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Project Title	Innovative Beneficiation Technologies for Green Ironmaking
Industry Partner	University of Adelaide
Industry Sector	Iron and Steel
Technology Pathway (Primary)	Alternative materials & more efficient processes
NIM Pillar	Technology Demonstration
Source	NIM Awards 2025
Description	Australia leads global iron ore production, accounting for 31% of reserves and 38% (953 Mt) of global production in 2024. However, declining availability of high-grade iron ores is driving the extraction of lower-grade ores, which present challenges for both traditional and green steelmaking due to their complex mineralogy and higher impurities. While beneficiation processes can be used to upgrade ore quality by increasing iron content and removing impurities, conventional beneficiation techniques such as size and density separation have limited effectiveness on these complex ores. Consequently, there is a need for advanced technologies to improve the beneficiation of lower-grade iron ores, ensuring they are compatible with both traditional and green steelmaking processes. This project aims to develop and upscale a transformative, low-carbon, and cost-effective thermal pre-treatment technology for beneficiation of a wide range of low-grade Australian iron ores. The technology uses high-flux radiation from renewable sources to efficiently heat crushed ores on a conveyor belt-type reactor at moderate temperatures. It is designed to remove detrimental impurities upgrading ores to Fe content levels of 60-66% wt, making them suitable for green steelmaking. Other significant benefits include reduced grinding energy, production of iron concentrates with very high surface area at relatively low cost and carbon-equivalent emissions, and activation of iron tailings towards accelerated mineral carbonation processes (permanent CO_2 storage via production of solid iron carbonates). The first 2 years of the research program demonstrated promising results via lab-scale trials (TRL 3/4) and techno-economics analysis. Building on this success, the next 3 years will focus on scaling up the technology to TRL 5/6. This phase will involve demonstrating the technology at sub-pilot scale, investigating the effects of rapid heating on ore grindability, physio-chemical transformations, and overall beneficiation performance. The project will also continue to refine the process for enhancing iron recovery, improving ore quality, and ensuring compatibility with emerging green steelmaking processes.
Innovations Employed	The bespoke conveyor-belt reactor technology under development has significant potential to upgrade Australian low-grade iron ores into value-added products at a lower cost and with a reduced carbon footprint, thanks to lower energy and water usage compared to previously proposed thermal beneficiation technologies. Traditional heating methods typically rely on slow convection-based heat transfer (order of 10 °C/min), which requires long residence times, large, complex equipment, and high capital costs. In contrast, the use of high-flux radiation, with fast heating rates (order of 10-100 °C/s), offers the opportunity to overcome these challenges while

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	also reducing grinding energy requirements through ore softening. Additionally, rapid heating enables the production of iron concentrates with very high surface areas, which can be highly beneficial for downstream processes such as leaching and hydrogen-based reduction (DRI/HBI), as well as for activating tailings for use in accelerated mineral carbonation processes. Beside a potential step-change in efficiency, the conveyor belt-type reactor technology also offers a leap in the scale of productivity. A full-scale conveyot belt reactor can process well over 1000 tonnes per hour of ore and has the capability to process heterogenous feed with varying particle sizes. The estimated levelised cost of beneficiation for this technology, at its current stage of development, when combined with grinding and magnetic separation downstream, ranges between 10-30 AUD/ton. This represents a 20-55% reduction in CAPEX per ton compared to other heating reactor technologies (such as drop tube and fluidised bed) at a 1-10 Mtpa scale. The high-flux radiation driving the process can be supplied by multiple renewable energy sources, including hydrogen combustion, resistive electrical heating, and concentrated solar thermal, either standalone or in combination (hybrid). For a fuel-based heating system, the estimated CO_2-equivalent emissions for the entire beneficiation plant - which includes rapid heating, heat recovery, grinding and magnetic separation - are estimated to be 4-10 $kgCO_2$-eq/ton for electrolytic H_2, and 15-28 $kgCO_2$-eq/ton for natural gas.
Dimension of Novelty	**New for the Company** **New in Country** Australia
Innovation Collaboration	**In house** Australia, Italy **Cooperation with scientific institution** HILT CRC **External Partners** Magaldi Power
Intellectual Properties	The novel intellectual property (IP) is protected through three innovation disclosures, all currently at the PCT stage. Two of these are directly owned by Magaldi, with researchers from the University of Adelaide as co-authors. These disclosures focus on the design and various configurations of a bespoken conveyor belt system that utilises rapid heating via high-flux radiation to pretreat iron ores (as bulk material). The third disclosure is owned solely by the University of Adelaide, with exclusive authorship from the University. It covers the method, key reactions involved, and optimal operating conditions for the process. Details of the innovation disclosures are as follows: 1) Thermal treatment of a material comprising a mineral. Patent filled by the University of Adelaide, describing a high-flux radiation method for thermally-assisted beneficiation of low-grade iron ores. PCT/AU2024/051157

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	2) System and method for the thermal processing of bulk material by intense concentrated solar power. Patent filled by Magaldi, describing a conveyor belt system for ore roasting using high-flux solar radiation. AU2021249572A1 3) Heating tower. Patent filled by Magaldi, describing a heating tower built using moving beds for ore roasting. BI5827R
IP Links	https://patents.google.com/patent/AU2021249572A1/fr
Timetable & Progress	Development commenced in 2022 The technology has been developed within the Heavy Industry Low Carbon Transition CRC (HILT CRC), in collaboration with key partners in the iron, pellet, and steel industries, including FMG, Roy Hills, Grange and Liberty GFG. Following two years of evaluation and lab-scale trials, the research team has secured three years of funding to scale up and demonstrate the technology at sub-pilot scale. By the end of the program, the technology readiness level (TRL) is expected to reach 5/6.
Financing (Public/ Private)	**Public funding** Australian Federal Government via Heavy Industry Low-carbon Transition Cooperative Research Centre
Finance Links	
Project Phase TRL	TRL 4
Problems to be Solved and Risks to be Managed	The primary challenge was developing a novel thermal beneficiation technology to upgrade Australian low-grade iron ores (LGIO) for both traditional and green steelmaking processes. Low-grade iron ores (Fe <57% wt.), particularly hematite-goethite blends and goethite-rich ores, present significant challenges due to their complex mineralogy, higher gangue levels, and finer grain size. These characteristics make them less compatible with traditional beneficiation techniques and emerging green technologies such as hydrogen-based reduction. One key issue was overcoming the limitations of traditional heating methods, which rely on slow convection-based heat transfer, resulting in long processing times, high energy consumption, and expensive capital costs. Another challenge was ensuring the novel technology could scale to handle large ore volumes at lower costs and reduced carbon emissions, while also processing highly heteregenous feed sizes (e.g., 300 microns to 30 cm) - a significant limitation of other reactor technologies like drop tube and fluidised beds. The risks included developing a high-flux radiation-based heating system that could consistently deliver effective upgrades (Fe > 60% wt., Fe recovery >70%) across different ore types at moderate heating conditions (roasting temperature in the order of 500-700°C) while remaining energy-efficient and scalable. Additionally, the integration of renewable energy sources and the process's compatibility with downstream processes, such as grinding and magnetic separation, posed further technical challenges.
Preliminary or Final Results Achieved	The project has achieved promising preliminary results, reaching TRL 4. The novel thermal beneficiation technology has demonstrated the potential to upgrade Australian low-grade iron ores (LGIO) with significant improvements in efficiency, cost,

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	and CO2 emissions reduction. The process operates at moderate temperatures (500–700°C), offering a more energy-efficient approach compared to traditional methods. Preliminary results showed a 30% reduction in grinding energy requirements compared to untreated ores, driven by the ore softening effect of rapid heating. This reduction contributes to process efficiency and cost savings. The technology successfully upgraded ore quality, with the final iron content in the concentrate reaching 60-65% Fe, an improvement from the initial low-grade ores (Fe <57% wt.). Additionally, Fe recovery rates exceeded 70%, indicating high recovery efficiency. Up to a ten-fold increase in the specific surface area of the iron concentrate was measured compared to untreated ore, which is beneficial for downstream processes such as leaching and hydrogen reduction. The conveyor-belt reactor is configured to integrate heat recovery, further enhancing process efficiency and reducing costs. Preliminary estimates suggest the levelized cost of beneficiation ranges between 10–30 AUD/ton, representing a 20–55% reduction in capital expenditures (CAPEX) compared to traditional reactor technologies like drop tubes and fluidized beds at a 1–10 Mtpa scale. The technology also showed the ability to process heterogeneous feed with varying particle sizes, a limitation of other methods. Renewable energy sources, such as hydrogen combustion and concentrated solar thermal, contribute to the sustainability of the process. CO2-equivalent emissions for the beneficiation process were estimated at 4–10 kgCO2-eq/ton for electrolytic hydrogen and 15–28 kgCO2-eq/ton for natural gas, showcasing significant reductions in emissions compared to conventional methods.
CO2 Emissions Reduction Potential - Implementation and Future Market	Australia has significant low-grade iron ores (<57% Fe) that require further beneficiation to meet future market specifications. The proposed thermal beneficiation technology offers strong market potential both domestically and abroad. With an estimated revenue potential of AU$30 billion per annum by 2050, this technology can help Australia retain a substantial share of the iron ore market, especially as global demand for high-grade DRI-grade ore (Fe > 65%) is expected to increase fivefold by 2050. This shift in demand puts at risk one-third of Australia's current iron ore exports, which would otherwise face declining marketability and revenue. By enabling the processing of lower-grade ores into high-quality products for green steel production, this technology can help Australia retain market share in the green steel era. Achieving a levelised cost of beneficiation (LCOB) of 10-30 AUD per tonne, the technology can process ores at a competitive cost while reducing transport costs due to lower product mass and moisture. Additionally, thermally assisted beneficiation, powered by renewable energy, achieves high-grade concentrates, high mass yields, and lowers slag volumes in high-temperature processes, reducing carbon intensity (Scope 3 emissions). This process also dehydroxylates goethite, improves pellet quality, and produces feedstock suitable for DRI/HBI processes, offering the potential to create high-grade hematite from Pilbara fine ores for green HBI or pellets. Preliminary techno-economic analysis shows the technology's LCOB is within the competitive range of 10-20 AUD per tonne, contributing to reduced water

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	consumption, Scope 3 emissions, and overall environmental impact. This positions Australia as a leader in the green steel market while protecting its iron ore sector from market disruptions caused by the growing demand for DRI-grade iron ores.
Market Positioning	While the technology is currently at TRL-4, it has a strong market positioning due to its innovative nature and the involvement of Magaldi Power, a global leader in supplying high-temperature belt solutions. Magaldi Power already serves the iron and steel industries with products like conveyors for hot Direct Reduced Iron (DRI) and casting. This thermal beneficiation technology, based on a bespoke conveyor-belt reactor, will expand Magaldi Power's existing portfolio, particularly in the upstream segment of the iron ore processing chain. The commercialisation of this technology by Magaldi Power will leverage their established market presence and expertise, making the solution highly attractive to the industry. Over the next three years, the research team will focus on scaling up the technology to TRL-6, with a goal to reach TRL-7/8 within five years. Partnerships with key players in the iron ore and steel production sectors, as well as mid-stream technology providers (such as pellet and DRI/HBI producers), will be critical in fast-tracking the commercialisation process. These collaborations will enable the technology to be quickly adopted and integrated into existing processes, accelerating its deployment and ensuring a strong market position moving forward.
Project Location	Australia
Project & Technology Links	https://www.adelaide.edu.au/cet/news/list/2025/07/23/new-technology-for-cleaner-greener-steel https://hiltcrc.com.au/projects/upscaling-novel-green-thermally-assisted-beneficiation-pathways-and-impact-of-beneficiation-on-direct-reduced-iron-and-pellet-production/
Technology Links	