Decarbonizing Saudi Arabia's cement sector

RIYADH: Cement sits at the center of Saudi Arabia's transformation. From giga-projects and housing developments to industrial zones and tourism infrastructure, demand for the material is expected to remain high as the Kingdom advances its Vision 2030 agenda.

But cement is also one of the world's most carbon-intensive industries, responsible for roughly 8 percent of global carbon dioxide emissions, according to the World Economic Forum. In Saudi Arabia alone, the sector emits an estimated 37.7 megatonnes of CO_2 annually.

As one of the Middle East's largest cement producers, with installed production capacity of around 85 million tonnes per year, Saudi Arabia now faces a critical challenge: how to sustain rapid construction growth while meeting its pledge to achieve net-zero greenhouse gas emissions by 2060.

For industries such as cement, steel and petrochemicals, decarbonization is particularly difficult because emissions are tied not only to energy use, but also to the manufacturing process itself.

FASTFACT

DID YOU KNOW?

- Global cement demand is projected to exceed 5.5 billion tonnes by 2030.
- Saudi Arabia ranks first in the Arab world and 10th globally in cement production.
- The Kingdom's cement sector supports up to 15,000 jobs and contributes $3.7 billion to the economy.

"First, approximately 60 percent of emissions are chemically inseparable from the production of clinker," Bassam Dally, professor of mechanical engineering at KAUST and head of its Future Cement Initiative, told Arab News.

“You cannot eliminate them through fuel switching, electrification, or renewable energy. They are a byproduct of the fundamental chemistry of converting calcium carbonate into calcium oxide.”

Clinker, the key ingredient in cement, is produced by heating limestone to extremely high temperatures in industrial kilns. The process releases carbon dioxide both from fuel combustion and from the chemical breakdown of limestone.

“Second, the remaining 40 percent of emissions come from fuel combustion in the kiln, which requires enormous and sustained high-temperature heat, typically 1,450°C,” Dally said.

That combination has made cement one of the world’s hardest industrial sectors to decarbonize.

Bassam Dally, professor of mechanical engineering at KAUST and head of its Future Cement Initiative. (SUPPLIED)

At the same time, cement remains essential to Saudi Arabia's economic ambitions. "Saudi Arabia's domestic cement demand is projected to reach approximately 67 million tonnes per year by 2030, driven by housing, industrial zones, and the giga-projects," Dally said.

"That demand will be met. The question is whether it will be met with cement produced at today's carbon intensity or with progressively lower-intensity alternatives that also deliver durable, long-lasting infrastructure."

According to Dally, the sector supports an estimated 13,000 to 15,000 direct jobs and contributes SR13.87 billion ($3.7 billion) in direct economic value, alongside wider impacts across construction, logistics and industrial supply chains.

"The challenge," he said, "is not choosing between expansion and sustainability, but finding a way to pursue both at the same time."

"This is the defining strategic question for the sector, and the frank answer is that the balance cannot be achieved by doing less of one or the other," Dally said. "It requires doing both simultaneously through a deliberate technology transition."

One of the fastest ways to reduce emissions is by lowering the amount of clinker used in cement and replacing part of it with supplementary cementitious materials.

Saudi Arabia may hold a significant advantage in this area because of its geology.

"Saudi Arabia does possess a genuine and substantial pozzolanic resource base that few other cement-producing nations can match," Dally said.

The Kingdom's volcanic Harrat fields contain reserves of scoria, pumice, basalt and tuff — materials that can partially replace clinker and lower emissions from cement production.

Drone photograph of a quarry in Kaolinitic sandstones near Al Jawf. (SUPPLIED)

These materials are already being used in major projects. “Natural pozzolans from the Harrat volcanic fields are already being used in Aramco-specified concrete mixes,” Dally said, adding that they have also been deployed in projects including the Jafurah Gas Development and Ras Al-Khair industrial projects.

At KAUST, the Future Cement Initiative was launched in partnership with the Ministry of Industry and Mineral Resources and the National Committee of Cement Companies.

“KAUST’s Future Cement Initiative is focused on building the scientific, industrial, and human capital foundation needed to transform how cement is made in Saudi Arabia,” Dally said.

The initiative is working to improve clinker production efficiency, develop lower-carbon cement materials using local resources, and advance carbon capture technologies, including early-age carbonation curing.

The sector is also exploring cleaner fuels, energy-efficiency upgrades and digital optimization technologies to reduce energy consumption in existing plants.

The Future Cement Initiative (FCI), launched in January 2025, is a national program led by KAUST with support from the Public Investment Fund, the Ministry of Industry and Mineral Resources, and the National Committee for Cement Companies. (SUPPLIED)

“AI-assisted process optimization requires no new plant investment and can reduce thermal energy consumption by 3-5 percent through advanced kiln control modelling,” Dally said. “At Saudi Arabia’s production volumes, this translates to meaningful absolute reductions.”

Still, Dally said deep decarbonization will not be possible without carbon capture technologies.

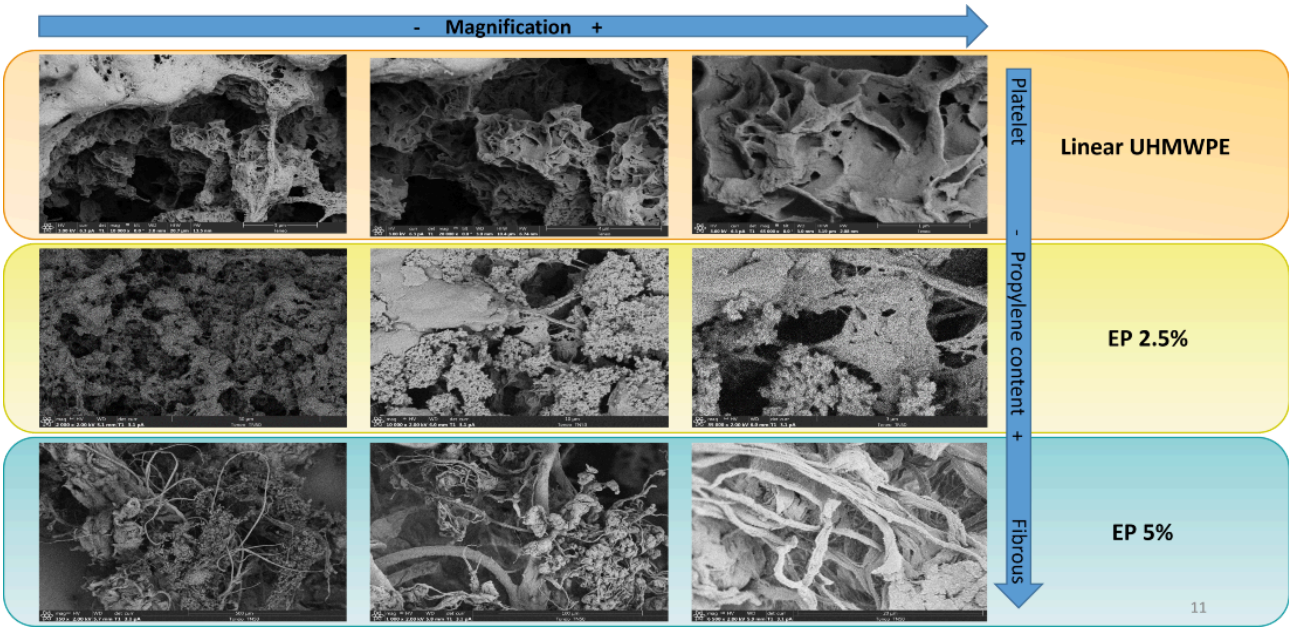
“CCUS is ultimately indispensable for deep decarbonization of cement,” he said. “This is not a matter of preference. It is a consequence of chemistry.”

Carbon capture, utilization and storage technologies are increasingly viewed as essential because they address the process emissions that cannot be eliminated through renewable energy or cleaner fuels alone.

Saudi Arabia may be particularly well-positioned to scale such technologies because of decades of experience handling carbon dioxide in the petroleum sector.

“Saudi Arabia is particularly well-positioned for broader CCUS deployment given its extensive CO2 injection and pipeline infrastructure experience from the petroleum sector, and the proximity of several cement plants to geological storage sites,” Dally said.

Another emerging technology gaining attention is early-age carbonation curing, which injects carbon dioxide into fresh concrete and permanently stores it within the material.



Materials studied by KAUST researchers for potential use in improving cement performance. (SUPPLIED)

“Early-age carbonation curing represents one of the most exciting emerging technologies in the global cement sector right now, and it is highly relevant to Saudi Arabia,” Dally said.

“For Saudi Arabia, where precast concrete is widely used in infrastructure and the prefabricated construction sector is growing, this technology offers a pathway to simultaneously decarbonize production and enhance infrastructure durability.”

Dally stressed that sustainability is not only about reducing production emissions, but also extending the lifespan of infrastructure.

“The sector must move toward a new sustainability metric,” Dally said.

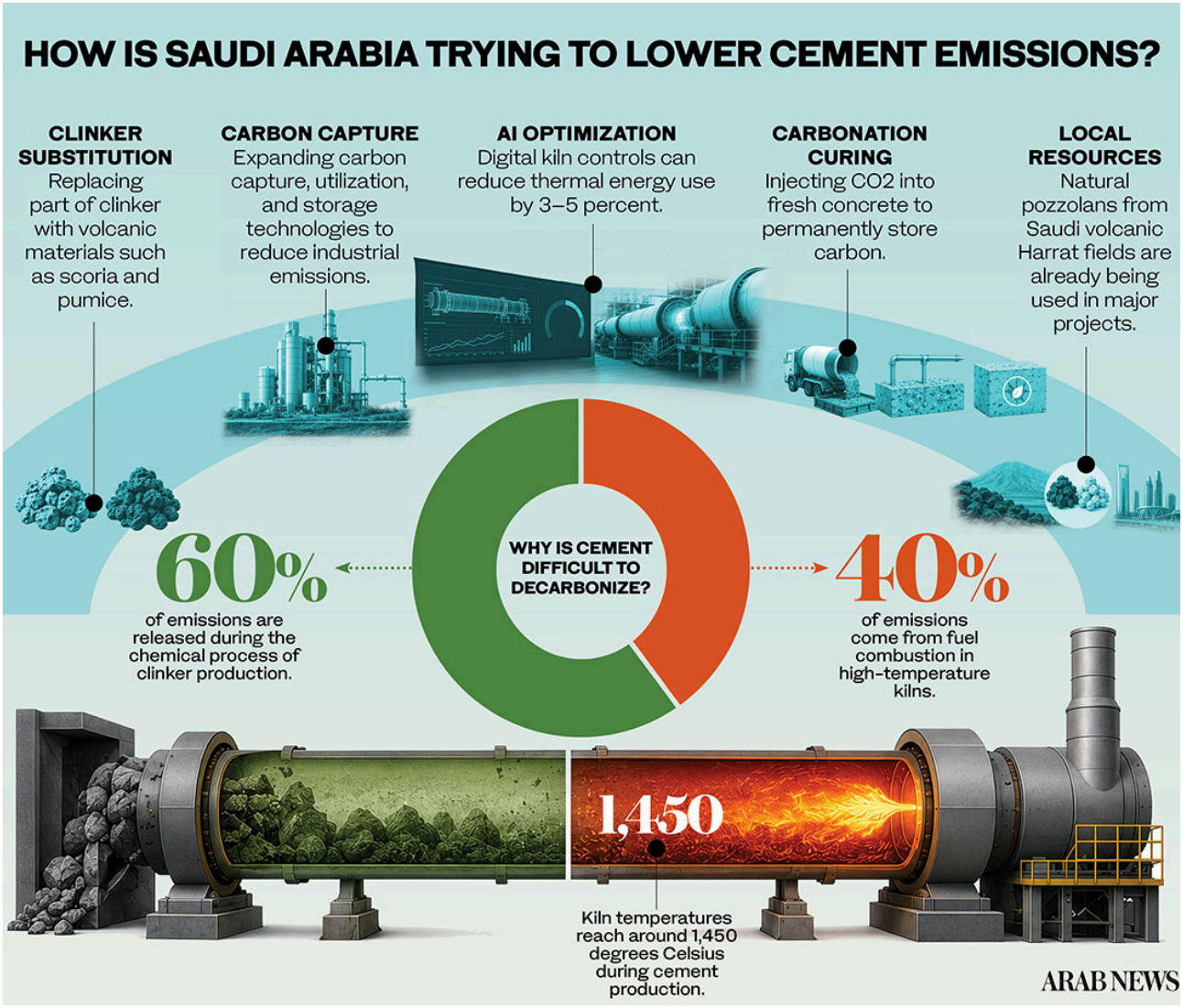
“This framing matters enormously for Saudi Arabia, where infrastructure is being built to serve for 50 to 100 years under aggressive environmental conditions.”

The issue is especially relevant in Gulf climates, where heat, salinity and sulfate-rich environments can accelerate concrete deterioration.

“A structure that deteriorates prematurely and requires repair or reconstruction generates lifecycle emissions that can offset the savings made during production,” Dally said.

However, several regulatory and commercial barriers remain.

“One of the key challenges is the need for updated technical standards for blended cements in the Saudi market,” Dally said.



“Without regulatory approval and product standards for lower-clinker formulations from SASO, even technically ready solutions cannot yet be deployed at scale.”

Dally added that the sector’s transition will also require stronger policy support and financial incentives.

“Neither carbon pricing nor emissions caps currently apply to the cement sector in Saudi Arabia,” he said.

“Without a cost on carbon, the financial case for investing in CCUS, switching to more expensive alternative fuels, or reformulating products is difficult to make purely on commercial grounds.”

He said one of the most effective short-term measures would be embedding low-carbon cement specifications into government procurement frameworks.

“The most impactful near-term measure would be embedding low-carbon cement specifications, utilizing locally sources materials, into public procurement standards for all government-funded projects, including the giga-projects,” Dally said.

Such policies could create stronger demand for lower-carbon materials while encouraging manufacturers to invest in cleaner technologies.

Still, procurement decisions in the Kingdom remain largely cost-driven.

“The majority of cement procurement in Saudi Arabia today is still driven primarily by price and availability, with carbon and durability performance as secondary considerations,” Dally said.

“Decarbonizing cement is therefore both a climate obligation and a trade competitiveness imperative.”

For Saudi Arabia, the issue reflects a broader challenge facing rapidly developing economies: how to continue building at scale while reducing industrial emissions.

“The potential is real, and the structural conditions to realize it are present,” Dally said.

“Whether the Kingdom leads or merely follows will depend on decisions made in the next three to five years.”