ASX Announcement

September 1, 2022

September Quarter Newsletter – Issue 42

Sydney, Australia | September 1, 2022 – Multi-award-winning Australian technology company Calix Limited (ASX: CXL 'Calix' or 'the Company') is pleased to announce it has released a comprehensive update on activities across its business segments. The newsletter is attached overleaf.

This announcement has been authorised for release to the ASX by:-

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About Calix

Calix is a team of dedicated people developing a unique, patented technology to provide industrial solutions that address global sustainability challenges.

The core technology is being used to develop more environmentally friendly solutions for advanced batteries, crop protection, aquaculture, wastewater and carbon reduction.

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

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

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calix

Innovating for the Earth

Calix News

September 2022

Highlights

Because Mars is for Quitters.

Phil Hodgson
CEO

Welcome to **Issue 42 of the Calix Newsletter**

As the financial year draws to a close, it is timely to reflect upon Calix's considerable achievements over the last 12 months.

In September 2021, we announced the conclusion of our first "spin-out", where 7% of the LEILAC Group (focussing on decarbonisation of cement and lime) was sold to US impact investor Carbon Direct for €15m. Calix will also continue to earn 30% of the royalty income into the LEILAC Group as a license fee, regardless of our ownership %. The deal is the first manifestation of our over-arching strategy to develop the next application of the technology and seek purpose-funding to commercialise, whilst retaining maximum head company value. We have been steadily building the LEILAC Group team as well as the project pipeline, and in May this year we were very pleased to announce two Australian-based projects with Boral and Adbri, with a combined $41m in federal Government support. An article on these two projects is in this newsletter.

In May 2022, we were also very pleased to announce $20m in Federal Government support for a project we are putting together with Pilbara Minerals (ASX:PLS). This project, to produce locally-manufactured lithium salts for batteries, is featured in this newsletter also. Our ambition is to produce low-carbon lithium here in Australia, and avoid the shipment of 94% waste material, as per the current situation in Australia, where spodumene (an ore containing about 6% lithium) is mined and shipped off-shore for processing. There is increasing focus on carbon emissions in the battery supply chain, and our project with Pilbara Minerals is anticipating increased demand for lower emissions products. There is also increasing alignment and interest in Australia in producing more here, rather than "digging it up and shipping it off-shore". We look forward to working with Pilbara Minerals on this exciting project.

On a similar theme, our advanced battery materials team made great progress during FY22, with the on-going development and then pilot-scale production of 350 kg of lithium manganese oxide cathode material, for assembly into pouch cells in a commercial production line in the UK by battery maker AMTE. This step is critical to proving we can produce quantities of material consistently in order to proceed to the next stage of scale-up, which is targeting 150Tpa electrode manufacturing capability as part of the Recycling and Energy Storage Commercialisation Hub (REACH) Trailblazer program lead by Deakin University. This newsletter features our advanced battery materials team and this recent significant progress.

Our biotech business also made great progress in FY22, achieving registration of our BOOSTER-Mag crop protection product here in Australia, great results from our marine coatings trials, and also a boost to progress our anti-"superbug" application with the recent announcement of the "CRC SAAFE" program, a $34.5m research and development partnership, of which Calix is a tier 1 partner.
The CRC SAAFE program is looking at controlling superbugs, whose evolution is rapidly out-pacing current anti-biotics, posing significant human and animal risk. We are proud to be working with the likes of the University of Queensland's Centre for Superbug Solutions on this exciting and critical initiative.

The Calix team is core to achieving these significant outcomes and central to our success going forward, and we feature several new members of our team in this newsletter, as well as several members who have been with us a while. The Calix team thanks you for your interest and support in our continued efforts to develop great businesses that solve significant global challenges.

The Calix Team is Growing!

Meet **Duy H. K. Nguyen**

Biotech R&D Program Lead

Duy Nguyen joined Calix in April 2022 as a Biotech R&D Program Lead and will be supporting development programs to enhance the bio-active materials portfolio.

He brings to the company 5 years of experience in the agricultural, biomedical and chemical fields. He has conducted projects covering anti-microbial technologies, bio-interfaces, product assurance and aftermarket service.

Duy completed a PhD in Nanobiotechnology from Swinburne University of Technology, Australia. His PhD research focused on the development of novel anti-microbial nano-structured surfaces. Before joining Calix, he held a post-doctoral research position at RMIT University and later worked as an Industrial Chemist at Cummins Filtration. He looks forward to working with Calix on the advancement of new bio-active material applications within the marine, agricultural, veterinary and human health sectors.

Outside of work, Duy loves being in his garden, growing and taking care of the plants with his wife. And of course, watching Gardening Australia on ABC TV channel every Friday.

Meet **Daniel Vasquez**

Process Engineer
Sustainable Processing

Daniel comes to Calix with outstanding training in Chemical Engineering from RMIT and a variety of relevant experience in both minerals processing (Gekko and Southern Pacific Sands) and business development (Mettler-Toledo and Diverseco) and will be doing business development in the Sustainable Processing team.

Outside of work, his passion is soccer/football and he follows the English premier league quite religiously. He also likes to paint, draw and play PC games.

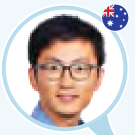
Meet **Duc Tai, Tommy Dam**

Process Engineer Batteries

Duc Tai, Tommy graduated from Nanyang Technological University (NTU), Singapore with a bachelor's degree in Chemical Engineering and PhD in Nanotechnology for energy storage and conversion.

Duc Tai started his career as R&D Process Development Engineer in both the backend and frontend semiconductor industry. He was responsible for development, commissioning and qualification of electromechanical equipment. He also developed chemical processes for production of nano-structures in electronic chips. Prior to joining Calix, he worked at Element Solutions Inc (ESI), a specialty chemicals company, as Process Development Engineer. He was responsible for scale-up of mass production of nano-particles for sintering paste applications.

Duc Tai joined Calix in May 2022 as Process Engineer Batteries and will be helping to scale up the manufacturing of lithium manganese oxide (LMO) and improve its electrochemical performance as a battery Cathode Active Material (CAM). He permanently relocated to Victoria, Australia in May 2022 and has been showered by a very warm welcome from the Calix team.



Meet **Yun Xia**

PhD, MEng, BEng
R&D Sustainable Processing
Program Lead

Yun has over 10 years research experience in Chemical and Metallurgical Engineering with extensive experience in solar energy utilisation, metallurgical separation and resource recovery. He joined Calix in April 2022 as an R&D Program Lead.

Before joining, Yun worked as Research Fellow in the Department of Chemical and Biological Engineering, Monash University. Yun completed his PhD at Monash University and first-authored 4 peer-reviewed papers with a total impact factor of over 63. He also holds a master's and bachelor's degree in Metallurgical Engineering. His research focused on the industry-oriented process including the production of tungsten, molybdenum and vanadium, as well as hydrometallurgical recycling of spent batteries.

Outside of work, Yun loves outdoor adventures such as fishing, camping and hiking.

Meet **Laurentiu Paun**

Senior Process Engineer

Lau graduated in 2009 as a Robotics Engineer. At the end of 2009 he started working for Lafarge Romania as a Process Engineer at one of their cement plants, where he was tasked with optimising the expert control system driving the kiln line and mills.

At the end of 2015, he took on an opportunity with Holcim in the UK and started working as a Process Engineer for the cement plant in Cauldon, Staffordshire. Since then, he has worked on many projects for plant optimisation with notable results, and has worked with a multitude of plant equipment ranging from crushers, ball mills, vertical mills to pyro processing related equipment like heat exchangers, rotary kilns and calciners, burners and fuel processing, abatement systems and gas conditioning and filtration, etc.

"I'm really excited to join the team here at Calix and I hope I get to meet and work with all of you on different challenges and solutions."

Meet **Ehsan Ghasemi**

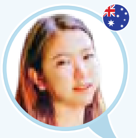
Battery Test Engineer

Ehsan joined Calix in May 2022 as a Chemical and Battery Engineer.

With a principal background in Chemical Engineering, he brings almost four years of practical research and extensive experience in material development for lithium and flow batteries. During his PhD at Monash University and CSIRO, he published high impact patents and papers featured in many outlets.

As a member of the Battery R&D team at Calix, he will be helping to develop and improve electrochemical performance of cathode materials.

Outside of work, he enjoys the outdoors, travelling, watching and playing sports.



Meet **Yingyi Huang**

Battery Test Engineer

Yingyi Huang holds an honours degree in Engineering in Material Science from Monash University. Her interest in the energy sector started in the last year of her undergraduate studies in her final year project. Following that, in 2019, she started a PhD at Monash University in the Department of Mechanical and Aerospace Engineering. Her PhD focused on improving the performance of various energy storage systems, including lithium-sulfur batteries and lithium-ion batteries. She is the author of a number of high-impact papers and patents in the battery field.

While completing her PhD thesis, Yingyi Huang joined Calix in May 2022 as a Battery Test Engineer and will be helping to examine and develop lithium manganese oxide (LMO) and lithium iron phosphate (LFP) as cathode active materials in batteries.

Outside of work she enjoys watching movies, swimming and travelling.

Meet **Peter Tilden**

Mechanical Project Engineer

Peter moved from New Zealand to join Calix in June 2022 to add to the rapidly expanding engineering team. He earned a bachelor of Mechanical Engineering from the University of New South Wales in 2015 and is registered as a Chartered Professional Engineer (CPEng).

Peter brings over 5 years experience in the design of mechanical equipment. He has lead projects involving large mobile port hoppers (tare weights ranging from 30-220 tonne), water/oil/acid/caustic/pulp storage tank repair projects, lifting equipment, belt conveyors and other port equipment projects (e.g. bulk grabs and log lifters).

After work he enjoys cycling, mountain biking, hiking and gatherings of friends and family.

WE ARE HIRING
To learn more and apply, email: hr@calix.global or check out our LinkedIn page:
https://www.linkedin.com/company/calix-limited/

Nano-active Electrode Materials for High Power Applications

Calix is developing an efficient, cost-competitive, and low-carbon platform technology to produce high performance, fast-charging electrode materials for lithium-ion battery and post-lithium-ion battery applications.

At the heart of this process is the **Calix Flash Calcination (CFC)** technology (Fig 1) which produces **highly porous, nano-structured and reactive (nano-active) materials** by flash calcining a micron sized powder precursor having a large mass fraction of volatiles. When lithiated, the electrode materials present a unique hierarchical porous onion (HPO) structure (Fig 2) which facilitates high charge-discharge rate applications (Fig 4).

Proof-of-concept was demonstrated with **lithium manganese oxide (LMO)** from flash calcined manganese carbonate ($MnCO_3$). Calix is scaling the manufacturing process for LMO and exploring opportunities to apply this process to other electrode chemistries.

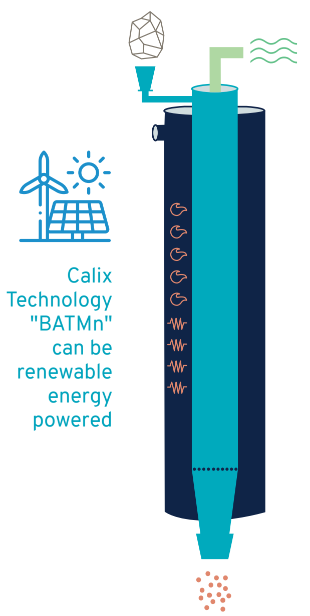
Current manufacturing and most R&D routes

- Exotic chemistries
- High purity pre-cursors

- Agglomerated nano-particles
- Long and energy intensive lithiation step
- Waste materials!

- Assembled poly- or single-crystal materials

Calix route



- Ag-grade manganese carbonate micro-particles ($MnCO_3$)
- Calix flash calcination
- Controlled flash heating, oxidation
- Low waste
- Strong, flexible nano-structured micron-sized particles with controlled hierarchical meso-porosity

Lithium addition (sol^n doping)
Short thermal lithiation
(≤2h)

Fig 1

Schematic of Calix Flash Calcination technology

Key benefits of Calix LMO

- Superior energy and power density (Fig 3)
- High power performance (Fig 4, >80% capacity retention @ 5C, full pouch cell with 2 mAh cm^{-2} loading)
- Cycle-life testing under evaluation (Fig 5)
- Much lower energy consumption (lithiation time ≤ 2h compared to typically > 12h)
- Low cost of production (lower energy, cheaper precursors)
- Lower CO_2 footprint

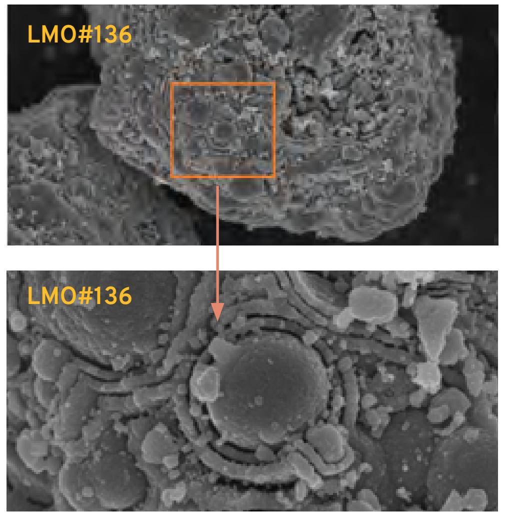


Fig 2

SEM image of Calix LMO presenting unique hierarchical porous onion (HPO) morphology.

Fig 3

Energy density versus power density of various cathode materials.

(Note: calculated based on weight of cathode with half cell results * Nano Research 2018, 11(8): 4038-4048)

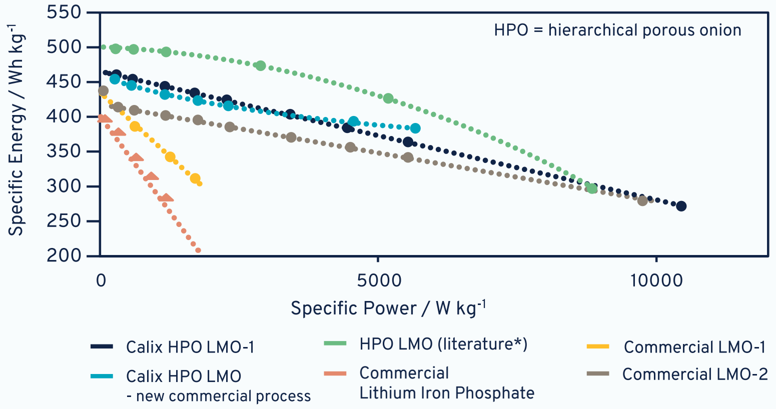


Fig 4

Asymmetric discharge test of LMO-graphite (LMO/Gr) single layer pouch (SLP) cell rate test results.

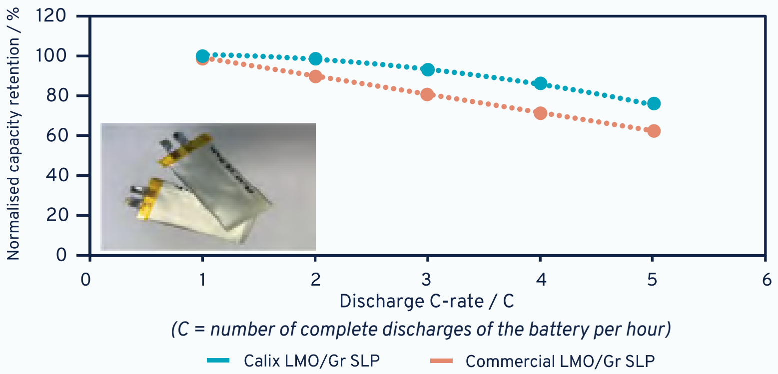
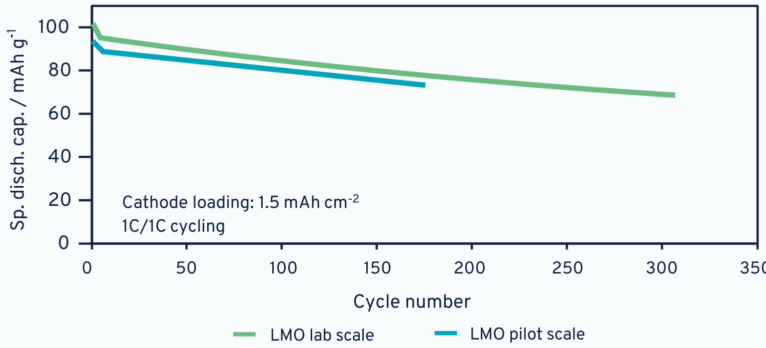


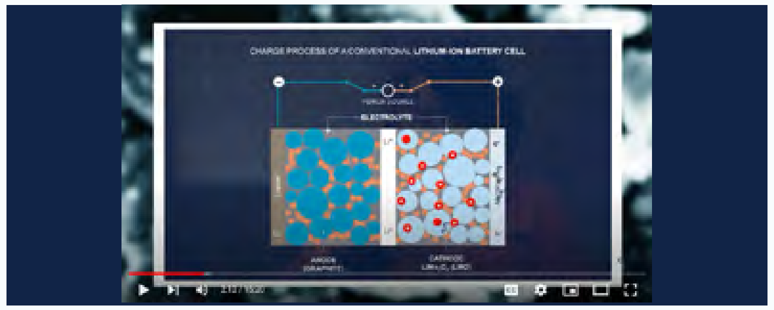
Fig 5

Cycle life test of full coin cell of LMO/Gr.



Under the microscope - Advanced Battery Materials

This video takes a deep dive into the unique Calix battery materials to help understand why they could be a game changer for the industry, and instrumental in enabling the pathway toward transformation of the global energy sector from fossil-based to zero-carbon by the second half of this century.



https://youtu.be/cYIAUM8uRSE

Australian Government Department of Industry, Innovation and Science · BATTRI BATTERY TECHNOLOGY RESEARCH AND INNOVATION HUB · Business Cooperative Research Centres Program · DEAKIN UNIVERSITY · BORON MOLECULAR

Progress on the pouch cell and battery pack prototyping and scale-up program with AMTE

Calix has been working with AMTE Power in the UK and BatTRI-hub in Australia for the development, prototyping and scale-up program of pouch cells featuring Calix's lithium manganese oxide (LMO) cathode active material (CAM). The program at AMTE is designed to transfer and scale up Calix LMO production technology to produce test cells for verification, which will be built into packs for testing in an identified end application, in this case, an E-scooter or E-motorcycle (Fig 1).

To supply the quantity of material for the program, the team at Bacchus Marsh have been hard at work on a campaign to produce 350kg of LMO CAM and to understand the processes required to optimise material properties (e.g. particle size distribution) to ensure success of the demonstration of the Calix technology. AMTE have started the development work around slurry mixing, coating, and calendaring (Fig 2) in the UK. The coated foils with Calix LMO were binding well to the substrate, however there were challenges around agglomeration formations during slurry preparation, leading to the rough texture of electrode films.

The team at Calix is working closely with Deakin University and AMTE to address the issue. Based on the current timeline, an E-scooter powered by the battery pack featuring Calix LMO material will be delivered to Australia in early 2023. The team at Deakin University is working on the state-of-the-art electrolyte systems that can potentially address the stability issue associated with manganese (Mn) dissolution of the LMO chemistry. At BatTRI-hub in Australia, pouch cells with up to 10 layers were made and tested with Calix LMO, to support the development and optimisation work with pouch cells.

Process flow and scale-up design work is now underway

Calix is developing plans as part of the recently awarded Recycling and Energy Storage Commercialisation Hub (REaCH) Trailblazer University Program, led by Deakin University, to deliver a 150 Tpa electrode manufacturing demonstration facility at Calix' Global Centre for Technology Development in Victoria, Australia. Work around identifying possible process flows and the related mass-energy balances and techno-economics analysis has been initiated to pre-determine the process flow that best suits and integrates the Calix technology for manufacturing electrode materials for batteries. The project will deliver:

- A facility capable of producing the active electrode material quantities required to supply a 50MW cell manufacturing micro-factory;
- A blueprint for a full commercial-scale advanced electrode manufacturing plant;
- An agile production capacity capable of producing minimum viable product (MVP) required for prospective customer and technology licensee qualification processes;
- Improved confidence in techno-economics and production cost projections; and
- A capability to allow continued process optimisation, material qualification, scale-up de-risking and IP development.

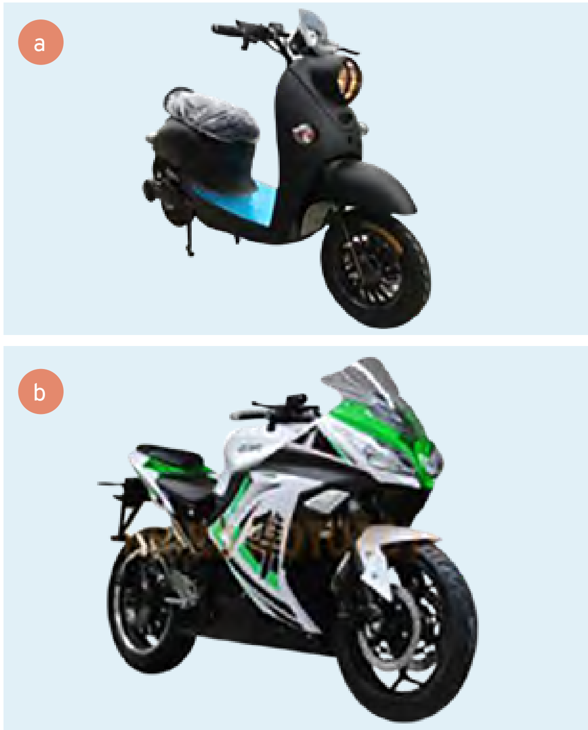


Fig 1

Photos of E-scooter (a) and E-motorcycle (b) that are being considered for demonstration of battery packs featuring Calix's LMO material.

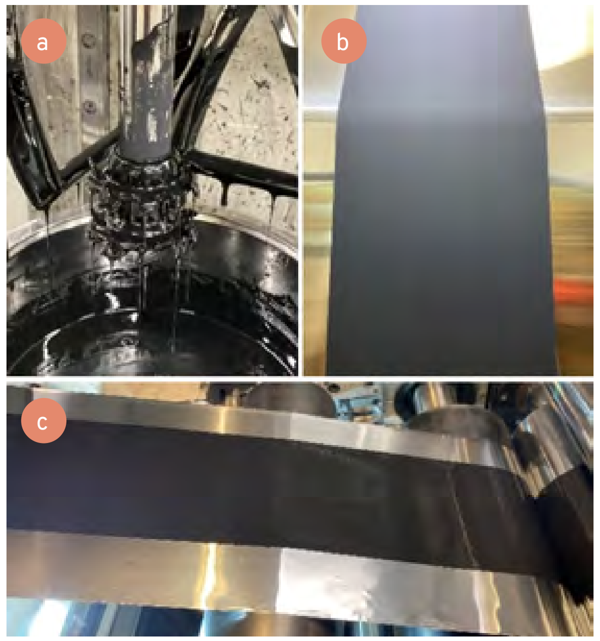


Fig 2

Photos of slurry mixing & coating trials at AMTE in the UK (a. slurry mix; b. coated foil; c. coating process).

New chemistries

Calix is also expanding the exploration of its technology in manufacturing new electrode chemistries. A program of work is underway to extend and adapt the Calix CAM manufacturing process to the next generation of Calix lithium-ion battery chemistries including lithium iron phosphate (LFP) and lithium nickel manganese oxide (LNMO). In addition, Calix will also be supporting a newly recruited PhD student at Deakin University through the Australian Research Council (ARC) funded storEnergy Training centre who will be exploring opportunities to apply Calix's proprietary electrode manufacturing processes to the production of electrode materials for next-generation sodium-ion batteries.

Growing the team

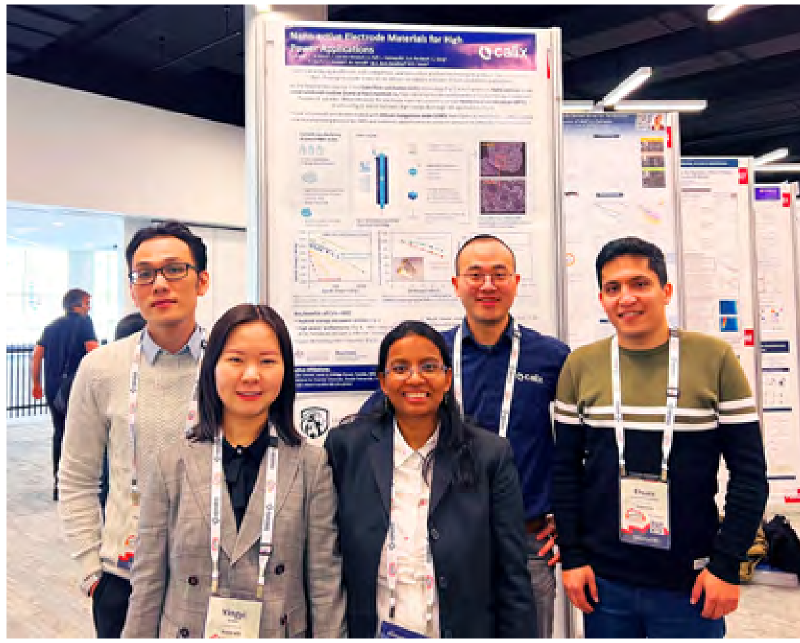
The Battery team at Calix is also growing! Shammi became part of the team in January 2022. She has been leading the LFP material development project aiming to apply the methods and processes developed for LMO to manufacture of LFP as part of the new chemistry exploration program.

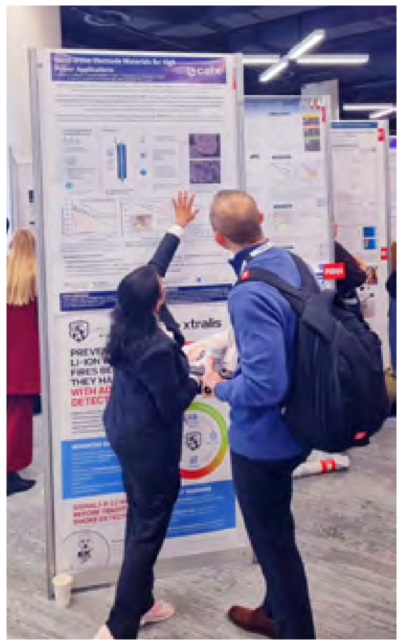
Duc Tai (Tommy) also joined the team in May 2022 as the Lead Process Engineer for batteries and will be responsible for battery materials scale-up at Calix. His role will involve process flow design and techno-economics analysis which are critical to ensure the processes being developed in the lab are commercially feasible.

Ehsan and Yingyi both joined Calix in May 2022 as Battery Test Engineers with extensive experience in electrochemistry and battery research. They will be responsible for coin cell fabrication and testing of battery electrode materials produced at Calix - the work will then form the electrode materials development and optimisation program at Calix.

IMLB 2022

The majority of the Battery team attended the 21st International Meeting on Lithium Batteries (IMLB) in Sydney, Australia. It is the largest lithium battery research conference of its type and is held every two years. Calix presented progress on its electrode materials development and commercialisation program to the lithium-ion battery community at the IMLB 2022 conference.





SLiCC (Sustainable Lithium Chemical Concentration) Project

Calix Technology for the production of low-carbon, high-quality lithium salt

Calix Limited and Pilbara Minerals are developing a Joint Venture known as the Sustainable Lithium Chemical Concentration project (SLiCC project), following a successful scoping study conducted late last year. The purpose of the SLiCC project is to manufacture a low-carbon, high-quality lithium salt for global distribution using Calix's patented technology. This will involve the construction of a demonstration facility at Pilbara Minerals' Pilgangoora Mine Site, located two hours south of Port Headland in Western Australia. The Pilgangoora deposit is one of the world's largest lithium resources and is strategically important within the global lithium supply chain.

Historically, ore mined at Pilgangoora underwent processing to manufacture a spodumene concentrate that was then shipped overseas for use in lithium battery production. The SLiCC project, however, moves lithium production to Australia by facilitating the processing of fine, lower grade spodumene concentrate followed by further chemical processing on-site to create a concentrated lithium salt.

In May 2022 the SLiCC project received grant funding of $20 million under the Australian Government's Modern Manufacturing Initiative (MMI) – Manufacturing Translation Stream. The grant will support the design, procurement, construction and commissioning of the demonstration plant at the Pilgangoora Site.

Key benefits of the SLiCC project include

Increased Processing Efficiency
Traditionally, spodumene was treated using direct-fire horizontal rotary calciners requiring a two-hour bake time. The SLiCC project will utilise the Calix technology solution for minerals processing by treating spodumene via a rapid thermal treatment in an externally heated kiln.

External heating separates the material from the energy source, enabling good heat distribution throughout the calcination process. This facilitates the change in spodumene material from Alpha to Beta without the associated melting observed in traditional methods. Naturally, this simplifies lithium extraction.

Safer Export Product
Traditional lithium salt, lithium hydroxide, is highly corrosive. The Calix technology solution creates a safer lithium salt, being lithium phosphate. Lithium phosphate salts also provide two components of the fastest growing lithium battery chemistry - Lithium Iron Phosphate - chosen for all Tesla 3 cars made in China.

Reduced Waste and Emissions
Calix technology can treat very fine spodumene concentrates at lower lithia grades. Traditionally, lower lithia grade materials have been problematic for calcination using conventional direct-fire rotary calciners and have been disposed of as waste. The capacity to treat finer materials not only reduces this waste, but vastly improves lithium recovery.

The chemical concentration step is simplified under the SLiCC project. This allows for processing to be completed in its entirety at the mine site, rather than being transported elsewhere for processing. In addition, all the waste material is disposed of at the mine site eliminating the need to ship overseas for disposal. As the Calix technology solution for materials processing produces a higher lithium content in the final product, shipping volume is reduced tenfold, thus vastly reducing carbon emissions.

Additionally, as the material is calcined using an external heat source, the entire lithium processing method can be completely electrified. This allows renewable energy sources to be used as a fuel source, eliminating fossil fuels from the thermal treatment process.

Calix Works on Antimicrobial Resistance (AMR)

A global crisis that could cost the global economy US$100 trillion and cause 10 million deaths per year by 2050*.

Antimicrobial resistance (AMR) – the ability of microorganisms to resist antimicrobial treatments, especially antibiotics – has a direct impact on the health of people and animals. In the European Union (EU) alone, it is responsible for an estimated 33,000* deaths per year. Its effects are also felt on a financial level worldwide, with AMR estimated to cost the EU €1.5 billion per year in healthcare costs and productivity losses.

Infections caused by antimicrobial-resistant bacteria are on the rise after years of overprescribing antibiotics.

If left unchecked, the scale of antimicrobial resistance will quickly outpace what we have experienced with COVID-19, with deaths rising to 10 million per year by 2050, according to the United Nations.

Urgent action and innovation is needed to avert a wave of antibiotic-resistant bacteria.

Calix is using its patented technology to develop bioactive materials that could help reduce our reliance on antibiotics and make a crucial contribution to getting ahead of the next pandemic.

Calix is a Tier 1 partner in the CRC SAAFE, an Australian Government initiative that aims to tackle AMR by recognising the interconnectedness of human, animal and environmental health.

SAAFE provides the means for Calix to fully exploit its core Biotech capabilities in agriculture, food safety and the environment more broadly. We anticipate that the collaboration with agricultural producers, industry partners and research groups will lead to rigorous programs targeting urgent industry needs.

SAAFE also complements a $1m Australian Government Manufacturing Modernisation Fund (MMF) grant to Calix in 2021, which is helping to develop and transform our Biotech manufacturing and research capability at Bacchus Marsh in Victoria.

* References

First study by the Review on Antimicrobial Resistance

https://health.ec.europa.eu/antimicrobial-resistance/eu-action-antimicrobial-resistance_en

(https://cooperativeresearch.org.au/crc-saafe/)

Calix Biotech

Bioactive material engineering – BIOME program:

- Develop & optimise novel materials
- Develop formulations
- Register and commercialise

CRC SAAFE

- Subject matter expertise
- Efficacy testing & optimisation
- End-user & market engagement
- Regulator engagement

Collective feedback / validation

Solution Focus

- Crop protection; soil & foliar
- Post-harvest spoilage
- Intensive livestock
- Veterinary (dermal antimicrobials)
- Aquaculture

Commercialisation by Calix

- Registration
- Channel partner engagement
- Manufacturing

Phil Hodgson
Calix Managing Director

"We are excited to be a Tier 1 partner in the CRC SAAFE and welcome this funding announcement from the Australian Government. It will provide opportunities for Calix to grow our expertise and networks with Australian Universities and research groups, agricultural producers, water authorities and regulatory authorities. We congratulate the CRC bid team and all partners."

Calix Bioactive Materials:

- Bioactivity: suppression of pathogenic microorganisms
- Low resistance development potential
- Non-lethal mode of action
- Synergistic with existing actives

CRC SAAFE

The Cooperative Research Centre for Solving Antimicrobial Resistance in Agribusiness, Food, and Environments

https://www.crcsaafe.com.au/about

"Containing antimicrobial resistance is one of the highest-yield development investments available to countries today." WORLD BANK

AMR is driven not only by the widespread use of antimicrobials for protecting human, animal and plant health, but also by the use of some industrial chemicals and even household cleaning products. Australia's agribusiness, food and environmental sectors are at risk of AMR. But they are also best placed to bring about solutions.

Leilac

Boral and Adbri Join Forces with Calix on Carbon Capture Projects

Exploring the manufacture of low-emissions lime and cement on a commercial scale.

Government grants and partnerships with Adbri and Boral advance Calix's Low Emissions Lime And Cement (LEILAC) technology in Australia and score a world-first

Following on from LEILAC's success in Europe, Australia is set to host the world's first commercial-scale process for the manufacture of low emissions lime.

Calix has been awarded an $11 million grant from the Australian Government's Carbon Capture, Use and Storage (CCUS) Hubs and Technologies Program to work with Adbri on low emissions lime for industries such as alumina and gold.

A lime kiln plant will be located in Kwinana, Western Australia and will use Calix's Low Emissions Intensity Lime and Cement (LEILAC) technology to demonstrate the use of renewable power, assess alternative energy sources such as hydrogen, and assess the efficient capture of CO_2 process emissions.

"Using renewable energy to power the technology will create truly zero emissions lime and cement," said Calix Managing Director Phil Hodgson.

Adbri is the largest producer of lime in Australia and the second largest cement and clinker supplier. Like the Federal Government, Adbri aspires to be net zero by 2050. To achieve this goal, the new Labor government has pledged a more ambitious emissions reduction target of 43 per cent by 2030.

Cement production is responsible for approximately eight per cent of global CO_2 emissions.

Both the International Energy Agency and Intergovernmental Panel on Climate Change regard carbon capture technologies as essential in achieving the goals of the Paris Agreement.

Boral project a game-changer for the cement industry

A further $30 million in federal government funding will be received by Boral to explore with Calix the feasibility of developing a CCUS project at its cement and lime facilities in the NSW Southern Highlands, targeting 100,000 tonnes per year of CO_2.

Boral is the largest integrated construction materials company in Australia, producing and selling a broad range of construction materials including quarry products, cement, concrete, asphalt and recycled materials.

Boral's Chief Operating Officer, Darren Schulz, said the company is committed to investing in projects that create high performing products while reducing its carbon footprint.
"This is game changing technology for our industry and will play a critical role in supporting customers' sustainability targets," Mr Schulz said.

"Together, Boral and Calix have access to the required infrastructure, technology and operational expertise required to deliver this project and lead the way in reducing emissions across the industry."

"By modernising Australia's cement industry, we are enabling the growth of lower carbon construction materials, which are essential to jobs and local economies."

The Boral project aims to:
- Develop CO_2 capture capability for Boral's cement and lime facilites; and,
- Assess alternative energy sources such as renewable energy and alternative fuels to further reduce CO_2.

Calix will be supplying its LEILAC technology to the project, which will help accelerate its expertise through development of both cement and lime deployment options, as well as alternative fuels and renewable energy use.

Phil Hodgson, Calix Manging Director said, "Calix has been working hard advancing our technology in Europe. The projects with Adbri and Boral represent an acceleration in carbon abatement ambition that has occurred in Australia over a very short time."

"It's great to be working with Australian companies such as Adbri and Boral on Calix's home-grown technology in these world-leading projects."

Captured CO_2 to supply South West Hub project

The Adbri project in WA will also see Calix working with CarbonTP and the Heavy Industry Low-carbon Transition Cooperative Research Centre (HILT CRC).

Captured CO_2 is planned to be provided to the South West Hub Carbon Capture and Storage (CCS) project in Western Australia.

When constructed, the low emissions lime kiln will:

- Produce lime using renewable power;
- Demonstrate flexibility by operating only during peak renewable electricity production or low electricity cost periods;
- Assess alternative energy sources such as hydrogen and alternative fuels; and,
- Capture the CO_2 emitted from the process.

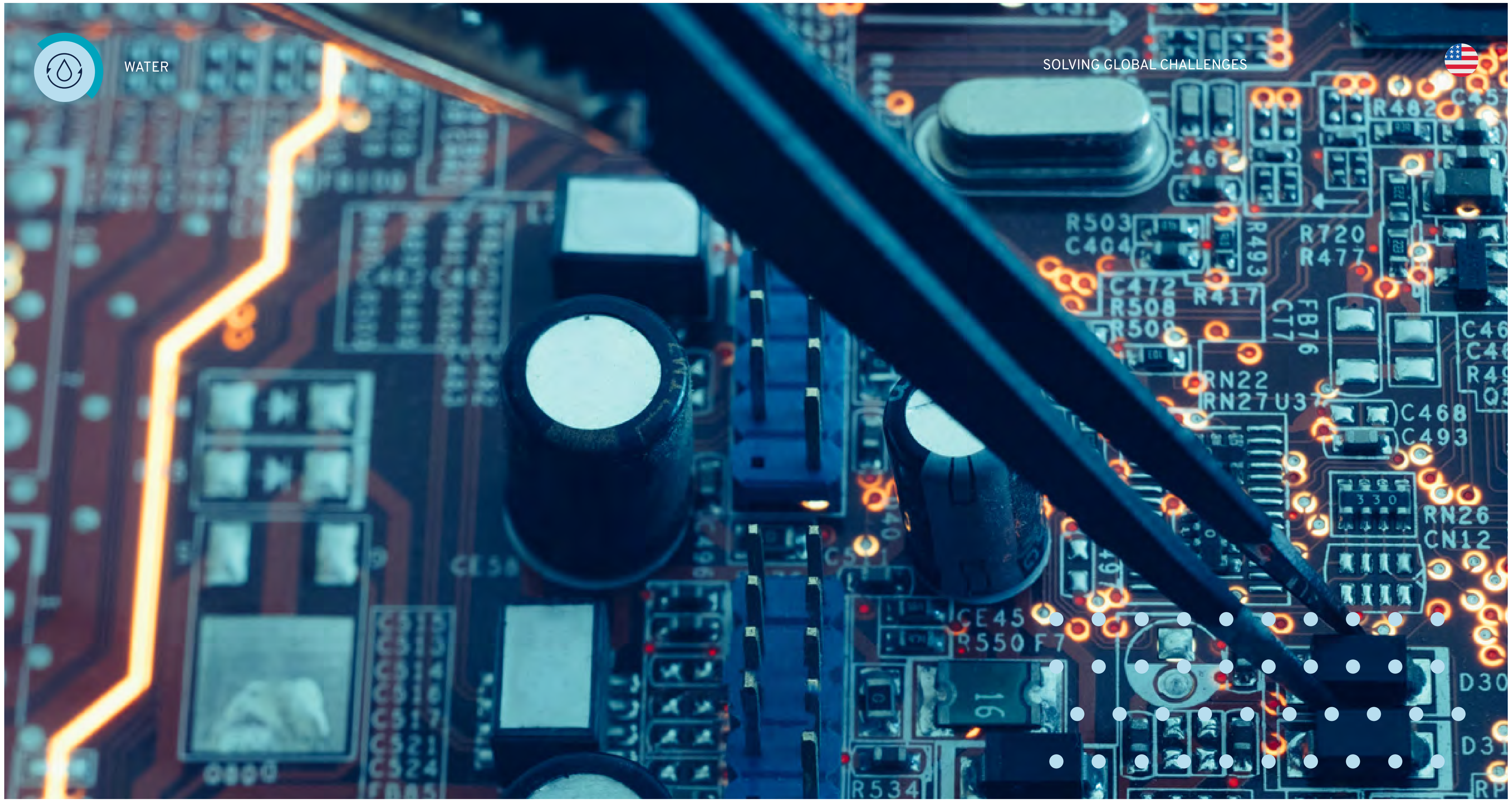
Once the proposed South West Hub CCS project is operational, CO_2 can be fed into the system for permanent storage, creating truly zero emissions lime.

Adbri Managing Director and CEO, Nick Miller, welcomes the Commonwealth support and acknowledges the project represents a significant milestone in its collaboration with Calix to develop its carbon capture technology to reduce emissions from lime production.

"As a leading Australian producer of lime, we recognise it is a difficult manufacturing process to abate."

"Transformative technology-led partnerships like this one with Calix form a key part of our own pathway to net zero by 2050, reducing our emissions profile while supporting the decarbonisation of our end-market customers in the alumina, gold and rare-earths sector."

Felicity Lloyd, HILT CRC CEO, said the project is an important step in demonstrating pathways to reduce the emissions of CO_2 from heavy industry. "The major sectors of aluminium and steel are users of lime, and the project will be of direct interest to them in better understanding how to reduce the emissions intensity of their products. Calix technology is also applicable to the green alumina and steel manufacturing process, so this project will build capacity and know-how to support such future opportunities."



AMALGAM-60

Another Interesting Application using Magnesium Hydroxide as a Replacement for Caustic Soda for Metal Ion Precipitation

At a microelectronics manufacturer in the Pacific Northwest, USA

A microelectronics manufacturer in the Pacific Northwest was using a complex system of chemical additions in order to effectively remove heavy metal contaminants from their wastewater stream.

Semiconductor wastewaters are inherently difficult to treat. They are usually characterised by strong color, high chemical oxygen demand (COD), high levels of volatile organic compounds (VOC) and heavy metals, resulting in potential contamination of the environment. Conventionally, chemical coagulation and biological treatment are used to treat wastewater before discharge.

* In 2022, AMALGAM-60 was renamed ALKA-Mag+, improved stability, flowability and reactivity from IER & Calix's synergy.

CHALLENGES

The wastewater operator – who was handling heavy bags of magnesium oxide (MgO) and feeding hazardous caustic soda in a complex metal-ion precipitation application – was looking for a safer, better performing and more cost-effective solution.

SOLUTION

- Bench testing showed potential cost savings of approximately $1400 per month.
- Calix's US-based business, IER, provided and installed an agitated storage tank and metering pump required for the large scale on-line test, along with the associated feed line for AMALGAM-60 product delivery into the pH adjustment tank.

BENEFITS

- AMALGAM-60 successfully adjusted the pH of the effluent stream to a safe level, to maintain the heavy metals concentrations well below the required permit limits.
- AMALGAM-60 also enabled more efficient waste solids settling, and thus a clearer, less cloudy treated wastewater stream compared to caustic soda.
- AMALGAM-60 also eliminated the need for the operator to use dangerous sulphuric acid, which was sometimes required to correct high pH "spikes" associated with caustic soda use.
- AMALGAM-60 proved to be a safe, cost-effective and highly performing alternative to caustic soda for metal ion precipitation.

Read the full Customer Story:
https://www.calix.global/what-we-have-done/replacing-caustic-soda-with-magnesium-hydroxide-for-metal-ion-precipitation/

MagOx: Magnesium Oxide Relationship with Magnesium Hydroxide

Differences and benefits explained

It is very common to hear someone in the wastewater treatment industry refer to something called "MagOx" as an alkaline additive used to control pH or low alkalinity conditions. Often this term is simply used as a nickname when referring to either magnesium hydroxide or magnesium oxide, which is the chemical precursor to magnesium hydroxide, but which has very different properties. So, when looking to obtain an additive that will provide the most cost-effective pH control performance for your wastewater treatment application, it is important to understand the relationship between magnesium oxide and magnesium hydroxide, and how not all products are equal.

First of all, the chemistry of magnesium oxide (MgO) and magnesium hydroxide ($Mg(OH)_2$) is based on the magnesium dication (Mg^{2+}). Magnesium is an essential macronutrient and is the core element in chlorophyll – the stuff that makes plants green and drives photosynthesis. While MgO and $Mg(OH)_2$ are very similar, knowing the differences in the manufacturing processes for each will help to understand the physical and chemical differences – which is very important in the selection process of the chemical best suited for your application.

Magnesium oxide (MgO) is typically obtained from the calcination (heating) of magnesite ore (magnesium carbonate or $MgCO_3$) in much the same way as quicklime (CaO) is formed from limestone (calcium carbonate or $CaCO_3$). By changing the temperature and speed of how fast the $MgCO_3$ passes through the heat zone, one can control the structure, porosity, and reactivity of the resulting MgO particles. You may ask why this matters? The more porous the particulate structure, having more available surface area, the more reactive the MgO. The ability to control structure and porosity can result in the development of a wide range of MgO products with diverse properties for numerous industrial applications.

The addition of water to dry MgO powder results in its conversion to $Mg(OH)_2$. Therefore, MgO is always purchased as a dry powder or granular material, while magnesium hydroxide is most regularly obtained as a liquid. So, when someone talks about feeding MagOx into water from a pallet of bags or a one-ton bulk bag, the product being used could very well be powdered magnesium oxide. However, if someone talks about feeding a liquid MagOx product into water from an IBC (intermediate bulk container) tote or storage tank, it is most likely a magnesium hydroxide liquid product or MHL.

There are three ways to manufacture magnesium hydroxide, which all result in a liquid slurry. We have mentioned the first method of adding MgO to water and stirring – a process known as slaking, in which energy is released into the water from the breaking of the Mg-O bonds. This reaction is so powerful that after minutes or hours, depending on the volume of the reaction and the reactivity of the MgO, the water temperature rises from ambient to boiling! After the reaction is completed and the temperature has returned to ambient, the conversion from MgO to $Mg(OH)_2$ is complete, resulting in a creamy, easy flowing slurry product. The advantage of this process is that by controlling the nature of the MgO starting material, one can control the settling stability and reactivity properties of the resulting magnesium hydroxide product. This is the process used by Calix and IER to develop magnesium hydroxide products which have improved settling stability and dramatically higher rates of reactivity.

Some may wonder why go through the slaking the process to react magnesium oxide with water, to produce magnesium hydroxide $Mg(OH)_2$ when you could simply add MgO straight into your wastewater stream. The problem is that by adding small amounts of MgO into wastewater, the conversion (slaking) reaction does not fully occur. Instead, the MgO particles can become hydrated on the outer shell, with the less reactive MgO remaining within the core of the particle. This results in a much more unstable product that is difficult to feed and can cause plugging. Secondly, the reactivity of the MgO particles is typically lower than $Mg(OH)_2$, requiring a much higher dose in order to achieve the same pH or alkalinity increase.

The other two processes of manufacturing magnesium hydroxide do not have a direct relationship with magnesium oxide. The first of these is the mining of a natural magnesium hydroxide ore called brucite, which is ground into a fine powder and added to water to make a slurry. The limitation with this process is that one does not have control over the structure, porosity and reactivity of the resulting product. It is exactly as mother nature intended. Since magnesium hydroxide is not the most thermodynamically stable form of magnesium, the fact that it can be mined as an ore in relatively rare locations on Earth suggests that it is quite unreactive. If it were reactive, it would not have survived for thousands of years waiting to be mined. This is shown when testing the much lower reactivity of brucite-containing $Mg(OH)_2$ products versus magnesium hydroxide products made using calcined MgO.

The other manufacturing process involves precipitating $Mg(OH)_2$ from a salt brine solution rich in magnesium chloride ($Mg(Cl)_2$) and calcium chloride ($Ca(Cl)_2$). This brine is treated with lime which raises the pH. As $Mg(OH)_2$ is less soluble than calcium hydroxide ($Ca(OH)_2$), it is the first thing that precipitates from solution. This precipitate goes through proprietary steps to make the product stable for shipping and feeding. As with the brucite process you do not have control over the molecular structure. Therefore, though the product can be made to be highly stable to settling, it is a less reactive product.

Unfortunately, all of the chemistries mentioned above are loosely referred to as MagOx, even though magnesium oxide is simply a building block for one type of magnesium hydroxide. Again, IER and Calix have decided to focus their manufacturing processes in the conversion of different types of MgO, having different particle sizes and porosities, and calcining at low temperatures so as to generate the most reactive magnesium hydroxide products available in the industry. This equates to needing less product to control your wastewater pH. So when looking for "MagOx", the goal should be to obtain the product that will give the best value for money, while still possessing the necessary stability for reliable ease of feed. A magnesium hydroxide derived from magnesium oxide is best suited for the control of pH and alkalinity, as well as for odour, corrosion and FOG (fats, oils and grease) reduction in wastewater collection systems.

ALKA-Mag+ a synergy of IER and Calix, for your wastewater pH, alkalinity, odour and corrosion needs

Through a combination of research efforts, our IER-Calix team has developed a magnesium hydroxide product having improved stability and flowability, along with a higher rate of reactivity. These upgrades in product quality have improved the nature of our product to the degree that deserves giving it a new name to celebrate the efforts and improvements - ALKA-Mag+.

https://youtu.be/FMdPqATdn_Q

We believe our people are key to achieving our purpose.

Introducing Youssef Aaraj

Process Engineer

Youssef Aaraj is a Process Engineer with experience in energy processes development and integration.

Youssef has a PhD from the “Ecole des Mines” in Paris in Energy Processes Optimisation. He joined Calix in 2019. Previously to Calix, Youssef worked on the development of a process for the purification and treatment of biogas.

Currently Youssef is working on the development of the combustion system and the material selection for LEILAC-2, in addition to participating in scoping studies concerning the installation of the LEILAC technology at different cement plants around the world.

Outside of work, Youssef enjoys cooking and trying new foods. He also likes to travel to experience new cultures and places around the world.

> *Working on the LEILAC technology is an opportunity to work with a motivated team that dares to innovate.*

> *We can be proud that our work in Calix positively impacts us and the rest of the world.*

Engineering for the Future

The unsung heroes of this world are engineers. Sure, people talk about Einstein and Marco Polo and Shakespeare and Steve Jobs and Winston Churchill and Nelson Mandela and Rihanna. And yes, good on them. Amazing stuff. But the fact is that none of these high achievers would have been able to do much at all without engineers.

Every time you drive on a road or a bridge or through a tunnel or get on a bus or a train or enter a tall building or open your laptop or tap on your phone, you're only able to do it because of engi-neers.

Maybe someone else had the idea to build the road or the laptop, although engineers have plenty of ideas, but engineers turn those ideas into things that actually work and that we can use. Without them we wouldn't be able to go anywhere or do anything.

In this new Episode of our podcast INNOVATING FOR THE EARTH, innovation expert and radio and TV presenter James O'Loghlin meets with Matthew Gill, Engineering Team Leader at Calix and Claire de Jacobi du Vallon, Process Engineer at Calix. Together they discuss the daily engineering routine at Calix and highlight their achievements so far.

PODCAST #8

Engineering for the Future Feat. James O'Loghlin & Matthew Gill & Claire de Jacobi

https://youtu.be/uTbSgBn249Y

Meet
Matthew Gill
Engineering Team Leader

On starting with Calix in 2012, Matthew's role was Mechanical Engineer for the Calix Flash Calciner (CFC), from conceptual process design through to commissioning and first production runs. Following the CFC's completion, Matthew was involved in the development of the ACTI-Mag product, spending many hours helping to develop the production process and first manufacturing plant at Calix's main production site located in Bacchus Marsh, Victoria. **Having gained experience developing the process for the ACTI-Mag product, Matthew was then put in charge of developing and delivering a high-volume output ACTI-Mag production facility in Queensland.** The project was developed under budget and ahead of schedule.

At the end of 2016, Matthew was seconded to the European branch of Calix to work on the LEILAC project. Matthew was placed in charge of delivering the Calix component of the FEED stage and developing the budget for the project. With the consortium approving the budget and the project moving into the detailed design and procurement stage, **Matthew was placed in charge of delivering the mechanical components of the project, which began construction in mid-2018.**

On returning back to Australia, Matthew was placed in charge of Calix's development program for an electric calciner for processing innovative battery materials. The program ran to schedule and was delivered early and under budget. **In 2019 Matthew moved into the Engineering Team Leader role, managing the engineering team based in Australia to help support the development of Calix's core technology, the European development program and the local water business.**

Meet
Claire de Jacobi du Vallon
Process Engineer

Claire joined Calix as a Process Engineer in January 2021. She started at Calix as the Primary BATMn Plant Operator, working to complete trials and assist in the development of test plans. **Claire was also involved with data processing and reporting of results from the BATMn plant to assist the Engineering Team with feasibility studies and design phases for various projects.**

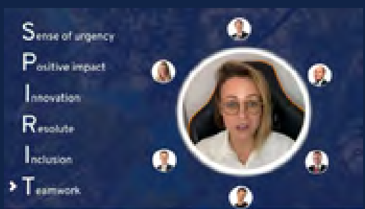
Now, Claire works as the R&D Plant Coordinator, where she is responsible for working with key stakeholders to identify and facilitate program and trial requirements in the BATMn plant. She is also heavily involved in ensuring safe operating procedures are maintained and utilised and that the plant, and its works, comply with all Safety, Environmental and Quality requirements.

Prior to joining Calix, Claire graduated with a bachelor of Chemical Engineering from RMIT University, where she spent her final year completing numerical studies to investigate flame speeds of alternative fuels.

calix

Driven by our purpose of solving global challenges, our aspiration is to urgently develop great businesses and leverage our patented technologies to deliver positive global impact.

THE VALUES THAT DEFINE US AND DRIVE US:



https://youtu.be/ndya-ZPfEwM

To learn more about Calix technology, products, applications and services:

www.calix.global
Or call 1300 0 CALIX

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