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POLICY ANALYSIS:

CONSIDERATIONS OF A SECTORAL APPROACH TO THE CEMENT INDUSTRY

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1 Executive Summary

Recent scientific research and findings related to climate change demonstrate that the accumulation of greenhouse gases in the atmosphere, driven by anthropogenic emissions, threatens the sustainability of ecosystems around the globe. As economist Lord Nick Stern recently concluded, “if no action is taken to reduce emissions, the concentration of greenhouse gases in the atmosphere could reach double its pre-industrial level by as early as 2035” (Stern 2007). This would virtually commit our planet “to a global average temperature rise of over 2°C. Such rise would be very dangerous indeed; it is equivalent to the change in average temperatures from the last ice age to today” (Stern 2007). The cement industry is one of the world’s most highly energy intensive economic sectors. Research from the International Energy Agency (IEA) and World Business Council on Sustainable Development (WBCSD) indicates that CO_2 emissions from cement production currently represent about 5 percent of anthropogenic global CO_2 emissions (IEA and WBSCD - CSI 2009). To put this in perspective, it is important to consider, for example, the impact that the aviation sector has on worldwide greenhouse gaseous emissions. According to the Intergovernmental Panel on Climate Change (IPCC), the total emissions from global aviation contribute to approximately 2.5 percent of the total global greenhouse gas (GHG) emissions (IPCC 1999). The projection of new cement plants in developing countries show that for example in China “under BAU (Business As Usual) the CO_2 emissions of the Chinese cement industry will have increased by over 100 percent from 2002 to 2020 and will have added 0.8 Gt CO_2 per year by 2020” (Müller 2009). This is quite significant given the role that China is taking worldwide as an economic powerhouse. According to Müller’s study, the cement production increase worldwide would account for 17 percent in the rise of CO_2 emissions in between 2002 and 2030 (Müller 2009).

These numbers make evident the importance that the cement industry has for CO_2 mitigation, and thus the focus of this study is to evaluate efforts that could scale up emissions reductions by employing standardized baselines to support sectoral approaches for the cement industry. As per the Cement Sustainability Initiative, a global initiative by 24 major cement producers with operations in over 100 countries which are engaging in sustainable processes for the industry, the sectoral approach consists of a combination of policies and measures developed to enhance efficient, sector by sector greenhouse gas mitigation within the United Nations framework. Projects that reduce emissions, and the host country governments where these projects are located, are required to adopt a set of emissions goals. These emissions goals may vary by country, and countries may be required to take other actions to help combat climate change (CSI 2009). Standardized baselines are the United Nations Framework Convention on Climate Change (UNFCCC) approved baselines for the Clean Development Mechanism (CDM) that could be applicable to multiple projects of similar nature for the cement industry. Under the current CDM cement projects have been treated on a case by case basis, and this has created redundancy, high costs for project managers and the UNFCCC etc. If a sectoral approach which uses the same baseline for multiple projects were taken instead, it would be much simpler for different countries to apply and get approved under the same considerations. The sectoral approach would be much simpler, cost-effective, all-inclusive and essential to emissions reductions efforts worldwide for the cement sector.

First the paper provides a brief overview of the CDM under the UNFCCC, the shortcomings of this approach and the innovation that sectoral approaches could bring forward. Secondly, a detailed analysis of the sectoral approach for the cement sector has been carried out using the European Union's Emissions Trading Scheme (EU ETS) design approach for energy intensive industries as an example and compares the same with the proposed UNFCCC standardized baseline approach. The sectoral approach will have to overcome several challenges, given that policies will need to be developed on a national level that 1) incentivize the cement producers to take energy efficiency measures across the industry, 2) elaborate on how the credits will be passed down from the sector as a whole at national level to the individual producers, and 3) determine a baseline for their country which, depending on the countries' means, location, i.e. manufacture process adopted, quality of raw materials available etc it could be based on Best Available Technology (BAT) deployment or through the use of cap and trade, carbon tax systems or other similar measures. Thirdly, a detailed description of the cement manufacturing process is given, from quarry operation, to raw material grinding, clinker manufacturing and cement grinding. A description of the sources of the emissions in the different stages of material preparation has been provided. There are two kinds of emissions that occur during cement production. Indirect CO_2 emissions occur due to the use of electrical energy purchased from the grid, and direct CO_2 emissions are released in the clinker manufacturing stage primarily from the calcination of limestone and combustion of fuels. Furthermore, the paper considers the potential for emission reductions in the cement sector using standardized baselines through the sectoral approach. This is done by analyzing:

1) The type of technology employed and the currently available commercial technologies existing for raw grinding, cement grinding, and kiln systems for clinker manufacturing and by providing recommendations to energy efficiency improvements either through the use of BAT or potential upgrades to the specific areas in the cement manufacturing process.
2) The impact that traditional fuel combustion for kiln operations has on CO_2 emissions. Moreover, the study also looks at the potential for the co-processing of alternative fuels that not only reduce the use of traditional fuels such as coal, natural gas, oil and the emissions generations by them, but also are a better choice for the people in and around the cement plants since these materials would otherwise be considered waste and thus landfilled.
3) The impact of adding mineral additives such as pozzolan, slag, fly ash to the cement grinding stage is assessed as it has been estimated that this could have the greatest potential for reducing CO_2 emission from cement plants. The relative clinker production per tonne of cement directly impacts the associated energy related and process emissions of CO_2. Reducing the clinker by use of additives results in significantly lower emissions compared to Ordinary Portland Cement clinker (Matthes 2008). Given that clinker production accounts for over 90 percent of the total industry energy use (Höhne and Ellermann 2008); this substitution could lead to great decreases in CO_2 emissions.
4) The concept of recuperating waste heat i.e., using heat from cooler or preheater tower in a co-generation plant to produce electricity, which has been proved to contribute up to 25 percent of the power consumption of a cement plant can be produced using these technologies without changes of kiln operation (ECRA 2009).

Finally the paper considers the most viable approach to sectoring of the cement industry based on research and analysis of the sector as summarized in this study. Important issues regarding the development of the sectoral approach will be the availability of data from the cement producers, the degree of correctness of these data, and the need for further monitoring and verification.

2 The Clean Development Mechanism and need for Sectoral Approaches

The Clean Development Mechanism (CDM) is an arrangement under the Kyoto Protocol which allows industrialised countries with a greenhouse gas reduction commitment (called Annex 1 countries) to invest in projects that reduce emissions in developing countries (non- Annex 1 countries) as an alternative to more expensive emission reductions measures in their own countries. The resulting Certified Emission Reductions (CERs) can then be used by any Annex 1 country to meet its emission reduction target under the Kyoto Protocol. CERs are like the stock certificates where one CER is equal to the emission reduction of one tonne of CO_2 equivalent (CO_2e) emission (ENVIS 2008). Thus, one CER represents the emission reduction of one tonne of CO_2 equivalent (CO_2e) emissions. The CDM Executive Board at the UNFCCC is authorized to issue CERs to any project in a developing country that has registered with the CDM board. The CDM projects must satisfy two important criteria, that of additionality and that of sustainable development. Additionality criteria imply that the anthropogenic emission reductions through the implementation are additional to any that would occur in the absence of the proposed project activity. While in order to fulfill the sustainable development criteria, the host country needs to provide an approval indicating the social, economic, environmental and technological well being through project implementation. The CDM projects need to be approved by the national governments of the respective countries certifying their contribution towards the sustainable development of the social, economic and environmental parameters. These may include healthy water and air, enhanced use of land, creation of employment opportunities, mitigation of poverty and less dependence on fossil fuels from other countries.

Some of the key shortcomings of CDM which needed to be addressed include:

1. Methodological issues: One of the key factors of CDM offset mechanisms is the concept of additionality. Under the UNFCCC, “a CDM project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM project activity” (3/CMP.1 2005). To avoid giving credits to projects that would have happened anyway ("free riders"), rules have been specified to ensure additionality of the project, i.e., the project results in a net greenhouse gas reduction. The approach that is currently being used to prove additionality has its own shortcomings. This approach is sometimes inadequate due to its considerable emphasis on only particular kinds of

climate benefits (those which can be easily quantified) and its lack of consideration for development or employment objectives (Muller 2009).

2. Management and institutional issues: The governing and regulation system of CDM is unreliable in decision making and is vulnerable to gaming by the project developers. In addition the system has become clogged with projects spending a significant amount of time in the project pipeline contributing to high transaction costs for the projects (Streck 2010).

3. Inadequacy of the existing portfolio: There has not been much sustainable development in the Annex 1 party countries and no new technology transfer has happened (WWF 2013). The inability of small projects to be able to expand, and the high transaction costs involved with projects have led to CDM programme of activities or sectoral approach projects from non-Annex 1 nations in a hope to overcome some of the issues with the ‘single project CDM’.

In order to address the inadequacies of CDM, like the issues with proving additionality with the projects under the CDM (i.e. to judge the intent behind provisions), provisions being too high or too low, improper operational structure and other issues, the idea of a “sectoral CDM” was suggested during the 10th Conference of Parties (COP) of the UNFCCC held at Buenos Aires in 2004. A sectoral CDM (S-CDM) may prove to be a big asset to help spur emissions reductions projects because of the following reasons:

1. Emission Reductions: At present CDM is only limited to specific projects, which are considered on an individual basis and does not encompass all the sectors of economy, thus it does not have the required transformation effect on a society towards sustainable development. It also does not propose far-reaching policy changes (for example in transportation or the power sector). The sectoral approach could entail different initiatives, be it nationally within the cement sector, or trans-nationally while being able to meet the standards defined by the UNFCCC baseline. A successful sectoral CDM program would concentrate on the main portion of the GHG, requiring action by the major producers and their host governments in the cement industry. “A sectoral approach does not impose growth limits on developing countries. On the contrary, emissions efficiency goals (emissions per unit of product) can move an industry sector towards improved efficiency, and improved competitiveness with better economic results, without limiting growth” (CSI 2009).

2. Gradual Capacity Building: It would help in large-scale data collection of various sectors which could be very useful in the future and will help in analyzing a nation’s economic and emissions situations.

The S-CDM is a voluntary approach. It is not based on the approach of national level emissions reduction target like the Annex 1 parties of the Kyoto Protocol, and, as such, it permits the developing countries to benefit by getting a chance to choose their country specific target for the sector they feel needs the most attention/ has the most potential. Some experts believe that the sectoral approach may bring in more real reductions as compared to present, in a short period of time as compared to the national level target approach as far as mitigation in developing countries is concerned (Kate Hampton 2008).

The Annex-1 countries would be aiming for the deeper cuts in emissions as compared to present agreements in the future, and this will create the market demand for the credits generated through the S-CDM. The CDM in its current form suffers from the issue of high transaction costs (Michaelowa and Jotzo 2003). The S-CDM presents an opportunity for reducing these costs by scaling up the projects into one massive sectoral project while allowing the nation to derive a method of distribution of the benefits from the project to each participant. Also, the higher volume of CERs that might be introduced to the market due to the S-CDM would go a long way in contributing to the Adaptation Fund being collected by the CDM Executive Board at the rate of 2 percent of the emission reduction proceeds (UNFCCC 2007). This approach also encourages the developing countries to put in more effort in emission reductions and thus prepares them for future participation in the Kyoto regime. Following the paper provides a detailed overview of the energy intensive sectoral approach for the cement industry proposed by the European Union as well as the UNFCCC.

3 The Sectoral Approaches

3.1 EU ETS: Design and Benchmarking

The European Union, through its policy to reduce the GHG emissions, established a cap and trade system-based emissions trading scheme that covers more than 11,000 power stations and industrial plants in 31 countries. The EU ETS makes use of industry benchmarks in terms of emissions in order to determine the allocation of emission allowances for the installations that participate in the ETS. The primary purpose that the benchmarking serves is for the determination of sector-wide caps, the determination of the amount of free allocation of emission reduction units (ERU/EUAs) to the participating installations, and the determination of the amount of free allocation of ERUs to the new entrants into the particular sectors that are already are a part of the EU ETS regime (Matthes 2008). These benchmarks are designed such that they do not distort the carbon market and give a wrong European Emissions Allowance (EUA) price, albeit theoretically. For example, the design needs to avoid plant-specific parameters that may address specific details that are reflected by carbon price already. They should not lead to or encourage unnecessary gains to the participants based on the installations geographic or system boundary, they should be uniform and implementable consistently all over Europe and the participating nations. So, if a cement plant is located in the EU, but buys electricity from a utility across a border from a non-participating nation, then this arrangement should not lead to gains for the cement manufacturer. As described on the EU ETS website, "The benchmarks were established on the basis of the principle 'one product = one benchmark', which means that the benchmark methodology does not differentiate by technology or fuel used, nor the size of an installation or its geographical location" (European Commission 2012). Furthermore, the EU has developed four allocation methodologies to facilitate the calculation of the amount of allocation of free allowances to the participant installations.

These methodologies are applied in the following order:

1. Product benchmark
2. Heat benchmark
3. Fuel benchmark
4. Process emissions approach

Product benchmark: The product benchmark for the EU ETS is derived on the basis of the value that reflects the average emissions of the 10 percent of the best performing installations within the EU. Fifty-six different products have been identified so as to create a standard profile under the EU ETS. E.g., for a certain grade of cement, the emission benchmark would be defined based on the BAT which would be different from another grade of cement. Only the installations that use BAT and are within 10 percent most efficient installations will receive allocations (European Commission 2012).

Heat benchmark: Allowances / TJ of heat consumed: The heat benchmark covers the following parameters for installation and sub-installation levels where the amount of heat used is measured (Directorate B - European & International Carbon Market 2011).

- The heat is used for a purpose like production of products, mechanical energy, heating, and/or cooling.
- The heat is not used for the production of electricity.
- The heat is not produced within the boundaries of a nitric acid product benchmark.
- The heat is not consumed within the system boundaries of a product benchmark.
- Heat is consumed within the ETS installation's boundaries and produced by an ETS-installation; or produced within the ETS installation's boundaries and consumed by a non-ETS installation or other entity for a purpose other than electricity production.

Fuel benchmark: Allowances / TJ of fuel used: In order for a fuel to be considered under the fuel benchmark criteria, the following conditions should be fulfilled by the installations or sub-installations (Directorate B - European & International Carbon Market 2011):

- The fuel is not consumed within the boundaries of a product or heat benchmark sub-installation.
- The fuel is not consumed for the production of electricity.
- The fuel is not flared, except in the case of safety flaring.
- The fuel is combusted for direct heating or cooling production, without heat transfer medium, or the production of mechanical energy which is not used for the production of electricity, or the production of products.

For the emissions to be considered under the fuel benchmark, the emissions arising from use of fuels for purposes other than covered under the heat or product benchmark need to be considered.

Process emissions approach: Allowances/tonne of process emissions: In order for a fuel to be considered under the process emission benchmark criteria, the following conditions should be fulfilled by the installations or sub-installations (Directorate B - European & International Carbon Market 2011):

- The emissions are not covered by a product benchmark or by any of the other "fall-back" approaches.
- The emissions considered 'process emissions' are:
  - Non-CO_2 greenhouse gas emissions listed in Annex 1 of Directive 2003/87/EC occurring outside of the system boundaries of a product benchmark.

- Only CO_2 as direct and immediate result of the production process or chemical reaction can be considered.
- CO_2 from the oxidation of CO or other incompletely oxidized carbon is not covered regardless if this oxidation takes place in the same or a separate technical unit. For example, CO_2 from the oxidation of CO in an open furnace cannot be regarded as process emission under this category (but may fall under the third category if the criteria are matched).
- Emissions stemming from the combustion of incompletely oxidized carbon produced as a result of any of the following activities for the purpose of the production of measurable heat, non-measureable heat or electricity excluding (deducting) emissions from the combustion of an amount of natural gas with equal energy content as those gases, taking into account differences in energy conversions efficiencies.
- CO_2 emissions as a result of any of the activities:
    1. The chemical or electrolytic reduction of metal compounds in ores, concentrates and secondary materials;
    2. The removal of impurities from metals and metal compounds;
    3. The thermal decomposition of carbonates, excluding those for the flue gas scrubbing;
    4. Chemical synthesis where the carbon bearing material participates in the reaction, for a primary purpose other than the generation of heat;
    5. The use of carbon containing additives or raw materials for a primary purpose other than the generation of heat;
    6. The chemical or electrolytic reduction of metalloid oxides or non-metal oxides such as silicon oxides and phosphates.

Non-eligible emissions under any of the four benchmark criteria are to be excluded from crediting. This concludes the explanation of sectoral approaches under the EU ETS. Following is an overview of the standardized baseline approach proposed by the UNFCCC for intensive energy industries to benefit from it.

3.2 UNFCCC: Standardized baselines approach

The UNFCCC and its member states, looking back at the CDM's successes and failures, have realized that certain industries can benefit from the standardization of baselines (which are similar to the benchmarks used by the EU ETS, but are arrived at using different methodology) for energy intensive industries. A post-2012 regime that would be in force with the Kyoto Protocol second commitment period could see sectoral approaches become more common as demonstrated with the implementation of standardized baselines under the CDM. The Kyoto Protocol was effectively approved for a second commitment period extending it to 2020 by 194 countries in Doha, Qatar in December 2012. Nevertheless, the world's biggest GHG emitters, the US and China, did not agree to the commitments; and to make matters worse Canada, Russia and Japan, countries that were part of KP1, dropped out. The European Union and Australia have made serious commitment pledges up to 2020. In view of this opportunity for refinement, two approaches for the establishment of standardized baselines within the UNFCCC were analyzed (EB 2010):

1) A bottom-up approach that would facilitate the submission of proposals for standardized baselines and clarify how such submissions will be processed by the CDM Executive Board; and
2) A top-down approach that would facilitate the request from CMP to the Board to develop standardized baselines.

The major effect of these approaches is the UNFCCC's plan to adopt a common, simplified baseline and monitoring methodology that could be applied on a much broader basis as compared to the CDM that works on project by project basis. The baselines have been intended to support countries and project types that are underrepresented in the CDM. Decision 3/CMP.6 of the UNFCCC has defined the concept of standardized baseline as "a baseline established for a Party or a group of Parties to facilitate the calculation of emission reduction and removals and/or the determination of additionality for CDM project activities, while providing assistance for assuring environmental integrity" (3/CMP.6 2010). This definition includes the provision of baseline scenario identification, baseline emissions determination, and additionality demonstration in the scope of a standardized baseline.

A standardized baseline can be determined by comparing GHG emissions from the sector (e.g. the cement sector in this case) with the other regions/countries having similar plants. In the main document elaborated for the establishment of standardized baselines, the UNFCCC suggests a four-step process to arrive on the necessary baselines (UNFCCC 2013). Initially, the performance indicator that would be used to determine the baseline would need to be decided. This task could prove to be challenging, since the baseline cannot be revised as frequently as compared with a stand-alone CDM project baseline. Moreover, different stakeholders will have diverse interests and views on the performance indicators, making it difficult to reach a consensus. Subsequently the fitting aggregation level of the standardized baseline would need to be decided. The aggregation level plays a crucial role in making the standardized baseline truly effective. There are various ways of aggregation based on production processes, product types, project vintages and geographical area (EB 2010). A very conservative and stringent aggregation level may lead to risk of projects being non-additional (and therefore not creditable), whereas a relaxed aggregation level would run into issues by not being able to capture country- or region-specific differences in project attractiveness (EB 2010). The project transaction costs are also impacted by the aggregation level selected. After that should be the choice of the stringency level of the standardized baseline. This stringency level is useful to prove additionality as it is the baseline and/or the level that needs to be surpassed for a project to be additional. The next step would be to select a time interval after which the standardized baseline would be required to be updated. Changing economic, social, technological, and environmental circumstances have an impact on the baseline and thus as the situations change the baseline also needs to be updated. The UNFCCC has clarified that the standardized baselines framework would be relevant only to those sectors where the projects are targeted towards the stationary emission sources. Crediting benchmark using the standardized baselines is set at the top 20 percent best performing technologies (EB 2010). The baseline energy efficiency and fuel switching is deemed efficient as far as the standardized baselines are concerned. In addition, the UNFCCC requires that the baseline data be updated every three years. This regular updating of baselines would help incorporate the technological advancements that take place in the sector over a period of time.

Country by country basis: The UNFCCC can develop these kinds of approaches without regard to national borders; therefore S-CDM can be used as an approach to reward policies and measures taken up at various industry association or country levels. Sectors where it could be problematic are the so-called ‘diverse industry sectors’; coming up with an appropriate crediting baseline and still having the buy-in of the industries while achieving a mechanism that engages governments is difficult (B. B. Richard Baron 2009). Also, in this case, the national government will get the carbon credits against the emission reductions. How credits will be distributed is an important consideration. They could be distributed ex – post or ex – ante and governments will be responsible for determining the same. The baseline document also needs to highlight the methodology, and the entity responsible for carrying out Measurement Reporting and Verification (MRV) of the GHG emissions reductions over time (EB 2010).

Countries would also need to decide on the schedule for these activities. This approach would require three levels of Measurement, Reporting and Verification (MRV) activity (EB 2010). First level of MRV would be the specific sector-based monitoring where the industry will be providing data. Secondly, the data would be reviewed by a national authority who would then report the same to the UNFCCC. The latter would then analyze the report in order to determine if there is a potential for gaming or cheating. Cost would be borne by the countries, since the country will be credited for the credits. The further modalities will depend on the choice of policies the country chooses to take on for that sector. Finance that is provided in advance of MRV will help take up the cost of financing, which is a priority for countries in the Least-Developed Countries (LDC) bloc. Monitoring would need to be done annually, or at least every couple of years.

4 Cement Sector Overview

4.1 Cement manufacturing: from quarry to cement grinding and the emissions impact per area

Cement has been in use since the time of early civilizations and buildings erected with this material from 60 AD are still seen standing today. Cement is a dust-like substance which has hydraulic properties and is a very important component of concrete, as it gives a concrete mixture its strength, and most importantly it is the ‘glue’ that holds the mixture together. Cement production is a very energy intensive process, and thus reducing emissions from cement production is crucial to a path to a lower energy future and to avoid the threshold of an increase in global temperatures. “CO_2 emissions from cement production currently represent about 5 percent of anthropogenic global CO_2 emissions” (IEA and WBSCD - CSI 2009).

The following section presents a description of the cement manufacturing process with a focus on understanding the process and the emissions generated from each step in the process.

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FIGURE 3 – FLOW SHEET OF DRY CEMENT MANUFACTURING PROCESS WITH STATE OF THE ART TECHNOLOGY

Cement manufacturing consists of several steps which can to a great degree be summarized as:

1. Raw material preparation, starting from the quarry to pre-homogenization of raw materials;
2. Clinker production from raw material grinding, to clinker formation in the kiln and clinker storage in the clinker silos;
3. Cement making from the clinker silos to cement dispatch.

4.1.1 Raw material preparation

Raw material preparation starts in the quarry, where the materials to be used for clinker production are mined. The quarry contains formations of limestone (marl, chalk, etc) deposits rich in calcium carbonates ($CaCO_3$) which is an essential element in the recipe for making clinker. Other materials that are necessary for having the correct proportions in the recipe of the raw mix are materials rich in SiO_2, Al_2O_3 and Fe_2O_3. These constituents come from argillaceous materials such as clay, shale or sand. Subsequent to the material having been mined in the quarry, it is transported to the crushers where the material diminishes in size. After that, the process follows with the pre-homogenization of the materials in a stockpile. Then the material is fed to a 'grinding station' which dries the moisture of the raw material reduces the material size to a powder or dust. The ground raw meal is transported from the raw mill grinding station to a storage silo.

4.1.2 Emissions Sources from Crushing to Raw Meal Homogenization

The steps described, from quarry to raw meal storage are mainly electricity consuming processes. They are considered as an indirect emission source given that the energy consumed comes from electrical plants. The "power consumption for raw material extraction and blending can be assigned to about 5 percent of the total power consumption, while for raw material grinding by means of a vertical mill or the like it can be assigned to 24 percent of the total power consumption" (ECRA 2009). In addition to the above, 6 percent of the power consumption in this process area is employed for raw meal homogenization.

4.1.3 Clinker Manufacturing

The clinker manufacturing area of a cement plant and especially the 'kiln' in itself is known to many people in the industry as the 'heart' of the plant. The steps carried out in the kiln system area lead to the formation of clinker. Clinker is created by burning and mineralizing a mix of limestone, clay, sand, iron and aluminum oxides which in the right proportions, under very high temperatures, lead to the formation of clinker minerals which give cement its hydraulic properties.

One very important reaction in the kiln system is the decarbonation of the raw meal or the decomposition of calcium carbonate (limestone) into calcium oxide (lime) and carbon dioxide (CO_2) gas:

DECARBONATION $CaCO_3 + \text{Heat} \rightarrow CaO + CO_2$ REACTION:

The reaction is very heat consuming and typically 55 to 65 percent of the fuel consumption in a kiln system occurs at this stage. The calcined meal is introduced into the kiln. The kiln rotates quite slowly at 3 - 5 revolutions per minute allowing the material to slowly tumble and move through the kiln gradually in the direction of the flame due to kiln rotation and its inclination. To facilitate the high temperatures, fuel (such as finely ground coal) is fired in the kiln, and as the fuel completes combustion the gas temperature reaches approximately 2,000°C. The intense heat generated causes chemical and physical reactions which lead to the clinkerization reaction and the formation of the clinker minerals. Modern type kilns have an average heat consumption of ~ 3200 MJ/ t of clinker (WBCSD-CSI 2009). The excess air, i.e.

the rest that is not needed for combustion is wasted and with it heat is lost. The clinker exiting the cooler is transported to clinker storage silos.

4.1.4 Emissions Sources from Kiln Feed to Clinker Manufacturing

Clinker production is the most energy-intensive production step in cement manufacturing, accounting for over 90 percent of total industry energy use (E. Höhne 2008). The decarbonation reaction emits 60 - 65 percent of total CO_2 emissions (IEA and WBSCD - CSI 2009). These emissions are due to the inherent properties of limestone and thus are considered process emissions and unless a new process for making cement is considered, these emissions will always be generated. The combustion of fuel in the kiln and calciner leads to further CO_2 emissions. The amount of carbon dioxide emissions due to the fuel combustion, is very dependent on the type of fuel used, i.e. coal will typically generate twice the amount of CO_2 emissions when compared to natural gas. Traditional fossil fuels such as coal, petcoke, heavy oil emit about 40 percent of the CO_2 in the cement manufacturing process (Müller 2009). In addition electrical energy requirements in the clinker production area, inclusive of solid fuel grinding amount to 22 percent of total power consumption in cement plant (ECRA 2009).

4.1.5 Cement Grinding

Clinker from storage silo is weighed and transported to the cement mill (finish mill) where in combination with other minerals such as natural gypsum, limestone are fed into a cement mill where they are ground into a very fine powder to produce cement. The finished product is transported to cement storage silos.

4.1.6 Emissions Sources from Cement Grinding

The cement grinding section of the plants is an electrical energy intensive production area. The energy requirements for cement are in the range 38 percent of the total energy in the plant, due to the higher fineness requirement and hardness of the materials used for cement (ECRA 2009).

4.2 Potential for Emission Reductions in the Cement Sector

There are several possibilities for improvement in the cement manufacturing thus this section will focus on the possibilities that exist for energy efficiency in cement plants. “t is estimated that the production of one tonne of cement released on average 0.87 tonne of CO_2 in 2000. This value nevertheless ranged from 0.73 to 0.99 t CO_2 / t cement between different regions of the world. In 2005, the world average was 0.83 with a range of 0.65 to 0.92 t CO_2 / t cement" (Müller 2009). There have been changes that have been slowly introduced to the industry and the aim here is to summarize the necessary updates / changes from an energy efficiency standpoint and as to how these can reduce the impact from greenhouse gaseous emissions for the cement manufacturing sector.

Four categories that could reduce the carbon footprint from a cement plant are presented:

1. Energy efficiency measures by promoting technology updates and the use of BAT for new plants and existing ones, with a focus on:
    a. Raw grinding and cement grinding efficiency
    b. Clinker manufacturing efficiency
2. Co-processing of alternative fuels in the cement kilns which would lead to a reduction of traditional fuels combustion, and furthermore a reduction of landfill materials.
3. Clinker Substitution, i.e. replacement of clinker by the use of mineral additives such as slag, pozzolan, flyash, etc that have properties similar to clinker.
4. Waste Heat Recovery – to capture heat that is being wasted from the cooler stream to produce energy that can replace purchased energy from the grid.

4.2.1 Energy Efficiency Measures by Using Technology Updates:

4.2.1.1 Energy in the Raw and Cement Grinding

This section presents a short overview of grinding systems. Figure 3 below depicts each system used for grinding as well as a comparison of energy efficiency for each system. Ball mills are the most energy intensive of the raw or cement mill grinding systems described therefore the benchmark would be to change to another type if possible (Worrell 2000).

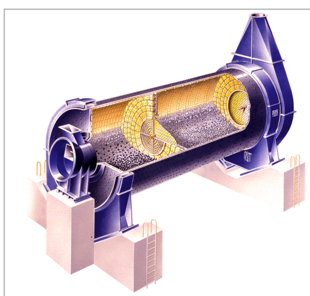
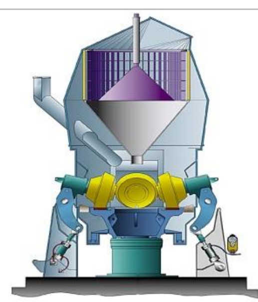
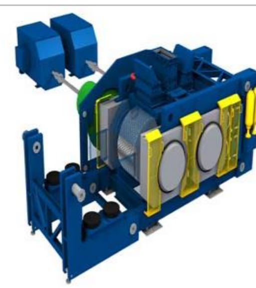
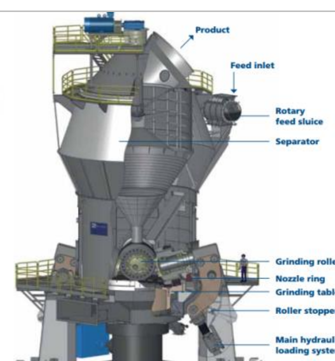
 Ball Mill for Raw or Cement Material Grinding *© Property of Flsmidth A/S, Used With Permission*	 Vertical Roller Mill for Raw Material Grinding *© Property of Flsmidth A/S, Used With Permission*	 Roller Press for Material Grinding *© Property of Flsmidth A/S, Used With Permission*	 OK Vertical Roller Mill for Cement Grinding *© Property of Flsmidth A/S, Used With Permission*
The most energy intensive system for Raw or Cement	~ 30 percent less Energy for Raw Meal Grinding in Ball Mills	~ 30 percent less Energy for Raw Meal Grinding in Ball Mills	~ 20 – 50 percent less energy than a Cement Ball Mill

FIGURE 4 – COMMON RAW OR CEMENT MILL GRINDING SYSTEMS

The total electrical consumption for cement plants is in the order of 111 kWh/ tonne of cement (WBCSD-CSI 2009). If BAT technology is used for both raw and cement grinding, cement plants could see a combined reduction of up 20 kWh / tonne of cement (following the assumption that raw grinding consumes ~ 24 percent and cement grinding about 38 percent and using average percentages presented above regarding savings in energy) electrical energy consumption, thus the footprint of CO_2 emissions generated from the source that provides electricity could be significantly reduced. Power consumed at a cement plant only contributes a small amount of CO_2 emissions i.e. ~ 0.1 kg CO2/kgcli; however, if the potentials described above can be reached it can lead to energy efficiency improvements and a reduction of the total energy consumption in the plant.

4.2.1.2 Energy in the Clinker Manufacturing Area

The clinker manufacturing area of a cement plant and especially the 'kiln' in itself is known to many people in the industry as the 'heart' of the plant. To our purpose clinker manufacturing is an area of high interest, since energy efficiency measures in this section of the plant can lead to significant savings and reduced CO_2 emissions. Energy consumption of the kiln system accounts for over 90 percent of total industry energy use (E. Höhne 2008). Part of the emissions in clinker manufacturing cannot be altered as they are due to the decarbonation of calcium carbonate. This reaction accounts on average for 60 percent of CO_2 emissions in a cement plant and the fuel combustion accounts on average for 40 percent of the emissions, depending on the type of fuel used and the technology available for pyroprocessing.

To understand the potential for reduction in this area we will consider pyroprocessing area conversions from Vertical, Wet, or Long Dry Kilns systems to BAT systems with preheater, or preheater and calciner which will give the most promising approach due to the savings in fuel consumption. A dry preheater with calciner system, as depicted in section 4.1.3 is the most efficient kiln system and on average consumes about 3200 MJ / tonne of clinker (WBCSD-CSI 2009). This system is the technology of choice for most new projects. However, there are still many older type kilns in use in the world which lead to high thermal consumption and high CO_2 emissions in a cement plant due to the inefficiencies of the technology.

These systems are:

1. Wet Kiln Systems
2. Semi- wet and Semi- dry Kiln systems
3. Dry Kiln Systems
    a. Vertical kilns
    b. Long Dry Kilns
    c. Preheater kiln systems
    d. Precalciner kilns (already covered)

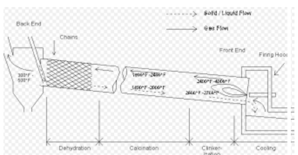
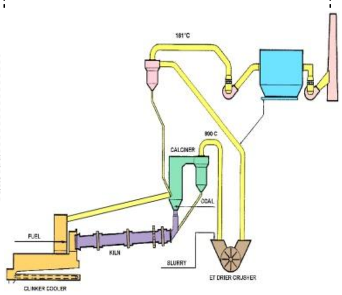
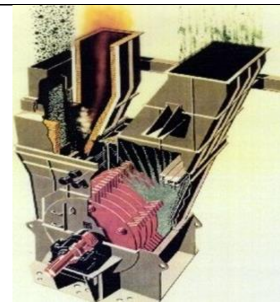
 © (Gossman 1992)	 © *Property of Flsmidth A/S, Used With Permission*	 © *Property of Flsmidth A/S, Used With Permission*	 © (Tonelli 2012)
Depiction Wet Kiln System	Depiction of Semi-Dry Kiln System	Dryer Crusher for Wet Conversion to Semi-Dry	Vertical Shaft Kilns – Lehigh Valley Museum

FIGURE 5 – OLDER TYPES OF KILN SYSTEMS

As it can be observed in the figures above, these kiln systems are extremely different and so is the total specific heat consumption in MJ/tonne clinker which is very dependant of the kiln system type. As it can be noted in the table below, specific heat consumption has decreased significantly due to the development of new, more heat efficient kiln systems. The addition of preheaters and pre-calciners increased the heat transfer in the system and consequently it significantly reduces the energy requirement for clinker production. The dry precalciner kiln process is the most efficient nowadays, and its efficiency can vary from 2,900 MJ/tonne clinker to 3,200 MJ/tonne depending on various factors such as raw material moisture type, fuel type and so on.

Heat Consumption of Different Cement Kiln Technologies

Process	Fuel Consumption GJ/t clinker
Wet process	**5.9 – 6.7**
Long dry process	**4.6**
1 stage cyclone pre-heater	4.2
2 stage cyclone pre-heater	3.8
4 stage cyclone pre-heater	3.3
4 stage pre-heater+pre-calciner	3.1
5 stage pre-heater+pre-calciner	3.0 – 3.1
6 stage pre-heater+pre-calciner	2.9

Source: FLSmidth, 2006.

It is noteworthy to state, that given the development in technology it is obvious that using BAT for the clinker manufacturing stage is immensely important for the energy a cement plant consumes and as consequence the emissions related from the energy efficiency of the plant. However, this is not what is presently happening around the world. While developed countries are trying to phase out the energy intensive wet or long dry processes, the developing world is found to be increasing its share of technologies that consume a lot of energy. The table above does not show the specific heat consumption for another very old kiln technology - vertical shaft kilns, which are inefficient and depending on the type they consume between 4,800 – 6,700 MJ/t clinker (OECD/IEA 2005). The study by IEA indicates that China for example has very high levels of cement production from inefficient vertical shaft kilns, which increased 42percent between 1997 and 2003. Further the report states that in 2005 the share of total production from vertical shaft kilns increased to 47 percent in China. Vertical shaft kilns are also very common in other developing countries, such as India, Peru, and Bolivia. Therefore while the developed world works to phase out older technologies, the developing world invests in cheaper, but much more energy and emission intensive technologies.

It would be the recommendation of this study that plants conduct feasibility studies to convert wet kiln systems into semi-dry or dry plants, and furthermore phase out the use of inefficient and immensely polluting vertical shaft kilns by replacing them with modern technology. The development of the sectoral approaches discussed in the sections following, under the EU ETS and the UNFCCC is of immense relevance to the introduction of these emission friendlier technologies in the developing world for cement plants. Nonetheless, the immersion of BAT could be mostly viable for new plants or for existing plants considering quarry life, suitable market conditions and future capacity requirements, emissions requirements as firstly the number of years in which the plant will be still operating is going to determine the amortization on the investment; however, market conditions, capacity and emissions requirements will impact the cost of the plant depending on future legislations.

4.2.2 Co-processing of Alternative Fuels in Cement Kilns

Traditionally the cement industry has been using fuels such as coal, anthracite, lignite and natural gas have been used in cement kilns. All these fuels have one thing in common, very high potential for CO_2 emissions. The replacement of traditional fuels with alternative fuels in the cement kiln will lead to lower emissions. The use of alternative fuels (AF) in the cement kilns can contribute to several environmental benefits: 1) it replaces the use of non-renewable fossil fuels (coal, oil, natural gas), 2) it reduces CO_2 emissions per tonne of clinker, 3) it reduces the amount of waste material that would otherwise be land-filled providing a social and environmental benefit, and 4) it reduces the amount of waste that would be incinerated and thus it contributes to a reduction in emissions from the incineration and the residual ashes that are left from this process. Cement kilns are very suitable for burning various alternative fuels given "material temperature at approximately 1450°C and kiln gas temperatures up to 2000°C, long residence time up to 8 seconds, or more, insures complete pyrolysis or breakdown of organic waste" (CEMBUREAU 2009). Any fuel that is not traditional is referred to as alternative fuel. There are various fuels from solid, to liquid to gaseous wastes that can be co-processed and used.

The quantity of waste to be used as alternative fuel worldwide is very high, thus if governments enabled different policies that encouraged recycling of material goods, and their burning in cement kilns for valorization of calories and reduced emissions their potential to replace conventional fossil fuels in cement kilns can be quite high. According to a study by the Cement Sustainability Initiative (CSI), for some European countries, the average substitution rate is over 50 percent in the cement industry … "CSI estimates propose that average global substitution rates could be 30 percent in 2030, and 35 percent in 2050, compared to today" (IEA and WBSCD - CSI 2009). Nevertheless conservative estimates for the use of AF indicate that their use could reduce emissions from the cement sector in 2030 by 0.16 Gt CO_2e per year

(Müller 2009). With the deployment of BAT for clinker burning, and adequate burning of alternative fuel these figures could double worldwide, however, policies on a local and global scale must be enforced worldwide to ensure that waste material is not landfilled, or incinerated to cause additional emissions, rather it can be adequately handled, prepared and burned in cement kilns providing many environmental and economic benefits.

4.2.3 Replacement of Clinker in Cement making and its impact on Cement Industry CO_2 emissions

Specific CO_2 emissions per tonne of cement can be greatly influenced by several factors. Electrical energy and heat consumption and the contribution they have on emissions were discussed above. Possibly the biggest potential for CO_2 reduction in the cement industry seems to lie in the replacement of the amount of clinker with hydraulic minerals similar in nature to clinker such as pozzolan, fly ash and slag, which are referred to as Supplementary Cementitious Materials (SCM). Ordinary Portland Cement (OPC) is produced by mixing ~ 94 – 96 percent clinker with 4 – 6 percent gypsum. "When it is ground and mixed with 4 – 5 percent gypsum it has hydraulic properties, i.e., it reacts with water and hardens" (WBCSD-CSI 2009). "CO_2 emissions reduction associated with an increased share of additives in blended cement could be roughly estimated at 0.009 tCO_2e per tonne of blended cement produced for each 1 percent of increased share of additives" (CFA 2009). Simply put for every 1 percent of mineral additives used in cement 90 percent of energy and emissions associated with the energy consumption for the production of clinker is saved. Accordingly, if we can achieve high clinker substitution rates the environmental benefits would be great. The use of SCM additions in cement or concrete has been known and used in several countries for a long time, and "the clinker content can vary between 10 percent and 90 percent, though the extremes are only applicable for special applications" (WBCSD-CSI 2009).

Given the relevance and impact it has on reducing the emissions of CO_2 per tonne of cement, it is extremely important for countries to work together to share the knowledge gained so far with the use of different types of SCMs, properties of different types of materials and their impact on the quality of cement and concrete, so that best practices become the standard worldwide. Although there could be challenges the goal should be to maximize the use of mineral additives so as to obtain the lowest possible clinker to cement ratio, while still maintaining quality (CFA 2009).

4.2.4 Considerations of Waste Heat Recovery Projects in a Cement Plant

Modern cement plants try to recuperate and use a great deal of the heat generated from the combustion of fuels in the cement kiln as combustion air for the kiln and calciner, however, even so cement kilns have excess heat that is wasted. When raw materials coming from the quarry have low moisture content, the heat that is not necessary for the drying and grinding of raw and fuels can be recovered and used to generate power. Excess heat from the clinker cooler is also added to the mixture. In order to generate energy, the installation of a waste heat recovery boiler (WHR) is necessary so that the available heat contained in the stream of gases can be introduced in a steam turbine to convert the heat or energy contained in these gases to electrical energy. A waste heat recovery system installation on a state of the art cement plant could recover electrical energy of up to "30 percent with steam turbine cycles and up to 60 percent using Organic Rankine Cycles (ORC) or Kalina Cycles" (Müller 2009). The investment would be very low when compared to the returns and to the carbon displacement that this investment would bring. This 30 percent energy generation could be especially important in countries with a carbon intensive electricity mix.

5 How Sectoral Approaches work for the Cement Sector?

5.1 Cement Sector Benchmarks in the EU ETS

EU member states have been using different methodologies as part of their National Action Plans to determine benchmarks for the cement sector. Most of the methodologies are based on a plants performance. The main parameters that are taken into consideration for deciding the benchmarks have been described below:

- Direct and indirect emissions
  The two kinds of emissions that have to be taken into account are Direct Emissions (from the manufacturing and combustions processes described above) and Indirect Emissions as a result of the electricity coming off the grid for use in the manufacturing process.
- Clinker or cement
  The big question to address in designing such a system is to decide whether to use cement or clinker for framing a benchmark. As shown in section 4 above, most of the emissions

in a cement plants are due to the clinker making process. The benchmark can however be defined as per tonne of cement or clinker. In terms of electrical energy consumption the most energy intensive processes are raw and cement grinding as well as blending of raw materials. The cement grinding process consumes 38 percent of the electrical energy in a cement plant and is required for converting clinker into cement (ECRA 2009). Typically the emissions from these processes are considered indirect emissions since the power sector is emitting CO_2 during energy generation, except for the case of the grinding plants, which purchase clinker to be used in their cement.

The simplest way to benchmark would be a benchmark based on per tonne of clinker. The other option could be a benchmark based on per tonne of cement. However the only shortcoming of a cement-based benchmark would be that it would encompass grinding-only plants which are presently not a part of EU ETS. In addition, there could be similar problems depending on the project boundaries selected for the particular S-CDM project. A cement-based benchmark would only apply to clinker kilns which are EU ETS participants and which include 'grinding only 'plants within their operations. This benchmark could also include a rectification for clinker produced on the site. In addition as pointed out in section 4 above, care needs to be taken when applying a cement benchmark given that some countries can produce blended cements which lower the carbon intensity per tonne of cement, while others due to policy are not allowed to mix the additives within the boundary of a cement plant, i.e. in a cement mill, but rather the concrete producers make these additions. Thus, if we compare, for example the United States in which concrete producers only make the additions of supplementary cementitious materials versus Mexico where cement producers can use the SCMs in cement grinding, the emissions per tonne of cement would appear to be much higher in the United States as compared to Mexico, when in reality two different mechanism are used for reporting.

- Use of appropriate technology
    - Out of the numerous existing technologies for the production of clinker, rotary dry kiln with a preheater, precalciner technology is the most efficient. It has the lowest specific heat consumption (SHC) and specific CO_2 emissions per tonne of clinker. As explained extensively in the energy efficiency sector older type technology such as the wet or vertical kilns are by and large much less efficient than the dry precalciner kilns. Thus given that different countries have different technologies and especially due to the fact that developing countries rely on older type kilns, the best approach would be to not include any kind of correction factor for the type of technology used (e.g. between preheater and pre calciner kilns).
- Age of the cement plant

    - The efficiency of a plant decreases with age and its carbon intensity increases unless it is retrofitted to reflect newer technology. Consideration of age as a factor for benchmarking would result in a negative incentive to switch to new, cleaner technology, which opposes the objective of the EU ETS scheme. Subsequently the age of the plant should not be criteria for benchmarking.
- Plant size
    - It has been seen generally that large cement plants are more efficient than small plants. No definite correction factor is necessary for small plants as larger and efficient plants are needed for the objective of the EU ETS.
- Moisture content of raw materials
    - Countries with different weather and environmental conditions may have different moisture content. Thus, the moisture content could only be a site–specific correction factor.
- Fuel emission factors
    - Fuel mix is not to be considered while setting a benchmark as it is unspecified by either the available feedstock mix or the required product mix. The use of alternative fuels or biomass can at times lead to a decrease in the energy efficiency depending on fuel properties, however, at the same time the use of alternative fuels also reduces the amount of traditional fuels such as coal or petcoke and thus it displaces CO_2 emissions.
- Alternative fuels
    - As the heat generated by the combustion of alternative fuels is higher in the case of cement kilns than in a waste incinerator, alternative fuels are slowly replacing coal or heavy oil in the cement kiln. The outcome is that cement companies receive incentives for proper disposal of waste in the cement kilns and there is a reduced need for emissions allowances. So in EU ETS no supplementary incentives are needed. A large number of European directives promise similar regulations but there are hurdles at the national level that limit the practical use of alternative fuels.
- Blending of Cements
    - Blending is a very dynamic process and much of it depends on the availability of the right kind of blending material and the prevalent market conditions. The EU has fixed standards for blended cements and it has been clearly specified in EU (ENV 197-2) and thus it can be put to practice easily. Exceptions occur in Italy where cement producers use naturally occurring pozzolans as clinker substitute for cement grinding which decreases the CO_2 intensity of cement.
- Additive drying
    - The drying of additives is necessary because of the high humidity of blast furnace slag or limestone. This is done by using the hot flue gases from the clinker cooler. Thus, no extra allowances are needed for the heat required to dry these additives.
- Bypass factor
    - Due to the high amount of chlorine, alkaline or sulfur presence in limestone and/or alternative fuels used in the cement kiln, plants might have to avoid taking into consideration some of the hot flue gases to exhaust these gases. So, a correction factor might be needed which takes into account the increased energy use due to the by-pass. This correction factor can be either plant specific (based

on plants previous data) or non-plant (using average bypass rate). The latter approach has been chosen for UK NAP phase II for new entrants.

- Self-generation of power
  - As the temperature inside a kiln reach to extremely high levels, so a cement kiln can have additional heat even after it has been circulated in pre-calciner, pre-heaters, and for the drying of raw materials and coal.

These considerations are quite important for the adequate performance of the sectoral approach for the cement industry under the EU ETS. This would simplify the crediting of CO_2 emissions certificates given that all cement plants in the member states would be bound to the same standards across the industry no matter what country the location is. Nevertheless, as mentioned above it is of utmost importance that an appropriate benchmark is used to hold the industry accountable for their emissions. As the clinker manufacturing process accounts for over 90 percent of the CO_2 emissions in a cement plant, it would be satisfactory to apply a per tonne of clinker benchmark. This would avoid issues brought upon from the low carbon intensity that plants using supplementary cementitious materials in the cement grinding phase have, while compared to plants that might not have availability of such materials. Therefore, the most straightforward and practical method to benchmark would be based on per tonne of clinker.

5.2 The Case of Ethiopia – Standardized Baseline for the Cement Sector

As mentioned earlier, the UNFCCC is working towards the use of standardized baselines for the cement sector. There exists one such methodology, developed for the Ethiopian cement sector, and thus this is included as a discussion point here to demonstrate the use of standardized baseline approach in practice. This approach can be used for single/multiple measures on existing and new plants. The standardized baseline was primarily developed for 1) determination of additionality, 2) identification of baseline, and 3) estimation of the baseline emissions.

Ethiopia is divided into 5 diverse cement regions based on geographical locations, raw material properties, and the availability and the type of cement manufacturing technology employed. There is a separate standardized baseline established for each “Cement Region”. The output recognized is clinker. The standardized baseline is suitable to weaken fuel and feedstock switch. It may also affect the switch of technology with/without change of fuel type (including energy efficiency improvement).

Additionality Criteria: The UNFCCC has developed a "positive list" of fuels and/or feed stocks and technologies that have been selected by the UNFCCC as automatically meeting the Additionality Criteria, which are finalized by the fast-start thresholds approved for Additionality by the CDM Executive Board under the "work program on standardized baselines" Version 01.0. The UNFCCC uses the term "Positive list" for certain clean technologies that it has listed.

1. Kiln Fuel switch (all cement regions): The kiln fuels to be selected should have carbon intensity less than that of coal. Kiln fuels with carbon intensity less than that of coal (which is the most carbon intensive fuel) among the fuels used to produce 90 percent (Xa = 90 percent) of the clinker manufactured by plants in the cement region, and facing barrier are included in positive lists. Switch to any of such fuel type is additional. There is a nationally enforced mandatory regulation in the host country enforcing switching from other historically practiced fossil fuels to use of coal as kiln fuel.
2. Feedstock switch: Feedstock types that result in carbon intensity less than that of limestone and clay (which is the feedstock types used to produce more than 90 percent (Xa=90 percent) of the clinker produced by plants in the cement region) and facing barriers or less commercially attractive (with their unit cost per tonne or cost per unit clinker higher than that of limestone and clay) are included in positive lists. Switch to any of such feedstock types is additional.
3. Technology switch: In the case of cement regions in the North cement region of Ethiopia, kiln technologies with carbon intensity lesser than the carbon intensity of the best kiln technology available (5 stage Pre-heater without pre-calciner and planetary cooler) among those used to produce aggregately 90 percent (Xa=90 percent) of the total clinker produced by plants in the cement region, and facing barriers or less commercially attractive (e.g., with their capital investment cost per unit of rated output higher than that of the above kiln) are included in positive lists. Switch to any of such technology types is additional.

In the Ethiopian cement regions of East, South and West, two stage pre-heater rotary kiln technology has to be taken as reference. In the Cement region of North, a five-stage pre-heater with pre-calciner and grate cooler is to be used as a reference technology, based on current practice.

Project participants may apply the following baselines:

1. Kiln Fuel switch (all cement regions): The choice of baseline fuel should be coal as it the fuel with the highest carbon intensity as compared to other fuels which are used for the production of almost 90 percent of clinker.
2. Feedstock switch for clinker manufacturing:
    a. Cement regions Central, East, South and West: The baseline feedstock should be limestone and clay as it is the only feedstock with lowest carbon intensity, which

will cause less emissions among the feedstock contributing to produce in aggregate 90 percent of the clinker output by plants in the cement region.

   b. Cement region North: The same as above applies to this region too.

3. Kiln technology switch/retrofit measure:
   a. Cement regions central: Five stage pre-heater without pre-calciner (as operated by Mugher with three years average SKCBSL value of 4.34GJ/t), the kiln technology with the lowest carbon emission factor among the kiln technologies contributing to produce in aggregate 90 percent (Xb=90 percent) of the clinker output produced by plants in the cement region, is the baseline kiln technology for clinker manufacturing. The baseline emission for fuel switch is calculated using equations in ACM003 V07.4.1. The baseline kiln fuel identified is coal whose emission factor is obtained from IPCC default factor for the relevant type of coal at the lowest confidence level. If applicable, the project may also reduce CH_4 emissions from preventing disposal or uncontrolled burning of biomass residues.
4. The baseline calcinations emission factor (EFfs) for feedstock switch CDM measure (tCO_2/t clinker) is a combination of emission factor for clinker production (BEcalcin/CLNKy) and emission factor for CKD dust (BEDust/CLNKy).

This document has been submitted to the UNFCCC and needs to be approved hitherto, nevertheless it provides good insight about what a standardized baseline looks like and how one should go about building one for the cement industry. The factors that affect how a standardized baseline is developed can be studied from this illustration. For example, how the geography of different regions lead to diverse approaches being followed by the manufacturers and their impacts on the emissions becomes very evident in the way various cement regions have been treated in this document. Similarly the document treats the issues about the plant size, fuel type, technology employed, in order to reach a common baseline for the entire country.

6 Discussion and Analysis

This study summarized proposed approaches from the EU and UNFCCC on sectoral approaches and standardized baselines regarding the cement industry. The cement industry offers a great opportunity for a standardized sector wide approach for the industry and organizations such as the Cement Sustainability Initiative, in conjuction with major world cement producers are working together to make a sectoral approach to the industry possible. There exist several areas of possible improvements in the cement industry and the changes that could occur are such that the industry can greatly reduce its carbon intensity.

A sectoral approach to the cement industry could be a benefit for both developed and developing countries alike. A standardized approach similar to the examples brought forward by the EU ETS sector benchmark and the UNFCCC standardized baseline, help aid the establishment of the amount of emissions that the cement sector would be allowed to emit under an emissions reduction scheme, thus facilitating the monitoring and verification phase by helping to streamline the baseline establishment process. In the case of standardized baselines under the S-CDM, the monitoring is done against a single value for the entire sector as compared to the individual projects in the case of the regular CDM. The bottom up approach, where governments determine the baselines for countries and regions, and delegate the cap to the cement plants operating within the specified geographic boundaries, could potentially lead to hampered growth of the sector, at least initially. In some instances this approach could lead to more carbon credits gained from the industry. In the process of defining fixed targets, the risk of higher-than-expected output growth could lead to an inflation of the target during the negotiation phase (B. B. Richard Baron 2009). This has clearly been the case in the first phase of the EU ETS, where governments had limited data to evaluate industry projections on future output and related emissions (A D Ellerman 2008). The strictness of the baseline thus plays an important role in the success of the mechanism rather than the methodology employed to establish the baseline. The major concern for such mechanism will be achieving its goal of preserving environmental integrity. Thus, without knowing the baseline level, it is not possible to indicate whether a crediting mechanism based on a fixed baseline could be more or less stringent, generate more or fewer credits than an intensity-based baseline (B. B. Richard Baron 2009). Just as with the CDM, the countries creating a baseline for any sector of their economy may have a motivation to inflate their baselines. This may lead to significant reductions in their reported emissions (relative to the baseline) without achieving significant actual reductions in reality.

One benefit for the cement sector is that the Cement Sustainability Initiative and major world cement producers have gathered many data and thus the industry has benchmarks to which it can conform. Current average total electrical consumption for cement plants is on the order of 111 kWh/ tonne of cement (WBCSD-CSI 2009). However, the deployment of best available technology, such as vertical roller mills for raw and cement grinding, could result in a combined reduction of up 20 kWh / tonne of cement. The IEA roadmap study predicts that by the year

2050 specific electrical energy consumption per tonne of cement can be in the order of 92 kWh/ tonne of cement, thus the footprint of CO_2 emissions displaced from the source that provides electricity could be reduced by at least 20 percent (IEA and WBSCD - CSI 2009). The clinker manufacturing process is responsible for over 90 percent of emissions in the cement plants due to the calcination reaction, fuel combustion and electrical energy consumption needed to drive the equipment. Many plants especially in developing countries like China and India still make use of very old and inefficient technology thus feasibility studies should be carried out to convert wet kiln systems into semi-dry or dry plants, and furthermore phase out the use of inefficient vertical shaft kilns by replacing them with modern technology. As Müller points out, "Japan has the most efficient cement industry, thanks to a vast majority of new dry kilns, 85 percent of which feature preheaters and precalciners. All other technologies have been phased out. The energy intensity is 3,100 MJ / tonne of clinker" (Müller 2009). Thus, installing state of the art technology or updating older systems with preheaters and pre-calciners, modern coolers, etc increases the heat transfer and heat recovery in the system and consequently it significantly reduces the energy requirement for clinker production, leading to great improvement in thermal and electrical efficiency and thus reduced CO_2 emissions per tonne of clinker.

The combustion of fuels leads to over 40 percent emissions of CO_2 in clinker manufacturing; however, this is greatly dependent on the kiln type and fuel type used in the kiln. Cement plants in several countries and especially in Europe have championed the use of Alternative Fuels, or waste from other industries in cement kilns thus making use of their energy and valorization of calories for clinker making while at the same time reducing CO_2 emissions. "Estimates propose that average global substitution rates could be 30 percent in 2030, and 35 percent in 2050" as compared to substitution rates nowadays (IEA and WBSCD - CSI 2009). With the deployment of BAT for clinker burning, as well as BAT for alternative fuels to allow proper burning these figures could be much higher worldwide, however, policies on a local and global scale must be enforced worldwide to ensure that waste material is not landfilled, or incinerated to cause additional emissions, rather it can be adequately handled, prepared and burned in cement kilns providing many environmental and economic benefits. The use of supplementary cementitious materials could be a great potential in reducing the carbon intensity per tonne of cement as "CO_2 emissions reduction associated with an increased share of additives in blended cement could be roughly estimated at 0.009 tCO_2e per tonne of blended cement produced for each 1 percent of increased share of additives” (CFA 2009). This means that for every 1 percent of mineral additives used in cement grinding 90 percent of the energy and emissions associated with it for clinker production is saved. The goal should thus be to maximize the use of mineral additives so as to obtain the lowest possible clinker to cement ratio, while still maintaining quality. Care should be taken though to make sure that for example the UNFCCC assigns a benchmark that can be followed by all countries since the use of the SCMs in cement grinding is not allowed in every country on the cement plant stage, rather some countries do this during concrete making. This could make a big difference however the benchmark used for a country or region should be developed keeping this in mind. Finally saving could also come through the use of waste heat recovery system installation on a state of the art cement plant. These plants could recover electrical energy of up to “30 percent with steam turbine cycles and up to 60 percent using Organic Rankine Cycles (ORC) or Kalina Cycles” (Müller 2009). The investment would be very low when compared to a reduction of the current plant electricity consumption by up to two thirds and thus given its potential it is a technology that should be pursued from all countries. As summarized above, the data to be used for benchmarks are available, so the goal should be to standardize across industry and countries to reduce the carbon intensity of the industry.

However, this is not to say that standardization would be easy. With various types of products, processes, technologies and raw material requirements for the cement sector, there could a problem in setting up a single baseline for the entire sector. Developing and monitoring the agreements and baselines will need extensive data and information and thus, collaboration of smaller companies with initiatives such as the Cement Sustainability Initiative and the industry experts is of utmost importance. Depending on the type of baseline and the input parameters considered during its development, appropriate monitoring methodologies will need to be outlined. The complexity of generating the baseline also permeates to the reviewing and verification stage of the project, thus making it a challenging task. Whichever the approach taken by the industry, whether it be benchmarking on carbon intensity of clinker and thus promoting the use of best available technology, or carbon intensity per ton of cement thus promoting the use of blended cements to reduce carbon intensity, care must be taken to ensure that developed and developing countries agree to this approach. As Höhne and Ellermann highlight, "Carbon constraints can have a major impact on the cost of cement production. Assuming a price per tonne of CO_2 of $30 and an international price of cement around $60-$100 per ton, the carbon constraint and the emission intensity can become one of the major factors affecting cost and competitiveness" (Höhne and Ellermann 2008). Thus, when considering that cement is a commodity that can be produced and shipped anywhere in the world, the issue of price sensitivity cannot be ignored.

Not only could cement prices be affected by carbon constraints in this industry, but also by carbon constraints in the power sector, as increases in electricity prices could cause increases in cement prices, and, unlike the power sector where the costs can be passed down to the consumer, with cement the situation is not the same. BCG contends that "sensitivity analyses show that, even with higher transportation costs, offshoring would still occur in view of higher production cost in the EU due interalia to high electricity prices and direct CO_2 cost" (BCG 2012). Countries could therefore move their operations to developing countries where the stringency of regulations is not as high, and the cost of productions are much lower. Given that cement can be produced cheaply in a developing country, international competition does not permit for cement producers to pass the increase in production costs down to the consumer. Sensitivity studies have shown that prices per tonne of cement are not expected to rise in the near future because international competition for cement products is considerably augmented. (BCG 2012). Therefore, specific agreements for participation will need to be decided by national or regional governments in consultation with industry and other stakeholders. "In some countries, participation may be through efficiency-based emissions goals; in others, through a cap-and-trade emissions trading system; in others through the adoption of technology or efficiency standards" (CSI 2009) Thus S-CDM has both pros and cons. It has been developed with the objective of improving the flaws of the existing clean development mechanism and is in a very nascent stage as of now. Just like the CDM, the actual effectiveness of the sectoral CDM will only come to light when it is unveiled and implemented.

7 Conclusions

Changes in climate patterns, including drought and flooding, are making many countries realize that climate change is not just a myth. PriceWaterhouse Cooper (PWC) stated in a report published in November 2012 that the world needs to reduce its carbon intensity (kgCO_2e emissions/GDP) by 5.1 percent every year to 2050 to have a fair chance of limiting warming to 2°C above pre-industrial levels. Even to have a reasonable prospect of getting to a 4°C scenario would imply nearly quadrupling the current rate of decarbonisation (Hone 2012). As a consequence it is important that countries and industries mobilize to reduce their carbon footprint. Analyses of the various sectoral approaches by Höhne and Ellermann (2008) and Victoria Alexeeva-Talebi (2012) suggest that the sectoral approach with a fixed baseline and credit system would be the best approach for the cement industry as far as the environmental, social, economic and distributional effectiveness is concerned. Since the sectoral baselines are developed keeping in mind the present situation of the industry and the specific sector performance to the region / nation, they reflect the techno-economic scenario of the country ultimately making the reduction targets more achievable. This goes a step beyond the emission offsets; the standardized baseline feature of the sectoral CDM becomes particularly important for the cement sector where both energy and process related GHG emissions occur.

As described in this paper, the technology used to produce cement plays an important role in determining the amount of emissions. A combination of bottom up approaches with best available technology transfer deployment would result in significant reductions. Since the sectoral approach can go a step further from the regular CDM approach, a list of technologies and benchmarks based on these can be put forth that automatically would qualify projects for the S-CDM. The cement sector has been experiencing low applicability of the existing approved CDM methodologies due to demonstration of additionality, high transaction costs, uncertainties in registration process, improper applicability of small scale projects and barriers in monitoring and verification (WBCSD-CSI 2012). The sectoral approach would speed up the implementation process, and reduce transaction costs since projects are implemented on the whole sector rather than individually and contribute to emissions reductions. In addition to the emissions reductions achieved, sectoral approaches will boost technology transfer between the developed and developing countries. Once a baseline is established, it becomes easier for the industries to demonstrate the emission reductions for their projects. Developing countries would have an easier way to prove and establish the additionality requirement, and developed countries would be able to meet their emissions reduction pledges, thus the sectoral approach will provide an opportunity to engage the industry on an international level while contributing to the global goal of reduced impact to climate change.

8 Bibliography

[-/CP.17], Draft decision. "Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention." n.d. http://unfccc.int/files/meetings/durban_nov_2011/decisions/application/pdf/cop17_lcaoutcome.pdf (accessed November 3, 2011).

3/CMP.1, UNFCCC. "Modalities and procedures for a clean development mechanism - Annex." UNFCCC, 2005. 16, Paragraph 43.

3/CMP.6, UNFCCC. "Further guidance relating to the clean development." 2010. http://cdm.unfccc.int/Reference/COPMOP/08a01.pdf (accessed November 1, 2011).

A D Ellerman, B K Buchner. "Over-Allocation Or Abatement? A Preliminary Analysis of the EU ETS Based on the 2005-06 Emissions Data." 2008. http://www.ucei.berkeley.edu/PDF/seminar110207.pdf (accessed November 1, 2011).

BCG. *Key arguments justifying the european cement industry's application for state aid to balance offshoring risk caused by the increase of electricity prices due to eu-ets.* CemBureau, 2012.

BCG. "KEY ARGUMENTS JUSTIFYING THE EUROPEAN CEMENT INDUSTRY'S APPLICATION FOR STATE AID TO BALANCE OFFSHORING RISK CAUSED BY THE INCREASE OF ELECTRICITY PRICES DUE TO EU-ETS." n.d.

CEMBUREAU. "Co-Processing of Alternative Fuels and Raw Materials in the European Cement Industry." CEMBUREAU, the European Cement Association, Brussels,, 2009, 7, 9.

CFA. *Cement Sector in Africa and CDM* -. Key Sheet, Carbon Finance Assist, World Bank Institute, Washington DC: World Bank Institute - Carbon Finance Assist, 2009, 15.

CSI. *Greenhouse gas mitigation in the cement industry.* Conches-Geneva, Washington DC: World Business Council for Sustainable Development, 2009, 3.

—. *World Business Council for Sustainable Development, Cement Sustainability Initiative (CSI).* 2012. http://www.wbcsdcement.org/index.php/about-cement/cement-production (accessed 2012 йил 25-October).

—. *World Business Council for Sustainable Development, Cement Sustainability Initiative.* 2012. http://www.wbcsdcement.org/index.php/about-cement/cement-production (accessed October 25, 2012).

Directorate B - European & International Carbon Market, European Commission. "Guidance on allocation methodologies- Guidance Document n°2 on the harmonized free allocation methodology for the EU-ETS post 2012." 2011. http://ec.europa.eu/clima/policies/ets/benchmarking/docs/gd2_allocation_methodologies_en.pdf (accessed October 30, 2012).

EB, 65. "Guidelines for the establishment of sector specific standardized baselines." 2010. http://cdm.unfccc.int/filestorage/4/I/Y/4IY1RB7DMKLWPGF59XC3UE6JNH8Q2A/eb62_repan08.pdf?t=YkZ8bWRob3hpfDCaSvFRR9W36fay1kDXKwmW (accessed October 30, 2011).

Ecofys. *Methodology for the free allocation of emission allowances in the EU ETS post 2012 - Sector report for the cement industry.* Study report, Ecofys , Fraunhofer Institute for Systems and Innovation Research, Öko-Institut, 2009, 4.

ECRA. *Development of State of the Art Techniques in Cement Manufacturing: Trying to Look Ahead.* Duesseldorf, Geneva: CSI Cement Sustainability Initative/ ECRA European Cement Reserach Academy, 2009, 31, 11.

ECRA. *Development of State of the Art Techniques in Cement Manufacturing: Trying to Look Ahead.* Document, Duesseldorf, Geneva: CSI / European Cement Research Academy , 2009, 31.

ENVIS. "Clean Development Mechanism (CDM)." *Envis, Environmental Information System India.* December 2008. http://envis.maharashtra.gov.in/envis_data/files/cdm/CDM.htm (accessed November 10, 2012).

Ernst Worrell, Michael Ruth, and Lynn Price. *Evaluating Clean Development Mechanism Projects in the Cement Industry Using a Process-Step Benchmarking Approach.* Berkeley, California: ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY, 2000, 3.

European Commission. 2012. http://ec.europa.eu/clima/policies/ets/benchmarking/index_en.htm (accessed November 3, 2012).

FLSmidth. *OK vertical roller mill.* Bethlehem PA: FLSmidth Inc, 2012, 2.

Höhne, Dr. Niklas, and Christian Ellermann. *A Sectoral Approach and Technology Transfer for the Cement Sector.* Switzerland: Ecofys; Federal Office for the Environment FOEN,, 2008, 3.

Höhne, Ellermann. *A Sectoral Approach and Technology Transfer for the Cement Sector.* Study, Switzerland,: Ecofys / FOEN, 2008, 3.

Hone, David. *A grim warning about the 2°C target – but then what?* November 12, 2012. http://theenergycollective.com/davidhone/142386/grim-warning-about-2-c-target-then-what?ref=node_related_posts (accessed November 13, 2012).

IEA and WBSCD - CSI. *Carbon emissions reductions up to 2050.* Document, IEA and WBSCD - CSI, 2009, 4, 17.

IEA and WBSCD - CSI. *Cement Technology Roadmap - Carbon emissions reductions up to 2050* . Document, IEA and WBSCD - CSI, 2009, 28.

IPCC. "Aviation and the Global Atmosphere." By D.H.Lister, D.J.Griggs, D.J.Dokken, M.McFarland (Eds.) - J.E.Penner. Cambridge University Press, 1999.

Kate Hampton, Steven Gray, Pedro Martins Barata. "Sectoral CDM." 2008. http://www.ccap.org/docs/resources/695/Sectoral%20CDM.pdf (accessed October 30, 2011).

Matthes, Felix Chr et.a.l. *Pilot on Bechmarking in the EU ETS.* Berlin, Utrecht: 'Oko' Institut e.V., Ecofys, 2008, 33.

Michaelowa, Axel, and Frank Jotzo. "Impacts of transaction costs and institutional rigidities on the share of the Clean Development Mechanism in the global greenhouse gas market." Rostock: Committee of Environmental Economics in Economic Association, 2003.

Muller, Benito. *Additionality in the Clean Development Mechanism- Why and What?* Oxford Institute for Energy Studies, 2009.

Müller, Jochen Harnisch and Nicolas. *A blueprint for a climate friendly cement industry.* PhD Thesis, Gland: WWF International, 2009, 13, 17, 27, 22, 3, 19.

Niklas Höhne, Christian Ellermann. *A Sectoral Approach and Technology Transfer for the Cement Sector.* Study, Switzerland,: Ecofys / FOEN, 2008, 3.

OECD/IEA. *Tracking Industrial Energy Efficiency and CO2 Emissions.* Paris: IEA, 2005, 144, 145.

Richard Baron, Barbara Buchner, Jane Ellis. *Sectoral Approaches and the Carbon Market* . IEA/OECD, 2009.

Richard Baron, Jane Ellis. "Sectoral Crediting Mechanisms for Greenhouse Gas Mitigation: Institutional and Operational Issues." 2006. https://www.iea.org/publications/freepublications/publication/greenhouse.pdf (accessed November 1, 2011).

Stern, Nicholas. *The Economics of Climate Change - Summary of Conclusions.* London: HM Treasury, 2007, vi.

Streck, Charlotte. *The Concept of Additionality under the UNFCCC and the Kyoto Protocol:Implications for Environmental Integrity and Equity.* London : UCL, 2010.

UNFCCC. "Adaptation Fund." UNFCCC, 2007.

—. "Guidelines for the establishment of sector specific standardized baselines Version 2.0." *UNFCCC.* April 12, 2013. https://cdm.unfccc.int/Reference/Guidclarif/meth/meth_guid42.pdf (accessed April 12, 2013).

Victoria Alexeeva-Talebi, Andreas Löschel and Sebastian Voigt. *Macroeconomic Impacts of Sectoral Approaches:The Role of the Cement Sector in China, Mexico and Brazil.* Mannheim; Germany: Centre for European Economic Research, 2012.

WBCSD-CSI. *Call for inputs on the reasons for no or low application of approved methodologies in CDM project.* WBCSD-CSI, 2012.

WBCSD-CSI. *Cement Industry Energy and CO2 Performance, Getting the Numbers Right.* Cement Sustainability Initiative, Conches-Geneva, Washington DC: World Business Council for Sustainable Development - Cement Sustainability Initiative, 2009, 4, 27, 21.

Worrell, Ernst, Ruth Michael , and Price Lynn. *Evaluating Clean Development Mechanism Projects in the Cement Industry Using a Process-Step Benchmarking Approach.* Berkeley, California: ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY, 2000, 3.

WWF. "Views on framework for various approaches." *UNFCCC.* March 2013. http://unfccc.int/resource/docs/2013/smsn/ngo/331.pdf (accessed April 10, 2013).

&D.