy Industry Low-carbon Transition CRC
Lot Fourteen, Frome Road
ADELAIDE SA 5000
Email: admin@hiltcrc.com.au
Web: www.hiltcrc.com.au

15 October 2025

Committee Secretary
WA Senate Economics and Industry Standing Committee

Dear Committee Secretary

Re: inquiry into the role of Western Australia in the decarbonisation of our major trading partners.

The Heavy Industry Low-carbon Transition Cooperative Research Centre (HILT CRC) is pleased to make a submission to the inquiry into the role of Western Australia in the decarbonisation of Australia's major trading partners.

The HILT CRC was established in November 2021 to support the decarbonisation of the Australian iron/steel, alumina, and cement/lime sectors. Since commencing operations, HILT has co-developed a groundbreaking research program to develop new technologies and address non-technological barriers and enablers to heavy industry decarbonisation, in collaboration with over 60 partners from industry (including heavy industry, end users and technology providers), government, academia, and non-governmental organisations. One aspect of HILT's ongoing mission is to pave the way for a prosperous, net-zero Australian heavy industry sector by providing high-quality, evidence-based information for decision-makers.

This submission focuses on the opportunity Western Australia has to contribute to decarbonisation of its major trading partners through developing net-zero green pathways for processing iron ore, iron, steel and alumina, and provides insights into the barriers and potential enablers to investment in large scale decarbonisation projects.

Australia is the largest exporter of both alumina and iron ore in the world, and Western Australia (WA) accounts for nearly two thirds of the alumina and over 95% of the iron ore exported from Australia. As such WA has the opportunity to play a very large role in reducing emissions for steel and aluminium supply chains globally, and within our trading partners. Reaching net-zero by 2050 for aluminium and steel supply chains will require gradual but dramatic transformation of processes throughout the supply chain. The characteristics of different ores will determine which low-emissions processes and pathways they are suitable for. As these supply chains decarbonise, they may also begin to reorganise; some processing steps may relocate to countries with access to abundant renewable energy resources, and producers will favour ores that are most suitable for their decarbonisation plans.

Our key insights are that:

- **Demonstrating the suitability of WA's ores for low-emissions processing routes is of primary importance to secure WA's position as a major supplier of ores in future decarbonised aluminium and steel making supply chains. WA could play an important role as a research hub to derisk and scale up technologies and processes suitable for WA iron ore and bauxite.**
- **There is an opportunity for WA to position itself further along the steelmaking supply chain by developing low emissions iron and steel processing industries onshore, leveraging WA's renewable energy resources and expertise in heavy industry. Exporting value-added green iron and steel products could help to accelerate the decarbonisation of our trading partners, lowering steel making emissions by ~80%, and bringing economic benefits to the region.**

Decarbonising heavy industry in WA will require multi-decadal planning and investment, with timing determined by capital renewal cycles as well as ongoing technology development. *Transformational technologies*, like new reactors and processes, will need to be developed and derisked in parallel to deployment of *transitional technologies*, like integrating competitively costed net-zero energy, requiring ongoing investment from before 2030.

The HILT CRC is undertaking research to inform decision makers within industry and government of the most prospective potential decarbonisation technologies and pathways for iron, steel and alumina industries, and to derisk specific technologies and processes suitable for WA's ores.

Government support for heavy industry decarbonisation will be needed at the state and federal level to derisk the large capital investments required, to develop markets for green commodities, and to provide the necessary regulatory and policy frameworks.

HILT's research and stakeholder engagement has identified the following as key actions by government to enable investment in large scale decarbonisation projects:

1. accelerate the deployment of net-zero emission energy (including but not limited to, renewable electricity) and invest in enabling infrastructure like electricity grids;
2. adopt long-term, bipartisan policies and incentives for decarbonisation to reduce investment risk and policy uncertainty for industry;
3. drive demand for low-emission commodities both domestically through demand side incentives, and through ongoing climate diplomacy with existing and potential international trading partners to encourage enhanced global climate ambition; and
4. ensure regulatory and approval processes are efficient, consistent, and co-ordinated across state and federal government.

HILT CRC is undertaking research aimed at providing evidence-based information to inform these key actions including:

RP 3.006: Certification and verification to enable a successful low-carbon transition for heavy industry. This project will enable Australian heavy industry to successfully engage with emerging regulatory and market regimes based on embedded emissions account, providing them with competitive advantage and supporting their successful transition to low carbon production – both financially and environmentally.

RP 3.007: Unlocking investment in energy infrastructure for net zero industrial hubs. This project will provide the information required to enable industry and other stakeholders to plan for the transformation of the energy supply system necessary for heavy industrial sectors to a net-zero carbon future.

RP 3.008: A policy roadmap for Australia's heavy industry low-carbon transition. This project will assist heavy industry partners and stakeholders to understand, manage and mitigate risks associated with the transition. It does this by deepening understanding of current and future policy developments at different government levels that directly impact heavy industry.

In the following we provide specific insights from HILT research on for decarbonised iron and steel, and alumina and aluminium supply chains.

IRON AND STEEL MAKING

Currently, over 96% of all Australia's iron ore exports are direct shipping ores (DSOs) from the Pilbara exported to Asia, mainly China. This established supply chain is highly carbon intensive, with most emissions (~90%) released within our trading partners borders. HILT research project RP3.004 undertook an economic and emissions analysis of potential future Australia-China green steelmaking value chains. A critical component of this work was the development of an ore and location specific techno-economic model for evaluating green supply chains from Australian mines to steel plants around the globe, incorporating ore dependent processing pathways.

The project found that China's iron ore consumption will likely reduce due to lower steel demand and increasing use of scrap as China moves to decarbonise its steel industry. Further, a shift to green steelmaking in China favours high-grade ores from our competitors in Brazil, Guinea and elsewhere, as they are more suited to single-step direct reduction using hydrogen, followed by steel making in electric arc furnaces (H_2-DRI-EAF). This means that demand for WA's DSO ores will likely fall further post 2030. However, when electric smelting furnace capacity (ESF) is available to refine iron after the DRI step, demand for Pilbara ores in green steel production routes increases. This result highlights the importance of the development of electric smelting furnace technology (such as in the NeoSmelt project) for the processing of WA's iron ores. The model also indicates that Australia's competitiveness as a supplier of green iron to China, via the H_2-DRI-ESF pathway, depends on achieving green hydrogen production costs below Chinese production costs.

Overall, green steel production routes were shown to cut lifecycle emissions by 70-95% depending on pathways and location of processing steps but would increase emissions in WA if iron processing is moved on shore, even using low-emissions pathways.

Follow on project RP3.009 will leverage the model to *assess the competitiveness of Australian iron ore, green iron, and green steel exports in global markets*, beyond the current Australia-China supply chain, and evaluate driving factors and key leverage points for Australian policymakers.

HILT projects are working to develop and derisk suitable low-emissions processing pathways for Pilbara ores, including novel beneficiation (upgrading) of ores so they are suitable for the DRI-EAF pathway, including thermal beneficiation and leaching technologies and the use of electric smelter furnaces. This work aims to demonstrate that WA's DSOs are suitable for decarbonised processes of our major trading partners.

As well as DSOs, WA has very significant economically demonstrated resources (EDR) of magnetite, representing over 40% of all EDR iron ore reserve. Currently only a small amount of magnetite ore is exported as these ores require upgrading to be cost effective for conventional iron making. However, magnetite can be more economically beneficiated to DRI grade than DSOs, and the upgraded ores are already suitable for single step low-emissions processing routes (H2-DRI-EAF). HILT projects are investigating technologies needed to beneficiate and process these ores for future green supply chains.

The future prospects for green iron and steel production in Australia remain highly uncertain. HILT project RP 3.005 employed expert elicitation to explore perceptions of future Australian iron and steel industries. Some key insights were that emergence of these industries will likely be determined by a range of intersecting drivers and barriers. Among them are the development of suitable technologies and the trajectory of technology costs; costs of low-emissions energy, capital, and construction in Australia relative to competitors; demand for green steel in intermediate and final goods in different markets; evolution of policy support; and how quickly Australia can move to develop a green iron industry.

An analysis of policy instruments to enable a green iron and steel processing in Australia was also undertaken as part of HILT project RP 3.005. As Australian green iron/iron ore would largely be exported, government support would need to consider distribution of benefits and costs between countries. This suggests that Australian policy support should focus on reducing investment and market risk for early movers and other enablers (suitable regulatory frameworks, skilled labour and shared infrastructure). It also highlights that Australia has a vital interest in demand-side policy measures in resource importing countries (e.g. carbon pricing coupled with border carbon adjustments). Domestic demand side policies (e.g. public procurement, consumer mandates) may help to catalyse green iron and steel industry in Australia, but more importantly influence the uptake of such measures in our trading partners.

Irrespective of where iron and steel making will occur in future decarbonised supply chains, demonstrating the suitability of WA's iron ores for low-emissions processing routes is of primary importance to secure WA's position as a major supplier of iron ores.

ALUMINA REFINING

South West WA hosts four of Australia's six active alumina refineries, which are among the lowest carbon-emitting globally, largely due to the use of natural gas for their high-energy processes. Despite this, they contribute significantly to WA's emissions (~12-15% annually). The industry is highly energy intensive, relying mainly on fossil fuels such as natural gas for process heating and electricity generation, especially in the calcination stage.

The capital-intensive nature of refinery operations, the complexity in trialing emerging low-emissions technologies at scale, and the significant renewable energy capacity needed to power these technologies create substantial barriers to decarbonisation. The path to deep decarbonisation is complicated by the limited maturity and commercial readiness of alternative low-emission technologies. WA refineries predominantly operate with low-temperature digestion processes due to the nature of the bauxite ore mined in the region. Developing and derisking low-emissions technologies suitable for these ores is critical.

HILT CRC flagship project RP1.013 AlumiNEXT™ explores innovative ways to decarbonise alumina refineries by transitioning from natural gas combustion to hydrogen or electrification in the calcination process and achieving net-zero steam generation and recovery within the Bayer Process (refining bauxite ore to produce alumina).

The project aims to de-risk high-readiness technologies with strong potential to reduce emissions and explores novel approaches to unlock significant efficiency gains using low-carbon energy sources. By targeting key processes in alumina production, the project aims to deliver practical, high-impact approaches to decarbonisation.

Further information and Supporting Evidence for these findings is provided below, referencing relevant HILT CRC research projects. More information can be provided on request.

The HILT thanks the Government for the opportunity to comment on the Senate inquiry and looks forward to continued engagement and discussion. If the Committee would like to discuss any elements further, I can be contacted via ceo@hiltcrc.com.au.

Kind regards,

Jenny Selway
Chief Executive Officer
HILT CRC Limited

SUPPORTING EVIDENCE

ABOUT THE HEAVY INDUSTRY LOW-CARBON TRANSITION COOPERATIVE RESEARCH CENTRE (HILT CRC)

The heavy industrial sector contributes significantly to the Australian economy, with an annual direct economic output of approximately $180 billion, representing around 9% of the national economy. However, the sector is also carbon intensive, with the iron/steel, alumina and cement/lime sectors alone accounting for approximately 9% of Australia total CO_2 emissions and downstream processing of Australia's resources globally (corresponding to indirect scope 3 emissions) accounting for three times more emissions than all of Australia's direct emissions. While some progress has been made in the decarbonisation of Australia's heavy industries, innovative technologies and transformative processing pathways are required to meet our 2050 net zero emissions targets while maintaining the international competitiveness of these industries.

The Heavy Industry Low-carbon Transition Cooperative Research Centre (HILT CRC) was established as a catalyst to propel Australia's heavy industries towards a sustainable future. Through industry-led research, HILT CRC endeavours to mitigate risks and pave the way for effective decarbonisation strategies with a focus on the iron/steel, alumina and cement/lime sectors. These sectors have a common interest in de-risking the integration of net-zero energy and developing decarbonisation technologies, and face many of the same barriers and enablers, presenting opportunities for collaboration and cost-sharing (see Figure 1).

Since commencing operations in November 2021, HILT CRC has successfully embarked on groundbreaking research in collaboration with over 60 partners. HILT CRC's vision is to facilitate prosperous and thriving heavy industries in the net-zero economy through de-risking the technical pathways to decarbonise, thereby supporting Australia's heavy industry during the transition to low-carbon products. HILT CRC aims to achieve this vision through the implementation of rigorous, targeted, and industry-led research aimed at resolving technical challenges and addressing sector-wide concerns.

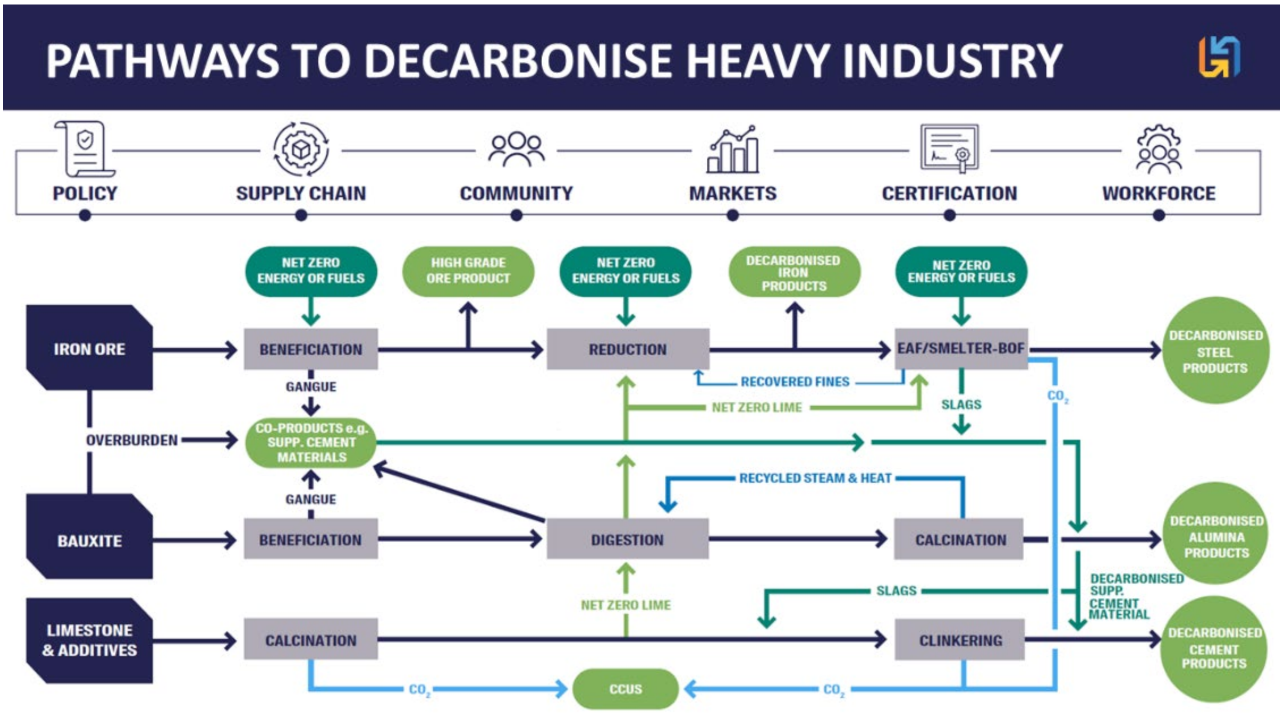


Figure 1: HILT CRC's vision of the interrelated technology pathways to decarbonise heavy industry, highlighting the shared barriers and enablers

PATHWAYS AND TIMELINES FOR HEAVY INDUSTRY DECARBONISATION

Reaching net-zero by 2050 for the heavy industry sectors will require gradual but dramatic transformation of processes throughout the supply chain. Many of the required technologies have not yet reached commercial maturity and are at various stages of development and/or require access to large-scale supplies of net-zero energy sources and/or CO_2 sinks at economically competitive rates. Heavy industrial processes for iron and steel making, and the production of cement, lime, and alumina require assets that generally have long lifetimes, meaning that **industry decarbonisation plans are multi-decadal, with timing determined by capital renewal cycles as well as ongoing technology development and access to competitively costed net-zero energy.**

In addition, **heavy industrial plants will need to develop bespoke decarbonisation plans to account for their unique circumstances**. Each individual plant will have been custom designed to process specific ores with properties that vary with geography, using location-dependent combinations of energy sources and supporting infrastructure. Plant-specific decarbonisation pathways will depend on the type and age of existing plant, as well as the unique combination of potential net-zero energy sources and CO_2 sinks available, spanning wind and solar resources, through to natural gas. Each plant will make different decisions as to which combination of technology options are most suitable for near-term, partial decarbonisation which we term '*transitional*'; and which technology pathway will be most effective for long-term '*transformational*' change to net-zero operation. Critically, ***transformational technologies* will need to be developed and derisked in parallel to deployment of *transitional technologies*, requiring ongoing investment from before 2030.**

Figures 2 and 3 illustrate HILT CRC's industry-informed vision of the technology pathways to progressively decarbonise steel and alumina manufacturing, with indicative timings. Required phased actions can be summarised as follows:

1. *Adapt 'transitional' technologies* via retrofits or brownfield installations, to partially decarbonise processes. Examples of transitional technologies can include the use of natural gas in place of coal as a feedstock and/or fuel; the partial or full replacement of fossil-fuel based electricity, fuels and feedstock with low or net-zero emissions electricity, hydrogen, biofuels and/or biomass in processes; and the deployment of carbon capture, use, and/or storage (CCUS).

   The majority of these transitional technologies come with the risk of increased production cost due to increases in the cost of energy and/or reduction in performance, the significance of which typically increases with the extent of decarbonisation. Even where some of these technologies may be commercially available for other processes or applications (i.e. CCS or renewable electricity), they typically require additional integration and/or adaptation for specific processes.

2. *Trial 'transformational' technologies* or low-carbon solutions in retrofit/brownfield installations to de-risk various components of a new production process which will be introduced at a time in the future. Such technologies have not yet reached commercial maturity and are at various stages of development, from the laboratory to pilot or small demonstration scale.

   Transformational technologies offer opportunity as well as risk. Re-designing part of a process to integrate a net-zero energy source, even within a brown-field site, offers the potential to increase process efficiency, and in turn, to offset the higher cost of net-zero energy. Nevertheless, significant risk is introduced due to uncertainty in which transformational technologies will be most cost-competitive, when different options will be commercially ready, and their likely performance in the plant in question.

3. *Demonstrate first-of-a-kind decarbonised production facilities in commercial operation,* to confirm viable, low emissions performance.

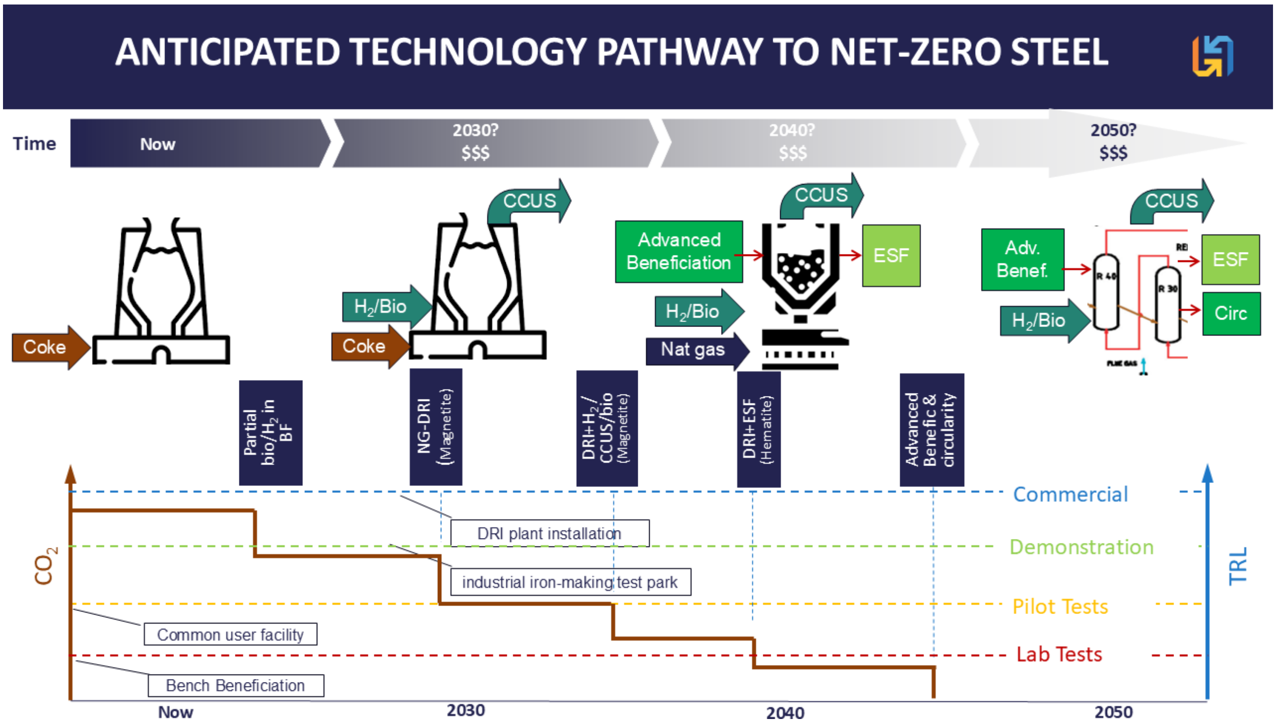


Figure 2: HILT CRC's industry-informed vision of the technology pathways to progressively decarbonise steel manufacture.

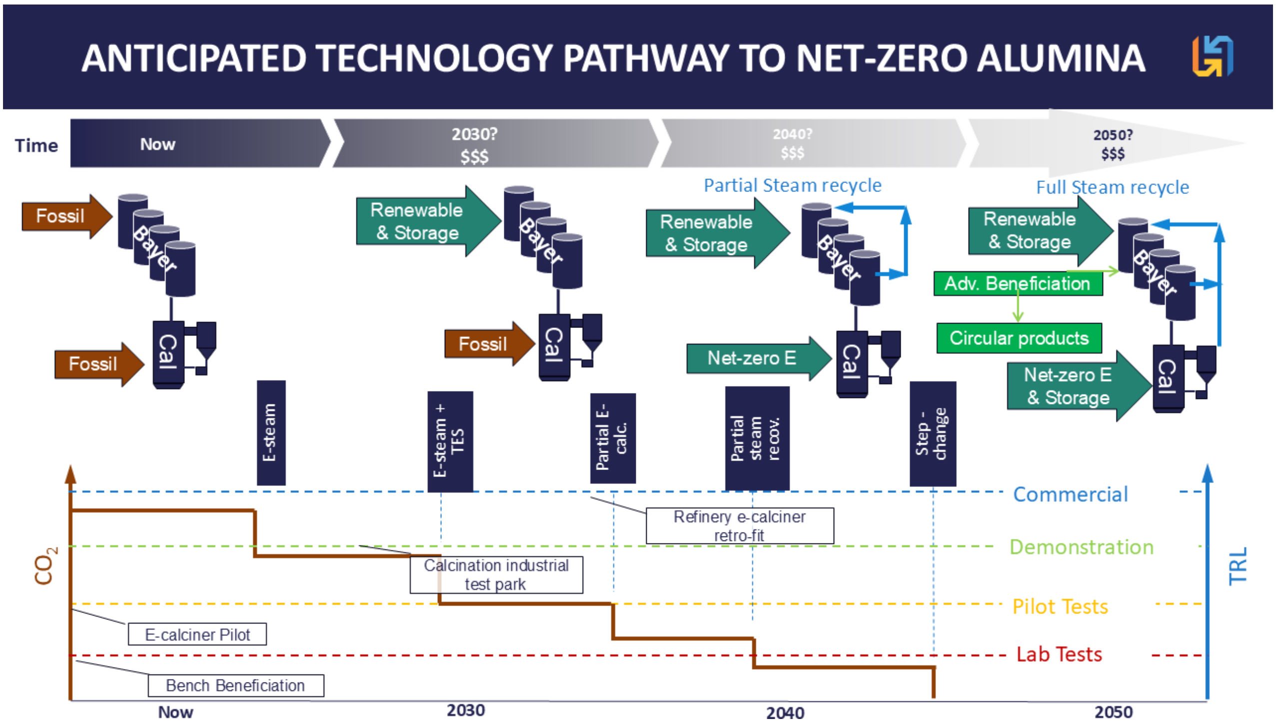


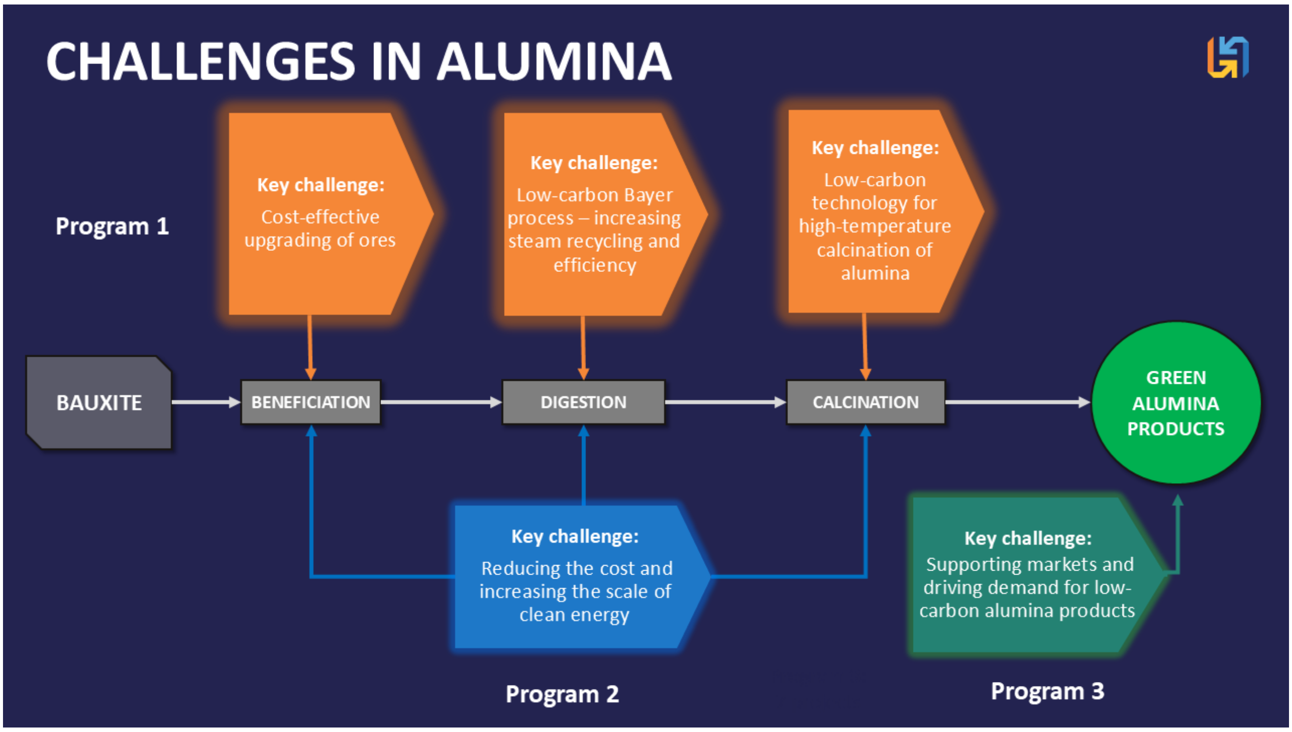
Figure 3: HILT CRC's industry-informed vision of the technology pathways to progressively decarbonise alumina making

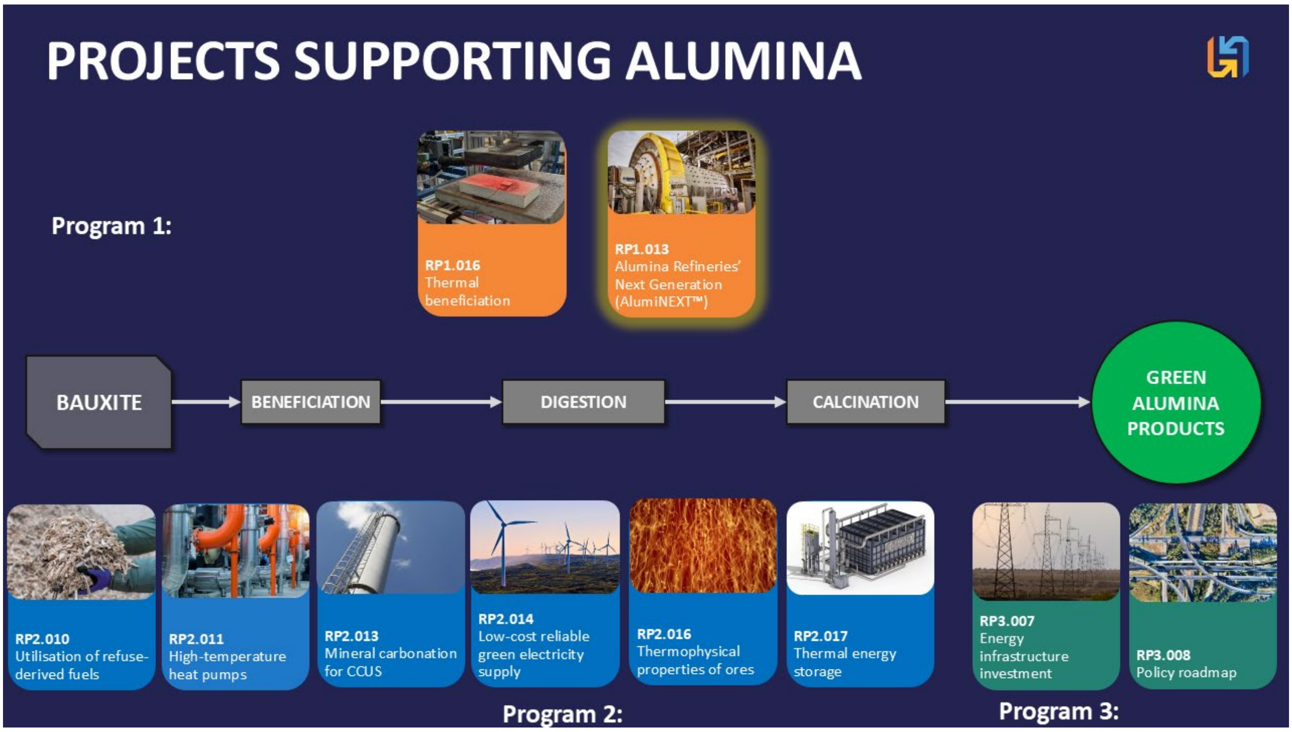
Despite the requirement for plant-specific decarbonisation solutions, sectors have a common interest in de-risking new technologies and evaluating different pathways, presenting opportunities for collaboration and cost-sharing. **The HILT CRC is undertaking research to inform decision makers, including within industry and government, of the most prospective potential decarbonisation technologies and pathways** for iron and steel, alumina and cement industries, accounting for their various stages of development and commercial readiness.

In particular, HILT CRC is progressively establishing a comparative analysis of the various potential transformational technologies under development using a common set of costing assumptions to provide guidance on the relative commerciality of these alternative potential pathways accounting for region specific differences in energy resources, ore type and processing pathway. More information on this initiative can be provided on request.

The following images summarise the key challenges that HILT research is tackling to derisk the decarbonisation of iron and steel, and alumina decarbonisation in Australia.

HILT CRC RESEARCH TACKLING CHALLENGES IN THE DECARBONISATION OF ALUMINA PROCESSING





AlumiNEXT™: Low-carbon alumina processing

2025

Low-carbon steam process design and evaluation: Development of optimised process configurations for low carbon steam generation and recovery for each partner refinery.

2026

Low-carbon calciner retrofit options: Evaluation of partial electrification and thermal energy storage integration in existing refineries.

Development of novel calciner designs: Design and evaluation of innovative calciner configurations.

2027

Technology pathways to next generation refineries: Integration of innovative calcination and energy recovery designs.

Commercial pathways to next generation refineries: – Techno-economic evaluations, customised for each partner refinery.

HILTCRC

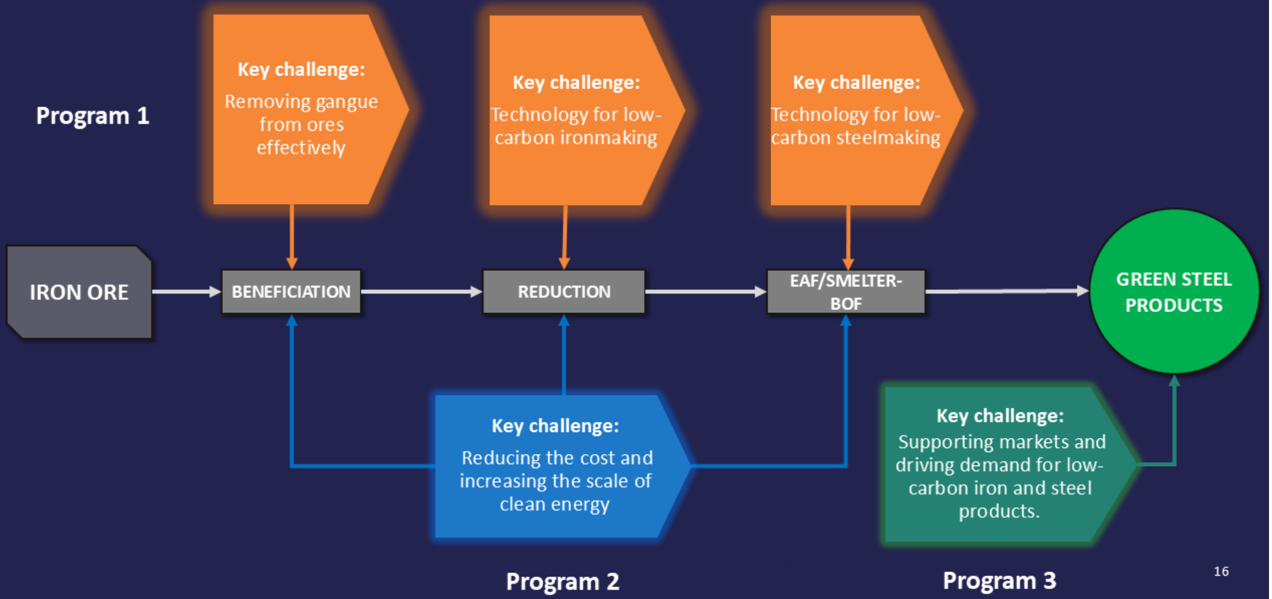
AlumiNEXT™: Low-carbon alumina processing

Target outcomes:

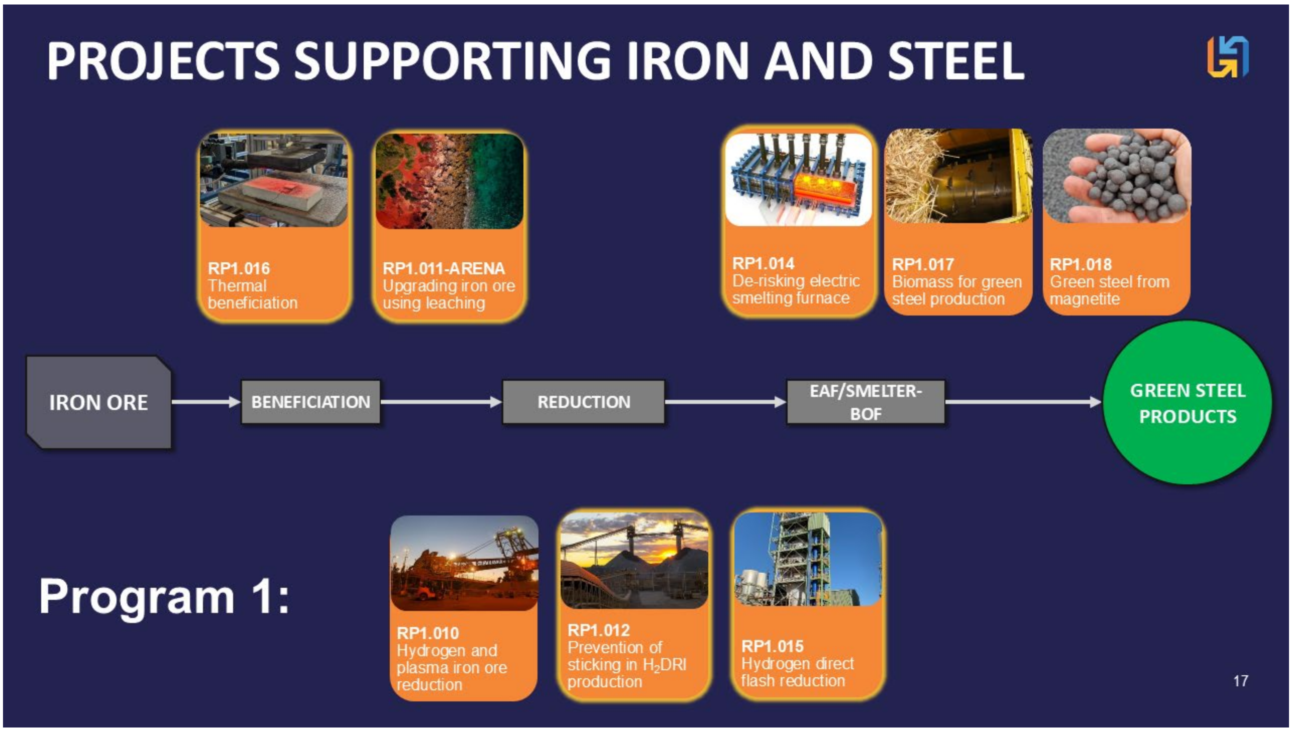
- Low carbon steam recovery and generation
- Low carbon calciner design and retrofit analysis
- Pathways to next generation refineries

HILT CRC RESEARCH TACKLING CHALLENGES IN DECARBONISATION OF IRON AND STEEL SUPPLY CHAINS

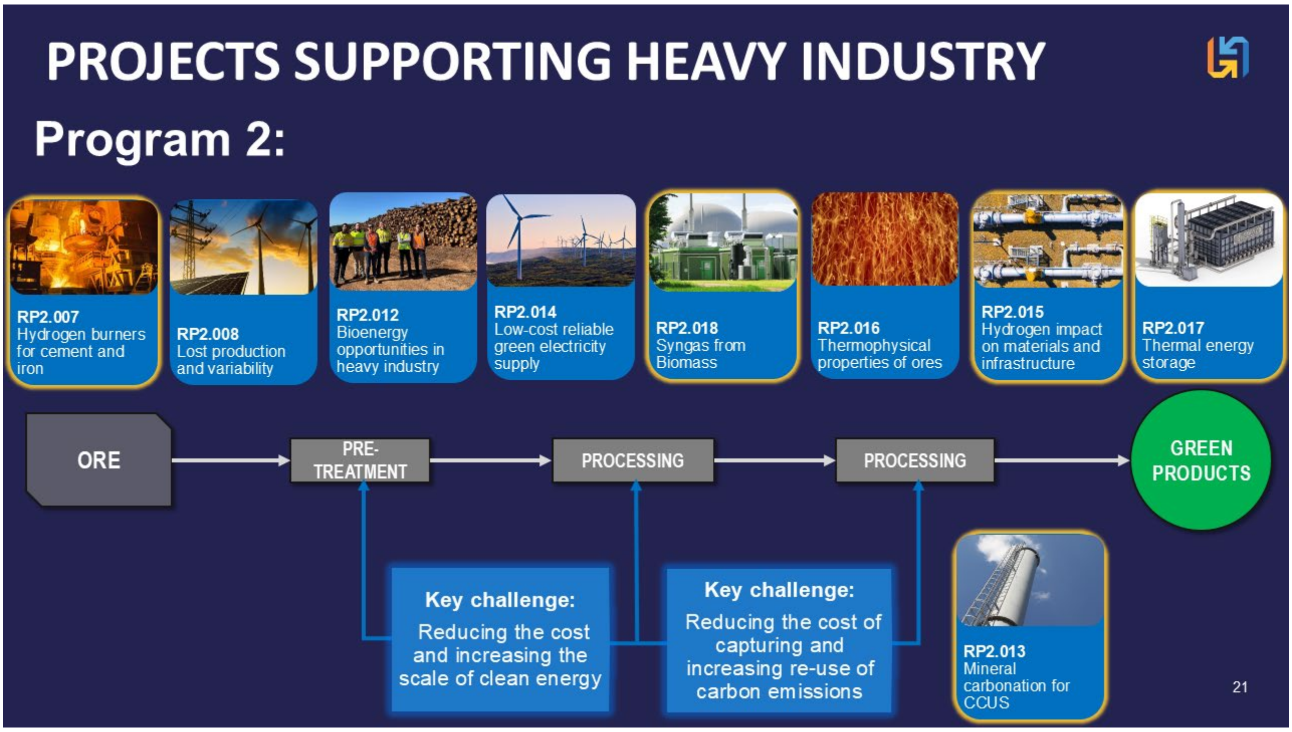
CHALLENGES IN IRON & STEEL



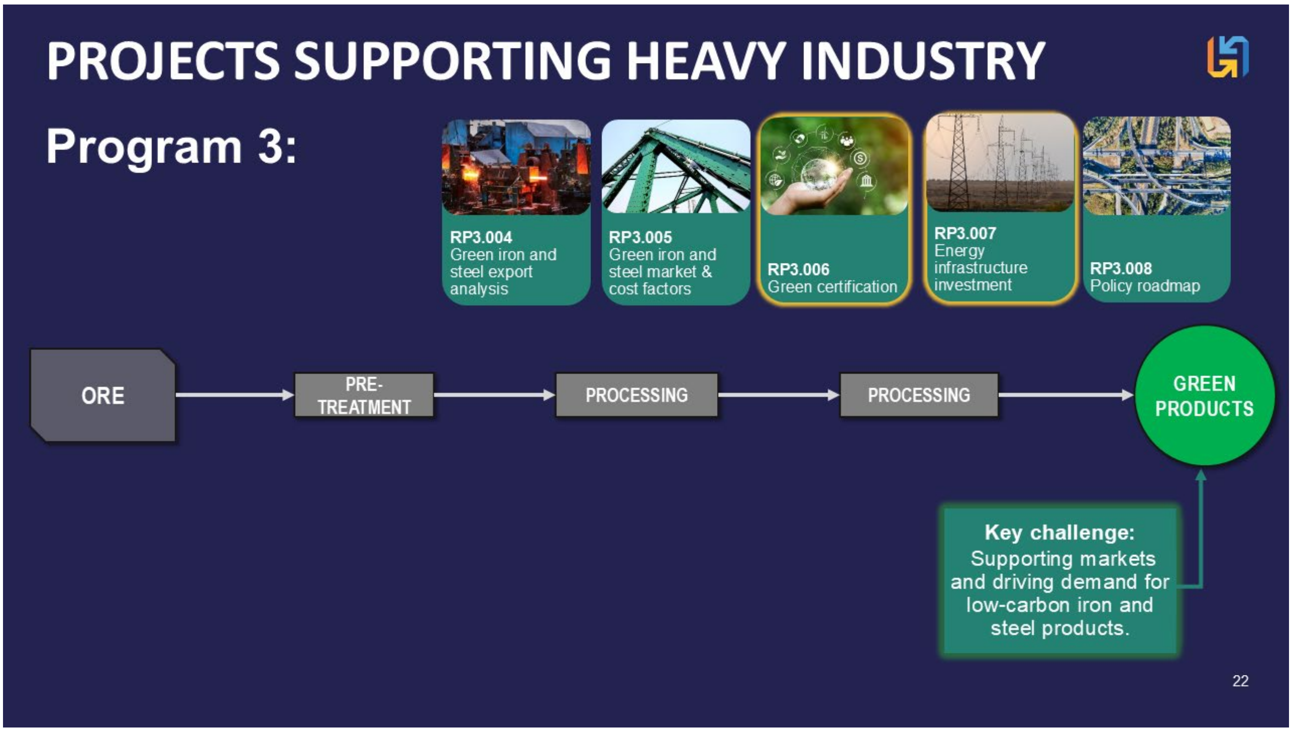
HILTCRC



PROJECTS SUPPORTING IRON AND STEEL
RP1.016 Thermal beneficiation
RP1.011-ARENA Upgrading iron ore using leaching
RP1.014 De-risking electric smelting furnace
RP1.017 Biomass for green steel production
RP1.018 Green steel from magnetite
IRON ORE
BENEFICIATION
REDUCTION
EAF/SMELTER-BOF
GREEN STEEL PRODUCTS
Program 1:
RP1.010 Hydrogen and plasma iron ore reduction
RP1.012 Prevention of sticking in H_2DRI production
RP1.015 Hydrogen direct flash reduction
17



PROJECTS SUPPORTING HEAVY INDUSTRY
Program 2:
RP2.007 Hydrogen burners for cement and iron
RP2.008 Lost production and variability
RP2.012 Bioenergy opportunities in heavy industry
RP2.014 Low-cost reliable green electricity supply
RP2.018 Syngas from Biomass
RP2.016 Thermophysical properties of ores
RP2.015 Hydrogen impact on materials and infrastructure
RP2.017 Thermal energy storage
ORE
PRE-TREATMENT
PROCESSING
PROCESSING
GREEN PRODUCTS
Key challenge: Reducing the cost and increasing the scale of clean energy
Key challenge: Reducing the cost of capturing and increasing re-use of carbon emissions
RP2.013 Mineral carbonation for CCUS
21



ECONOMIC AND EMISSIONS ANALYSIS OF AUSTRALIA-CHINA GREEN STEELMAKING VALUE CHAINS

HILT research project RP3.004 *Economic and emissions analysis of Australia-China green steelmaking value chains* assessed the cost-competitiveness of, and greenhouse gas emissions associated with, Australian exports of direct shipping ore, beneficiated ores, iron (either in the form of Hot Briquetted Iron (HBI) or pig iron), or steel. This was achieved by 1) developing a techno-economic supply chain model that considered how different ore types and composition affect CAPEX and OPEX including energy and material input requirements in different processing steps, a key oversight in much earlier work; and 2) undertaking full Life-cycle assessment of different potential *Australia-China* steel supply chains, both existing and decarbonised.

Currently China is responsible for over half of global steel production and consumes a little over 80% of Australia's iron ore exports. of find that:

1. China's plans for decarbonisation, with reduced steel demand and increasing use of scrap recycling, put strong downward pressure on iron ore consumption. As a result, China's ore consumption is expected to fall to about 950 Mt by 2035 and 650 Mt by 2050. A shift to green steelmaking further affects demand for Australian iron ores most strongly, as these ores as less suited to the H_2-DRI-EAF pathway, relative to high-grade ores from Brazil, Guinea and elsewhere.

2. Australia's competitiveness as a supplier of green iron into Chinese markets hinges on achieving green hydrogen production costs of A$0.50/kg hydrogen below Chinese production costs. At such a cost differential, our model suggests Australia would supply 320 Mt green iron to China in a 2035 scenario where China demands 100% green steel. This would grow to about 430 Mt if the cost differential is as large as A$1.25/kg H2.

3. The Electric smelting furnace (ESF) technology is pivotal for the use of Pilbara ores in green steel production routes. In a 2035 scenario where China demands 100% green steel, our model suggests Australian iron ore consumption would climb together with ESF capacity, from 130 Mt in

a scenario with 100 Mt of ESF capacity, to 420 Mt of Australian iron ore consumption in a scenario with an ESF capacity of 400 Mt or above.

4. Green steel production routes could cut lifecycle greenhouse gas (GHG) emissions to about 0.6 to 0.7 t CO2/t crude steel, or a reduction of about 70% compared with conventional fossil fuel pathways. Shifting green processing to Australia could reduce overall lifecycle emissions by a further 10 to 15%, though it would shift emissions into Australia's emissions inventory.

These results should motivate policymakers to help accelerate development of low-cost renewables and hydrogen, de-risk ESF demonstration and early deployment, and pursue targeted Australia–China supply-chain configurations that align competitiveness with decarbonisation.

PROSPECTS FOR AUSTRALIAN GREEN IRON AND STEEL EXPORTS

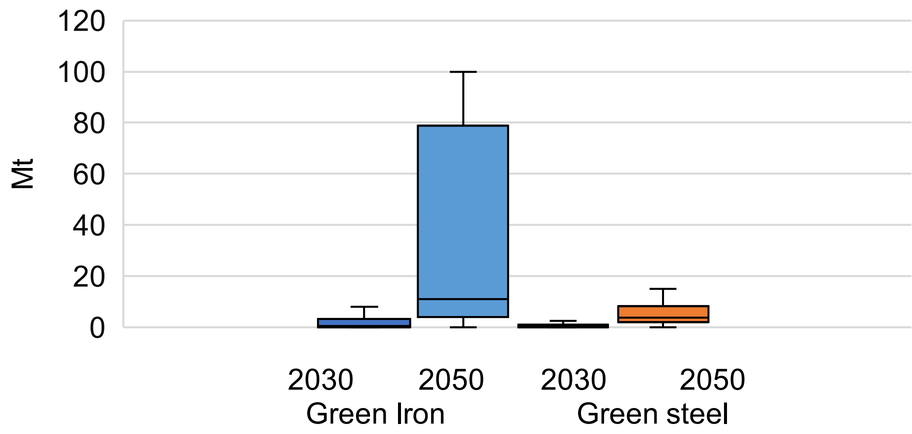
The future prospects for green iron and steel production in Australia remains highly uncertain and will likely be determined by a range of intersecting drivers and barriers. Among them are technologies and relative technology costs, locational factors that may affect green iron/steel production in Australia relative to other geographies, demand for green steel in intermediate and final goods markets in different countries, availability and evolution of policy support, and timelines for emergence of a green iron/steel industry.

HILT research project RP3.005 *Analysis of market, cost and locational factors for green iron and steel in Australia* conducted an expert elicitation of professionals in industry, government, consultancy, NGOs, and academia, to gather insights on the future of green iron and steel production in Australia.

Almost all experts expected green ironmaking to be commercial in Australia by 2050 (97% from magnetite ores, and 95% from hematite). Expert opinions on capacities are more variable, spanning 0 to 100 Mt. Some 38% expect modest production capacities of 5 Mt or less, and a further 25% between 6-20 Mt, with a median of 11 Mt. Participants also hold different opinions about the most prospective technologies. Industry experts expect a mix of technologies to be in play, including BFs, both unabated and with CCS, and small but significant amount of biomass and electrolysis-based reduction processes. Experts from other areas believe that iron making process will be dominated by H_2-based DRI and blended Gas-H_2 based DRI. Most experts do not expect significant quantities of domestic green iron production before 2030.

By 2050, 92% of participants anticipate commercial scale green steelmaking in Australia. Most (77%) expect modest capacities between 1 and 6 Mt, with a median of 4Mt. All experts expect EAF to dominate steelmaking in 2050 but differ in their beliefs regarding the type of feedstock. Industry experts see no role for EAFs processing only primary DRI and expect most EAFs to accept a mix of DRI and scrap steel, with a small capacity dedicated to scrap only. In contrast, Academia/Science and NGO experts see no role for scrap. Most respondents expect a small but significant role for BOF (~20%), except for consultants and academics.

Only around 13% of participants expected green steel to reach commercial scale (>1Mt) by 2030.



Expert elicitation: future quantities of green iron and steel production for 2030 and 2050, illustrating the range and distribution of estimated production levels.

Trade in and demand for green iron and steel

Expectations of potential future markets for Australian green iron largely reflect current steel production and iron ore supply chains. Experts identified Japan, South Korea, and China as the most significant markets for green iron.

Brazil, the Middle East, Africa, and China are viewed as primary competitors for Australia in the green iron market, while China, South Korea, and Japan are seen as the main competitors in green steel. This reflects existing and emerging supply chains for iron ore, iron and steel.

Future demand is largely expected to be dominated of the automobile sector as the lead market for green steel. Driving factors evidently are that steel, and the cost premium for green steel, is only a very small share of the price of cars, while the visibility and branding benefits could be relatively high. Significant uptake is also expected in the appliance and renewable energy generation sector, where similar though arguably weaker factors exist. The construction and infrastructure sectors are anticipated to lag in adopting green steel, which is as expected given the bulk nature of steel in these applications. Europe, Japan, South Korea, North America, and Australia are projected to lead in green steel adoption, while Southeast Asian countries and India are expected to lag behind.

This report maps and evaluates policy instruments that may be used to promote the emergence of green iron and steel. It provides a discussion of the basis for policy interventions, a taxonomy of supply and demand side interventions, analysis of the effects of policy support on investment decisions under uncertainty, and some principles that may guide instrument choice.

HILT research project RP3.005 *Analysis of market, cost and locational factors for green iron and steel in Australia* also undertook an analysis of policy instruments to support a green iron and steel industry global, and assessed which policies could be relevant for Australia.

The work evaluated the characteristics and effects of a suite of demand and supply-side policy support instruments along a range of criteria. To evaluate both the likely effect and desirability of different instruments, an understanding of the nature of investment decisions for decarbonised production is needed, taking into account uncertainty about future market conditions and technological pathways, and information asymmetry between project proponents and government.

The suitability or otherwise of particular policy instruments depends on the specific circumstances and objectives. However, two broad conclusions can be made:

1. Financial risk is a major obstacle to green iron and steel investments. Governments can reduce investment risk for projects which are subject to high levels of uncertainty in future prices and

costs, for example through contracts-for-difference and similar instruments, or by reduce financing costs through concessional finance.

2. Supply-side policy instruments tend to have more balanced distribution of costs and benefits and can have better prospects to provide sustainable policy support over time and at scale, especially for export industries.

Current green industry policy, both internationally and in Australia, typically favours supply-side measures. However, demand-side policy instruments have an important role to play and warrant further development.

For Australia, where green iron and other green commodities would largely be exported, the findings suggest that governments could usefully focus policy support for green iron and steel on instruments that reduce investment and market risk for early investments, as well as on foundational measures such as regulatory frameworks, skills, and infrastructure. Further, demand-side policy measures in resource importing countries, in particular carbon pricing coupled with border carbon adjustments, hold promise as a support to the development of an enduring green iron industry.

ENABLERS AND BARRIERS TO HEAVY INDUSTRY DECARBONISATION

The HILT CRC has analysed partner and stakeholder perspectives on enablers and barriers to heavy industry decarbonisation collected through expert elicitations, roundtables, and surveys, as detailed below, as well as ongoing engagement with partners in HILT research projects. The HILT has over 60 partners and a wide network of stakeholders from industry (including heavy industry, end users and technology providers), government, academia, non-governmental organisations and consultancies.

HILT research project RP3.005 *Analysis of market, cost and locational factors for green iron and steel in Australia* conducted an expert elicitation of 42 experts to better understand the expectations for green iron and steel in Australia. Views on barriers and enablers for an Australian green iron/steel industry paint a complex picture, with a sizeable number of barriers as well as enablers identified as materially important.

Lack of government support and high capital costs are most frequently described as major barriers. Carbon pricing and border carbon adjustments are the most frequently identified potential enablers, followed by a range of measures that governments could take to support emerging producers, mostly by way of bringing investment risks and production costs down.

These expert views illustrate the importance of demand-side policy instruments as potentially long-term sustainable solutions to create green iron and steel demand at scale, while also pointing to the need for supply-side support to help with the emergence of such industries in Australia in the context of international competition.

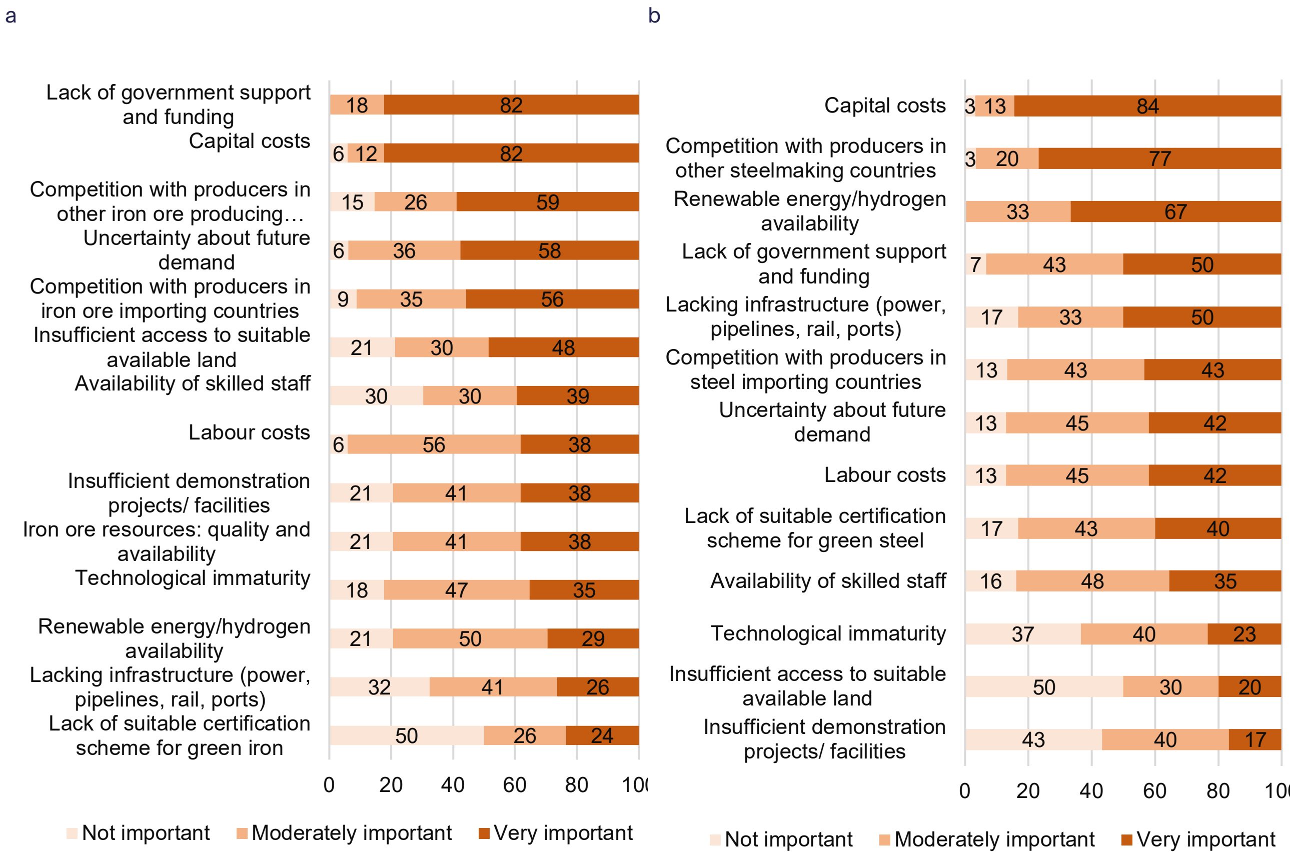
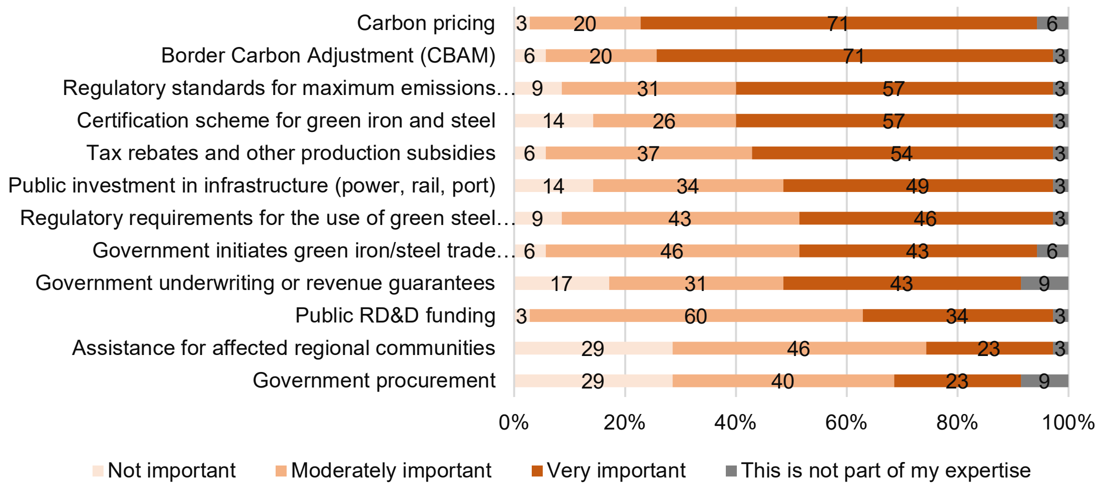


Figure 2: Expert elicitation - major obstacles for the development of a) green iron and b) green steel industry in Australia



Expert elicitation - ranking of enabling measures to facilitate the development of green iron and steel industry in Australia

HILT hosted a series of roundtables with stakeholders, including industry partners and government representatives, across Australia in 2023 on “Facilitating Transformation” to discuss non-technological barriers holding back the deployment of decarbonisation technologies. When considering polling results from all Roundtables the top four ranked themes were:

- Enabling infrastructure
  - Access to low cost, low emissions energy and hydrogen on required timescale
  - Coordination and investment in energy infrastructure and
  - Non-energy infrastructure such as roads, rail, water, housing
- De-risking decarbonisation investment
  - Ensuring regulations and approval processes are efficient, consistent and co-ordinated and across state and federal government
- Policy signals and enablers
  - Co-ordinated trade and industry policy to assist Australian industry in attracting capital investment, in accessing technology, and remaining internationally competitive with their products
- Trade barriers and market drivers
  - Developing internationally recognised and interoperable net-zero product certification and verification.
  - Driving demand for green commodities domestically and through engagement with existing and potential international

Text in italics provides more detail and is based on further analysis by HILT program leadership, with feedback from partners.

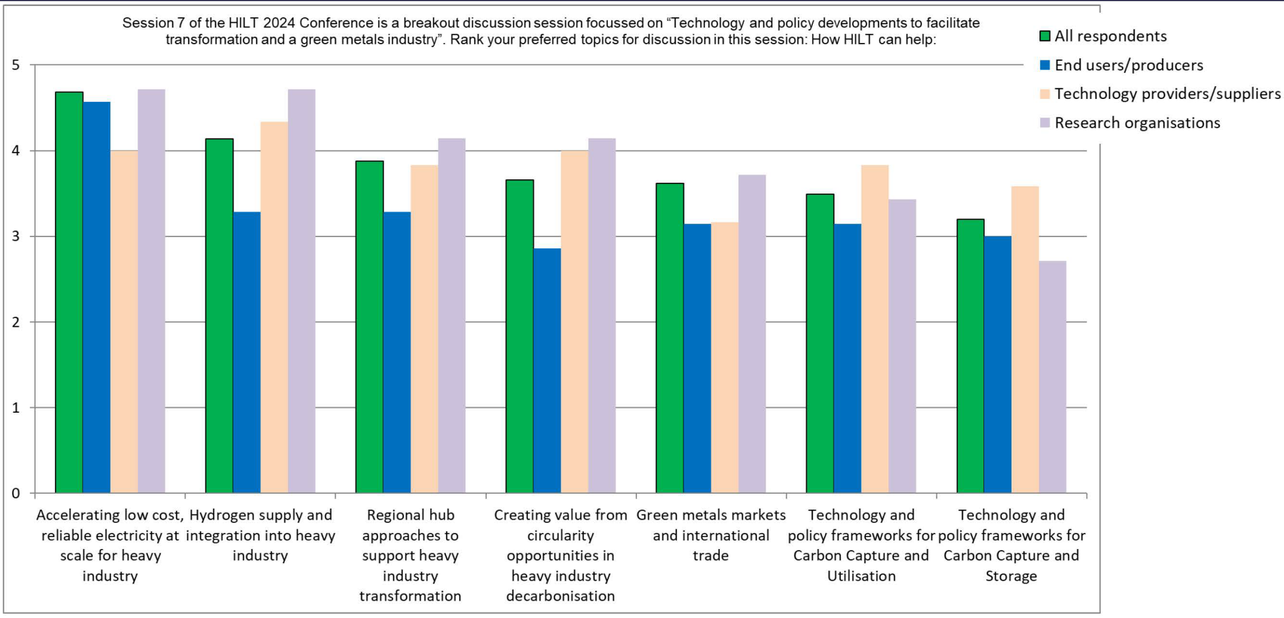
Clustering analysis of discussion relating to these themes identified five topics that could address these barriers, as summarised in the matrix below.

Common Feedback Topics:	Priority Themes: Enabling Infrastructure	De-risking decarbonisation investment	Policy signals and enablers	Trade barriers and market drivers
Mapping cross-border impacts of existing LCT policy settings.	✓	✓✓	✓✓✓	✓✓✓
Policy scenario modelling of reaching net zero by 2050.	✓✓	✓✓✓	✓✓✓	✓✓
Harmonising LCT regulation, compliance & certification.	✓	✓✓	✓✓✓	✓✓
LCT stakeholder engagement & collaboration.	✓✓	✓	✓✓✓	✓
Coordinated LCT investment planning & knowledge sharing.	✓✓✓	✓✓✓	✓✓	✓

HILT conducted a survey of partners at the HILT CRC conference in October 2024 to rank the most important topics for discussion on technology and policy developments to facilitate transformation and a green metals industry. Participants ranked “Hydrogen supply and integration” as a priority, second only to “Accelerating low-cost, reliable electricity at scale”.

Results from HILT CRC Conference, October 2024 in response to the question: Rank the most important topics on technology and policy developments to facilitate transformation and a green metals industry for discussion.

Q11: Session 7 topics at HILT conference



HILT's Program 3: Facilitating Transformation has the following flagship projects now underway to address these barriers and potential enablers:

RP 3.006: Certification and verification to enable a successful LCT for heavy industry. This project will enable Australian heavy industry to successfully engage with emerging regulatory and market regimes based on embedded emissions account, providing them with competitive advantage and supporting their successful transition to low carbon production – both financially and environmentally.

RP 3.007: Unlocking investment in energy infrastructure for net zero industrial hubs. This project will provide the information required to enable industry and other stakeholders to plan for the transformation of the energy supply system necessary for heavy industrial sectors to a net-zero carbon future.

RP 3.008: A policy roadmap for Australia's heavy industry low-carbon transition. This project will assist heavy industry partners and stakeholders to understand, manage and mitigate risks associated with the transition. It does this by deepening understanding of current and future policy developments at different government levels that directly impact heavy industry.

CRITICAL ROLE OF THE COST OF LOW EMISSION ZERO HYDROGEN FOR DECARBONISATION OF HEAVY INDUSTRY

While the costs of different decarbonisation technologies and pathways are still evolving, **HILT analysis indicates that the cost of renewable energy and hydrogen will make up a significant fraction of the cost of heavy industry decarbonisation.**

HILT research projects RP 1.004/1.005 undertook an end-to-end technoeconomic analysis of green steel making in the Australian context, with an emphasis on understanding the impacts of Australian ore grades on the overall process design[1]. From preliminary estimates of technology costs, the project concluded that the cost of hydrogen made up roughly half of the levelised cost of green steel (assuming hydrogen costs of 3.5 USD/kg), and that green steel was 45-60% more explensive than conventional steel making.

HILT research projects RP1.002/1.007 demonstrated that converting alumina refineries to utilise either electricity or hydrogen at current prices and efficiencies is likely to add approximately 50% to the cost per tonne of product alumina. That would translate to 15% addition to the cost per tonne of aluminium. HILT CRC research activities in new project RP1.013 are aligned with increasing the process efficiencies with optimised incorporation of low-cost variable renewables to minimise the costs of firming of the energy inputs. This research indicates power demand reduction of between 20-25% may be realisable.

HILT is continuing research to further inform the location-specific energy demand (electricity, heat, and hydrogen) and supply infrastructure required for heavy industry to transition to net-zero in Australia. Flagship HILT project *PR3.007 Unlocking investment in energy infrastructure for net zero industrial hubs* kicked off in August 2024 and will greatly improve our understanding of the public investment in energy capacity and infrastructure required to achieve net zero by 2050 under a series of scenarios that major stakeholders, including the industry, considers to be plausible. Specific aims include:

1. developing plausible scenarios both for the transition of existing processes and the establishment of new processes needed to reach net zero emissions by 2050 for major industrial hubs in Australia.
2. developing energy system modelling tools to estimate demand for electricity and fuels for these processes, and the capital cost-optimised infrastructure needed to meet these demands.
3. estimating the potential government co-investment that may be required and justified based on future economic benefits, such as employment, royalties/revenues, social/regional benefits and private co-investments.

CERTIFICATION OF GREEN COMMODITIES

HILT Research Project RP3.006 *Certification and verification to enable a successful LCT for heavy industry* aims to provide our partners with evidence-based information to enable them to engage in processes around the development of embedded emissions accounting regimes in Australia. This includes options for as-yet unresolved questions around accounting complexity for circularity and co-products. The project kicked off in June 2024.

Preliminary findings highlight that ensuring alignment and interoperability will enable Australia to seize significant opportunities in developing a net-zero heavy industry, particularly for commodities green metals with international supply and value chains.

[1] Specifically, the project compared pathways incorporating different ore upgrading processes (beneficiation), low emissions iron making (direct iron reduction via a shaft furnace or a fluidised bed) and steelmaking options (the electric arc furnace or smelter plus basic oxygen furnace).

ALUMINA REFINERIES' NEXT-GENERATION TRANSITION (AlumiNEXT™) PROJECT

HILT CRC project RP1.013 AlumiNEXT™ explores innovative ways to decarbonise alumina refineries by transitioning from natural gas combustion to hydrogen or electrification in the calcination process and achieving net-zero steam generation and recovery within the Bayer Process (refining bauxite ore to produce alumina).

The project addresses the short-term need to: (a) de-risk relatively high technology readiness level (TRL) technologies that can retrofitted into current alumina refineries to reduce emissions; and (b) develop novel technologies to unlock a step-change in efficiency, reduced CO2 emissions, and reduced cost in next-generation net-zero refineries.

The project aims to de-risk high-readiness technologies with strong potential to reduce emissions and explores novel approaches to unlock significant efficiency gains using low-carbon energy sources. By targeting key processes in alumina production, the project aims to deliver practical, high-impact approaches to decarbonisation.

AlumiNEXT™ is driving the transition of alumina refineries to net-zero CO_2 emissions by addressing both transitional low-carbon solutions for the short and medium term and transformational net-zero technologies for the long term.

The project aims to develop and demonstrate steam recovery technologies, including thermal vapour recompression (TVR) and mechanical vapour recompression (MVR), to improve efficiency and reliability. Preliminary assessments suggest these approaches can make net-zero alumina production economically viable, with competitive costs compared to natural gas when carbon impacts are considered.

The project focuses on:

- Achieving net-zero steam generation and recovery within the Bayer Process (refining bauxite ore to produce alumina) to improve the sustainability and efficiency of alumina production. This involves optimising existing processes and integrating innovative technologies to reduce emissions.
- Decarbonising the energy-intensive calcination process, the final heating step in alumina production, where hydrated alumina (aluminium hydroxide) is heated to very high temperatures to remove chemically bound water, converting it into pure alumina (aluminium oxide). This research component will develop strategies to significantly lower calcination's carbon footprint.

These two project components are further divided into research areas that address specific challenges and opportunities, ensuring that AlumiNEXT™ systematically tackles barriers to decarbonisation.

Further details of HILT projects and stakeholder engagement can be provided on request.