BUILDING CARBON NEUTRALITY: WORKING TOGETHER ON CONCRETE SOLUTIONS

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ABSTRACT
The Paris Agreement [1] brought about globally a departure from business as usual in many respects. The transition towards net Greenhouse Gases (GHG) neutrality is a global trend that generates opportunities as well as risks for both society and industry. As part of a wider global sustainability agenda, reducing all GHG emissions, must be fully consistent with all UN Sustainable Development Goals [2] and be backed up by a sustainable industrial policy. In Europe achieving the climate change targets while reinforcing Europe's industrial competitiveness at global scale requires urgent action, long-term political leadership, planning, and a stable legal framework over the next decades; both at EU level and in the Member States. The European cement industry has conducted a roadmap based on common metrics to assess the future impact of current climate action. It aims helping to determine the most effective and cost-efficient road towards achieving the Paris goals and beyond. It is estimated [3] that by 2050 specific GHG emissions would be reduced by 32% using conventional technologies and by 80% exploiting breakthrough carbon capture storage/utilization (CCS/U) technologies. The cement sector has taken up a carbon neutrality strategy following a life cycle approach. This approach focuses on four pillars of the sector's industrial roadmap: resource efficiency, energy efficiency, CCS/U, and product and construction efficiency. The circular business economy model to achieve energy and material recovery from waste is utilized to enhance resource efficiency. Moreover, investment in innovation aims in improving the overall energy efficiency of the industry. Finally, although CCS/U technologies research is already being conducted there are still numerous obstacles and limitations that need to be overcome.

INTRODUCTION
Every country in every continent is nowadays affected by climate change. If no action is taken, the world's average surface temperature is foreseen to increase more than 3 degrees centigrade this century [1]. Tackling this global challenge calls for international coordination to assist countries moving towards a low-carbon economy [1]. In that respect, 2015 was a landmark for multilateralism and international policy shaping as both the Paris Agreement and the 2030 Agenda for Sustainable Development were adopted [3,4].

At the 21st Conference of the Parties (COP21) in Paris in 2015, Parties to the United Nations Framework Convention on Climate Change (UNFCCC) agreed on the Paris Agreement to address crucial areas necessary to combat climate change and adapt to its effects [3]. The Agreement among other goals aims to accelerate and intensify the actions and investments needed for a sustainable low carbon future, as well as to strengthen the efforts of limiting the global temperature rise to 2 degrees centigrade [1,2].

The Parties have acknowledged their common long-term vision on the importance of fully realizing technology development and transfer in order to globally build a low Greenhouse Gases (GHGs) emissions and climate-resilient future [3].

In addition, at the UN Sustainable Development Summit in 2015 the UN Member States adopted the 2030 Agenda for Sustainable Development[4]. At the core of the Agenda are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership [4].

THE ROLE OF CEMENT

Cement, considered a cornerstone of infrastructure, is characterized by simplicity, durability, strength, affordability, and the ability to be moulded [5]. Consequently it is the third most used material in the world after air and water [5]/second most used material in the world next to water [6].

Today 70% of the world's population lives in concrete structures [7] making cement a staple in the built environment. In addition cement is used in numerous other infrastructure sectors such as offices, sports facilities, schools, universities, hospitals, transportation, energy and water management, and waste water management [6].

Thus, the manner in which concrete is used can have a profound effect on global emissions. Globally cement production accounts for around 5% of man-made CO_2 emissions [5]. Moreover in the period 1990 – 2015 cement production in EU reduced direct emissions by 36%, shifting from 3rd to 4th place in ranking of industrial emitters [6].

Over the past decades, continuous improvements in Europe have resulted in the reduction of the energy used in cement manufacturing by about 30% [5,8]. And five years ago the European cement industry published its Low Carbon Roadmap [5,8,9] presenting the technology-specific reduction potentials over three time periods, as illustrated in **Figure 1**. According to the roadmap the sector using conventional technologies can reduce CO_2 emissions intensity by 32% (compared to 1990 levels) by 2050 and potentially further by 80% by the application of emerging new technologies that will become widely available, such as Carbon Capture Storage (CCS) [8].

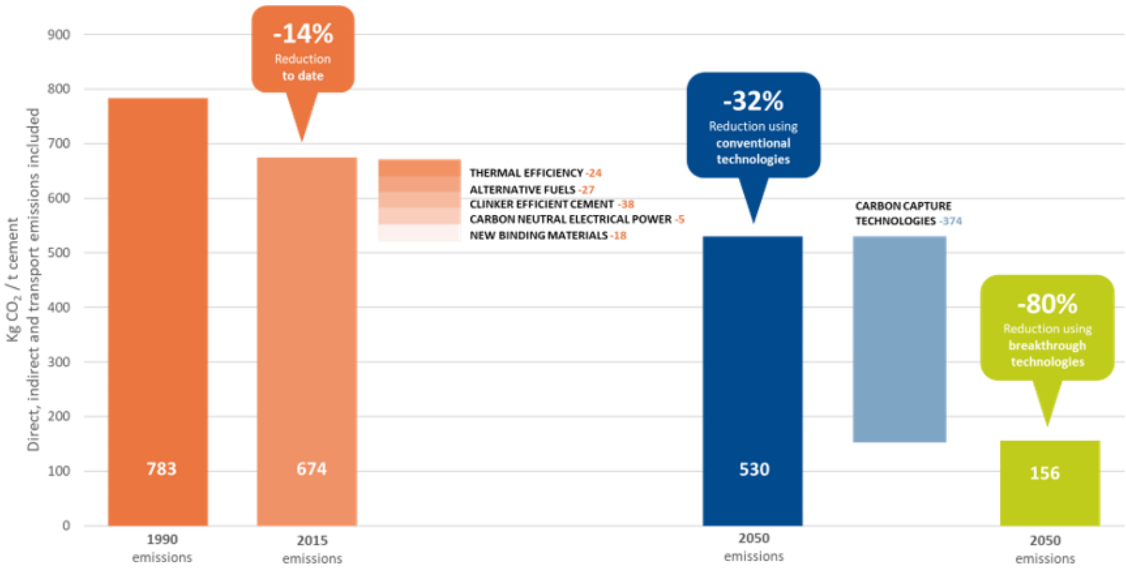

Figure 1*. Technology-specific reduction potentials over three time periods according to ECRA and CEMBUREAU own calculations* [8].

The solutions proposed span over the entire life cycle of the cement and concrete value chain: from raw materials to production, use, re-use, recovery and recycling [8].

CEMBUREAU ROADMAP

The Low Carbon Roadmap of the European Cement Association (CEMBUREAU) analyses different routes and possibilities for achieving a substantial reduction in emissions in cement production. The proposed alternatives are not limited to reducing only CO_2 emissions, but can also contribute to a meaningful decrease in other GHG emissions, as well as to improving energy and resource efficiency [5].

The industry has focused on five routes to achieve these objectives [5]: resource efficiency, energy efficiency, carbon capture and utilization, product and production efficiency, and downstream. The first four routes are relevant to this article's scope and thus presented in further detail.

Resource Efficiency

The cement sector's end goal is to develop and implement a circular economy business model that will make use of waste for energy and material recovery. Research is presently focused and conducted in four areas, co-processing, raw material substitution, clinker substitution, and transport efficiency with most progress and thus focus being on co-processing [5,10,11].

Co-processing of waste is a sustainable development concept that also offers a cheaper solution than investing in dedicated facilities, which require a huge capital investment and often higher operating costs [5].

Co-processing does not only help reducing GHG emissions but it has additional benefits as well. Co-processing will help to conserve non-renewable fuels and raw materials, reducing landfill space as well as achieving zero ash production.

Moreover, the economy will become more competitive as fewer fuels will need to be imported meaning lower fuel costs, and less CO_2 costs.

Finally co-processing offers a safe and low cost waste management solution for member states, which will in turn create jobs resulting in overall growth also in gross domestic product (GDP) increase.

In detail, under a 60 % co-processing rate scenario in EU it is estimated [10] that the member states would cumulatively:

1) Avoid 26.0 Mtonnes of CO_2 emissions

2) Utilise 15.7 Mtonnes of waste

3) Save 11.1 Mtonnes of coal equivalent

4) Avoid 12.2 EUR billion investment in dedicated waste-to-energy (WtE) plants

Energy Efficiency

As displayed in **Figure 2** from 1990 to 2014 kiln thermal consumption (MJ/tn Clinker) in EU was reduced by 18% [12] mainly due to technological innovations. The dry method employed in the production process is combined with a five stages preheater as well as an in-line calciner and a grate clinker cooler. The new burners becoming available can be coupled with modern gravimetric fuel feeding systems and allow for automatic operation and quality control. Advancements in technology also allow for the use of mineralizers for low clinkerisation temperature and can provide an oxygen-enriched environment for fuel burning.

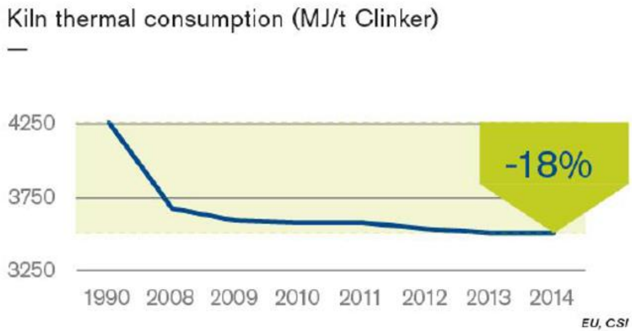

Figure 2. *Kiln thermal consumption reduction in EU from 1990 to 2014* [13].

At the same time the electrical energy consumption in EU (kWh/t Cement) was reduced by 10% [12] as shown in ***Figure 3***. The reduction was mainly also due to innovative solutions becoming available. Indicative innovations include the vertical cement mills, the highly efficient separators, the roller-press for pre-grinding, and the motor inverters. Moreover, the initially used electrostatic precipitators (ESP) have been replaced by bagfilters. Finally, waste heat recovery (WHR) is now used for power generation and drying of fuels and raw materials.

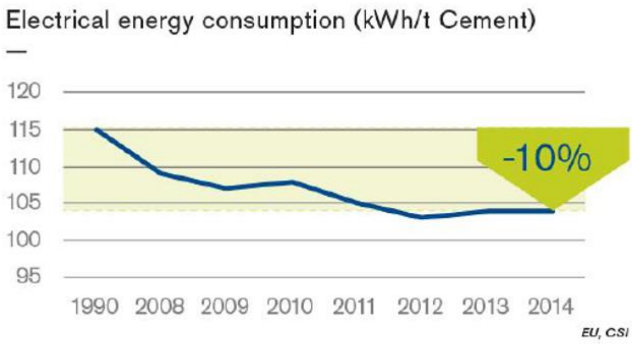

Figure 3. *Electrical thermal consumption in EU from 1990 to 2014* [13].

Following the industry's commitment to investing in innovation the cement sector is at the moment [5,9] involved in several promising research projects. It is expected that these technologies will become commercially available after 2030 as large-scale demonstration projects but education and training of the value chain are necessary before widespread use and being commercially viable [9].

Carbon Sequestration and Reuse

Outside conventional technology, one possible breakthrough and long-term solution is carbon capture, whereby CO_2 is captured at the source and it can then be re-used or stored. Initial results show that currently available technologies could capture 90% of CO_2 emissions [5].

The European Cement Research Academy (ECRA), being at the foreground of innovation, initiated in 2007 [14] a demonstration project to test a new breakthrough technology for the future of carbon capture termed oxyfuel technology. In this procedure, exhaust gases are recirculated to the burner while pure oxygen is added to keep combustion effective. As a result, the share of CO_2 in the exhaust gas reaches 70% or higher and in turn significantly increases the potential for carbon capture.

Based on extensive undertaken research the cement plant of HeidelbergCement in Collefero (Italy) and that of LafargeHolcim in Retzenei (Austria) have put to test for the first time in 2018 this cutting edge technology [14] in order to evaluate in practice if and how it can be incorporated in their cement production process.

Product Efficiency

One of the challenges that we face today regarding renewable energy is the mismatch between energy supply and demand during the day. Flexibility in the electricity grid is of high importance in order to make the most of the energy generated by renewable energy sources (RES), such as wind and solar. Heavyweight buildings can provide this flexibility by allowing consumer energy demand to be shifted in time. That can be achieved by taking advantage of a previously untapped benefit of the thermal mass of buildings. Thermal mass is traditionally used to improve the energy efficiency of buildings and provide a stable indoor temperature. In particular, concrete buildings can provide substantial energy savings during their lifetime. The high level of thermal mass in concrete constructions means that indoor temperatures remain stable irrespective of external fluctuations. But we could now further use the thermal storage capacity offered by the such structures to provide flexibility in energy grids and boost the uptake of renewable energy [15]. This will sharply also reduce the need for extra heating or cooling as well as providing greater comfort. Given that the energy use of buildings accounts for the largest part of their environmental impact, an increased energy efficiency in buildings offsets the impact resulting from materials production.

By taking advantage of the thermal mass of concrete there will be numerous benefits for the society, the environment, and the economy. It is estimated [16] that there will be a 50% reduction in peak electricity as well as a 25% CO_2 reduction per dwelling. In addition, the penetration of RES is foreseen to double.

CONCLUSIONS

The European construction sector aims to be carbon neutral, circular, and yet remain globally competitive. The cement sector can have a pivotal role in addressing many of today's critical issues mainly through sustainable building and infrastructure development. However, for the cement sector's efforts to be effective they have to go hand in hand with concerted efforts supported by the policy makers along the complete value chain to reduce our emissions. The EU rules for by-product and end-of-waste status need to be harmonized and should be complimented by industrial symbiosis national plans. In addition, central monitoring and control will help to achieve economies of scale. Policy makers should focus on rewarding energy storage through concrete to help the overall GHG reduction efforts. Likewise, defining sustainable concrete and low CO_2 structures as funding criteria for awarding circular investments and contracts and in Green Public Procurement will act as additional incentives to accept and embrace sustainable choices.

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