

Issue 22 DECEMBER 2020 - JANUARY 2021



Resourceful

BRINGING CSIRO RESEARCH TO THE MINERALS INDUSTRY

FUTURE INNOVATIONS FOR NEW JOBS AND INDUSTRIES

Smart science for a
sustainable mining future

CSIRO Australia's Innovation Catalyst



CHIEF EXECUTIVE'S COMMENT FROM DR LARRY MARSHALL

HARNESSING SCIENCE FOR AN INNOVATION-LED RECOVERY

There's no doubt that 2020 has dealt us some tremendous challenges – from prolonged drought, to catastrophic bushfires, COVID-19 and now a pandemic-induced recession.

Many of these issues were present before this year, but together they have escalated to crisis point and necessitated an acceleration in our response.

Companies that are navigating the crisis well have done so by embracing innovation, like the explosion of telehealth, virtualisation, and the accelerated adoption of many digital technologies across multiple sectors.

In the case of our economy, ironically, this recession may be the greatest opportunity for innovation-led growth we've had in decades.

The last 30 years of economic growth in Australia have lulled us into a false sense of security, and over that time business investment in R&D has fallen. But there's nothing like a crisis to snap us back into action.

We've known for years that we need to transform our economy and lift

the complexity of our exports. Our Australian National Outlook report, which looked out to 2060, predicted the slow decline of our great industries if we don't reinvent them.

COVID-19 and the current economic crisis has brought this issue to the fore and helped to create urgency around solving it.

It has also shown us the incredible impact we can have when we work together under shared goals – like achieving, in months, milestones in vaccine development that can take decades, or mobilising Australian industry in an effort reminiscent of war-times to establish sovereign supply of critical personal protective equipment.

If we can harness this level of collaboration and goodwill and focus it on a mission of recovery and resilience, we can accelerate our recovery, create new jobs, and grow our economy.

With that in mind, in August this year, CSIRO and our partners announced a program of missions to help prepare Australia for our future challenges and grow the future industries and jobs that will secure our prosperity.

The missions address challenges like our food security and water quality, our energy and sustainability, our health and wellbeing, as well as future-proofing our industries.

Minerals and resources have been a historic strength, but they have dipped from historic highs and experienced a profound contraction before COVID-19. The market shifted, and again, innovative companies adapted and found ways to flourish.

To maintain our leadership, our minerals and resources must evolve with the market-trend towards low emissions, and transform to create unique, higher value products from our commodities and technology exports that differentiate us globally.

Australia has the potential to lead in this area, together with the adoption of new technologies like artificial intelligence and autonomous systems for remote operations, sensing and characterisation techniques, selective extraction and low-emission technologies.

Digital technology has enabled precision AG, precision Health, and may well lead to Precision Mining where only the ore is extracted with minimal impact on the environment.

Australia has rallied around great challenges before – as a fledgling nation we emerged from Spanish Flu, war and Depression to prosper and grow strong. I believe we will do it again, with science to guide our way. ♦

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EXTRACTING OPPORTUNITY FROM INNOVATION



Mr Jonathan Law, Director
CSIRO Mineral Resources

Our Chief Executive Dr Larry Marshall recognises Australia's challenge of growing the strength and complexity of the national economy, especially in the post-COVID-19 era where new challenges and opportunities abound. Leveraging our mineral resource wealth is a critical part of this transition. **JONATHAN LAW** writes

Australia has a strong national resource base and a history of innovation that has positioned our resources industry at the heart of the national economy. The industry is also poised to expand into new areas as the global economy grows and continues to differentiate into new technologies and underpinning resource demands.

In positioning for these changes, we need to find strong commercial opportunities and support these with effective research and development.

This approach relies on strong partnerships with a shared vision of the future, and promises big rewards based on speed to market and the ability to scale rapidly into new opportunities.

In this issue of Resourceful, we focus on a suite of opportunities that rely on an effective innovation ecosystem, rather than a specific technological solution for a focussed problem:

Supercritical CO₂ turbine powered by solar thermal energy is a great example. With the ability to replace diesel energy at mine sites, provide stored energy at night, and provide direct thermal energy to processing circuits, this energy could be a key driver for green steel options reducing downstream

process emissions and supporting the drive to net zero emissions.

The energy transition globally is driving demand for a suite of enabling metals often further complicated by geo-political considerations linked to clean, safe, competitive and reliable production.

These critical metals provide many opportunities for Australia and come with a suite of uncertainties around demand and availability. CSIRO works closely with the Critical Mineral Facilitation Office to help Australia make the right choices.

At the same time, we are supporting industry by demonstrating Li and Ni battery products as we move downstream to supply raw materials and Australian manufacturing opportunities.

Our gold analytical technology commercialised with Chyrros Corporation continues to deepen its engagement with global gold producers using their innovative technology to provide a fast, safe and reliable alternative to fire assay. This technology enables effective management of gold grade across the value chain making near real-time control available to industry.

The community impact of mining continues to grow in importance and independent engagement is necessary to maintain strong links between mining and the broader community. Our Voconiq spin out is taking our technology to market to provide a long-lived community interface to help build an industry valued and supported by all our stakeholders.

Our researchers have also collaborated with Australian technology start-up SenseOre and brought modern and cutting edge digital and machine learning approaches to support new exploration success.

In each of these cases, Australian science and technology is unlocking value propositions far broader than the individual technologies. This value lies at the heart of CSIRO's role as an innovation catalyst for Australian innovation. ♦

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THE NEW GOLD STANDARD FOR ASSAYS

Chrysos™ PhotonAssay, a fast, accurate and environmentally friendly technology to detect and analyse gold samples, is a boon to the global mining industry, writes **JANE NICHOLLS**

Almost 20 years ago, Dr James Tickner and his CSIRO colleagues were using a Sydney hospital's radiotherapy equipment out-of-hours to test whether X-rays could activate gold in rock samples. He was a research scientist working in the then CSIRO Minerals Division, chasing different approaches for assaying precious metals such as gold. A basic physics paper from the 1960s discussing X-ray activation processes had sparked his curiosity and "looked like an interesting route to explore," he says.

So it was that the young physicist would lace up his running shoes for the experiment. "We'd turn on the X-rays for 20 seconds to activate a sample, and you only had a few seconds before that activation would disappear," he recalls. His job was to race in through the radiation-protective maze of the radiotherapy suite, grab the sample and speed it back to their detector system in the hospital corridor. "It wasn't very sophisticated, but it was where we first figured out, 'Hey, this all hangs together', and that we could build something," he recalls.

Today Dr Tickner is the co-founder and CTO of Chrysos Corporation, the company that was successfully spun out of CSIRO in 2016. "After those early experiments, development went on the backburner due to other projects," he says. "Then around 2012, as gold prices went up, there was renewed interest in finding better ways to detect and measure gold."

A fortuitous introduction to a Canadian X-ray accelerator manufacturer led Dr Tickner to spend "several summers in Ottawa running a campaign of test-work", which paid off. "We came up with a concrete demonstration that we could use this method to measure gold in samples, quickly and with great precision."

PhotonAssay is a chemical-free, non-destructive technology that supersedes the traditional fire-assay method for measuring gold concentrations in samples. Fire assay is a fiddly, complex and hazardous process, using toxic chemicals and requiring sample fusion at temperatures up to 1200 degrees centigrade. Due to its laborious nature, turnaround times for analysis using the centuries-old technique could often be weeks.

Chrysos's PhotonAssay sees a sample loaded into a barcoded jar, which is placed on an automated conveyor. High-powered X-rays hit the sample and 'excite' the nuclei of any gold atoms present. The unique signatures from the activated atoms are picked up by the system's highly sensitive detectors, enabling accurate analysis of precious metal concentration. The analysis is complete in as little as two minutes.

Having access to almost real-time information has the potential to increase gold recovery during processing by 1% to 3%, significantly raising the profitability of mining operations – an efficiency estimated to be worth at least \$2 billion

per year to the global gold industry. Because it eliminates the need for hazardous substances, PhotonAssay also improves environmental outcomes and workplace health and safety.

For Dr Tickner, the path to Chrysos also tells the story of his own scientific journey. "I joined CSIRO from a very academic background in high-energy particle physics – I was absolutely a lab nerd," he says. "Over the years, my role inside CSIRO evolved; I was leading teams and increasingly focused on external projects – I've always been very interested in talking to industry and understanding how our technology could solve real-world problems. I love the intersection between science, engineering and practical application – that's what motivates me."

Once the technique was validated, CSIRO partnered with a network of experienced investors to commercialise the PhotonAssay technology, naming the company Chrysos Corporation after the Greek word for gold. "The cost just to build the prototype was going to be several million dollars," explains Dr Tickner of the decision to launch a spin-out. He and CSIRO colleagues built the initial business model and then partnered with Sydney investment company RFC Ambrian to raise money. Chrysos started as a very small and lean company. "My first day in the office was January 2, 2017, assembling furniture with the CEO, and for the first year of operations there were just five of us in total."



**CHRYSOS
CORPORATION**
Assays at the speed of light



**Chrysos PhotonAssay
delivers faster, more
accurate gold analysis**

In late 2019, Chrysos had a successful capital raise of \$30 million. “Half of that became new investment into the company and half was an opportunity for early investors to realise some returns,” says Dr Tickner. “That was a substantial return for people who’ve supported us from the beginning, and most of our investors stayed with us. We’re anticipating an ASX listing in 2021.”

Dr Tickner says despite the upsides of being part of a commercial spin-out, he does miss old colleagues at CSIRO and working on lots of different projects. “In the commercial world, it’s a much more single-minded focus on getting one thing to work really well, which is absolutely necessary,” he says. “And these days I find it hard to explain to people what I do; when I was with CSIRO, I’d just say, ‘I’m a nuclear scientist’. Now I give a very long-winded explanation of all my different roles; I’m always hunting for ways to describe what I do!”

Chrysos is headquartered in South Australia and currently employs



The technology has tested more than 500,000 samples, including detailed evaluations for more than 60 major Australian and international mines.

23 people “but every time I check, it’s gone up by two more”, he says. “There’s a lot of strong tech coming out of Adelaide units and we’ve got the space research programs happening here,” says Dr Tickner. “Chrysos received early support funding from the South Australian Government to help us get started – I’m very impressed with Adelaide as a place to set up a high-tech company.”

The jobs at Chrysos are changing as the company grows. “For the first couple of years, most of the people were involved in product development,” says Dr Tickner. “We had a lot of physicists and programmers – the detector systems and X-ray sources we deploy are complex and needed a significant hardware and software development team.”

Now the operations and service side of the business is growing rapidly. “Installation, commissioning, ongoing service and maintenance – that side of the business has to scale almost linearly with the number of units deployed, so that’s the area where we’re rapidly appointing people at the moment,” he explains.

For those jobs, Chrysos recruits people with electrical or mechanical engineering backgrounds, and industry experience in similar roles as field service technicians. “We have complicated electromechanical systems, radiation detectors, interlocking safety systems and software, so we’re always hunting for very smart people with a broad interest in engineering and technology.”

Chrysos has two business models: supplying the technology to existing commercial assay labs, which on-sell the analysis service to miners, or providing equipment directly to mine sites.

“We provide the hardware against an agreed contract of a minimum number of samples to be analysed per month ... a bit like the old Xerox model,” explains Dr Tickner. “We wear the upfront equipment cost and offer a model where customers can dip their toe in the water at relatively low risk to themselves. It seems to make commercial sense – and it’s proving quite popular with industry!”

To date, four Chrysos™ PhotonAssay units have been deployed to sites around Australia. The technology has tested more than 500,000 samples, including detailed evaluations for more than 60 major Australian and international mines. Chrysos’ most recent installation in Bendigo, Victoria will provide rapid analysis for Kirkland Lake Gold’s Fosterville mine.

“At the beginning of 2021, we will have our first international installation,” says Dr Tickner, who sees multiple paths for Chrysos to continue to grow. “It’s lots of fun working on really cool technology, engaging with customers and seeing people use a product that you’ve worked on for so long.” ♦

Dr James Tickner, Chief Technology Officer and Founder, Chrysos Corporation



Chrysos PhotonAssay is a chemistry-free replacement for fire assay



BATTERY METALS

VALUE ADDING TO TECH METALS

Australia has the ingredients to be a leader in the world's energy transition, but it can also be compared to a well-stocked kitchen in need of a chef with a recipe to combine the raw materials in a practical and profitable way.

TIM TREADGOLD reports

Across regional Australia are world-class deposits of the minerals and metals needed in a range of new and emerging technologies such as solar panels, wind turbines and batteries which first generate and then store the electricity to replace fossil fuels.

Lithium, nickel, copper, cobalt, rare earths, manganese and cobalt are readily available in Australia and already exported as partly unprocessed ore, in a concentrated form, or as metal.

In the longer term, a national manufacturing industry supporting clean energy technologies would add value to our raw materials production to create a new industry for Australia and position

the country as a significant force in clean and renewable energy.

At the moment we have many of the raw ingredients for this vision, but we need a technically and commercially viable pathway to build sustainable manufacturing options – a critical role for the R&D community to drive innovation in partnership with industry.

Multiple factors are driving innovation for the national energy transition with the CSIRO active on a number of fronts in pure research and working with private sector participants in looking for ways to harness natural resources in a way that creates business opportunities and new-technology jobs.

Chris Vernon, senior principal scientist at CSIRO's Waterford laboratories in Perth, said that Australia was uniquely placed at a special time in the evolution of global energy production.

"There are a number of interconnected drivers behind the shift to clean energy production and storage, with Australia at the point where those drivers intersect," Vernon said.

"There is the driver of sovereign capability, and there is the driver of international demand to ensure a supply of metals critical to a future powered by new sources of energy."

"What's needed now is the driver which will come from a combination of government encouragement and private sector investment."

Vernon acknowledged that Australia had found itself in a similar position during earlier shifts in demand for raw materials and efforts to add value to minerals exported in an unprocessed form.

Major commercial deployments pose significant risks. In Australia,

billions of dollars have been invested in various technology pathways that ultimately failed including, attempts to convert iron ore into a semi-finished product such as Hot Briquetted Iron (HBI), or pig iron through the Hismelt process. Investments in magnesium and germanium production have similarly failed.

In battery metals, Australia is already one of the world's biggest exporters of lithium ore upgraded to a concentrate while a number of projects to produce semi-finished lithium as carbonate or hydroxide are in different stages of construction.

Nickel, another key battery metal, is blazing a value-added trail, largely through innovation and investment at BHP Group's Kwinana nickel refinery which, for the past 50 years has supplied nickel powder and briquettes to be used in making stainless steel, and is increasingly shifting to being a supplier of nickel sulphate for battery makers.

It's the close proximity of the nickel refinery and lithium processing plants which makes Kwinana one of the logical locations in Australia for a battery precursor production project with other centres having the right combination to be a "tech-metal hub", including Townsville in Queensland and Parkes in NSW.

"Making it happen is the challenge we face," Vernon said. "We've reached this point in the past with 2012 a prime example because there was a push then to get Australia's rare earths out of the ground to meet the demands of developing technologies.

"The big hole in that concept was that no-one could get their rare earth mine funded and even if they did there were limited markets apart from selling it into China.

"So the important thing we have to do in rare earths is create a value chain that gets us from the mine to a value-added state, otherwise it has to be sold to the Chinese rare earth processing industry."

Vernon said government leadership was important at this stage of Australia's evolution as a supplier of value-added battery and new technology materials even if that meant picking winners from the many emerging opportunities.

"Whether government wants to take that step is a strategic question in the context of developments in international affairs and the urgency in some countries, such as the U.S., to secure a reliable future supply of critical minerals to manage energy transition," he said.

"But it's not just a challenge for government. Large parts of the private sector are involved or keen to be involved in the shift to a future based on renewable energy and new technologies.

"We have big mining companies saying they want a much lower carbon footprint. We have transport companies saying they will do what they can to become zero emitters, and we have banks and investors concerned about the economic effects of climate change."

Vernon said Australia's potential to be a global leader in the energy transition starts with its geological endowment.

"We have all of the minerals to make into the metals required for the energy transition and that's not only some reasonably advanced rare earth projects to make magnet metals but we've also got nickel, copper, cobalt, vanadium, manganese and lithium needed to make batteries."

Missing from Australia's drive into a new-energy future is a big internal market which is an advantage held by countries such as Germany, China and the U.S.

"Making electric vehicle (EV) batteries in Australia for shipment to Europe or the U.S. sounds a bit of a stretch at this stage of energy transition," Vernon said.

"What doesn't seem like a stretch is making precursor materials which are a little bit further along the value chain for use in batteries. Examples are the cathode and anode precursors".

Vernon described a cathode precursor as an engineered material created by mixing pure nickel sulphate, pure cobalt sulphate, pure manganese sulphate, in the right ratios.

"It's a similar story with battery anodes which, at the end of the process are simply grey powders which are turned into sophisticated batteries," he said.

"None of this is beyond Australia as a way of adding significant value to a raw material."

Vernon said plans were already being made by a consortium of Australian companies through the Future Battery Industries Cooperative Research Centre, to pilot processes for cathode precursor, and another Australian project, to formulate anode precursor.

Getting the chemistry right is one test for a future battery products industry, convincing investors that there is a business case to justify development is a second challenge especially as the science behind battery design is not yet settled.

For Australia, however, whatever the preferred combination of metals in a battery is largely irrelevant because almost everything required is mined locally and available "off the shelf".

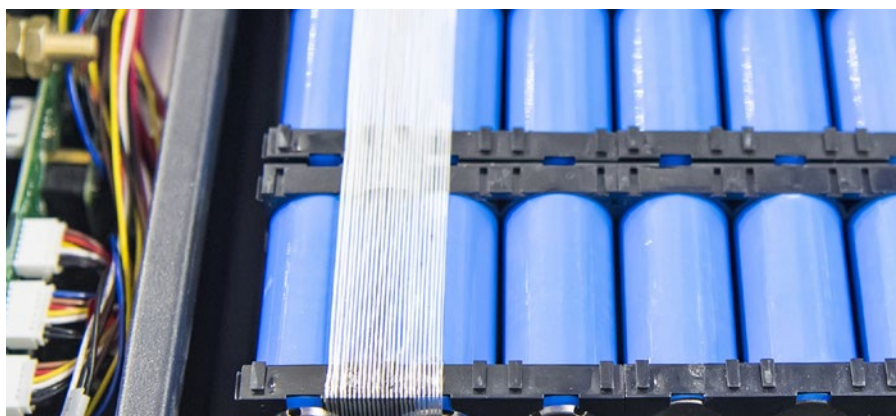
What's needed is government encouragement, banks and investors prepared to back a new industry, and a recipe book to create Australia's battery-metals kitchen. ♦

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“The important thing we have to do in rare earths is create a value chain that gets us from the mine to a value-added state.

Dr Chris Vernon, CSIRO



KNOWN UNKNOWN: THE DEVIL IN THE DETAILS OF ENERGY METALS DEMAND

It's become clear that the global transition to clean energy will need a lot of metal. For example, annual demand for battery metals – like lithium and cobalt – is expected to increase by over 450% by 2050.¹

By **JERAD FORD** and
JIM WEST

Conceptually, we know this demand will be met through a mix of new mining, recycled materials and even reuse. The timing and trade-offs between those different sources of supply is not, however, something traditional forecasts can tell us.

This is because they rely on things like an assumed supply from recycling, but don't reconcile this component against scrap availability, which in turn depends upon the ever-changing technology mix in the broader economy. Such internally inconsistent forecasts can be misleading – important if you're planning new mines.

Global metal flows are dynamic and complex. Metals can be locked up for decades in durable consumer goods. Product life spans differ and change. Some technologies, like electric vehicle (EV) batteries, may enter second life applications like home energy storage. Underlying material compositions change as technology evolves. The uptake rates of technologies will differ under different policy settings. And so on.

Painting an accurate picture of the supply and demand that develops

from this requires tracking for ALL these individual factors. That's why CSIRO's Critical Energy Metals mission has been developing a special tool called a Physical Stocks and Flows Framework (PSFF).

This tool is a relatively straightforward – though data intensive – integrated accounting and modelling framework. It provides a great way for keeping your forecasting assumptions organised, transparent, and consistent. But the real value comes from being able to see the interactions between seemingly simple individual factors. This is where complex outcomes and counter-intuitive insights reveal themselves.

Early insights

Currently our prototype can run supply and demand scenarios for battery metals out to the year 2060. With it, we have explored the EV market to reveal possible demand profiles of key metals – notably lithium, nickel, and cobalt.

Early results reinforce the commonly held view that there is strong demand for these metals. But it is the insights into the timing of mining and recycling opportunities, under subtly different scenarios, that are most novel and revealing. For example:

Second life

A major influence on primary demand (mining) is the service life batteries. If most EV batteries go on to serve a second life (e.g. home storage) then these metals might be locked up for an additional decade or more.

In this case, mined metal demand may continue nearly unabated. However, if the reverse is true – for example, Tesla has no plans for second life – then recycled battery metals might start displacing mining growth within the decade.

Technology change

Another insight is that primary demand for lithium, nickel, and cobalt can diverge quite radically depending on the pace of technology change. More rapid evolution of battery chemistries, and shifts in market share, mean that the currently similar bright demand outlooks for these metals could decouple rapidly.

Much, much more

The current EV model already includes information on a host of critical metals related to major componentry of these vehicles, even rare earths (for example: Al, Co, Cu, Dy, Fe, Li, Mn, Nd, also P).

We are also extending the model to explore the other important energy transition technologies including solar PV and wind generation technologies. The framework is expandable to accommodate other technologies as well (fuel cells, electrolyzers, etc.)

Work with us

We want to engage directly with industry partners to build meaningful scenarios using our new model. We seek industry perspectives on key variables like technology adoption rates, the pace and direction of technological evolution, market pull and recycling trends – to name a few.

Purpose built scenarios that reflect the best estimates of industry partners are crucial to understanding size and timing of investment opportunities. Let's work together to build insightful, long-term modelling using our new metals accounting framework. ♦

If you are interested in learning more or collaborating with us, please contact:

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¹ Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition. World Bank Group. 2020.

RARE EARTHS AND CRITICAL MINERALS PROVIDE SIGNIFICANT OPPORTUNITIES FOR AUSTRALIA

Until recently, critical minerals and rare earths were relatively unknown terms outside of niche mining quarters. Now at the close of 2020, barely a week goes by without reference to these terms and their growing importance to advanced and renewable technologies. Outgoing Head of the Critical Minerals Facilitation Office **JESS ROBINSON** shares

Rare earths and critical minerals such as lithium, graphite, cobalt, tungsten and nickel are essential to many of the technologies that are key to Australia's continued prosperity and security, including high-tech electronics, telecommunications, transport and defence.

They are also vital to renewable energy technologies that underpin global energy supplies and emissions reduction measures.

But they are highly vulnerable to supply disruption. For many critical minerals, the world's supply comes from geographically concentrated locations.

With the uptake in electric vehicles, battery, solar and wind technologies expected to soar over the coming decade, demand for some critical minerals will outstrip current sources of supply, creating bottlenecks and straining increasingly fragile supply chains.

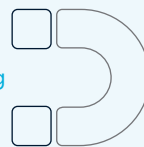
Industry and governments around the world have realised the problem, and that action is needed to strengthen and diversify global supply chains.

Electric vehicles

Sales are forecast to increase by at least **25%** a year over the next 10 years



Electric vehicles use neodymium magnets containing **30%** rare earths



Batteries

EV batteries use lithium, cobalt and rare earths

Lithium battery demand forecast to grow by

25% exceeding 1400 GWh per year, by 2028

The challenge has provided an enormous opportunity for Australia.

Australia is well known as a resources powerhouse. Australia is also blessed with significant natural endowments of rare earths and many critical minerals deemed essential by key trading and strategic partners and organisations such as the World Bank, OECD and the International Energy Agency.

For some of these minerals, we are already producing a significant share of raw materials. For example, Australia is

the second largest producer of rare earth elements and holds high-quality deposits of both light and heavy rare earths. We are also the world's largest lithium exporter.

For these reasons, the Australian Government is placing significant priority on developing Australia's full critical minerals supply potential. Apart from exploration and extraction, Australia is keen to move up the value chain to processing, separation, refining and niche manufacturing capabilities.

This approach will not only help diversify global supply chains, but will significantly increase the value of Australia's exports and play a vital role in underpinning the growth of advanced manufacturing and niche technology capabilities in Australia.

The road to success requires significant whole-of-sector effort.

It is not enough that Australia possesses some of the best rare earths and critical minerals resources in the world combined with a highly innovative, technology advanced and efficient mining and services sector.

The concentrated and opaque nature of supply-chains, marked by monopolies, market failures and price volatility, creates significant challenges for new entrants. These dynamics make it difficult for companies to secure both project finance and supply contracts.

Australia's Federal Government has been working to support the development of Australia's nascent critical minerals sector for some time, including through the publication of Australia's Critical Minerals Strategy and a Critical Minerals Prospectus in 2019 to promote Australia's supply potential. However, these efforts have been significantly dialled-up over 2020 with a range of important measures.

One of the most important measures was the establishment of the Critical Minerals Facilitation Office, known across the sector as the CMFO.

The CMFO opened in January 2020 with a mission to drive a coordinated, whole-of-government and national effort to build Australia's critical minerals sector, and to work with the international community to diversify and strengthen global supply chains.

The complexity of the supply chain issues required deliberative, highly-coordinated and integrated action at home and abroad.

The CMFO is pursuing a comprehensive strategy to unlock Australia's full supply potential and support demand for Australian supply. And it is driving collective action to improve the functioning of global markets and create a level-playing field.

On the domestic front the CMFO has forged a close partnership with the sector, engaging extensively with all levels of government, industry and the research and science community.

The project facilitation role is helping to connect projects with potential sources of government finance, such as Export Finance Australia, Northern Australia Infrastructure Facility (NAIF), the Clean Energy Finance Cooperation, and non-government finance. The CMFO is also helping to link prospective projects with international partners, as well as supporting regulatory approvals processes.

Through the \$4.5 million Critical Minerals R&D program, the CMFO is leveraging Australia's national science capability to support downstream activities, including through:

- Partnering with ANSTO to develop more clean and efficient processes to separating rare earths;
- Partnering with CSIRO to deliver an Energy Metals Roadmap to provide a blueprint for how the Australian critical minerals and technology sectors can play a leading role in underpinning the global uptake of clean and renewable forms of energy; and
- Partnering with Geoscience Australia to deliver a critical minerals online portal which will provide a publicly-accessible database and interactive tool for investors, policy makers and geologists on Australia's critical minerals deposits and projects.

At a national-level, the CMFO is leading a National Critical Minerals Roadmap with state and territory governments to grow the critical minerals sector.

The CMFO is also supporting the work of key initiatives such as the Future Batteries Industry Cooperative Research Centre that is driving an entire batteries value chain approach to support a batteries industry in Australia.

At the same time, Resources Technology and Critical Minerals Processing has been identified as one of six priority areas in the government's new Modernising Manufacturing Strategy.

Our work at home to grow Australia's supply potential is being matched by an ambitious international engagement agenda.



Jess Robinson, Outgoing Head of the Critical Minerals Facilitation Office

Over the past 10 months we have secured strong partnerships with countries such as Japan, US, India, the European Union (EU) Commission and a number of EU Member States, with discussions also underway to lock-in bilateral arrangements with the UK and Korea.

In November 2020, Australia was also welcomed as a member of the EU, US and Japan Trilateral on Raw Materials along with Canada.

To improve governance, transparency and ethical and environmental standards for critical minerals supply chains, Australia is also playing an influential role in the development of international technical standards through our participation in the International Standards Organisation (ISO).

Despite the enormous challenges 2020 presented, with COVID-19 significantly changing our operating environment, Australia is making significant strides.

After 12 months, my time at the CMFO has come to an end. I look back on a year of significant progress and achievement, and feel positive about what the coming 12 months will bring. ♦



The road to success requires significant whole-of-sector effort.

Jess Robinson, Outgoing Head of the CMFO

HOW SOCIAL LICENCE IS DRIVING INNOVATION IN THE MINING INDUSTRY



Social licence to operate – where the wider community accepts that an organisation’s contribution to society is legitimate and necessary – has had a seismic shift in importance in recent decades.

FRAN MOLLOY writes

Once seen as a corporate ‘nice-to-have,’ social licence is now a critical part of industry operations in mining, forestry, agriculture and beyond – and actions that damage society’s trust and respect in a company can have serious bottom-line consequences.

The mining industry is no stranger to negative impacts on their reputation and social licence.

Examples abound and include the Panguna gold and copper mine in Bougainville which impacted local rivers, threatening livelihoods and inflaming conflicts; criticism of new coal developments and their potential impact on climate change and the energy transition; and destruction of sacred sites in the Pilbara where there is evidence of 46,000 years of human occupation.

Rising importance of social licence

Unlike fixed, tangible environmental and legislative licences issued by governments, the relationship between a company and community that constitutes a social licence is under constant renewal and renegotiation, says Dr Justine Lacey.

Dr Lacey is Director of CSIRO’s Responsible Innovation Future Science Platform, a program exploring the social, legal and ethical impacts of disruptive technologies across various industries, including mining. She cites the OECD Trust in Business Initiative that points out that “maintaining the social licence to operate [has] never been higher on the business agenda.”

Dr Justine Lacey, Director
Responsible Innovation
Future Science Platform



“A senior OECD regulator has been quoted as saying that social licence is actually far more powerful than government or regulators, on the consequences it can have for corporations, in their reputation, their standing with investors and consumers and, ultimately, profitability,” she adds.

CSIRO’s Australian National Outlook 2019 reported that financial valuation of social licence in the mining industry found that failure to earn and maintain community support and approval could reduce the market value of a project by up to 70 per cent.

“The mining industry engaged early with the ideas and debates around societal acceptance of their role and the reputation of organisations within their industry.”

“Letters of complaint, community backlash and adverse media or other reports about environmental damage or other harm were early signals that a company or industry didn’t have a social licence,” she says.

Over time, Lacey says, companies realised they needed to get ahead of social licence, engaging with potential threats to their reputation and operations before they occurred.

“Our work asks, how do you know when you have social licence? Is it when there is no-one outside your office holding up a sign? Is it when more letter-writers support your work than object?”

Social licence, responsible innovation and the bottom line

Lacey and her CSIRO colleagues use a variety of social science research techniques to identify the various drivers of people’s trust and their acceptance of different activities in the landscape, particularly those – like mining – that can be contentious.

The team has worked with the mining industry and the communities where miners operate to develop and validate these techniques, using the findings to inform more effective industry engagement, reduce social conflict and support increased social acceptance.

“Social licence is part of a push for change in the mining industry, and concerns around the management of impacts such as carbon emissions play a big role in this,” Lacey says.

In a survey of 150 global mining companies about business risks in 2020, Ernst and Young found that 44 per cent cited social licence to operate as the number one risk to their business.

These results are all the more remarkable when set against mining’s growing global challenges: falling commodity prices, rising production costs and difficulties, diminishing ore grades, and the climbing costs of site rehabilitation.

Lacey explains that societal expectations have changed. Industry now faces greater scrutiny from consumers who demand a transparent and ethical supply chain and a lower environmental footprint, and from shareholder activists who press for the divestment of coal investments.

From ‘social licence’ to ‘social value’

Last year, BHP announced to shareholders that the company would go beyond seeking a social licence to operate, to ensuring that both ‘social value’ and financial value drove core business decisions.


Former Chief External Affairs Officer, Geoff Healy, told shareholders the company must move from ‘tolerance and acceptance’ to ‘trust and partnership.’

“Healy was arguing that social licence had been reduced to simply meeting requirements, rather than looking for improvements – they were interpreting it as being too transactional but they importantly highlight the role of social objectives in driving innovation,” says Dr Lacey.

BHP’s future actions around ‘social value’ include reducing carbon emissions in both its own operations and in customers’ operations and a focus on better water management, in recognition that population growth and climate change place increasing pressure on global water resources.

“To achieve ‘social licence’ we must obtain relevant permits, meet legal requirements and avoid water discharge breaches,” Healy said. “However, we recognise that ‘a licence’ to use water is not enough – because water is a precious global commodity; the management of which is emerging as one of the world’s most pressing long-term issues.”

Lacey says that despite BHP’s views on the definition of ‘social licence,’ its core objectives remain: that organisations adapt and respond to the needs of the communities in which they operate.



“ Our work in the Responsible Innovation Future Science Platform aims to make sure that these future-facing developments are designed and delivered for the benefit of all Australians.
Dr Justine Lacey, CSIRO

VOCONIQ

THE POWER OF HARNESSING REAL SOCIAL DATA

“Mining companies in particular must sometimes balance what they are capable of doing within the letter of the law, with what is the right thing to do,” says Dr Kieren Moffat, the CEO and co-founder of social licence research company Voconiq.

Last year, Voconiq spun out from CSIRO’s foundational social science that he helped to develop.

An organisational psychologist by training, Moffat now heads up an international team of social and data scientists, and business consultants who use software tools, surveys and

online data collection to help organisations engage with communities over time.

He says that presenting data about community sentiment in charts, graphs and numbers means ‘social licence to operate’ is discussed within mining companies in the same language used by planners, engineers and business analysts who typically inform decision-making in large organisations. These measures of people’s experiences, their concerns and their objectives are then more able to be understood by companies and acted upon.

Innovation and Responsibility

Lacey says that the concept of a ‘social licence to operate’ also speaks to ideas of responsible innovation – which looks at the role of new and innovative products, processes and business models in society, and how potentially disruptive areas of science and technology can deliver positive social benefits.

These can include ‘green mining’ processes – technologies and practices employed to optimise energy efficiency (via ‘intelligent mining’) and to lessen mining’s environmental impacts. Green mining involves reducing greenhouse gas emissions, minimising mining’s ecological footprint, lowering chemical and water use, and upscaling wastewater processing.

Lacey cites CSIRO’s Deep Earth Imaging Future Science Platform as another example of responsible innovation driving change. Deep Earth Imaging engages smart analytics and algorithms to build geological simulations so that mining can be targeted more precisely – and the deep sub-surface can

be explored through tools to let people ‘see’ what is underneath, as if looking through a ‘glass Earth.’ By generating new kinds of knowledge using these new approaches, decision-makers can access better support for the choices they need to make.

“More information allows decision-makers to work out whether the course of action they select is a responsible one, whether a new technology or process is being adopted at the right time, and what trade-offs they are making when they engage in a proposed course of action,” she explains.

“Just because something is technically feasible doesn’t always mean it is socially feasible; we need to keep in mind the need to design innovation that is fit for purpose.”

Forward-thinking

Lacey says that after ten years of research into the drivers, and impacts, of social licence to operate, CSIRO scientists have developed proven techniques and data that can help design responsible

innovation into forward-looking activities for the industry.

“Our research into social licence lets us leverage these trust-based relationships that organisations have with their stakeholders and use these to help resolve complex challenges faced by Australian industry,” she says.

There are huge benefits promised by future science and technology – but these come with risks and uncertainties.

“Our work in the Responsible Innovation Future Science Platform aims to make sure that these future-facing developments are designed and delivered for the benefit of all Australians, and also to help communities and end-users of these technologies to be fully informed about the challenges that are associated with their adoption.” ♦

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“This gives voice to communities that often don’t get heard, in the rooms where decisions are made which deeply affect them,” he says.

“The platform gives a real-time view of what matters to the communities they work alongside,” he adds – “and that’s important because relationships between a community and a company change constantly and respond to what’s going on at the time.”

“We find almost universally in Australia that the level of responsiveness of a company, and their willingness to change their actions and behaviours based on community concerns, is the strongest driver of trust in a company,” he says.

“Just like any productive relationship, trust is built on listening with respect and responding effectively.” ♦

VOCONIQ

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Voconic team L-R: Dr Kieren Moffat, Co-founder and Chief Executive Officer, Naomi Boughen, Co-founder and Service Director and Dr Rolf Fandrich, Co-founder and Business Development



LOW EMISSIONS TECHNOLOGY

CSIRO is part of a program for a next generation supercritical carbon dioxide powerplant being constructed by the Gas Technologies Institute (GTI), General Electric and other industry partners in the United States

CO₂ TECHNOLOGIES SET TO DELIVER LOW EMISSIONS FOR MINING OPERATIONS

New low emission technologies for powerplants could be a game changer for mining operations.

DOMINIC ZAAL writes

A next generation supercritical carbon dioxide (sCO₂) powerplant will help accelerate mining operations to low emission outputs and meet large renewable energy targets.

Constructed by the Gas Technologies Institute (GTI), General Electric and other industry partners in the United States, Australia's national science agency, CSIRO, is part of the program to explore the use of sCO₂ powerplants.

The 10 megawatt-electric sCO₂ pilot plant, currently being constructed in Texas, will demonstrate a fully integrated power cycle that can be easily configured to operation on renewable energy. When completed in June 2021, it will be the largest sCO₂ powerplant demonstration facility of its kind in the world and will represent a significant step toward sCO₂ technology commercialisation.

“ Widespread implementation of sCO₂ power generation technologies could be a game changer for the mining industry globally and help accelerate the world's transition to a low carbon future.

Powered by high temperature CO₂

While most powerplants use steam turbines to produce electricity, sCO₂ powerplants use high temperature CO₂ instead. By avoiding the use of water, advanced sCO₂ power plants using renewable energy inputs have significant potential to transition mining operations to a low emission future.

The advantage is that sCO₂ is a higher density working fluid, which means sCO₂ power plants can be smaller, more efficient and not reliant on water for steam and cooling. sCO₂ powerplants can also be autonomous and operate using a wide range of heat sources.

This makes such powerplants an ideal candidate to replace diesel generation in off-grid mining operations, as renewable energy can be used to power their operations for longer periods of time.

Many mining companies are committed to transitioning to low emissions technologies.

Widespread implementation of sCO₂ power generation technologies could be a game changer for the mining industry globally and help accelerate the world's transition to a low carbon future.

CSIRO's partnership in the Gas Technologies Institute Program will improve understanding of how sCO₂ powerplants can enable lower and zero emission technology solutions, and how they might be used in remote off-grid mining and community locations as a low-cost alternative to diesel fuel power generation.

sCO₂ powerplants also provide a potential future replacement for large grid-connected electricity generation.

A renewable energy solution

For CSIRO, the use of concentrated solar thermal (CST) technologies to provide the renewable energy solution for these sCO₂ power plants is also a focus. CST technologies capture and store heat, which make it an ideal solution for a sCO₂ powerplant. The Australian Solar Thermal Research Institute (ASTRI), which is managed by CSIRO, is leading efforts in this area.

For mining operations, the use of portable, scalable and low-cost Thermal Energy Storage (TES) will be a critical enabler for sCO₂ power plants. TES can be used to store heat, which can then be used day or night to run a sCO₂ power plant.

The addition of TES can make 24/7 renewable mining operations a reality. Australia's TES efforts under the GTI Program will be delivered in partnership with Graphite Energy, and has the potential to create new market and job opportunities.

Keith Vining, Research Group Leader for Carbon Steel Materials, CSIRO Mineral Resources, said taking advantage of Australia's world class solar resource to operate sCO₂ powerplants for the purposes of mineral processing is a positive development.

“Metal production is highly energy intensive. In most cases metal production from Australia's mineral resources is performed overseas using traditional fossil fuel energy sources,” Mr Vining said.

“In a low carbon world, there is an opportunity to perform more on-shore processing and replace traditional fossil fuel energy sources with renewable energy resources in the commodity value chain. The use of sCO₂ powerplants operating on renewable energy could make this opportunity a reality.”

Supercritical Transformational Electric Power (STEP)

This research is part of the Joint Industry Partnership (JIP) of the Supercritical Transformational Electric Power (STEP) project known as STEP Demo.

The construction of the STEP Project demonstration plant is nearing completion, with equipment installation underway in San Antonio Texas. It is expected to be operational in mid-2021.

The site will be able to demonstrate performance over a range of operating conditions and allows flexibility to be reconfigured to accommodate ongoing testing and technology optimisation.

The supercritical CO₂ cycles will be able to operate using a wide range of heat sources, including fossil fuel (natural gas), renewables (concentrated solar, biomass, geothermal), next-generation nuclear, industrial waste heat recovery, and shipboard propulsion.

This project is an exciting step in renewable energy innovation to help meet the world's future carbon needs while reducing costs and providing cleaner sources of electricity. ♦

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MAKING SENSE OF BIG DATA

The acquisition of large legacy data presents a golden opportunity for big data business in mineral exploration. Variable formats, style and quality, and making sense of the wealth of data requires specialist skill and expertise. With matched funding from the CSIRO Kick-Start program, Australian start-ups like SensOre can access CSIRO experts to accelerate innovation.

Robbie Rowe, SensOre Ltd

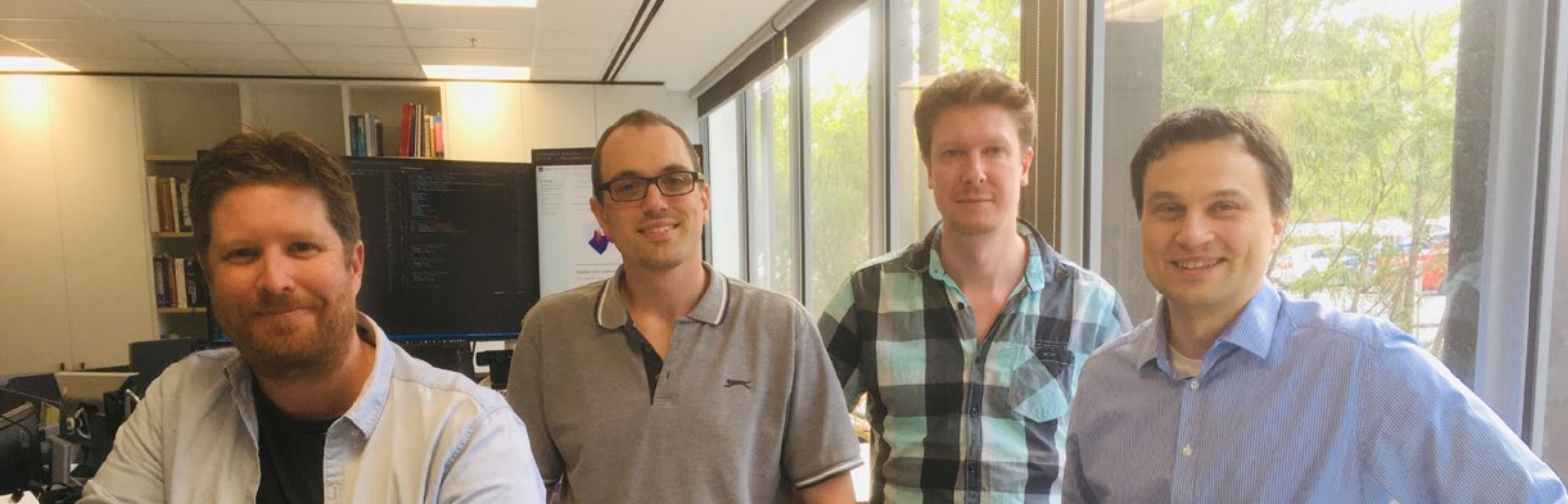
Robbie is Chief Operating Officer at SensOre Ltd (SensOre), a technology company working in mineral exploration, specialising in targeting mineral commodities using artificial intelligence (AI) and machine learning (ML) techniques. SensOre is currently focussing on gold and nickel targets in Western Australia.

SensOre began as a technology start-up company in 2018 and aims to become the highest performing minerals targeting and discovery company in the sector. To achieve this, we have developed a proprietary Discriminant Predictive Targeting® (DPT®) platform to make predictions regarding the location, depth, grade and endowment of economic mineral deposits.

We use ML techniques in our DPT® workflow to unlock the true value from massive geoscience data. We are currently focused on mineral targets in WA having acquired a vast tranche of valuable data, such as the Geological Survey of Western Australia's (GWSA) drillhole and surface databases. These databases equate to over 30 million individual assays and over 8 million surface sample assays.

The SensOre team L-R: Mike Woodbury, James Potter, Dane Burkett, Alf Eggo, Chris McIntyre and Jo Ann Hilario





The CSIRO team L-R: John Hille, Sam Bradley, Gerhard Visser, and Vasek Metelka

I became aware of CSIRO's skill compatibility with our R&D objectives through my association with the Academy of Science UNCOVER initiative. From those initial connections CSIRO and SensOre scoped out projects which would be able to leverage the multidisciplinary CSIRO expertise we needed to further develop our technology. SensOre has now undertaken two projects with CSIRO, we applied and were awarded a CSIRO Kick-Start voucher which has resulted in accelerated technology development.

CSIRO have been helping SensOre map the DPT® workflow. This quickly helped us identify portions of the workflow which could benefit from automation, and to create a working plan to have portions of the workflow developed into modules. One of the most significant portions of the DPT® workflow which CSIRO has mapped is the ingestion of large, geochemical database. Now that the mapping process has concluded SensOre looks forward to working with CSIRO in the early part of 2021 to further develop and potentially automate these modules.

It has been very easy to work with CSIRO, even through COVID-19 restrictions. The scientists we collaborated with brought a diverse range of skills in computer science, spatial statistics and GIS. Together we discovered a range of new and unique approaches to improve automation and our DPT workflow.

The CSIRO scientists were very forthcoming in providing solutions to a range of challenges facing SensOre, including extracting and collating information from very large databases. Our teams meshed extremely well, especially having to collectively navigate COVID-19. The 'can do' attitude was infectious and something we look forward to with future CSIRO-SensOre collaborations.

Our aim and ambition is to disrupt conventional exploration. We believe improved minerals discovery performance will benefit many stakeholders including the broader Australian community. As such CSIRO involvement is an investment not only in SensOre but in sustaining and expanding the minerals production base of traditional and critical minerals that are becoming important for renewable energy transition and for Australia's future economy.

“ Our teams meshed extremely well, especially having to collectively navigate COVID-19. The 'can do' attitude was infectious and something we look forward to with future CSIRO-SensOre collaborations.
Robbie Rowe, SensOre Ltd

Dr Vasek Metelka, CSIRO

Vasek is a geologist and data scientist who leads the CSIRO team working with SensOre

Our team began working with SensOre to provide support in designing and implementing solutions that would handle the large cache of legacy data they had acquired. Our initial time was spent quality checking the datasets, many of which were not in the format or style required for ML applications.

As we've progressed with the optimisation of the workflow, we have overcome several bottlenecks in data processing and are now focussed on ways to automate and enhance the process. We are very much looking forward to our continued collaboration with SensOre with quite a few ideas and plans that we drafted together.

One of the benefits CSIRO brings to this kick-start project is our big data processing capability and digital expertise. We have access to a powerful distributed computer network and multidisciplinary and highly technical teams. Our core CSIRO project group encompasses experience and expertise spanning software engineering, mathematics, data science and geology. Still, we do leverage our access to the broader CSIRO community, including Data61.

We found working with SensOre has reciprocal benefits for CSIRO, giving us a closer understanding of industry challenges. This allows us to hone our expertise and align our research focus to support innovations in mineral exploration and discovery, which will truly benefit the Australian industry.



Dr Megan Sebben, CSIRO

Megan is the CSIRO Kick-Start Program Manager

I assist Australian start-ups and small business access facilitation and dollar-matched funding through the CSIRO Kick-Start program so they can undertake a research and development (R&D) project with CSIRO to help them boost their business.

The scheme started nearly four years ago and has awarded over 140 vouchers to businesses across a wide variety of industries.

CSIRO Kick-Start is a non-competitive, eligibility-based program specifically designed to help new businesses less than three years old, or with an annual turnover and operating expenses less than \$1.5 million, gain access to world class science and innovation from CSIRO's unrivalled brain bank of experts.

Projects are capped at 12 months duration, but eligible companies can apply for up to two Kick-Start vouchers, ranging from \$10,000 to \$50,000.

For SensOre, Vasek facilitated the connection to the Kick-Start team but companies can directly contact our office. The CSIRO Kick-Start team can connect eligible businesses to the right CSIRO research expertise through our national network of facilitators and contacts.

If you are interested in CSIRO Kick-Start funding or have an R&D project you want CSIRO to help with, please contact me to take the initiative. [▶](#)

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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.

Resourceful is printed using vegetable-based inks by Printgraphics, which is ISO14001 Environmental Management System certified.



RESOURCEFUL is produced by CSIRO Mineral Resources. Views expressed do not necessarily reflect those of CSIRO Mineral Resources management.

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