

ASX Announcement

October 7, 2021

Calix's LEILAC project consortium releases final output report, including a techno-economic study for cement and lime decarbonisation

Highlights:

- The LEILAC (Low Emissions Intensity Lime And Cement) project has released its final output report - "Roadmap 2050" - following the conclusion of the LEILAC-1 project that piloted Calix's break-through CO₂-capture technology for cement and lime at HeidelbergCement's CBR Lixhe facility in Belgium.
- The LEILAC Consortium, comprising many of the leading cement and lime companies globally, has jointly developed and endorsed the report, which includes a commercialisation and deployment roadmap with full techno-economic modelling.
- Key conclusions are:
 - For a full scale, developed and retrofitted LEILAC plant, CO₂ capture costs (including Capex and Opex) for cement is estimated to be in the range of around €14 to €24 per tonne of CO₂ avoided – **the lowest reported of any technology** – with scope for further cost reductions possible¹.
 - For full-chain CO₂ mitigation projects, depending on the transport and storage options, total costs may be in the region of €39 to €80 per tonne CO₂ avoided. Current EU ETS allowances recently traded at €62 per tonne of CO₂, and have been consistently rising over time despite the impacts of Covid.
- The report also provides a holistic view of the sector, including a full overview of the industries and available decarbonisation options, capture technologies, CO₂ transport options, how the CO₂ could be used and how it could be sequestered or stored.
- The report includes a full techno-economics study, providing further insight into the CAPEX and OPEX costs of the LEILAC technology at full scale, in a range of scenarios.
- Calix is also pleased to report that a further 2 LEILAC projects, one for a lime plant and one for a cement plant, have entered pre-Front-End-Engineering and Design ("FEED") phase, under confidential project scoping agreements.

Sydney, Australia | October 7, 2021 – Multi-award-winning Australian technology company Calix Limited (ASX: CXL) ("Calix" or "the Company") is pleased to announce the release of the final LEILAC-1 project report and techno-economic study. Developed by the LEILAC Consortium, including some of the world's largest cement, lime, chemical and utilities companies, the report provides a vision for how Calix's carbon capture technology could significantly contribute to industrial CO₂ mitigation.

1. The anticipated costs for a full-scale LEILAC installation - capturing all of a plant's unavoidable process CO₂ emissions – excluding compression, but including all other CAPEX, OPEX, and retrofitted to an existing plant and capable of 500ktpa CO₂ captured and avoided. Lower range is RDF (waste fuel), upper is natural gas fired (€7.5 / GJ - long term EU average).

Overview and summary

Calix's LEILAC technology aims to apply Calix's breakthrough approach for low-cost carbon capture to the cement and lime industries to significantly reduce their CO₂ emissions.

The LEILAC-1 Project commenced in January 2016, following a grant of €12m from the EU Horizon 2020 research and innovation program, and comprised a consortium, led by Calix, of key industry companies (HeidelbergCement, CEMEX, Tarmac, Lhoist, and Solvay) and engineering, analytical, and research entities (TNO, Imperial College, PSE, Quantis, and Carbon Trust). The first-of-a-kind pilot plant, capable of up to 25kTpa CO₂ separation, was built on time and on budget. It has operationally proved the technology at pilot scale, and formed the basis of the techno-economic roadmap for scale-up and application of the technology.

The LEILAC-2 project – currently in FEED stage – is focussed on proving key development steps, such as alternative fuel and energy use, process and heat integration with an existing cement plant, and multi-tube furnaces as part of the scale-up. The LEILAC-2 project, which will be located at HeidelbergCement's Hannover facility, is scheduled for final investment decision in early 2022, and is targeting commissioning in late 2023 / early 2024.

The LEILAC final report - "Roadmap 2050" - includes a techno-economic study and a variety of scenarios investigating the costs associated with the technology, including different energy sources (such as renewable electricity) and synergies with other capture technologies, based on the validated results of LEILAC-1 Pilot and LEILAC-2 pre-FEED engineering. Several development and scale-up steps are required to fit a complete LEILAC system to a cement plant, but in theory, as there is minimal energy requirements and relatively small capex, **a full scale, fully developed LEILAC facility capture costs are expected to be in the range of around €14 to €24 per tonne of CO₂ avoided – the lowest reported of any technology – with scope for further reduction in cost.**

Given this analysis, and assuming benchmarked transport and storage costs from CO₂ infrastructure, it is estimated that future, fully developed and full scale retrofit LEILAC installations using waste fuel could achieve **full chain CCS abatement costs (capture, transport, storage, including CAPEX costs) of around €39 per tonne of CO₂ avoided.** Around half of these costs relate to transporting and storing the CO₂, and nearly a quarter to the capital and operating costs associated with CO₂ compression.

The report also outlines some significant areas for further cost reduction associated with the LEILAC technology. The energy penalty has been conservatively assessed, and ideally and theoretically could approach zero (and, in fact, a fully electric installation has been shown to have a **net energy saving** against current best available technology cement plants of 0.7 GJ/TCO₂).

In summary, LEILAC technology (both alone and alongside other decarbonisation methods) can enable net zero production of lime and cement at low cost, assuming:

- policy support to ensure that global targets are met, and that there is a level-playing field for industrial producers.

- sufficient transport and storage infrastructure is put in place, and regulated for fair access to small players, to ensure that society's unavoidable industrial emissions are not released into the atmosphere.
- the main technological challenges for capture continue to be addressed, with support from governments and industrial partners.

Should incentive frameworks and transport and storage infrastructure be in place, decarbonisation of industry is a very real possibility. Net zero emissions are required by 2050, and LEILAC is well placed to enable the cement and lime industries to contribute towards these targets in a timely, effective and cost-efficient manner.

Read LEILAC Roadmap to 2050:

<https://www.calix.global/news/leilac-roadmap-2050/>



Highlights from the Report

- **The Cement and Lime industries play a vital role in our society**

Cement is used in our roads, buildings, homes, offices and almost all our infrastructure. Lime is used in a variety of applications, including in the iron and steel, chemical, paper, pharmaceutical, drinking water, food and farming industries. EU recognised these sectors as being 'indispensable' to the economy. Global cement and lime demand will increase due to the global population growth and the trend of further urbanisation. They play a vital part of our society and economy.

- **The Cement and Lime industries are dedicated to decarbonising**

Cement and lime industries, both through their associations and individual corporate pledges, have made clear commitments to carbon neutral emissions production by 2050.

These industries recognise that reaching carbon neutrality requires the use of carbon capture, utilisation and storage.

Two-thirds of emissions from the production of cement and lime are unavoidable 'process emissions'.

Almost half the weight of limestone – the main ingredient in the cement making process – is released as CO₂.

While several approaches can be taken to reduce the volumes of CO₂ generated – and these should be pursued strongly – the most viable means of ensuring process emissions do not reach the atmosphere is by capturing and permanently safely storing the CO₂, typically in minerals or by sequestration. Using the CO₂, for example in the chemical industry and for creating synthetic fuels, may be an important enabler for capturing CO₂ from the cement and lime industry.

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- **The LEILAC process represents a low cost, eco-efficient means of capturing process CO₂, and can be run on renewable energy**

A variety of approaches and technologies are being developed to capture the CO₂ emissions from the cement industry, and they all need to be urgently developed and scaled up.

Supported by industry and the EU, the LEILAC technology aims to capture unavoidable process CO₂ emissions for minimal expense, as it does not need additional processes or chemicals. It can work in synergy with other technologies and approaches. It can also be fully powered by renewable energy and/or hydrogen, and all units will be 'electrification' ready.

- **The LEILAC process**

The LEILAC projects are developing a new technology, aiming to enable the cement and lime industries to capture specifically those unavoidable CO₂ emissions released from the raw limestone.

The LEILAC process (also known as indirect heating, or direct separation) works within a normal cement plant's process.

It is based on "indirect calcination", by heating the limestone via a special steel tube, effectively becoming a new type of 'precalciner', which is currently used in all modern cement plant. This unique system enables pure CO₂ to be captured as it is released from the limestone, as the furnace exhaust gases are kept separate.

"Calcining", or heating, raw cement meal by indirect heating (LEILAC) or by direct heating (conventional calciner) can be done in principle with the same specific energy.

The process does not involve any additional processes or chemicals, and simply involves a novel "pre-calciner" design (or new kiln, in the case of a lime plant).

This type of pre-calciner aims to use any type of fuel or heat source. This makes achieving a very efficient zero-emissions cement kiln, using biomass-rich fuels, green electricity, or hydrogen, a very real possibility with the same basic technology.

If alternative fuels, biomass, or conventional fuels are used, any of the previously mentioned conventional carbon capture techniques can be applied to capture the combustion (heating) emissions. There would be synergies to such a combination, as the lowered energy requirements and capital of such a combined system would result in a very efficient means of achieving 'negative emissions' cement plants.

The LEILAC-1 Pilot was built on time and on budget and proved the technology concept. It has the capacity to separate about 5% of a cement plant's emissions.

LEILAC-2, currently undergoing engineering for installation at HeidelbergCement's plant in Hannover, and is targeted to directly separate – using a replicable module – around 100ktpa of CO₂. Construction is due to start in 2022.

- **The LEILAC process is being designed for efficient, global roll out**

A LEILAC module, addressing 20% of a cement plant's emission, is targeted begin constructed in 2022. The intent behind the commercial, global rollout of the technology is for the modular, scalable design to capture the process emissions from a plant of any size. The designs will eventually be 'blueprinted' and applied by engineering firms on a global basis to cement and lime plants, enabling localised expertise to be developed and used.

- **CO₂ transport and storage availability is vital to enable industrial decarbonisation and, without it, the ability for our society to reach its climate change ambitions will be limited.**

The consortium considers the development and availability of transport and storage infrastructure to be vital for decarbonising the cement and lime industries. Unlike examples in the power and refining sector, the volume of CO₂ to be stored per plant is less. This opens local storage opportunities and industries. Given the very small size of most of the cement and lime players, steps must be taken to quickly develop storage sites of all sizes; ensure larger storage developments are appropriately sized for 2050 (particularly, if using public money and only facilitating bigger players); and enable fair access.

- **Societal acceptance and government support are essential**

While pursuing every option available to decarbonise, the cement and lime sector needs the help and assistance of our society (from both project stakeholders and product consumers) as it decarbonises. On a local level, that can range from small increases in prices of cement, through to active support of decarbonisation projects so they remain competitive.

- **Appropriate long-term incentive frameworks and public financing for early movers are critical**

Effective policy environments and incentive mechanisms are required globally to ensure that vital industries can continue to operate, while taking necessary decarbonisation steps.

Public subsidies and investments are required to allow these technologies to continue to be quickly developed and installed globally. Support is required to enable and widely deploy transport and storage infrastructure, ensuring the captured CO₂ does not reach the atmosphere.

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 sustainable processing, 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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