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Calix submission to the Australian Government Critical Minerals Strategy 2023 discussion paper

Introduction to Calix

Calix Limited (ASX: CXL) is an Australian environmental technology company solving global challenges in industrial decarbonisation and sustainability, including CO_2 mitigation, sustainable processing, advanced batteries, biotechnology and water treatment.

Calix's patented core technology platform delivers efficient indirect heating of raw materials to enable industrial decarbonisation and create innovative environmental solutions, including the electrification of industries, efficient capture of unavoidable emissions and clean industrial processing solutions.

Leveraging its core technology platform and a global network of research and development collaborations, Calix is urgently developing sustainable mineral processing technologies that deliver positive global impact. Low touch business models such as licensing, joint ventures and spin-out strategies are helping to commercialise each new application at speed, seizing every opportunity to urgently address sustainability challenges.

The core Calix calcination technology has already demonstrated technical viability and positive environmental impact in the magnesite and cement markets. Calix is in discussions with Australian mineral companies to adapt the technology for lithium, iron, rare earths, vanadium, nickel and other battery input materials. Case studies for Calix's solutions for sustainable processing of iron and lithium are included on pages 6 and 7, respectively.

The competition from international technologies and minerals producers gives us a short window of opportunity to ensure that Australia is the clear leader in developing, owning and operating these mineral processing industries. The right government support will help to enable rapid technology rollout, and level the playing field when competing with companies supported by foreign government programs and subsidies.

Australian critical minerals: current challenges and opportunities

The critical minerals industry is a vital sector of the Australian economy, providing jobs and resources for a wide range of industries. It is also facing a period of significant risk and disruption, as global decarbonisation efforts and supply chain issues manifest for Australian producers and their exports.

As Australia's processing capacity and influence in critical minerals expands, the industry will become a significant contributor to Australia's greenhouse gas emissions. There is also increasing pressure to reduce the emissions intensity of mineral products in line with global commitments to combat climate change. For critical minerals, decarbonisation is a particularly acute challenge, given the inherently

energy-intensive nature of processes such as mining, smelting and refining that dominate the sector's emissions.

It is imperative for the critical minerals industry to find ways to reduce emissions intensity to meet global emissions reduction commitments and for Australia to maintain and improve its international competitiveness in a decarbonising global market.

Additionally, the industry's reliance on global supply chains leaves it vulnerable to disruption and volatility. The increasing complexity and interdependence of supply chains leaves them vulnerable to disruptions caused by natural disasters, political instability, economic volatility, and other factors. These disruptions can lead to significant economic losses, as well as negative environmental and social impacts. It is crucial for the critical minerals industry to find ways to mitigate these risks in order to ensure the continuity of supply and maintain a competitive edge. At the same time, increasing global demand for a reliable and sustainable supply of critical minerals presents a moment of significant opportunity for Australia.

Responses relevant to Discussion Paper questions 5, 6 and 14:

5. What are the specific opportunities Australia should seek to realise while developing downstream processing and manufacturing capabilities?

6. For key technologies and value chains, such as batteries, magnets, alloys and other clean energy technologies, what are the key obstacles to Australia moving up the value chain?

14. What are the opportunities for critical minerals projects to maximise their ability to support clean energy supply chains and technologies?

Decarbonisation and value creation

Electrification of mineral processing

Industrial decarbonisation to meet global climate commitments will lead to significant disruption to the critical minerals industry. A transition to sustainable processing of Australian minerals is essential to ensuring the industry maintains its competitiveness in a future low carbon global economy. For Australia, the transition towards net zero emissions production of critical minerals also represents a unique moment of opportunity.

Australia possesses a potentially unrivalled combination of critical mineral and renewable energy resources. Together with significant industry expertise and innovative Australian technologies, these natural advantages can enable the Australian critical minerals industry to create and capture more of the critical minerals value chain through innovative and sustainable downstream processing and the export of premium, low carbon products.

Emissions reduction

Electrification is a key enabling technology for the Australian critical minerals industry to contribute towards our national emissions reduction commitments. The electrification of mineral processing would allow the critical mineral industry to decouple its energy intensive processing requirements from the generation of carbon dioxide, other greenhouse gas emissions and pollutants.

Electrification of mineral processing can also incentivise further investment and development of renewable energy generation capacity, as well as help facilitate the incorporation of increasing amounts of renewable generation by enabling large industrial energy consumers to provide grid-load balancing capabilities.

At-mine processing

Low and zero emissions processing at the mine site promises a new paradigm in the supply of critical minerals, and one that can be a key advantage for Australian heavy industry. By processing minerals at the mine site, Australian producers can dramatically reduce the creation and 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 would be particularly beneficial for remote mining operations where transportation costs can be a significant proportion of the overall cost of production.

At-mine processing involves the thermal treatment of raw mineral ore to enable on site solvent extraction of the valuable mineral. 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.

Value capture and creation

As international trading partners decarbonise their economies and introduce prices on the carbon emissions of their imports, Australia should look to maintain and improve its competitiveness by providing sustainable sources of critical minerals to the world.

Electrification of mineral processing and the use of locally sourced renewable energy offers significant opportunities for Australian producers to develop highly competitive and future proof downstream processing solutions. By doing so, producers can add value to minerals by converting low-value ores into high-value products.

Processing minerals at the mine site with locally produced renewable electricity has the potential to significantly reduce the cost of production. In addition, decarbonised mineral products can be increasingly expected to attract a premium price with trading partners and increase revenues from the sector, particularly as carbon pricing mechanisms and carbon border taxes become more prevalent.

By combining Australia's significant natural advantages in mineral and renewable energy resources, Australian producers can not only move up the value chain to capture more value from our resources, but also create value by delivering a reliable supply of premium, low carbon intensity refined mineral products.

Synergies with Australian green hydrogen

Australia's abundant renewable resources can also translate into a natural competitive advantage for the generation of 'green' hydrogen. Sustainable processing solutions that use green hydrogen as a

reducing agent can enable significant value creation in the production of high-value refined products. This is in addition to the dramatic abatement of CO_2 emissions that would otherwise result from the processing of ores to metal when fossil-based reductants are used.

The use of green hydrogen as a reductant, in combination with renewably powered thermal processing, offers enormous potential for Australian production of green iron, rare earth metals and vanadium. As well as creating high-value decarbonised products for export, domestically refined metals can also supply Australian manufacturing industries to provide a competitive advantage in the production of lithium-ion batteries, vanadium redox flow batteries and rare earth magnets for vehicle and wind turbine motors, amongst other things.

For the production of metals by green hydrogen to be economically viable, expensive green hydrogen must be used as efficiently as possible. This can be achieved by using hydrogen only as a reductant, and recycling it in the process, rather than also combusting it as a fuel.

Improving supply chain security

Developing sustainable downstream processing capabilities in Australia would also diversify supply chains of critical minerals for Australia and its trading partners.

The ability to process minerals at the mine site would enable the production of critical minerals that are in high demand for Australian manufacturing supply chains, reducing Australia's reliance on imported minerals and helping to ensure the continuity of supply for the manufacturing industry.

Moreover, Australia can provide a stable and dependable source of critical minerals to international trading partners around the world.

Catalysing innovation and economic growth

Developing downstream processing capabilities for the sustainable production of critical minerals on shore and at-mine sites can also create jobs and economic growth in the mining sector, particularly in regional Australia. Additionally, the production of high-value products can help make the Australian minerals industry more attractive to buyers and investors, further improving growth and job creation.

Downstream processing and the domestic creation of high-value intermediate and end products from critical minerals can also promote the development and commercialisation of Australian technologies. These include enabling technologies for more sustainable production of critical minerals, and technologies that utilise local sources of critical mineral products.

Responses relevant to Discussion Paper questions 7, 8 and 9:

7. How can governments, industry, and researchers support Australia's critical minerals industry to move further downstream and develop new sovereign capabilities?

8. What can Australia do to better develop and retain IP and to attract IP investment from like minded partners?

9. How can government support the capability of critical minerals companies and other relevant entities to identify, engage and grow new target markets?

Supporting the development of technologies that enable local minerals processing using locally produced energy can bring significant economic benefits for Australia. To seize this opportunity, the industry needs a certain and stable policy base from which it can make long term investment decisions. Policies that neutralise and or leverage the policy settings of competing governments and trading partners are particularly welcomed.

Calix supports the recently announced changes to the Safeguard Mechanism. A price on carbon provides strong incentives for emitters to decarbonise and a stable base from which investment decisions on decarbonisation strategies and technologies can be made.

Calix also supports the introduction of a carbon border adjustment mechanism (CBAM) in Australia. The competitiveness of Australia's critical minerals industry, as an emissions-intensive exporter, is exposed to international competitive pressures as it becomes subject to tightening emissions reduction standards. An Australian CBAM can both protect Australian producers by placing foreign imports on a level playing field and increase the competitiveness of our exports into major economic blocks with similar policy frameworks, including the European Union. Together, the Safeguard Mechanism and an Australian CBAM can act as a catalyst to develop significant competitive advantage in low carbon products.

One potential barrier to the development of domestic downstream processing capabilities is direct intervention by other governments in the market. Some countries are using direct subsidies and indirect energy subsidies, tariffs, and other forms of protectionism to give their own mining industries an advantage over foreign competitors. This can make it difficult for the Australian critical minerals industry to compete and can lead to reduced profitability and job losses.

To counter this barrier, the Australian Government can take a number of actions to level the playing field for the Australian critical minerals industry. In addition to negotiating trade agreements that include provisions to address unfair trade practices such as subsidies and tariffs, the Australian Government could also consider implementing its own energy subsidies, zero interest renewable energy loans or project loan guarantees to support investment in the Australian critical minerals industry. Continued support for research and development of new technologies is also welcomed to further drive innovation and competitiveness.

Finally, further incentives that encourage investment in industrial decarbonisation now will help Australia capitalise on its natural competitive advantages to become a global leader in the sustainable supply of critical minerals. The alternative is a laggard approach that sees decarbonisation forced on Australian critical minerals by the policies of our trading partners. This scenario must be avoided if Australia's critical minerals industry is to realise its potential.

Calix's sustainable processing solutions for critical minerals

Industrial decarbonisation tailwinds continue to drive demand for renewably powered, low waste processing solutions for the materials of our future economy.

Calix's patented core technology platform is ideally suited to help mineral and chemical processing enter the electric age. Our indirect heating approach is compatible with renewable sources of energy and alternative fuels, while separating the heat source from the chemical reaction enables the efficient use of green hydrogen in place of conventional, carbon intensive reducing agents.

Calix is also developing innovative refining solutions that enhance recovery of ore and create near zero-waste products. Renewably powered at-mine processing can enable both a significant reduction in the total CO_2 footprint of critical minerals, and the local creation and capture of significant additional value within the critical mineral value chain.

Iron and steel, lithium and other critical minerals are essential and also 'hard-to-abate' sectors where Calix's decarbonisation technology is currently being applied.

Case study 1: Decarbonising iron and steel

Iron and steel are materials essential to our economic prosperity and continued development. Responsible for 7% of global CO_2 emissions[1], 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.[2] As the second largest source of industrial emissions after cement and lime, iron and steel producers are under intense pressure to decarbonise.

Zero Emissions Iron and Steel TechnologY

Calix is applying its technology to develop green iron and steel. Our Zero Emissions Steel TechnologY (ZESTY) uses hydrogen in a renewably powered reactor to produce green iron and ultimately, green steel.

ZESTY can be electrically heated and is compatible with intermittent sources of renewable generation and grid load balancing applications. The unique, indirect heating approach not only enables efficient electrification, but also removes sources of combustion and the generation of hydrogen-oxygen flames, allowing a simpler design and processing at significantly lower temperatures than a conventional blast furnace.

Unlike other direct reduced iron technologies, Calix's indirect heating of the reduction reaction with renewable power means hydrogen is not consumed as a fuel, only as a reductant, and is easily recycled in the process. As such, ZESTY is targeting the minimum hydrogen use of 54 kilograms of hydrogen per tonne of iron, enabling more efficient and economical production of green iron and steel.

ZESTY is compatible with iron ore fines, reducing waste and removing the need for pelletisation. This ability to handle small particle sizes may also make it easier to remove impurities compared with other (DRI) processes, which require pelletised and typically higher grade iron ores. Further testing and validation of this potential is underway.

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.

Calix's ZESTY steel process involves the use of the ZESTY iron process feeding a standard (continuous) electric arc furnace (C-EAF), with the addition of a Leilac kiln to produce zero-emissions lime. No pelletisation of the lime is required, while the lime can also be used to scrub excess carbon dioxide as well as other pollutants from the exhaust gases. ZESTY steel aims to enable steel

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

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

producers to add ZESTY directly into their process to produce lower carbon, and ultimately zero emissions steel products.

A unique Australian opportunity

Australia's combination of globally leading iron ore and renewable energy resources promises to provide a unique global competitive advantage for green iron production. Australia supplied over 53%[3] of the world's iron ore in 2021, contributing nearly 44% of Australia's total export earnings[4]. Haematite, however, makes up 96% of Australia's exported iron ore and is not suited to most electric arc furnace (EAF) methods[5].

Calix's ZESTY seeks to facilitate the transition to green steel, adding value to local iron ore exports as well as future-proofing local iron and steel production. ZESTY is compatible with multiple iron ore types, including haematite, providing pathways for one of Australia's most important exports to become sustainable in a low carbon world.

The Basis of Design (BOD) and Front-End Engineering and Design (FEED) for a renewably powered 30,000 tonne per annum demonstration plant for ZESTY iron are underway, supported by a A$947,035 grant from the Australian Renewable Energy Agency.

Case study 2: Sustainable lithium

In a joint venture, Calix and Pilbara Minerals (ASX: PLS) are developing an innovative decarbonised lithium refining process that aims to create a new, high value and low carbon intensity lithium product in the Pilbara. Australia currently produces nearly half the world's lithium, with the global market for lithium carbonate and equivalents projected to grow six times by 2030[6]. Currently, Australia exports lithium as spodumene concentrate, typically containing approximately 7% lithia (Li_2O) and 93% waste. This process not only moves much of the lithium value chain off-shore, it also creates significant economic and environmental cost.

An innovative "mid-stream" process

The Calix and Pilbara Minerals joint venture aims to develop a renewably powered at-mine processing innovation via Calix's calcination technology for sustainable processing of minerals.

The proposed mid-stream process aims to produce a refined lithium salt product that greatly reduces the cost, waste, and CO_2 footprint of Australian lithium, creating a significantly higher value export product.

The project includes the potential development of a demonstration plant at Pilbara Minerals' Pilgangoora Project and is supported by A$20m in Australian Government funding announced under the Modern Manufacturing Initiative. A Financial Investment Decision on the proposed demonstration plant is planned before the end of the 2023 financial year.

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[3] https://www.statista.com/statistics/300328/top-exporting-countries-of-iron-ore/

[4] https://www.minerals.org.au/news/record-high-resources-export-revenue

[5] Iron Ore | Geoscience Australia

[6] Lithium mining: How new production technologies could fuel the global EV revolution - McKinsey Apr 2022

A successful “mid-stream” project will enable the joint venture to license the technology to the global spodumene processing industry.

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About Calix

Calix is a team of dedicated people who are urgently developing great businesses, leveraging our patented technology, that deliver positive global impact.

The core technology is being used to develop more environmentally-friendly solutions for water treatment, CO_2 mitigation, biotechnology, advanced batteries, and more sustainable mineral and chemical processing.

Calix develops its technology via a global network of research and development collaborations, including governments, research institutes and universities, some of world’s largest companies, and a growing customer base and distributor network for its commercialised products and processes.

Because there’s only one Earth – Mars is for Quitters.

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