NET-ZERO INDUSTRIES
MISSION

Project Title	ZESTY (Zero Emissions Steel TechnologY)
Industry Partner	Calix
Industry Sector	Iron & Steel
Technology Pathway (Primary)	Electrification of Production & Process
NIM Pillar	Technology Demonstration
Source	NIM Awards 2024
Description	Calix's Zero Emissions Steel TechnologY (ZESTY) is a renewably powered hydrogen direct reduced iron (H-DRI) technology for the production of green iron and steel. ZESTY uses Calix's unique platform technology to replace fossil fuel combustion with precise and renewably powered electric heating. Like other H-DRI technologies, ZESTY uses hydrogen to remove oxygen from the iron ore to produce metallic iron and water. Unlike other approaches, however, ZESTY separates the heat source from the reaction to ensure hydrogen is not combusted or used as a fuel and is easily recycled. This allows ZESTY to target the most efficient use possible of hydrogen in the production of green iron. The ZESTY project at the Calix Technology Centre has thoroughly tested and proven the technology at pilot scale. This work has included over 130 test runs from 9 different sources, including both hematite/goethite and magnetite ores, covering a range of grades and particle sizes, with throughputs up to 100 kg/h. The ZESTY project delivered excellent metallisation rates of up to 98%. Most test runs achieved metallisation suitable for downstream use in either a melter or blast furnace, while several tests reached sufficient levels for feed directly to an electric arc furnace. Notably, these results include for hematite/goethite ores, representative of around 96% of Australia's iron ore exports, or around 50% of global iron ore supply, and typically considered unsuitable for downstream processing in an Electric Arc Furnace. As such, ZESTY is pioneering solutions to make existing iron ore assets and supply chains compatible with low emissions steel making. H-DRI produced by ZESTY has been used to make green iron briquettes for export. A detailed techno-economic study found efficient electric heating, minimal hydrogen use, and elimination of additional processing steps, mean ZESTY has the potential to produce iron with near zero emissions at costs close to conventional fossil fuel-based approaches.
Innovations Employed	ZESTY uses a unique combination of efficient electric heating and minimal hydrogen use. Renewable electricity is used to deliver high temperature heat, with hydrogen used only as a reductant, helping to minimise costs. ZESTY is ideally suited to process small particle sizes, including fines that may otherwise be discarded as waste. ZESTY also removes the requirement for iron ore fines to be pelletised, eliminating process steps and avoiding significant capital and energy costs. ZESTY's compatibility with lower grade ores provides a pathway to decarbonise much of the world's current iron ore supply. ZESTY also delivers a highly simplified process for the processing of iron ore fines and ultra-fines without fluidised beds.

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	Compatible with intermittent and renewable sources of electricity, ZESTY may also provide a versatile load-balancing service to the grid, due to its ability to match its energy sue to the grid's requirement across a wide range.
Dimension of Novelty	It was new on the International Market
Innovation Collaboration	In house (Australia) External: HILT CRC (Australia)
Intellectual Properties	Calix has 29 patent families covering its core technology and applications, including 8 patent families relevant to ZESTY.
IP Links	Calix
Timetable & Progress	ZESTY was first developed and patented in 2021
Financing (Public/ Private)	Calix was awarded a A$947,035 grant by the Australian Renewable Energy Agency (ARENA) to help fund the Basis of Design and Front-End Engineering Design (FEED) study for a ZESTY demonstration plant.
Finance Links	ARENA - Calix Zero Steel Technology (ZEST) pre-FEED / FEED Study
Project Phase TRL	TRL 6
Problems to be Solved and Risks to be Managed	The ZESTY project aimed to thoroughly test ZESTY at pilot-scale, to the enable the design of a commercial demonstration plant. To undertake pilot-scale testing, Calix's multi-purpose electric calciner at the Calix Technology Centre on Victoria, Australia, was converted to operate with a hydrogen environment and handle a fine direct reduced iron product. This work was undertaken safely and effectively. Working with various iron ores provided by multiple partners in the HILT CRC, each ore source required appropriate processing conditions to be developed and optimized. Rapid material characterization and analysis expedited feedback to inform the next test run and accelerate the optimization of process conditions. Strong collaboration with industry partners enabled tailored conditions for each ore to be found, demonstrating the technology's potential to provide industry-wide solutions across a range of ore types.
Preliminary or Final Results Achieved	Pilot-scale tests delivered metallisation of 75-98%. Most test runs produced green iron suitable for use in either a melter or blast furnace, while several tests produced green iron suitable for feed directly to an electric arc furnace. Notably, these results are for hematite ores. First green iron briquettes were made from ZESTY H-DRI with highly encouraging properties. ZESTY's energy requirement is projected to be 4.2–4.6MWh / tonne of iron. Excluding hydrogen production, ZESTY is projected to require 0.9–1.3MWh / tonne of iron. The project found that even at demonstration scale, ZESTY could produce green iron for ~US$410-520/tonne[1]. This is close to conventional, carbon intensive HBI costs, and includes capital and processing costs. No credit is taken for a carbon price.

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	ZESTY's economics are driven by minimal hydrogen use, efficient electric heating, and the elimination of the agglomeration and induration process steps. The ZESTY project took the technology from TRL 3 to TRL 6.
CO2 Emissions Reduction Potential - Implementation and Future Market	ZESTY can be integrated directly at the iron ore source for the export of green iron, or by a steelmaker to feed a blast furnace, basic oxygen furnace, or electric arc furnace. Near zero emissions DRI or HBI produced by ZESTY can substitute up to 25-40% of the iron ore charge to a blast furnace. This leverages existing infrastructure and would reduce carbon intensity by a ratio of approximately 0.7 tonnes of CO2 for every tonne of H2-DRI fed to the Blast Furnace. ZESTY can also deliver near-zero emissions DRI/HBI to a renewably powered electric smelter. The smelter removes impurities from DRI to deliver a product suitable for use in basic oxygen steelmaking. A DRI to electric smelter route can replace coal and blast furnaces to make steel with ~80% reduction in emissions, while maintaining compatibility with a variety of input ores. ZESTY may also process higher grade ores such that the DRI product can be used directly in an electric arc furnace for near zero emissions steel.
Market Positioning	Calix is currently working with a range of iron ore producers to produce Direct Reduced Iron products from their ore materials and intends to provide an efficient and scalable solution to process iron ore into high value green metallic iron for export. For steelmakers, ZESTY intends to provide a technology solution to preprocess iron ore into metallic iron with low or zero emissions as a feedstock to their existing blast furnaces. Ultimately, ZESTY aims to provide an integrated solution for steel makers to make low and zero emissions steel using Direct Reduced Iron, in addition to zero emissions lime, as a feed for an electric arc furnace. A ZESTY demonstration plant is designed to process multiple ore types to develop and demonstrate an industry-wide solution for green iron, with continued collaboration with leading global iron ore miners and steelmakers supporting commercialization of the technology.
Project Location	Australia
Project & Technology Links	ZESTY - Zero Emissions Steel Technology Video Calix's ZESTY study finds high potential for economic green iron Calix's ZESTY wins global Net-Zero Industry Award at COP29