Decarbonisation and preservation of natural resources along the cement and concrete value chain

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Abstract

There are major challenges which the cement industry in Germany and the entire cement and concrete value chain are facing in their quest for climate neutrality and preservation of natural resources. The studies on decarbonisation and resource conservation recently published by VDZ underline the claim of German cement manufacturers to actively promote decarbonisation and to further significantly reduce the use of primary raw materials in the value chain of cement and concrete. Within the context of a 2050 scenario, various potentials for decarbonisation and resource conservation are being identified and quantified. In addition, the necessary prerequisites and action strategies for implementing the savings potential are explained.

Keywords

cement, concrete, decarbonisation, resources, climate neutrality, circular economy, recycled concrete aggregates, concrete fines

1 Introduction

The cement industry and the entire cement and concrete value chain in Germany and worldwide are facing major challenges in their quest for climate neutrality and the preservation of natural resources. The VDZ studies "Decarbonising cement and concrete: A CO_2 roadmap for the German cement industry" and "Resources of the future for cement and concrete" show possible ways of mastering this transformation.

The most important results of the studies are explained below. The base year of the "CO_2-Roadmap" is 2019 and a period until 2045 is examined. In the "Resource Roadmap", a scenario 2050 is compared with data from 2020. Data are given in Mt per year. Further details can be found in the studies available via the following links:

www.vdz-online.de/dekarbonisierung

www.vdz-online.de/ressourcenschonung

2 Decarbonisation: Challenges and opportunities for the cement sector

A particular challenge for cement manufacturers is the fact that approximately two thirds of the CO_2 released in the production of cement can be attributed to raw material-induced process emissions from limestone calcination, whilst energy-related CO_2 emissions from the fuels used account for roughly the remaining third. The German cement industry has taken extensive measures to reduce its carbon footprint in recent decades and has thus successfully cut its CO_2 emissions by

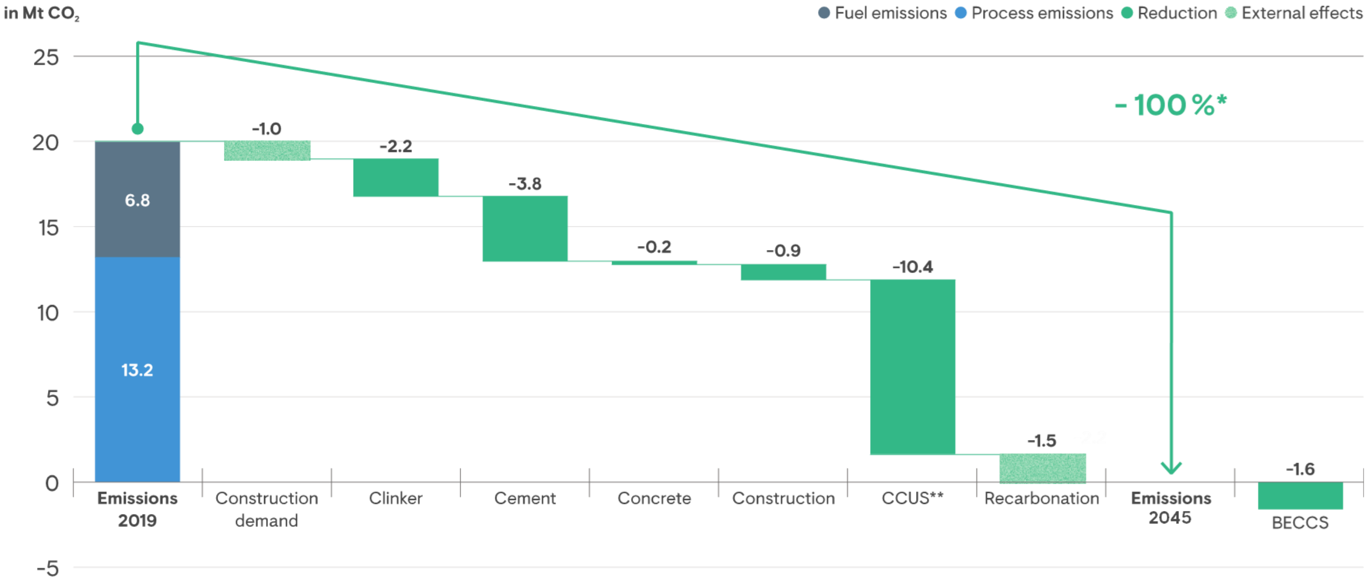
Manuscript for ibausil 2023 - https://doi.org/10.1002/cepa.2814

around a quarter since 1990. Alongside improvements in the area of thermal efficiency, two factors in particular have been crucial to achieving this success: Firstly, a reduction in the clinker content in cement, and secondly, the increased use of alternative fuels containing biomass as a substitute for the majority of fossil energy sources.

The cement industry is, however, reaching the limits of its potential to further reduce CO_2 emissions, as in particular the process-related CO_2 emissions associated with clinker production cannot be lowered by employing conventional means. In addition to partly new CO_2-efficient raw materials for the production of clinker and cement, the further reduction of the clinker content and alongside innovations in concrete manufacturing and construction, efforts to fully decarbonise the sector will rely heavily on carbon capture at the cement plant and its subsequent utilisation and storage (CCUS).

2.1 Climate neutrality scenario 2045

With the exploitation of all available potentials for CO_2 reduction along the value chain, including recarbonation (-1.5 Mt) and slightly lower construction demand (-1.0 Mt CO_2, -5%), the cement industry will achieve net zero emissions by 2045 (Fig. 1). This scenario goes beyond the limits of what is technically feasible today and requires the application of breakthrough technologies.



Source: VDZ / Notes: *Thereof about 88 % reduction through measures along the value chain. Remaining emissions are reduced by a decreasing construction demand as well as the contribution of recarbonation. ** CCUS: Carbon Capture technologies aiming at reducing CO_2 emissions in the atmosphere through CO_2 storage (CCS) and appropriate procedures for CO_2 utilisation (CCU). BECCS: Bioenergy with Carbon Capture and Storage

Figure 1 Scenario climate neutrality – CO_2 reduction by 2045

Clinker

Around 2.2 Mio. t CO_2 can be saved annually in the climate-neutral scenario in cement clinker production. Beside improvements regarding thermal efficiency, the fuel mix consists on average of 90% alternative fuels with a biomass content of 35% and 10% hydrogen.

In addition to the data given in Fig. 1, process-related CO_2 emissions could be further reduced up to 0.6 Mt by using not yet carbonated cement paste from crushed concrete as a largely CO_2-free calcium source for raw meal production of the clinker.

Cement

The further reduction of the clinker factor in cements from currently 71% to 53% in 2045 generates a drop in the clinker demand from around 25 Mt today to around 15 Mt. In addition to CEM II/C cements, CEM VI cements (clinker content between 35 and 50%) are also achieving significant market shares. A considerable use of calcined clays (approx. 4.3 Mt) is assumed in order to compensate for significantly declining blast furnace slag and fly ash quantities. In addition, clinker will have to be replaced to a much greater extent than today by unburned limestone as a locally available raw material and recycled concrete fines. The share of new binders not based on Portland cement clinker is estimated in the study at a maximum of approx. 5% of the cement demand.

Concrete and Construction

The climate-neutrality scenario also requires a different way of thinking about construction. The concrete technology challenges are enormous and implementation requires close cooperation between all those involved in construction. Accordingly, the rules and regulations - especially the concrete standards - must be aligned more closely to the application-specific use of the new cements and concretes. Against this background, the broad market penetration of CEM VI and comparable cements can ultimately be classified as a breakthrough technology. In addition, an increased use of construction methods which achieve a consistent performance with a lower concrete volume (e. g. hollow slabs, carbon/textile concrete) was assumed.

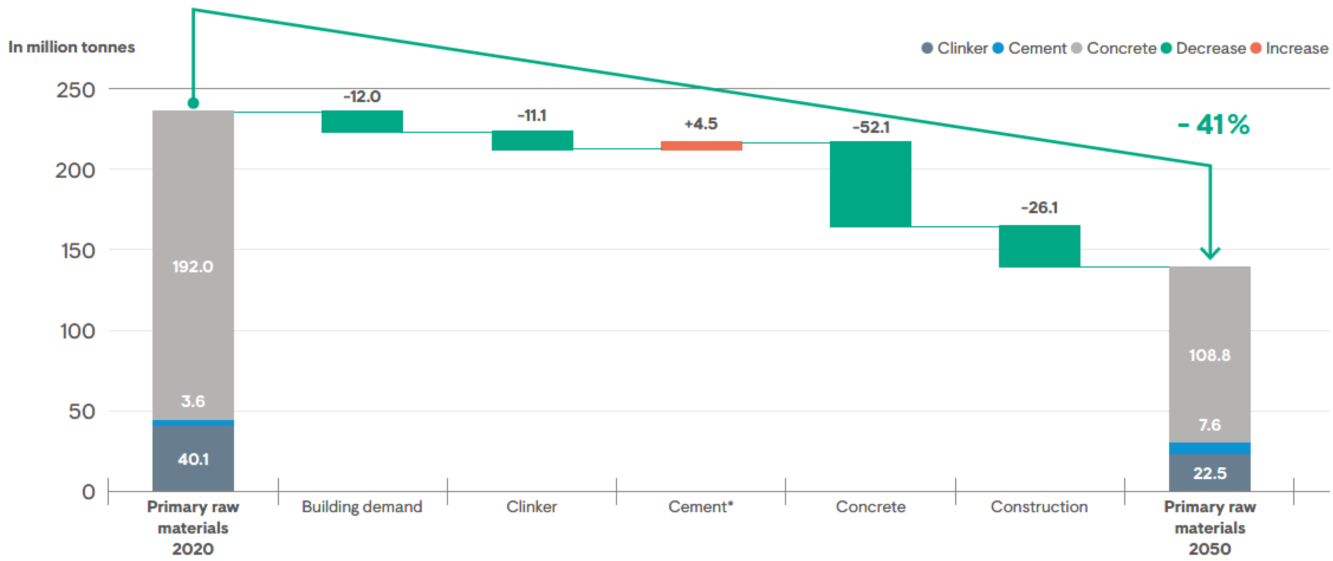
CCUS, (Re)Carbonation

Finally, the climate neutrality scenario also includes carbon capture and its subsequent utilisation and storage (CCUS). This is based on the prerequisite that all other potential levers available for reduction have been exhausted to such an extent that the use of CCUS is solely restricted to the amounts of CO_2 which cannot be reduced by other means (-10.4 Mt).

In the scenario, 20% of the process emissions of the clinker production are recaptured by the concrete (Recarbonation).

In addition to the data given in Fig. 1, a large part of the process-related CO_2 could be recaptured by enforced carbonation (e. g. by the use of flue gas from cement kilns) of not yet carbonated hardened cement paste in crushed concrete or recycled concrete fines. Accordingly, the proportion of CO_2 could be further reduced by approx. up to 2.5 Mt.

Through the sustainable use of biomass-containing waste as fuel in combination with carbon capture (BECCS; Bioenergy with Carbon Capture and Storage) it is possible that the cement industry could even provide a carbon sink with a removal of roughly 1.6 Mt of CO_2 from the atmosphere.



Source: VDZ

Note:

* *Includes primary main constituents and sulphate agents; clinker is considered separately.*

Figure 2 Resource savings along the value chain in the 2050 scenario

3 Preservation of natural resources along the cement and concrete value chain

The production of cement and concrete accounts for around one fifth of the primary raw materials used in Germany each year (approx. 236 Mt, see Fig. 2, 2020). In addition to a small quantity of fossil fuels, these include above all mineral raw materials such as limestone, gravel and sand. Cement and concrete producers are aware of this demand for resources and have long been working on how the production of building materials can be made more efficient and resource-friendly. Alternative raw materials already cover almost 20% of the resources for cement production in Germany, saving around 10 Mt of limestone per year.

3.1 Resource-saving cements and concretes – scenario 2050

In VDZ's resource roadmap a total reduction in the use of primary raw materials along the cement and concrete value chain of approx. 97 Mt, corresponding to a decrease of -41% as compared to 2020, has been determined for 2050 (Fig. 2). The assumptions on the slight de-cline in construction demand in 2050 correspond to those of the CO_2 -roadmap and lead to a saving of around 12 Mt primary resources.

Clinker

In addition to the contributions to CO_2 savings described above, the use of primary raw materials in clinker production can be reduced by around 11.1 Mt. Two measures contribute to this: 2.5 Mt of natural resources can be saved by replacing 10% of the raw meal with recycled concrete fines. With improved separation of the sand components, this proportion could even be increased. A further 8.6 Mt of natural resources can be saved by reducing the proportion of clinker in cement (reduction of clinker factor from 0.71 to 0.53).

Cement

In order to reduce the proportion of clinker in cement and compensate the foreseeable decreasing quantities of granulated blast furnace slag and fly ash, various cement constituents, some of them new, will be required. If the quantities were replaced by natural materials such as calcined clays (4.3 Mt) and limestone alone, this would result in an additional demand for natural raw materials of 8.4 Mt. The use of approx. 4 Mt of recycled mineral fines from crushed concrete or masonry as limestone substitute (approx. 80%) partially compensates for the additional raw material. The additional demand for primary raw materials thus amounts to a total of around 4.5 Mt. Since much larger quantities of recycled mineral fines should be available, further savings could be made.

Concrete and Construction

The greatest potential for savings of natural resources is to be found in the area of concrete manufacture (-52.1 Mt) by replacing a significant proportion of the natural aggregate in the concrete (gravel, sand, natural stone) with recycled aggregates. This quantity was obtained from the estimated concrete volume of around 203 Mt derived for 2050, taking into account the guideline of the German Committee for Reinforced Concrete (DAfStb) on the use of recycled aggregates in concrete. Thus, about one third of the natural aggregates can be replaced by recycled aggregates from the demolition and dismantling of structures. It is expected that the necessary quantities for this can be generated from the construction waste, especially since the proportion of concrete in the structures to be demolished is increasing.

Through the increased use of innovative concrete construction methods (e. g. prestressed ceilings, carbon concrete, functionally graded concrete) around 15.7 Mt of natural resources can be saved. A further reduction of 10.4 Mt was assumed by extension of the service life of structures and the reuse of concrete components.

4 Prerequisites and fields of action

Renewable energy, alternative fuels, CO_2-infrastructure

The decarbonisation of cement and concrete depends to a considerable extent on a supply of green power. More than double the amount of power will be required for clinker production as a result of the widespread use of carbon capture technologies, for example. A further factor of particular significance for the cement industry is long-term access to adequate amounts of alternative fuels containing biomass. There is a need to balance the potential impacts of waste and resource policies on specific material streams accordingly.

From a technical point of view, it will only be possible to successfully master this transformation with the necessary infrastructure, for example for widespread carbon-free power consumption and the transportation and storage of CO_2 and hydrogen. In particular, solutions are needed on how the captured CO_2 can be transported from the cement plant to its destination, for example a chemical park, refinery or storage site.

Level playing field and Green Markets

An effective policy framework which will ensure a level playing field to allow the competitive production of low-carbon, resource-saving cements and concretes is needed. It is necessary to promote markets for “green” products, taking into account that these tend to be considerably more expensive than those produced conventionally.

The demand for resource-saving and CO_2-saving construction must be promoted. Barriers to the use of recycled materials must be removed and targeted incentives must be provided. As large purchasers of construction services, federal, state and local governments can demand recycled building materials and clinker-efficient cements in a selective manner and thus act as trendsetters for private investors. Geographically differentiated recycling quotas in tenders, taking into account local availability, can be an effective instrument for initialising sales markets.

Sustainable material supply management

In the context of the circular economy of cement and concrete, suitable source streams for a continuous supply with recycled building materials must be identified and mobilized. Urban mining, the systematic management of anthropogenic raw material deposits, is of central im-portance. Processing methods, e. g. for waste concrete, must be further developed for efficient urban mining. In urban regions, areas must be provided for the processing of building materials and the intermediate storage of processed materials in order to ensure short transport distances. Ultimately, both the local population and society as a whole will also have to be engaged in this process at an early stage in order to create a common understanding of the technological and economic changes involved to achieve a climate-neutral society.

Communication and qualification

A further decarbonised and resource-saving construction sector will require the cooperation of the entire value chain, from equipment suppliers and concrete manufacturers through to contractors, designers and architects. Along the value chain, much more pronounced awareness and know-how with regard to durability, material efficiency, reuse and recycling will be required in the future. An efficient and successful circular economy requires joint action by all those involved in construction and also thinking in terms of material flows from a life cycle perspective across the entire value chain. In this context, training and further education are of particular importance.

Providing primary raw materials

The raw material mix of the future will contain increasing proportions of recycled materials and reused components, but it will still also be composed of minerals obtained from natural sources such as limestone, gravel, sand, natural stone, clay and gypsum. In other words, the securing of domestic raw material supply remains a further central area of action, as this forms an existential basis for cement and concrete manufacture. Dialogue between members of the political administration, trade, industry and society in general must emphasise the significance of domestic raw materials alongside the increasing use of recycled materials.