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OECD ENVIRONMENT DIRECTORATE
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INTERNATIONAL ENERGY AGENCY

**AN INITIAL VIEW ON METHODOLOGIES
FOR EMISSION BASELINES:
CEMENT CASE STUDY**

INFORMATION PAPER



FOREWORD

This document was prepared by the OECD Secretariat in June 2000 at the request of the Annex I Expert Group on the United Nations Framework Convention on Climate Change. The Annex I Expert Group oversees development of analytical papers for the purpose of providing useful and timely input to the climate change negotiations. These papers may also be useful to national policy makers and other decision-makers. In a collaborative effort, authors work with the Annex I Expert Group to develop these papers. However, the papers do not necessarily represent the views of the OECD or the IEA, nor are they intended to prejudge the views of countries participating in the Annex I Expert Group. Rather, they are Secretariat information papers intended to inform Member countries, as well as the UNFCCC audience.

The Annex I Parties or countries referred to in this document refer to those listed in Annex I to the UNFCCC (as amended at the 3rd Conference of the Parties in December 1997): Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, the European Community, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland, and United States of America. Where this document refers to “countries” or “governments” it is also intended to include “regional economic organisations”, if appropriate.

<p>This case study is part of a larger analytical project undertaken by the Annex I Experts Group to evaluate emission baselines issues for project-based mechanisms in a variety of sectors. Additional work will seek to address further the issues raised in this and other case studies.</p>
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CEMENT CASE STUDY¹

Executive summary

Cement is produced in more than 80 countries. Its manufacture is very energy intensive and results in significant energy-related and process emissions of greenhouse gases, mainly CO₂. There are a number of ways in which the greenhouse gas “intensity” of cement could be reduced. Thus, cement manufacture could potentially be an object for joint implementation (JI) or Clean Development Mechanism (CDM) projects. This case study explores if and how emission baselines for different types of JI or CDM projects in the cement sector could be standardised.

There are three main steps in cement manufacture: 1) preparing the raw materials; 2) producing an intermediate “clinker”; and 3) grinding and blending clinker with other products to make cement. Clinker production is the most energy intensive of these steps and is also the source of process CO₂ emissions. Process emissions can account for half or more of emissions from cement manufacture.

Clinker can be produced by a number of different manufacturing processes. The “dry” process is much more energy-efficient than the “wet” process (which is gradually being phased out). Which process is used to manufacture cement thus influences the greenhouse gas (GHG) intensity of cement. Other factors that affect the energy and/or GHG intensity of cement production include:

- which fuels are used in the manufacturing process (*e.g.* coal, oil or solid waste);
- which exact technologies are used (*e.g.* which type of cement grinder, exact kiln specifications *etc.*);
- the type of cement that is produced (not all cement types are suitable for all applications and some cement types are more energy-intensive to produce than others);
- the physical and chemical properties of the raw materials used;
- the GHG intensity of electricity used in cement manufacture; and
- the proportion of clinker, the most GHG-intensive component, in cement.

Cement manufacturers have different degrees of influence over these different factors. For example, they generally cannot choose electricity of a particular GHG intensity - they use what is available to them.

Potential JI/CDM project types in the cement sector can be divided into two broad categories: energy-related and non-energy related. Energy-related GHG emissions from clinker manufacture could be reduced by:

- increasing the energy efficiency of cement production, *e.g.* by optimising heat recovery or installing an efficient pre-heater,

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- changes in the production process, *e.g.* by changing the process by which raw materials are ground, mixed and fed into the kilns from wet to dry, or
- changing the input fuel, *e.g.* by using an increased proportion of waste fuels.

In addition, process CO₂ emissions could be significantly reduced per ton of cement produced by blending (mixing) clinker with an increased proportion of other products (“additives”) in cement. This can be done in some cases without incurring significant incremental costs. Potential GHG reductions from cement blending may outstrip those from energy efficiency projects by a significant margin.

Some elements of emission baselines for potential JI/CDM projects in the cement sector could be standardised. Which elements depend on the type of project that is being undertaken (see below). Changes at an individual plant could make it eligible for one or more of these project types.

For energy-efficiency projects, standard energy values for different manufacturing steps could be established, such as x GJ fuel per ton clinker produced. These values would be based on the energy intensity of new technology installed at present, which is a good indication of “what would have happened otherwise”. A project that produces cement at a lower energy intensity than the standard threshold value could generate emission credits. These standardised energy values could apply internationally to both existing and new plants. Basing a standardised energy value on technology-specific data has the advantage that such data are readily available (and could be easily updated, if necessary).

Emission baselines need to be expressed in terms of emissions. However, a standardised value for CO₂ emissions/ton clinker cannot be drawn up across countries without effectively prescribing which fuels are used (and for electricity, how efficiently it is generated). Nevertheless, standardised “energy baselines” could be drawn up and then “translated” to GHG emissions. The information needed for “translation” could be default, country-specific or project-specific data, such as multi-project electricity baselines, IPCC emission inventory methodologies and default or site-specific emission factors.

Standardised energy values could also be drawn up for production process change projects. These values would need to reflect both the technology in place and its rate of conversion to efficient technology under BAU conditions and may therefore need to be drawn up at the national level.

For JI or CDM projects that change the fuel used in cement manufacture, the most difficult part of setting a baseline is assessing the quantity of waste fuels that would have otherwise been used, as this can vary significantly over time as well as from site to site. This difficulty is compounded for new plants, where historical “alternative fuel” use data is not available. Thus, no standardised values for the amount of baseline alternative fuel use can be drawn up. Nevertheless, once this amount, the fuel’s emission factor and what it is displacing has been established, a standard methodology to “translate” this activity into GHG equivalent is available in the IPCC inventory guidelines.

For all energy-related projects in the cement sector, baselines should be expressed in terms of energy use per ton clinker produced for each of the three main process steps. Since the characteristics of “cement” can vary widely, expressing standardised baselines in terms of tons of cement would not lead to comparable values across projects. An internationally standardised baseline value for the energy required to manufacture cement should be set towards the upper end of the best practice range for energy-efficiency type projects, such as 3.1 GJ/t clinker direct fuel use for the pyro-processing step. This value compares to estimated best practice of 2.9 - 3.2 GJ/t clinker and performance of 2.93 - 3.10 GJ/t clinker in new, best practice cement plants. A lower value would result in fewer “free riders”, but could also result in some additional projects not generating any emission credits. It may be more appropriate to set a less stringent baseline (*i.e.* at a higher level) for process change projects, in order to encourage conversion from highly inefficient plant types. The large volumes of cement produced means that the number of credits generated by a particular

project is highly sensitive to the baseline level: credits could more than double with a 0.1 GJ/t increase in baseline levels.

Setting standardised values for electricity consumption for each of the main process steps is also possible in theory, although more difficult in practice, as significant variations ($\pm 15\%$) in technology performance are found from site to site. Moreover, more than one standardised energy value would be needed for cement grinding, to reflect the different energy consumption requirements of producing different quality cements (different quality cements are needed for different applications: one cement cannot always be substituted for another). Information on total fuel and electricity use from the three process steps should be included when calculating the emission reductions and related emission credits generated by a project, as projects could reduce the energy requirement in one step but increase it in another.

The energy-related emissions of CH₄ and N₂O combined typically represent less than 0.5% of total energy-related emissions, so could be omitted from emission baselines without having a significant impact on either the stringency of the emissions baseline or on the uncertainty of credits. Thus baselines for energy-related projects in cement manufacture could be simplified to include energy-related CO₂ emissions only. Since process-related CO₂ emissions are not impacted by energy-related projects, they would also not need to be included in the emissions baseline for energy-related projects.

For blending projects, it would be difficult to set either international or national standards for the clinker content of cement produced because the clinker content of cement varies significantly within and between countries, cement plants and cement types and can change significantly from year to year. Moreover, for plants already in operation, data on clinker and cement production before and during a project are likely to be both easily available at the project level and more accurate (and available) at this level than at the country level. However, using a project-specific and potentially highly variable number, increases the opportunity for gaming. This is exacerbated for greenfield plants, which by definition do not have any historical data on which to base emission baselines. Emission baselines for any blending-type projects should include components related to both energy-related and process CO₂ emissions. These components should be separated for transparency and verification purposes. Baselines for blending projects in cement manufacture should be reported in terms of energy-related and process CO₂ emissions per ton cement produced.

This study recommends quantifying the major emission sources that are influenced by a project. For energy projects, the major emission sources are the three major process steps: raw materials preparation, pyro-processing and cement grinding. Process CO₂ emissions are unchanged by energy-related projects and so could be omitted from the project baseline for simplicity. For blending projects, process emissions, emissions from additive preparation as well as energy-related emissions should be included in the project boundary. Emissions from other activities related to cement manufacture (such as transport of raw materials, bagging and transport of finished cement) could be addressed by applying a constant multiplier, *i.e.* as a percentage of baseline or project emissions, to the quantified emission sources. Using this method to quantify small emission sources addresses both simplicity and leakage concerns, but could be contentious because any multiplier used will necessarily be approximate.

Determining the crediting lifetime of potential JI/CDM projects in the cement sector is difficult, because there are no general standards (across different countries and companies) for the technical lifetime of equipment or for how long it is used before being refurbished. For example, although cement plants can have a 50y life, some companies/plants may replace major pieces of equipment, such as kilns, after 25y. Other companies/plants will continue operation using old and inefficient technology until the supply of raw materials is exhausted. Refurbishment (or not) of existing plants will also depend on the competitiveness of the cement supply market. Thus, some plant refurbishments will be business-as-usual activity, while others could be "additional".

It may be possible to set up rough "rules of thumb" to help determine the crediting lifetime of energy efficiency and process change projects. However, great care would need to be taken in order to avoid

creating either non-additional credits or perverse incentives that would, for example, reward installing inefficient technology. The best way of doing this may be to opt for either relatively short crediting lifetimes for energy efficiency and process change projects (*e.g.* 5-10y) or baselines that are revised relatively frequently (*e.g.* every 5y) for all project types.

Determining whether a project is truly “additional” may be as difficult as determining for how long an “additional” project should receive credits. Therefore, it may be appropriate to include some qualitative additionality checks as well as the quantitative baseline “test” when determining whether a project should be eligible to generate emissions credits.

1. Broad Overview of the Cement Sector

Cement is the key component of concrete, used in the construction of, for example, buildings. The raw materials needed for cement production (limestone, chalk, clay and sand) are widely available and cheap, but expensive to transport over long distances. This has led to cement being produced in over 80 countries. Cement production is highly energy-intensive, leading to significant energy-related and process CO₂ emissions. Energy costs represent 30-40% of the costs of cement production (Cembureau 1997).

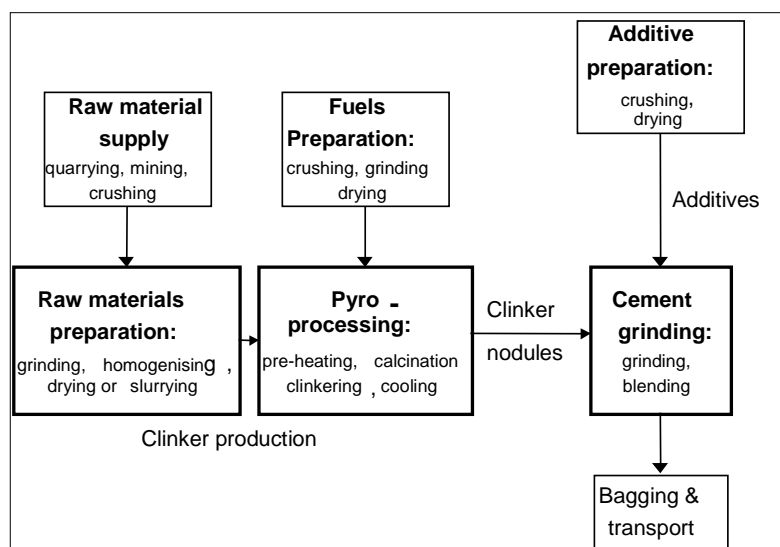
Global cement production in 1995 was estimated at 1.45 billion tons (IEA GHG R&D 1999). Total (energy-related and process) emissions from global cement production in 1994 were estimated at 1.1 billion tons CO₂ (Marland *et. al.* 1998), or 5% of global energy-related CO₂ emissions in the same year. Cement production accounted for an estimated 1-2% of global primary energy consumption (WEC 1995, quoted in IEA GHG R&D 1999). There is one AIJ project in the cement sector (between the Czech Republic and France). In addition, Japan has initiated feasibility studies for potential JI or CDM projects in China and Russia and other countries.

There are three main steps to cement production (see Figure 1):

- preparing the raw materials;
- producing clinker, an intermediate; and
- grinding and blending clinker with other products to make cement.

The raw materials obtained from the quarry are crushed, ground and mixed (either as a powder or as a slurry). This mixture may then be fed into a pre-calciner and/or pre-heater before being fed into the kiln, for “pyro-processing” (clinker formation). The kiln can reach temperatures greater than 1450°C. The clinker nodules produced and any additives are then ground to the desired fineness in the cement grinder.

Figure 1
Process steps in cement manufacture

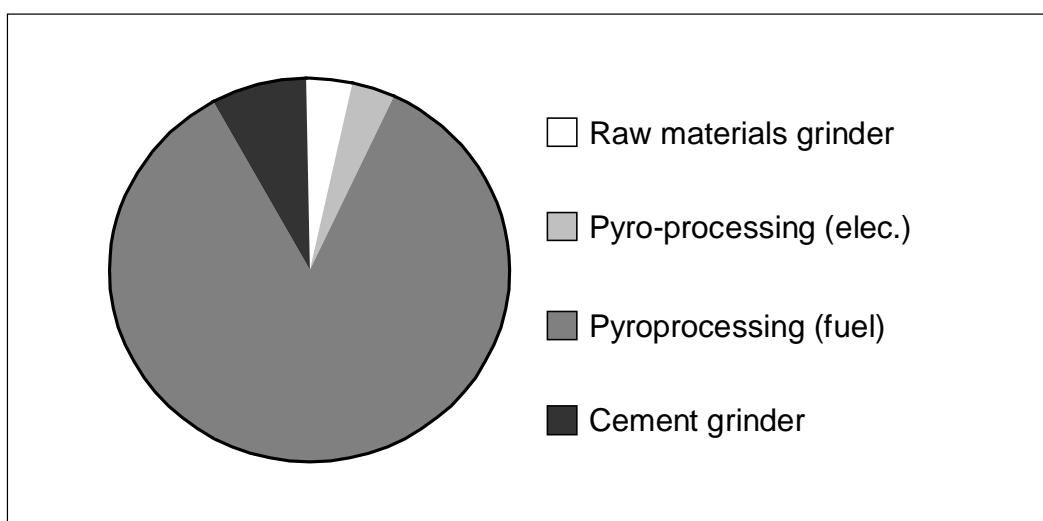


Source: adapted from Ruth *et. al.* (2000)

The second step, pyro-processing, is the most energy intensive (see Figure 2) and requires up to 80% of the total energy consumed for cement production (the exact amount will vary depending on the proportion and type of additives in the final cement mix). The majority of fuel inputs, typically coal or fuel oil, are used in the pyro-processing step, whereas electricity is mainly used in crushing/grinding. Pyro-processing also results in process CO₂ emissions from the decarbonisation of limestone. Per ton of clinker produced, approximately half emissions are process-related and the other half are energy-related (fuel combustion and, to a much lesser extent, electricity use)².

Figure 2

Energy use of different steps within “best practice” cement manufacture



Source: based on figures from Cembureau, (1997) and IEA GHG R&D (1999)

Clinker can be produced by two main processes: dry or wet. Two other processes, intermediate (semi-dry or semi-wet) and shaft, are also used in some countries. The name of the process refers to how the raw materials are mixed. The dry process is much less energy-intensive than the wet process and typically requires energy input of 3.3 MJ/kg clinker, whereas the wet process needs 5.7 MJ/kg clinker (IEA GHG R&D 1999). The wet process is being phased out in many developing countries (Price *et. al.* 1999) and is rarely used for new plants.

Many different types of cement are produced, varying in, for example, strength and setting (hardening) time. Differing proportions of clinker and other additives in the final product cause these variations. The most common type of cement, Portland cement, contains 95% clinker. Other types of cement (such as composite, pozzolanic, blastfurnace or Portland composite cements) can contain between 20-94% clinker (Cembureau 1991, quoted in IEA GHG R&D 1999). Since clinker is the most GHG-intensive component of cement, it is important to know the proportion of clinker in the cement being manufactured when determining the emissions from cement production.

There has been a sharp increase in cement demand in many developing countries since the mid 1980s (IEA GHG R&D, 1999). This growth in demand is met by either extending the manufacturing capacity of existing plants or by building new cement plants. Cement demand is influenced by the demand for construction and is consequently linked to the economic growth of countries.

² The relative proportion of process and energy-related CO₂ emissions can vary significantly depending on the emission factors of the fuel (and electricity) used in cement manufacture.

Cement plants are highly capital intensive. Thus, when looking to extend production capabilities, refurbishing an existing site can be considerably cheaper than building a new plant. New plants are generally designed to operate continuously, although if demand drops (*e.g.* in winter) and stockage capacities are limited they may temporarily shut. Although cement manufacture uses significant quantities of electricity, most cement plants do not include facilities for on-site electricity generation. However, there are some exceptions. These are found where, for example, the cement plant is in a remote area far from the electricity grid, or where grid-supplied electricity is unreliable (*i.e.* in an area of brown/blackouts).

Outside the Chinese market, cement production is dominated by a handful of multinational companies. These companies often own a majority stake in local cement producers: international trade in cement is limited because of the relatively high cost of transporting a bulky and relatively low-cost product.

There are a number of potential JI/CDM project types in the cement sector. These can be divided into two broad categories: energy-related and non-energy-related. Energy-related GHG emissions from clinker manufacture could be reduced by:

- increasing the energy efficiency of clinker production (*e.g.* by optimising heat recovery or installing an efficient pre-heater);
- changing the manufacturing process (*e.g.* by converting wet process plants to dry process plants); or
- changing the input fuel (*e.g.* by using an increased proportion of waste fuels).

Limiting non energy-related emissions, *i.e.* process CO₂ emissions from clinker production, would be difficult as these emissions are an inherent part of the decarbonisation of limestone (CaCO₃) to lime (CaO) during the formation of clinker³. However, process CO₂ emissions could be significantly reduced per ton of cement produced by blending clinker with an increased proportion of additives (such as fly-ash, blast furnace slag, pozzolana) in cement, *i.e.* by reducing the proportion of clinker in cement.

This report examines the cement sector in three countries in more detail. The choice of case study countries and the information presented in the remainder of section 1 was limited by the information available. In particular, information on the costs and benefits of plant refurbishments was difficult to find. Section 2 explores how potential baselines could be constructed and section 3 assesses what baseline assumptions could be made. Section 4 examines the different options for the potential stringency of baselines and section 5 outlines conclusions of the study.

³ Capture of the CO₂ emitted through calcination is possible in theory but not carried out in practice.

Table 1

Summary of factors that determine GHG emissions from cement manufacture

Factor	Ability by manufacturers to influence this factor	Comments
Fuel inputs	High	Coal, coke or oil are usually used as fuel inputs. The high temperatures of a cement kiln make it a suitable place to safely dispose of rubber/plastics or other waste types (<i>e.g.</i> hazardous waste). The use of these “alternative fuels” can have positive environmental impacts, as well as positive economic impacts for the cement manufacturer. However, the greenhouse gas impacts of using alternative fuels depends on what would have happened to these alternative fuels otherwise.
Process used (<i>i.e.</i> wet, dry or other)	High or low, depending on site layout	A potential process change only applies to plants already in operation, as new plants are almost always based on the dry process. The layout of some wet-process plants precludes their conversion.
Technologies used for individual process steps	High	Within each process, a number of different technologies are available. The choice of one technology in one part of the cement production chain does not necessarily affect choices for the next part. However, the technologies used can influence the capacity of a plant (<i>e.g.</i> adding a precalciner can increase production capacity).
Properties of raw material inputs	None (unless raw material source changed)	The chemical and physical properties of the limestone used in cement manufacture can impact the GHG-intensity of clinker production to a certain extent. High moisture content limestone may lead to a choice of using wet or semi-dry processes. High silica content needs a higher kiln temperature for clinker formation and thus higher energy requirements.
GHG-intensity of electricity inputs	None	This can only be altered if the cement manufacturer installs on-site generation, which is not common practice.
Type of cement produced (<i>e.g.</i> fineness)	High to medium	The extent to which a manufacturer can change the type of cement produced will depend on the demand for cement and if/how such demand could be met with alternative cement specifications (strength, hardening time, <i>etc.</i>).
Proportion of clinker in cement	High to low	This is linked to the point above. There is a significant variation within and between countries and companies on blending regulations and practices. Increased use of additives may be precluded by national legislation and is also affected by the nearby availability (or not) of such additives. Blending is already used by some companies/countries as a means to reduce the GHG impact of cement manufacture. Increased blending is likely to increase the amount of cement produced by a given plant.

1.1 India case study

This section is based on information in Schumacher and Sathaye (1999) unless otherwise indicated.

India is the fourth largest cement producer in the world. India manufactures 13 different types of cement, with Portland cement (one of the most common cement types and containing 95% clinker) accounting for 70% of the total.

Cement is manufactured using the dry, semi-dry and wet processes (Sathaye and Gadgil 1999), although the share of kilns operating by the wet process has dropped substantially from 62% in the mid 1970s (Price *et. al.* 1999) to 12% in 1997. The importance of the wet process is expected to fall further as total production capacity increases and through conversion to the dry process.

Growth is variable, but averaged 8.7% p.a. 1973-1993. Production capacity almost tripled between 1982-1996, when it stood at 105.2 Mt and production more than tripled in the same time period. Cement demand is projected to continue growing and is expected to be at 200 Mt/y in 2011 compared to 105 Mt/y in 2001.

Sathye and Gadgil (1999) indicate that if all 61 kilns in India that use the wet process to produce cement convert to the dry process, 1.2 Mt of coal could be saved per year. However, the same source also indicates that only about a quarter of these wet kilns are amenable to conversion (*e.g.* because of current plant layout).

India has substantial reserves of coal and coal is used for the pyro-processing stage of cement manufacture. Coal also generates approximately 70% of India's electricity. India also produces some natural gas (15.6 Mtoe in 1995), but all this is used in the chemical industry (for fertiliser production) and in electricity production (IEA 1997). Schumacher and Sathaye (1999) indicate that reducing GHG emissions from the cement industry by using natural gas instead of coal for the pyro-processing step is unlikely.

India has a significant number of small cement plants. In 1995-96, approximately 9% of cement capacity were "small plants" and they produced just over 7% of cement. These small cement plants were set up throughout the country, in order to promote regional development and to reduce the strain on transport infrastructure. Smaller plants are often less efficient than larger plants, because energy efficiency equipment such as waste heat recovery systems are not economic to install given the small volume of cement manufactured.

However, the cement industry in India is modernising, as well as expanding. The share of dry kilns was more than 70% of the total in 1994 (Price *et. al.* 1999) and many more modern kilns include technologies aimed at increasing energy efficiency, such as multi-stage suspension preheaters and precalciners. The modern, dry, process plants are therefore relatively energy efficient.

There is a large variation in emissions performance between the different type of plants used in India, reflecting the different plant sizes and processes used. Moreover, the average performance of different plant types can fluctuate from year to year. Schumacher and Sathaye (1999) indicate that while the use of "best technology" could reduce emissions from dry process plants by 10-15%, it could improve the performance of an "average" plant by 24-35% (Table 2). Ruth *et. al.* (2000) give a similar figure: 28% of CO₂ emissions from the Indian cement sector (21 Mt CO₂) could have been mitigated by use of best practice technologies.

Table 2
Energy Intensity of Cement Production, India

Plant type	Specific Energy Consumption (GJp/t cement*) (<i>clinker in brackets</i>)		
	Electricity	Fuel	Total
Dry process (1993 performance)	1.21	3.00	4.21
Average over all plant types (1993 performance)	1.27	3.58	4.85
Best practice dry process	1.06 (1.21)	2.71 (3.08)	3.77 (4.29)
Best practice dry process with structural change**	0.32	2.14	2.46

Source: Adapted from Schumacher and Sathaye, 1999

To note: GHG emissions depend on electricity and fuel sources.

*Assumes a clinker/cement ratio of 0.88. "Best practice" is defined here as a dry process short kiln with a 4-stage pre-heater.

** Structural change would change the relative proportion of the different type of cements produced. Increasing the production of Portland Slag Cement and reducing that of Ordinary Portland Cement would increase use of blast furnace slag from India's iron & steel industry and could reduce the clinker/cement ratio from 88% to 68%. Combined with potential savings for energy efficiency, this could result in cumulative energy savings of 38% per ton of cement at current production levels. It would also reduce process CO₂ emissions.

Nevertheless, a number of energy conservation options are open to the Indian cement industry, often at little or no cost. However, many of these options have not been taken up, partly because of capital constraints, partly for other technical or technology-related reasons. For example, the adoption of more efficient mills (e.g. roller press) is inhibited by the high quartz content of raw materials which leads to increased abrasion of the rolling surfaces and therefore to a shorter lifetime for the mill.

1.2 Czech case study

Czech cement is manufactured in five cement plants. Czech production exceeds demand and the country exports some of its cement (to Germany)⁴. Many different types of cement are produced. In the late 1980s and early 1990s, some western European companies (German, Danish and French) invested in refurbishing existing cement plants to modernise and increase their capacity. For example, a German company (Dyckerhoff) modernised the Hranice plant between 1987-1991 to convert it from a wet to a dry plant and to increase production capacity (Cement Hranice 2000). The capacity changes and technology upgrades in another manufacturing plant, Cízkovice, have been approved as an AIJ project by the French and Czech governments.

This project at Cízkovice is the only AIJ project to date in the cement sector, although Japan has also initiated feasibility studies for different potential projects in a number of countries (such as Vietnam and China) under their "joint implementation feasibility study" programme. The Czech/France AIJ project involved refurbishing an existing cement plant by adding a 5-stage pre-heater and increasing the output from the plant by 150%. Energy consumption from the AIJ plant is planned at 3.385 GJ/t clinker (of which 3.22 GJ is in the pyro-processing step), compared to a national average (excluding the AIJ project) of 3.582 GJ/t clinker. The energy consumption of the AIJ project is essentially the same as that of the best technology operating in the Czech republic (excluding the AIJ project), which is 3.580 GJ/t clinker (Table 3).

⁴ No information on the recent growth rates and type of cement produced nationally was available to the author.

Table 3
Energy Intensity of Cement Production, Czech Republic

Plant type	Specific Energy Consumption (GJp/t clinker)		
	Electricity	Fuel	Total
Best practice (Cembureau 1997)	0.79	2.9	3.69
National average over all plant types (1996 performance)	n/a	3.58	n/a
Cizkovice (approximately equal to the best national plant, 1996 performance)	0.97*	3.22	4.19

Source: Cembureau 1997 and calculated from figures presented in French/Czech AIJ project report (UNFCCC 1998) and assuming electricity efficiency at 33%.

* Including electricity needed for cement grinding.

The emissions performance of cement production in the Czech republic is rapidly improving: average thermal energy requirements for the plants excluding the AIJ project dropped from 3.76 GJ/t clinker in 1993 to 3.58 GJ/t cli in 1996 (UNFCCC 1998). Moreover, emissions from electricity production dropped from 865 g CO₂/kWh in 1993 to 707 g CO₂/kWh⁵ in 1996, which helped to reduce the GHG-intensity of cement produced (UNFCCC 1998).

1.3 China case study

China is the world's largest cement producer, accounting for approximately a third of global cement production. Cement production in China has been growing rapidly and production reached 512 Mt in 1997, compared to 210 Mt in 1990 and 37.3 Mt in 1973 (LBNL 1999). The majority of production is Portland cement (approximately 71% of total production in 1997) (LBNL 1999). Other cement production includes blast furnace cement (approximately 26% of the total in 1997), with small amounts of fly ash and white cement (LBNL 1999).

The cement sector in China is very heterogeneous, with many small and a few large production facilities (using both the wet and dry process). Approximately 80% of cement is produced in small, mechanised shaft kilns (NEDO 1998a). These kilns can have relatively low fuel and electricity intensities, but result in significant emissions of particulates and produce poor quality cement⁶. The electricity intensity of cement production in China is rising as more electrically-run process and environmental controls are being used. The total number of cement kilns in operation in China is unknown, but estimates of total numbers are in the order of 6000-8000⁷.

The technology of recently constructed plants in China is different from that elsewhere: some new wet process kilns have been built in the 1990s (although are being phased out in other countries) and many new shaft kilns were also constructed. The advantage of shaft kilns is that they are smaller and relatively quick to construct and could therefore satisfy the rapid growth in demand noted above. However, widespread use of shaft kilns is limited to China and, to a much lesser extent, India. The energy efficiency of shaft kilns can vary significantly, with estimated fuel intensities of 3.2-6.6 GJ/t clinker (IEA GHG R&D 1999).

⁵ These figures refer to average national emissions per kWh.

⁶ Jonathan Sinton, LBNL, personal communication, 22.12.1999

⁷ Jonathan Sinton, LBNL, personal communication, 22.12.1999

The primary energy intensity of cement production in China has been estimated at 5.8 GJ/t (Price *et. al.* 1999). This high value reflects the use of wet process plants and the predominance of (small-scale) shaft kilns. The same analysis indicates significant technical potential to reduce the energy consumption of cement manufacture in China. The theoretical CO₂ impact of using best practice cement manufacture for all Chinese cement production has been estimated (Price *et. al.* 1999) at 2.0 GJ/t cement produced. This is equivalent to a reduction of 96.3 Mt CO₂ (approximately equivalent to the total energy-related CO₂ emissions of Sweden and Norway in 1990) if China's 1995 production of cement had been manufactured using best practice rather than current technology⁸.

The Chinese cement industry is undergoing a period of change, with the government's policy of "making large larger and small smaller" (NEDO 1998b). For shaft kiln facilities this could mean either closure of existing facilities or refurbishment with capacity increases.

China and Japan have carried out feasibility studies on projects converting two shaft kilns to fluidised bed cement kiln systems⁹ (NEDO 1998a). These projects would increase the production capacity and decrease the GHG impact of clinker production in two plants (Table 4). The GHG-intensity of the whole process is reduced, although the electricity intensity increases.

Table 4
Effect of a process change on the energy intensity of clinker production
in two cement plants in China

	Tianjin cement plant	Huaxin cement plant
Production capacity (kt/y):		
• pre-project	144	140
• post-project	217	186
Fuel consumption in kiln (GJ/t cli):		
• pre-project	5.12	4.1
• post-project	3.14	3.14
Electricity consumption in kiln (kWh/t cli):		
• pre-project	23.5	23
• post-project	40	40
Total CO ₂ (t CO ₂ /t cli):		
• pre-project	0.518	0.420
• post-project	0.345	0.345

Source: NEDO, 2000 (assuming anthracite is used both for direct fuel use and for electricity generation at 32.5% efficiency).

* These figures are not directly comparable to those in the previous two tables, as the figures in this table do not include the energy required for cement grinding.

⁸ Of course, for technical, financial and policy reasons, this maximum theoretical impact will not be met.

⁹ This technology is still under development - and therefore not widespread - and is assessed as suitable only for small plants producing under 360,000t/y (IEA GHG R&D 1999).

2. Baseline Construction

Emissions from the manufacture of clinker can be expressed by the following equation:

Equation 1:

$$\text{Total emissions} = \text{Process emissions} + \text{emissions from fuel combustion} + (\text{indirect}) \text{ emissions for clinker prodn. from electricity consumed}$$

However, an emissions baseline for energy efficiency and process change projects in cement manufacture may only need to take the energy-related emissions into account. This is because, while the fuel and electricity-related GHG emissions may vary between the baseline and the JI/CDM project, it is unlikely that the process emissions would be significantly different per ton clinker produced¹⁰. Thus, focusing baselines on the GHG-intensity of clinker production would enable analysis to focus on differences in the fuel and electricity-related emissions between a CDM/JI project and a non-CDM/JI project.

These two components can be disaggregated further:

Equation 2:

$$\text{Emissions from fuel combustion} = \text{Quantity of fuel(s) used (GJ)} * \text{Fuel emission factor(s) (t CO}_2\text{/GJ)}$$

$$\text{Emissions from electricity use} = \text{Quantity of electricity used (MWh)} * \text{Electricity emission factor (t CO}_2^{11}\text{/MWh)}$$

For blending-type projects, an estimation of the process emissions is needed. According to the 1996 IPCC guidelines, process CO₂ emissions should be calculated by estimating the CaO and clinker fraction of cement and then applying a clinker-based emission factor (IPCC 1996).

Equation 3:

$$\text{Process emissions} = \text{Emissions from clinker production} + \text{emissions from additional lime used in masonry cement}$$

$$\text{Emissions from clinker production} = 0.5071 \text{ t CO}_2\text{/t cli} * \text{tons clinker produced}$$

Most cement types do not include additional lime. Therefore, equation 3 can be simplified in most cases as process emissions = emissions from clinker production.

Blending projects would also need to take into account the GHG intensity of additive preparation. This will vary according to which additive is used (and is discussed further in section 2.3).

¹⁰ Process-related emissions can vary with the proportion of the clinker lime content. However, since trade in cement is limited, demand for any cement not produced by a CDM/JI project is likely to be produced by a local plant using raw materials of similar characteristics. Thus, process emissions from a potential CDM/JI project and from an alternative non-CDM/JI supplier are likely to be very similar.

¹¹ Emissions of other GHG are also likely to be produced from the combustion of fuels to produce electricity, but their relative GWP-weighted emissions are small compared to those of CO₂. Since electricity-related emissions are only a small proportion of total emissions from clinker production, non-CO₂ emissions from electricity production are likely to represent less than 0.5% of total GWP-weighted energy-related emissions and may therefore be omitted without significantly affecting the emissions baseline.

Thus, emissions from the manufacture of cement can be expressed as following:

Equation 4:

$$\begin{aligned}
 \text{Total emissions for cement} &= \text{Process emissions} \\
 \text{production} &+ \text{emissions from fuel combustion} \\
 &+ (\text{indirect}) \text{ emissions from electricity consumed} \\
 &+ \text{emissions from any additional lime used} \\
 &+ \text{emissions associated with additive preparation}
 \end{aligned}$$

The indirect emissions from electricity include those from electricity consumed at all stages of the cement manufacturing process (such as raw material preparation and cement grinding).

2.1 Key underlying assumptions

The key underlying assumptions of emission baselines in cement manufacture relate for the most part to the energy used in the different manufacturing processes. The amount of energy used (*i.e.* fuel use per ton clinker produced, electricity use per ton clinker produced) is determined predominantly by which technology is used for a particular process. Which technology is used is in part determined by the chemical/moisture characteristics of the raw materials.

Cement has been produced since 1824, with technology evolving steadily. Recent improvements (1970s) have included introducing precalciners¹², which improve energy efficiency and also help to increase the productivity of kilns. The introduction of precalciners has helped to reduce the energy intensity of clinker production in Europe from approximately 4.7 GJ/t clinker in 1973 to 3.7 GJ/t clinker in 1995 (Cembureau 1999).

New cement plants installed under business-as-usual conditions are often state-of-the-art equipment comprising a dry process kiln with a 5-stage preheater/calciner. Such plants have been constructed all over the world during the 1990s, including in Asia and Africa (*e.g.* IFC projects 4955 and 7717 in China and project 8657 in Senegal (IFC 1999) and by Holderbank in Viet Nam (Holderbank 1999)). Plants of this type are considered standard for ordinary new plants in Europe (Cembureau 1997) and are also the most common choice for new plants constructed elsewhere (see example, Ruth *et. al.* 2000, Picard 2000¹³).

Dry kilns with a 5 stage pre-heater/calciner could therefore be considered as business as usual technology for new plants who use raw materials with a relatively low water content¹⁴. It would therefore be difficult to argue that plants of this type should be eligible for JI/CDM status as credible emission baselines for new cement plants are likely to be based on this technology in most cases. Such plants could nevertheless be eligible for JI/CDM status, for example, by using waste fuels instead of fossil fuels in the pyro-processing step, or if they are towards the lower end of best practice energy use for this plant type.

¹² Pre-calciners are situated between the pre-heater and the kiln. They are equipped with a burner that enables partial (80-95%) decarbonisation of limestone to lime (IEA GHG R&D 1999). Having a precalciner enables a shorter and, therefore, more energy-efficient kiln to be installed, thereby reducing the energy (and GHG) intensity of clinker production.

¹³ M. Picard, Lafarge, personal communication, 10.1.00.

¹⁴ Pre-heaters contain 2-6 stages. Some state-of-the-art plants have been installed using a 6-stage pre-heater, although this is not common practice and is only possible if raw materials have a low moisture content. Plants using raw materials with a relatively higher moisture content may opt for a 3 or 4-stage pre-heater, or for a semi-set or semi-dry process instead of a dry process.

Wet, semi-wet or semi-dry process plants are rarely constructed nowadays and are only used when the raw material inputs have an extremely high water content. However, given the relatively long lifetime of a cement plant (up to 50y), some wet process plants and many semi-wet and semi-dry plants are still in operation in some countries (including China, US, India and UK).

Given the relative importance of energy costs in cement manufacture, there is a strong economic incentive to increase the energy-efficiency of cement production. Thus, many wet process plants are being phased out under BAU conditions through conversion to other process types, (such as in China, India, Brazil (Price *et al.* 1999 and Shumacher and Sathaye 1999) and the Czech Republic (Cement Hranice 2000)). However, not all wet process plants are amenable to conversion because *e.g.* of the plant layout.

Refurbishment of dry process plants also occurs, *e.g.* installing a 5-stage preheater/ precalciner at existing facilities in Italy and Slovenia (Ruth *et al.* 2000). However, since wet process plants are still in operation in some countries, converting a wet process plant to a dry process plant, or making other energy efficiency improvements be considered as “additional” in some cases, even though conversion also takes place in other cases under BAU conditions. Standardising a methodology to determine when plant conversions are additional or not would be difficult. Nevertheless, some qualitative and quantitative criteria (such as whether similar plants were converted and at what rate) could be developed that may be useful in this regard.

No generalised assumptions about which fuels are used and what the GHG-intensity of electricity used are possible between different countries as there are significant variations, particularly in the GHG-intensity of electricity. Similarly, it is difficult to generalise “key underlying assumptions” for either the amount or type of waste fuels used, or the amount and type of extenders added to clinker, because these vary significantly from plant to plant and country to country. Thus, while production process technologies and their performance could be standardised to a greater or lesser extent across countries/regions, information on which fuels are used may need to be drawn up at a more disaggregated level (possibly even plant-specific).

2.2 Aggregation

The level of aggregation of an emissions baseline needs to include an assessment of and decisions on:

- the type of projects to which an emissions baseline can apply (*i.e.* all projects within the sector, all comparable processes *etc.*);
- whether each source of emissions (*e.g.* direct and indirect energy-related emissions) and each gas should be estimated individually or for the entire manufacturing process; and
- geographic levels of aggregation (*i.e.* international, country, sub-country).

There are three major components to emissions from cement manufacture. These are:

- on-site fuel combustion (producing CO₂, CH₄ and N₂O);
- process CO₂ emissions; and
- emissions from electricity used in cement manufacture (also producing CO₂, CH₄ and N₂O, but off-site).

Potential projects could impact the energy use and GHG intensity of one or more of the discrete cement manufacturing steps. Thus a standardised value could be set for the energy use of 1) the entire manufacturing process (*i.e.* from limestone to cement), 2) for the major process steps (*e.g.* raw material preparation), or 3) for a step within each major process step (*e.g.* clinker cooling). A standardised GHG value could not be set for any of these aggregation levels (*e.g.* entire manufacturing process, major process steps). This is because a standardised GHG value would need to incorporate assumptions (or prescriptions)

across countries on technology use, fuel use for pyro-processing and GHG intensity of electricity generation. The technologies and fuels used can vary from site to site and the GHG intensity of electricity generation can also vary within a country.

However, setting one standardised value for the energy use of the entire cement manufacture process, rather than at a more disaggregated level, may not be appropriate for two reasons. Firstly, a standardised “energy” (rather than fuel and electricity) standard would need to incorporate an assumption about the efficiency of electricity generation, which can vary significantly within and between countries. Secondly, one standardised value could allow credits to be generated by changing the quality of cement manufactured (*e.g.* coarser cement requires less energy to grind, although the consequent GHG reductions are not the result of any “additional” GHG reduction activities)¹⁵.

Setting standardised energy values for sub-process steps (at the international or national level, depending on the project type) may also not be appropriate, as the energy use for one sub-process step may be influenced by the mode of operation of the previous sub-step. For example, optimising heat recovery in the clinker cooler will reduce the amount of energy needed in the kiln and pre-calciner (IEA GHG R&D 1999). Moreover, the number of potential sub-process steps is by definition greater than that of the number of process steps, so disaggregating a baseline to this level of detail would require more data and would be more time-consuming.

As a compromise between the two suggestions above, standardised values for the amount of fuel and electricity (rather than “energy”) used in each of the three main process steps could be drawn up, *i.e.*:

- raw material preparation (including crushing, grinding, homogenising);
- pyro-processing (including pre-heating, calcining, cooling); and
- cement grinding (excluding additive preparation).

In addition, information on the preparation of additives would be needed for blending projects. It should be feasible to standardise this energy use (*e.g.* x kWh/t blast furnace slag, y kWh/t pozzolana).

Information on each of these steps would need to include information on which energy source(s) were used, their emission factors, emission factors for the electricity used and information on the process-related emissions. Default emission factors for GHG emissions from fuel combustion and for process emissions are available (IPCC 1996). However, significant variations in emission factors for electricity production occur between countries due to national/sub-national variations in the fuel mix, technologies used and efficiencies of those technologies. Thus, a baseline would be more realistic (and credible) if it distinguished electricity intensities between (and possibly even within) different countries. This is examined further in the Electricity Case Study.

The advantage of aggregating emission baselines by major process step would be that plant refurbishments (the majority of capacity extensions¹⁶) would still be able to generate emissions credits by improving the performance of a process step. In some old plants, the layout may preclude the installation of a more efficient calcining process (Schumacher and Sathaye 1999) or grinding process (Cembureau 1997).

¹⁵ It is not always possible to substitute finer cement (higher strength) with coarser cement (lower strength).

¹⁶ Michel Picard, 20.3.2000, personal communication.

Recommendations

- Baseline values for fuel and electricity use should be standardised at the major process step level (raw material preparation, pyro-processing, cement grinding). These values can be applied worldwide for energy-efficiency type projects, with the possible exception of China, which uses a cement manufacturing process not widely used elsewhere. The values for cement grinding may need to be further disaggregated to include, for example, information on the fineness of cement and type and proportion of additives used. This distinction is needed in order to account for the effect of these variables on grinding energy use.
- For projects that change the production process technology, a national component in the baseline energy value may need to be taken into account. However, a wet process plant should not be considered as an appropriate technology on which to base an emissions baseline. (For some plants using raw materials with a high moisture content, a baseline based on *e.g.* a semi-dry plant could be more appropriate).
- To increase transparency, separate emission baselines should be calculated for the energy-related and process-related emissions involved and then summed to obtain a baseline expressed in terms of CO₂-equivalent emissions.

2.2.1 Units for emission baselines

Which units to use for emission baselines is a potentially complicated issue for projects in the cement industry. A credible standardised emissions baseline is one that can be applied to a number of similar projects with homogeneous output. However, as noted in section 2, the clinker content of cement can vary by almost a factor of five, in theory and variation in clinker content by a factor of two is common (Cembureau 1997). Since clinker is by far the most GHG-intensive component of cement, the GHG-intensity of cement can also vary by up to a factor of five.

The properties (strength, hardening time, *etc.*) of cements with different clinker contents vary to some extent. Properties of cement with the same clinker proportion can also vary (depending on the fineness to which the clinker is ground, whether the particle size is more or less homogeneous and depending on which other additives are present in the cement). Some cement types are best for certain applications and other cement types for other applications - for example, cement for building bridges needs to be relatively strong. Thus, "cement" is not a homogeneous product, although there is an area of overlap where cements of different types can be used¹⁷. "Clinker" is more homogeneous and could therefore be used as the basis on which to determine the emission mitigation impacts of projects in the cement sector¹⁸.

However, if emission benefits from energy-related cement projects were expressed in t CO₂/t clinker, projects that aimed to reduce GHG emissions by reducing the clinker component of cement would not be eligible. Thus, if blending-type projects were approved as eligible projects, the GHG benefit resulting from blending would need to be reported in terms of changes in t GHG/t cement.

¹⁷ Stronger cements are generally those that are more finely ground and, therefore, more energy and GHG-intensive. The extent of overlap between different cement types will depend on their relative costs and availabilities, which may vary from site to site. The impact of this potential overlap on the implications for setting standardised energy values for emission baselines in the cement sector could benefit from further examination.

¹⁸ The most homogeneous unit is likely to be clinker nodules (from pyro-processing). However, projects in the cement grinding step would not be able to use this as a unit.

Recommendations

- Emission baselines for energy-related projects in the cement sector should be expressed in units of t (energy-related) CO₂/t *clinker* produced.
- Blending-type projects could only generate emission credits if they were expressed in terms of t CO₂/t *cement* produced. They would need to include both process-related and energy-related baseline CO₂ emissions.
- Projects that influenced both the energy intensity of cement production and the clinker to cement ratio should report separately the effect of the project on energy-related and process emissions.

2.3 System boundaries and data issues

2.3.1 System boundaries

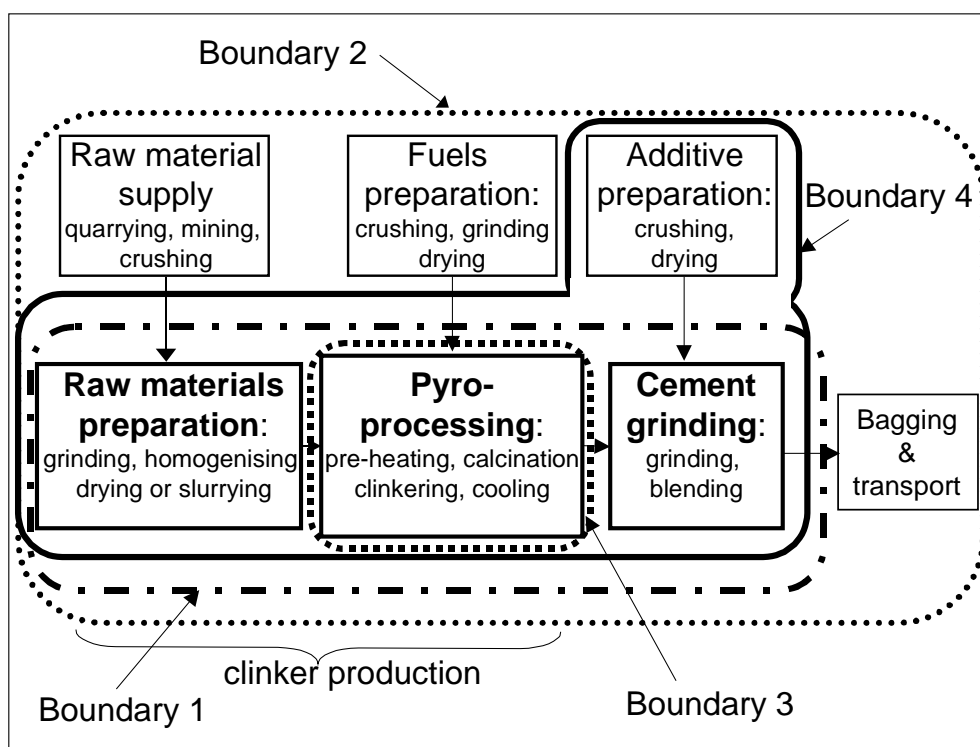
There are several steps involved in the manufacture of cement. A JI/CDM project could impact the fuel and/or electricity use of one or more of these steps and thus influence the direct and indirect energy-related emissions of cement manufacture. A project could potentially also influence process emissions through increased blending of clinker with other additives. This could impact the project boundaries used for different project types (see Figure 3).

“Boundary 1” includes the energy-related emissions and potentially the process-related emissions, arising from the three most GHG-intensive steps of cement production. It is a reflection of Equation 1 (outlined in section 3). Using this boundary would capture the majority of energy and process-related emissions from a cement plant and may be considered appropriate for greenfield cement projects or refurbishment projects that involve a process-change or that influence both the fuel and electricity intensity of cement production.

“Boundary 2” includes all energy and process emissions arising from all steps associated directly or indirectly with cement production (but excludes emissions embodied in the materials used for cement manufacture). This boundary is more comprehensive than “Boundary 1”, but would be significantly more data and time-intensive to construct and would not be substantially different from “Boundary 1”. Given that the majority of emissions associated with cement manufacture would be accounted for in “Boundary 1”, it may be considered that “Boundary 2” would not need to be constructed. A further reason for not using “Boundary 2” is that emissions from some steps (such as from the transport of additives to the cement plant) may be off-site and difficult for the project participants to control and/or monitor.

Figure 3

Potential project boundaries for JI/CDM projects in cement manufacture



Source: adapted from Ruth *et. al.*2000.

However, a compromise between boundaries 1 and 2 is also possible. Recognising that boundary 2 is more complete than boundary 1, a constant multiplier (such as “boundary 1” * 1.02¹⁹) could be applied to boundary 1 in order to capture some of the effects included in boundary 2. This would in effect estimate the impact of the identified but non-quantified emissions and thus reduce the level of leakage associated with boundary 1. Such a compromise would have to be applied to both the estimation of the baseline and the monitoring of project emissions in order to be consistent²⁰. As for boundary 1, this type of boundary could be applied to refurbishment or greenfield projects.

For boundaries 1, 2 and the compromise boundary, process emissions may not need to be included if it is assumed that the cement produced by a JI/CDM plant would have been produced by a nearby plant in the absence of the JI/CDM project. This is because the process emissions from clinker production at one plant will be almost identical (per ton clinker produced) to process emissions from clinker production at another plant. Small differences can occur due to differences in chemical composition of the raw materials. However, since raw materials are expensive to transport over long distances, nearby cement plants are likely to have raw materials from the same (or similar) source.

¹⁹ The primary energy equivalent of the approximately 2kWh electricity needed for raw material crushing (from Table 5) and for conveyor belts for the cement produced (IEA GHG R&D 1999) represents under 1% of best practice energy consumption in cement manufacture. However, cement packing has been estimated to account for up to 5% of total power use (IEA GHG R&D 1999), or up to 4% of best practice energy use. This amount will vary according to the proportion of cement shipped in bags.

²⁰ The “constant multiplier” will have a slightly different effect on the baseline and the project emissions if it is based on a percentage of these emissions.

“Boundary 3” includes the energy (and potentially the process emissions) from a single process step in either clinker or cement manufacture. This boundary could be appropriate for a refurbishment project that changes only one part of an existing installation, such as cement grinding, while leaving the remainder of the installation (including total capacity) unchanged. However, in order to use this more restricted boundary type, a developer would presumably have to prove that their project did not adversely affect emissions from another part of the cement manufacturing process. If such “proof” is quantitative, it essentially means that a larger boundary has to be constructed anyway, it would essentially mean constructing Boundary 1. For example, changing the way in which raw materials are mixed and the moisture content of this mixture, will affect both the energy used in raw materials preparation and in pyro-processing.

“Boundary 4” includes the energy and process emissions for cement manufacture. This is equivalent to equation 4 in section 3. Process emissions would definitely need to be included in a blending-type project as this type of project creates GHG benefits by reducing process CO₂ emissions per ton cement produced. Including the (energy-related) emissions associated with additive preparation would also be needed in any project that claims emission credits for changing the proportion of clinker in the cement produced because some of the clinker additives used can have significant GHG impacts (*e.g.* blast-furnace slag). Not including the energy and emissions needed to grind these additives, which would be done on-site, could lead to a significant over-estimation of a project’s GHG benefits (the actual effect depends on which additive is used).

Which gases to include in any project boundary and baseline will also have to be chosen. Process emissions are of CO₂ only, while energy-related emissions are of CO₂, CH₄ and N₂O. Energy-related emissions could be calculated by using the IPCC default emission factors for fuel use in cement kilns. These default emission factors are available for coal, oil and gas but for CO₂ and CH₄ only. However, the GWP-weighted emissions of methane from cement kilns are only approximately 0.02 kg CO₂-equ./GJ fuel input, compared to CO₂ emission factors of approximately 56, 77 and 95 kg CO₂/GJ fuel input for gas, oil and coal respectively. The IPCC guidelines also supply default N₂O emission factors for “manufacturing industries”, which would indicate N₂O emissions of approximately 0.4 kg CO₂-equ./GJ coal input (other fuels would produce lower N₂O emissions). Emissions of both methane and nitrous oxide could therefore be excluded from an emissions baseline without significantly altering its accuracy or environmental effectiveness.

Recommendations

- The “compromise” boundary between 1 and 2, *i.e.* emissions from the three major process step times a multiplier, should be used for estimating an energy-related CO₂ emissions baseline for energy-efficiency, production process-related or input fuel-related greenfield projects. This boundary should also be used for refurbishment projects that significantly increase manufacturing capacity and/or affect more than one process step. This “compromise” boundary would not need to include process CO₂ emissions.
- Boundary 4, *i.e.* including emissions from additive preparation, should be used for projects that claim credit for changing the clinker proportion of cement. This emissions baseline could include process CO₂ emissions only (if the only aspect of the project was increased blending) or both process and energy-related CO₂ emissions if the project involves capacity construction or upgrades.

2.3.2 Data needs

Which boundary is chosen for the emissions baseline will affect the data needed to construct the emissions baseline (and will also have an impact on what data need to be monitored to assess project performance and calculate emissions credits).

Given the equations outlined above, an emissions baseline for energy efficiency, process change or input fuel change project types would therefore need to focus on the following items (assuming it was being drawn up per ton of clinker produced):

- i) quantity of fuel(s) used (in terms of energy);
- ii) emission factor(s) of fuel(s) used;
- iii) quantity of electricity consumed; and
- iv) emission factor of electricity consumed.

This information should be broken down for each major process step.

Blending-type projects would need data on:

- v) clinker to cement ratio before the project;
- vi) clinker to cement ratio during the project;
- vii) information on which additives are used and how they are prepared; and
- viii) amount of clinker produced by the project site.

If blending was the only aspect of an existing plant that was being considered as a potential project, data items i-iv would not be needed and an emissions baseline could consider just items v to viii. If, however, increased blending was part of a larger project, data on i-viii would be needed.

The quantity of fuel and electricity used in cement manufacture depends mainly on the technologies used in the different stages of manufacturing (see Table 5), but also on potentially site-specific data such as the moisture and silica content of raw materials²¹. (Moreover, the choice of technology may be determined by these site-specific data).

²¹ The energy intensity of the pyroprocessing step can vary between two sites that use the same technology. In particular, kilns using raw materials with a high silica content will need to operate at a higher temperature (*e.g.* nearer 1500°C than 1400°C) than those kilns using raw materials with a lower silica content. The silica content of raw materials can vary slightly depending on the source of those raw materials (*i.e.* the chemical composition of limestone and other raw materials used may vary slightly depending on the source of these raw materials). If the variation in energy-intensity that is caused from such variations in silica content is high, it may be decided that the silica content (or kiln temperature) is a critical factor that needs to be specified when determining an emissions baseline for a CDM/JI project in the cement sector.

Table 5
Variations in fuel and electricity intensity of different components of the cement manufacturing process

Manufacturing step	Unit	Range	Lower intensity technology (typical value of “best practice”)	Higher intensity technology (typical value)
Blasting/transport of raw materials	GJ/t	0.023	-	-
Crusher	kWh _e /t input#	0.3 - 1.6	Roller crusher (0.4-0.5) or Gyratory crusher (0.3-0.7)	Hammer crusher (1.5-1.6)
Grinder (raw materials)	kWh _e /t input#	12 - 22	Roller press (integral), (12)	Ball mill (22)
Kiln (electricity use only)	kWh _e /t clinker	26 - 30	5-stage pre-heater, pre-calciner (26)	Semi-dry (30)
Kiln (direct fuel use)	GJ/t clinker	2.9 - 5.9*	Short kiln, 5-stage pre-heater, pre-calciner (2.9-3.2)	Wet kiln (5.9)
Grinder (clinker)	kWh/t cement**	24.5 - 55	Roller press (24.5)	Ball mill (55)
Sub-total (elec.)	kWh _e /t clinker	70.8 - 124		
Sub-total (fuel)	GJ/t clinker	2.9 - 5.9		
Total***	GJ/t clinker	3.69 - 7.25		

Source: drawn from data included in IEA GHG R&D, 1999

An estimated 1.5-1.75 t input are needed for 1t output.

* Shaft kilns, found in China, have a range of 3.7 - 6.6 GJ/t clinker.

** Data for Portland cement, 95% clinker, 3500 Blaine. More finely ground cement, or cement with additives that need grinding (*e.g.* blast furnace slag) would require more electricity for this grinding step. For example, grinding portland cement to 4000 Blaine with a roller press requires 28 kWh/t (IEA GHG R&D 1999), whereas grinding portland cement to 3500 Blaine with the same technology requires only 24.5 kWh/t (Cembureau 1997).

*** Assuming generation efficiency of 33% and 1.65t raw material input needed for 1t output.

Thus, in order to set up a baseline for a cement plant, default figures for energy use could be estimated from the technology used in different process steps. However, since energy consumption in the three major process steps and therefore GHG emissions, may vary by $\pm 15\%$ within one technology type (Cembureau 1997), defaults may need to be adjusted with information on actual energy use, if this is available.

Obtaining the emission factor for the fuel(s) used should be a straightforward step. If site- or country-specific values are known they could be used. Otherwise, IPCC defaults (IPCC 1996) could be used and result in only small errors. (Given the uncertainty surrounding the number of credits generated by an emission baseline, the small variation in carbon content within a fuel type is of little importance).

The quantity of electricity consumed in cement manufacture should also either be known or easily measurable. The missing and most difficult component is therefore the emission factor of electricity generation avoided by the project. Calculating the emission factor for the electricity used can require detailed information to do accurately. Simple pro rata estimations could be made per country, for example by using annual fuel input data and type. More detailed estimations (*e.g.* distinguishing between demand for baseload and peak electricity and between different electricity systems within a country) may also be

appropriate in some cases. (This topic is the subject of the Electricity Case Study.) Alternatively, emission reductions from electricity avoidance could be omitted from the calculation of emission credits, as in the French/Czech AIJ project.

Energy consumption at the lowest end of the range corresponds to clinker production at different GHG intensities, depending on which fuels are used and how efficiently electricity is generated. For example, using residual fuel oil and gas-fired electricity would result in energy-related emissions of 248 kg CO₂/t clinker, whereas using coal and coal-fired electricity would result in energy-related emissions of 341 kg CO₂/t clinker.

2.3.3 Data quality and availability

The data needed to construct an emissions baseline is different for different project types. The data quality and availability will also differ.

For projects relating to energy use, emission factor(s) would be needed to “translate” baselines²² from energy use to emissions. As previously indicated, default emission factors for direct fuel use are available (IPCC 1996) and estimations of, or methodologies to, determine the GHG-intensity of electricity may also be available for some countries (see Electricity Case Study). CO₂ emission factors for other fuels (*e.g.* tyres) that may be used in cement manufacture are less widely available, but may not be needed if their energy content is known²³.

2.3.3.1 Energy efficiency and process change projects

Different types of data could be used as the basis on which to calculate emission baselines for energy efficiency and process change type projects. These can be grouped as two major types:

- technology-based data (*e.g.* fuel use per process step for a given technology or “best practice”);
- sector-specific data (either technologies and processes in place or energy use) for a country. This data could include the types of technology and historical or projected trends in technology use, which processes are used and whether there is any trend in process use (*i.e.* whether process changes happen in BAU investment), the energy used in cement manufacture, the types of cement produced and the amount of clinker produced.

Technology-based data (*i.e.* energy use for different technology types) is widely available for the technologies used in raw materials preparation and pyro-processing. Thus, standardising the energy use component of an emissions baseline would be relatively simple if this baseline were set per ton of clinker produced. Basing this energy component on the performance of recently installed technology (which is similar worldwide) would obviate the need to gather country-specific data on the manufacturing technologies used, their performance and their ages. Thus, a default (international) value for energy use could be allocated to different components of the clinker manufacturing process. The energy use of the process step(s) involved in a JI/CDM project would also be monitored and the difference would define the maximum number of CERs/ERUs that could be transferred. However, determining a baseline purely on technology-based data does not take into account the potentially significant site-specific variations ($\pm 15\%$) that may occur in operating similar technologies at different sites (Cembureau 1997).

²² Or project data.

²³ IEA GHG R&D 1999 gives the energy content for the following alternative fuels as follows (MJ/kg): scrap tyres, 21; plastics, 33; waste oil, 38; paper residues, 6; and waste solvents 18-33.

Technology-based data on cement grinders is also available. However, the energy required to grind cement depends not only on the technology used, but also on the fineness required for the cement produced (and on whether or not any additives are ground before or with the clinker). Thus, any standardised energy value set for the cement grinding step would need to distinguish *e.g.* between cements of different fineness.

Some country and *sector-specific data* may also be relatively easily available (such as total energy used in the cement sector, by fuel type, for a given country in a given year). However, a breakdown of how much electricity is used in the different process steps is less readily available²⁴. This means that it may not be possible to estimate the national average electricity intensity of the different process steps within a country. Thus, estimating the electricity intensity of individual process steps by technology type in countries with many types of cement producing plants (*e.g.* India and China) would be impossible with only sector-specific electricity consumption figures.

2.3.3.2 *Fuel input change projects*

The GHG mitigation of a fuel input change project is proportional to the amount of “alternative” fuel used. This amount will therefore need to be monitored in order to calculate the CERs/ERUs accruing from a project. Thus, historical data on which alternative fuel is used and in what quantities, will be available at the project level for a JI/CDM project (although such data may not be available at a national level).

The use of “alternative” fuels can vary significantly from year to year²⁵, depending on, for example, relative fuel availability and prices. Thus, levels of historical alternative fuel use may not provide an accurate indication of future alternative fuel use for plants already in use and are obviously not available at all for greenfield projects.

2.3.3.3 *Blending type projects*

Data on cement production by product type is also patchy. It exists for some larger developing countries, but not for smaller ones (Price *et. al.* 1999) or for some countries with economies in transition (Phylipsen *et. al.* 1998). Moreover, the type of cement produced may vary substantially from plant to plant as well as from country to country²⁶. The clinker content of any one cement type can also vary by up to 25 percentage points for composite cements (although variation is much smaller for Portland cement). Thus, the cement produced by a particular plant may diverge significantly from the “average” or most common cement produced in that country in the same year, so rendering inappropriate comparison to an “average”. However, the operator of a particular cement plant should know how much clinker and cement that plant produces in a year (although this may change from year to year). Thus, project-specific values should be used to determine the baseline clinker use for plants already producing clinker as these data are both more available and more accurate. Equivalent figures are of course not available for greenfield plants.

²⁴ Since almost all direct fuel use is in the pyro-processing step, the lack of a breakdown is less problematic for direct fuel use: it can all be assumed to be used for pyro-processing.

²⁵ Jan-Willem Bode, Ecofys, personal communication, 18.4.2000.

²⁶ Christopher Boyd, Lafarge, personal communication, 20.3.2000.

Recommendations

- For energy-efficiency type projects and potentially also for process change type projects, a standardised value for the baseline energy use of the raw material preparation and pyro-processing steps in cement manufacture should be based on the technology performance of new technology additions/upgrades rather than country-specific sectoral data. Thus, standardised values would be based on *e.g.* kilns with a 5-stage pre-heater precalciner. However, country-specific data may need to be used for China, which has an atypical technology structure.
- Projects that change the production process technology would probably also need to include some country-specific information (*e.g.* on whether or not process changes are happening under BAU conditions) in order to help indicate the “additionality” or not of the project. This information could be both qualitative (*e.g.* whether this has happened already) and quantitative (how often/regularly).
- For fuel change type projects, at sites already in operation, historical site-specific data on which alternative fuel is used and in what quantities, will be available (although previous use of such fuels is not necessarily a good indication of future use). Thus, no standardisation of such information is needed. However, given the potential day-to-day variability in the quantities of alternative fuels used, it may be best to use annual or multi-year averages when determining emission baselines. For greenfield projects, rules of thumb should be developed that link potential alternative fuel use with distance from alternative fuel sources.
- Similarly, for blending type projects, data on clinker and cement production before and during a project are likely to be both easily available at the project level and more accurate (and available) at this level than at the country level. Thus, project-specific information should be used to determine the baselines for this project type for plants already in operation. For greenfield plants, assessing levels of additive use that are additional is difficult, although rough rules of thumb may be able to be developed that link cement type produced, proximity of sources of additives and levels of additive use.
- The energy required to grind additives (*e.g.* blast furnace slag) should be reported explicitly and separately from the cement grinding step in order to ensure that it is included in both the baseline and monitoring of blending-type projects.

3. Potential Baseline Assumptions

This section examines both the level at which the baseline could be set and the time for which emission credits could accrue to different energy-related and “blending” projects.

3.1 Energy efficiency and process change projects

Both energy efficiency and process change projects could reduce the energy intensity of clinker manufacture. Energy efficiency measures can be taken in any of the three major steps of cement manufacture (raw materials preparation, pyro-processing, cement grinding) and could be part of a plant’s refurbishment or as an “additional” investment to a planned new plant. Process changes can occur in raw materials preparation or pyro-processing and are only likely to occur for plants currently in operation. Both process and energy efficiency projects could affect the fuel and/or electricity intensity of cement.

A question of debate is whether or not greenfield projects and refurbishment projects should be judged against the same baseline. Arguments for treating greenfield and refurbishment cement projects in a similar fashion include:

- It can be difficult to draw the line between a large-scale refurbishment project and a greenfield project.
- Setting less stringent baselines for refurbishment projects may create incentives for relatively inefficient plants to continue operating.

Arguments for different treatment for greenfield and refurbishment projects are that:

- Refurbishment of older plants could substantially reduce their GHG emissions, although it may not bring them to as high an energy efficiency as new plants. Creating only one baseline for greenfield and refurbishment projects would either make the majority (and possibly all) refurbishment projects ineligible for JI/CDM status - if it was set at the level of new plants, which would drastically reduce the number of potential JI/CDM projects in the cement sector. Alternatively, it would allow new BAU operations to generate (non-additional) credits.
- Not all technologies are suitable for both refurbishment and greenfield projects (for example, Cembureau’s BAT document suggests that different types of grinders should be installed for new plants than for plant upgrades).
- Not all old plant layouts are amenable to allow changes from a wet process to a dry process, so improvements on the existing process would be ineligible for JI/CDM status.

This argument has both political and technical components and may sensibly be resolved in different ways for different JI/CDM project types. Ideally, if there were separate standardised baselines for greenfield and refurbishment projects, they would on average require the same level of effort by a manufacturer in order to perform better than the baseline.

Given that the norm for new installations worldwide is a dry process kiln with a 5-stage pre-heater and a pre-calciner, this technology should generally be assumed as the baseline for new plants. Non-AIJ refurbishment projects also install this technology (Ruth *et. al.* 2000, Cement Hranice 2000). This technology corresponds to an energy use in the different process steps as outlined in Table 6.

Table 6
Suggested baseline energy components and other
assumptions for energy-related projects in the cement sector

Process step	Energy use (units)
Raw materials preparation	16* kWhe/t raw material input (or 27 kWhe/t clinker ¹)
Pyro-processing ²	3.0 GJ/t cli + 26* kWhe
Cement grinding (new plants)	28.2 kWh/t cement (assuming a roller press, 1-4% moisture content and ground to 3500 Blaine ³)
Cement grinding (capacity upgrades) ⁴	36.8 kWh/t cement (assuming a two-stage grinder with roller press, 1-4% moisture content and ground to 3500 Blaine)
Additive grinding	32.8 kWh/t

Source: Adapted from data in Cembureau 1997 and * IEA GHG R&D 1999

¹ Assuming 1.65 t raw materials needed for 1t clinker. This value does not include energy use for drying the raw materials.

² This does not include energy use for grinding the fuel

³ Producing cement with different characteristics (*e.g.* fineness) is likely to require another standardised energy value.

⁴ Cembureau (1997) indicates that different technologies would be used for new plants and for capacity upgrades.

The figures in this table represent the lower end (*i.e.* higher energy consumption) of the range of energy requirements for cement manufacture using the most energy-efficient of “standard” technologies.

3.2 Fuel input change projects

Projects that change the fuel inputs could be of two types - either they focus on the direct fuel use (in the pyro-processing step), or they could aim to reduce the GHG-intensity of electricity used in any of the three process steps²⁷.

In the first type of fuel input project, alternative fuels such as different types of waste (tyres, hazardous waste, or even “animal flour” - parts of animals not used in the food or other industries) could substitute for the use of fossil fuels. Use of alternative fuels is possible in all cement kilns because of the high temperature reached and is routinely used in some plants (for example, in countries where landfilling waste is difficult/prohibited, or where sources of hazardous waste are not too distant from the cement works). The proportion of fuel energy demand from waste fuels has recently been increasing in some countries (IEA GHG R&D 1999).

The amount and type of fuel that would otherwise have been used would represent the baseline. Once assumptions have been made for these factors, IPCC defaults for emission factors and methodology can be used to assess the GHG equivalent of a baseline. However, determining the baseline level of alternative fuel use is difficult, given the variability in actual and potential use of alternative fuels. For plants already in operation, the level of - and/or trend in - alternative fuel use for that particular plant over one or more years may be an appropriate baseline assumption²⁸. For greenfield plants, the level of alternative fuels that would

²⁷ The second type of project should be treated as an electricity-sector project and a baseline developed accordingly.

²⁸ However, testing additionality of alternative fuel use is difficult even for plants already in operation because of variations in alternative fuel use at a site over time. It is further complicated by the fact that alternative fuel use potential is not equal for different sites within a country (as the potential depends on the proximity to sources of alternative fuels).

have otherwise been used is difficult to assess, given variations between different plants. It may be possible to draw up a rule of thumb linking alternative fuel use with other factors, such as proximity to sources of these fuels, but this would need further research.

Recommendations

- Assessing the quantity of baseline alternative fuel use is tricky, particularly for greenfield plants. However, once these assumptions have been made, IPCC default methodologies and emission factors can be used to calculate the baseline.
- No international standardisation is possible on the *values* of the GHG mitigation potential of different “alternative” fuels because the impact of the fuel used depends on the GHG intensity of the alternative fuel and the GHG intensity of the fuel being displaced.

3.3 Blending projects

Process emissions from calcination are significant and estimated by the IPCC at 507 kg CO₂/t clinker produced (IPCC 1996). Reducing the proportion of clinker in cement would lower its GHG-intensity as clinker is by far the most GHG-intensive component of cement. A US cement producer (Holnam 1999) indicates that increased cement blending can “significantly and painlessly” reduce CO₂ emissions in cement manufacture. The GHG-intensity of cement could also in theory be lowered if the process CO₂ emissions could be “captured”. However, no such process is in use as capturing and storing the large quantities of CO₂ emitted from cement manufacture (half a million tons of CO₂ per year just from process emissions from a plant producing 3000t clinker/day) would be costly.

Materials that could be added to clinker could include either by-products of other processes, such as fly ash (from coal-fired power stations) and blast furnace slag (from iron and steel production), or natural materials, *e.g.* pozzolana and limestone. The GHG impacts of potential additives are significantly lower than those of clinker: fly ash only needs to be transported, whereas pozzolana, limestone and blast-furnace slag need to be transported and ground.

Analysis here and elsewhere (*e.g.* Ruth *et. al.* 2000) indicates that the potential GHG reductions from cement blending may outstrip those from energy efficiency by a significant margin. Use of extenders is increasingly being undertaken by some cement works such as those in Nigeria, Malaysia (Blue Circle 2000), Panama and Columbia (Cemex, 1998) as a means to reduce the environmental impact of cement use. However, increasing the use of extenders is not always feasible, such as in cases where there is no nearby source of such materials. (Transporting such low-value materials over long distances would be too expensive).

Thus, the use of extenders may vary significantly between different cement works within a country because of the differences in the relative locations of cement works and sources of additives and because of variations in demand for different cement types (for a given plant). So while a clinker/cement ratio may be known at the national level, it may mask significant variations between plants and therefore be misrepresentative at the level of an individual plant. Moreover, the clinker production to cement production ratio may vary significantly within a country (and plant) from year to year - see Table 7 (Price *et. al.* 1999). These fluctuations of “what would have happened otherwise” could potentially give rise to significant amounts of gaming when setting an emissions baseline for one particular facility or for a group of facilities.

Table 7
Clinker to cement ratio in key developing countries (1980, 1990, 1995)

	1980	1990	1995
Brazil	0.81	0.74	0.80
China	0.73	0.74	0.70
India	0.85	0.84	0.90

Source: Price *et. al.* 1999

The volume of cement production means that small changes in the clinker proportion assumed in an emissions baseline would have large effects on the number of credits generated by a project. For example, if a factory producing 1 Mt clinker per year reduced the clinker content of its portland flyash cement by 10 percentage points, *e.g.* from 94% to 84%, it could reduce its clinker production by 100,000t. Using equation 3 (section 3), this could equate to 50,000t process CO₂ emissions and at least 22,000 t energy-related CO₂ avoided²⁹ (or almost US\$200,000 equivalent if the carbon value is US\$10/ton). Alternatively, clinker production could be maintained and cement production raised by approximately 126,700 t/y, which should create additional revenue.

Moreover, wider variations than this example are possible, as a single type of cement can have a clinker content that varies by up to 24 percentage points. Setting a standardised clinker content for any particular type of cement would be arbitrary and could be used to create significant numbers of non-additional credits unless the value chosen was at the bottom of the range (in which case, some additional projects would not qualify for credits).

Establishing a credible standardised value for a baseline clinker/cement ratio may therefore not be possible at a national level (and it may even vary from year to year for individual plants). However, some other standardisation formula could possibly be used. (For example, cement type T at plant no more than D distance from a source of potential additives should have a clinker content no greater than X %³⁰). However, even estimating the clinker content of cement of a particular type is subject to significant error because of the potential variation in clinker content within a cement type.

3.4 Baseline lifetime

The technical lifetime of a cement works can be many tens of years: up to 50 years is common. The actual lifetime of a cement works is often determined by the lifetime of the quarry that is used to supply raw materials (limestone) to the works. Different pieces of equipment may be replaced during the life of a cement works and at different times. Thus, a cement plant may have up to two major “revampings” (refurbishments) during its lifetime. However, major pieces of equipment (*e.g.* pre-heater and grinders)

²⁹ Using the GHG-conservative assumptions that the fuel used directly is oil and the electricity used has a GHG intensity of zero.

³⁰ If such a formula were to be used, the indication of which type of cement is produced would have to be fairly specific so that the clinker content varies by no more than 15 percentage points within one cement category. For example, a producer of Portland fly-ash cement (clinker content 65-94%) should specify whether the cement produced is equivalent to the Cembureau classifications CEM II/A (80-94%) or CEM II/B (65-79%).

would normally only be considered for potential modernisation after 20-25 y or even longer for the kiln³¹ although they may continue operating for much longer³².

Refurbishing parts of a cement plant after a certain number of years, irrespective of the country in which the plant is located, is BAU practice both in Europe and elsewhere for some larger, private cement manufacturers. Refurbishment of existing plants also occurs in plants in developing countries such as India, China and Brazil (Price *et. al.* 1999, Schumacher and Sathaye 1999). However, the exact timing of any refurbishment is likely to depend on the detailed operating performance of a plant, as well as the financial capacity of the plant's owner. Whether or not a refurbishment of a plant occurs will also depend on the remaining lifetime of the quarry that supplies the plant.

Routine refurbishment has implications for the lifetime over which a project could accrue emissions benefits. If the potential availability of ERUs/CERs hastens a modernisation project that would otherwise have occurred later, emission credits should not accrue to the project for its entire life, but only for the number of years that the project was hastened. For example, if factory A was planned to be refurbished in 2005, but was refurbished in 2001 because the availability of ERUs/CERs made the project more feasible, it should receive credits for 4 years. Of course, determining this number with precision is almost impossible in practice, as it would involve scrutiny of company-specific decisions and priorities, which are likely to be confidential.

It may be possible to develop "rules of thumb" for timelines for energy-efficiency and process change type projects in the cement sector, *e.g.* by using the current age of a plant as an indication of whether and when it would have otherwise been refurbished. Alternatively, projects with more stringent baselines (such as those based on best available technology performance) may be allocated lifetimes that are longer than projects with less stringent baselines (such as those based on the lower end of the range of best practice).

However, great care would need to be taken when setting any rules of thumb in order to avoid creating perverse incentives that would, for example, reward installing inefficient technology or creating overly lax baselines, *e.g.* by allowing a project whose additionality is questionable to generate credits over a long time. Moreover, any rules of thumb may need to be different for different pieces of equipment within any one industry. It is likely that any rules of thumb developed for one equipment type in one industry may not be appropriate for the same equipment type in another industry. The Iron and Steel Case Study indicates that this arbitrary approach is unlikely to be useful for determining timelines in the iron and steel sector.

In addition, the timeline for a project may depend on what technology the project is replacing. For example, a fixed 5y crediting lifetime may be suitable for a project that refurbishes an existing 20y old plant so that it includes a 5-stage pre-heater pre-calciner, as it could be judged that this project hastens BAU investment. However, a project that refurbishes an existing 20y old plant so that it includes a 6-stage pre-heater pre-calciner, or that installs similar equipment in a greenfield project, goes beyond current BAU investment and so it may be appropriate to allocate a longer crediting lifetime to this project. Alternatively, this latter project could have a baseline that is fixed for a longer time period with the possibility of continuing after a baseline revision. Making the fixed lifetime longer for a project that installs advanced technology would help encourage the take-up of this technology.

The Czech/France AIJ project has an initial baseline lifetime of 5y, although this may be extended (the different documents containing information on this project were not clear). The lifetime for the China/Japan project is 20y and based on the technical lifetime of the equipment installed rather than on the projected lifetime or refurbishment plans for equipment that it replaced.

³¹ Personal communication, Michel Picard, Lafarge, 10.1.00 and Malte Becker, Cembureau, 3.4.00.

³² Personal communication, M. Bigum, FLS Industries, 6.4.2000

The economic benefits of potential JI/CDM emission credit revenues from energy efficiency or process change project types are likely to be tiny in comparison to the total costs and revenues involved in those projects. The economic benefits of GHG mitigation from a particular project are thus likely to have only a marginal impact on company decisions on if and when to refurbish a particular plant and on the equipment used for a new plant³³.

The feasibility of other potential project types in cement manufacture (such as blending and fuel input changes) can change significantly over a short period of time because of policy changes in the project-site country. For example, changes in legislation regarding waste disposal may mean that waste can no longer be landfilled. This may make waste incineration more common and/or profitable than it was before. This will affect the additionality of cement plants that incinerate waste. The feasibility of blending cements can also change for policy or for other reasons. For example, construction of a coal-fired plant near to a cement plant would provide a potential supply of additives and such a construction could make blending a possibility somewhere where it had not been a possibility before. Thus, the crediting lifetime of blending or fuel-input changes could in theory extend throughout the lifetime of the cement manufacturing plant. However, baselines for these project types would need to be revised at regular intervals to take into account policy changes and other potential changes that impacts actual or potential supply of alternative fuels or additives in order to ensure that they remained credible.

Economic benefits of potential JI/CDM revenues

This example illustrates the magnitude and importance of potential JI/CDM revenues that could be generated from a project that increases energy efficiency or changes the production process in a cement works.

For example, the range in electricity use for clinker production is 70.8 - 109 kWh/t clinker produced (Table 5). Major refurbishment of an inefficient plant may lead to energy efficiency improvements that reduce electricity consumption by 30 kWh/t clinker produced. This would avoid 10-30 kg CO₂ emissions, depending on the assumptions used to calculate the CO₂ intensity of avoided electricity. Taking the highest assumption (corresponding to emissions of 1 kg CO₂/kWh, *i.e.* inefficient coal-fired production) and assuming a price for avoided C emissions of US\$10-25/t C (US\$2.7-6.8/t CO₂) would give a benefit of 8-20 cents/t clinker produced. This corresponds to an extra income of US\$240-600/day for a standard new plant with capacity of 3000 t clinker/day, assuming that the baseline is continued operation of the old plant, which may or may not be a valid assumption. However, these JI/CDM revenues are tiny compared to the revenues of that plant, which would be of the order of US\$110,000-US\$210,000/day depending on the assumptions of clinker cement content (70-95%) and price of cement (US\$35-50/t) used.

³³ The extent of this impact could usefully be explored further in additional analysis.

Recommendations

- The age of any technology to be replaced in a JI/CDM project may influence the crediting lifetime of a project and should be reported by the project developer.
- Which technology is installed and, potentially, which technology is being replaced, should influence the crediting lifetime for an energy-efficiency or process change type project. For cement projects where BAU technology is used to refurbish a relatively young plant, the crediting lifetime should be limited, *e.g.* fixed at 5-10y. In projects where advanced (beyond BAU) technology is installed, the crediting lifetime could be longer (*e.g.* 8y) and/or the baseline revisable.
- Credits should be calculated on a yearly basis.
- The crediting lifetime for fuel input change and blending type projects could be longer than that for energy efficiency and process change type projects, but would need to be regularly revised in order to ensure that it remained credible.

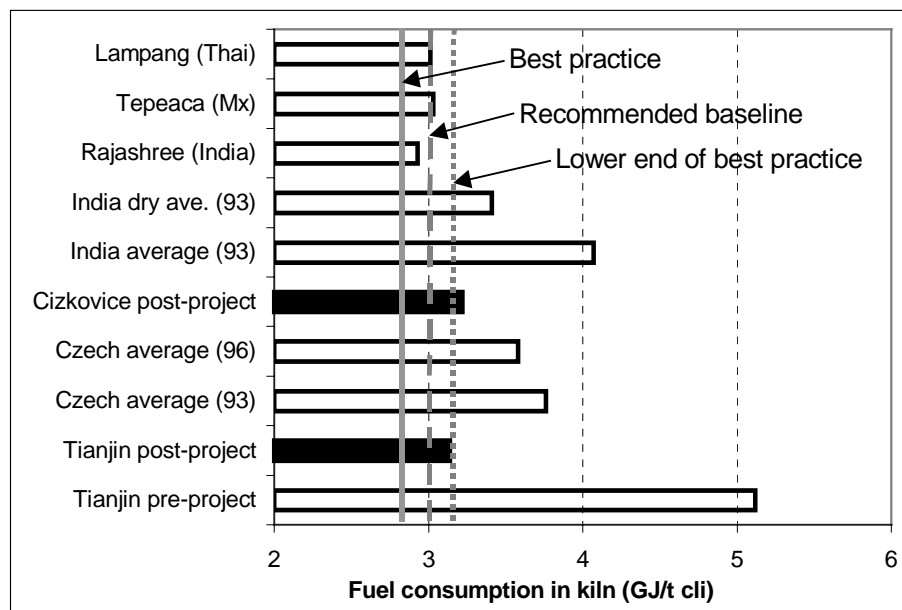
4. Potential Stringency of Baselines

Decisions on which technology and/or energy use to use as the basis for calculating baselines has significant impact on the number of credits generated from a particular project. Thus, an emissions baseline set at the level of an “average plant” (including both wet and dry plants) would be higher and therefore generate many more ERUs/CERs for an investor, than a baseline set at the emissions level of an “average dry process plant”. The gap between “average plant” performance and “average dry process plant” performance will obviously be greater for countries with a greater proportion of wet/semi-wet plants, such as India and China. However, given that recent industry trends towards investment is in highly energy-efficient plants, the most realistic and credible baseline is likely to be equivalent to a “5-stage preheater, precalciner dry process plant”, *i.e.* even lower (more stringent) than that of “average dry process” plants.

The difference in energy requirements of different cement plants and potential baseline energy levels for fuel use in pyro-processing varies considerably (Figure 4). The figure also illustrates the significant improvements in energy efficiency that have occurred over the 1990s (such as in the Czech Republic) and the differences between the average value for all plants, all dry plants and recent additions (*e.g.* in India). The “recommended baseline” for this process step is 3.1 GJ/t clinker (towards the lower end of the 2.9 - 3.2 GJ/t clinker “best practice” range and a lower energy efficiency than some new plants installed under BAU conditions, see *e.g.* Ruth *et. al.* 2000).

Figure 4

Different plant performances and potential baseline values for pyro-processing



Sources: Data on China from NEDO 2000, data on Czech plants from UNFCCC 1997, data on Indian average performance from Schumacher and Sathaye 1999, other data from Ruth *et. al.* 2000. Data on “best practice” and lower end best practice from Cembureau 1997.

The figure also presents possible baseline values for the fuel input into the pyro-processing step³⁴. The fuel use in this step varies from 2.93 (Rajashree) to 5.14 (Tianjin, pre-project) GJ/t clinker produced. This compares to an estimated best practice (dry process) kiln fuel use in a standard kiln, *i.e.* dry process 5 stage

34 Not enough consistent data were available to carry out a similar analysis for electricity use.

preheater pre-calciner, of 2.9 - 3.2 GJ/t clinker. A solid line and a dotted line in the figure shows this range of “best practice”.

The figure also shows that the energy consumption of the AIJ project in Cízkovice and of the potential AIJ project in Tianjin, do not have the highest energy efficiency of the different plants examined. For example, plants recently constructed in India, Mexico and Thailand (none of which were constructed as part of an AIJ or potential CDM project) all have higher energy efficiencies (lower energy consumption) in the pyro-processing step.

This creates a problem as to where to set the standardised values to be used in an emissions baseline. Should it be at the higher (most energy-efficient) end of “best practice”? If so, none of the plants considered would be eligible to generate emission credits, even though they are amongst the newest and most efficient plants in operation and in the case of the Rajashree plant install technology superior to that of standard best practice³⁵. Alternatively, could the baseline be set at the lower (less energy efficient) end of “best practice”, *e.g.* 3.2 GJ/t clinker production? If so, four of the five plants considered would be eligible to generate credits (although the AIJ project would not), even though three of these four eligible plants were constructed as part of BAU plans.

However, the plant at Tianjin has greatly improved its energy intensity as the result of a process change (the existing shaft kiln was replaced). As indicated in section 3, this process change project may sensibly be judged against a different baseline than Cízkovice and other energy-efficiency type projects. This is because although the Tianjin project ultimately improves the energy efficiency of production, it does this by changing the manufacturing process, rather than just modernising existing equipment with a more efficient version. In this and similar cases, basing a baseline on the upper range of “best practice” might be too stringent to stimulate a large volume of investment in more efficient plant and in turn worthy emission reduction investments. The project developers in Tianjin chose to assess the number of potential credits from the plant according to a baseline based on the plant’s previous performance, *i.e.* 5.14 GJ fuel input/t clinker³⁶. This effectively assumes that this plant would not have been refurbished or scrapped. However, given the restructuring of the cement industry in China (outlined in section 2.2), this may not be the case. To take this uncertainty into account, a more stringent baseline could be applied, such as the average between an “energy efficiency” project and previous plant performance. This would equal 4.02 GJ fuel input/t clinker for the Tianjin plant.

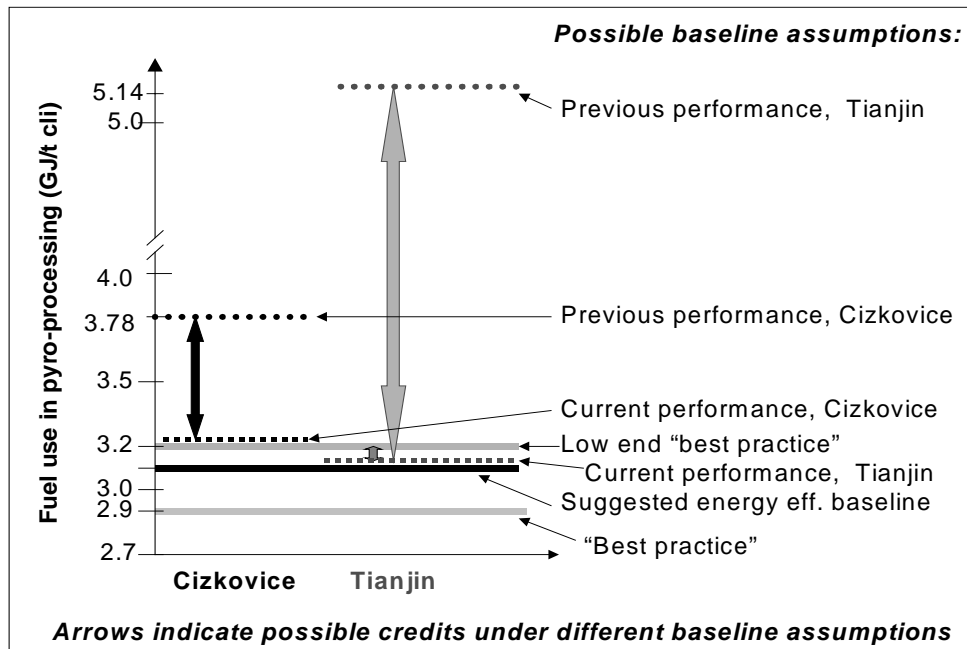
Small differences in baseline energy use per ton of clinker produced can make a large difference to the number of credits obtained by a project (Figure 5) because of the large volumes of cement manufactured by a plant and is quantified in Table 8 for four plants. Figure 5 shows that, for example, the Cízkovice plant could only generate credits under an energy efficiency baseline if it were compared to the performance of the plant operating before the project and not if compared to “best practice”. The figure also illustrates the relatively high energy use of some manufacturing processes and the potential energy efficiency gains that could be made by encouraging process change.

35 The Rajashree plant has a 6-stage preheater.

36 The project developers accounted for the fact that increased electricity use of the new kiln offset some of the reductions from decreased direct fuel use. This section assesses only the affect of direct fuel use.

Figure 5

The effect of different baselines for different project types on potential credits



For the energy efficiency projects, no credits would be obtained if the high end of best practice is used as an energy baseline. The number of credits obtained could more than double for the plants in India and Mexico depending whether or not a value of 3.1 or 3.2 GJ/t clinker was used for the baseline. However, for an individual project, credits could range from 0 to 30,660 t CO₂/y depending on which baseline is used (see table for assumptions on baseline and production levels). If the value of 1 t CO₂ was US\$10, the total volume of credits that could be generated by the Tepeaca plant³⁷ could be worth between US\$0 and US\$293,000 per year for each year of the crediting lifetime of the project. (This would be a net present value of almost US\$1.1m assuming a crediting lifetime of 5y and a discount rate of 17%).

Table 8

The effect of different standardised energy baseline values on the number of credits

Plant	Capacity (t/d)	Kiln energy use (GJ/t clinker)	Credits (t CO ₂ /y) at full capacity compared to:		
			Best practice	Lower end best practice	Other
Tepeaca (Mexico)	6500	3.03 (fuel oil)	0	29300	12070*
Rajashree (India)	3500	2.93 (coal)	0	30660	19306*
Cizkovice (Cz)	2700	3.22 (waste oils and used tyres)	0	0	0
Tianjin (China)	620	3.14 (anthracite)	0	1264	18400**

* 3.1 GJ/t clinker for potential "energy efficiency" projects (*i.e.* Tepeaca, Rajashree, Cizkovice)

** Average of "best practice" and pre-project performance for the process change project at Tianjin (*i.e.* 4.02 GJ/t cli).

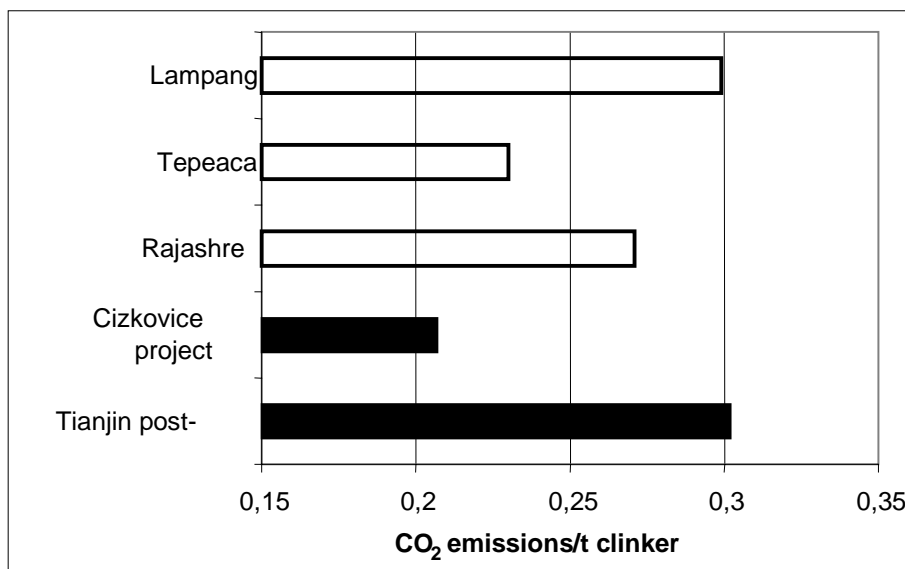
The process change project at Tianjin, would barely generate any credits (1264 t CO₂/y) if judged against an energy efficiency baseline, but would generate substantially more if judged against a process change baseline (15 times as many credits, in the example below). The variation in credits would have a consequent

³⁷ If this plant were proposed and approved as a CDM project.

effect on the value of credits obtained from a project and potentially on the likelihood of other similar projects being undertaken.

Figure 6

CO₂ intensity of pyro-processing in selected plants



Sources: Data on China from NEDO 2000, data on Czech plants from UNFCCC 1997, other data from Ruth *et. al.* 2000.

Despite an energy intensity that is higher than other plants, the plant at Cízkovice has relatively low CO₂ emissions per ton of clinker produced (Figure 6). This is because Cízkovice uses waste fuels (assumed as CO₂-neutral) as well as fossil fuels in the pyro-processing step, whereas the other plants use fossil fuels only. Thus, the plant at Cízkovice may be eligible to generate emissions credits as a “fuel input change” type project. (Not enough information was available to assess how many credits should be generated by fuel switching).

Whichever format for a standardised value is chosen for an individual process step, the level of credits generated under the “cement production” level and the “major process step” level could be significantly different. This is what would be expected intuitively for projects that have opposite effects on fuel and electricity use. For example, initial data indicates that the Tianjin plant would qualify for credits for relatively low electricity use under a baseline set at either the best practice or low end of best practice level. This would occur despite the project almost doubling the electricity intensity of cement production compared to the pre-project level. However, the same plant would only qualify for credits in the pyro-processing step if compared to the top end of best practice (even though the project significantly reduces fuel consumption).

This section illustrates how important the baseline unit and aggregation is in assessing the relative environmental performance of different projects. It also illustrates that changes in the way an individual plant operates may make it potentially eligible for up to four different types of JI/CDM projects.

Note on additionality of projects

The most difficult aspect of assessing potential JI/CDM projects in the cement sector could be in determining whether or not the proposed project is “additional” to what would otherwise occur at the time of investment. This is because the cement industry is a sector which is operated by private, highly competitive companies and where energy costs form a large part of total costs. Thus, it could reasonably be expected that business as usual investment is energy-efficient.

For example, the additionality of the French/Czech AIJ project was questioned by the French government, particularly since the energy efficiency improvements to existing plants occurred before the project was put forward as a potential AIJ project. Nevertheless, the project was finally accepted as an AIJ project by both host and investor country governments (although with a lower baseline than that originally suggested and with a limited lifetime: 5 years).

The difficulty in determining the additionality or not of projects, the fact that cement production is high volume and highly energy-intensive and the differences between the energy (and GHG) intensity of old and new plants could lead to many non-additional credits being obtained if baselines are lax. Thus, baselines for all energy efficiency type projects should be based on marginal (new) additions rather than averages across all vintages of facilities.

Recommendations

- A standardised baseline value for the energy required to manufacture cement should be set towards the lower end (*i.e.* higher energy consumption) of the best practice range for energy-efficiency type projects, *e.g.* 3.1 GJ/t clinker direct fuel use. If a project developer can demonstrate that their project only affects one process step, the baseline could be calculated for that step. If, however, the project affects both the fuel and electricity intensity of cement manufacture and more than one process step, the project developer should calculate the aggregate effect of the project for energy-related emissions from the whole manufacturing process.
- For process change type projects (which are by definition only applicable for refurbishment projects) the baseline may need to be somewhat less stringent than for energy efficiency type projects in order to encourage a greater number of projects. This level may vary from country to country, although a standardised methodology for calculating the baseline level could be developed. However, basing a baseline on the continued operation of an inefficient plant would lead to a lax baseline and many potentially non-additional credits.
- In order to better attest to the additionality of projects, some qualitative or quantitative “additionality checks” may be needed (such as asking for indications of regulatory or behavioural additionality), in addition to the baseline “test”. This might usefully be explored further in additional work.
- Given the continued improvement in energy intensity (and therefore GHG-intensity) of different parts of the cement manufacturing process under BAU investment, any multi-project baselines for this sector may need to be updated frequently (*e.g.* every few years). Alternatively, baselines established in year *n* for projects approved in that year could be modified and used for projects that start in subsequent years (*e.g.* *n*+1, *n*+2) by applying an autonomous energy improvement factor to the original baseline. (Or both types of adjustments could be used, for example by using assumed energy efficiency improvements - a downwards sloping baseline – in between more “major” baseline updates).

5. Conclusions

Cement manufacture is an energy-intensive process and results in significant quantities of both energy-related and process CO₂ emissions. There are four main types of potential JI/CDM projects in the cement sector: energy efficiency, process change and fuel input changes (all energy-related) and blending (not energy-related).

There are three main process steps in production of the cement intermediate, “clinker”: preparation of raw materials, pyro-processing and grinding the clinker. Each of these main steps can be divided into two or more discrete sub-processes that could be the subject of a JI/CDM project. However, it is recommended that emission baselines be established at the main process step level or at the clinker manufacturing level (which would encompass emissions from all three main steps).

Elements of emission baselines for potential JI/CDM projects in cement manufacture could be standardised to a certain extent, depending on the project type. This is outlined below. Changes in the way an individual plant operates may make it potentially eligible for more than one different type of JI/CDM project in the cement sector.

For *energy-efficiency projects* in cement manufacture (*e.g.* replacing an existing pre-heater with a more efficient one), standard energy values for different manufacturing steps could be established. The energy used for each of these steps is essentially governed by the technology used. Therefore, a standard emissions baseline could be based on the energy use for a “standard” technology, *e.g.* that installed under BAU investment conditions (which is a good indication of what would have happened otherwise). These standardised energy values could apply internationally to both existing and new plants. Basing a standardised energy value on technology-specific data has the advantage that such data are readily available (and could be easily updated, if necessary). However, this level of aggregation also has disadvantages. For example, such baselines would reward large plants that benefit from economies of scale more than small plants. Standardised values would be simpler to set up for direct fuel use in the pyro-processing step, *e.g.* 3.1 GJ fuel input/t clinker produced, than for electricity use in the different steps, as this can vary significantly within technologies.

However, emission baselines for each of these steps would, by definition, need to be expressed in terms of emissions. A standardised value for CO₂ emissions/ton clinker, unlike a standardised energy value, cannot be drawn up across countries because it would need to incorporate assumptions about, for example, which fuel is used in the cement kiln and which fuels are used to generate electricity at what efficiencies. “Translation” from a standardised energy value to GHG emissions would therefore need to be carried out using some project-specific and/or country-specific data for these variables. This could be done by using *e.g.* IPCC emission inventory methodologies to calculate fuel-related emissions and suggested methodologies (see Electricity Case Study) to calculate emissions from avoided electricity use.

For projects that change the production process (*“process change” projects*), *e.g.* conversion of an existing plant from the wet process to the dry process, standardised energy values could also be drawn up. However, these may need to be drawn up at a higher level of disaggregation (such as by country, rather than internationally) than energy-efficiency type projects. This disaggregation would allow for regional variations in plant conversion rates (*e.g.* because of lack of capital availability) to be taken into account, *i.e.* would essentially allow process change projects to have a less stringent baseline level than energy efficiency projects.

For *fuel input change projects* (*e.g.* using waste fuels to displace fossil fuel use in the pyro-processing step), assessing the quantity of waste fuels that would have otherwise been used is difficult, as this can vary significantly over time as well as from plant to plant. This difficulty is exacerbated for new plants, where historical “alternative fuel” use data is not available. However, it would not be possible to set international

default values for the GHG mitigation potential of different “alternative” fuels because the fuels they are displacing varies. For greenfield projects, rules of thumb should be developed that link potential alternative fuel use with distance from alternative fuel sources. Nevertheless, once the amount of alternative fuel use, its emission factor and what it is displacing has been established, a standard methodology to “translate” this into GHG equivalent is available in the IPCC inventory guidelines. It may be possible to estimate at a national or multi-country level which fuels are likely to be displaced by alternative fuels, but this would require further analysis.

For all energy-related projects, baselines should be expressed in terms of energy use per ton clinker produced for each of the three main process steps. Since the characteristics of “cement” can vary widely, expressing standardised baselines in terms of tons of cement would not lead to comparable values across projects. An internationally standardised baseline value for the energy required to manufacture cement should be set towards the upper end of the best practice range for energy-efficiency type projects, *e.g.* 3.1 GJ direct fuel use /t clinker. This value compares to estimated best practice of 2.9 - 3.2 GJ/t clinker and performance of 2.93 - 3.10 GJ/t clinker in new cement plants using standard technology. It may be more appropriate for process change type projects to have a less stringent baseline (*i.e.* at a higher energy level), in order to encourage conversion from highly inefficient plant types.

Because of the high volume of cement production, the number of credits generated by a particular project is highly sensitive to small changes in baseline value. For example, the hypothetical level of credits that could be obtained from two recently constructed cement plants in India and Mexico was examined. These plants have not requested AIJ or CDM approval, but if they did, they could qualify for credits under certain baseline assumptions. Moreover, the number of credits obtained could more than double depending whether or not the baseline was based on a value of 3.1 or 3.2 GJ fuel use/t clinker. The value of these credits could be more than US\$300,000 per year for an individual plant, if the value of 1t CO₂ was US\$10.

Energy-related emissions of CH₄ and N₂O combined represent less than 0.5% of total CO₂-equivalent energy-related emissions. The importance of the variability in energy use and therefore energy-related CO₂ emissions, is an order of magnitude higher ($\pm 15\%$). Thus, omitting estimations of CH₄ and N₂O will simplify the baseline-setting procedure without having a significant impact on either the stringency of the emissions baseline or on the uncertainty of credits. It is therefore recommended that baselines for energy-related projects in cement manufacture should include energy-related CO₂ emissions only. Since process-related CO₂ emissions are not impacted by energy-related projects, they would not need to be included in the emissions baseline for energy-related projects either.

For *blending projects*, it would be difficult to set either international or national standards for the clinker content of cement produced because the clinker content of cement varies significantly within and between countries, cement plants and cement types and can change significantly from year to year. Moreover, data on clinker and cement production before and during a project are likely to be both easily available at the project level (for plants already in operation) and more accurate (and available) at this level than at the country level. However, needing a project-specific number on which to base credits from blending projects increases the opportunity for gaming by the project proponents. Blending projects would need little if any technology input and are also relatively cheap (given the proximity of a potential source of additives). Emission baselines for any blending-type projects may need to include components related to both energy-related and process CO₂ emissions. These components should be separated for transparency and verification purposes. Baselines for blending projects should be reported in terms of energy-related and process CO₂ emissions per ton cement produced.

This study recommends quantifying the major emission sources that are influenced by a project for both energy and non energy-related projects in the cement sector. For energy projects, the major emission sources are the three major process steps: raw materials preparation, pyro-processing and cement grinding. Process CO₂ emissions are unchanged by energy-related projects and so could be omitted from the project baseline for simplicity. For blending projects, process emissions, emissions from additive preparation, as well as

energy-related emissions in the three major process steps should be included in the project boundary. Emissions from other activities related to cement manufacture (such as transport of raw materials, bagging and transport of finished cement) could be addressed by applying a constant multiplier to the quantified emission sources. Attempting to quantify small sources by using a multiplier addresses both simplicity and leakage concerns, although it is approximate and may therefore raise some accuracy issues.

Determining the lifetime of potential JI/CDM projects in the cement sector is extremely tricky, because there are no general standards (across different countries and companies) about the technical lifetime of equipment or how long it is used for before being refurbished. For example, some companies may replace kilns after 25y, whereas others will continue operation until the supply of raw materials is exhausted. Refurbishment (or not) of existing plants will also depend on the competitiveness of the cement supply market.

The long technical life (>50y) of cement plants mean many existing cement plants manufacture cement using old and inefficient technology. Although refurbishments, often combined with capacity increases, are undertaken under commercial business-as-usual conditions, refurbishment of such plants also could be a potentially promising area for JI/CDM projects.

It may be possible to set up rough “rules of thumb” to help determine the crediting lifetime of energy efficiency and process change projects. However, great care would need to be taken in order to avoid creating either non-additional credits or perverse incentives that rewarded installing inefficient technology. The best way of doing this may be to opt for either relatively short crediting lifetimes for energy efficiency and process change projects (*e.g.* 5-10y) or baselines that are revised relatively frequently (*e.g.* 5y) for all project types. However, any multi-project baseline used for the cement sector may need to be updated frequently (*e.g.* every few years) in order to reflect trends in BAU energy intensity, fuel use and blending practices within the cement industry.

Determining whether or not a project is truly “additional” may be as difficult as determining for how long an “additional” project should receive credits for. Thus, it may be useful to ask for some qualitative additionality checks when assessing whether or not a proposed project is eligible for JI/CDM status. These could include, *e.g.* indications of policy, regulatory or behavioural additionality of the proposed project. The use of qualitative additionality checks in conjunction with a quantitative baseline “test” could help to reduce the risk of non-additional projects generating emissions credits.

Glossary

Additive (or extender)	Material(s) added to clinker to make cement
AIJ	Activities implemented jointly
Blast furnace slag	One of the common additives used in cement. It is the by-product of iron and steel manufacture, and grinding this additive for use in cement is energy intensive
CDM	Clean Development Mechanism
CH ₄	Methane
Cli	Clinker
Clinker	The key component, and most GHG-intensive, of cement
CO ₂	Carbon dioxide
Dry process	A process whereby the raw materials for cement production are ground and then mixed (as a dry powder)
GHG	Greenhouse gas
GWP	Global warming potential
JI	Joint implementation
kWhe	Kilowatt hours of electricity use
Mt	Million tons
Mtoe	Million tons of oil equivalent
N ₂ O	Nitrous Oxide
Pozzolana	A natural cementitious material that can be ground and used as a cement additive
Process emissions	This refers to the CO ₂ emitted from decarbonisation of limestone. It takes place during the pyro-processing step
Production process change	Refurbishment of an existing plant that would change the process by which clinker is manufactured to a more efficient process (e.g. wet to dry, or semi-dry to dry)
Pyro-processing	This is the process of turning the raw materials into clinker (and takes place in the cement kiln)
Shaft kiln	The kiln, where clinker is produced, is vertical (whereas in other cement processes the kiln is slightly tilted, e.g. 1-3 degrees, from the horizontal)
Wet process	a process whereby the raw materials are ground, with water added, and mixed (as a slurry). The wet process is more energy-intensive than the dry process as energy is needed to evaporate the water in the raw material mix

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