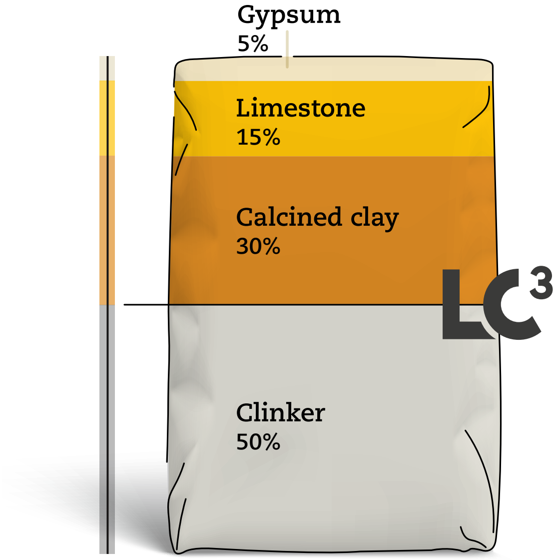
LC^3

A sustainable alternative for the cement industry



LC3 – A low-carbon alternative

Limestone Calcined Clay Cement (LC3) is a new low-carbon blended cement that allows cement manufacturers to reduce the CO_2 emissions from production. Funding from the Swiss Agency for Development and Cooperation (SDC) helped bring the LC3 technology from the lab to large-scale commercial production. The SDC supported the development of the scientific basis for LC3 and the testing of production, and is promoting the adoption of LC3 standards and supporting global outreach.

Figure 1

Five good reasons for adopting LC3

Reduced carbon

LC3 **reduces the energy-intensive clinker**[1] content to **50 per cent**, thus **reducing the CO_2 emissions** by up to **40 per cent** compared to Ordinary Portland Cement (OPC).

Scalability

The **abundance of suitable materials** means **LC3 can be produced in 75 per cent of cement plants worldwide.**

Resource efficiency

For LC3, both **limestone**, which is not suitable for clinker production, and **non-ceramic clays**, **which are often waste, can be used**.

Cost effectiveness

Because **calcining clay is often cheaper than clinker**, LC3 **saves up to 25 per cent of the production costs.**

High performance

LC3 performs as well or better than OPC with the advantage of **greater resistance** to the penetration of chloride ions – the main cause of **reinforcement corrosion**.

[1] Clinker: dark grey nodular material made by heating limestone and clay at a temperature of about 1400-1500 °C.

The cement industry challenges in reaching net zero

Concrete is the most widely used building material in the world, and its main component is cement. The chemical and thermal combustion processes involved in the production of cement are major sources of CO_2 emissions, 60 per cent of which are direct emissions from the heating of limestone to produce clinker, with 40 per cent coming from the combustion of the fuels used in cement kilns (GCCA 2022). Cement production accounts for about 8 per cent of global CO_2 emissions.

The world is becoming increasingly urbanised, particularly in Asia and sub-Saharan Africa. In 2020, 56 per cent of the world's population resided in cities, and the urban population is projected to double by 2050 (WB 2020). Concrete is expected to play a vital role in the expansion of the built environment, especially in emerging economies. The increase in concrete production will require an increase in cement production from the current level of more than 4 billion tonnes per year to more than 5 billion tonnes a year by 2050 (Chatham House 2018).

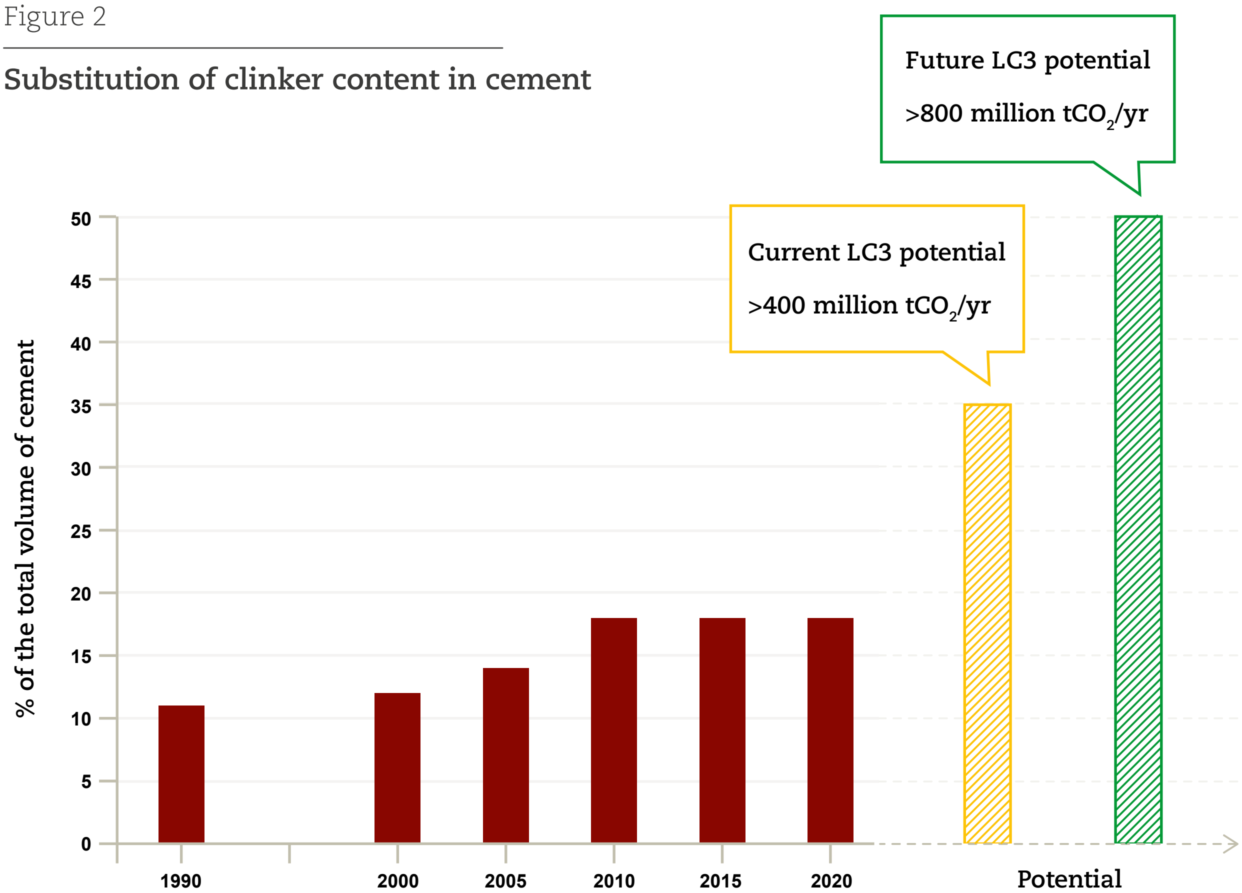
At the same time, meeting the goal of the Paris Agreement to limit global warming to well below 2 °C, preferably to 1.5 °C, requires significant efforts to decarbonise all sectors. Net-zero carbon emissions must be achieved across the overall life cycle of building construction by 2050 (Global Climate Action Pathway 2021). The direct CO_2 intensity of cement production increased 1.5 per cent per year during 2015–2021. In contrast, 3 per cent annual declines to 2030 are necessary to get on track with the Net Zero Emissions by 2050 Scenario (IEA 2022).

LC3 on the path to a net-zero future

To achieve a net-zero future, the construction sector needs to adopt sustainable, resource-efficient and circular approaches, including the reduction of cement and steel consumption and the use of sustainable building materials. The contributions of cement and concrete use to net zero must include improvements in design and construction efficiency; savings in cement and binders; savings in clinker production; efficiency in concrete production; and the use of carbon capture, utilisation and storage technology (GCCA 2021). LC3 contributes to the reduction of CO_2 emissions mainly by substituting energy intensive clinker content contributing to emission reductions in the area of "savings in cement and binders". Depending on the type of cement that is replaced by LC3, the reduction in CO_2 can reach up to 40 per cent.

Figure 2

Substitution of clinker content in cement



Although calcined clay and limestone are already commonly used as supplementary cementitious materials, the major innovation in LC3 is to reduce the clinker content to 50 per cent and add a mixture of 30 per cent low-grade kaolinite clay, 15 per cent limestone and 5 per cent gypsum. The materials have a synergistic effect and perform similarly to OPC. The lower use of clinker reduces the CO_2 emissions released (up to 40% compared to OPC) by the limestone and the less fuel used for clinker burning. Significant energy savings are achieved because calcined clays are more malleable and are heated at approximately 700-800 °C whereas the manufacture of clinker requires a temperature of 1400-1500 °C. LC3-50 with a clinker content of 50 per cent is widely promoted and accepted under cement standards applicable in Europe, India, the United States, Cuba and much of South America. The potential for LC3 formulation with clinker contents less than 50 per cent – which would lead to further CO_2 reductions – is being studied.

By using industrial waste materials such as clay waste, LC3 increases resource efficiency and reduces the utilisation of the scarce raw materials that are necessary for producing clinker. Calcined clays and limestone are widely available while fly ash – a component of blended cements – is getting scarce in some areas and is likely to become rarer as coal-fired thermal power plants phase out. Similarly, slag as a blending agent is already scarce and will become scarcer with the decarbonisation of the steel industry. In addition, the high chloride resistance and dense microstructure with high surface resistivity of LC3 makes it suitable for harsh weather conditions in marine environments.

Figure 3

Production of LC3

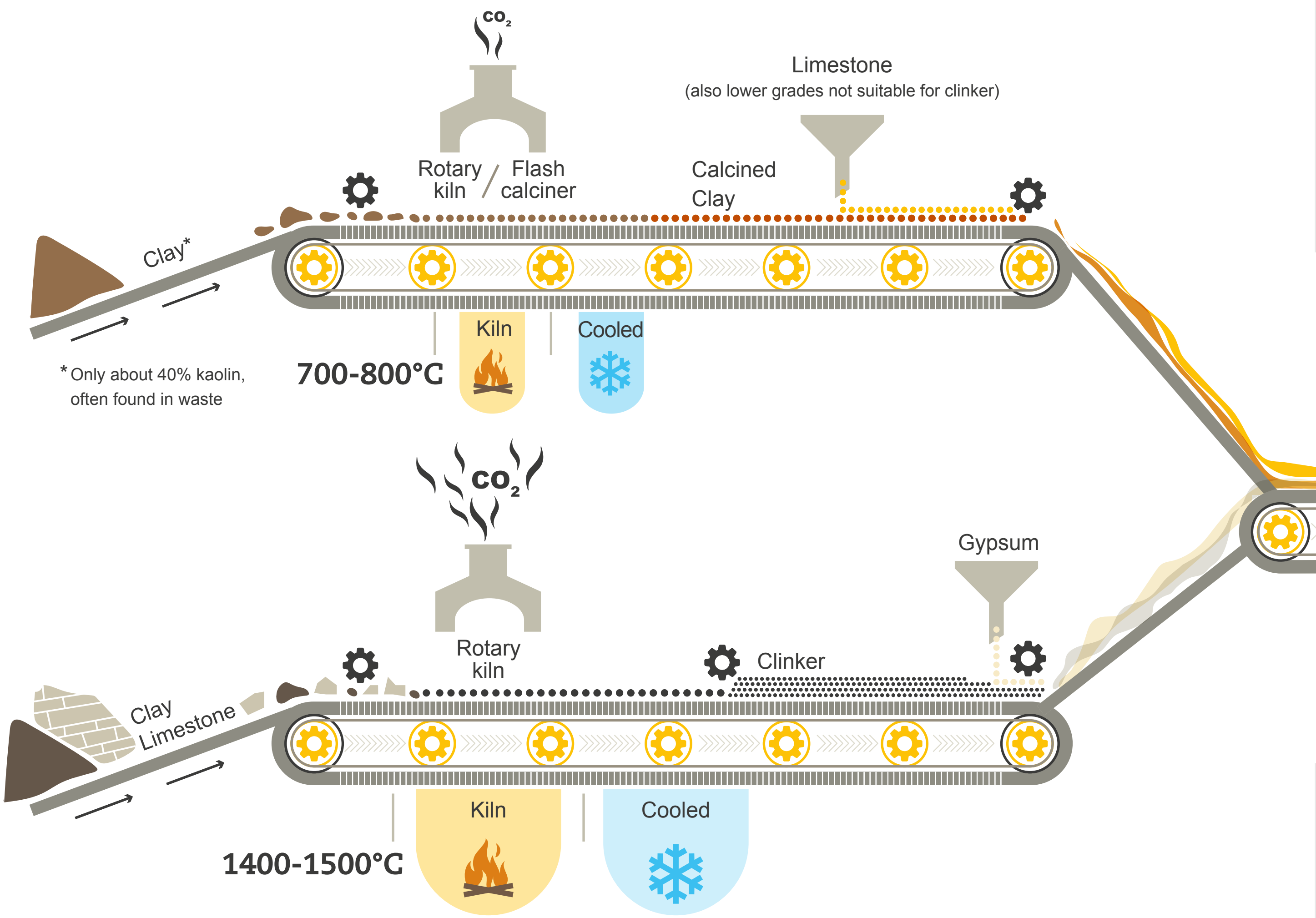
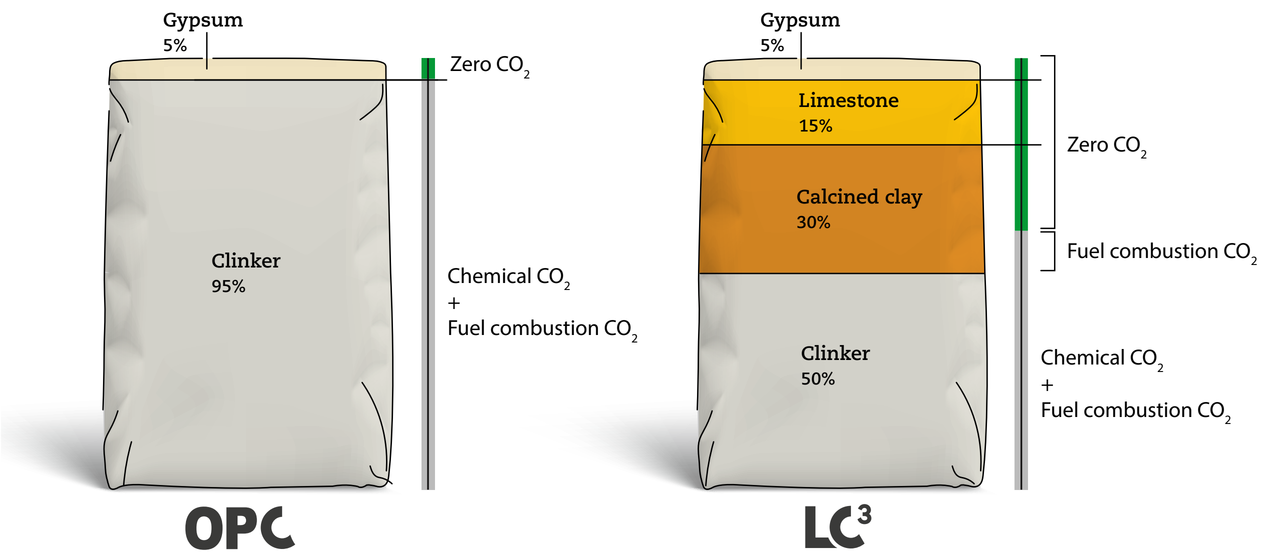
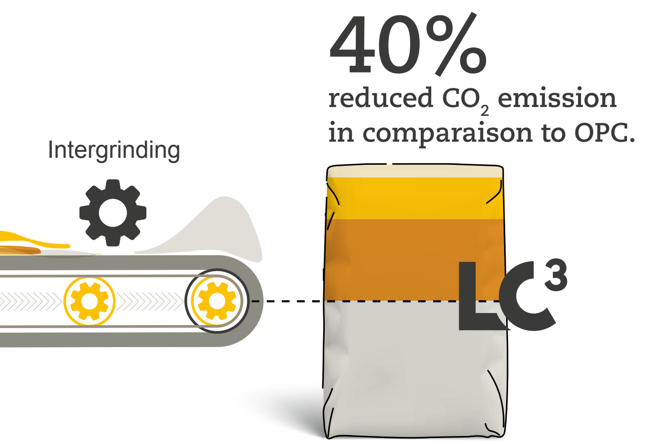


Figure 4

CO_2 reduction using LC3





Source: Adapted from LC3 website

Note: LC3 can be produced in a manner similar to OPC. Clay must be heated in a rotary kiln, but at lower temperatures.

The road to market success

Research

2005-2008

First research project on the use of calcined clays supported by the Swiss National Science Foundation (SNSF)

2009-2012

Follow-up research on blending cement with calcined clay and limestone supported by the SNSF

2013-2022

SDC-supported LC3 research, technical validation, standardisation and knowledge dissemination

The production costs for LC3 can be up to 25 per cent lower than for OPC due to savings from energy and material. Where clinker has to be imported, the savings can be even greater. Last but not least, LC3 technology is readily available and can be commercialised. About 75 per cent of cement plants worldwide can produce LC3 with slight adjustments in their production lines and with their current infrastructure and abundantly available materials. No special training is required, and conversion to LC3 production can be combined with other decarbonisation technologies, available or in development.

The SDC engagement in developing and scaling-up low-carbon cement

In 2013, the Indian Institutes of Technology in Delhi, Bombay and Madras along with Technology and Action for Rural Advancement, an Indian NGO, joined the SDC-funded research partnership between the École Polytechnique Fédérale de Lausanne (EPFL) and the Universidad de las Villas in Cuba, and contributed to the development, testing, production and dissemination of LC3. The involvement of the Swiss National Science Foundation (SNSF) at the initial stage helped strengthen the project partnership, make optimal use of Switzerland's innovative research community and expand the engagement globally. The open-source approach and continuous exchange of knowledge among Switzerland, India and Cuba stimulates international research and the advancement of sustainable solutions.

Figure 5

LC3 contributions to achieving the Sustainable Development Goals

Standardisation, market preparation and first applications

2013

First industrial production of LC3 in Cuba.

House in Santa Clara, Cuba, completely built with LC3

2014

ASTM approves C595 standard with new formulation for blended cements

House in Jhansi, India, using first production of LC3 for walls, roofing tiles and floors

2015

New office for the SDC at the Swiss embassy in New Delhi, India, using LC3 blocks

2017

Verification of the economic advantages of the material

2018

Cuba approves NC 1208 Cemento Ternario, which includes LC3

2021

2021, European Union approves EN 1975, which includes LC3

Progress and prospects – concrete results

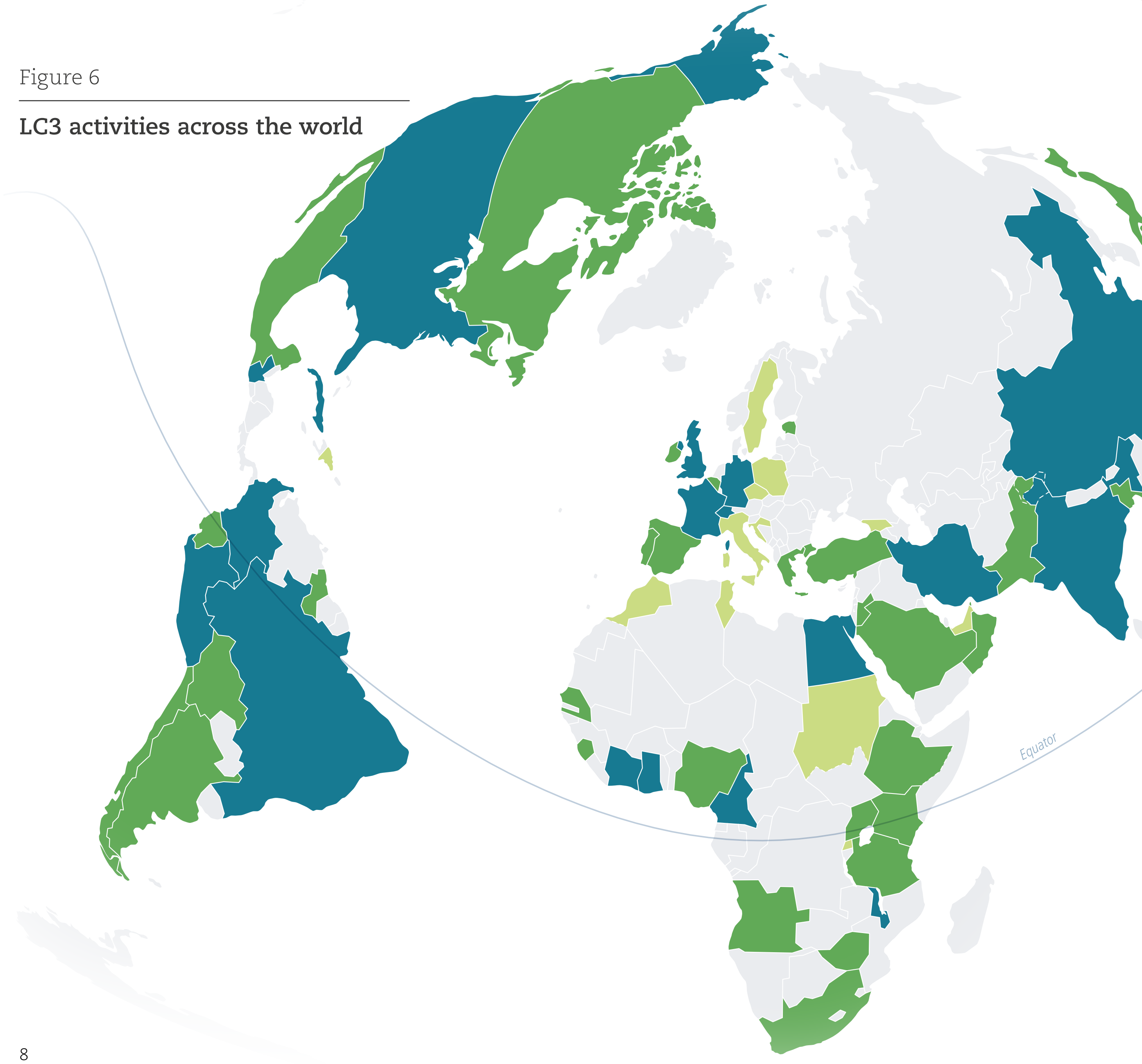
SDC's pioneering efforts to support the launch and dissemination of LC3 has produced scientific investigations and publications that establish the environmental and economic viability of the technology, and has contributed to the integration of LC3 into policy and road maps for the decarbonisation of the building and construction sector. The technical resource centres in Cuba and India serve as the interface with the industry and are supporting cement companies in the adoption of LC3. Meanwhile, industries worldwide are conducting their own research and contributing to the LC3 revolution.

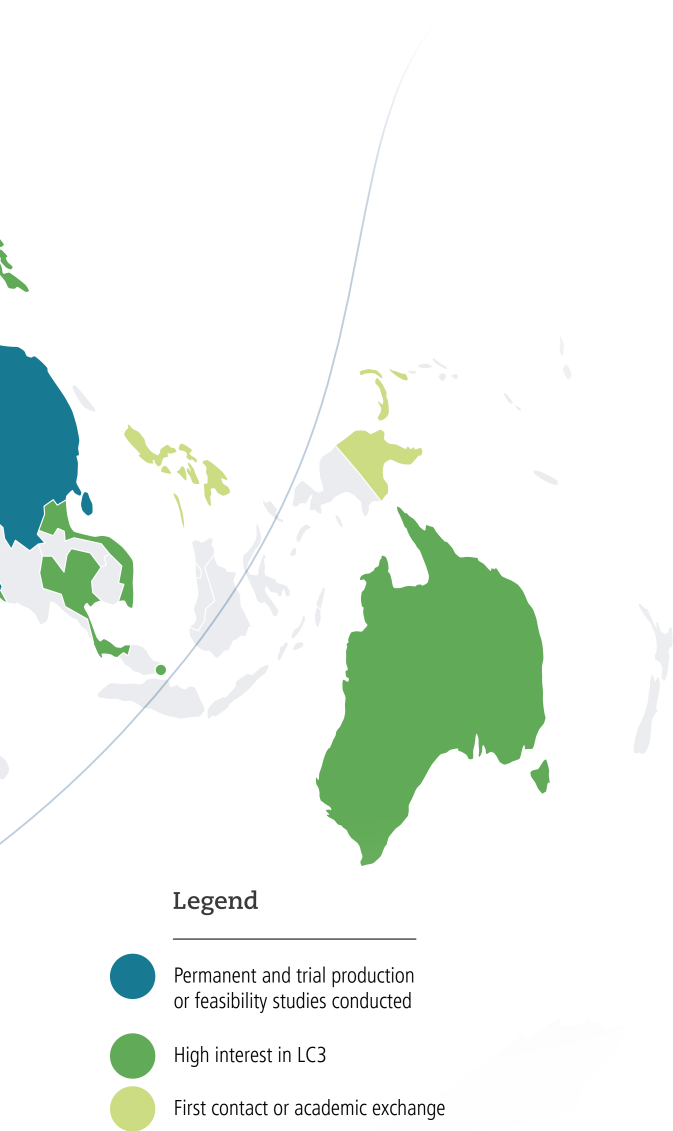
The map below shows the spead of LC3 across the globe. In Africa, growing demand, the high costs of imported clinker and the wide availability of raw materials are giving rise to many LC3 projects and initiatives, and in Europe, analysts expect to see more calcined clay installations as the market prices for emission credits under the European Union Emissions Trading System increase (CN Cement 2022).

Still, further engagement is needed – in the rapidly growing countries in South East Asia and among the industry's smaller companies, which serve 70 per cent of the global market. Governments can engender a more sustainable building and construction sector by adopting ambitious public procurement policies, setting industry standards and emissions norms and developing decarbonisation road maps.

Figure 6

LC3 activities across the world





Private sector uptake

2019

LC3 plant in Cuba is operational

2020

ARGOS starts the production of Cemento Verde in Colombia

CIMPOR begins production of DeOHclay in Ivory Coast

Scaling-up

2020 and beyond

The Technical Resources Centres in Delhi and Santa Clara provide consultancy services to the industry

2022 and beyond

More than 50 countries producing or conducting research and development on LC3

Focus on scaling-up the technology in smaller companies, especially in South East Asia

Focus on adopting ambitious public procurement policies, and setting industry standards and emissions norms

SDC engagement

The SDC supported the scientific development of LC3, and is contributing to the dissemination of the technology in low- and middle-income countries and to the implementation of industry standards. The results are available as open-source documents.

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Links

www.lc3.ch

www.lc3trcindia.com

www.ecosolutions.gl/lc3-trc-latam

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