sandbag

The Final Carbon Fatcat

How Europe's cement sector benefits and the climate suffers from flaws in the Emissions Trading Scheme

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EXECUTIVE SUMMARY

Cement is the most widely used man-made material in the world, responsible for 5% of worldwide man-made greenhouse gas emissions.[1] The cement sector in Europe contributes as much carbon pollution as the whole Belgian economy. The **EU's 'flagship' climate change policy, the Emissions Trading Scheme (ETS),** is intended to incentivise emissions cuts and innovation in the cement sector. However, this report finds that whilst most industrial sectors are now facing reducing allowance surpluses, the cement sector surplus continues to grow (see Figure 1), hampering progress towards decarbonisation.

Perverse incentives in free allocation design mean that the EU ETS is likely to have caused emissions in the cement sector to have risen beyond business as usual; we estimate by more than 15 million tonnes. In effect, **'Carbon Leakage' has happened in reverse.** Emissions have been imported into the EU that would not have occurred without the ETS.

We also identify five "Carbon Fatcat Companies" from the cement sector who have **collectively received nearly €1 billion worth of spare EU allowances (EUAs) for free between 2008 and 2014**.

This report shows that deep reductions in cement emissions are possible, if the carbon price rises, over-allocation of allowances is ended, and the ETS is redesigned to support innovation, including new processes beyond Portland cement, and Carbon Capture & Storage.

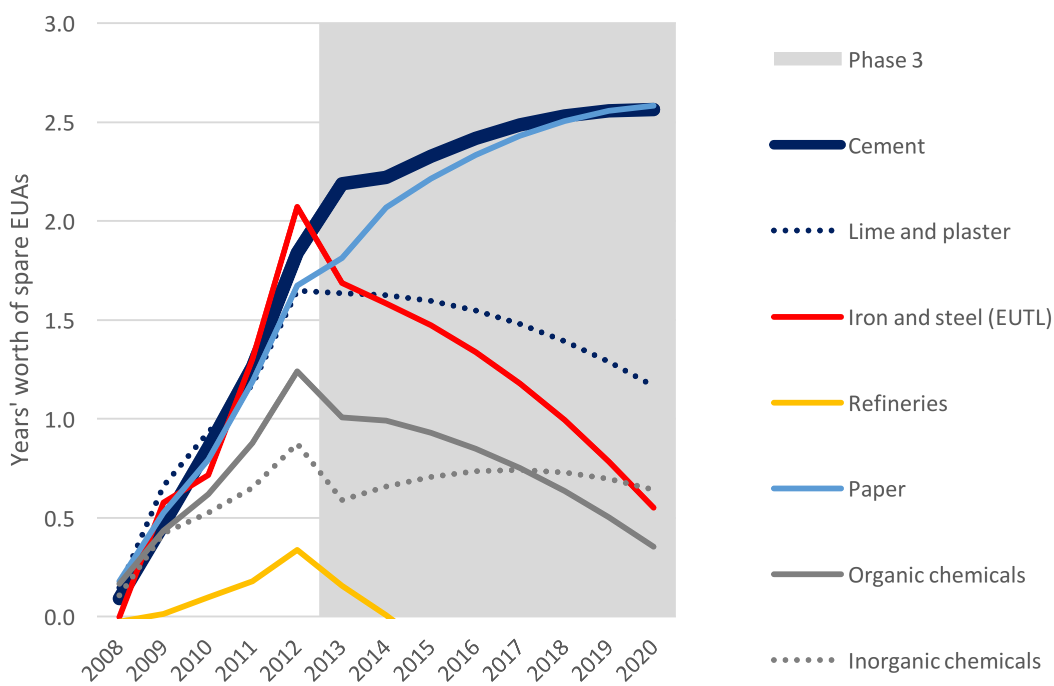

Figure 1: Expected development of allowance surpluses for major industrial sectors until the end of Phase 3. Source: EUTL (Sandbag calculations).

[1] **Low Carbon Technology Partnerships initiative.** (2015) Cement (link).

Cement and emissions trading

Emissions from the production of cement are regulated under the EU's Emissions Trading Scheme (ETS). In 2014 they accounted for 6.3% of ETS emissions. Around two thirds of the sector's emissions are process emissions from chemical reactions in the production of clinker. Clinker is an intermediary material in the manufacture of Portland cement – the variety that dominates the global cement market. The Commission proposal to revise the ETS post-2020 implies a **complete decarbonisation of all industrial sectors by 2058**. To meet this challenge, cement companies will need to fundamentally reinvent themselves – and even swifter emissions reductions may yet be required of them if Europe steps up its ambitions following the Paris Agreement. Fortunately, many technological options exist to decarbonise the sector but existing policy levers are pushing in the wrong direction.

The ETS could assist this transformation, but it is not currently providing a market signal that would set this sector on a transformative pathway, through investments into carbon capture or mass production of low-carbon or carbon-negative cements. Instead, our analysis shows that the existing rules for free allocation act as perverse incentives keeping the production level of high-carbon clinker artificially high. Poor rule design is effectively resulting in the import of carbon emissions into the EU.

We identify six different options for decarbonising the cement sector:

1. Capturing and storing/using direct emissions (CCUS)
2. Burning cleaner fuels
3. Improving kiln efficiency
4. Reducing the share of clinker in cement
5. Replacing Portland cement with non-conventional varieties
6. Developing carbon-negative varieties of cement

The first four levers lie within the scope of activities that the ETS could influence but a number of rules must be improved before carbon pricing can effectively encourage them. Delivering the last two will require additional policy incentives. Outside the ETS, a host of supporting product standards at both the EU and Member States (MS) level certifying new low-carbon cement or cementitious products, as well as demonstration projects and procurement rules, will be required to facilitate the diffusion of innovation in this sector.

So far emissions reductions in the sector have been overwhelmingly incentivised by policies outside the ETS. For example, switching to biomass is supported by the EU-wide 2020 renewable energy target (Renewables Directive 2009/28/EC) and other Directives and MS policies. The widely divergent progress across MSs (see Table 1) demonstrates that national-level targets relating to waste handling and renewable energy have had a stronger impact on fuel switching than the ETS.

Germany	Czech Republic	Poland	United Kingdom	France	Spain	Italy
64.4%	59.5%	47.3%	49.1%	32.3%	29.4%	13.0%

Table 1: Weighted averages for the use of alternative fuels and biomass in the thermal energy consumption of grey clinker production. Source: CSI 2013 (dataset 25aAGFC).

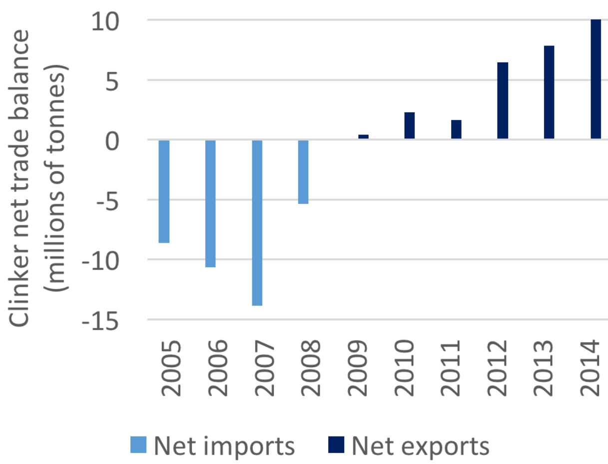

Figure 2: EU net clinker trade. Source: UN COMTRADE (Sandbag calculations).

The ETS so far: A licence to pollute

The depressed carbon price under the EU ETS has done little to effect a reduction in emissions from the European cement sector. A surplus of more than 2 billion EU allowances (EUAs) has built up in the European carbon market since 2008 with no expectations for the situation to change significantly over the medium term. Industry sources cite that the costs of upgrades to best available technology are tantamount to greenfield investments. The current low carbon price alone is not enough to render such investments economic, especially in the context of a depressed cement market. This applies even more so in the case of CCUS which at this stage seems to be an expensive technology merely in the development stages across Europe.

The rules governing free allocation of allowances have failed to incentivise abatement in the cement sector. In particular, the sector's inclusion on the list of sectors exposed to the risk of carbon leakage, as well as insensitivity to production changes will cause its over-allocation to balloon. As we reveal in Figure 1, if activity levels continue at 2014 levels, **by 2020 this surplus will be larger than 2.5 years' worth of emissions**. This is more than would be the case for almost any of the other major industrial sectors, practically all of whom expect to lose all or most of their earlier surpluses by the end of this decade.

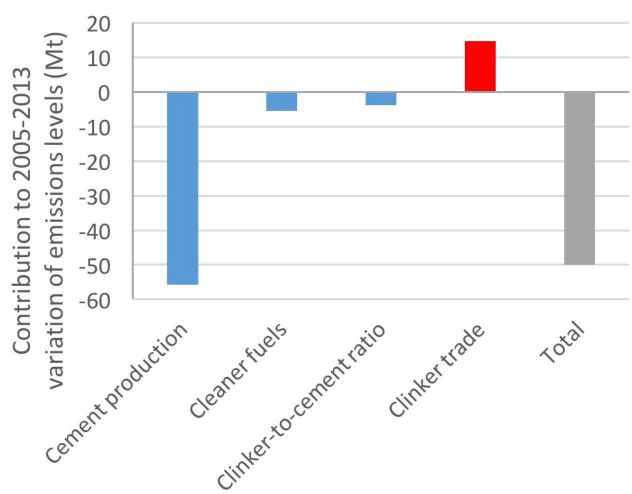

Figure 3: Different factors' contribution to cutting the cement sector's emissions EU-wide during 2005-2013. Source: Cement Sustainability Initiative 'Getting the Numbers Right' database (Sandbag calculations).

The chronic oversupply of EUAs to the cement sector is partly due to the fact that cement firms are able to optimise their production of different products across different facilities to maximise their free allocation. Free allocation to cement installations is based on benchmarks relating only to the manufacture of clinker, an intermediate product. Many firms have been able to retain maximum free allocation, corresponding to peak production, by keeping a range of their facilities operating at just above 50% of their historic activity levels – the level required to retain 100% free allocation. **This free allocation loophole has resulted in both windfall profits and a de facto production subsidy for highly carbon-intensive clinker.** This clinker is then either blended in higher than necessary shares into cement or, as we show in Figure 2, actually exported, as EU cement subsidised by free allowances has a competitive advantage compared to manufacturers outside the ETS. **This creates a net *import* of emissions to the EU – the complete reverse of the carbon leakage threat that many industry groups have emphasised.** As we show in Figure 3, this stimulation of clinker exports to countries outside the EU has been the single most damaging factor to the decarbonisation of this sector, pushing 2013 emissions nearly 15 million tonnes higher than they could have been.

As well as causing a surge in emissions, the insufficiently responsive free allocation rules leave cement companies strongly over-allocated. Table 2 shows the surpluses we estimate that the five cement majors have accumulated (or monetised) since the beginning of Phase 2.

Company	**2008-2014 surplus (Mill. EUAs)**	**Value[2] (Mill. EUR)**	**2014 emissions (Mill. tonnes)**
Lafarge-Holcim	49.8	299.7	18.2
Heidelberg-Italcementi	45.8	275.5	28.1
CRH	31.9	191.8	10.3
Cemex	26.2	157.5	8.0
Buzzi Unicem	10.4	62.5	7.3

Table 2: Largest cement companies' surpluses and emissions (millions of EUAs, euros and tonnes). [3]
Source: EUTL (Sandbag calculations).

These five 'Carbon Fatcats' from the cement sector have collectively received nearly €1 billion worth of spare EU allowances (EUAs) for free between 2008 and 2014. As the number of free allowances available to all industry is fixed, over-allocation to cement companies reduces the allowances available to other sectors that might really need protection.

The ETS therefore provides few incentives for these firms to invest in decarbonisation technologies. Given widespread expectations for an over-supplied carbon market well in to the 2020s and, consequently, a low carbon price, the opportunity cost of holding onto allowances is negligible when compared to the high cost of investment in abatement technologies.

Urgent need to revise the free allocation system

If the ETS is to incentivise change in the cement sector it needs to deliver a higher carbon price. Companies make ongoing investment decisions on a short-term basis. The distant prospect of high carbon prices and a shortage of free allowances in the 2030s provides only a weak guide for investment decisions today, particularly if production levels and cash flow are in decline. The easiest way to increase the short term carbon price signal is to make the ETS carbon budgets more ambitious, thereby reducing the market surplus pre- and/or post-2020. This remains our lead recommendation.

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[2] Carbon price from March 9, 2016.
[3] We ignore offset use here, because the EUTL stopped reporting installation-level data about offset use in 2013. Because offsets are entirely fungible with EUAs, surpluses would be significantly higher, both in terms of allowances and monetary value.

However, irrespective of the question of ambition, it is still essential that policy makers change the free allocation rules to make them both more responsive to production changes and more in line with sectors' actual risk of carbon leakage. **Effective reform can be achieved by introducing more granular production thresholds to existing ex-post adjustments to allocation and by shifting from a binary carbon leakage system (with sectors either on or off the leakage list) to a system that recognises different tiers of risk exposure.** These are two of the most effective tools for changing the status quo. More responsive allocation would mitigate the gaming of production thresholds and the windfall profits to failing industries. Tiered free allocation would continue to protect Europe's most leakage exposed sectors, not least by minimising the risk that a cross-sectoral correction factor will be triggered. It would also avoid giving free allowances to installations that do not really need them.

Need to boost support innovations in industrial abatement

The abovementioned reforms of the ETS would go a long way in driving emission reductions. However, they are unlikely to raise the carbon price to a level which could support the development and deployment of technologies that address the most fundamental obstacle to fully decarbonising the cement sector – its process emissions. **Without Carbon Capture and Utilisation/Storage (CCUS) there will be no future in Europe for the Portland family of cements as the cap approaches zero by mid-century.** An Innovation Fund proposed for Phase 4 of the EU ETS could stimulate innovation in this area. However, we reiterate a previous recommendation that, because this Fund would be financed through the auctioning of allowances, it will need to be contain more of them than currently proposed to compensate for a low carbon price. It will also need to be more targeted towards industrial sectors. We therefore re-emphasise that it will be **necessary to continue funding through programmes dedicating fixed amounts of money for RD&D efforts (e.g. Horizon2020) or for infrastructure (e.g. the European Fund for Strategic Investment).**[4] We also stand by our earlier recommendation that Member States should consider using ETS revenues to support in deep decarbonisation technologies in industrial sectors through instruments such as the UK's contracts for difference or other diffusion-orientated measures.[5]

Policymakers need to create further incentives for the two decarbonisation levers beyond the reach of the ETS – non-Portland and carbon capturing cements. For instance, since the ETS regulates this sector by focusing on the direct emissions from the production of clinker for Portland cement, it is unable to reward the mitigation opportunities to be found in the production of other forms of cement, or to encourage manufacture of cements that produce negative emissions by absorbing carbon dioxide chemically. Unconventional low-carbon cement and concrete products which attain European certification should be backed by public procurement programmes and enabled by climate-sensitive product standards to support the transition to a green construction industry.

Though emissions are down overall compared to 2005, when the ETS was launched, this is thanks to a collapse in demand and to incentives promoting the use of renewable energy, such as the Renewables Directive (2009/28/EC), Waste Framework Directive (2008/98/EC) and Landfill Directives (1999/31/EC). The decarbonisation of the cement sector has not yet seriously begun. It is time for Europe to provide the proper incentives to develop zero-carbon solutions for the future. If it does not, other geographic regions will develop these products and processes for themselves, hurting the future competitiveness of European industry more than any differentials in climate policy could.

[4] 'Discharging the political storm'.
[5] 'Financing deep decarbonisation in industry'.

SUMMARY OF RECOMMENDATIONS

Sandbag advocates strengthening the EU's climate ambition as the best solution to increase ETS scarcity, raise the carbon price and stimulate the transition towards a low-carbon economy – both generally and in the case of the cement sector.

In addition to that we make the following more specific recommendations:

Emissions Trading Scheme (ETS):

- Stop the accumulation of surplus allowances to cement companies by making carbon leakage provisions sensitive to actual risk (tiered free allocation);
- Introduce higher granularity adjustments to free allocation to eliminate perversely rewarding over-production of high-carbon clinker;
- Recycle Member States' auctioning revenues to finance industrial abatement;
- Increase the size of the Innovation Fund;
- Introduce an MRV and crediting mechanism for carbon negative forms of cement.

Non-ETS:

- Develop an EU-level framework to support the generation and diffusion of innovation in industrial decarbonisation through fixed sums of money that are unaffected by fluctuations in the carbon price;
- Harmonise EU-wide landfill regulations, as well as regulations permitting the incineration of these non-conventional fuel types;
- Phase out inefficient production facilities through introducing minimum efficiency standards;
- Narrow the range of allowable clinker shares in Portland cements in European norms of cement and concrete;
- Extend the European norms on cement and concrete beyond the paradigm of Portland cement and promote performance-based standards;
- Engage in demand creation for low-carbon and carbon-negative cements.

1. INTRODUCTION: Cement – The Final Carbon Fatcat

Since its introduction in 2005, the European Emissions Trading Scheme (EU ETS) has regulated emissions of greenhouse gases from all large point sources, including power and heavy industry. Over the years Sandbag has tracked the relationship between the EU ETS and emissions from the sector it regulates. We uncovered the fact that in industrial sectors often emissions were well below the level of allowances given to companies for free, and coined the term 'Carbon Fat Cats' to refer to such over-allocated companies. In 2013 new rules were introduced that changed the way industrial sectors are allocated allowances. Our forward projections from that point on showed that the majority of the fat cats we had identified in the past began to slim down. One large sector, however, stood out, as it continued to grow substantially its surplus emissions, now and into the future: the cement sector.

Cement is the most widely used man-made material in the world, but it is also responsible for 5% of worldwide man-made greenhouse gas emissions.[6] If this sector were a country, it would contribute as much carbon pollution as the whole Belgian economy. In this report we show that, rather than incentivise emissions reductions, the current EU ETS rules are acting in counterproductive ways. Free allocation of allowances to industry is limited in total volume. Therefore, over-allocation to any one sector leads to under allocation to others that may need more protection. A failure to address the growing surpluses in the cement sector will damage the ETS as a whole and exacerbate the risk of carbon leakage, where it genuinely exists. Urgent reforms are needed, and this report contains clear recommendations that must be implemented in the forthcoming review of the EU ETS Directive.

Emissions are down in the cement sector thanks to reduced demand and to a shift towards cleaner fuels that has been brought on by supplementary policies that support switching to waste and biomass. However, the ETS caps will decline to zero eventually. The cement sector has a number of additional options available to it to fully reduce its emissions, but as yet there are insufficient policies to drive investment towards such a transition. In addition to highlighting the flaws in the ETS rules and how to fix them, this report also considers what more needs to be done to support deep decarbonisation. These technologies exist for current cement production processes, as well as for new approaches that, thanks to their reliance on different feedstocks, can potentially turn cement into a net carbon negative product.

About this report

In writing this report Sandbag used in-house data analysis based on publicly available data that we curate ourselves. In addition to the EU ETS Transaction Log (emissions and free allocation), other databases we relied on include the United Nations Comtrade (for cement and clinker trade), the Cement Sustainability Initiative's (CSI) 'Getting the Numbers Right' (cement and clinker production and emissions) and the US Environmental Protection Agency (fuel emission factors).

Much of our analysis relies on a number of analytical tools we have developed in-house. The first one of these allows us to reconstitute what determines Phase 3 free allocation at the installation-level. Building upon its output, we are also able to calculate, with a high level of accuracy, future free allocation under a variety of policy scenarios – also with installation-level granularity. Another spin-offs of our work on Phase 3 allocation allow us to identify variations in activity and instances of partial cessation or closure at the installation level. (It is briefly described in the Annex.)

[6] **Low Carbon Technology Partnerships initiative.** (2015) Cement (link).

We are grateful to the European Climate Foundation for funding this work.

2. CEMENT IN CONTEXT

The production of cement (NACE 23.51) is the third biggest industrial sector in terms of emissions (Figure 4). Following a fall in production of nearly 41% as a result of the economic crises since 2008, the cement sector's emissions are down by 33% relative to a 2007 peak. However, as we show in this report, this fall in emissions is not due to mitigation action prompted by the EU ETS.

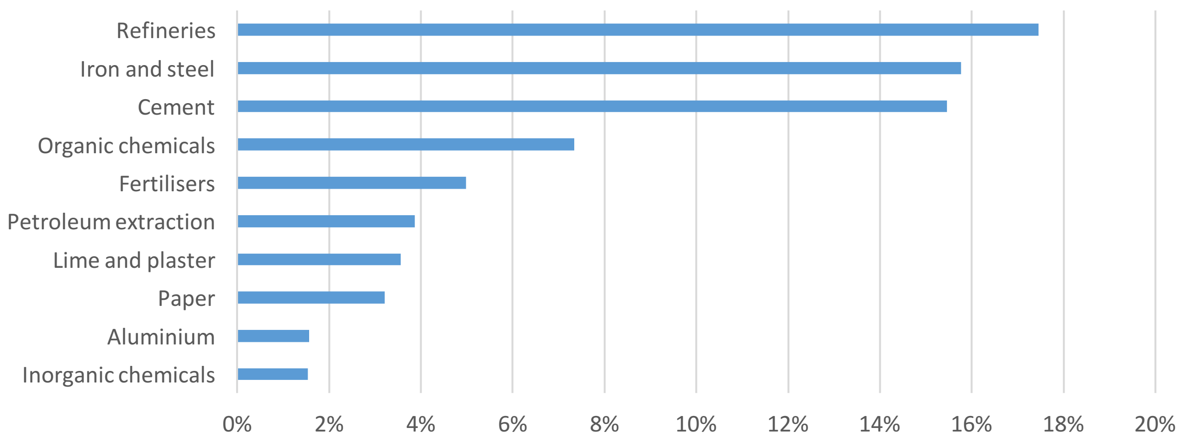


Figure 4: 2014 cement emissions relative to other industrial sectors (all sectors depicted cover 75% of industrial emissions). Source: Source: EUTL (Sandbag calculations).

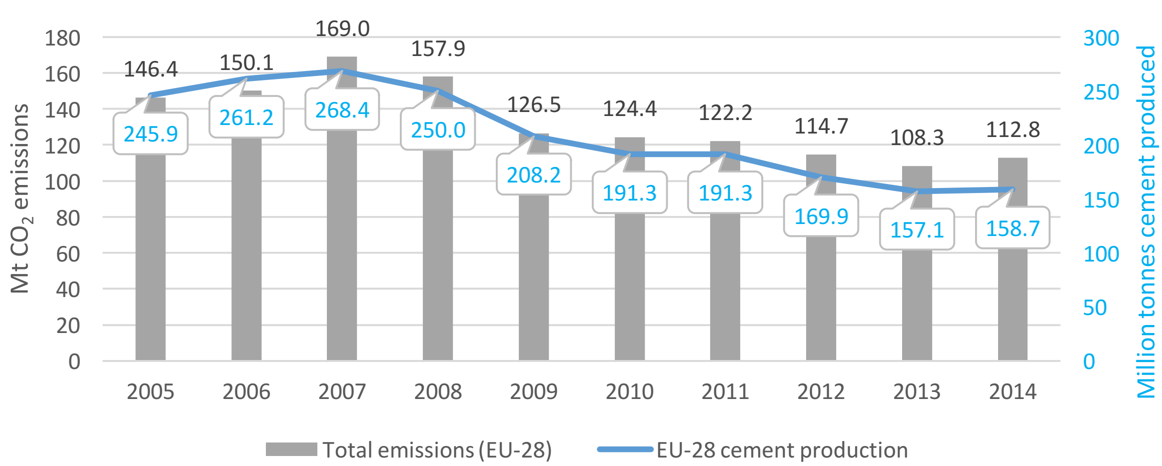


Figure 5: Trends in the cement sector since 2005. Sources: EUTL (Sandbag calculations), Cembureau.[7]

In 2014, ETS emissions from cement production stood at slightly over 114 Mt (just over 6.3% of all ETS emissions, and just over 15% of all non-power emissions under the ETS). As shown in Figure 6, in 2014, nine EU Member States (MSs) accounted for nearly 77% of emissions - with Germany, Spain and Italy in the lead. Corporate ownership is much more concentrated: only five entities were responsible for more

[7] Cembureau's figures consistently represent the same 28 countries, whereas the EUTL data only captures emissions as countries join the EU.

than 80% of this sector's greenhouse gas (GHG) emissions. These companies owned[8] 138 of the 232 cement producing installations listed in the EUTL during the 2014 compliance year.

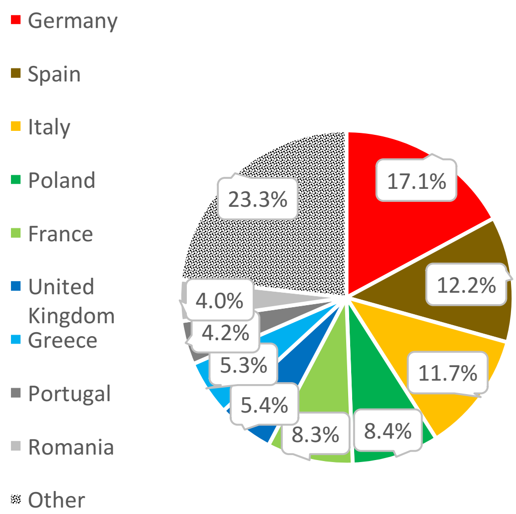


Figure 6: Countries with the highest shares of 2014 ETS emissions from the manufacture of cement. Source: EUTL (Sandbag calculations).

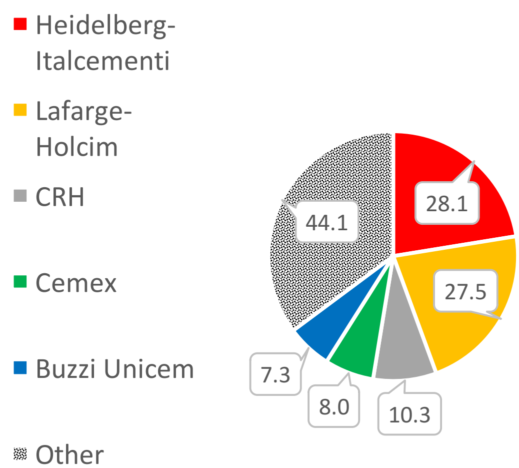


Figure 7: Companies with the highest shares of 2014 ETS emissions from the manufacture of cement. Source: EUTL (Sandbag calculations).

3. LEVERS FOR DECARBONISING CEMENT

The value chain for what is conventionally referred to as "the cement sector" revolves around a product paradigm defined by the Portland process. As depicted in Figure 8, this process extends from limestone to concrete. The vast majority of direct emissions in this value chain occur up to the stage of production of clinker. Two thirds of total emissions emanate from the calcination process, i.e. the chemical transformation of limestone into lime. These "process emissions" are inherent to the production of lime and are therefore unavoidable in the case of Portland cement. The remaining third of emissions are thermal emissions stemming from the combustion of fuels to create the heat required for this calcination and the heat required for the further transformation of lime into clinker in kilns – a process called sintering. Relatively little direct emissions occur further downstream.

Figure 8 depicts six major levers for achieving emission reductions from the cement sector: applying carbon capture and usage or storage (CCUS) to process emissions; increasing kiln energy efficiency; using alternative fuels; substituting clinker with other materials; using non-Portland cements; and developing cements that can actually capture carbon. Of these, the EU's emissions trading scheme (ETS) can directly incentivise only the first four. Additional policies are needed to trigger the others. Section 6 of this report looks at the different levers for decarbonising the cement sector in more detail.

[8] By "owned" we mean "held at least 50% of shares".

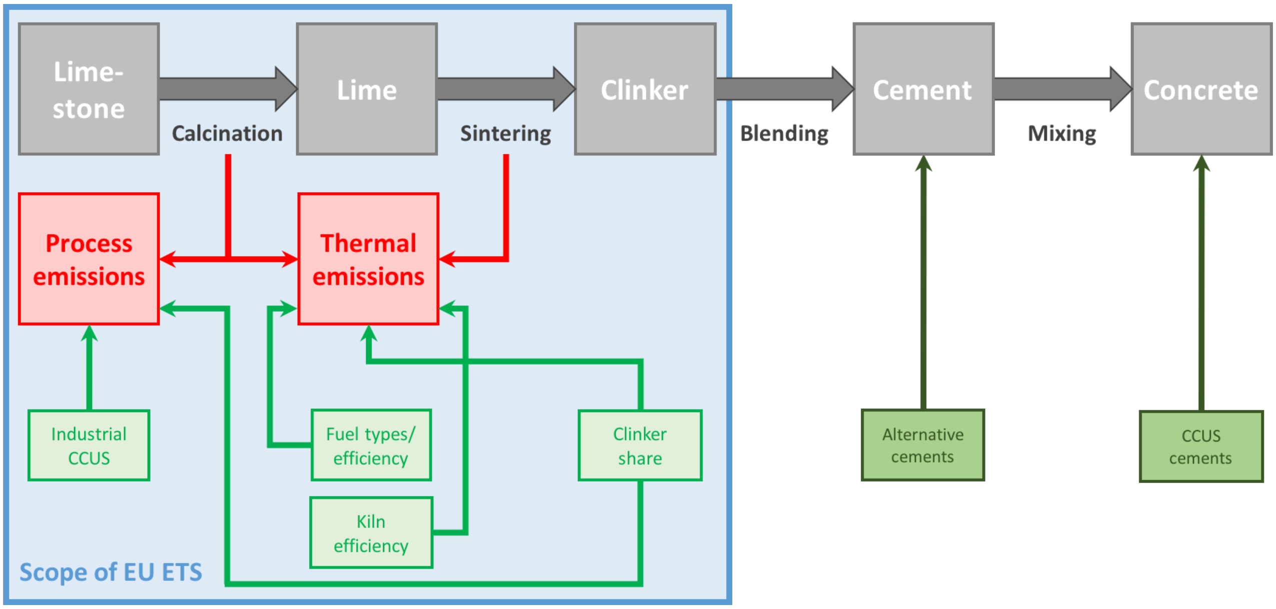


Figure 8: Schematic representation of the Portland cement paradigm.
Note: Red = emissions sources. Light green = decarbonisation levers for Portland cement. Dark green = decarbonisation levers for non-Portland cement.

4. CEMENT UNDER THE ETS

4.1. Ineffective decarbonisation incentives

Phase 3 rules on free allocation have turned the ETS into a production subsidy for clinker – a material with high embedded carbon content. This is hugely counterproductive for decarbonising the cement sector. To understand why this has occurred it is crucial to grasp that the ETS, though nominally regulating the cement sector, is largely focused on the production of clinker. Both measures determining free allocation, i.e. historical activity levels and product benchmarks, refer only to this stage of the value chain.

Although Europe has indeed steadily improved the efficiency of clinker production (Figure 9) this has very little to do with the ETS (see sections 6.2 and 6.3 for details). Furthermore, data from the CSI reveals that, in some regions outside Europe, performance is better than the EU average and that laggard regions are catching up. We acknowledge that CSI covers 96% of European cement production whereas the coverage is much more severely restricted in other regions. However, the point still holds - the European average efficiency is being held back while much more efficient entities are emerging elsewhere.

While Europe may be among the world's leaders in the carbon efficiency of clinker production, the efficiency gains in Figure 9 are only an improvement of 9% relative to 1990. This is why the emergence of incentives to overproduce is cause for alarm. As we show in Figure 10, clinker and cement production historically used to evolve hand-in-hand until 2011. However, since 2012 the trend has been to overproduce clinker relative to cement. In section 6.4 we show that in some countries this extra clinker has gone into cement, increasing the proportion of clinker share in the final product. The remaining excess clinker, as Figure 10 reveals, has gone abroad.

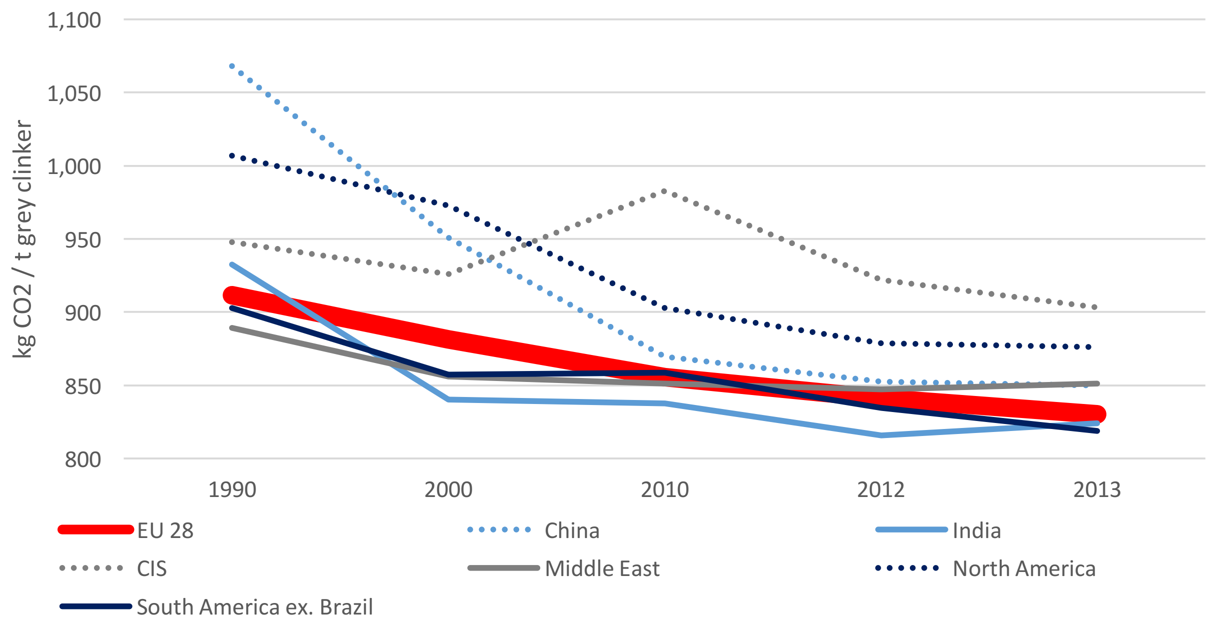


Figure 9: Regional trends in gross CO_2 efficiency of grey clinker production. Source: CSI 2013 (dataset 59cAG).

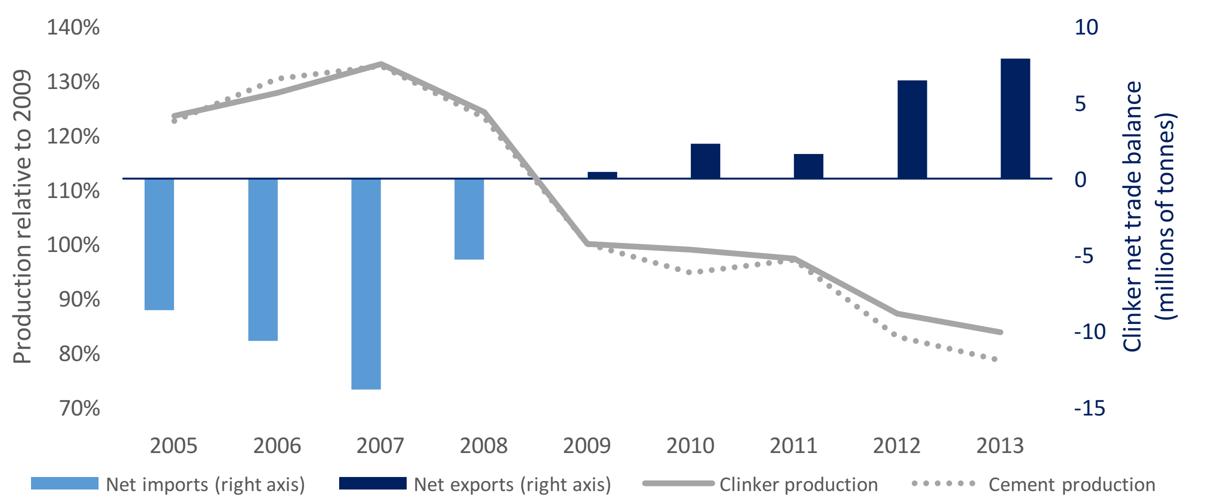


Figure 10: Divergence in clinker and cement production (2009 level = 100%), against the EU's net clinker trade with the non-EU world. Source: CSI 2013 (datasets 8TG, 21TGWcm) and UN COMTRADE.

These exports of clinker are a noticeable drag on decarbonising the sector. As we show in Figure 12, in 2013, the latest year for which data on cement production parameters is available, the production of traded clinker has pushed the sector's emissions 15 million tonnes above what they would have been if the trade balance had been the same as in 2005. We show below how the ETS has driven this increase in cement sector emissions.

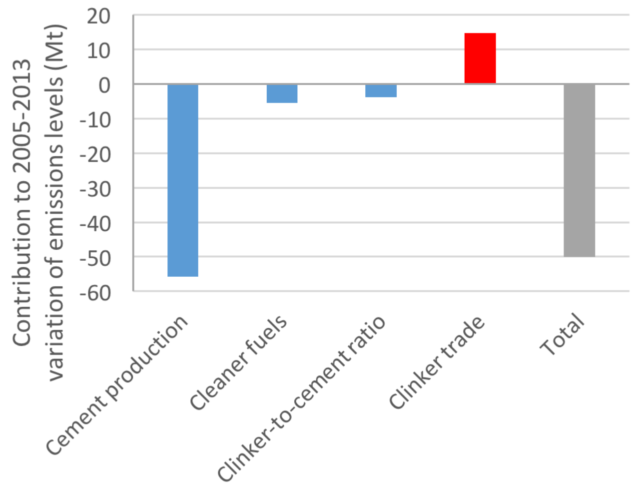


Figure 11: Different factors' contribution to cutting the cement sector's emissions EU-wide during 2005-2013. Source: Cement Sustainability Initiative 'Getting the Numbers Right' database (Sandbag calculations).

We trace this tendency towards overproduction to new rules that were introduced in 2013. These reduce free allocation if clinker production dips below certain thresholds in a previous year (see section 4.2 for details). In the case of the cement sector these rules create a strong incentive to keep clinker production levels just above those thresholds in order to capture free allocation in full. **Far from exposing the sector to carbon leakage, the ETS has incentivised the importation of carbon emissions to serve other markets by creating a subsidy for European producers.**

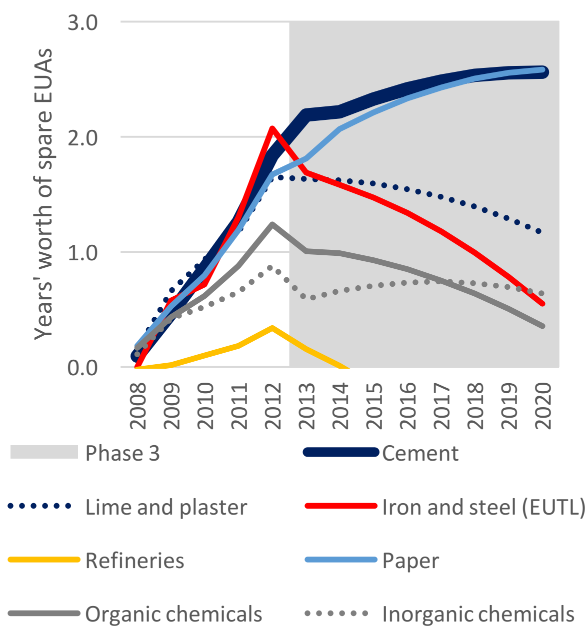


Figure 12: Expected development of allowance surpluses for major industrial sectors until the end of Phase 3. Source: EUTL (Sandbag calculations).

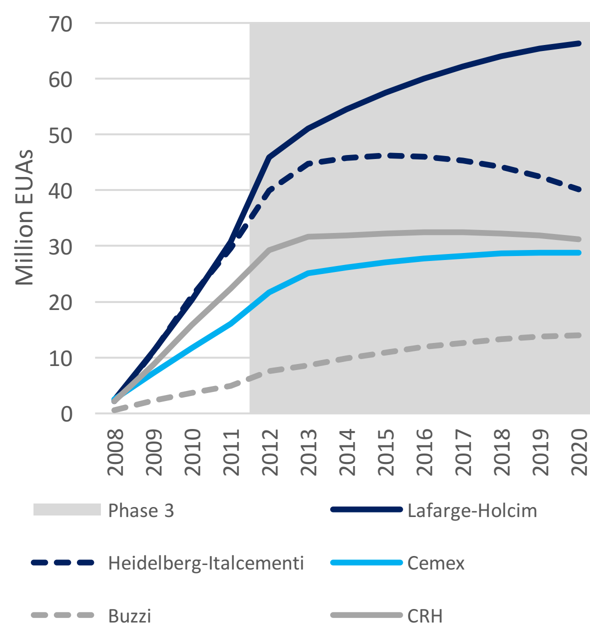


Figure 13: Estimated scale of allowance surpluses by end of Phase 3 for the five largest cement manufacturers of 2014. Source: EUTL (Sandbag calculations).

This possibility to gain free allocation by overproducing a carbon-intensive material means that the cement sector can actually still increase its surplus – unlike other sectors which lost this ability in 2013 when harmonised product benchmarks were introduced. Figure 12 reveals that this surplus will continue to grow in each year of Phase 3 – although at a slower pace than in Phase 2.[9] This finding also holds for the largest companies in this sector, our 'Carbon Fatcats'. These have managed to accumulate considerable surpluses since 2008 (see Table 3) and, as we show in Figure 13, their surpluses mostly continue rising towards 2020.[10] This creates a problem for incentivising decarbonisation. The price signal cannot get through when the regulator allocates more allowances than there are corresponding emissions.

Company	**2014 surplus**	**Value (March 9, 2016)**	**2014 emissions**
	Mill. EUAs	Mill. EUR	Mill. tonnes
Lafarge-Holcim	49.8	299.7	18.2
Heidelberg-Italcementi	45.8	275.5	28.1
CRH	31.9	191.8	10.3
Cemex	26.2	157.5	8.0
Buzzi Unicem	10.4	62.5	7.3

Table 3: Scale of largest cement companies' surpluses and emissions (millions of EUAs, euros and tonnes). Source: EUTL (Sandbag calculations).

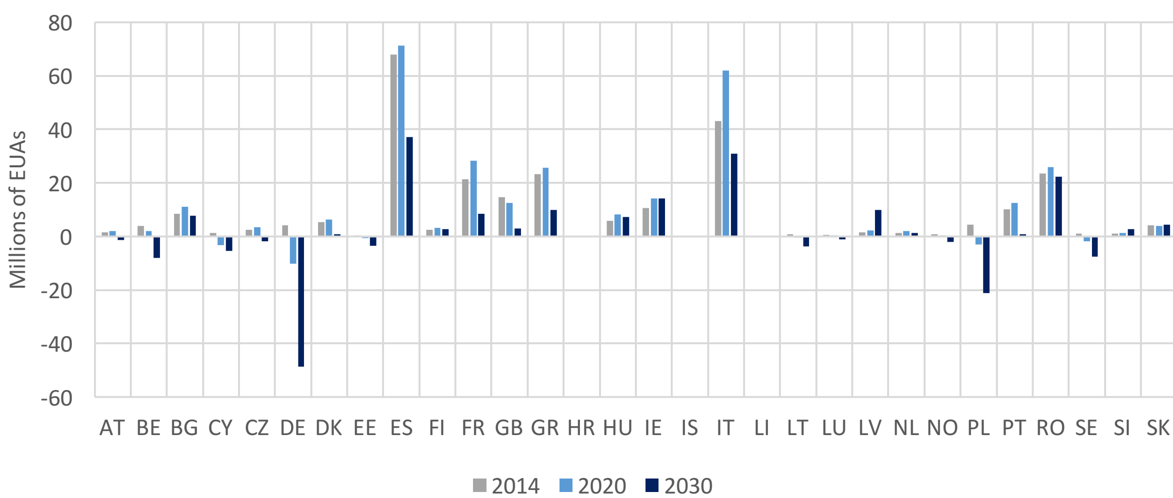


Figure 14: Expected surplus volumes for cement sector companies across EU MSs – now and in the future.[11] Source: EUTL (Sandbag calculations).

[9] We present surpluses in terms of the years' worth of emissions they could cover to account for differences in sector sizes. Emissions are held constant at 2014 levels.

[10] We acknowledge some of these companies' statements about having sold off large parts of these surpluses. However we point out two things: first, that they have received tens, if not hundreds, of millions of euro for these allowances, and second, as Figure 13 implies, the rising slope of the surplus curves during Phase 3 means that they could rebuild these surpluses from scratch towards 2020.

[11] Future emissions are projected forward at constant 2014 levels.

Allowances continue to be allocated in full to companies in the cement sector all across the EU despite substantial falls in production, triggering chronic surpluses across the EU (Figure 14). Particularly egregious are the cases of Italy and Spain, where surpluses are expected to total over 60 million EUAs even in 2020. Although the Commission's Proposal for the ETS Review would reduce the amount of allowances allocated to cement companies, around half of these volumes could persist until 2030 in these two countries.

More pressing than the problem of surplus sizes is the problem of how many years' worth of emissions these surpluses could cover. Under the current Proposal, not only in Italy and Spain but in the majority of MSs, these surpluses could in fact last all the way to 2030, at which point they would still cover very many years' worth of emissions (see Figure 15). This means that the system of free allocation for Phase 4 must be radically revised if incentives to decarbonise are to return to this sector.

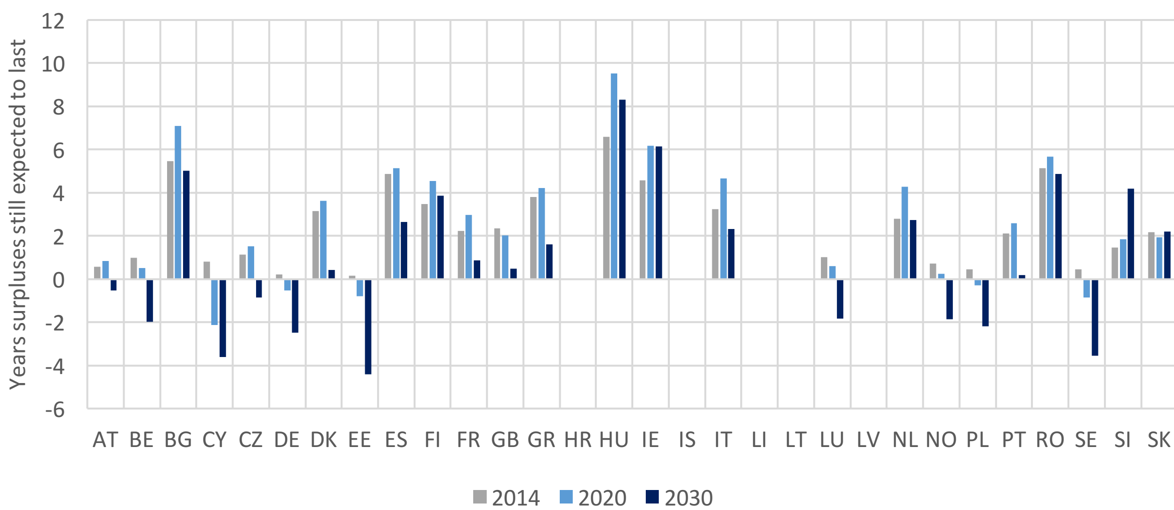


Figure 15: Expected years of emissions surpluses could cover for cement sector companies across EU MSs – now and in the future.[12] *Source: EUTL (Sandbag calculations).*

There are two reasons why the cement sector is so strongly over-allocated relative to others. First, the volume of allowances it receives for free is disproportionate to its exposure to the carbon leakage risk. Second, it retains a far too large volume of allowances in spite of significant falls in production. Below we explore these causes and how to solve them.

4.2. Problem 1: Too little adjustment

4.2.1. Cause

The current rules adjusting installations' free allocation are too coarse and must be changed. As of Phase 3, ETS installations receive free allocation in proportion to their respective historic activity level. This is determined ex-ante before the Phase even began – locking in free allocation for all years until 2020. So,

[12] Future emissions are projected forward at constant 2014 levels.

if production suddenly falls, allowances are still allocated each year even though there are no corresponding emissions. This imbalance between supply and demand causes the ETS-wide surplus to rise. Furthermore, because allowances have value, installations in this situation gain windfall profits. Rules on partial cessation and closures (PCC) were designed to limit the impact of these two problems.[13] Unfortunately, as we show in Figure 16, the current rules only adjust allocation if production falls by 50% or more, creating a strong incentive to maintain production at just over 50%.

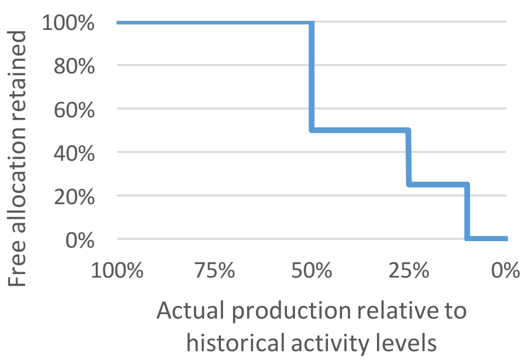


Figure 16: Current rules for adjusting free allocation. Source: Decision 2011/278/EU.

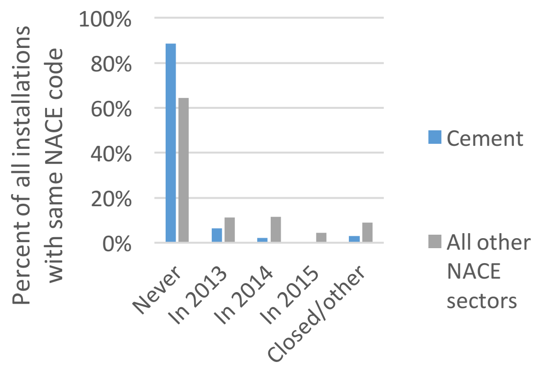


Figure 17: Estimated ability of Phase 3 PCC rules to capture changes in cement sector relative to other sectors. Source: EUTL (Sandbag calculations).

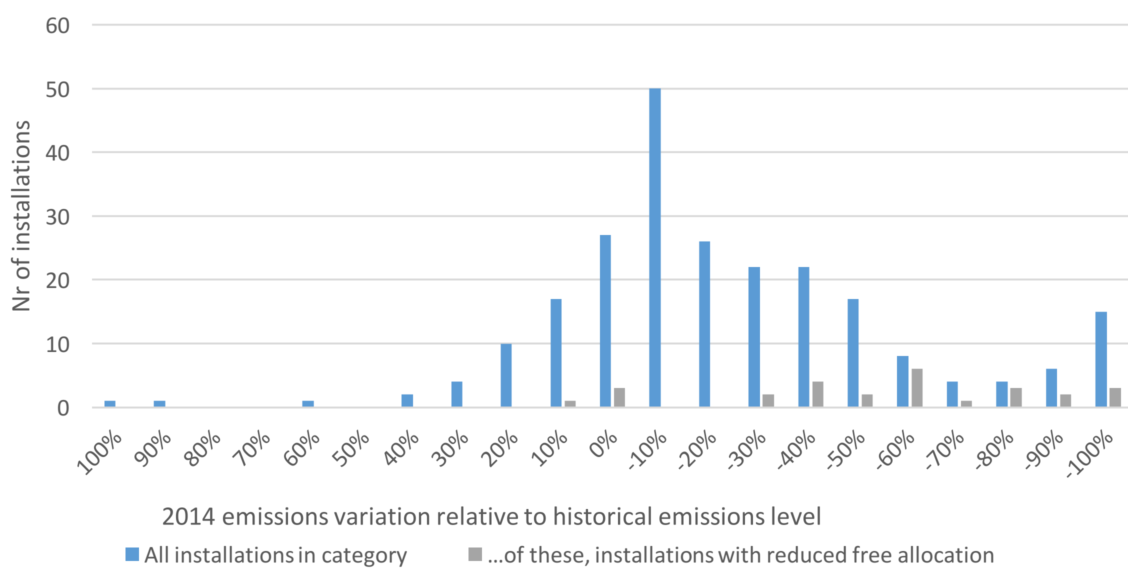


Figure 18: Ability of the PCC rules to adjust the cement sector's free allocation levels relative to variations in production. Source: EUTL (Sandbag calculations).

Our analysis of Phase 3 free allocation shows that, of all sectors, the cement sector seems particularly adept at gaming the PCC rules (see Figure 17). So far in Phase 3, cement installations have been nearly a

[13] There is a slight simplification here: free allocation is actually determined on the sub-installation level. Unfortunately, the EU Transaction Log only provides public data at installation-level granularity, which is why "installation" is commonly substituted.

third more likely to reap windfall profits due to the design limitations of PCC rules than installations in any other sector. Conversely, installations in all other sectors have been more than three times as likely to suffer PCC adjustments at least once.

PCC rules seem particularly ill-suited for coping with the range of changes that happen in the cement sector. As we also show in Figure 18, most cement sector installations experience variations in activity levels that are below the first threshold of the current rules for withholding allowances.[14] The figure groups all cement installations into categories based on how much they have diverged from their historical activity levels. It then also reveals how many installations the PCC rules have actually captured in each category. The difference between those two values in absolutely all categories unequivocally shows how poorly these rules limit surpluses and windfall profits in the cement sector.

The poor design of these rules means that emissions in the cement sector are actually higher than they need to be. Large companies that own multiple kilns are able to optimise production levels across multiple installations in order to get 100% free allocation even though most, if not all, installations are not running at full capacity. This keeps inefficient installations with high carbon intensity running. As we show in Figure 19, the variation in activity levels between pre-crisis years and 2013 in the most efficient three categories of kilns is larger than the total 2013 production volume in the least efficient kilns. This means that there is more than enough efficient production capacity in the EU to make inefficient kilns redundant, but the crude PCC rules, by giving these installations millions of euros worth allowances, keep these installations emitting CO_2.

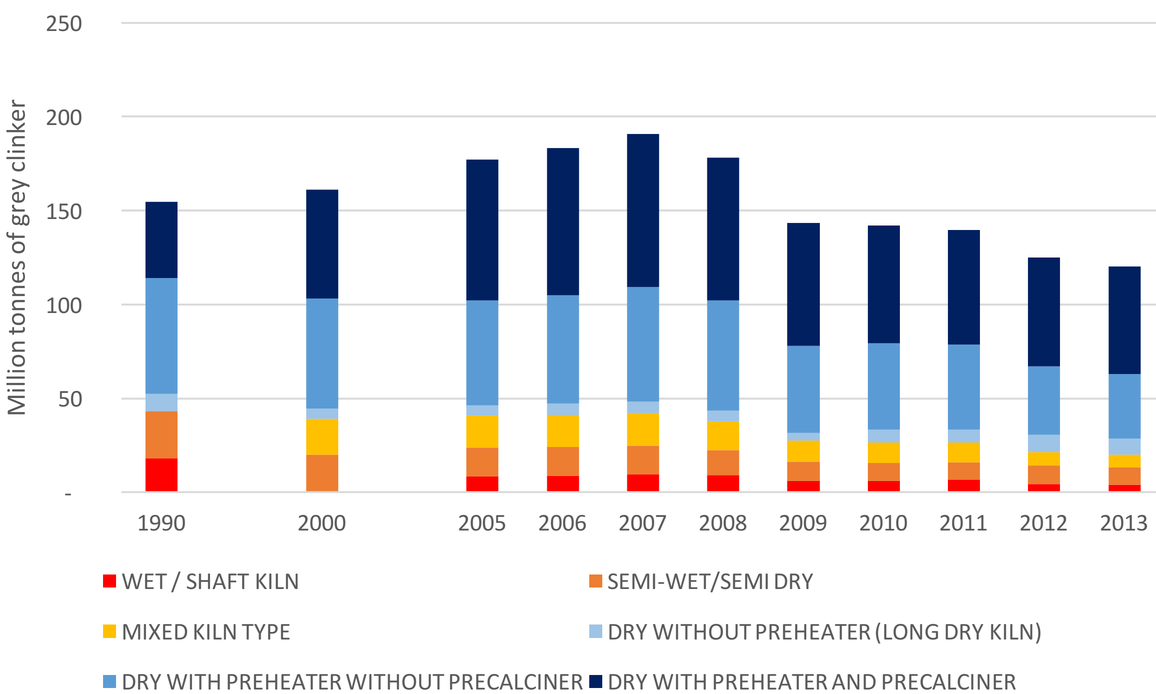


Figure 19: Grey clinker production type over time. Source: CSI 2013 (dataset 8TGK).

[14] Because the EUTL does not offer data on installations' activity levels, we had to rely on emissions as a proxy for activity. Using the methodology described in the Benchmarking Decision, relying yearly mean values, we calculated "historical emissions levels" for each installation in the cement sector. Figure 18 compares 2014 emissions against these levels.

4.2.2. Solution: Introduce a higher granularity of free allocation adjustments

We believe that introducing 10% adjustments to free allocation for each 10%variation in activity levels, as depicted in Figure 20, would be the most effective way of dealing with this problem. Such a change would not only be able to deal with such problems no matter what sector they appear in, but would also allow for increasing free allocation in case production rises above the historical activity levels – something that is not possible under current rules.

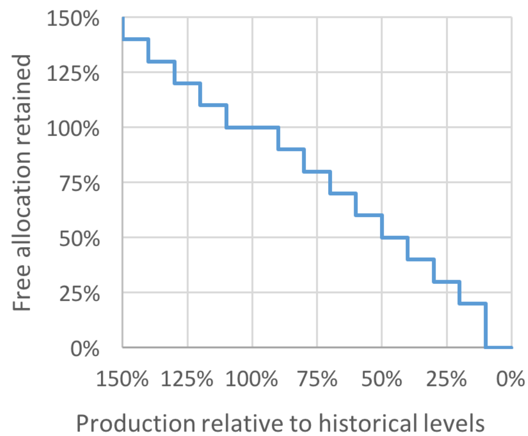


Figure 20: Suggested rules for Phase 4 free allocation adjustments. Source: EUTL (Sandbag calculations), Sandbag proposal.

4.2.3. Expected results

We calculate in Figure 21 that, if such rules had been in place already at the beginning of Phase 3, the net result after also allocating allowances for installations experiencing growth would have been to withhold nearly 180 million EUAs over the duration of the Phase – almost 5 times more than we estimate were withheld under the current rules. This would not only have dampened cement surpluses, but, being such an enormous value (a fifth of all free allocation for all stationary ETS sectors for one year), would also have gone a long way towards reining in the overall ETS surplus.

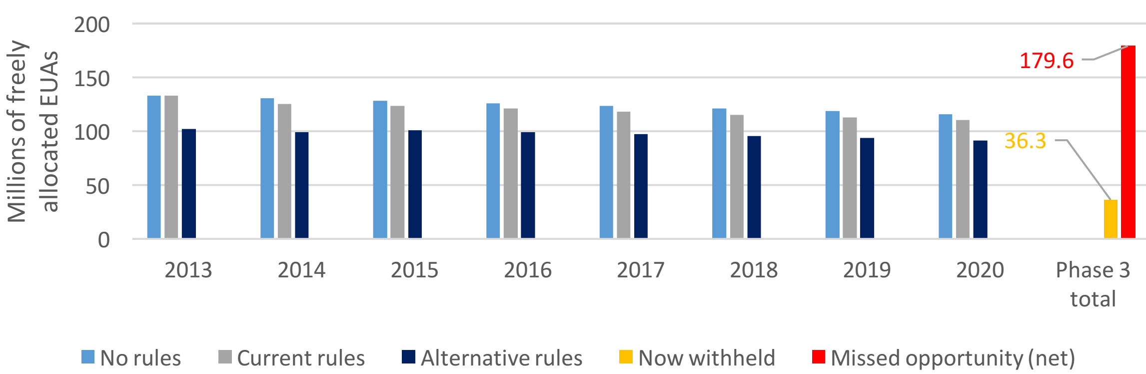


Figure 21: Estimated net adjustment to the volume of allowances allocated to cement sector if Sandbag proposal were introduced from the beginning of Phase 3.

At Sandbag we expect the market surplus in 2020 to still be around 2 billion allowances after the MSR has acted. Better PCC rules would have withheld nearly 10% of that volume from the cement sector alone. This represents a huge missed opportunity – and we strongly recommend including such provisions into the design of Phase 4 free allocation.

4.3. Problem 2: Too much allocation

4.3.1. Cause

If the cement sector were receiving free allocation in accordance with the same principles as most other industrial sectors, the volume it would get would be much lower. The ETS grants free allocation in order to shielded sectors against unfair competition from jurisdictions where no carbon price is imposed and thereby prevent relocation of industry away from Europe, i.e. carbon leakage. To qualify for protection against carbon leakage risk in Phase 3, sectors needed to meet minimal carbon cost intensity and trade intensity criteria. Cement, as well as the related lime and plaster sector, were the only two activity types that were placed on the carbon leakage list during Phase 3 due to their carbon cost intensity alone. They in fact did not meet the minimum threshold for the trade intensity criterion, and therefore are treated as a fully leakage-exposed sector due to a Directive article establishing an exception from the general rule. As a result, the cement sector is entitled to apply to receive 100% of its benchmarked free allocation for free, instead of only a progressively diminishing share thereof.

Besides diluting the effect of the carbon price, another negative consequence of placing such large sectors on the same footing as others in terms of leakage risk is that all industrial sectors' free allocation suffers. Only a limited amount of allowances is available for free allocation. Unfortunately, the Phase 3 list of risk-exposed sectors is overcrowded, so it was not possible to grant all installations their full application. This has resulted in the enforcement of a cross-sectoral correction factor (CSCF) – a mathematical haircut applied to all free allocation applications which uniformly reduces the amount of allowances across all recipients to fit the available ceiling on free allocation. Highly risk-exposed sectors are extremely critical of the CSCF, as it results in them receiving less protection than their benchmarked entitlement.

4.3.2. Solution: Adopt a tiered system of leakage protection

Policy-makers should acknowledge that, due to differences in risk exposure, the cement sector along with other sectors, might need fewer allowances in Phase 4 than other industrial sectors. We support the Commission's idea to move in Phase 4 from binary leakage provisions (either on or off the list) to an approach recognising that sectors fall into different tiers of progressively diminishing risk. Under this approach, each activity type's risk exposure would be assessed by combining its trade and emissions intensity into a single metric. The Commission suggests four tiers. The less risk-exposed the tier to which an installation belongs, the more its application for free allocation would be reduced – with only the highest tier eligible to receive 100% of its application.

4.3.3. Expected results

A tiered system would swiftly reduce the cement sector's surplus. This is because, while it is a highly carbon intensive sector, it has a much lower trade intensity than others. One would therefore expect it to fall into a lower risk tier. The Commission's Impact Assessment to the ETS review estimates, based on data that is not publically available, the cement sector would have its application reduced to 80%. Sandbag, based on publically available information, expects a reduction to 60%.[15] As we show in Figure

[15] Neither of these values are definitive, as the data used to determine trade intensity is likely to change in the future.

22, adopting a tiered approach could significantly bring forward the date by which cement majors will have to internalise the environmental cost of their activities and cease to be mere compliance actors.[16]

The additional benefit of a tiered free allocation system would be that allowances, which would otherwise be allocated to cement, would become available to other sectors. Consequently, sectors at the highest risk of carbon leakage can apply for 100% of their benchmarked free allocation without fearing that this would trigger the application of the CSCF. As we show in Table 4, these volumes can be quite substantial. Therefore, as well as incentivising low-carbon investment in cement, tiering can have very concrete co-benefits for the protection of risk-exposed sectors – all while avoiding any violation of the environmental integrity of the Phase 4 package.

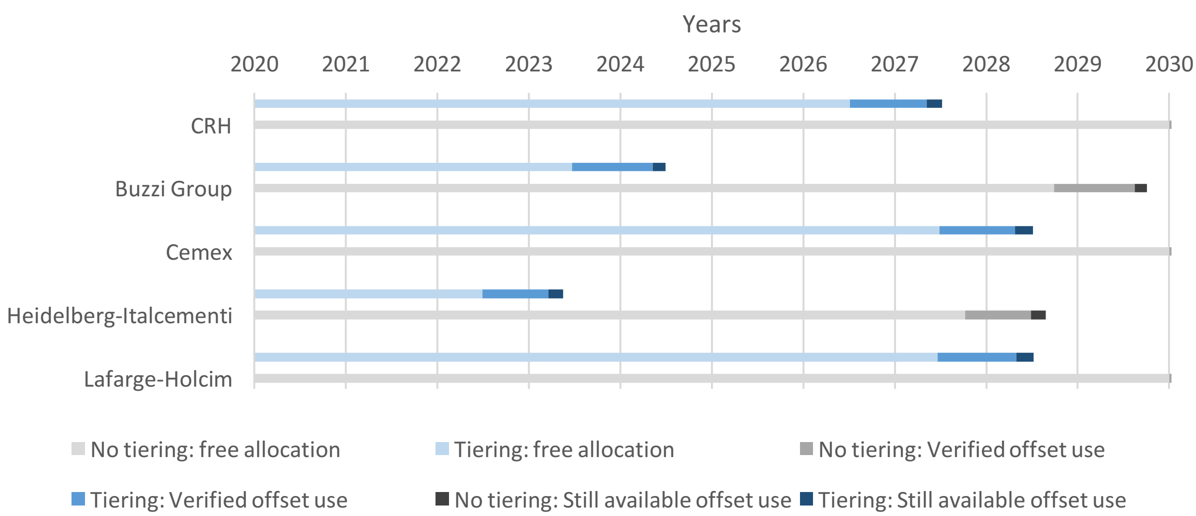


Figure 22: Impact of binary versus tiered leakage provisions on the surpluses of largest five EU cement companies (Sandbag's risk assessment). Source: EUTL (Sandbag calculations).

Tier for cement	Metric	Growth scenario		
		+2%	+1%	+0%
80%	Million EUAs made available to other sectors	197.3	190.6	184.1
	…as share of all Phase 4 free allocation	3.1%	3.0%	2.9%
60%	Million EUAs made available to other sectors	394.6	381.2	368.3
	…as share of all Phase 4 free allocation	6.3%	6.1%	5.6%

Table 4: Volumes re-channelled from cement to other sectors, as a function of cement's risk exposure and overall industrial growth. Source: EUTL (Sandbag calculations). Note: Industrial growth is year-on-year, and continues uninterruptedly from 2014 onward.

5. SUPPORTING INNOVATION

[16] Refer to Figure 12 to see how these earlier dates are still significantly later than the years when surpluses are exhausted in other sectors, e.g. refineries, steel or organic chemicals.

Unlike decarbonisation through the use of renewable energy in power, heat and transport, the landscape for supporting the decarbonisation of industry is much sparser. The lack of incentives for innovation and investment has forced all industrial sectors to focus their requests about climate policy on compensation payments in the form of free allocation. The distortions highlighted in the previous section clearly demonstrate that a different approach is required to break the impasse preventing deep decarbonisation.

The proposed Innovation Fund can potentially alleviate some of the shortcomings of the ETS in driving technological change. In the absence of prospects for a high carbon price, industry board rooms do not feel that it is justifiable to invest into RD&D for expensive technologies for cutting process emissions or for creating carbon-negative products. The Innovation Fund can act as an alternative source of funding for first-of-a-kind projects in industrial abatement. Overcapacity in the European cement sector and the resulting shortfall in investment for long term decarbonisation projects means that EU funding is particularly necessary for stimulating decarbonisation in the sector.

Despite this promise, we fear that the volume of allowances in the Fund will not be sufficient to make a difference. The NER300, the equivalent of the Innovation Fund in Phase 3, contained only 300 million allowances, equivalent to 37.5 million allowances per year. For the 10 years of Phase 4, the Innovation Fund would award 40 million allowances per year.[17] Since we do not expect the cap and the MSR to resolve the problem of oversupply, we anticipate that allowances will fetch very little revenue when monetised. We are concerned that the finance will be spread too thinly and, as with NER300, be biased towards low-budget projects, especially as the Innovation Fund also has to finance renewables and CCS in addition to industrial abatement. Recognising the need to tighten the cap and to avoid unduly increasing supply through a raid on the MSR, we therefore advocate altering the break-down of the Phase 4 cap so that more allowances are placed into the Fund.

However, it would be dangerous to entrust the financing of expensive, yet vital, RD&D into low-carbon products and production methods entirely to funds raised by auctioning allowances. This is because the volume of financing available would rendered unpredictable by carbon price fluctuations. To circumvent this volatility problem, EU-level programmes with pre-determined budgets should be drawn up to finance such projects. Accordingly, the EU should plan to include industrial abatement projects under the post-2020 continuations of the European Fund for Strategic Investments and Horizon2020.

6. OVERVIEW OF DECARBONISATION OPTIONS

In this section we take a more detailed look at the different technological options for reducing emissions from cement production including using alternative materials. Alone, even a reformed ETS cannot be relied upon to bring about the necessary investment in low carbon technologies. We have included specific non-ETS recommendations to incentivise the uptake of these technologies wherever we have been able to identify them. These supplement our core recommendations above on fixing the incentives within the ETS.

[17] We are aware that in fact the auctioning of the allowances in the NER300 was frontloaded to the beginning of Phase 3, and that the schedule for monetizing allowances in the Innovation Fund has not been set yet. Therefore, these figures are meant to merely illustrate the relative impact of different volumes of allowances in phases of different lengths.

6.1. Industrial CCS

CCUS has the largest emissions abatement potential of any technology for decarbonising the conventional cement-making process. Total emissions from Portland cement manufacture cannot be reduced by more than 30% without using CCS since that is the share of emissions resulting from thermal emissions. The remaining share comes from process emissions unavoidable under the Portland paradigm, and therefore these process emissions must be captured.

Unfortunately, retrofitting cement plants with carbon capture is often difficult and expensive. Industry sources indicate that integrating carbon capture into new plants will double construction costs and increase production costs by 40-90% per tonne of clinker once transport and storage costs are taken into account.[18] Also, some larger cement plants are located at considerable distances from potential storage sites.[19] We therefore recommend:

- **Granting further support for the RD&D of carbon capture in cement.**
- **Developing policies supporting the growth of a European sector for the transportation and storage of carbon.**

6.2. Fuel switching

Switching from the traditional source of thermal energy for cement plants, such as petcoke and coal, to alternative energy sources can reduce thermal emissions (Figure 23). Co-incinerating biomass in cement kilns is a popular way of reducing ETS emissions and has brought net CO_2 intensity from of grey clinker production 9% below gross in 2013. The Renewables Directive (2009/28/EC), Waste Framework Directive (2008/98/EC) and Landfill Directives (1999/31/EC) have created indirect incentives for cement makers to use alternative fuels such as biomass or pre-treated waste sourced from other industries face increasing landfilling costs for their wastes. This has led, as we show in Figure 24, to a strong divergence between gross and net carbon intensity in the EU, markedly improving its average performance relative to other areas when compared to the situation on gross emissions intensity (Figure 9, on page 14).

[18] ECRA. (2009). Tehcnical report on CCS (p. 6) (link).
[19] **The European Lime Association**. (2014). A Competitive and Efficient Lime Industry (p. 41)

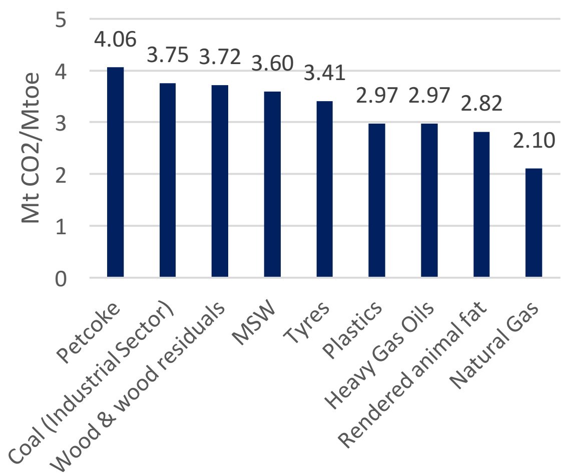


Figure 23: Direct emission factors for different fuel types. Note: MSW = municipal solid waste. Source: US EPA 2015 (link).

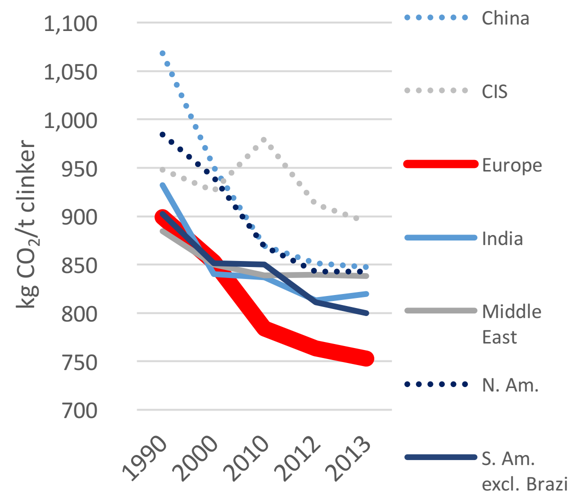


Figure 24: Regional trends in gross CO_2 efficiency of grey clinker production. Source: CSI 2013 (datasets 71AG and 59cAG).

Decarbonisation would proceed faster if there were a more harmonised approach to the use of alternative fuels and biomass. During 2005-2013 the average share of thermal energy obtained from incinerating waste-derived fuels and from biomass in EU cement installations more than doubled and tripled respectively (Figure 25). However, the economics of co-incinerating waste-derived fuels depend on the availability of waste processing infrastructure, the relative cost of fuels and on nationally-determined landfilling taxes which vary considerably between different MSs.[20] As we show in Figure 26, progress on fuel switching has been uneven across the EU – with some Western European countries, which we expected to be very forward thinking on climate policy, lagging behind Eastern European MSs.

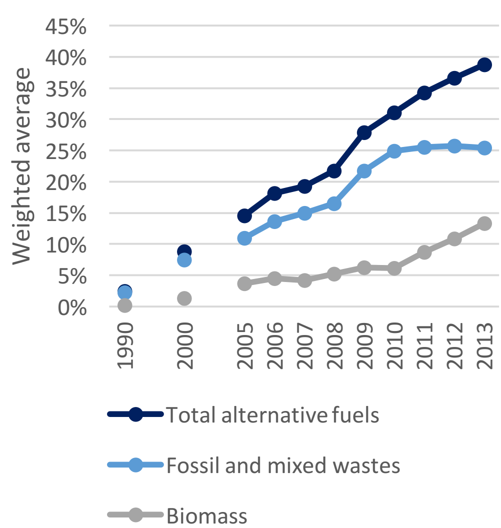


Figure 25: Thermal energy consumption per tonne of clinker by fuel type. Based on grey clinker

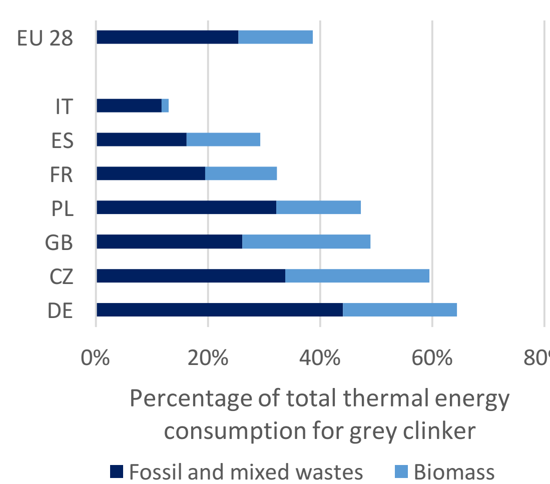


Figure 26: Weighted averages for the use of alternative fuels and biomass in the thermal

[20] **ETC/SPC**. (2012). Overview of the use of landfill taxes in Europe. (link)

production in EU 28 countries.
Source: CSI 2013 (dataset 25aAGFC)

energy consumption of grey clinker production.
Source: CSI 2013 (dataset 25aAGFC).

A properly aligned incentive system would need to make it both legally possible and financially attractive for cement makers to take advantage of the technological possibility to burn these less polluting fuels. This can be achieved by:

- **Harmonising EU-wide landfill regulations, as well as regulations permitting the incineration of these non-conventional fuel types.** This will broaden the possible scope of the materials flow towards the cement sector.
- **Reducing the administrative burden of cross-border transport of wastes for co-incineration.**

6.3. Kiln efficiency

Improvements in energy efficiency can be achieved by using best available technology (BAT) kilns and by operating them at close to nominal production capacity. Upgrades to kiln efficiency are driven primarily by long term investment decisions and compliance with regulatory requirements.

BAT in the cement sector consists of dry kilns with multistage preheater and precalciner equipment. These use half as much energy as wet kilns per tonne of clinker produced.[21] In 2013, 83% of cement production in Europe was based on the dry process (Figure 27) compared to 78% in 1990. Over the same period, thermal energy consumption for grey clinker production fell by 10% EU-wide.

While new kilns are typically built using BAT, a significant number of less efficient kilns have yet to be replaced. Overcapacity in the cement market has resulted in a shortfall in investment. The costliness of shipping clinker and cement overland reinforces this aspect for companies in landlocked EU countries that may be contemplating such investments.

[21] **International Energy Agency**. (2009). Energy Technology Transitions for Industry. p.78 (link)

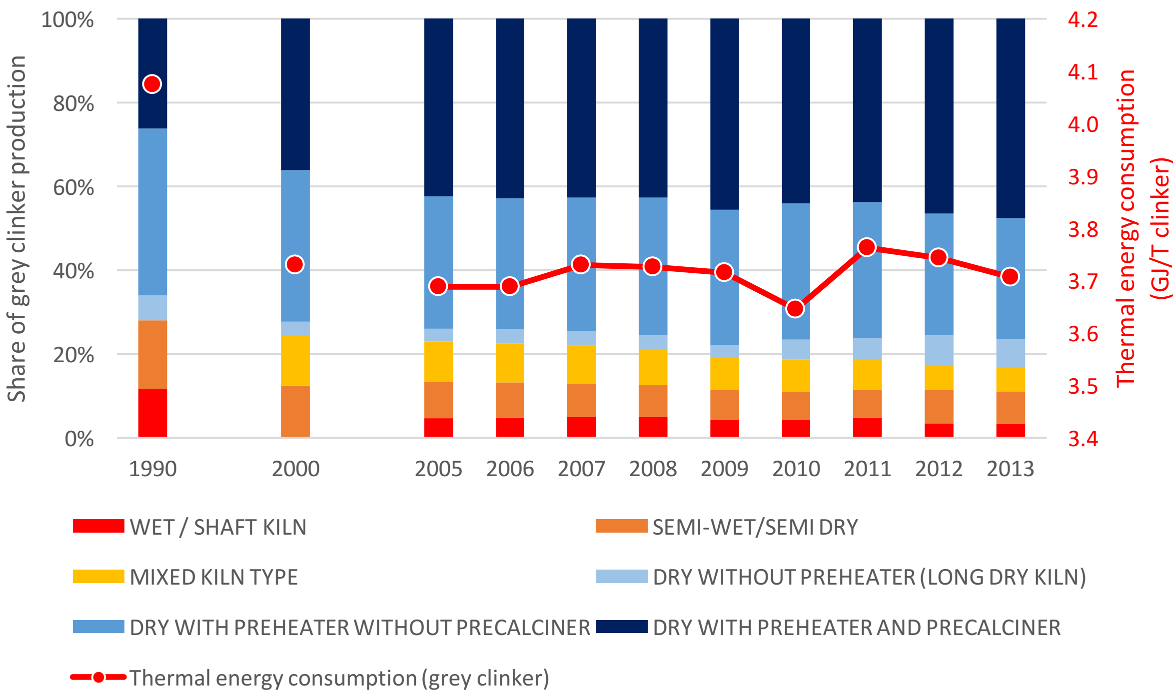


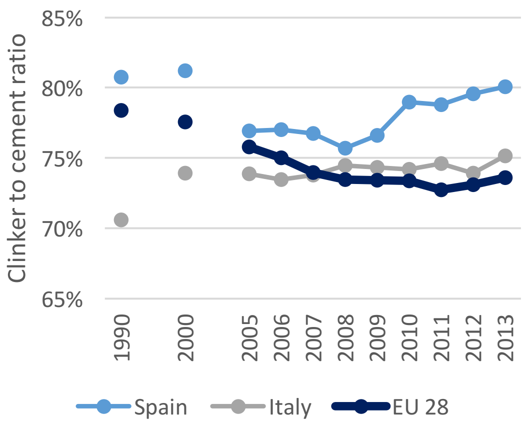
Figure 27: Trends in grey clinker kiln technology. Source: CSI 2013 (datasets 25aAG and 8TGK).

Furthermore, our discussions with industry suggest that climate policy is not strong enough to drive this replacement. Lafarge for instance acknowledges that equipping all kilns with BAT could reduce specific heat consumption to 2.9 GJ/t (more than 20% lower than the 2013 EU average reported in Figure 25). However, they also add that this would costs in excess of €100 per tonne of CO_2 saved[22] – far in excess of the current carbon price.[23] HeidebergCement and Carbon8 also corroborate that upgrading extremely old kilns to BAT is tantamount to greenfield investment.[24]

6.4. Clinker shares

It is possible to achieve emissions reductions by substituting clinker with materials that have lower embedded carbon such as pulverised fly ash, ground granulated blast-furnace slag, limestone or calcined clay minerals. The EU-wide trend has been towards using less clinker but progress under this lever has been uneven. While Austria reportedly reduced clinker content from nearly 79% in 1997 to less than 70% in 2015,[25] the share of clinker in some Member States has risen despite the introduction of the ETS. Figure 28 shows how the clinker ratio has risen from 76% in 2008 to 80% in 2013 in Spain, while in Italy it has been rising continuously from 71% in 1990 to 75% in 2013. As we show in Figure 29, the utilisation rates for slag, fly ash and puzzolana remain low. Scarcity of these materials is a factor but the low carbon price makes it difficult to achieve higher levels of clinker-substitution as the benefits of so doing are outweighed by logistical costs such as transport. Substantial volumes of waste are therefore remaining unused.

[22] **Gimenez, M. [Lafarge]**. (2015). Harnessing CO2. International Cement Review.
[23] EUR 4.88/tCO2 (ICE – March 4, 2016).
[24] **CEMBUREAU**. (2016). Personal communication with CEMBUREAU on 5 February 2016
[25] **Cemtech Vienna** (link, accessed February 2, 2016).



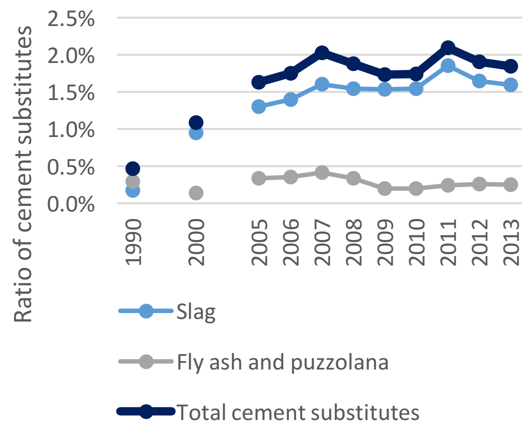


Figure 28: The clinker-to-cement ratio for the EU 28, Spain and Italy

Figure 29: Use of cement substitutes as a percentage of all grey cement in EU 28 countries.

Sources: CSI 2013 (datasets 92AGW and 19AGW)

The amount of clinker used in the production of cement fundamentally determines this sector's direct emissions. It is therefore imperative to eliminate incentives to include increased levels of clinker in cement. The very fact that clinker shares vary according to country suggests that this is not a technically challenging hurdle but, instead, largely a problem of incentives. We therefore recommend:

- **Narrowing the range of clinker in Portland cements in European norms of cement and concrete.** All 27 categories of cement recognised under EN 197 prescribe a fairly wide range of Portland clinker content, e.g. 80-94% for CEM II A-S. Regulating clinker content into the lower end of the content range might be a solution worth exploring.

6.5. Non-Portland cements

Cement alternatives differ from clinker-substituted Portland cements in that they are produced via separate processes, which often use none of the traditional raw ingredients of ordinary Portland cement. A number of these cements have lower embedded carbon. Examples include geopolymer cement and concrete (Wagners), and magnesium carbonate cements (Novacem). Altering the chemistry of clinker can also reduce its carbon intensity. This is the case for the low-carbon clinkers kilned at lower temperatures (Lafarge).

Lack of proper certification can hurt the market acceptance of these cements. Existing standards prescribe chemical compositions that have been determined in the past to guarantee the particular performance of a Portland cement. Non-conventional cements, eschewing the Portland process entirely, cannot meet such standards by definition. This is unfortunate, as many non-conventional cements can in fact attain greater strength than Portland cement, especially when performance is assessed at 56 days rather than the 28-day period specified in Norms for cements in the Portland family.

As in the case of clinker substitutes, the economics of non-Portland cements are highly dependent on manufacturers' ability to source feedstocks affordably. CEMBUREAU estimates that novel cements will achieve a 5% market share by 2050.[26] They cite market acceptance as the main barriers limiting non-Portland cements to niche applications. Yet some novel cements could replace Portland cements in a great variety of environments.

Non-Portland cements suffer from lack of experience of using them among intermediate and final consumers. Their marketability can be greatly improved if buyers are reassured that these cements conform to product safety standards. Currently, European norms on cement and concrete (EN 197 & EN206 respectively) cover imperfectly products that eschew the Portland paradigm altogether, and often the implementation of these norms is left up to individual MSs. This has resulted in a situation where diverging safety regulations prevent the same product from being marketed uniformly across the EU.

Furthermore, regulations should not prevent innovations to diffuse throughout the EU. In terms of products, subsidiarity in the European Norms on cement and concrete (EN197 & EN206 respectively) means that several forms of low-carbon cement that already exist cannot be marketed in most EU MSs – despite being deemed safe in others.

- **Extending the European norms on cement and concrete beyond the paradigm of Portland cement.** Standards should be decided with climate benefits in mind, mirroring for instance the Californian system where the performance assessment period is 56 days long. The fragmentation of the norm system among MSs should be avoided as much as possible.

- **Engaging in demand creation for non-Portland cements.** Even with new standards, we expect adoption to be slow. To address this, governments should showcase the reliability of non-conventional cements through demonstration projects and public procurement programmes, and should eventually introduce maximum national requirements for the average embodied carbon of cement, which should decrease in a predictable manner over time.

- **Addressing shortcomings in the building market that cause consumers to select against low-carbon cements.** Contractors face competitive pressures to specify shorter construction timeframes. They need incentives to use cements that attain peak performance more slowly.

6.6. CCUS cements and concrete

Cements that can re-absorb CO_2 are sold as precast concrete blocks by CarbonCure (Canada), and Iron Shell LLC and Solidia in the US. Carbon8 in the UK produces a synthetic carbon-negative aggregate which can be mixed with ordinary cement to form a concrete with lower embodied carbon. These products hold great potential for acting as a carbon sink but the mixture of high RD&D and production expenses together with low carbon prices, lack of consumer interest or incentives has a strongly negative influence on the possibility to commercialise them. However, questions surrounding the long term performance of such cement types are just as salient as in the case of non-conventional cements which is why we make similar recommendations for CCUS cements as well.

An interesting point to make about these cement types is that, while the induced absorption of CO_2 may significantly reduce lifecycle emissions, its accounting falls outside the scope of the ETS. To circumvent this problem, Sandbag strongly supports the introduction of a negative emissions accreditation scheme.

[26] **CEMBUREAU**. (2013). Novel Cements (link, accessed on 8 March 2016)

This would raise consumers' awareness of the value these novel products add, as well as providing consumers with an incentive to purchase them.

A transfer of wealth, from MSs obligated under the ESD to project implementers, would fund demand creation for products taking advantage of the levers for cement sector decarbonisation that the ETS, by its very design, cannot reach. Beyond the capture of carbon dioxide in CCUS cements, this would be helpful in the production of non-Portland cements as well. It would also eliminate the need for MSs to generate their own policies because private actors would be able to seek out mitigation opportunities throughout the EU once MRV methodologies were enacted. Because MSs would be acquiring credits generated within the EU for ESD compliance, it would create a price signal under the non-traded traded sector without compromising the "domestic-only" nature of the EU's 2030 climate objective. Therefore, in addition to the recommendations made for non-Portland cements, we recommend:

- **Creating a MRV and crediting process that allows for captured and stored CO2 and negative emissions to be credited for use in the EU's climate policies.** While using such cement types will make compliance with the ESD easier for MSs, a crediting scheme generating revenues for the actors using them would increase demand and accelerate diffusion. Such a demand-creation exercise would in turn make it more attractive for cement makers to invest into production lines producing these cements.

7. ANNEX: METHODOLOGY

Sandbag's projections for how different policy scenarios would affect free allocation in the cement relies on a suite of tools developed in-house:

- The starting point is an estimation for the numerical values that were used to determine actual Phase 3 free allocation at the installation-level, i.e. their application for free allocation based on their sector's product benchmarks. We mathematically back-casted the values for 10,400 installations to generate the most accurate estimation for how their free allocation in the EU Transaction Log (EUTL) was calculated. Upon reapplying the various correction factors used during Phase 3, our estimates were able to reproduce the actual EUTL values to within 5 allowances in every year for installations amounting to 99% of 2014 free allocation.
- We concluded that an installation's activity had partially ceased if our estimate for their application for benchmarked free allocation only managed to reproduce the EUTL values for a limited sequence of years.
- We had to rely on emissions in order to estimate variation on activity types, as the EUTL does not provide installation-data on activity levels. Because the real-life Historical Activity Level (HAL) is not publically available, we followed the methodology implied by the Benchmarking Decision to estimate a Historical Emissions Level (HEL). We used variations in emissions to estimate variations in productions for installations where we had been unable to mathematically verify the occurrence of partial cessation.
- We made sure to change the reference year for the HEL to account for sectors and installations that had only joined the ETS in 2013 due to scope change.
- We used a simple linear adjustment to activity levels to generate applications for free allocation for future years. We adjusted product benchmarks uniformly by the 1%/year suggested by the Commission proposal.
- We calculated each the correction factor for carbon leakage during Phase 4 for each NACE code based on information present in the Commission's Impact Assessment and other similar documents. We applied these correction factors to each installation in all NACE codes to generate their application for free allocation.
- Comparing the sum of all installations' application for free allocation with the Phase 4 ceiling on free allocation implied by the Commission's Proposal for the ETS Revision, we generated a cross-sectoral correction factor for each year of Phase 4.
- We applied these two correction factors to each installation we generated the free allocation values for each installation in each year of Phase 4.
- These values were then aggregated into different entities, e.g. a cement company, an industrial sector, a country, etc. based on our in-house curated data base of installation ownership.

For the analysis decomposing the effect of individual factors on cement sector emissions we relied on the Log-Mean Divisia Index method described in Branger & Quirion (2015) "Reaping the carbon rent: Abatement and overallocation profits in the European cement industry, insights from an LMDI decomposition analysis", *Energy Economics* (available here – accessed March 15, 2016).

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