Innovating for a

low carbon Transition of

European Cement

Dominik Wlodarczak

1. Introduction

With regards to combating climate change, the cement industry currently finds itself trapped in a deadlock without easy escape. It generates considerable CO_2 emissions (7% of global CO_2) but in the last decade made no progress in reducing them (Figure 1). At the same time, commercially available abatement technologies already have been exploited to a large extent and strong forces discourage low carbon innovation. To overcome the current CO_2 mitigation deadlock new breakthrough technologies must be developed. This paper explores respective opportunities and addresses the technological as well as the equally important institutional aspects of innovation for a low carbon transition of the European cement industry.

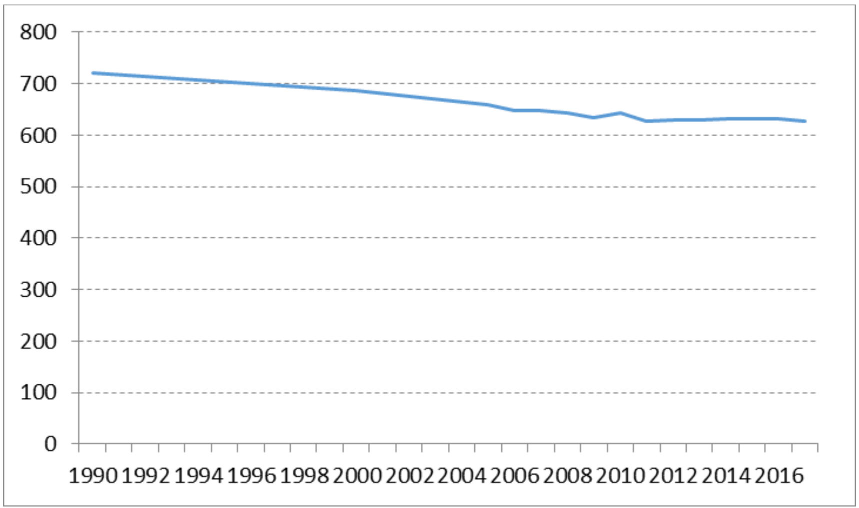

Figure 1: Direct emissions (kg CO_2/t cementitious), CSI/GNR database,EU28

2. Lack of effective mitigation technologies

In cement production, the intermediary product called clinker, generates most of the CO_2. About 60% of the emissions arise from the chemical reaction when burning limestone (process emissions), another 40% from the combustion of fossil fuels. Besides those direct CO_2 emissions, the grinding of raw materials and clinker consume significant amounts of electricity, which, depending on the power mix, generate additional CO_2 indirectly. The industry applies a number of commercial technologies to reduce its CO_2 footprint: clinker substitution, improvement of thermal and electrical efficiency, replacement of primary fuels with waste derived fuels, installation of waste heat recovery systems and development of low carbon cements. Those commercially available technologies are around for a long time and have continuously been deployed and optimized. They mainly aim at improving production efficiency and reducing cost, whereas CO_2 mitigation is a positive side effect. Consequently, the additional CO_2 reduction potential of those technologies remains limited, which explains why no progress was achieved in recent years. If best available technologies would consistently be deployed across Europe, a relatively modest additional reduction of 100 kg CO_2/t cement could be achieved (Table 1). That best case scenario will bring (direct + indirect) CO_2 from the current European average of 670 kg CO_2/t cement down to only 570, leaving the sector still far from an acceptable emission level.

At the same time this scenario requires some expensive measures such as replacing old kiln systems which can cost EUR 80m or installing modern mills which typically come at EUR 20-30m. Because European cement markets offer little growth prospects and some regions suffer from overcapacity, the industry hesitates to commit such large investments. Mobilizing the small remaining mitigation potential of best available technologies thus will be a slow process. For example, since 1990 old kiln systems were replaced with modern ones at an average rate of 0.9% per year. At that pace it will take another 20 years to phase out the remaining old systems.

Lever	Measure	Performance			Reduction ($kg CO_2/t$ cement)
		Unit	Current	Potential	
Thermal efficiency	Upgrade to modern dry precalciner preheater kilns	MJ/t clinker	3'690	3'200	28
Alternative fuels	Increase the thermal substitution rate	%	43	60	19
Electrical efficiency	Replace ball mills with vertical roller mills…	kWh/t cement	116	100	8
Waste heat recovery	Install in all plants	kWh/t cement	0	15	6
Clinker substitution	Reduce the clinker-to-cement ratio with SCMs	Clinker content in %	74	69	41
Low carbon cement	Product innovation	Market share of low carbon cements %	0	0	0
					~100

Table 1: Mitigation potential of best commercially available technologies (author's estimate)

3. Lack of innovation

The European cement industry needs low carbon technology breakthroughs. Yet it only spends about 1% of sales on R&D, figuring at the low end of the industrial universe (Figure 2). The simple reason is: innovation does not pay. Strong institutional, technical and economic barriers discourage innovation.

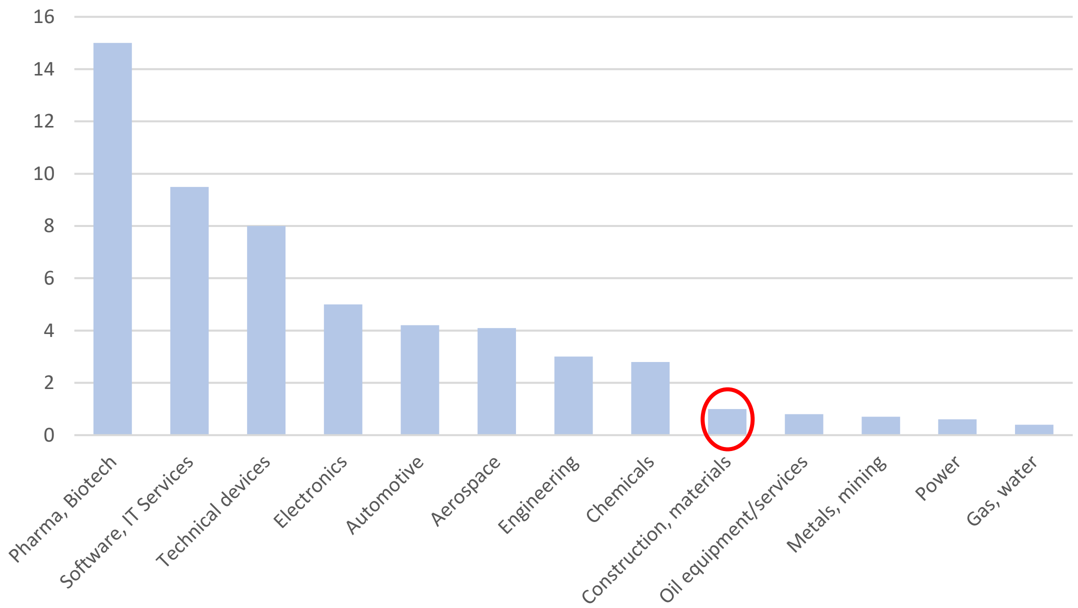

Figure 2: R&D spending in % of sales (Grubb et al., Planetary Economics, 2014)

The existing standard cements have evolved over 200 years and during that time became highly integrated into building codes, processes and construction technologies. They benefit from a long history of learning, experience and optimization. To replace this deeply entrenched system across a fragmented value chain with multiple stakeholders, demands large efforts. New cements for structural applications must meet high performance and safety standards, which can only be proven in real life tests that typically last 10 years or more. Only a handful of major corporations have the stamina to deliver such demanding proofs of concept. Limited raw material availability confines innovation to niche products, preventing full amortization of the large upfront R&D investments. At the same time, low volume cements cannot attain the cost degression needed to compete against the cheap established mass cements. This closes the route to market via niches, a strategy typically followed by innovators. All this turns product innovation into a difficult business case. No wonder that decades of R&D did not produce a new (low carbon) mass cement, despite that every year 100-200 new patents on cement technology are filed globally.
Cement production is highly capital intensive turning innovation into a potential threat for the large installed asset base. This prompts producers to focus on incremental instead of step-changing innovation, which conserves high emission technologies.
Cement and concrete are by far the most consumed building materials. No other material exists in such abundance that could substitute a good part of those extraordinary volumes. Without the risk of being replaced, the current cement system does not experience much pressure to innovate.
Finally, cement is a commodity hard to differentiate with new product features or services. Thus innovation does not offer a competitive advantage. Competition prompts firms to lower prices rather than to intensify innovation. The termination of the cement cartel in Switzerland in the 90s or the cement "price war" in Germany at the beginning of 2000, exemplify those dynamics.
While all these arguments explain the lack of a technology push, a market pull is missing too. Standard cements have matured over such a long time and to a degree where they satisfy most customers' needs. Cement and concrete are cheap and extremely simple and universal to use. Clients do not ask for new products, on the contrary, they rather shy away from innovations. In Europe 95% of construction companies employ less than 10 people. They lack the resources and risk bearing capacity to experiment with new unproven building materials, bearing in mind, that ill performing new building materials can cause severe safety and financial damage. Cement also does not directly interact with end consumers and hence is not subject to changing lifestyle or consumption patterns. For those reasons the market neither demands new innovative cements nor is it willing to pay a premium for it, also not for low carbon cement.
On top of these industry specific issue, some general barriers to innovation exist:

- Profit and growth prospects normally stimulate innovation naturally. But such incentives are missing with CO_2 mitigation technologies as they normally just increase costs but not revenues.
- Investing significant sums into the development of early stage technologies is too risky for the private sector. The same holds for low carbon innovations.
- The commercialization of innovative technologies often requires large scale demonstration projects which are too costly for innovators to build.
- Decarbonizing cement generates large positive returns to society but low or even negative returns to the industry, as climate protection is a public good and knowledge spillovers prevent the innovator from capturing the full benefit from his R&D efforts. Such asymmetric pay-offs discourage private sector innovation.

4. Innovating for supply-side solutions

Given the lack of commercially available low carbon solutions and the slow pace of innovation in the sector, stepping up efforts to develop low carbon breakthroughs is essential. Currently all hopes rest on carbon capture and storage (CCS, see Figure 3). As a result that technology attracts most R&D resources in Europe. Nevertheless, CCS faces multiple headwinds. First, costs are high: retrofitting an existing cement plant with CCS costs at least 2/3 of a brand new plant, subsequently also increasing operating costs by 50% or more.

Second, while the capture technology is currently piloted in the cement industry, the storage part is a bottleneck. Efforts to establish exhausted oil fields in the North Sea as Europe's carbon storage center are in its infancy and the technical and financial feasibility is not proven yet. To put a European wide distribution and storage infrastructure in place will take considerable time and will cause extraordinary costs. Finally, public acceptance of storing CO_2 underground is questionable. Those challenges raise doubts as to whether the current concept of CCS will disseminate fast enough. To address those concerns simpler and cheaper capture concepts should be explored as well. Given the uncertainties surrounding CCS, it would be a highly risky bet to rely mainly on a future breakthrough of this technology. Other low carbon solutions with mainstreaming potential must be developed in parallel and much more R&D resources should be dedicated to them. Clean fuels, cement recycling, heat electrification and certain alternative binders are key options here.

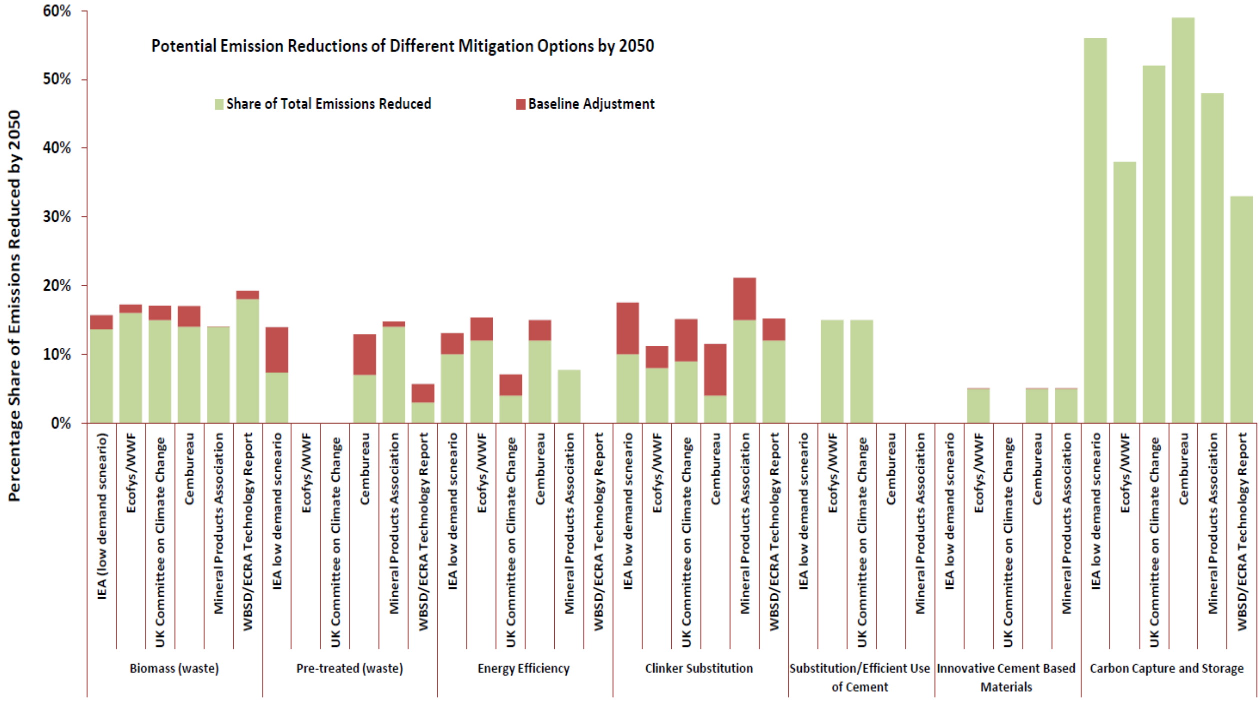

Figure 3: CO_2 mitigation potential estimated by different cement roadmaps (compiled by DIW, Berlin)

5. Innovating for demand-side solutions

As decarbonization of the supply side poses important challenges and will take considerable time, demand-side measures should seriously be envisaged too. Many of these technologies are ready and can be deployed in the short term. They involve strategies such as improving the efficiency of material consumption or extending the life of built objects. A new type of floor slab illustrates the technical potential of such measures. While conventional slabs are made from monolithic concrete blocks, this design consists of a hollow shell with reinforcement ribs all made from fibre concrete. It has the same load bearing capacity as the conventional monolithic version but consumes 70% less concrete. Recent research by Material


Figure 4: Material efficient floor slab (Block research group, ETH Zurich

Economics and others confirms the large potential of demand-side measures. The challenge on the demand side is not so much technology development but rather the integration of multiple stakeholders across the value chain. Implementing respective solutions requires the collaboration of researchers, architects, engineers, investors, standard setters, authorities and the cement sector. As long as cement production continues to emit CO_2, demand-side measures cannot reduce emissions to zero. But they offer an important mitigation potential in the short term, till supply-side solution become available for full decarbonization.

6. Conclusions

The cement industry is deeply embedded in an institutional, technical and economic environment characterized by high standardization and continuity. These conditions enable the sector to operate very efficiently, to produce at an extraordinary scale and supply a high performing, low cost product. However, strong path dependence and resistance to change are the flip side of this highly productive system. The mitigation deadlock prevailing for the last decade (Figure 1) reflects this.

Developing specific low carbon technologies takes a big effort in itself. Putting them to work will not be less demanding, as it requires broader changes to the cement system and value chain. Accomplishing this in an environment that discourages innovation, exacerbates the challenge. Obviously, neither the market nor the private sector are up to such an extraordinary task. Under those circumstances public institutions must take the lead and play an active role in initiating, executing, funding and orchestrating R&D efforts. The complexity of the task, the high risks and resources involved, call for mission-oriented R&D programs which cover all relevant elements needed to bring new low carbon solutions to life.

As it is not possible to predict the success of a new technology, a portfolio of options should be developed. This will increase the chances of getting winners and producing solutions suitable for different environments. In this respect, the current R&D focus on CCS should be revisited in favor of a more balanced technology promotion. Equal priority should be given to the development of alternative technologies such as clean fuels, cement recycling, heat electrification and demand-side measures.