CRITICAL MINERALS
Not just buzz words, but essential for modern life

CSIRO Australia’s Innovation Catalyst
Discovery Innovation Minerals Exploration Seminar

#DIME2022

15 September 2022
08:30 to 18:00 AWST

Beaumonde on the Point
306 Riverside Dr, East Perth WA

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Further information
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Come and discover CSIRO’s latest innovations in mineral exploration at #DIME2022.

Formerly known as the Exploration Seminar, this annual industry-focused showcase highlights our recent scientific and technological advances aimed at lifting success rates in mineral exploration.

Our mineral discovery R&D program is focused on developing new, innovative, and disruptive technologies that lead to increased, more cost-effective mineral discovery rates.

As well as sharing our latest research, the event also provides an opportunity for us to hear from industry about challenges they face.

Through dynamic topic-focused Q&As and broader panel discussions throughout the day your participation can help shape future CSIRO research.

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Managing Editor: editor.resourceful@csiro.au

Design: brand@csiro.au

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Cover: Critical minerals are regarded as essential to modern life.
CRITICAL POINT

The success of the global energy transformation relies heavily on the mineral resources sector, to satisfy an increasing demand for a range of minerals for the manufacturing supply chain to deliver key technologies that the world needs.

This is a whole of value chain demand accompanied by a consumer and investor expectation of the highest standards of ESG accountability in this supply. Australia is very well placed, and widely regarded as not only a jurisdiction with a reputation for high standards in resource development, but also with a rich endowment of existing resources and very high exploration potential for new resource discoveries. In this issue of Resourceful, we focus on our critical minerals, the essential ingredients for the technologies that will power the energy transformation and that provide solutions as we strive towards achieving a Net Zero world.

We describe some of these minerals as ‘critical’, in part in testament to their importance for the technologies that are made from them and in turn the importance of those technologies to the world, but critical also due to a lack of transparency, certainty of supply, sovereign capabilities to maximise value and from our dependence on single countries in what can easily and frequently be disrupted supply chains.

Many of our articles in this issue of Resourceful will touch on these aspects of criticality and outline how increasing volumes of these minerals are required for these technologies compared to similar products in the past.

Exploration activity in the search for new critical mineral deposits is increasing and efforts by groups like CSIRO (new exploration technologies) and Geoscience Australia (pre-competitive data) are targeting support for Australian industry to discover these new mineral resources that can speed up the process of bringing on the urgently required new supply.

With the International Energy Agency (IEA) forecasting we require at least 60 new Lithium mines within a decade to meet current commitments alone, the exploration challenge is truly set! While these minerals might not currently be a major export commodity for Australia compared to iron ore or gold, it is certain that they will increase in importance in the future. An added dimension is that there is significant extra value to be gained for Australia by taking these minerals further along the value chain, to deliver high value chemicals and materials, and high value components.

The articles on our graphite work, solar, and our feature on Lab22 are great examples of these opportunities being pursued right now, while our discussion on Australia’s role with critical minerals for the global energy transition with Jerad Ford, outlines with Jerad Ford, outlines the significant future upside if we grow our value-added resource industries as was featured in our recent Critical Energy Metals Roadmap.

Australia not only has a strong resource base, but also has world class and arguably world leading research expertise and facilities. We continue to maintain and modernise these capabilities for Australia, supporting industry and government through science and technology. This issue of Resourceful is a snapshot from CSIRO (and our partners) and highlights how our capabilities play an important part in the critical minerals supply chain research.

With CSIRO’s long history in mineral resources innovation we can, and are, pivoting to support the growth of the critical minerals sector and to ensure it can meet the demands of quality, environmental and social performance, to be a trusted and certified provider of products.

Our article on blockchain, for example, shows how we can help certify our future trade and provide the kind of guarantees expected in the provenance of any products used in modern day life, particularly in the context of green energy technologies as solutions being delivered to help tackle climate change.

These capabilities strengthen our global role in the energy transformation challenge, providing opportunities for new international collaborations with the many countries that share the same goals to build resilient and diverse supply chains in critical minerals.

We feature the opportunity for collaboration and our relationship with India relationship with India, an elegant example of how two nations can come together to consider how science and technology can help grow shared value from the sector and meet shared needs.

Ultimately, we are setting an exciting challenge, to maximise Australia’s critical minerals potential, to create value, and to sustainably and securely supply quality and certified products into a value chain that can deliver to the global energy transformation. Our national science, engineering and technology expertise coupled with our ability to rapidly translate innovation into impact is already on the move!

DR ROB HOUGH
DIRECTOR, CSIRO MINERAL RESOURCES
+61 8 6436 8763
rob.hough@csiro.au
AUSTRALIA’S CRITICAL MINERALS LIST

A SHORT HISTORY OF CRITICAL MINERALS

They are the very definition of a modern hot commodity. JANE NICHOLLS reports on how governments decide what minerals are added to the critical minerals list, and why it’s a brilliant opportunity for the Australian resources industry.

Innovation is the simple reason that attention to critical minerals is in such sharp focus. Numerous technologies – from EV batteries to PV cells, from fibre-optic cables to semiconductor chips – rely on these minerals, which means we’re using more of them and in greater volumes.

“A hundred years ago, we were using a dozen main metals, and that was it,” says Ms Allison Britt, Director Mineral Resources Advice and Promotion at Geoscience Australia.

“These days, we’re using almost all of the periodic table in some fashion in various technologies. We need to better understand critical mineral supply chains, diversify them and make them much more robust than they have been.”

These minerals are critical across numerous technologies driving energy transition, medical devices, aerospace and even banknotes, and are also crucial for products we regard as everyday, such as stainless steel and electronic appliances.

“The definition we use for critical minerals is that they are metallic or non-metallic elements that are essential to the functioning of our modern technologies, economies and national security, and that there is a risk that their supply chains could be disrupted,” says Ms Britt, who is a commodity specialist and expert in critical minerals.

In addition to minerals listed as critical, others are classed as strategic, and the list varies slightly from country to country, based on local uses and threats.

“I was once in a meeting with a famous American geoscientist discussing what’s a critical resource and what’s strategic,” recalls Dr Chris Vernon, Senior Principal Research Scientist at CSIRO Mineral Resources.

“He said it really simply: It’s stuff you need that you can’t get. That struck me as a good touchstone!”

THE EVOLUTION OF LISTING CRITICAL MINERALS

Ms Britt says, for example, “lithium, cobalt and tungsten are regarded as essential to modern life”.

They are all in geological abundance in Australia and on the critical minerals lists of the US, EU, Japan and India.

“Supply chain disruption to those minerals could come in the form of market monopolies – or near-monopolies such as we see with Chinese control of rare earths – or it could be market immaturity, political decisions, social unrest, natural disasters, mine accidents, geological scarcity, and recently we’ve seen pandemic and war.”

War was the reason the US made its first list of critical minerals. During WWI, five key minerals – tin, nickel, platinum, nitrates and potash – were scarce on its own soil and within two years of the conflict beginning, were becoming difficult to obtain.

“The Americans drew up a list of War Minerals,” explains Ms Britt.

By 1917, the US Geological Survey had reoriented its work to aid the search for minerals needed for the war effort.

“Later they split it into three lists, strategic, critical and essential minerals, but by World War II the lived war experience had shown those distinctions were largely academic.” That is, they were all critical in one way or another.

Many critical minerals aren’t necessarily scarce in Australia, but as well as vulnerable supply chains, keeping up volume to meet surging demand from allied manufacturing sectors is a potential issue.

“If you’re relying on imports of all resources, that makes everything critical,” says Dr Vernon.
“Minerals that are on Australia’s critical list are usually major inputs to the economies of our allies and end up in things that we buy back in a finished form. Rare-earth elements are on the Australian critical minerals list, for example, not because we make things out of rare earths here, rather in recognition that allied economies rely on them.”

HOW AN ABUNDANT MINERAL CAN QUICKLY BECOME CRITICAL

“When it came to developing Australia’s first Critical Minerals list, which was published in 2019, the Australian Government’s approach reflected the fact that our mineral economy is dominated by mineral exports, not manufacturing,” says Ms Britt.

“The original list of 24 minerals was based on the strategic needs of our partners – such as the United States, the EU, Japan, the UK and South Korea – combined with Australia’s high geological potential to supply those minerals.”

The 2022 Critical Minerals Strategy published in March by the Department of Industry, Science and Resources saw the addition of high-purity alumina and silicon, both abundant in Australia.

“They are both important for a range of technologies including batteries, quantum computing and semiconductors,” says Ms Britt.

She says the addition of those two to Australia’s list, to bring the total to 26, is a classic example of how the importance of minerals shifts over time.

“They reflect changes in technologies, in geopolitics, supply chains and processing techniques,” says Ms Britt.

“Technically, neither high-purity alumina or silicon are available as minerals in the raw – the base minerals are bauxite and silica sand – but it is a recognition that those are materials that are incredibly important,” says Dr Vernon.

“Silicon has been added in part because there is a global computer-chip shortage. When the chip shortage became apparent, governments scrambled and had a look at the supply-chain for computer chips and went, ‘Ah, actually a lot of these chips are made in Japan, South Korea, Taiwan, the US, and Europe, but manufacture of the base substrate material is concentrated in three or four individual manufacturers in China’. That’s a weak point in the supply chain.”

Enter the pandemic for a live demonstration of how a supply chain gets smashed almost overnight.

“When COVID hit China, factories closed down and they stopped producing as much of this high-purity silicon wafer, that’s essential for semiconductors,” says Dr Vernon.

“It was a pretty broad impact. The US can’t make enough of their own silicon wafers for these microchips. Solar photovoltaic panels are also made of high-quality silicon, so while the world is not running out of silica (quartz and sand), it’s running out of high-purity silicon, because it’s not produced in enough places to keep the supply chain open and viable. That’s why silicon was added to the list this year.”

The demand for certain critical minerals will continue to fluctuate.

“It’s hard to believe today that asbestos and arsenic were once considered critical minerals,” says Ms Britt.

“It definitely keeps people busy trying to forecast what commodities will be regarded as critical minerals in the future! With renewable energy technologies in demand, we might find that Australia adds nickel, copper, tin and zinc to the list,” she says.

All except copper are already on the US Geological Survey’s List of Critical Minerals, which was first published in 2018 and had 15 added in 2022 to bring it to 50.

“The Australian government regularly reviews our Critical Minerals list, and those of our partners, to ensure it reflects those changing conditions in technology, economics and geopolitics,” says Ms Britt.

“We want to make sure we are in the best position to build our own domestic capability for critical minerals discovery, processing and supply chains, which is a real opportunity for Australia.”

THE CRITICAL MINERALS LIST IS AN IMPORTANT SIGNAL TO MARKETS

Ms Britt says that the addition of the two new minerals to Australia’s list in 2022 means they are now supported by the government’s Critical Minerals Strategy. It sends a signal to the resources industry and helps to unlock investment in both mineral exploration, processing and downstream value-adding.

“The Australian government regularly reviews our Critical Minerals list, and those of our partners, to ensure it reflects those changing conditions in technology, economics and geopolitics.

Allison Britt, Geoscience Australia
“The strategy includes a range of actions to help build Australia’s critical minerals capabilities,” explains Ms Britt.

The Federal government’s $2 billion Critical Minerals Facility was announced in 2021 and is already providing loans to the sector. A $50 million virtual National Critical Minerals Research and Development Centre, hosted by CSIRO in conjunction with Geoscience Australia and the Australian Nuclear Science and Technology Organisation (ANSTO) is another important initiative. It was announced in March 2022 to help unlock new sources of economically viable critical minerals, develop Australian IP in critical mineral processing, target technical bottlenecks in strategic supply chains and drive collaborative research breakthroughs.

Ms Britt says once a mineral is on the list, companies can apply to the Critical Minerals Facilitation Office for connection to government funding facilities.

“For example, now that high-purity alumina is on the list, a company can apply for a range of financial support for its high-purity alumina project that will help improve access to it, secure supply, or advance its processing,” says Ms Britt.

“If a mineral is not on the list, that’s not an option.”

AUSTRALIA’S POTENTIAL AS A CRITICAL MINERALS SUPERPOWER

“The surge of electric vehicles and renewable energy projects around the world is a huge opportunity for Australia,” says Ms Britt.

“People want their cars to be made of materials that have been produced responsibly – they don’t want the cobalt in the battery to come from child labour, or the rare earths in a motor to have contributed to irreversible environmental destruction. Manufacturers want secure supply of those minerals, and other critical minerals such as lithium, graphite, manganese, and vanadium, all of which occur abundantly in Australia.

“The challenge is to value-add to our natural mineral wealth. Australia is a mining superpower, but with a few exceptions, such as the aluminium industry, we haven’t been so good at taking the next steps in the supply chain that would enable us to realise better returns.”

As Ms Britt says, most of our minerals are shipped out in bulk or minimally processed into concentrates or basic metals.

“The high-value critical mineral purification, chemicals and componentry are all created in other countries, and the technology using these materials and components are manufactured in other countries – then Australia buys it back.”

Dr Vernon and Ms Britt also stress that value-adding to our minerals onshore will not only bring economic benefits, but it will also bolster global security around these minerals.

“It’s incumbent on us to lengthen and strengthen these critical minerals supply chains,” says Dr Vernon.

“It’s exciting to dig up and concentrate an ore of something that’s scarce, but if you export it in raw form, you’ve lost all control over the supply chain. Value adding within Australia to strengthen global supply chains is an important aspect to ensure we are not perpetuating the current situation, where some minerals are critical only because there’s a pinch point in the supply chain, and it’s in a country that’s not necessarily transparent in its dealings.”

He calls out two Australian companies that are forging a value-add path for our critical-minerals wealth by doing more downstream processing onshore.

“Lynas Rare Earths is building a processing facility in Kalgoorlie, creating far more security in the supply chain,” he says. The company is the only producer of separated rare earths at scale outside China.

“Iluka Resources is building a refinery in Western Australia which will produce purified rare earths to feed into a rare-earths metal refinery, with the product going to magnet makers. Those are both examples of companies lengthening their supply chains.”

Ms Britt says there’s immense scope for more projects like those.

“The growth in the critical minerals sector means we have this opportunity to reinvigorate our own domestic manufacturing sector, and to do more of that value-adding right here in Australia,” she says.

“Any downstream manufacturing needs a reliable feedstock and that’s where Geoscience Australia comes in – we uncover mineral potential which helps companies make those discoveries to provide the raw feedstock that will underpin a lengthened, diversified supply-chain manufacturing sector here in Australia.”

For the Australian resources sector, it’s not so much a matter of ‘watch this space’ as watch this list.

DR CHRIS VERNON
+61 8 9334 8043
chris.vernon@csiro.au

Value-adding to our minerals onshore will not only bring economic benefits, it will also bolster global security around these minerals.

Dr Chris Vernon, CSIRO
CSIRO’S SCIENCE UNDERPINNING THE AUSTRALIA-INDIA CRITICAL MINERALS PARTNERSHIP

An alliance with Australia is set to help India realise their net zero emissions plans by offering a secure, stable supply of the critical minerals they need for the technologies to achieve it. TIMOTHY CONNELL writes

Not for the first time, “the lucky country” is positioned to capitalise on the status backhandedly bestowed by Donald Horne. Australia is geologically blessed with minerals that India has earmarked as critical, such as nickel, vanadium, titanium, lithium and rare-earth elements. As India embarks on an energy transition, it is looking to safeguard against uncertainty in the global supply of these minerals.

In May 2022 in Tokyo the Quad nations – the US, Japan, India and Australia – finished mapping the capacities and weaknesses in supply chains. That summit was Anthony Albanese’s first as Prime Minister.

Two months earlier, the India-Australia Critical Minerals Research Partnership had been established, with CSIRO awarded about $12 million to lead Australia’s contribution.

India’s desire to rely less on China for supply and processing coincides with a forecast increase in demand for critical minerals in line with global trends.

A GROWING NEED

In a country that in 2020 unveiled the largest stadium in the world – the 132,000-seat Narendra Modi Stadium in Ahmedabad, where a crowd cheered then-US President Donald Trump’s attempts to pronounce the names of Sachin Tendulkar and Virat Kohli – there is a growing push for self-reliance.

The Make in India strategy and Atmanirbhar Bharat, the government’s industrial self-sufficiency and growth program, are emblematic of a country that sees itself emerging as a manufacturing hub. The Indian government has adopted a renewable energy and battery storage target of 175 gigawatts by 2022, and 500GW by the end of the decade. By that time, the country aims also to have 30 per cent of vehicles powered by electricity.
India’s High Commissioner to Australia Manpreet Vohra says his country has already begun a transition that will require a secure, reliable source of critical minerals.

“We already have a fair amount of our energy mix coming from the renewable sector, particularly solar and wind. And so the requirement for critical minerals is critical, indeed, for India,” His Excellency says.

“We are convinced that what is needed for around-the-clock dispatch of renewable energy is large battery storage.”

As a study of scale, consider the renewed media deal for cricket’s Indian Premier League. The broadcast rights for the next five years will be shared between Disney and Reliance Industries and are worth almost A$9 billion. With a viewership in the hundreds of millions, the league generates endless streams and highlights for viewing on mobile phones, which require “battery minerals” such as nickel, lithium and cobalt. All are produced in Australia, with the potential for more.

UNTAPPED POTENTIAL

Mr Andrew Jenkin has been to India six times, a trip he says he has been “lucky enough” to make in previous roles. He knows he will soon increase that tally as CSIRO’s Research Program Director, Mineral Processing, as part of the countries’ critical minerals partnership. He is also adamant about Australia’s potential as a producer and, further down the value chain, a processor of critical minerals.

“The analysis we see is often a bit biased and I’d be interested to hear what Canada have to say,” Mr Jenkin says.

“But if you straw-poll experts around the world, I’d be really surprised if we weren’t number one on the vast majority of lists.”

With a vast land mass, geology that is conducive to minerology and an advanced extraction industry, Australia is positioned, says Mr Jenkin, to reap the benefits of being the friend India wants. Western Australia dominates the nation’s known critical mineral resources, but there are deposits in all other states and territories.

THE START OF A PARTNERSHIP

Mr Jenkin is recruiting people and scouting projects and investment opportunities within CSIRO for the new partnership from across its mining, energy and manufacturing teams. He is also working on identifying key contacts in the Indian Ministry of Mines, the nation’s science body CSIRO, and top-tier Indian universities.

Top of about 20 projects on Mr Jenkin’s radar is a novel process devised in Perth’s CSIRO Waterford facility to treat titanium and vanadium ores where they coexist. The centre’s funding may afford researchers the opportunity to build a pilot plant and scale up their efforts. Serendipitously, titanium and vanadium are on India’s wishlist of critical minerals. The method’s end application could be a cheaper and more environmentally friendly way to process both metals.

The “holy grail”, says Mr Jenkin, is to use every part of what is extracted in critical mineral processing and to minimise the environmental footprint of the entire mineral and metal supply chain. Shipping anything across the world adds to emissions and there is, it can be argued, a moral imperative for a developed country to strip critical minerals out as close to the source as possible and deal with any waste and low value products there.

It is an opportunity that Mr Jenkin is confident can be met by both countries in the years to come.

“Both countries have so much to gain by collaborating on critical mineral supply chains and so much to give in support of global emission reduction efforts.” Dr Jenkin says.

“But critical minerals are complex and our research and development efforts are going to be important for the entire world to increase supply sustainability.

MR ANDREW JENKIN
+61 3 9545 2499
andrew.jenkin@csiro.au
Most of us become familiar with graphite as early as primary school: it’s what you find running through the core of a pencil. This soft, lightweight mineral made of carbon has dozens of other important uses though. It’s a key component of brakes, lubricants, fire retardants, inks, electronics and – most crucially – batteries. **RUTH DAWKINS** writes

Graphite is an ideal conductor for battery anodes, and with the increasing popularity of lithium-ion batteries, the World Bank estimates that demand for this critical mineral will increase by 500% between 2018 and 2050. The process of extracting graphite from the ground and getting it ready for use in batteries is a long and complex one. The graphite has to be mined, concentrated, shaped and sized into small balls in a process known as spheronisation, purified, and then finally carbon coated.

Currently, the global value chain for graphite is quite disjointed, with many unconnected companies providing single services along the value chain. But as demand for graphite continues to grow, more companies are looking to do more in-house; expanding their services along the value chain and creating value-added products from their graphite ore.

“CSIRO is one of the very few research organisations with capabilities and skills spanning across the entire value chain for natural graphite battery anodes,” says Dr Joanne Loh, Senior Research Scientist with CSIRO Mineral Resources. “In conjunction with CSIRO Manufacturing, we can provide real continuity – from the fundamental science that provides a solid evidence base for work, through to demonstrating impact and outcomes for clients within industry. In effect, we are a one-stop shop for graphite processing.”

**HOW CSIRO IS HELPING INDUSTRY MEET DEMAND FOR GRAPHITE**

In order to meet the expected demand for graphite in an environmentally sustainable way, there are a number of challenges that need to be overcome. CSIRO has been collaborating with the Australian mineral industry to find the best way forward.

One of the key challenges for the industry is that battery grade graphite needs to be very high purity and traditionally the only process for achieving this is a highly toxic one.

“For use in battery anodes, the graphite needs to be ultra-high purity,” says Mr Karl Bunney, an Experimental Scientist with CSIRO Mineral Resources. “Not quite as stringent as nuclear grade, but we’d be looking for a purity of 99.95% or more, compared to around 95% for things like pencils and lubricants. The only source for purified graphite to date has been China, where it’s processed using hydrofluoric acid. It’s an enormously toxic process and has huge impacts on health and the environment.”

With the large-scale use of hydrofluoric acid banned in most countries, Australian companies are seeking alternative methods that will still allow them to value-add and produce battery grade graphite, without such serious environmental costs. That’s where CSIRO’s broad range of expertise and multidisciplinary approach has now come into play.

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AN EXCITING INDUSTRY COLLABORATION

In 2019, CSIRO began a partnership with Mineral Commodities (MRC) – a global mining and development company with a primary focus on the production of high-grade mineral sands and natural flake graphite. MRC own and operate a graphite mine at Skaland in Norway. They also have a graphite development project at Munglinup in Western Australia, which has been classified as a critical minerals project by the Federal Government.

For the last two years, CSIRO and MRC have been working together through a Cooperative Research Centre Project (CRC-P), supported by the Federal Government. The focus of the CRC-P was to develop an environmentally friendly and commercially viable method for purifying graphite.

This initial project, which ended in March 2022, was a resounding success, with battery grade purification achieved for both Skaland and Munglinup samples. The CSIRO-developed purification process achieved the same results as the traditional purification process, but avoids the use of environmentally-unfriendly hydrofluoric acid.

“We’re really pleased with the results,” says Dr Surinder Ghag, Chief Technology Officer with MRC.

“It’s been brilliant working with Karl and the team at CSIRO, and to collaborate with researchers who are such highly-skilled experts in their field. Now we’re excited to move onto the next phase of the work.”

Mr Karl Bunney, Experimental Scientist, CSIRO

Dr Joanne Loh leads the graphite processing team at CSIRO graphite

REAL WORLD IMPACT

In April 2022, MRC were awarded a $3.94 million Critical Minerals Acceleration Initiative (CMAI) grant, that will allow the collaboration with CSIRO to continue and expand.

While the initial project involved working with samples of 1 kilogram at a time, the CMAI project will scale up to running 20-kilogram samples.

“The big challenge for us with the new pilot will be scaling up,” says Mr Bunney.

“Running at 20 kilograms per batch puts us about halfway between [the order of magnitude of] a laboratory pilot and an industrial scale operation. At this point it becomes less of a science problem and more of an engineering one.

“We know the chemistry works – but if you take a part of the process like stirring, we need to find out if that works as well in a 20 cubic foot tank as it does in a little beaker in my laboratory.”

For MRC, scaling up brings a number of advantages. Firstly, they will be able to provide larger samples to their own customers for qualification and feedback. But a larger pilot project will also take them a step closer to commercialisation.

“This is a big step up,” says Dr Ghag.

“It will provide us with data for the engineering design for a commercial scale plant, and it will allow us to update our feasibility study for the Munglinup deposit and downstream activities. If we achieve everything we’re hoping for with this stage, we’ll be ready for a vertically integrated mine to anode materials development.

“Obviously, there will still be work to do on the financing, but this helps to de-risk that step.”

Industry collaborations such as this one will become more crucial than ever as Australia moves towards net zero emissions, and the demand for low emissions technologies continues to grow.

And for researchers like Karl Bunney, it’s enormously rewarding work.

“Clients working with CSIRO benefit from that multidisciplinary approach that moves you from fundamental science all the way through to real world impact,” he says.
CSIRO established Lab22 with a vision to grow a new manufacturing industry as Australia’s Centre for Additive Innovation. From day one, critical minerals have been key. JANE NICHOLLS reports

“Lab22 was set up to help develop the additive manufacturing industry in Australia,” says Stefan Gulizia, Research Group Leader with CSIRO, where he’s also the Research Group Leader overseeing additive manufacturing, powder technologies, solid-state forming, surfaces, alloys, metal composites within Lab22.

The clue to how closely Lab22 works with critical minerals is right there in its moniker, bestowed when it was set up back in 2015.

“It takes its name from titanium’s atomic number, and our focus on titanium and many other critical minerals,” says Mr Gulizia, who has more than 30 years’ experience in materials science and process engineering across roles at CSIRO.

“We have about 30 scientists working at Lab22, and another 30 affiliates, including distinguished scientists, Post Docs, PhD and Masters students from all around Australia and the world, and we are a trailblazer in additive manufacturing,” says Mr Gulizia, who was a pioneer of cold spray technology in 2002, which revolutionised additive’s place in solid-state part manufacture.
We have the technologies to extract metal, and to make products using AM, but you can’t print anything without metallic powders. That’s the weak link – we need a commercial AM powder processing plant in Australia.

Mr Stefan Gulizia, CSIRO
Mr Gulizia says Lab22 is doing world-leading research in materials science developing hybrid critical minerals for AM applications.

“It’s going to play an important role in helping Australia develop sovereign capability in this space,” he says.

“We are creating new materials and process technologies and it’s very exciting.”

Lab22 is in Melbourne’s Clayton, which has become Australia’s AM hub.

“Our colleagues at Monash University also have an AM centre, and quite a few of the companies that have taken on Lab22’s technologies have established themselves in the area,” Mr Gulizia says.

Lab22 itself has a steady stream of visitors touring the facilities.

CHALLENGES AND OPPORTUNITIES AHEAD

As passionate as he is about AM’s future to create high-skilled jobs and a sustainable manufacturing industry in Australia, Mr Gulizia says there are still several issues to solve.

One is around the AM process itself: because it’s so new and using new material processes, the path to qualification or certification of parts is in development; particularly the qualification and certification of AM parts.

Our understanding of the mechanical properties of these parts, such as fatigue, is still being developed, by Australian and international researchers,” says Mr Gulizia.

Nevertheless, companies from startups to multinationals are investing in AM, such is the enormous potential of AM. The ability to personalise and “print” parts in remote locations on a just-in-time basis makes AM appealing to industry.

The other issue from a business model perspective is who owns the design when AM parts have their origins in a conventional part, but the materials have since been modified, and very likely consist of fewer components.

While Lab22 is driving world-leading AM innovation for Australia, Mr Gulizia flags a gap in our sovereign capability.

“The majority of powders used in AM today – including critical minerals – are imported,” he says.

“We have the technologies to extract metal, and to make products using AM, but you can’t print anything without metallic powders. That’s the weak link – we need a commercial AM powder processing plant in Australia.”

He also says there’s a skills shortage to fill the growing number of jobs in AM and that at the moment it’s falling mostly to companies to train up technicians.

“A lot of AM facilities are run by post-grads, but in my opinion, it should be taught at TAFE level,” says Mr Gulizia.

“The technicians can then run the machines and scientists can work on developing the materials that go into them.”

In the meantime, the Lab22 team will continue to build sovereign capabilities and instead of sending processed ores overseas and importing them back as powders, we will forge on finding new ways to turn Australia’s critical minerals into the additive manufacturing innovations of tomorrow.

MR STEFAN GULIZIA
+61 3 9545 2069
stefan.gulizia@csiro.au

Lab22 is Australia’s centre for innovation in metallic additive manufacturing.
MINERAL EXPLORATION AND DISCOVERY

THE SHIFT IN EXPLORATION TO SECURE THE $5 TRILLION GREEN ENERGY FUTURE

Australia’s national science agency, CSIRO, estimates more than AUD$5 trillion of metals will be needed by 2050 to construct technologies for the green energy transition. Of that, over half is slated to come from critical minerals. DIANA TAYLOR reports

CSIRO is looking to partner with companies which are leveraging the critical minerals industry, as Australia moves to unlock the full economic potential seen in every part of the supply chain.

“Critical energy metals present a tremendous opportunity for us to offer unique, high value products to the rest of the world,” says CSIRO’s recent report, Critical Energy Minerals Roadmap.

“Not by simply exporting raw minerals, but by upgrading our ores to metals, chemicals and alloys and in some cases finished products for niche markets. Without this, we will only capture a fraction of these trillion-dollar markets.”

Australia has designated 26 minerals such as lithium, cobalt, vanadium, titanium, graphite and rare earth elements as the critical ingredients essential to build clean energy infrastructure, technologies for aerospace and defence, as well as the electric vehicles of the future.

The global supply of critical minerals has historically been dominated by countries with increased sovereign risk such as China, Russia and the Democratic Republic of Congo.

RESOURCES RICH AUSTRALIA

However, the need to decouple from traditional suppliers and secure geopolitically safe and reliable sources of critical minerals has abruptly changed the focus of the Australian mining industry, according to CSIRO’s Research Director Dr Sandra Occhipinti, who heads the mineral resources Discovery Program.

“It has been a seismic pivot; we are seeing a significant shift in exploration for critical minerals which previously may have been overlooked,” Dr Occhipinti says.

“There are rich deposits here; we have very supportive geology in Australia and extensive surveys from previous exploration which will stand us in good stead.”

RARE EARTHS ELEMENTS

Dr Occhipinti explains that rare earth element minerals can be found in mineral sand deposits, across different parts of the continent.

“They are, however, often included as tiny particles in other (fairly small) minerals, which means that we need to do a bit of science to understand how to release them and concentrate them. In addition, critical minerals, such as lithium, needed for making batteries for electrification are often found in coarse grained granites or pegmatites,” Dr Occhipinti says.

“We are working with companies, using hyperspectral data or radiometric data collected from spaceborne systems of air to delineate areas that may contain these deposits, where we haven’t focused on looking for them before, and looking at new ways to delineate areas of higher prospectivity for a range of critical minerals through mapping indicator minerals in parts of the soil or weathered rock to map out possible footprints of these important deposits under the surface.”

OD6 Metals Ltd non-executive chair and co-founder, Dr Darren Holden said the company had sought out CSIRO’s advice to assist with discovery and mapping of important rare earth elements in the company’s tenements near Esperance in Western Australia.
“Developing a rare earth minerals project is complex and can be technically challenging so we’ve turned to CSIRO’s smart science and innovation to help us explore for and define a resource in our tenements,” says Dr Holden.

Dr Occhipinti said CSIRO would assist OD6 Metals by delineating the deportment or where the minerals sit in relation to each other.

“We have talked to OD6 about the potential of working with them across the value chain, and of supporting the company as they move from mining, to processing and manufacturing,” Dr Occhipinti says.

“Our achievements with OD6 Metals will have implications for other exploration companies, and that is ultimately good for our national interests.

“It’s about supporting an Australian company and at the same time, CSIRO is learning about processes and ways of delineating rare earth element deposits, so we may find some keys in looking for another deposit.

“That knowledge becomes part of Australia’s knowledge.”

CHARACTERISATION OF MINERALS

CSIRO Science Director, Dr Louise Fisher says that CSIRO’s cutting edge Microbeam laboratories have a long history of working with industry to provide detailed characterisation and understanding of mineral samples.

“This includes high resolution micro-characterisation and mapping, using our electron microprobes, to provide better solutions to production and analytical problems,” Dr Fisher says.

Dr Fisher says CSIRO has developed novel methods to support in-situ measurement of critical metals including rare earth elements and lithium.

“The CSIRO lab team have modified and customised hardware and software to create new functionality”.

“The translation of knowledge through lab-based analysis and characterisation into exploration tools has been greatly facilitated by the emergence of a new range of rapid analysis tools that can be deployed into the field or mine site. Our Geoscience Research Drill Core Laboratory provides a platform to connect these METS sector tools to our broader research infrastructure.

“Adding value to our raw materials, requires us to understand those materials so we can optimise processes.

“CSIRO’s Characterisation Program continues to develop the technologies to enable this understanding, and to work with broader teams across CSIRO Mineral Resources,” says Dr Fisher.

AUSTRALIA OFFERS SAFE, SECURE SUPPLY AND OPPORTUNITIES TO VALUE-ADD

Dr Occhipinti believes Australia is well-positioned to disrupt the current global supply status quo, with United States, India and the European Union turning to Australia as a trusted global supplier, citing our history as a mining superpower, along with a political and environmentally stable environment, one that can produce minerals to high standards.

“Australia can capitalise on its geology, and our international reputation that those minerals will be sourced in an environmentally and socially responsible way, within a stable governance structure,” she says.

Beyond the dig and ship model, Dr Occhipinti said Australia was also taking action to support greater development of processing and manufacturing.

“Manufacturing initiatives are connected, because if you get manufacturing happening onshore, then you also need the raw materials to support it, which feeds back into the mining industry.”

Dr Occhipinti says ultimately, to decarbonate and move away from coal, oil and gas to a truly green energy model, we are going to need to develop more mines.

“It is ironic, but our challenge is to ensure those mines are built in a responsible way, an environmentally safe way and to make sure they are socially accepted,” she says.

“We need to get the balance right, between the looming requirement for reliable sources of critical minerals, as well as ensuring we have checks and balances in place.

“Ultimately this will support the development of a robust and long-term industry, which will then underwrite the national security and economic prosperity of Australia.”

DR SANDRA OCCHIPINTI
+61 8 6436 8655
sandra.occhipinti@csiro.au

Developing a rare earth minerals project is complex and can be technically challenging so we’ve turned to CSIRO’s smart science and innovation to help us explore for and define a resource in our tenements.

Dr Darren Holden, OD6 Metals Ltd
GLOBAL ENERGY TRANSITION

AUSTRALIA’S ROLE IN THE CRITICAL MINERALS ESSENTIAL FOR OUR ENERGY TRANSITION

CSIRO experts explain the roadblocks, the challenges and the opportunities that Australia’s resources sector will face, in the fast-shifting market for the metals that play a vital role in the worldwide transition to renewable energy. FRAN MOLLOY investigates

CRITICAL MINERALS

As our global systems of energy production, transmission and storage rapidly shift to renewable and low-carbon systems, CSIRO research published last year reveals that some metals will face demand increases approaching 500 per cent by 2050.

That’s because renewable technologies such as offshore wind turbines and large-scale battery storage are more mineral-intensive than existing energy production facilities like gas-fired power plants.

As fossil-fuel generators are retired, the building and maintaining of new renewables infrastructure and the large-scale manufacture of essential components such as electric vehicle (EV) batteries, will ramp up demand for various metals.

Most of the ‘critical minerals’ essential for the global energy transition have deposits in Australia – examples include copper, lithium, nickel, manganese, cobalt and neodymium – but mining is just one part of the equation.

To effectively map out the industries, the support structures and the funding to support Australia’s future as a key supplier of critical minerals, we must take into account global markets, environmental risks and the impact of recycling as the world moves towards a circular economy.

“Figuring out how to supply which metals for the energy transition is a very interesting challenge, because there are so many different scenarios to model,” says Dr Jerad Ford, former head of CSIRO’s Critical Energy Metals Mission.

EMERGING TECHNOLOGIES

Critical minerals can refer to anything on the periodic table that will be important for upcoming challenges, such as manufacturing the advanced technologies used in computing and increasingly, in our global energy transition, he says.

“The amount of new mining we will need to support this transition will be influenced by how things play out between many technologies that are just emerging now,” Ford says.

Ford cites the electric vehicle revolution as an example, where many kinds of battery technologies are being developed which often use very different metal combinations.

Copper is needed in almost every single renewable energy technology, and likely will continue to play a big role, as will lithium; but while cobalt is currently in hot demand for its use in very high efficiency EV batteries, cheaper emerging battery technology now doesn’t use cobalt at all.

Australia has the world’s sixth-largest reserves of rare-earth minerals including the group of 15 metals known as the lanthanides, which include scandium (used widely in aerospace components), cerium (popular in both self-cleaning ovens and to coat wind-turbine blades) and neodymium (a powerful permanent magnet).

“The really interesting story about rare earth metals and critical minerals is actually about permanent magnets,” says Ford.
“Neodymium is the element most commonly used, but other rare earth minerals also play a role – and their ability to never lose their magnetic field makes them essential in things like EV motors and in spinning wind turbines, where very powerful magnets drive the generator to make as much electricity as possible.”

Green hydrogen is another emerging renewable technology – and critical minerals will play an important role here, Ford says.

This could include non-corrosive electrolyzers like titanium to help split water into its component parts; palladium and other minerals used in the fuel cells that transform hydrogen into power; and vanadium used in membranes that allow hydrogen to be converted to and from ammonia for storage and transport.

MODEL FUTURE

Working out how to meet future metal demand is not as simple as just taking a look at our current supply levels, or counting up known deposits available to be mined, Ford says.

Most metals are infinitely recyclable – which means that the global flow of metals is complex and dynamic, with metals sometimes locked-up for decades in durable consumer products with variable lifespans. ‘Second life’ applications can also extend the life timeframe of such products as EV batteries, repurposed for home or grid energy storage.

Ford’s group has developed a modelling and accounting method that tracks the dynamics of metal supply and demand at a global scale over long timescales, called a Physical Stocks and Flows Framework (PSFF), which can help strategic planning around metal supply and demand for governments and organisations.

“Australia has traditionally been good at producing the raw materials that the world needs, but we also need the end-product goods ourselves,” he says. “There’s real opportunity for us to add value to mining before we export; for batteries, we can make better chemicals that are much higher value and even vertically integrate and grow our local battery industry here.”

Ford says that CSIRO’s Critical Energy Metals Mission aims to connect Australia’s mining and manufacturing sectors to maximise these opportunities – and to help alleviate future roadblocks.

PRESSURE POINTS

One of the biggest challenges in the critical minerals sector is the current concentration of renewable technology supply chains in China, says Ford – adding that Australia is looking to improve renewable energy trade partnerships with other allies such as India, Japan and South Korea in order to help diversify global supply chains.

“Whether it’s battery chemicals or the high-grade silicon used in solar PV, China dominates the market – and having so much depend on one country, this weakens the resilience of a supply chain that is already under pressure from high global demand,” says Ford.

He cites the impact of the US Congress Uyghur Forced Labor Prevention Act, barring imports from China’s Xinjiang region, where around 40 per cent of the world’s solar panels are made.

“This regulation has impacted an entire year’s pipeline, gigawatts of installed solar in the US.”

Another challenge is the need to comply with growing regulation around circular economy and sustainable manufacturing and end-of-product-life plans.

“The EU is considering a mandated proportion of recycled materials in all batteries, and demand will grow for circular economy to be built into manufacturing processes,” he says.

“Much of the hydrometallurgy and other techniques and capabilities we use to produce the chemicals for battery and other energy technologies, can also be deployed at the other end of the process, to extract these important minerals out of products at their end of life.”

Ford notes that market pressures for increased use of recycled materials will lead manufacturers to design products so it’s easier to get the materials back at the end. “We just need to be smart about how we deploy the skills we already have in this area,” he adds.

The scale and the speed of the global energy transition is mind-boggling, he adds – and while that’s great news for our battle to mitigate climate change, there is a real risk that we may not be able to produce enough of the necessary materials – leading the energy transition to slow down.

“Global PV will be 10 times the size that is now in a decade’s time. Think of the supply constraints and the challenges we have right now – everything will be 10 times greater by 2032.

Dr Greg Wilson, CSIRO
The rapid acceleration of renewable technologies globally – specifically solar PV – is something that keeps CSIRO Energy Technologies Principal Research Scientist Dr Greg Wilson awake at night.

Solar photovoltaic (PV) has the largest compound annual growth rate of any energy technology in the world, growing year-on-year at around 25 per cent – a rate that’s hard to get your head around, he says.

“Global PV will be 10 times the size that is now in a decade’s time. Think of the supply constraints and the challenges we have right now – everything will be ten times greater by 2032.”

While the Covid-19 pandemic and Ukraine war have had enormous impacts on global supply chains, Wilson says that shortages of key materials could have a domino disruption effect.

He says that solar grade silicon metal is the key underlying material in PV, and while currently most active high-purity-quartz (HPQ) deposits are in the USA, Australia is sensibly looking to exploit our own reserves.

The next step will be to use HPQ materials to produce the higher-value product of polysilicon, which can also be engineered from recycled materials.

“Silicon is a critical mineral, as we transition our society to a renewable energy future – and there are competing demands, including for its use with semiconductors in everything from computers to mobile phones and EV smart vehicles,” he says.

The solution is research and innovation, he says. “This will lead to improved pathways for identifying where resources are, and refining those raw materials into something that is marketable and exportable, adding value along the way.”

CSIRO is involved in developing the research to inform government policy in this area, he adds – and can recommend the research outcomes that show promise for increased production efficiency and yields, or that can create sovereign manufacturing and value-add to the resources sector.

“For example, there’s increasing interest in developing green steel; we should also be looking at the development of green silicon, so that we can produce high-quality silicon without using fossil fuels in the multi-stage refining process, some of which occurs at 1400 degrees Celsius.”

Nobody has yet capitalised on a green silicon pathway which uses a far less energy-intensive, lower temperature electrical process, which can convert sand through to a silicon product, he says, because there’s a need for significant research investment to make the process more efficient.

Another example is the 30-metre tall solar thermal energy towers which use heliostats to concentrate sunlight to produce temperatures over 1000 degrees Celsius, which CSIRO’s Solar Thermal Research Initiative is piloting in Newcastle in NSW.

“These technologies can all play a significant role to help Australia achieve our goal to move towards a sustainable energy future by 2050, so that’s where government policies and industry and government investment can make a real difference.”
Soon after Russia invaded Ukraine, a team from Everledger—the commercial company that was first to track the world’s diamonds—got together. Over the space of a weekend, they updated their platform to allow their clients to choose to exclude diamonds within their network originating from or passing through Russia. Tim Thwaites reports that ability illustrates the power of blockchain, which is at the heart of an array of digital technologies Everledger uses to trace and certify the characteristics and progress of diamonds along the supply chain—from where they are mined, through processing, cutting and polishing, to the final products and buyers.

In July 2021, the Australian Government awarded a $3 million grant to a consortium of Everledger, CSIRO Mineral Resources and Data61 together with 11 other partners, to investigate how blockchain technology could be applied to the critical minerals—such as nickel, cobalt, copper and lithium. These minerals are used to produce the wind turbines, batteries, solar cells and many other devices we need to decarbonise the world. Australia is a significant source of them.

The grant, under the Blockchain Pilot Grants program, was to produce a prototype as a demonstration and proof-of-concept of how blockchain could be employed to track the origin and supply of nickel—an increasingly important part of batteries—from mine to metal product.

The idea was to allow transparency and certification of the environmental, social and governance (ESG) processes at each stage. Such ESG certification is becoming an increasingly important part of international trade in a world of blood diamonds and Fair Trade coffee, and where minimising the use of carbon and water and the assuring that working conditions are humane are becoming critical considerations to governments, companies and consumers. Compliance with ESG provisions, for instance, is an important part of discussions on a proposed EU Australia Free Trade Agreement.

“The project is all about improving the linkage between industry and government regulators,” says CSIRO’s Dr Ewan Sellers, Program Director Hard Rock Mining, whose team provided input from Mineral Resources to the project. Automating such certification digitally would help companies comply with regulations, while lowering costs, making Australian minerals more attractive in the marketplace.

Interest is huge. Among the consortium partners are the Queensland and West Australian governments and the International Initiative for Responsible Mining Assurance.

Blockchain allows information to be held in an immutable form and made accessible to all that need access. Along the critical minerals supply chain, for instance, blockchain would allow certification of compliance with energy and water use standards, as well as human rights considerations to be stored in blocks along with supporting data and information. These information blocks are then digitally linked to other similar blocks along the supply chain in such a way as to make it impossible to change any information in any block. Certification can be made freely accessible to participants.

In the seven years since it was established, Everledger has built blockchains to certify supply chains not only of diamonds, but of apparel, art, wine and other luxury goods. Critical minerals is not only an area of increasing importance, but comes with its own particular difficulties.
As Australia’s national science agency and innovation catalyst, CSIRO is solving the greatest challenges through innovative science and technology.

CSIRO. Unlocking a better future for everyone.

“We wanted this to be useful to industry,” says Rakalene Condon, Head of Product at Everledger in Brisbane. “So we spoke to a variety of companies: miners big and small; explorers and those operating mines; some involved with critical minerals, some not; some in Australia, some not; people right across the supply chain; financiers and established ESG experts.”

“Everledger called on the CSIRO for its expertise. CSIRO’s Mineral Resources business unit were able to provide knowledge, understanding and access to subject matter experts in the mining industry. In addition, a CSIRO Mineral Resources research team had developed a cutting-edge spatial and temporal data storage platform called VoxelNET. VoxelNET is ideal at consuming the data generated by real world processes and has the ability to track critical minerals through a global supply chain.

“Unlike diamonds, bulk shipments of ore are hard to trace back to their origin in Earth. It is also difficult to determine what processes the ore has been through. However, by using VoxelNET to record and simulate the material processes performed, each discrete volume of ore is tagged with a trackable receipt of all this data. This system can return the material properties of the ore at a given time, along with its associated emissions and resource costs matched to the custodian responsible,” says Condon.

“By using VoxelNET to simulate what happens to the ore across each step of the supply chain, clients can gain a clear understanding of the material history of their ore sources, the impact that material has had on the environment, and the impact it has had on communities worldwide.”

Data61 has developed a system to identify who is trustworthy and properly credentialled without referring to centrally stored data or involving passwords, both of which are vulnerable to hacking or loss. The idea of the system, a self-sovereign identity and key management app known as Macrokey, is that ability to authenticate a user’s identity is carried with him or her, and is used in such a way that it is automatically recognised and verified by every other member of the system using cryptography.

It is critically important that anyone accessing the blockchain and adding data or certification of compliance be instantly recognised as trustworthy by all the other participants. The blockchain pilot has been used to demonstrate the utility of Macrokey in achieving this.

The blockchain for critical minerals needs to incorporate a vast amount of data to support certification of compliance with the ESG requirements of government and industry worldwide. Some of that information will necessarily be commercially sensitive. It must be there for the purposes of certification but, unlike situations where blockchain is used to back up financial transactions (as in cryptocurrencies), not everyone needs access to the data, only those certifying that standards have been met. To others, only the certification is important.

So, the developers of the blockchain had to design a system that ensured only those who needed to, had access to commercially sensitive data, and all others only to certification that that part of the supply chain complied with all requirements.

More positively, the blockchain process results in the accumulation and linkage of vast amounts of information relating to the supply of critical minerals, especially, for instance, to how much energy and water are used in mining the ore, transporting and processing it, transforming it into metal, and fashioning products.

That information may well eventually be used to expose weak links in the supply chain, those areas where the industry needs to work on coming up with better ways of utilising water and energy – the focus of future research.

“This is not simply looking at energy efficiency, but also at where energy comes from, reducing the carbon footprint, for instance, by employing solar panels or offsetting carbon usage,” Sellers says.

CSIRO, Everledger and the industry now have a prototype of a blockchain-based system to trace and certify the source and processing of critical minerals which they hope will stimulate a lot of interest.

It not only digitally automates and simplifies the process of compliance for companies, says Rakalene Condon, but is designed to align with the standards of the Battery Passport of the Global Battery Alliance, which likely will be adopted by the EU for companies selling electric vehicles into Europe. Modules of the Everledger platform already address recycling, re-use and repurposing programs geared to reducing the environmental concerns connected to the wholesale introduction of electric vehicles. Ford is already using this technology in the US.

DR EWAN SELLERS
+61 7 3327 4162
ewan.sellers@csiro.au