Excerpts from ECRA, State of the Art Cement Manufacturing: Current technologies and their future development (2022)

Note: the transformation of captured CO2 to combustion fuel is not included for obvious reasons [1]

ECRA's key findings are:[2]

Page 10, on the thermal energy-demand of the clinker-production process:

> The weighted average of the specific thermal energy demand for this kiln type in 2019 was 3,360 MJ/t cli. The respective figure for 1990 was 3,590 MJ/t cli, equivalent to a reduction of ~230 MJ/t cli over 29 years…Breakthrough technologies which could lead to a significantly higher thermal efficiency are not in sight…Based on these assumptions, the specific fuel energy demand of clinker burning (as a global weighted yearly average) may decrease from 3,460 MJ/t cli in 2019 to a level of 3,300 to 3,400 MJ/t cli in 2030 and to 3,150 to 3,250 MJ/t cli in 2050.

Pages 12–13, on the electricity demand during the cement-production process:

> The global weighted average of the specific electrical energy demand for all participating companies has not been reduced over the past 10 years…Based on these assumptions, the specific electric energy demand of cement production without carbon capture may decrease from 102 kWh/t cement in 2019 to a level of about 100 kWh/t cement in 2030 and to 90 to 95 kWh/t cement in 2050 on average. But this strongly depends on market developments and the required product fineness.

Page 13, on CO2 capture during the clinker-production process (here, "CCUS"):

> If CCUS is applied on an industrial scale, the power demand of cement manufacturing will increase significantly. As described, carbon capture technologies will require high power consumption to e.g. supply consumables like oxygen, pump solvents, operate power driven separation devices like membrane or cryogenic units and purify and compress the CO2 in order to meet the required conditions of downstream processes. Therefore, CCUS will increase power consumption by 50 to 300% at plant level.

Page 15, on the use of Hydrogen during the clinker-production process:

> The biggest challenge is the availability of a sufficient amount of carbon neutral "green" hydrogen, and in particular carbon neutral electricity needed for its production. Currently, the use of hydrogen as a fuel in the cement industry is of no relevance. In the future, an average share of 10% hydrogen of the total thermal energy demand seems possible.

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[1] "The European Cement Research Academy (ECRA) was founded in 2003 as a platform on which the European cement industry supports, organises and undertakes research activities within the context of the production of cement and its application in concrete. By creating and disseminating knowledge from research findings, ECRA's aim is to facilitate and accelerate innovation to guide the cement industry…ECRA understands itself as part of a network which comprises various research facilities such as universities, federal institutes and the research centres of cement companies or equipment suppliers. In this context it is able to develop a knowledge centre which benefits from cooperation with the best institutes in the respective areas of research and acts as a core competence centre providing a broad platform for top researchers in each field…The Academy is steered by a Technical Advisory Board staffed with representatives from major European cement producers under the chairmanship of Ernest Jelito (HeidelbergCement). The Board is responsible for defining the focus and scope of ECRA's seminar programmes and research projects and monitors the Academy's finances" (**here**)

[2] 217 pages, PDF **here**. *See, esp.,* p.2: "The report represents the independent research efforts of ECRA to identify, describe and evaluate technologies which may contribute to increasing energy efficiency and reducing greenhouse gas emissions from global cement production today, and in the medium and long-term future. It includes emerging technologies which aim to achieve net-zero CO2 emissions in the production of clinker and cement". ECRA's stated membership largely mirrors that of Cembureau (**here**).

Page 16, on the use of alternate fuel such as biomass during the clinker-production process:

It is very difficult to predict levels for the future substitution of conventional fuels by waste or biomass fuels due to the large number of economic, political and societal criteria described above. It has to be stressed that the achievement of higher substitution rates depends more on political and legal aspects than on technical ones.

Page 17, on the properties of SCMs and natural pozzolans in concrete:

SCMs can have hydraulic and/or pozzolanic activity or filler properties and contribute positively to the cement performance…All pozzolanas contain siliceous or aluminosilicate phases which can react in the hardening cement paste and contribute to its strength development. In comparison to Portland cement, the early strength of pozzolana-containing cements decreases with the increasing proportion of pozzolana. They show a similar workability, a higher long-term strength and in particular an improved chemical resistance.

Page 19, on the use of natural pozzolans in concrete:

So far and on a global average, the volumes of cement being produced with natural and natural calcined pozzolans is rather low. However, due to their good availability, their lower CO_2 footprint as compared to clinker and their very good contribution to cement performance, these materials will have a great potential to replace granulated blast furnace slag and fly ash as well as clinker in future clinker-efficient composite cements.

Page 20, on the use of SCMs (including so-called LC3 approaches) in concrete:

The increased use of calcined clays, natural pozzolans, ground limestone or recycled fines as SCMs will not only compensate for the decreasing quantities of fly ash and granulated blast furnace slag. These SCMs will also allow to further reduce the clinker factor in all regions. Average cement compositions with 8% to 16% calcined clays or natural pozzolans and up to almost 20 % limestone are partially predicted for 2050. A reduction of the worldwide clinker-to-cement-ratio to approx. 59% seems possible…While SCMs will play a growing role in tomorrow's cements, clinker will still be the most important cement constituent. There is no material in sight today which could replace clinker on a broad scale — with respect to the amount of clinker needed, the availability of sufficient raw materials to produce it, and with respect to its performance in concrete, which ensures safe and durable buildings and infrastructures.

Page 23, on binders as a direct alternative to clinker (i.e. including belite and geopolymers):

The new binding materials and systems presented will develop and enter the market for niche products with regional importance, e.g. for repair mortars, quick cements and other cementitious preparations. Their use and further development depend among other things on legal framework, standardisation processes, CO_2-emission costs, market acceptance etc. Some similarities to Portland cement properties might be of help in developing and understanding the key parameters that determine the long-term performance of the binders.

Page 26, on the use of CO_2 capture during the clinker-production process:

To reduce the technological complexity of the integration of new technologies on the conventional kiln system, separate indirect calcining is proposed to focus on capturing CO_2 from the calcination process only. The capture efficiency is high but still limited to 60-70% of the total CO_2 emissions from the clinker process…Pipelines will be the only long-term solution to transport relevant amounts of CO_2 from industrial point sources to the storage sites. Depending on the local circumstances, in the short-term CO_2 transportation by ship or railway can play an important role. R&D and standardisation efforts for the planning and development of CO_2 pipelines as well as investigations into reusing existing pipelines for natural gas are advancing. Today's projects face transport and storage costs, which can amount to more than 100 €/t CO_2. It is expected that costs will de- crease down to 60 €/t CO_2 based on a fully developed infrastructure.

Page 31, on long-term re-carbonation using concrete:

Compared to the existing recycling practice for concrete, enforced carbonation requires as much concrete as possible which has to be collected for recycling, such as the reuse of crushed concrete components for the production of new fresh concrete (recycled aggregates) or for the cement production (recycled hardened cement paste as an SCM)…For all CO_2-treatment systems, the highly corrosive effect of the resulting carbonic acid on metal elements must be taken into account.

Page 74, on the use of Hydrogen (here, "H_2") during the clinker-production process:

In the future scenario of 2050, where an average share of 10% H_2 of the total thermal energy demand has been assumed, the fuel-based CO_2 emissions decrease by ca. 10% respectively. Long-term tests need to be carried out in order to study the influence of hydrogen on the clinker burning process, and long-term equipment corrosion over a longer period of time… H_2 can be supplied externally in small quantities to a cement plant by truck or train, if larger volumes are needed a pipeline or electrolysis on site is required. In this assessment, hydrogen is produced by water electrolysis. The electrolysis consumes 44 MWh electric energy to produce 1 ton of H_2 with an electrolyser efficiency of 75%. Its production and use are assessed as carbon neutral i.e. the used power originates completely from carbon neutral sources. The mass-based calorific value of hydrogen is higher than that of oil or coke (120 MJ/kg) but, on the other hand, the volume-based calorific value is very low (10.8 MJ/m^3).

Page 110, on the reduction in the availability of GGBFS (slag):

In the long-term, pig iron production will be increasingly shifted to the Direct Reduced Iron-process (DRI) with hydrogen in the context of global decarbonisation. This is expected to lead to a significant decline in the available quantities of blast furnace slag. Findings on the properties of the resulting DRI-slag and its suitability as a cement component are not yet available. Intensive research is currently being carried out on this.

Page 136, on the use of geopolymers as a non-clinker alternative binder:

An up to "90%" CO_2 emission reduction compared to Portland cement is postulated. However, this does not take into account emissions due to the production of the activators (e.g. sodium silicate). In comparisons between Portland cement concrete and geopolymer concretes with an equal performance, geopolymer concretes are mostly more expensive and exhibit mostly a significantly higher resource depletion potential, a higher cumulative energy demand. The global warming potential can even exceed that of Portland cement concrete.

EMC Cement