International Journal of Advance Research and Innovation
Vol. 6(3), Jul-Sept 2018, pp. 54-59
Doi: 10.51976/ijari.631809
www.gla.ac.in/journals/ijari

Article Info

Received: 18 Aug 2018 | Revised Submission: 28 Aug 2018 | Accepted: 02 Sept 2018 | Available Online: 15 Sept 2018

Cement Industry and Strategies for Mitigating Carbon Emissions: An Overview

Ahana Ghosh and Anubha Mandal***

ABSTRACT

Cement is the largest mass manufactured man made product on earth. The demand for cement is on a continual rise, as more and more developing countries strive for better infrastructure. This demand has, however, entailed an unacceptable increase in the carbon emissions as the cement manufacturing industry is one of the most carbon releasing industries in the world; responsible for more than 5% of the global carbon emissions. The dangerously high levels of Carbon Dioxide have contributed to a large scale climate change which has global repercussions. The need of the hour is an effective yet inexpensive mechanism to trim down the carbon emissions from the cement factories. In this paper, the main industrial as well as the governmental strategies for alleviating the carbon emissions of the cement industry are reviewed, focusing on the carbon taxation for the latter. This review has observed a comprehensive literature in term of the peer reviewed journals, research papers, industry reports, authentic websites etc on the cement industry and the strategies to reduce the carbon emissions.

Keywords: *Cement; Carbon; Strategies; Carbon Tax; Industrial; Environment*.

1.0 Introduction

The manufacture of most industrial materials has some form of impact on the environment. Research is being conducted to reduce this impact and promote sustainable development.

One such industrial material which has a substantial effect on the environment, specifically on the carbon levels in the atmosphere is the vastly manufactured and consumed raw material: cement.

Currently, the cement industry accounts for almost 5%-7% [1] of the global CO_2 production. Over the recent years, cement production has witnessed an exponential increase in developing countries to meet the needs of a rapidly urbanizing civilization [2] and the carbon levels in the environment have seen a proportional increase. If nothing is done to control them, this ubiquitous industry will account for nearly 33% of the global carbon levels by 2050. [3]

This is indeed a cause for worry, as CO_2 is a greenhouse gas which when present in large quantities in the atmosphere can contribute to dangerous phenomena like global warming and climate change.[4] In such a situation, it is the need of the hour to find economically viable methods to help propagate a low CO_2 emitting cement industry.

It has been estimated that fossil fuel combustions account for a mere 30% of the amount of CO_2 generated during the production of cement whereas the calcination of the limestone accounts for almost 60% of the total carbon emitted.[5] This is both good as well as bad news. The carbon emissions cannot be controlled in the cement industry by simply increasing the energy efficiency; the problem must be tackled at the very base itself, by adjusting or changing the constituents of the cement, while keeping in mind the economic feasibility of the cement.

This paper gives an overview of the various major strategies that the government as well as the cement industry have considered to lessen the amount of carbon released from the cement production process. The rest of the paper is organized as follows: The next section reviews the industrial plans and the subsequent section focuses on the governmental initiatives. After that, the conclusions are discussed and suggestions are made for the areas that merit further research.

**Corresponding Author: Department of Environmental Engineering, Delhi Technological University, Delhi, India (E-mail: ahanaghosh1997@yahoo.com)*
***Department of Environmental Engineering, Delhi Technological University, Delhi, India*

2.0 Industrial Plans

If the carbon emissions are to be reduced, it is essential that the industries take initiative without any external pressure. For this, awareness as well as incentives by the government is necessary. Discussed below are some of the strategies applied by different cement companies to mitigate their emissions.

2.1 Carbon capture and storage

Carbon Capture and Storage (CCS) is one of the foremost technologies that are available in the industry today. It is the process of capturing the carbon from the source site (like a cement plant) and then transporting it to a storage facility and depositing it in a location where it will not impair the environment. Over the last two decades, the feasibility of this method has been researched upon considerably. [6] Research has shown that the expenditure of this strategy would cause in increase in the cost of cement production 2-3 times. [7] As such, it is yet to be proven for large scale use and is mainly suitable for those industries which do not have any other option to reduce their carbon footprint.

2.2 Use of supplementary cementitious materials

These materials can be used to replace a certain percentage of the clinker that is used to manufacture the cement and hence reduce the carbon content of the clinker. These materials are mostly the by-products of other industries like fly ash, calcined clay, natural pozzolans or geopolymers and silica fume. Due to their advantages like cost effectiveness [2], long term durability [8] and ease of use, they have been used since the 1990s in the cement industry [9]. However, they come with their own set of disadvantages. The availability of these materials varies regionally [7] and the potential for their usage for most of these materials has already been explored. Hence there is little scope for further carbon reduction using these methods. Moreover, the biggest question that most research done till now fails to answer is that exactly upto how much percentage can the substitution be done without compromising on the durability of the cement? [10, 2] Furthermore, the cost analysis in terms of the labour required is still vague in most literature. For example, geopolymers are hailed to have widespread advantages like reduction of the CO_2 emissions by 44-64% [11] over Ordinary Portland Cement, increased durability and better workability [12]. However, the disadvantages of these geopolymers like the fact that the making of the geopolymer concrete requires handling of the hazardous wastes and hence requires specialized training [13] and other technical difficulties were not accounted for in the cost analysis. Lastly, field studies have not yet proved conclusive for most of these materials and further research is needed to improve their usage in cement.

2.3 Use of cement made from alternative clinkers

The main source of the carbon emission during cement manufacture is the stage at which the calcination of the CaO occurs. [14]. Hence, cement made from the alternative clinkers may allow for a substantial reduction in the carbon production. The paper by Gartner and Sui [15] provides an exhaustive analysis of the alternatives to Portland cement. Some of their conclusions are given in Table 1..

2.4 Use of alternative fuels

Fuels account for only 25-30% [16] of the carbon released during the cement manufacturing process and hence changing their compositions does not have a massive impact on the carbon emissions. The area does not have much more scope for exploitation [7] as a variety of alternative fuels have already been tried and tested and are currently being used in the cement industry.

Fig 1: Global Carbon Emissions From Cement Production (Boden, T.A., G. Marland, and R.J. Andres. 2010. Global, Regional, and National Fossil-Fuel CO2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2010)

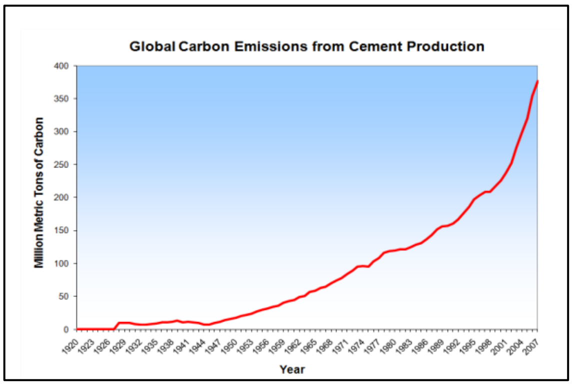

Table 1: Comparison of Alternative Clinkers

CEMENT	ADVANTAGE	DISADVANTAGE
1] Belite rich Portland Cement	Carbon reduction upto 10% per unit clinker	Takes more time to gain strength as compared to OPC
2] Belite Calcium Sulfo-aluminate (CSA) Cements	Carbon reduction upto 20% per unit clinker.	The cost of the raw material is very high.
3] Magnesium Based Cements	Made from ultramafic rocks which have the inherent ability to capture carbon. Globally abundant raw materials.	As of now, no energy efficient industrial manufacturing process has been invented.

3.0 Governmental Policies

Due to the difficulty faced by the cement industry in reducing the carbon emissions, the attention of the worldwide leaders and organizations as well as the governments of individual countries have riveted towards policies and strategies that could reduce the domestic greenhouse gases emissions. They can be very broadly divided into 3 types of approaches:

Voluntary approaches (VA), Trading and Carbon Taxes (CT). In this section, after a brief overview of VA and Trading, we shall focus on the discussion of Carbon Taxes.

3.1 Voluntary approaches

VAs can be classified into one of four types: unilateral commitments by industry; private agreements between industry and stakeholders; environmental agreements negotiated between industry and government; voluntary programmes developed by government that individual firms can join. [17].

While this policy has been applauded for its flexibility and it's relatively less effect on the competitiveness of the companies which produce cement, it has also been criticized for the laxity in the coverage of the industries and the ineffectiveness of the implementation.

3.2 Carbon trading

Carbon trading is a flexible mechanism introduced by the Kyoto Protocol, which limits the carbon emission from the industries by granting companies the permit to emit only a certain amount of carbon. This cap and trade mechanism, although effective to a certain degree, as proved by the studies of Shammin and Bullard (2009), is also a very complicated and expensive mechanism to implement. This system requires a completely new administrative system to aid the establishment of a competent trading market. [18] Moreover, the carbon trading mechanism merely shifts the production of carbon from one country to the other; which cannot be a permanent solution to the carbon problem as this issue is a global issue.

3.3 Carbon taxes

Due to the vast carbon footprint of the cement industry, the governments of various countries have tried implementing a tax known as Carbon Tax in order to hold the cement companies answerable for the carbon that they generate. If set high enough, it becomes a potent financial incentive that motivates switches to clean energy across the economy, simply by making it more economically rewarding to move to less carbon intensive manufacturing methods. Carl and Fedor (2016) have come to the conclusions that an effective carbon tax with a good rate has been preferred over other governmental policies, especially since the last decade. Research has been done exhaustively in quite a few areas relating to the carbon tax. Certain conclusions from them are discussed below.

Research done states that the different impacts of the carbon tax could arise from the fact that different rates are followed in different countries [19] and that the design of a proper carbon tax may be able to alleviate the negative impacts of its implementation. [20].

Moreover, the carbon tax can be considered an efficient system only when the tax is set high enough that companies have enough incentive to switch to a lower carbon intensive manufacturing process.[20]. However in China, an analysis done to evaluate the preference of companies to carbon tax found that companies prefer a low rate of carbon tax in the beginning; about 1 to 4 US dollars per tonne of CO_2 emitted.[21].

This, they claim, will reduce the carbon emissions and at the same time, not affect the competitiveness of the companies. A research done based on the Saudi Arabian cement industry suggests a compromise at 27 US dollars per ton of carbon [6] claiming that at this rate the profit of the industries would not be compromised and the emissions would significantly be reduced. Suggestions have also been made of starting at a low carbon tax rate and then gradually moving to high rates to avoid a sudden economic pressure on the industries. [22]

A survey done in the University of Geneva evaluates carbon taxes with respect to their competitiveness, distributional and environmental effects. [23]. Competitiveness indicates the ability of a company to sell its goods and services in the domestic as well as the global market. Distributional effects can be regressive i.e. the bulk of the tax falls more on the low income population or progressive i.e households with higher income pay proportionately more. The studies conclude that revenue recycling may be an interesting method offset the losses due to reduction in competitiveness and that in general; carbon taxes are indeed regressive unless subsidies are provided to the low carbon intensive companies. Moreover, carbon leakage is a said to be major a cause for concern [24] as companies may simply shift the manufacture of carbon intensive merchandise to countries without a carbon tax or with lax governmental regulations. The conclusions drawn from this discussion are presented below.

4.0 Conclusions

The main conclusions of the above review can be summarized as follows:

1. From the discussion on industrial policies, it can be concluded that CCS is not yet a feasible option and could be made more cost effective by methods like Carbon Capture and Usage, where the stored carbon can then be used profitably.
2. Supplementary cementitious materials are already in use in the cement industry and further research has to be done to ascertain the exact amount of substitution that can be done in the cements without affecting their strength. If the strength is affected by the substitution, the substitution becomes redundant as more amounts of the same clinker will be needed to achieve the same strength.
3. Alternative fuels for the cement industry have already been explored exhaustively and not much potential for further CO_2 reduction exists in that area. However, using alternative fuels may have other advantages to the environment.
4. The use of alternative cement clinkers with a different composition is one area that merits further research. If the cost analysis of different types of cements is done, they could begin replacing the OPC in the markets. For this, the market bankability of the Portland cement has to be taken into account. It would definitely help if experts and educationalists raised awareness about the benefits of using different types of cements and hence increase their reliability.
5. From the governmental policies it can be concluded that while Voluntary Approaches are flexible mechanisms, their effectiveness is very difficult to gauge and may require more standardization.
6. Carbon trading while having the advantage of giving flexibility to the companies who can decide which method they want to use to reduce their carbon emissions, has the disadvantage of not being transparent and being very easy to evade. Moreover, the method is expensive to execute and often complicated.
7. Carbon taxes on the other hand are simple enough in theory but may give rise to multiple complications. They are transparent and easy to implement. However, the imposition of carbon taxes raises quite a few problems. If set too high, they may affect the competitiveness of the industry and raise carbon leakage issues, if set too low, they lose their effectiveness as they do not provide sufficient incentive to the companies to reduce the emissions. If the companies are dissatisfied with the imposition of this tax, it may promote them to produce carbon in covert operations, which may cause more damage to the environment. Policies by the governments need to address the issue of competiveness directly through compensation mechanisms for the deserving companies. Moreover, most research finds that carbon taxes are regressive in nature.
8. In such a scenario, the design of a carbon tax is highly important and very few studies exist where the design of the carbon tax is given sufficient consideration. The design of the carbon tax should also be done taking into account

different cements and technologies available. Moreover, most studies do not account for uncertainty and perform no risk analysis. This could be an important missing link as every factor affecting the carbon tax is subject to a lot of variability.

9. The promotion of a less carbon intensive cement industry requires that the government and the industries work together through a mixture of strategies and technologies based on the different domestic conditions of various countries.

Acknowledgements

I would like to thank Dr. Anubha Mandal for sparing her valuable time and mentoring me throughout this paper.

References

[1] PK Mehta. Reducing the Environmental Impact of Cement", Concrete International, 2001.

[2] A Bilodeau, VM Malhotra. High Volume Fly Ash System: Concrete Solution for Sustainable Development, ACI Materials Journal, Title No. 97-M6, 2000.

[3] J Davidovits. Global Warming Impact on the Cement and the Aggregates Industries, World Resource Review, 6(2), 1996, 263-278.

[4] Z Chen, P Nie. Effect of carbon tax on social welfare: A case study in China, Applies Energy 183, 2016, 1607-1615.

[5] X Liu, Y Fan, C Wang. An estimation of the effect of carbon pricing for CO_2 mitigation in China's cement industry, Applied Energy 185, 2016, 671-686.

[6] W Matar, AMElshurafa. Striking a balance between profit and carbon dioxide emissions in the Saudi cement industry, International Journal of Greenhouse Gas Control 61, 2017, 111-123.

[7] KLScrivener, VM John, EM Gartner. Eco-efficient cements: Potential, Economically viable solutions for a low CO_2, cement based industry, UNEP report, 2015.

[8] C Valderrama. Implementation of the best available techniques in cement manufacturing: a life cycle assessment study", Journal of Cleaner Production 25, 2011, 60-67.

[9] N Muller, J Harnisch. A blueprint for a climate friendly cement industry,2008http://assets.panda.org/downloads/english_report_lr_pdf.pdf

[10] YC Diaz. Limestone Calcined clay cement as a low carbon solution to meet expanding cement demand in emerging economies, Development Engineering 2, 2017, 82-91.

[11] BC McLellan. Costs and carbon emissions for geopolymer pastes in comparison to ordinary Portland cement, Journal of Cleaner Production 19, 2011, 1080-1090.

[12] M Bediako. Maximizing the Sustainability of Cement Utilization in Building Projects through the Use of Greener Materials.", Journal of Engineering, ID 1375493, 2016, 6.

[13] http://civilengineersforum.com/geopolymer-concrete advantages-disadvantages/

[14] S Mishram, NA Siddiqui/ A Review on Environmental and Health Impacts of the Cement Manufacturing Industry, International Journal of Geology, Agriculture and Environmental Sciences, 2, 2014.

[15] World Steel Association, 2015, Worldsteel in figures, Brussels.

[16] Eugeniusz Mokrzycki, Alicja Uliasz-Bochenczyk, Alternative Fuels for the Cement Industry, Applied Energy 74, 2003 95-100.

[17] S Bygrave, J Ellis. Policies to Reduce Greenhouse Gas Emissions in Industry - Successful Approaches and Lessons Learned: Workshop Report,OECD and IEA report, 2003.

[18] ZE Gevrek, A Uyduranonglu. Public Preferences to Carbon Tax Attributes, Ecological Economics 118, 2015, 186-197.

[19] B Lin, X Li. The effect of carbon tax on per capita CO_2 emissions", Energy Policy 39, 2011, 5137-5146.

[20] TC Kuo, IH Hong, SC Lin. Do carbon taxes work? Analysis of governmental policies and enterprise strategies in equilibrium", Journal of Cleaner Production 139, 2016, 337-346.

[21] X Liu. An analysis of company choice policy preference to carbon tax policy in China, Journal of Cleaner Production 103, 2014, 393-400.

[22] Z Zhang. How to improve the performance of Carbon Tax in China, Journal of Cleaner Production 142, 2016, 2060-2072.

[23] A Baranzini. A future for carbon taxes", Ecological Economics 32, 2000, 395-412.

[24] R Sathre, L Gustavsson. Effects of energy and carbon taxes on building material competitiveness, Energy and Buildings 39, 2000, 488-494.