Technology Roadmap

Low-Carbon Transition in the Cement Industry

International Energy Agency
Secure
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Together

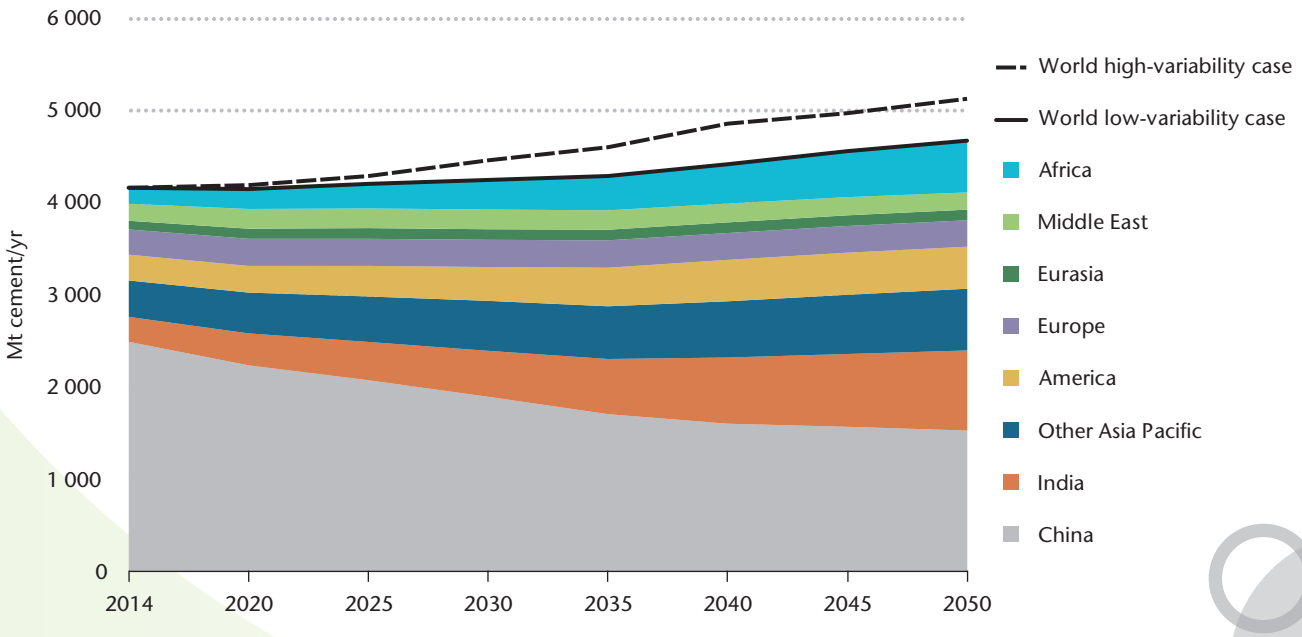
Cement Sustainability Initiative

Key findings

- Cement is used to make concrete for buildings and infrastructure, which are important for quality of life, and social and economic wellbeing. The cement sector is the third-largest industrial energy consumer, comprising 7% of the global industrial energy use 10.7 EJ. Cement production involves the decomposition of limestone (calcium carbonate), which represents about two-thirds of the total CO_2 emissions generated in the process, with the remainder of CO_2 emissions being due to combustion of fuels. Thus despite considerable progress on energy efficiency, the use of alternative fuels and clinker replacements, the sector has the second-largest share of total direct[1] industrial CO_2 emissions, at 27% (2.2 $GtCO_2$/yr) in 2014.
- Rising global population and urbanisation patterns, coupled with infrastructure development needs, drive up the demand for cement and concrete. Global cement production is set to grow by 12-23% by 2050 from the current level. Direct CO_2 emissions from the cement industry are expected to increase by 4% globally under the IEA Reference Technology Scenario (RTS) by 2050 despite an increase of 12% in global cement production. Realising the sustainable transition of the 2 degree Celsius Scenario (2DS) implies a significant reduction of the global direct CO_2 emissions by 24% compared to current levels by 2050 still with the expected increase in global cement production. This represents cumulative emissions reductions of 7.7 $GtCO_2$ compared to the RTS by 2050, equivalent to around 90% of current total global industrial direct CO_2 emissions.
- Adopting a whole life-cycle approach and working collaboratively along the whole construction value chain offers additional opportunities for carbon emissions reductions beyond cement manufacturing. Optimising the use of concrete in construction by reducing waste, encouraging reuse and recycling, maximising design life and using concrete's properties to minimise operational energy of the built environment, are key strategies in this area.

1. Direct CO_2 emissions refer to emissions that are generated and released in the cement production process.

Cement production by region



Roadmap vision

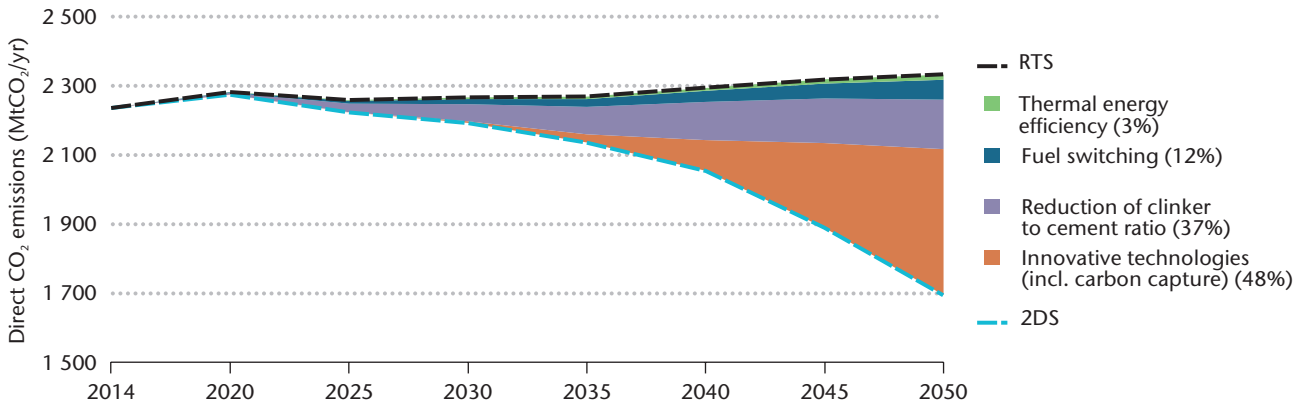
		RTS Low-variability case			Roadmap vision (2DS) Low-variability case		
	2014	2030	2040	2050	2030	2040	2050
Cement production (Mt/yr)	4 171	4 250	4 429	4 682	4 250	4 429	4 682
Clinker to cement ratio	0.65	0.66	0.67	0.66	0.64	0.63	0.60
Thermal energy intensity of clinker (GJ/t clinker)	3.5	3.4	3.3	3.2	3.3	3.2	3.1
Electricity intensity of cement (kWh/t cement)	91	89	86	82	87	83	79
Alternative fuel use (share of thermal energy)	5.6	10.9	14.4	17.5	17.5	25.1	30.0
CO_2 captured and stored ($MtCO_2$/yr)	-	7	65	83	14	173	552
Direct process CO_2 intensity of cement (tCO_2/t cement)	0.34	0.34	0.34	0.33	0.33	0.30	0.24
Direct CO_2 intensity of cement [tCO_2/t cement]	0.54	0.53	0.52	0.50	0.52	0.46	0.36

Notes: *Thermal energy* and *electricity intensities* exclude impacts related to the implementation of other carbon mitigation levers beyond energy efficiency. Electricity intensity excludes reduction in purchased electricity demand from the use of waste heat recovery equipment. *Alternative fuel use* includes biomass as well as renewable and non-biogenic waste. *Direct CO_2 intensity* refers to net CO_2 emissions, after carbon capture. There is an urgent need to mobilise public-private investment to support the sustainable transition of the cement industry. Realising the RTS would require between USD 107 and 127 billion global additional cumulative investments by 2050 compared to the status quo. Achieving the 2DS would require increasing those investments by between USD 176 and 244 billion cumulatively.

Carbon emissions mitigation levers

- **Improving energy efficiency:** deploying existing state-of-the-art technologies in new cement plants and retrofitting existing facilities.
- **Switching to alternative fuels (fuels that are less carbon intensive than conventional fuels):** promoting the use of biomass and waste materials in cement kilns to offset the consumption of carbon-intensive fossil fuels.
- **Reducing the clinker to cement ratio:** increasing the use of blended materials and the market deployment of blended cements.
- **Using emerging and innovative technologies that:**
  - contribute to the decarbonisation of electricity generation by adopting excess heat recovery technologies and support the adoption of renewable-based power generation
  - integrate carbon capture into the cement manufacturing process for long-lasting storage.

Global direct CO_2 emissions reductions between the 2DS and the RTS by mitigation lever



Note: Percentages provided refer to the contribution of each carbon emissions reduction lever to the total direct CO_2 emissions reductions cumulatively along the modelling horizon.

Spotlight: Alternative binding materials

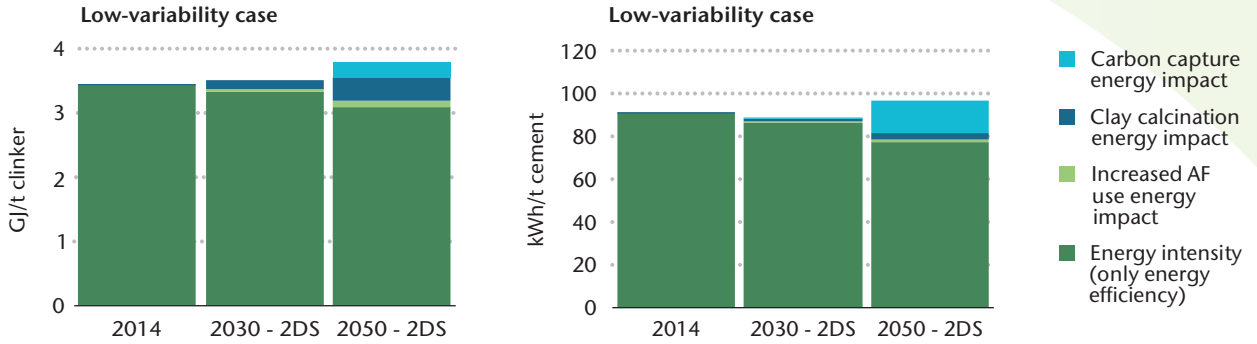
Converting to alternative binding materials: offering potential opportunities for process CO_2 emissions reductions by using different mixes of raw materials or alternatives compared to Portland cement, although their commercial availability and applicability differ widely. Due to the current lack of an independent, publicly available and robust life-cycle assessment for a comparative quantification of the benefits of alternative binding materials, it has not been possible to include them in this techno-economic-based evaluation of least-cost technology pathways for cement production.

Roadmap milestones

	2020	2025	2030	2035	2040	2045	2050
Energy efficiency	Eliminating energy price subsidies.						
	Phasing-out inefficient long-dry kilns and wet production processes.						
	Plant-level or sector-level energy efficiency improvement target setting programmes.						
Switching to alternative fuels and raw materials	Deployment of a circular economy.						
	Strengthening waste management regulations and give priority to waste co-processing versus incineration and landfilling.						
	Exchanging international best practice for traceability, impact monitoring. Training of authorities for permits, control, and supervision. Raise public awareness of the benefits of optimal waste management.						
Reduction of the clinker-to-cement ratio	Developing cement and concrete standards and codes that allow more widespread use of blended cements while ensuring product reliability and durability at final application.						
	Fostering the use of blended cements in sourcing and public procurement policies.						
	Ensuring traceability/labelling/ ethical and responsible sourcing of construction materials.						
	R&D efforts in potential cement blending materials that cannot currently be used due to quality constraints.						
	Promoting international training with national standardisation bodies and accreditation institutes.						
Emerging and innovative technologies	Mitigating risks through investment mechanisms that leverage private funding for low-carbon innovative technologies and through the promotion of private-public partnerships.						
	Achieving the commercial-scale demonstration of oxy-fuel carbon capture in cement production and gain experience in operating large-scale post-combustion technologies in cement plants.		Continuing to accelerate commercial deployment of CCS.				
	Co-ordinating the identification and demonstration of CO_2 transport networks on a regional, national and international level to optimise infrastructure development.						
	International co-operation to harmonise approaches for safe site selection, operation, maintenance, monitoring and verification of CO_2 permanent storage.						
	Developing internationally co-ordinated regulatory frameworks for CCS and to educate and inform public and key stakeholders about carbon storage to build social acceptance.						
	Rewarding clean energy investments and provision of flexibility to local energy grids, for example fiscal incentives for excess heat recovery.						
Alternative binding materials	Supporting the demonstration, testing and earlier stage research for cements based on alternative binders, and to develop standards to facilitate market deployment.		Continuing the commercial deployment of alternative binding materials.				
Transitioning to a low-carbon built environment	Pursuing efforts towards stable and effective international carbon pricing mechanisms encompassed with interim financial stimulus packages and complementary measures to compensate asymmetric pricing pressures in different markets.						
	Strengthening and implementing building regulations aiming at achieving carbon neutrality of the built environment over its entire life-cycle.						
	Enhancing the development and deployment of low-carbon solutions in the construction sector that consider a life-cycle approach, by including them in their public procurement policies.						
	Training architects/engineers on the applicability of low-carbon concrete mixes and blended cements fostering eco-design opportunities in buildings and infrastructure.						

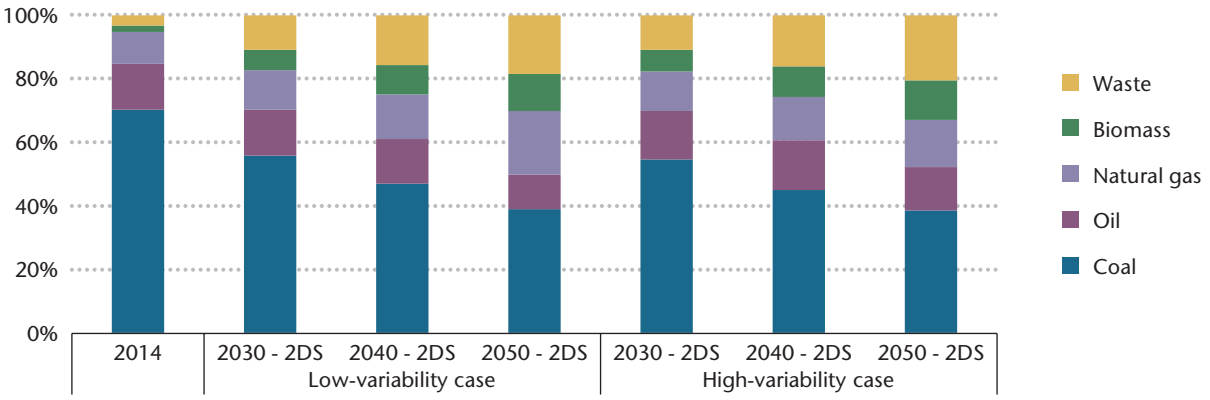
Carbon mitigation levers

Global aggregated thermal energy intensity of clinker and electricity intensity of cement production in the 2DS



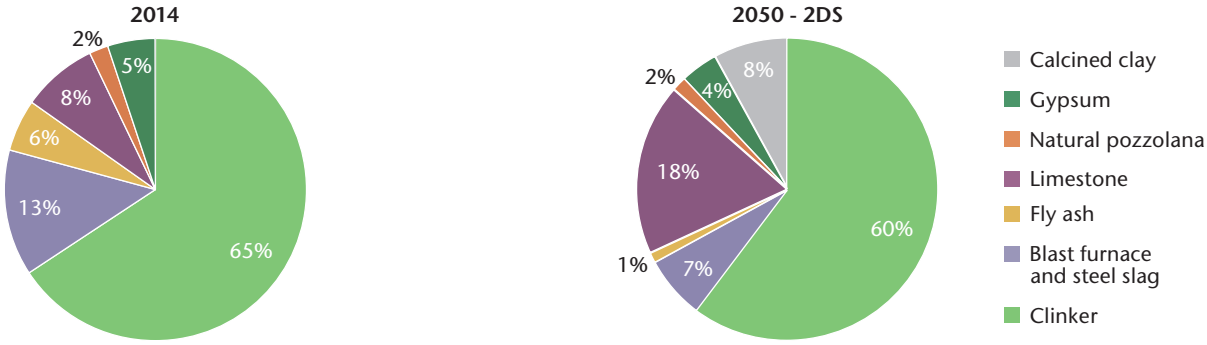
Notes: AF = alternative fuels. Alternative fuels refer to fuels from full or partial biogenic origin or from fossil fuel origin and not classified as traditional fossil fuels, which are used as a source of thermal energy.

Global thermal energy mix in cement in the 2DS



Note: Waste includes biogenic and non-biogenic waste sources.

Global average estimates of cement composition



Notes: Cement composition estimates are provided as shares of cement production on a mass basis. 2050 global average cement composition estimates are based on the low-variability case of the 2DS.

Global deployment of carbon capture for permanent storage in the cement sector in the 2DS