Calix submission to the Australian Government Green metals consultation

A Future Made in Australia: Unlocking Australia's Green Iron, Steel, Alumina and Aluminium Opportunity

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Introduction to Calix

Calix Limited (ASX: CXL) is an Australian environmental technology company solving global challenges in industrial decarbonisation and sustainability.

Calix's patented core platform technology of indirect heating[1] is ideally suited to help mineral processing enter the electric age. In the context of green metals, Calix is delivering green solutions in three ways:

1. Production of zero emissions iron and steel, aluminium and other metals such as magnesium and manganese, using renewable power for heating processes to replace the use of fossil fuels.
2. Production of zero emissions lime (ZEL) which is used extensively in the production of steel and aluminium and other metals, using indirect electric heating with renewable power to calcine limestone and capture a high purity CO_2 stream that is released directly and unavoidably from the raw carbonate material for sequestration (CCS) and use (CCU).
3. Renewably powered at-mine processing, such as lithium and rare-earths, can enable both a significant reduction in the total global CO_2 footprint of minerals mined in Australia, and the capture of greater value from for our domestic minerals using our renewable energy resources.

Through these processes, Calix aims to deliver significant impact on the development of green metals for Australia.

An introduction to ZESTY: Calix's Zero Emissions Steel TechnologY

Calix's Zero Emissions Steel TechnologY (ZESTY) is a renewably powered hydrogen direct reduced iron (H_2-DRI) technology for the production of green iron and ultimately, green steel.

ZESTY's indirect heating enables inefficient combustion to be replaced by precise and renewably powered electric heating. Hydrogen is used to remove oxygen from the iron ore to produce metal iron and water. Hydrogen, however, is not combusted or used as a fuel, and is easily recycled. Through efficient electric heating, the most efficient use possible of hydrogen, and the elimination of additional processing steps, ZESTY aims to deliver the lowest cost decarbonisation solution for green iron and steel.

Further information on Calix's ZESTY is available in Annexure 1.

An introduction to ZEAL: Calix's Zero Emissions Alumina technology

Calix's Zero Emissions Alumina (ZEAL) technology is a unique, indirectly heated electric calciner designed to provide the lowest cost, lowest emissions and highest efficiency solution for smelter-grade alumina calcination.

Ideally suited to renewable energy sources and grid-load balancing applications, ZEAL builds upon many years of development of Calix's core platform technology to replace inefficient and carbon-intensive combustion processes with clean, efficient and precise electric calcination.

In addition to enabling zero scope one emissions, Calix's ZEAL technology aims to deliver the lowest cost calcination solution to the industry through the elimination of fuel and combustion exhaust, elimination of hard face refractory and through the use of steam

[1] https://calix.global/technology/

recycling. It is noted that the Calix technology has already been demonstrated to activate bauxite for production of Green Alumina.

Further information on ZEAL is provided in Annexure 2.

An introduction to Leilac – Calix s Low Emissions Intensity Lime And Cement technology – and the ZETA Project

Cement and lime are hard-to-abate industries as most of their emissions are process emissions – CO_2 released directly and unavoidably from the raw material. Unlike conventional carbon capture technologies that require an additional, energy intensive process to separate gases from gases, Calix's Leilac technology Leilac employs a "process modification" to cement and lime production to efficiently capture unavoidable process emissions. It works by simply preventing CO_2 emissions released from the raw material from being contaminated by exhaust gases and air, thereby enabling their capture as high-purity CO_2, without additional chemicals or solvents and for minimal energy penalty. It is also energy agnostic and fully compatible with alternative and clean fuels, including hydrogen and electrification.

The Leilac technology has been successfully proven at pilot-scale through the Leilac-1 project in Belgium, and is being scaled by the European Union funded Leilac-2 project in Germany. Both projects include a consortium of industry partners, are supported by European Union funding, and are located at Heidelberg Materials cement plants.

Calix's Zero Emissions Lime and Cement Technology Made in Australia (ZETA) Project in South Australia is a world-first demonstration project that will use an electric and renewably powered version of the Leilac technology to efficiently capture unavoidable process CO_2 emissions and produce near zero emissions lime and cement. Captured process emissions will be used to make methanol as a CCU product for shipping in the Solar Methanol 1 Project, a HyGate funded project delivered by a consortium including Vast and Mabanaft.

At industrial scale, zero emissions lime (ZEL) can be used in both steel and aluminium production to reduce scope three emissions. These are both very large markets for lime worldwide, and of national strategic importance. Thus, the use of ZESTY plus ZEL and ZEAL plus ZEL can enable pathways to near zero emissions steel and aluminium in Australia.

Australia's Green Metal Opportunity

For Australia, the global transition towards net zero emissions represents a unique moment of opportunity. Australia has the potential to unlock significant international comparative advantage in a decarbonising global economy, thanks to its potentially unrivalled combination of renewable energy resources and iron ore, bauxite, spodumene (lithium) and other critical minerals. Together with Australia's deep industry expertise and innovative enabling technologies, these natural advantages can enable downstream processing to capture more of the minerals' value chain, create value with the export of premium, low carbon products, and make an impactful contribution to national and global decarbonisation goals.

Iron and steel perhaps best encapsulates the risks and opportunities of decarbonisation for Australia. Australia produces over half the world's iron ore[2], and iron ore dominates Australia's export earnings[3]. Almost all Australian ore, however, is of the hematite

[2] https://www.statista.com/statistics/300328/top-exporting-countries-of-iron-ore/
[3] https://www.minerals.org.au/news/record-high-resources-export-revenue

/ goethite variety[4], considered low-grade and not suitable for use in the electric arc furnaces that are expected to dominate the future of steelmaking. Ensuring the compatibility of Australian iron ore with future low-carbon steelmaking is therefore a national priority.

With iron and steel being responsible for ~8% of global CO_2 emissions, turning Australia's iron ore into a green iron product could mitigate up to ~4% of global CO_2, or around four times the total emissions Australia produces domestically. Furthermore, the production of green iron can enable the capture of significantly more value from Australia's resources, not just protecting Australia from climate risk, but seizing the economic opportunities global decarbonisation presents.

Beyond iron ore, the processing of alumina, lithium and other critical minerals, as well as metals such as magnesium, all require sustainable processing solutions compatible with renewable energy sources. Given Australia's comparative advantage in these minerals too, the opportunity for Australia is not just to become a renewable energy superpower, but to embody its clean energy into domestically produced and value-added green metal and mineral products.

Realising the Opportunity

Calix commends the Australian Government on its targeted support for the domestic production of green metals through the Future Made in Australia Innovation Fund and associated enabling infrastructure support, such as measures to drive down the cost of renewable energy and green hydrogen.

Q12. What are the key barriers to investing in new green metals facilities or decarbonising existing facilities?

Australia's green export opportunity and comparative advantage in green metals is predicated on the expectation that abundant renewable energy resources will translate into low-cost renewable power and green hydrogen. This outcome remains uncertain, and significant national investment is required to improve the international competitiveness of Australian industry. The Capacity Investment Scheme, Rewiring the Nation program and Powering the Regions Fund all provide critical support to help translate Australia's renewable energy resources into low-cost clean electricity.

Access to low-cost renewable electricity generation and green hydrogen it can produce, coupled with supply and demand side incentives to drive domestic green metal production, can position Australia to become a leading producer and exporter of green metals. Suggestions for targeted policy support are provided later in this submission.

Q17. What factors would enable the acceleration of metals decarbonisation?

and

Q24. Are there parts of the value-chain that require particular support (for example, energy inputs, green alumina or iron inputs, or green aluminium or steel production)?

[4] Iron Ore | Geoscience Australia

Electrification of mineral processing

In heavy industry, the electrification of high temperature industrial heat is an opportunity to reduce industrial emissions and increase Australia's international competitiveness in sustainable mineral processing. Proven electrification technologies now exist to deliver the heat required for many industrial processes, including the production of metallic iron from iron ore and the calcination of bauxite to produce smelter grade alumina.

The electrification of mineral processing can deliver several key benefits. By replacing the combustion of fossil fuels with renewably sourced electric heating, the energy and carbon intensity of mineral processing is decoupled, enabling the potential elimination of scope one and two emissions.

Electric heating is also more efficient and more precise. Calix has found that its electric calciners reduce the energy required for the processing of metals and critical minerals by over 40% relative to conventional rotary kilns. By electrifying mineral processing, a traditional kiln with one heat source powered by fossil fuel combustion is replaced by arrays of electric heating elements, each of which can be tuned to deliver the required heat output. The result is a highly efficient electric calciner with many controllable temperature zones that can be tuned to deliver optimised temperature profiles for a given mineral. In this way, mineral particles can be precisely heated to drive the desired physical or chemical transformation whilst avoiding sintering or melting, improving extraction rates and efficiency.

Electric calcination is also compatible with intermittent renewable energy sources, flexible operations and power generation response to improve energy security and deliver more cost-effective operations. Calix's electric calcination technology enables fast start-up and shut down, and highly flexible production rates through a high turndown ratio. By leveraging this capability, green metal producers can improve their operating economics by matching output to demand and renewable energy costs.

For grid-connected facilities, electric mineral processing could ramp down production and associated energy requirements at times of high demand, thereby providing a valuable load balancing service to the energy grid. Given the large energy requirements of industrial alumina or green iron production, the electrification of such facilities and use of demand side controls can deliver a valuable stabilising service to renewably powered grids, complementing supply side measures such as battery storage. In turn, this can support a reduction in grid infrastructure costs, increased levels of renewable generation, and more cost-effective operations for mineral producers.

The development of electric mineral processing and its application to grid-load balancing is an area of high potential to simultaneously support national priorities in emissions reduction, stable and lower cost electricity supply, and cost-effective production of green metals and critical minerals.

Recommendation 1: Provide targeted support for the electrification of mineral processing and the development of grid-load balancing applications for energy-intensive industrial facilities, such as renewably powered alumina calciners and green iron plants.

Targeting support for hydrogen to green metals

The production of green iron and steel using hydrogen direct reduced iron technologies (H_2-DRI) holds significant potential for Australia to capture more value from its iron ore resources

and contribute significantly to global decarbonisation goals. As recognised in the Future Made in Australia National Interest Framework supporting paper, however, "*the majority of current green metals pathways require large quantities of cost competitive renewable hydrogen*."[5]

Continued government support to develop sovereign capabilities in hydrogen generation, as well as prioritising hydrogen uses during the scale up of an Australian green hydrogen industry will be important. Ideally, green hydrogen applications should be prioritised according to their potential to deliver the maximum reduction in global emissions and generate the greatest economic value for Australia. In this context, the production of green iron is rightly a national priority under the Future Made in Australia National Interest Framework.

Green hydrogen is the most significant cost driver for H_2-DRI technologies like Calix's ZESTY, as described later in this submission. Access to sufficient supplies of green hydrogen is also the rate limiting step in the speed at which Calix can deploy the technology and the locations it can consider.

Calix commends the Australian Government's investment to establish an Australian green hydrogen industry, including through the Hydrogen Headstart program and the Hydrogen Production Tax Incentive. Given the limiting constraints with current green hydrogen availability, further support could consider mechanisms that help target the use of green hydrogen towards national priority areas, such as the production of green iron.

Green Metal Hydrogen Production Tax Incentive

One way to achieve this would be through an increased Green Metals Hydrogen Production Tax Incentive. For example, green hydrogen produced for green metals could receive an incentive greater than the $2 per kilogram currently available for other hydrogen use cases, providing a clear price signal to prioritise green hydrogen investment and providing targeted support to establish green metals production.

A targeted sector specific increase in the Hydrogen Production Tax Incentive would leverage the existing funding support infrastructure that has been established for hydrogen and support strategic aims of targeting hydrogen use to value-adding activities. As stated in the Future Made in Australia National Interest Framework supporting paper, *"It is in Australia's interests to position adaptively for a range of hydrogen-adjacent opportunities besides hydrogen export – for example, using hydrogen as a feedstock in clean-energy embodied goods, such as green iron, as a practical way to embed hydrogen in energy-intensive goods."*[6]

To this end, providing an increased Hydrogen Production Tax Incentive targeted at green iron and other value-adding domestic activities can help add value to both Australia's renewable energy and mineral resources.

Recommendation 2: Provide an increased Green Metal Hydrogen Production Tax Incentive to support the establishment of a green metals industry and embody green hydrogen in green iron and other value-added products.

Temporary market creation mechanisms could also be employed to limit the exposure to green hydrogen prices for early green metals projects. For example, the government could

[5] Future Made in Australia National Interest Framework. Supporting paper. Australian Government. 14 May 2024
[6] Future Made in Australia National Interest Framework. Supporting paper. Australian Government. 14 May 2024

consider introducing a cap on the green hydrogen costs for qualifying green iron and steel projects, such as demonstration scale and first-of-a-kind commercial projects. The government could then run competitive auctions for green hydrogen producers to supply such projects, with the price differential subsidised either through Production Tax Incentives and/or a contract for difference.

By acting as a market creator, the government could accelerate the development and scale up of green iron and steel projects by limiting their risk and uncertainty relating to hydrogen pricing, help unlock private sector investment, match high priority hydrogen users with green hydrogen suppliers, and help to foster competition and downward pressure on the cost of green hydrogen production.

Recommendation 3: Consider market creation mechanisms that limit green hydrogen prices for green metal projects and create downward pressure on green hydrogen prices.

Incentivising action: Reducing global emissions through domestic green metals

Onshoring mid- or down-stream activity, such as processing of raw minerals into concentrated low-carbon mineral products can reduce global emissions, rationalise global supply chains, and capture and create significant value from Australia's natural resources.

Our ultimate goal should be to deliver the greatest possible reduction in global, rather than domestic, carbon emissions as quickly as possible, at the lowest possible cost, and to maximise the economic benefits to Australia of a decarbonising global economy. National frameworks, however, and particularly those that consider only scope one and two emissions, risk disincentivising new onshore economic activity and global emissions reduction in favour of meeting national emissions reduction targets.

Q23. We are seeking views on the types and design of supply side options that should be considered. What approach do you consider to be most effective?

Policies that facilitate onshoring of activity, including the production of green metals, will be important to ensure Australian industry is incentivised to capitalise on its opportunity to reduce global carbon emissions and capture economic value. For example, Australian mineral producers should be incentivised to undertake new downstream activity that significantly reduces their scope three emissions, despite a modest increase in scope one or two emissions that may result from that activity.

Recommendation 4: Ensure the onshoring of economic activity that creates value and reduces global CO_2 emissions is incentivised, even if it may increase national emissions.

Green Metals Production Tax Incentives

Production tax incentives offer a way to incentivise onshoring of green metal production. One possible scheme could be to correlate the tax incentive offered with the overall emissions reduction achieved, using the prevailing Safeguard Mechanism carbon price as a measure of the value created.

Under a production tax incentive linked to total emissions savings and the Safeguard Mechanism pricing, a green metal producer could qualify for a production tax incentive for

each tonne of green metal produced that is equal to the difference in emissions intensity of the green metal product versus benchmarked industry standard production, multiplied by the Australian Carbon Credit Unit fixed price under the Safeguard Mechanism.

For example, each tonne of iron produced from Australian iron ore in an international trading partner's blast furnace results in approximately 1.9 tonnes of carbon dioxide emissions[7]. Alternatively, converting the iron ore to green iron can reduce these emissions to near zero[8]. Under such a scheme, each tonne of green iron produced would qualify for a production tax incentive of 1.9 (CO_2 emissions saved per tonne) x $75 (Fixed Australian Carbon Credit Unit price) = $142 per tonne of green iron.

As described in answer to question 21, this level of incentive for green iron would support and accelerate economic green iron production by making a significant contribution to covering the 'green premium' of H_2-DRI production relative to carbon intensive methods, particularly as H_2-DRI technologies are scaled and green hydrogen prices decrease.

Structuring a production tax incentive in this way would correlate the incentive provided with the global environmental benefit delivered and tie scope three emissions avoidance with existing pricing of scope one and two emissions domestically. A mechanism tied to emissions avoided also provides significant flexibility for producers to identify optimal points along the metal processing value chain at which to operate to deliver the greatest economic and environmental benefit.

Recommendation 5: Consider introducing a Green Metals Production Tax Incentive, with the value of the incentive correlated to the value of the total greenhouse gas emissions reduction achieved relative to industry standards.

Alternatively, a flat production tax incentive could be introduced for each type of green metal, with differing price points dependent on the material and level of beneficiation. For comparison, Japan offers a tax incentive of $209/tonne of green steel produced.

An Australian Green Metal Production Tax Incentive can also be complemented by other forms of support, such as subsidies for renewable power or green hydrogen, grants to support the capital costs of demonstration and first-of-a-kind commercial projects, or contracts for difference. As described earlier, strong and targeted support for green metals production can also create clean energy and green hydrogen embodied goods for export, adding value to Australian renewable energy resources and supporting Australia's ambition to become a renewable energy superpower.

An Australian Carbon Border Adjustment Mechanism can also help introduce robust carbon accounting standards and practices across international supply chains and the life cycle of the mineral product. Such carbon accounting practices can both protect Australian industry from higher carbon-intensity imports and provide the framework for Australia to export verified premium low-carbon mineral products to trading partners around the world.

Ultimately, a green metal production tax incentive could be phased out as international trading partners introduce their own carbon border adjustment mechanisms, and carbon prices or emissions trading schemes. As such, a green metals production tax incentive represents an effective and time limited supply side policy mechanism that can provide targeted support to establish a leading domestic green metals industry.

[7] Climate change and the production of iron and steel. World Steel Association. 2021
[8] CALIX – ZERO EMISSIONS STEEL TECHNOLOGY (ZESTY). FEED Study Report. ARENA. Apr 2024

Recommendation 6: Leverage the introduction of an Australian Carbon Border Adjustment Mechanism to introduce robust carbon accounting standards and practices across metal and mineral supply chains.

De-risking adoption by first movers: supporting demonstration and first-of-a-kind commercial projects

Q22a. What impact will the government's industry investment measures, such as the National Reconstruction Fund and Future Made in Australia Innovation Fund, have on your transition?

Additional support for a green metals industry could focus on de-risking early demonstration and first-of-a-kind commercial projects to unlock co-investment from the private sector.

Industry-wide support, such as that delivered through the tax system and/or green metal procurement standards, can provide a low-cost means of developing the broad infrastructure required to support the establishment of industries. In the short term, however, project specific support will likely be necessary to accelerate technology development and commercialisation. It will also be important to ensure that both public and private sector investment supports innovation tailored to Australian opportunities and challenges, such as the processing of hematite iron ores to green iron and steel.

In addition to the subsidy of renewable power and hydrogen, this shorter-term support can include capital grants for early projects, and/or contracts for difference to cover the gap between existing market costs and the additional cost of green metals, particularly as green metal production is scaled.

In particular, capital grants can be essential for demonstration projects to be successfully established, helping to reduce both technical and economic risk for technologies not yet proven at commercial scale. Eligibility criteria for capital grants can be linked to the project's alignment with the Future Made in Australia National Interest Framework and the technology's scalability, industry-wide replicability, and the extent to which it can deliver community benefits. In turn, this helps to develop industry-wide solutions by avoiding capture of early-stage technologies by a vested interest, and ultimately supports adoption of innovative but commercially unproven technologies from, at times, risk-averse incumbents.

Recommendation 7: Provide project specific capital grant support for innovative demonstration and first-of-a-kind commercial green metal projects.

Q31. What demand side options would best drive confidence for green metals producers? Should the government consider regulation, procurement rules for government purchasing, voluntary targets or other demand options?

Strong demand signals are necessary to derisk adoption of new technologies and establish a robust market for lower-carbon products. Measures that stimulate demand for low-carbon-intensity products can complement the various supply side incentives and drive adoption of green metal solutions.

Establishing robust government procurement policies at a federal and state level could create a strong market signal (e.g., low-embodied carbon requirements, auctions for low-embodied carbon products). In addition to government procurement requirements and incentives for lower embodied carbon products, policy concepts such as a carbon contract for difference (CCfD), as seen in Germany and other European countries, could help bridge the cost gap between business-as-usual products and low-carbon products until customers are ready to pay a green premium.

Recommendation 8: Implement policies that drive demand for low-carbon intensity green metal products, including through procurement standards and carbon contracts for difference to cover 'green premiums' during the scale of up green metal production.

Powering green metal collaborations

Despite Australia's comparative advantages, delivering an impactful green metals industry will require industry-wide and cross-sector collaboration. Many early projects will require consortia-based approaches that combine the capabilities of miners, metal producers, renewable energy companies, hydrogen producers, enabling technology providers, financiers, engineering firms and others. Such collaborations can be challenging and slow to establish.

Building on the successful, research-focused Heavy Industry Low Carbon Transition CRC, and the proposed Green Metals Innovation Network, a commercially focused 'Powering Green Metals' network could establish a coalition of the willing for the demonstration and commercialisation of first-of-a-kind commercial scale projects.

Establishing such a network could remove barriers to project establishment and accelerate the collaboration and partnerships needed to produce green metals.

Members of a 'Powering Green Metals' network could benefit from introductions to complementary project partners and other network building; stronger links to federal and state government agencies and advisory support on appropriate project funding; focused roundtables and other events designed to establish collaborative projects; fast-tracked permitting support; pre-existing MoUs or other frameworks from which partnerships and projects could be more quickly established; and pre-established guidance on renewable energy pricing (e.g., behind the meter pricing with government subsidy).

A 'Powering Green Metals' network would complement the HILT CRC and Green Metals Innovation Network by providing a similarly collaborative framework to build upon previous research and development, this time with a commercial focus to accelerate first-of-a-kind demonstration and scale up of innovative green metal projects. Alternatively, the newly announced Green Metals Innovation Network could provide this service, if its scope includes a focus on the demonstration and commercialisation of green metals solutions.

Recommendation 9: Establish a 'Powering Green Metals' network focused on the demonstration and commercialisation of green metal technologies.

Processing at the mine site

At-mine processing involves the thermal and/or chemical processing of the raw mineral ore to a beneficiated product with concentrated value. This allows the valuable portion of the mineral to be extracted on site while the gangue mineral can be returned to the mineral deposit, both eliminating the cost and environmental impact associated with transportation of the gangue mineral and the environmental impact that would otherwise occur with waste disposal off-site. This is particularly important for minerals like rare earths and vanadium, where the waste rock can be very damaging to the environment when not managed well.

By processing minerals at the mine site, producers can dramatically reduce the transport of waste, simplify logistics and streamline mineral supply chains, thereby significantly reducing the economic and environmental cost associated with current practices. At-mine processing could be particularly beneficial for remote mining operations where transportation costs can be a significant proportion of the overall cost of production. Refining and concentrating the mineral product at source can mitigate challenges such as long distances to export infrastructure or customers, potentially unlocking remote hard-rock assets.

Increased utilisation of mineral resources

An additional advantage of processing minerals at the mine site is the potential to increase the utilisation of the mineral resource and reduce waste. Fines and ultra-fines are the spectrum of the mined material with a small particle size. Fines are often incompatible with conventional thermal processing, where flue gases can simply blow the fine material out of the kiln. Alternatively, fines can be pelletised or agglomerated, however, this adds a potentially cost-prohibitive processing step. As such, fines are often considered too difficult or expensive to handle and consigned as waste or tailings.

Electric calcination and Calix's flash calcination technology is ideally suited to processing small particle sizes, enabling the use of fines that would otherwise be discarded as waste. As such, electric calcination at the mine site offers significant potential to provide greater recovery and utilisation of the mineral resource and deliver improved operating margins.

Rationalising Supply Chains

Countries around the world are considering their sovereign capability to source essential metals and critical mineral products and analysing the risks associated with current supply chains. As electrification and the switch to low-cost renewables gathers pace, at mine processing is becoming cost competitive with traditional fossil fuel-based approaches. This mitigates the need to transport and process raw materials to where fossil energy inputs are cheapest. In this way, sustainable downstream processing at the mine site can create further value for trading partners by securing supplies and mitigating geopolitical risks.

Enabling green metals with zero emissions lime

Lime is an essential material used in the iron & steel, alumina, paper, pharmaceuticals, food, farming and chemical industries, and demand for lime in Australia is predicted to grow by 57% between 2022 and 2050[9]. Like cement, lime is made from the processing of limestone to form quicklime (calcium oxide). When limestone is heated in this process, carbon dioxide is unavoidably released directly from the raw material. This 'process' CO_2 accounts for ~60-70% of the emissions released during the production of lime[10,11]. Collectively, lime and cement account for ~8% of global greenhouse gas emissions[12].

[9] Decarbonisation Pathways for the Australian Lime Sector. VDZ. 2023
[10] Decarbonisation Pathways for the Australian Lime Sector. VDZ. 2023
[11] Decarbonising the lime industry: State-of-the-art. Renewable and Sustainable Energy Reviews. 168. 1127652022. 2022.
[12] Trends in Global CO2 emissions. Netherlands Environmental Assessment Agency. The Hague, 2016

In addition to enabling electric calcination, Calix's Leilac technology is purpose built to efficiently capture unavoidable process CO_2 emissions from cement and lime production, without additional chemicals or processes. Leilac's technology is also being developed to deliver zero emissions lime for capture of emissions from other hard-to-abate sectors, as well as Direct Air Capture of CO_2 from the atmosphere in partnership with Heirloom, a DAC company.

The production of near-zero emissions lime by electric calcination and capture, use and storage of unavoidable process emissions is an important enabling capability to produce green metals, particularly near-zero emissions steel and aluminium.

Recommendation 10: Support the decarbonisation of the lime industry to enable green metal production, including through funding support for carbon capture, use and storage for lime.

Cross-cutting support for other green mineral opportunities

Although beyond the scope of this consultation, other green metals and minerals warrant consideration, given Australia's comparative advantages in mineral and renewable energy resources similarly apply. The sustainable and secure supply of critical metals and minerals such as magnesium and lithium also strongly align with Australa's national interest and priority areas, and indeed those of key trading and security partners, such as the United States, United Kingdom, and European Union.

Calix supports the Australian Government's Critical Minerals Strategy and commends support mechanisms such as the Critical Minerals Production Tax Incentive, Critical Minerals Facility, and the Climate, Critical Minerals and Clean Energy Transformation Compact with the United States.

Much of the support needed to establish an Australian green metals industry is not sector specific, but cross-cutting, and many of the mechanisms outlined in this submission could equally apply to the sustainable downstream processing of critical minerals. Recognising this further strengthens the business case for supporting the fundamental building blocks required for Australia to become a renewable energy (and green metal and critical minerals) superpower.

Calix's green metal technology solutions

Q7: *Is your organisation currently undertaking or planning to undertake any major green metal investments or facility refurbishments?*

Yes. Calix recently completed a Front-End Engineering Design study[13], supported by funding from ARENA, for a 30,000 tonne per annum green iron demonstration plant, in addition to extensive pilot scale testing of its H_2-DRI technology, ZESTY. Commercial and financing contracts are now being negotiated to enable the location of the Demonstration Plant to be selected and a Final Investment Decision (FID) to be made. The location of the ZESTY Green Iron Demonstration Plant remains under discussion. Calix's preferred option is co-location with an Australian hydrogen hub, but other options, including offshore, are being considered.

[13] CALIX – ZERO EMISSIONS STEEL TECHNOLOGY (ZESTY). FEED Study Report. ARENA. Apr 2024

Q7a. When are these expected to begin, and what are the anticipated completion dates?

Following FID, Calix is targeting a period of 18 months for Detailed Engineering to be completed, with construction completed 30 months after FID. Following a commissioning and testing phase of ~4 months, the ZESTY demonstration plant is then expected to move into operations as a demonstrator for the production of commercial grade green Hot Briquetted Iron (HBI) from low grade iron ore from multiple iron ore providers.

Q14b) What levels of emissions reduction might be achievable for your facility or in your industry under different levels of investment and ambition?

ZESTY could reduce the emissions intensity of converting iron ore to metallic iron from 1.89 tonnes of CO_2 / tonne of iron[14] to near zero[15], assuming the use of renewably generated electricity.

Q15. What are the technologies associated with meeting green thresholds?

Calix's Zero Emissions Steel TechnologY (ZESTY) is a renewably powered H_2-DRI technology for the production of green iron and ultimately, green steel.

ZESTY leverages the indirect heating approach of Calix's platform technology, enabling inefficient combustion to be replaced by precise and renewably powered electric heating. Like other H_2-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.

Through efficient electric heating, the most efficient use possible of hydrogen, and the elimination of additional processing steps, ZESTY aims to deliver the lowest cost decarbonisation solution for green iron and steel.

ZESTY depends on the cost-effective use of several enabling technologies, including renewable electricity generation and hydrogen electrolysis.

Calix's ZEAL technology uses the same core technology platform to deliver electric calcination of bauxite to alumina.

Q16. Are these technologies being developed or commercialised? If yes, when do you expect these to be ready for commercial scale deployment?

Yes. As stated in response to question 7, Calix is progressing towards a Final Investment Decision for a green iron demonstration plant, following the completion of pilot-scale testing and a FEED study. First green iron production is expected approximately 34 months after FID. The availability of sufficient volumes of green hydrogen is a critical determining factor for location and speed at which ZESTY can be deployed.

Q19. What are the key production volumes, cost profiles and price assumptions that would support minimum commercial viability for green metals production?

Calix is targeting the commercial demonstration of green iron production by a 30,000 tonne per annum green iron demonstration plant. This scale up step has been chosen for two key

[14] Climate change and the production of iron and steel. World Steel Association. 2021
[15] CALIX – ZERO EMISSIONS STEEL TECHNOLOGY (ZESTY). FEED Study Report. ARENA. Apr 2024

reasons. First, it is equivalent to the full-scale implementation of a single ZESTY reactor tube, representing the core of Calix's modular technology. Further scale up will be via duplication of this tube, providing a low risk scale up pathway. Second, a 30,000 tonne per annum plant will enable production of sufficient quantities of green iron for further downstream testing (steelmaking) at full scale to validate the product.

Q20. How would adopting renewable energy and green hydrogen impact on your current costs and the commercial viability of your operations, if you were able to implement them right now?

and

Q21. What are your estimates of the cost-gap differences between producing green metals and traditional metals, across your planned decarbonisation pathway (per tonne)?

As enabling green metal production technologies, Calix's ZESTY and ZEAL are predicated on the use of renewable energy inputs, and for green iron and steel production, green hydrogen. A techno-economic analysis undertaken as part of the ZESTY Demonstration Plant FEED study[16] found that, even at demonstration scale, ZESTY could produce a green Hot Briquetted Iron product for a levelised cost of (LCO-HBI) between $632-$802 / tonne of green iron. This range assumes a levelised cost of hydrogen of $5.5-6.2/kg.

The estimated production cost is made possible by a combination of ZESTY's minimal use of hydrogen, the relative simplicity and efficiency of the electrically heated process, and the elimination of the agglomeration and induration process steps.

ZESTY's energy requirement is projected to be 4.2–4.6MWh / tonne of iron, with most of this energy going towards the generation of green hydrogen. Excluding hydrogen production, ZESTY is projected to require 0.9–1.3MWh / tonne of iron.

The major cost components of the production costs, accounting for two-thirds of the total cost are:

- Energy cost electrolyser - 21%
- Capital of ZESTY plant – 18%
- Capital of electrolyser – 14%
- Energy cost of ZESTY plant – 6%

Electrolyser CAPEX and electricity costs are the key factors influencing the effective hydrogen price of $5.5 - $6.2 per kg. Cost of electricity is based on forecast spot market pricing for each of the different sites where available, with an average cost of $36-48 AUD/MWh plus transmission and connection costs. This is in line with levelised cost of electricity (including transmission and connection costs) provided in figure 1 of the Green Metals consultation paper[17].

The overall capital and operating costs are expected to reduce further as the core technology is scaled and refined. For ZESTY to become even more economical for green iron and steel production, the fundamental path is the reduction in hydrogen costs from current prices to the target of approximately $3/kg.

At a high level, ZESTY's expected LCO-HBI ($632-$802) is competitive with zero-carbon or carbon-adjusted iron products ($762-1295) and close to the range of existing, non-hydrogen based DRI and HBI production ($617-900). Further details are available in the ZESTY

[16] CALIX – ZERO EMISSIONS STEEL TECHNOLOGY (ZESTY). FEED Study Report. ARENA. Apr 2024

[17] Green metals. A Future Made in Australia: Unlocking Australia's Green Iron, Steel, Alumina and Aluminium Opportunity. Consultation paper. Australian Government. Department of Industry, Science and Resources. 2024

Demonstration Plant FEED Study report[18].

Delivering community benefits

Q8. What are the benefits to the local region or community when developing a green metals project?

Industrial decarbonisation and clean energy projects themselves should help us meet climate goals, and these are a green metals project's primary community benefit. From reduced exposure to toxic materials and the reduction of extreme weather, such projects can also be directly responsible for improving the quality of life and health outcomes for communities, and particularly disadvantaged communities, both locally and globally.

However, meeting national climate goals, while critical, is not the only reason to expand clean energy and decarbonisation infrastructure. These projects can also address local climate- and pollution-driven inequities if activities to address these challenges are included in the original project plans.

Community Benefits Plans (CBP) can be a formal way to document how a project will engage with local and disadvantaged communities to define commitments that will bring diverse local benefits. These plans also demand that investments and activities that will advance equity, civil rights, and equal opportunity, including access to jobs and other economic opportunities.

The development of a green metal industry can also be a significant source of sustained economic activity in Australia. As such, green metal projects can both support the retention of jobs and existing economic activity to become sustainable in a low-carbon economy, and create new, high-value and long-term jobs associated with the onshoring of new activity. This is opposed to the sometimes spurious promotion of 'green jobs', that at best may not lead to permanent roles, or worse reflect inefficient operations and technologies that require significant additional labour resources and are therefore detrimental to sustaining competitive industrial operations in the long term.

Embedding local community considerations into green metal projects can also help to deliver local environmental and health benefits. When community benefits are considered as part of a holistic assessment of a project's merits, the chosen technical solution can deliver benefits beyond reducing greenhouse gas emissions. For example, switching industrial inputs from coal to renewably generated electricity can deliver improved air quality to the neighbouring communities. Electrification can also help reduce fugitive dust emissions in the alumina industry by eliminating the combustion exhaust and recycling steam produced during calcination. In this way, electrification can improve local environmental outcomes, in addition to providing a sustainable pathway for local jobs and manufacturing, and supporting the integration of local renewable generation into the electricity grid.

Other benefits could include new skills development and additional infrastructure facilities, such as childcare centres and better roads. Additionally, partnerships with local businesses for the supply of specific products needed in the construction and operation of industrial decarbonisation projects can boost local economies. Benefits can also focus on advancing diversity, equity, inclusion, and accessibility (DEIA) principles across a project, from hiring strategies to community education. Calix is committed to ensuring its projects deliver local community benefits through detailed community benefits plans, including using local firms and resources to implement its technology solutions.

[18] CALIX – ZERO EMISSIONS STEEL TECHNOLOGY (ZESTY). FEED Study Report. ARENA. Apr 2024

Q9. How are you considering these benefits in evaluating projects? Are there ways to increase opportunities for the local community or broader industry?

Calix believes that Community Benefit Plans (CBP) should have a specific budget allocation within a project's budget. This will enable the project to engage with local communities and determine the activities that will increase opportunities through the creation of new local jobs, the improvement of infrastructure, and the enhancement of community health. If these goals are realised, the project can be considered positive for society because it increases the economic, social, and environmental quality of the region.

Other strategies could include hiring services and purchasing materials from small minority-owned businesses, thus boosting the local economy. Another idea is to establish and support educational projects fostered by local NGOs that could introduce the community and their children to sustainable practices that could be incorporated into their daily lives, or the lessons of diversity, equity, inclusion, and accessibility (DEIA) into hiring and management practices.

Providing high-quality job opportunities is important, but equally crucial is enhancing the skills of local communities through training and educational initiatives. Collaborating with local educational NGOs, offering apprenticeships, or providing in-house training can also raise awareness and foster acceptance of decarbonisation technologies.

Moreover, businesses can contribute significantly to local economies by sourcing materials and services from local suppliers. This not only supports local businesses but also stimulates economic growth within the community. Additionally, investing in local infrastructure improvements, such as roads, schools, and healthcare facilities, can bring substantial benefits to community members.

Q10. How can the government support industry to enable communities and workers to share in the benefits of transitioning to green metals?

The benefits of new projects may not naturally flow to local and disadvantaged communities without an explicit request for them to be considered. To protect against this, the government can mandate the development of a Community Benefits Plan (CBP) as a prerequisite for public funding support.

Community Benefits Plans are typically based on a set of four core policy priorities:

- Engaging communities and labour
- Investing in local workers through quality jobs and training
- Advancing diversity, equity, inclusion, and accessibility through recruitment and training
- Ensuring disadvantaged communities receive a significant portion of the value created by decarbonisation projects to help deliver a just transition to net zero.

These key principles, when incorporated comprehensively into project proposals and applications and executed upon, will help ensure broadly shared prosperity in the clean energy transition.

These plans should be carefully designed to respond to each community's unique needs, and a CBP should address how a project will engage with local communities to better understand their needs. Early engagement with communities, including through mechanisms such as establishing community advisory panels, can empower local and disadvantaged communities to have a voice in decarbonisation projects that affect their environment and health, resulting in increased support and public acceptance for such projects.

These CBPs should not be a “one plan fits all” approach. Instead, plans should reflect creative strategies to address local needs, and include SMART milestones that are specific, measurable, attainable, realistic, and timely.

Additionally, the government can support community-led initiatives and financially aid research and development that promotes the benefits of environmental sustainability and economic resilience.

Recommendation 11: Embed community benefits as a critical consideration in the support for green metal and Future Made in Australia projects.

Q11. Are you aware of case studies where private companies have established community benefit sharing with communities, and whether this has worked particularly well or poorly?

The following two cases provide examples of how community benefits sharing can be embedded within clean energy and decarbonisation projects. We note that Calix is a partner to Heirloom in Project Cypress, a Direct Air Capture project in Louisiana, USA funded by the US Department of Energy’s Direct Air Capture Hubs Program.

- Project Cypress, a Direct Air Capture (DAC) Hubs Program to capture and store atmospheric Co2 in Louisiana
- ARCHES, California’s initiative to accelerate renewable hydrogen projects

Q30. How could eligibility criteria be most appropriately linked to the delivery of strong community benefits?

Like the U.S. Department of Energy, funding authorities for clean energy and decarbonisation projects could require the submission of a Community Benefits Plan (CBP) within the general grant application and assign it a value in the application grading process. In the U.S., these plans are scored by the DOE at ~20% of the technical merit review of an overall proposal.

In this way, a CBP becomes a strategic initiative aimed at creating positive social, economic, and environmental impacts in the communities where a business operates. There is no one-size-fits-all solution for every community, so the benefits plan implemented by each project may vary based on specific community circumstances, location, and timeframe. Therefore, it is crucial for each business to thoroughly analyse the community context and engage with local leaders, such as local NGOs and residents, to fully understand local challenges before completely defining a CBP. This collaborative approach will ensure that the plan addresses the community's real needs.

When an applicant is selected, their CBP should become a part of the contractual obligation of the funding recipient. A summary of the plan could also be publicly posted on the funding agency’s website for transparency and accountability. Finally, the sharing of knowledge and best practices on this topic can enhance the long-term impact of corporate commitments.

Summary

By incentivising the onshoring of green metal production, the government can help establish an Australian green metal industry that has the potential to deliver a reduction in global emissions that is greater than Australia's current total domestic contribution to greenhouse gas emissions, while creating significant economic value.

The viability of Australian iron ore with future low-carbon steelmaking is also a source of significant sovereign risk. Developing local solutions tailored to Australian ores through the establishment of an Australian green metals industry will likely be essential to mitigating this risk and future-proofing Australia's largest source of export earnings.

Technology solutions, such as Calix's ZESTY and ZEAL, are being developed and scaled in collaboration with Australian industry and research organisations to meet this challenge. Their commercialisation in Australia, however, is predicated on Australia's renewable energy resources being translated into comparative cost advantage in renewable electricity and green hydrogen, and the incentivisation of mineral producers to move downstream and produce green metal products for export.

Support for a green metals industry therefore represents an important step to establish Australia's leading market position as a secure and sustainable source of green metal and critical mineral products in a future low-carbon economy. This submission highlights a number of mechanisms that could be considered by the government to support the production of green metals in Australia. These include supply side options such as an increased Hydrogen Production Tax Incentive for green metal applications, a Green Metal Production Tax Incentive correlated to the value of scope three emission abatement, capital grant support for early adopters, and market creation mechanisms, such as demand side signals and contracts for difference to drive green metal production.

Calix is encouraged by accelerating policy support for the creation of a globally leading green metals industry in Australia and thanks the Department of Industry, Science and Resources for the chance to provide input to the government's efforts to unlock Australia's green iron, steel, alumina and aluminium opportunity. Calix welcomes the chance to participate in additional conversations with the Department and all interested parties on this crucial topic to provide further information about our solutions and answer any questions that may arise.

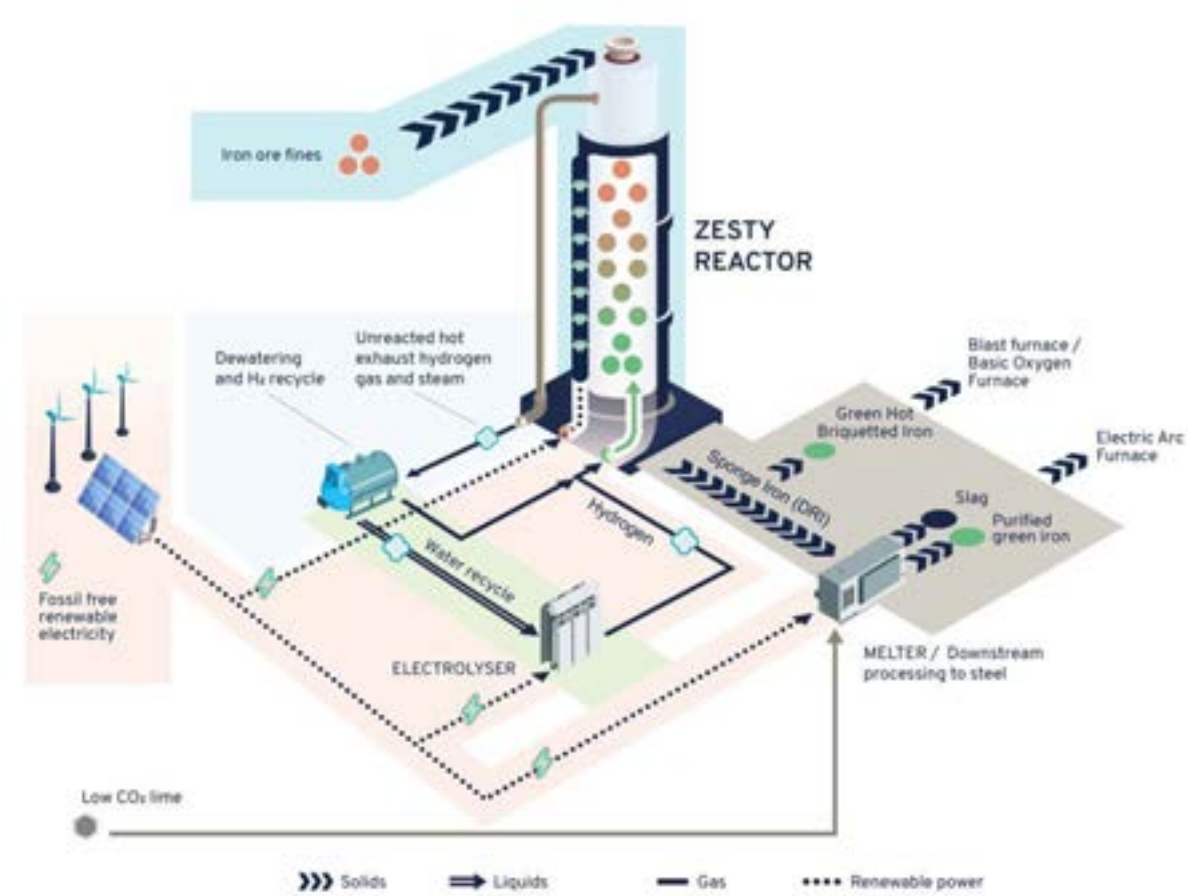
Annexure 1: ZESTY – Calix's Zero Emissions Steel TechnologY

Iron and steel are materials essential to our economic prosperity and continued development. Responsible for ~8% of global CO_2 emissions, they are also one of our most carbon intensive and hard-to-abate industries. Currently, approximately 90% of iron is produced by metallurgical coal and coke-fuelled blast furnaces. This conventional method of iron ore reduction is responsible for 80-85% of the industry's CO_2 footprint.[19]

Calix's Zero Emissions Steel TechnologY (ZESTY) is a renewably powered H_2-DRI technology for the production of green iron and ultimately, green steel.

ZESTY leverages the indirect heating approach of Calix's platform technology to enable inefficient combustion to be replaced by precise and renewably powered electric heating. Like other H_2-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.

Through efficient electric heating, the most efficient use possible of hydrogen, and the elimination of additional processing steps, ZESTY aims to deliver the lowest cost decarbonisation solution for green iron and steel.



ZESTY's key features & benefits:

- **Electrification & renewable power** – The entire ZESTY process can be renewably powered, including the delivery of high temperature heat required to convert iron ore

[19]Climate change and the production of iron and steel. World Steel Association. 2021

to metallic iron.

- **Minimum hydrogen consumption** – Calix's unique indirect heating approach ensures that hydrogen is used only as a reductant in the production of green iron and steel. Hydrogen is not combusted or used as a fuel, and unreacted hydrogen is simply recycled.
- **Process fines & lower grade ores** – ZESTY is ideally suited to process small particle sizes, creating multiple beneficiation opportunities for lower grade ores and fine material that may otherwise be discarded as waste. ZESTY's compatibility with lower grade ores provides a pathway to decarbonise much of the world's current iron ore supply that is otherwise not suitable for use in electric arc furnaces.
- **No pelletisation** – ZESTY removes the requirement for iron ore fines to be pelletised, eliminating process steps and avoiding significant capital and energy costs.
- **No fluidised beds** – ZESTY delivers a highly simplified process for the processing of iron ore fines and ultra-fines without fluidised beds.
- **Flexible operation** – Compatible with intermittent and renewable sources of electricity, ZESTY's electric heating provides a high degree of temperature control with fast start-up and shut down, and highly flexible production rates. As such, it may provide a versatile load balancing service to the energy grid.
- **Easily scalable** – Calix's modular technology can be simply scaled through duplication, de-risking technology scale up and enabling flexible production volumes.
- **Targeting lowest cost** – By enabling efficient electric heating, minimal hydrogen use, and eliminating additional processing steps, ZESTY aims to deliver the lowest cost decarbonisation solution for green iron and steel.

Flexible pathways to green steel

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. Multiple processing routes provide flexible near-, medium- and long-term decarbonisation pathways for the industry.

For a fast and efficient route to emissions reduction, ZESTY can produce zero emissions Direct Reduced Iron (DRI) or Hot Briquetted Iron (HBI) to replace some of the iron ore charge to a blast furnace. This pathway leverages existing steelmaking infrastructure, and as over 80% of the emissions from steelmaking come from the conversion of iron ore to metallic iron, it can provide significant emissions reduction in the near-term. However, it is anticipated around 30% of the overall charge to the blast furnace can be replaced by DRI.

ZESTY can also deliver zero emissions DRI/HBI to a renewably powered electric smelter, such as that proposed in the collaboration between BHP, Rio Tinto and Bluescope. The smelter provides an additional process step that removes impurities from DRI to deliver an iron product suitable for use in basic oxygen steelmaking. In this way, a DRI to electric smelter route can replace coal and blast furnaces altogether to make steel with ~80% reduction in emissions, while maintaining compatibility with a variety of input ores.

Alternatively, ZESTY may process higher grade ores, or provide sufficient beneficiation of lower grade ores, such that the DRI product can be used directly in an electric arc furnace for close to zero emissions steel.

Testing ZESTY's economic and environmental credentials

To demonstrate ZESTY at a commercially relevant scale, Calix is building a 30,000 tonne per annum ZESTY Demonstration Plant. The FEED study for the plant, completed in February 2024, was part funded by the Australian Renewable Energy Agency (ARENA) and supported by an expanded ore testing program at Calix's pilot scale facility in collaboration with the Australian Heavy Industry Low-carbon Transition Cooperative Research Centre (HILT CRC) and its partners.

The extensive pilot-scale tests included over 130 test runs using nine different Australian ores from multiple providers, covering a range of grades and particle sizes. The results are extremely encouraging.

Even at pilot-scale in a multi-purpose R&D plant, ZESTY delivered excellent metallisation rates. Most test runs at the targeted temperature range achieved the level of metallisation suitable for downstream use in either a melter or blast furnace, while several tests reached sufficient metallisation levels for feed directly to an electric arc furnace. Notably, these results are for hematite / goethite ores, representative of around 96% of Australia's iron ore exports.

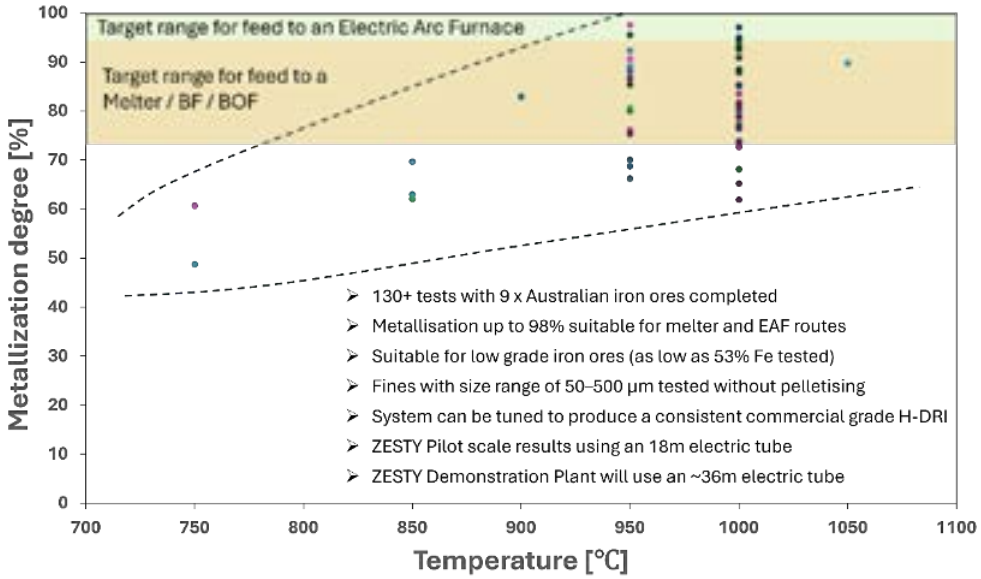


Figure 2. Pilot-scale results showing metallisation as a function of processing temperature for a range of ores.

The ZESTY Demonstration Plant FEED study found that HBI from low grade iron ore could be produced for ~AUD$630-$800 / tonne[20]. This cost includes the capital cost of the plant and processing costs, and excludes the cost of land and transport of the input and output materials.

The study showed that, even at demonstration scale, ZESTY could produce zero emissions iron at a cost close to the range of existing conventional HBI processing costs[21], despite using hydrogen as a reductant. Furthermore, it does not take credit for any carbon price, carbon border adjustment mechanism, or other green premium that a near zero emissions iron product may attract.

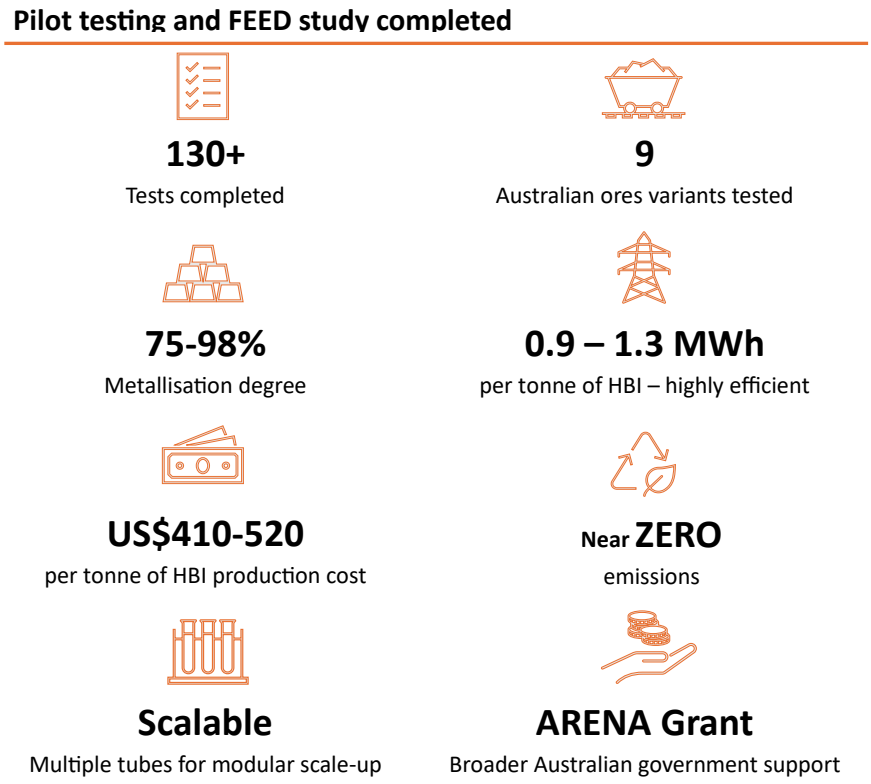
The estimated production cost is made possible by a combination of ZESTY's minimal use of hydrogen, the relative simplicity and efficiency of the electrically heated process, and the

[20] CALIX – ZERO EMISSIONS STEEL TECHNOLOGY (ZESTY). FEED Study Report. ARENA. Apr 2024
[21] IEA. Simplified levelised cost of competing low-carbon technologies in steel production

elimination of the agglomeration and induration process steps.

ZESTY's energy requirement is projected to be 4.2–4.6MWh / tonne of iron, with most of this energy going towards the generation of green hydrogen. Excluding hydrogen production, ZESTY is projected to require 0.9–1.3MWh / tonne of iron.

The overall capital and operating costs are expected to reduce further as the core technology is scaled and refined.



Towards commercial demonstration

With the ZESTY technology proven at pilot scale, and a FEED study for a commercial demonstration plant completed, commercial and financing contracts are now being negotiated to enable the location of the Demonstration Plant to be selected and a Final Investment Decision to be made. Announcements will be made as key milestones are achieved.

ZESTY iron aims to enable steel producers to add green iron directly into their existing processes to provide a simple and efficient route to emissions reduction.

Annexure 2: ZEAL – Zero Emissions Alumina technology

Calix's Zero Emissions Alumina (ZEAL) technology is a unique, indirectly heated electric calciner designed to provide the lowest cost, lowest emissions, and highest efficiency solution for smelter grade alumina calcination.

Ideally suited to renewable energy sources and grid-load balancing applications, ZEAL builds upon many years of development of Calix's core platform technology to replace inefficient and carbon-intensive combustion processes with clean, efficient, and precise electric calcination.

In addition to enabling zero scope 1 emissions, Calix's ZEAL technology aims to deliver the lowest cost calcination solution to the industry through the elimination of fuel and combustion exhaust, elimination of hard face refractory, and steam recycling.

Calix has successfully completed pilot scale testing of ZEAL. Feasibility studies are underway for both a 40T/hr demonstration plant and full-scale Calix ZEAL calciners.

Features & benefits:

- **Electrification** - Calix's ZEAL technology uses clean and precise electric heating. It is compatible with intermittent renewable energy sources, flexible operations and power generation response to improve energy security and deliver more cost-effective operations.
- **Emissions reduction** – By replacing combustion and fossil fuels with electric heating, Calix's ZEAL technology can deliver a 100% reduction in scope 1 emissions by enabling the whole refinery to be powered by locally sourced and renewably generated electricity.
- **Higher efficiency** – Calix's ZEAL technology uses a first principles approach to deliver best in industry energy efficiency. Avoiding the combustion exhaust gas stream and creating a pure steam stream that can recover and recycle energy is expected to enable approximately 10% reduction in energy intensity of alumina calcination.
- **Lower cost** – Efficient electric heating through Calix's ZEAL technology is designed to deliver lower operating costs than natural gas, hydrogen or fuel oil.
- **Improved product quality** – Indirect heating enables low particle velocity and precise heating through the calciner. This unique approach can help reduce particle breakage and the formation of alpha alumina, in addition to delivering a premium low-carbon alumina product.
- **Lower maintenance** – The elimination of hard face refractory lining helps reduce maintenance requirements, downtime and cost.
- **Future-proof** – Electric calcination provides a low-cost and future-proof pathway for the alumina industry to reach net zero. It can enable alumina producers to avoid carbon taxes and tariffs, and support national and international decarbonisation targets.
- **Local benefits** – Electrification can help reduce fugitive dust emissions by eliminating the combustion exhaust and recycling steam produced during calcination. In this way, electrification can improve local environmental outcomes, in addition to providing a sustainable pathway for local jobs and manufacturing, and supporting the integration of local renewable generation into the electricity grid.

About Calix

Calix Limited (ASX: CXL) is an environmental technology company solving urgent global challenges in industrial decarbonisation and sustainability.

Calix's unique patented core platform technology delivers efficient indirect heating of raw materials to enable renewably powered mineral processing and efficient capture of unavoidable industrial emissions.

With strong and increasing demand driven by global commitments to net-zero emissions, Calix is applying its core technology to the decarbonisation of cement, steel and alumina, sustainable processing of critical minerals, direct air capture of atmospheric carbon dioxide, and sustainable environmental products.

Each application of the technology is being deployed through a proven licensing, joint-venture and spin-out model. Subsidiary businesses focused on a specific application and target market accelerate commercialisation and enable a flexible equity funding model to support exponential growth.

Leveraging its core platform technology and a global network of partners, Calix is urgently developing multiple environmental businesses that deliver positive global impact. Because there's only one Earth.

www.calix.global

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