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The Impact of Multi-Project Baselines on CDM Projects in the Cement Industry in Brazil

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Abstract

This study aims to test a methodology for developing standardized approaches for setting multi-project baselines, to test reference values for multi-project emissions factors (MPEFs), and to apply these to the cement industry in Brazil as an alternative to project-specific baselines for purposes of CDM projects in the industrial sector. Its purpose is to contribute to improve the consistency, transparency and credibility of the process to establish CDM project additionality, and to reduce establishment and validation costs of CDM projects in general and of CDM cement projects in Brazil in particular. It does so by constructing four kinds of multi-project baselines: weighted average, 25th percentile, 10th percentile and best plant.

Baselines are set from fourteen relatively new existing cement plants in the country, five of which are oil-fueled, four are coal-fueled and five are multi-fueled. These plants were chosen because they are the most recently built and the most modern in operation in the country, and also because data on plants under construction and/or planned are not currently available.

Although electricity consumption data for grinding are not available on a plant-by-plant basis in Brazil, because more than 95% of all electricity consumed in the country is hydro-based, electricity–efficiency gains in grinding would only have minor impacts on carbon credits for future CDM-candidate cement plants. Also, in spite of the fact that cement production also includes process CO_2 emissions (which can be reduced through blending), only emissions associated with energy use were examined here.

Having all these constraints in mind, results show that the widespread potential availability of alternative fuels in most regions of the country (renewable charcoal and sugarcane bagasse mainly) make fuel switching, rather than energy-efficiency improvements, the most effective carbon-savings option for energy-related CDM cement projects in Brazil. And with respect to setting the most appropriate multi-project baselines, and reference values for MPEFs, the 10th percentile and the best plant approaches seem to be the most adequate ones for future CDM baselines, by no means being too restrictive in the case of the cement industry in Brazil.

Keywords: Multiproject baselines, CDM, cement industry

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1. Introduction

The entering into force of the Kyoto Protocol implies that Annex B countries (38 nations and the European Union) will have obligations to comply with quantitative limitations of greenhouse gas (GHG) emissions in the near term. Because of that, the utilization of the flexible mechanisms agreed upon in Kyoto to help achieve their emissions reduction targets (Emissions Trading-ET, Joint Implementation-JI and the Clean Development Mechanism-CDM) will certainly play an important role in the agenda of some of Annex B countries in the near future.

Of the three flexible mechanisms that grew out of the United Nations Framework Convention on Climate Change (FCCC) and its Kyoto Protocol, CDM seems to be the most innovative one. CDM, defined in Article 12 of the Kyoto Protocol to the FCCC, combines technology transfer, sustainable development and climate change mitigation through specific projects in developing countries, with emission reductions resulting from each project activity having to be certified by operational entities to be designated by the Conference of the Parties on the basis of, among other things, real and measurable reductions in emissions that are additional to any that would occur in the absence of the certified project activity. If properly deployed, CDM could result in substantial cost savings in meeting national emission reduction targets for Annex B countries, while potentially helping to transfer technology and resources to developing countries and countries with economies in transition (Metz et al., 2000).

One critical difficulty associated with CDM lies in determining how to count the emissions reductions that would accrue from projects. Because the Kyoto Protocol called for no new commitments for developing countries, there would be no national "cap" on emissions against which reductions might be measured and, as such, CDM was to count reductions project by project only (OECD/IEA, 2000).

One solution is to develop emission baselines for projects. But the main question with respect to CDM baselines seems to be to find a methodology able to balance the conflict between maximizing the environmental integrity of a project and minimizing the transaction cost of the CDM. One possibility of finding a cost-effective way of determining a baseline while, at the same time, ensuring environmental integrity is to develop standardized, or multiproject, baseline procedures (Joint Implementation Quarterly, 2000).

This study aims to test a methodology for developing standardized approaches for setting multi-project baselines, to test reference values for multi-project emissions factors (MPEFs), and to apply them to the cement industry in Brazil as an alternative to project-specific baselines for purposes of CDM projects in the industrial sector. Its purpose is to contribute to improve the consistency, transparency and credibility of the process to establish CDM project additionality, and to reduce establishment and validation costs of CDM projects in general and of CDM cement projects in Brazil in particular.

2. Methodology

The authors collected data; modified and adapted a model originally developed by researchers from the Lawrence Berkeley National Laboratory (LBNL), University of California, Berkeley, U.S.A., to establish an emissions factor for a multi-project baseline; and applied the modified model and conducted studies on the cement industry in Brazil.

Initially the authors collected data on individual cement plants in Brazil about energy use, carbon emissions and output. Then, after modifying and adapting the model to the specificities of the Brazilian cement sector (a function, mainly, of the widespread use of renewable biomasse energy), the authors estimated the weighted average, top 25th and 10th percentile and best plants MPEFs for fourteen recent cement plants -- increasing methodological accuracy (but decreasing certainty) of MPEFs would have been obtained if emissions for under-construction or near-future cement plants were estimated instead. Unfortunatelly, no data of this kind are currently available in Brazil. Finally, the authors compared estimated MPEFs with CDM-project energy-efficient or CDM-project fuel-substitution plants to calculate additional carbon emissions reduction.

3. Outlook for the cement sector in Brazil

Cement production has grown steadily in Brazil in the past three decades (see Figure 1). Just five years ago, in 1995, Brazil was the thirteenth largest cement producer in the world (SNIC, 1996). In 1996, the country was already the eighth largest producer, the seventh in 1997 and the sixth in 1998 (SNIC, 1999).

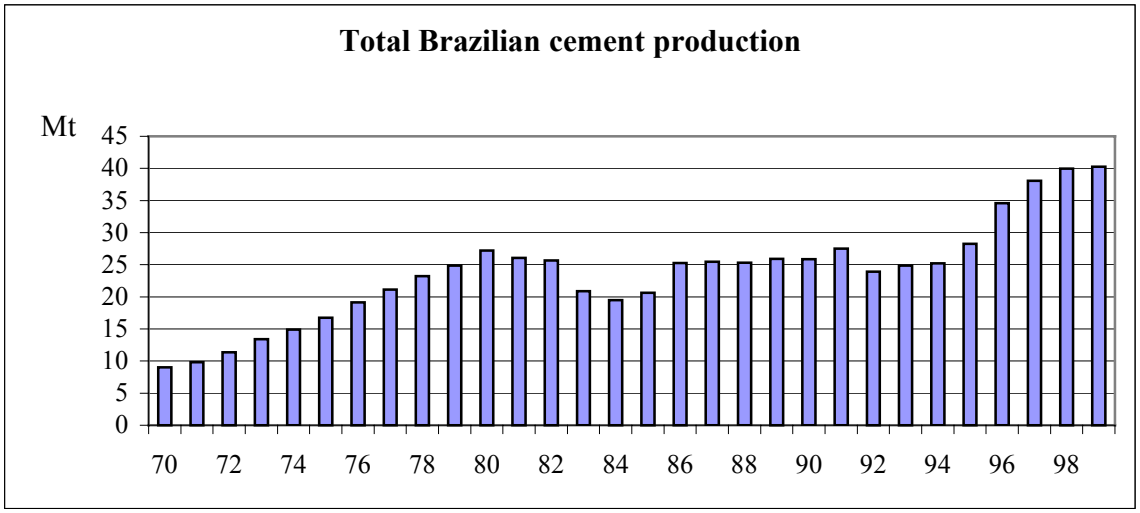

Figure 1. Portland cement production in Brazil, 1970-1999

In 1998, the country had a total production/consumption of some 40 Mt of cement (or some 250 t of cement/capita), out of a world production of 1,536 Mt of cement (SNIC, 1999). That year, 41 different companies, with 59 producing plants (with 11 grinding-only plants), were in operation in Brazil.

4. Energy use and carbon dioxide emissions from cement production

Cement manufacture is very energy intensive and results in significant energy-related and process emissions of greenhouse gases, mainly CO_2.

Basically, there are three main stages in cement production: (a) raw materials preparation; (b) clinker production; and (c) clinker grinding and blending with other products to produce cement. Of these three main steps in cement manufacture, the second one, clinker production, is the most energy intensive and is also the main source of process CO_2 emissions. Although process emissions can account, in some cases, for more than half of emissions from cement production (OECD/IEA, 2000), only energy-use-derived emissions are dealt with in this work.

Clinker can be produced by four different manufacturing processes. The name of the process refers basically to how the raw materials are mixed: (a) dry process; (b) wet process; (c) intermediate process (semi-dry or semi-wet); and (d) shaft. The first two are the main processes in use in Brazil.

The dry process is much less energy-intensive than the wet process, normally requiring 50% less energy input. The wet process is gradually being discontinued in many countries and is rarely used for new plants (OECD/IEA, 2000).

Several factors affect the energy and/or carbon intensity of cement production: (a) the process used in the manufacturing process; (b) the energy carriers consumed; (c) the manufacturing technologies deployed; (d) the type of cement produced; (e) the physical and chemical properties of the raw materials used; (f) the carbon intensity of electricity consumed in cement manufacture; and (g) the proportion of clinker in cement (OECD/IEA, 2000). All these factors have been considered in, and influenced the results of, this work.

In the case of Brazil, installed capacity for clinker production was 40.2 Mt clinker/year in 1995, with 114 kilns in operation. Of this total, 96.2% of total production was dry process, 3.3% was wet process and 0.5% was semi-dry process, with the sector being relatively efficient compared to other countries. The total energy use per unit of output, or specific energy consumption (SEC), for clinker production averaged 3.6 MJ/kg clinker, with a range of 3.09-4.42 MJ/kg clinker for the dry process plants and 6.02-7.59 MJ/kg clinker for the wet process plants (SNIC, 1996).

Due to its extremely high energy intensity and large volumes of production involved, cement manufacture in Brazil accounted for 7%, 4% and 5% of total energy use in the industrial sector in

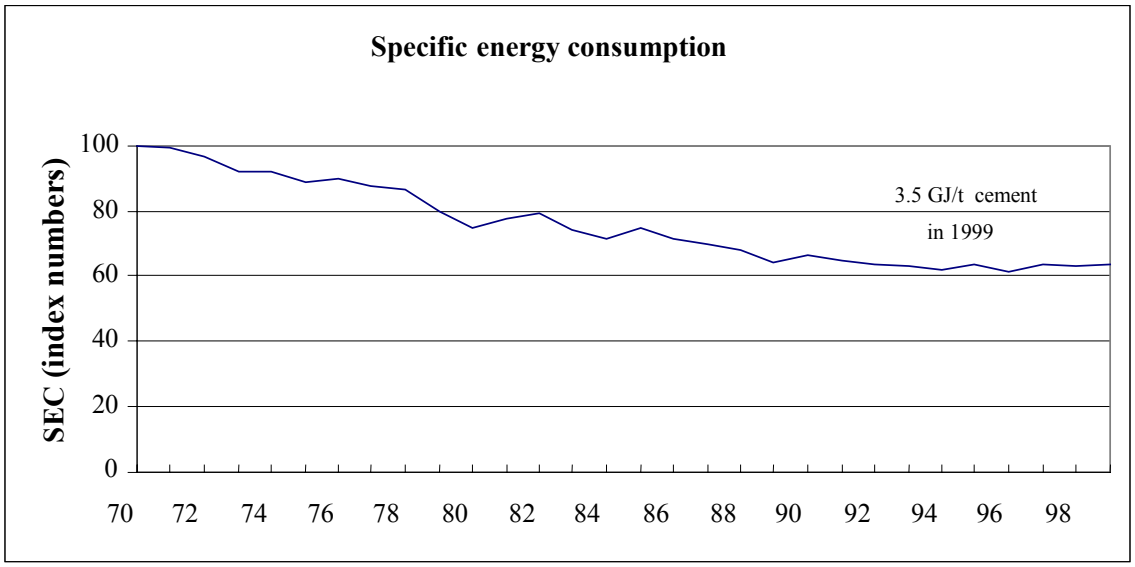

Figure 2. Specific energy consumption (SEC) for cement production in Brazil

1970, 1995 and 1999, respectively, behind only the food and beverages sector (20% of total energy use in the industrial sector in 1999), the iron and steel sector (19%), the non-ferrous metals sectors (12%), the chemicals sector (11%), and the pulp and paper sector (9%). In terms of carbon emissions from energy use, cement manufacture accounted for 7% of total industrial emissions in the country in 1994 (MME, 2000). Figures 2 and 3 depict, respectively, SEC (total

energy use per tonne of cement) and specific carbon emissions (SCE)(total carbon emissions per tonne of cement) from energy use for cement production in Brazil during the past 30 years.

Interestingly enough, several factors have contributed to these decreases in specific energy and carbon intensities of cement production over time in Brazil. Among those are worth mentioning, in different proportions, are the changes in the production process by which raw materials are ground, mixed and fed into the kilns from wet to dry (with impacts in both energy use and carbon emissions), the increase in the energy efficiency of cement production in general by optimizing heat uses (also with impacts in both energy use and carbon emissions), and changes in the input fuel (with impacts mostly on the carbon intensity from energy use). This latter factor explains the increase in SCE from energy use for cement production in Brazil in the last couple years: the substitution of higher-carbon-content petroleum coke for lower-carbon-content fuel oil, coal and charcoal as an input fuel.

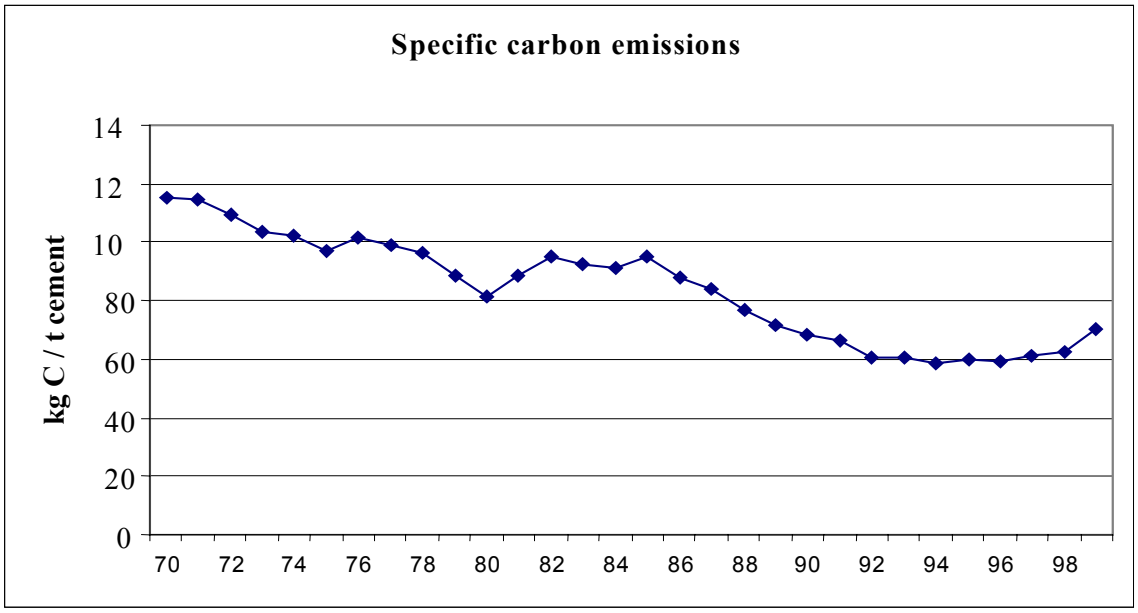

Figure 3. Specific carbon emissions (SCE) from energy use for cement production in Brazil

Figure 4 presents shares of different energy carriers used as fuel inputs in cement production in Brazil during the past 30 years. Due to the high temperatures present in a cement kiln (in the range of 1500 ^{o}C), a wide range of input fuels, including waste fuels, can be, and were, safely used.

While in the early 70s fuel oil was almost exclusively used as the fuel input for cement manufacture in Brazil, its use decreased steadily until the middle of the 80s, when it started to grow in importance again until approximately 1989. The roles of coal and charcoal were exactly the opposite of – and compensating – the role of fuel oil, growing in importance until the middle of the 80s, and decreasing after that. Oil prices in the domestic market and domestic policies after 1985 requiring renewable charcoal to be used (Figure 5 shows, for the 90s, the growing share of renewable charcoal on total charcoal use in Brazil) explain most of these trends. In 1999, with natural gas becoming increasingly available in Brazil, the excess of petroleum coke in the market found its way as an important fuel input for cement production in the country.

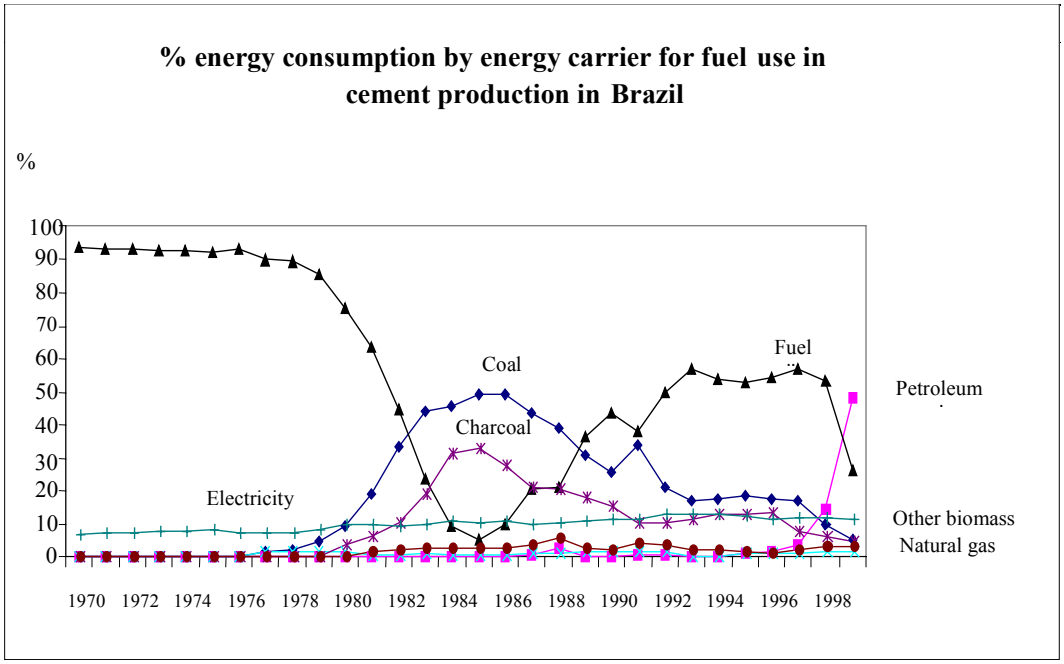

Figure 4. Share of different energy carriers as fuel inputs in cement production in Brazil

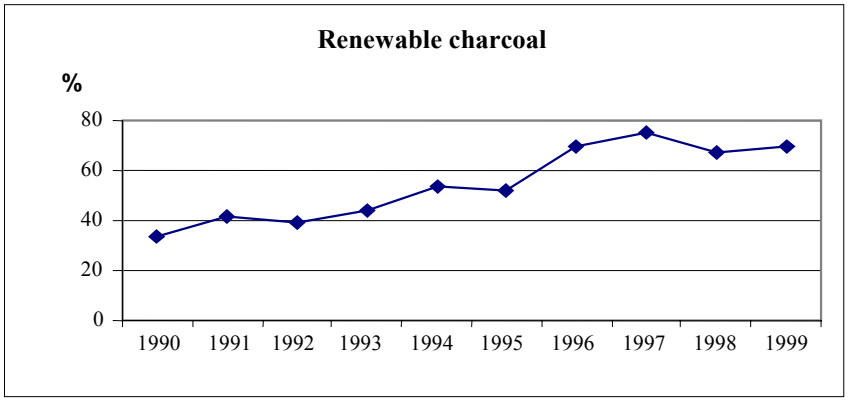

Figure 5. Share of renewable charcoal on total charcoal use in Brazil

5. Multi-project baselines construction

Emissions from the production of cement depend on various factors (see section 4). Even so, emissions from energy use from the manufacture of cement can be expressed as following:

Total emissions from energy use for cement production	=	emissions from fuel combustion + (indirect) emissions from electricity consumed

As we can see, the key underlying assumptions of emission baselines in cement production concern, mostly, the energy used in the different manufacturing processes. In our case, the multi-project baseline energy and carbon (from energy use only) intensities of cement manufacture are

based on data from 1995, the last year for which information on fuel energy consumption is available on a plant-by-plant basis.

Regarding electricity consumption, data on a plant-by-plant basis is not currently available in Brazil. For the whole Brazilian cement sector, on the other hand, the electricity consumption was 116 kWh per tonne of cement in 1995 and 112 kWh per tonne of cement in 1999 (MME, 2000). However, it should be noted that total energy consumption remained the same, 3.5 GJ/t cement, from 1995 to 1999 (MME, 2000). Considering that the average clinker/cement ratio has kept at the same level (0.8) over time and that no significant process changes have occurred since 1995, using 1995 data by plant seems to be reasonable.[1] It is true that petroleum coke consumption for clinker production increased heavily in 1999 (Figure 4), resulting in higher carbon emissions per ton of clinker produced (Figure 3), as petroleum coke presents a higher carbon content than coal and fuel oil.

Net specific carbon emissions from energy use are shown in Table 1. Notice that sugarcane bagasse is a renewable energy source, resulting in zero net carbon emissions. The evolution of charcoal renewability in Brazil is presented in Figure 5.[2] In 1999, 70% of the produced charcoal was renewable, resulting in net carbon emissions of 9.7 kg C/GJ of charcoal.

Therefore, baseline intensities based on 1995 data are more restrictive, meaning that if a CDM project is approved for 1995 baselines, it will certainly be approved for 1999-constructed baselines as well.

In this study, baselines are set from fourteen relatively new existing cement plants in the country, five of which are oil-fueled, four are coal-fueled and five are multi-fueled. The main criterion used for choosing plants was to build a baseline composed only of highly energy efficient clinker production units. These fourteen plants are the most recently built and the most modern plants in operation in the country today. A baseline that included plants under construction or planned plants is not considered because such information is currently not available in Brazil.

Table 1. Net carbon emissions from selected energy carriers in Brazil

Net carbon emissions (kg C/GJ)	
Coal	25.8
Natural gas	15.3
Fuel oil	21.1
Petroleum coke	27.5
Charcoal (0% renewable)	32.2
Charcoal (70% renewable)	9.7
Sugarcane bagasse	0.0

As shown in Table 2, the energy and carbon intensities of oil-fueled plants (numbers 1-5) vary between 3.19-3.36 MJ/kg clinker and 67.33-70.99 kg C/t clinker, respectively. For coal-fueled plants (numbers 6-9) the ranges for energy and carbon intensities are 3.09-3.43 MJ/kg clinker and

[1] As a matter of fact, from the early 70s to the end of the 90s the use of additives for cement production has increased slightly in Brazil. As such, the average clinker/cement ratio decreased slightly in the period, which explains part of the decrease in the SEC for cement production in the country over time.

[2] Charcoal "renewability" refers to whether or not the wood for charcoal production has been harvested sustainably, i.e. produced from renewable forests rather than from deforestation.

79.69-88.47 kg C/t clinker, respectively. The group of plants (numbers 10-14) consuming more than one fuel presents energy intensities varying between 3.22-3.41 MJ/kg clinker and an extremely wide range of carbon intensities (31.73-79.91 kg C/t clinker). The plant with the highest share of charcoal consumption on total fuel inputs presents the lowest carbon intensity, 31.73 kg C/t clinker.

Baselines for the raw material production and the cement grinding stages require information on electricity consumption on a plant-by-plant level. However, such information is not currently available in Brazil and estimated values of 26 kWh/tonne (0.12 kgC/tonne) for raw material production and 42.6 kWh/tonne (0.2 kgC/tonne) for cement grinding were used for setting the baselines for these two process steps. These estimates are based on total electricity consumption, 116 kWh/tonne cement, in the Brazilian cement sector in 1995, applying percentual values for each step in typical portland cement plants in Brazil (dry process). However, carbon emissions derived from electricity generation are extremely low in Brazil due to the fact that about 95% of all electricity generated and consumed in the country has a hydroelectric origin. Thus, electricity savings technologies are not considered in this study and the estimates for electricity consumption are illustrative only.

Also, it should be observed that some plants in Table 2 present higher figures for clinker production than for cement production. This is explained by the fact that some plants in Brazil sell part of their clinker production to third parties (to grinding-only plants).

Finally, the multi-project-baseline for the fourteen plants chosen to integrate the benchmarks yields a weighted-average SEC of 3.30 MJ/kg clinker, as shown in Table 3.

The "best plant" benchmark with respect to carbon emissions refers to a plant using almost 100% charcoal. If we consider several options for projects using different input fuels plus bagasse, we can easily calculate the maximum percentage of any fuel in these projects required to achieve this best plant benchmark, as shown in Figure 6. For example, 63% is the maximum amount of natural gas to be used (together with 37% of bagasse) in a clinker kiln in Brazil today, in order to have that plant achieving the best-plant benchmark available in the market.

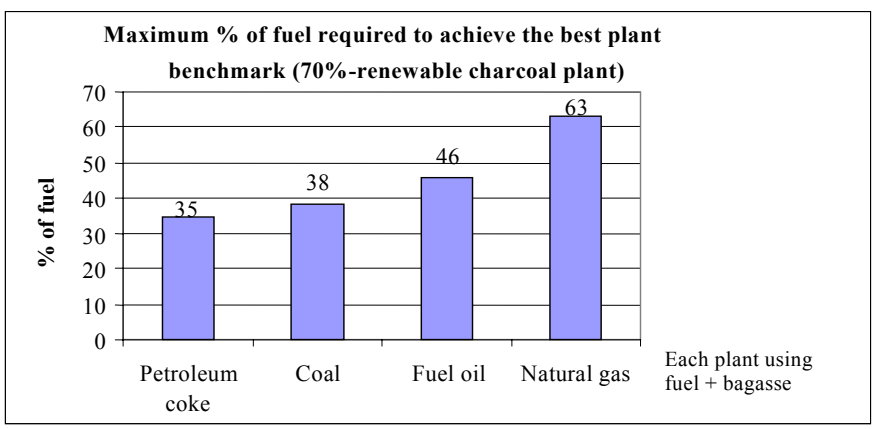

Figure 6. Maximum share of a fuel in a dual-fuel cement plant, with sugarcane bagasse as the second fuel, to achieve Brazil's best plant benchmark

Table 2. Technical characteristics of fourteen "recently-built" cement manufacturing plants in Brazil used for the construction of multi-project baselines for CDM projects

PLANT		1	2	3	4	5	6	7
I. Plant Performance								
Capacity	t clinker/day	3000	7200	1500	1000	900	2665	4500
raw material throughput	Mtonne/year	1.169	2.662	0.503	0.410	0.490	0.505	1.969
clinker production	Mtonne/year	0.649	1.479	0.280	0.228	0.272	0.281	1.094
cement production	Mtonne/year	0.566	2.160	0.323	0.174	0.279	0.667	1.071
Fuel consumption								
Coal	GJ						904,518	3,378,309
Charcoal	GJ							
Natural Gas	GJ							
Fuel Oil	GJ	2,072,263	4,921,445	938,363	766,881	882,756		
Other (100% renewable)	GJ							
II. Plant Intensities								
total fuel usage	GJ	2,072,263	4,921,445	938,363	766,881	882,756	904,518	3,378,309
total carbon emissions	tonne C	43,725	103,842	19,799	16,181	18,626	23,337	87,160
energy intensity	GJ/t clinker	3.19	3.33	3.36	3.36	3.25	3.22	3.09
carbon intensity	kg C/t clinker	67.33	70.22	70.79	70.99	68.48	83.11	79.69

PLANT		8	9	10	11	12	13	14
I. Plant Performance								
Capacity	t clinker/day	2200	2200	2000	2910	2200	10200	1920
raw material throughput	Mtonne/year	1.109	0.752	0.810	1.725	1.140	4.014	0.809
clinker production	Mtonne/year	0.616	0.418	0.450	0.958	0.633	2.230	0.450
cement production	Mtonne/year	0.692	0.557	0.590	1.150603	0.717218	2.036486	0.36176
Fuel consumption								
Coal	GJ	2,053,902	1,433,205		40,432		3,817,247	1,129,037
Charcoal	GJ			1,425,405	677,200	803,681		
Natural Gas	GJ							
Fuel Oil	GJ			21,099	2,440,744	1,264,397	3,777,810	19,197
Other (100% renewable)	GJ							356,723
II. Plant Intensities								
total fuel usage	GJ	2,053,902	1,433,205	1,446,505	3,158,376	2,068,078	7,595,057	1,504,956
total carbon emissions	tonne C	52,991	36,977	14,272	59,112	34,474	178,197	29,534
energy intensity	GJ/t clinker	3.33	3.43	3.22	3.30	3.27	3.41	3.35
carbon intensity	kg C/t clinker	85.99	88.47	31.73	61.69	54.46	79.91	65.68

Table 3. Multi-project baseline outputs based on fourteen "recently-built" cement plants in Brazil

Clinker Production Stage			*Benchmark Basis:* Average	Weighted Average	Percentile 25%	Percentile 10%	Best Plant
energy intensity	GJ/tonne	all	3.29	3.30	3.16	3.09	3.09
		coal	3.27	3.23	3.09	3.09	3.09
		charcoal	*****	*****	*****	*****	*****
		ng	*****	*****	*****	*****	*****
		fuel oil	3.30	3.30	3.20	3.19	3.19
carbon intensity	kg C/tonne	all	69.90	71.56	55.25	44.27	31.73
		coal	84.31	83.22	79.69	79.69	79.69
		charcoal	*****	*****	*****	*****	*****
		ng	*****	*****	*****	*****	*****
		fuel oil	69.56	69.53	67.46	67.33	67.33

6. Hypothetical CDM-candidates cement projects

Tables 4 and 5 present information on the six hypothetical CDM-candidate cement projects considered in this study. Project 1 refers to a plant with 0.65 Mt of clinker annual production and 0.57 Mt of cement annual production using 100% of fuel oil with the "best plant" SEC of 3.09 GJ/t clinker. Projects 2-4 refer to plants with 1.09 Mt of clinker annual production and 1.07 Mt of cement annual production, with the "best plant" SEC of 3.09 GJ/t clinker and using 100% of a different fuel each (natural gas, charcoal and bagasse). Projects 5-6 refer to plants with 1.50 Mt of clinker annual production and 1.90 Mt of cement annual production using 100% of coal and 100% of natural gas respectively, both with SECs of 3.15 GJ/t clinker.

Table 4. Basic description of hypothetical CDM-candidate cement manufacture projects

Project #	Fuel	Clinker Production (Mt)	Cement Production (Mt)	Specific Energy Consumption (GJ/t clinker)
1	Oil	0.65	0.57	3.09
2	Natural gas	1.09	1.07	3.09
3	Charcoal	1.09	1.07	3.09
4	Bagasse	1.09	1.07	3.09
5	Coal	1.50	1.90	3.15
6	Natural gas	1.50	1.90	3.15

7. Results

Table 6 and Figures 7, 8, 9 and 10, present the final results of the study. SCE reductions (in terms of kg C/t cement\) and total carbon emissions reductions (in terms of kg C/year) for each of the six different CDM-candidate cement projects are shown. Results are presented compared to multi-project emissions factors (MPEFs) from the multi-project baselines given in terms of weighted average, 25% percentile, 10% percentile and best plant. Comparisons are made both fuel specific, in the cases of Projects 1 and 5 (how a CDM-candidate cement project stands against the weighted average, 25% percentile, 10% percentile and best plant of plants fueled by the same kind of fuel), and sector wide, in the cases of all projects (how a CDM-candidate cement project stands against the weighted average, 25% percentile, 10% percentile and best plant of all plants considered for the baselines).

Table 5. Detailed data for hypothetical CDM-candidate cement manufacture projects

Data for Project Evaluation

PLANT NAME		Project #1	Project #2	Project #3	Project #4	Project #5	Project #6
Capacity	t/day						
I. Plant Performance							
Raw Material Grinding Stage							
raw material annual throughput	Mtonne	1.17	1.97	1.97	1.97	2.70	2.70
annual electricity consumption	GWh	30.39	51.19	51.19	51.19	70.20	70.20
Clinker Production Stage							
annual clinker production	Mtonne	0.65	1.09	1.09	1.09	1.50	1.50
annual fuel usage information:							
Coal	GJ				0.001	4,725,000	
Charcoal	GJ			3,378,309			
Natural Gas	GJ		3,378,309				4,725,000
Fuel Oil	GJ	2,005,410					
Other	GJ				3,378,308		
More than 1 fuel used?	(Y/N)	N	N	N	Y	N	N
Cement Grinding Stage					N		
annual cement production	Mtonne	0.57	1.07	1.07	1.07	1.90	1.90
annual electricity consumption	GWh	24.10	45.62	45.62	45.62	80.92	80.92
II. Plant Intensities							
Raw Material Grinding Stage							
energy intensity	kWh/tonne	26.00	26.00	26.00	26.00	26.00	26.00
carbon intensity	kg C/tonne	0.12	0.12	0.12	0.12	0.12	0.12
Clinker Production Stage							
total fuel usage	GJ	2,005,410	3,378,309	3,378,309	3,378,308	4,725,000	4,725,000
total carbon emissions	tonne C	42,314	51,688	32,770	0	121,905	72,293
energy intensity	GJ/tonne	3.09	3.09	3.09	3.09	3.15	3.15
carbon intensity	kg C/tonne	65.16	47.26	29.96	0.00	81.27	48.20
Cement Grinding Stage							
energy intensity	kWh/tonne	42.59	42.59	42.59	42.59	42.59	42.59
carbon intensity	kg C/tonne	0.20	0.20	0.20	0.20	0.20	0.20

Note: The annual electricity consumption values were calculated indirectly from the set values for energy intensities

In the case of CDM-candidate cement project 1 (oil), in a fuel-specific comparison the project performs well against any baseline. In a sector wide comparison, on the other hand, carbon reductions are only possible against the weighted-average baseline. The reason for these outcomes is that the SEC of CDM-candidate cement project 1 (3.09 MJ/kg clinker) is equal to the SEC of the most efficient cement manufacture plant in the country today (a coal-fueled cement plant), and as such is lower than the SEC of any other fuel-oil-fueled cement plant available. But in a sector-wide comparison, even the high energy efficiency of this plant cannot compete, in terms of carbon emissions, with other less energy-efficient cement plants fueled with natural gas and partially-renewable (70%) charcoal.

In the case of CDM-candidate cement project 2 (natural gas), in a sector-wide comparison carbon reductions are only possible against the weighted-average and the 25th-percentile baselines. In this case, the reason is that the 10th-percentile and best-plant baselines are composed of charcoal plants, which, although not being as energy efficient, in terms of carbon emissions, at least, perform better than even an energy-efficient natural gas cement plant.

Table 6. Carbon emissions reductions for hypothetical CDM-candidate cement projects against multi-project emissions factors (MPEFs)

Carbon intensity reductions [kg C/ tonne cement] (clinker production only)
Project performs this much lower *than benchmark; bigger number is better*

Compared to	*Benchmark standard*	Project #1	Project #2	Project #3	Project #4	Project #5	Project #6
Fuel specific	Weighted average	4.367	dna	dna	dna	1.952	dna
	25th percentile	2.294	dna	dna	dna	-1.585	dna
	10th percentile	2.172	dna	dna	dna	-1.585	dna
	Best plant	2.172	dna	dna	dna	-1.585	dna
Sector wide	Weighted average	6.394	24.301	41.597	71.556	-9.714	23.361
	25th percentile	-9.908	7.999	25.295	55.254	-26.016	7.059
	10th percentile	-20.889	-2.982	14.314	44.274	-36.996	-3.921
	Best plant	-33.430	-15.523	1.773	31.732	-49.538	-16.463

Carbon reductions [kilotons per year; '000s of tons] (clinker production only)

Compared to	*Benchmark standard*	Project #1	Project #2	Project #3	Project #4	Project #5	Project #6
Fuel specific	Weighted average	2.8	dna	dna	dna	2.9	dna
	25th percentile	1.5	dna	dna	dna	none	dna
	10th percentile	1.4	dna	dna	dna	none	dna
	Best plant	1.4	dna	dna	dna	none	dna
Sector wide	Weighted average	4.2	26.6	45.5	78.3	none	35.0
	25th percentile	none	8.7	27.7	60.4	none	10.6
	10th percentile	none	none	15.7	48.4	none	none
	Best plant	none	none	1.9	34.7	none	none

Note: dna stands for "does not apply"

In the cases of CDM-candidates cement projects 3 (charcoal) and 4 (bagasse), in sector wide comparisons carbon reductions are possible against any baselines. In these cases, the outcomes are obvious. No cement plants in operation in Brazil today can perform better, in terms of carbon emissions, than energy-efficient plants fueled by 70%-renewable biomass (in the case of CDM-candidate cement project 3, which is fueled by charcoal) or 100%-renewable biomass (in the case of CDM-candidate cement project 4, which is fueled by sugarcane bagasse).

In the case of CDM-candidate cement project 5 (coal), in a fuel-specific comparison the project performs well only against the weighted-average baseline. In a sector-wide comparison, the project never performs well. It yields carbon emissions that are higher than any baseline considered. Here, too, these results come at no surprise. The very existence of cement manufacture plants in Brazil running on renewable biomass precludes the possibility of less energy-efficient coal-fueled cement manufacture plants performing well against sector-wide multi-project baselines.

Finally, in the case of CDM-candidate cement project 6 (natural gas), in a sector wide comparison carbon reductions are only possible against the weighted-average and the 25th-percentile baselines. The reasons for that performance are similar to those presented for the results of CDM-candidate cement project 2.

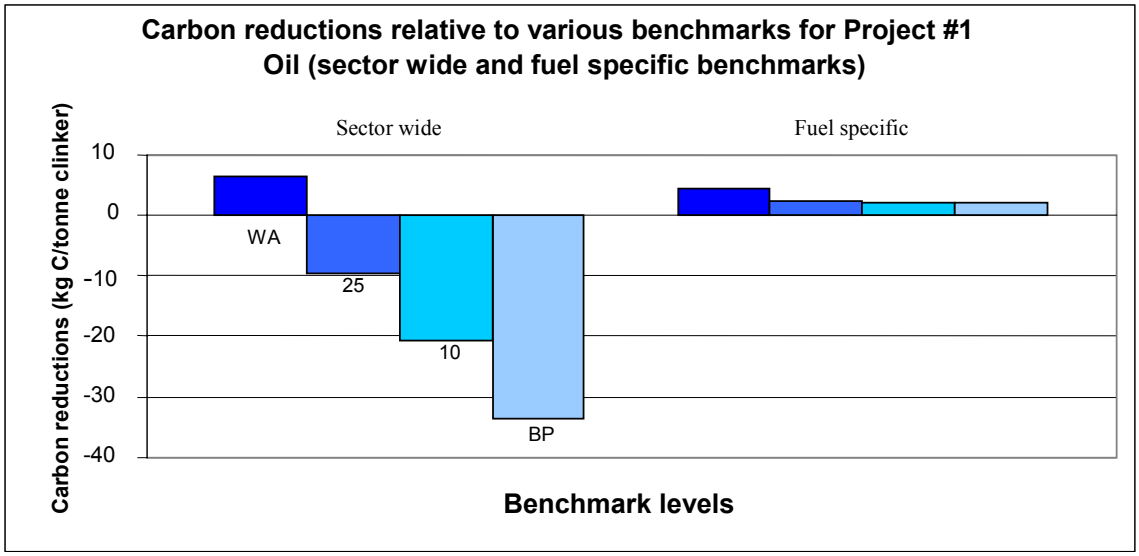

Figure 7. Carbon reductions for CDM-candidate cement manufacture Project #1 against fuel-specific and sector-wide multi-project baselines

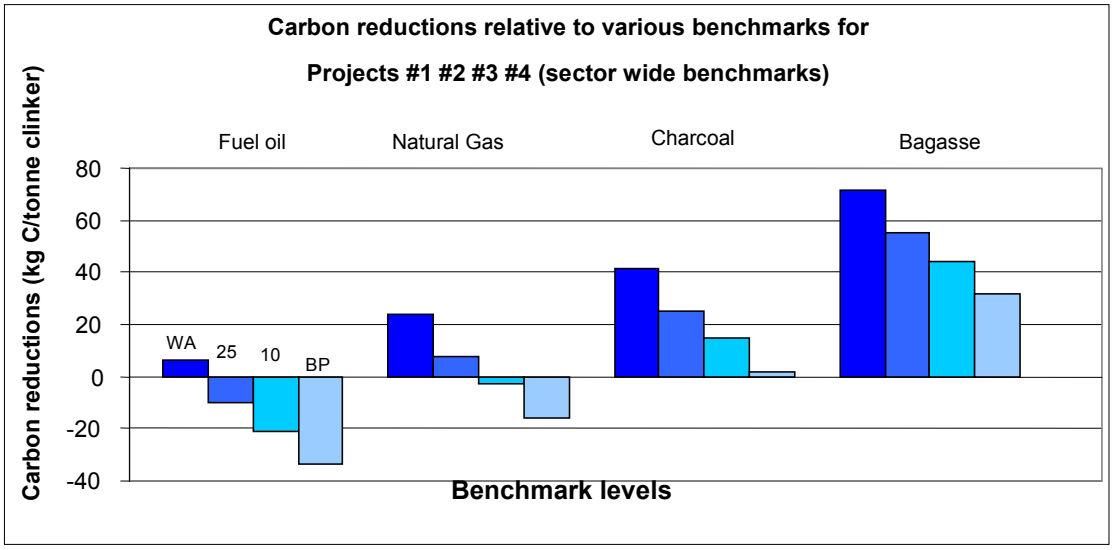

Figure 8. Carbon reductions for CDM-candidate cement manufacture Projects #1-4 against sector-wide multi-project baselines

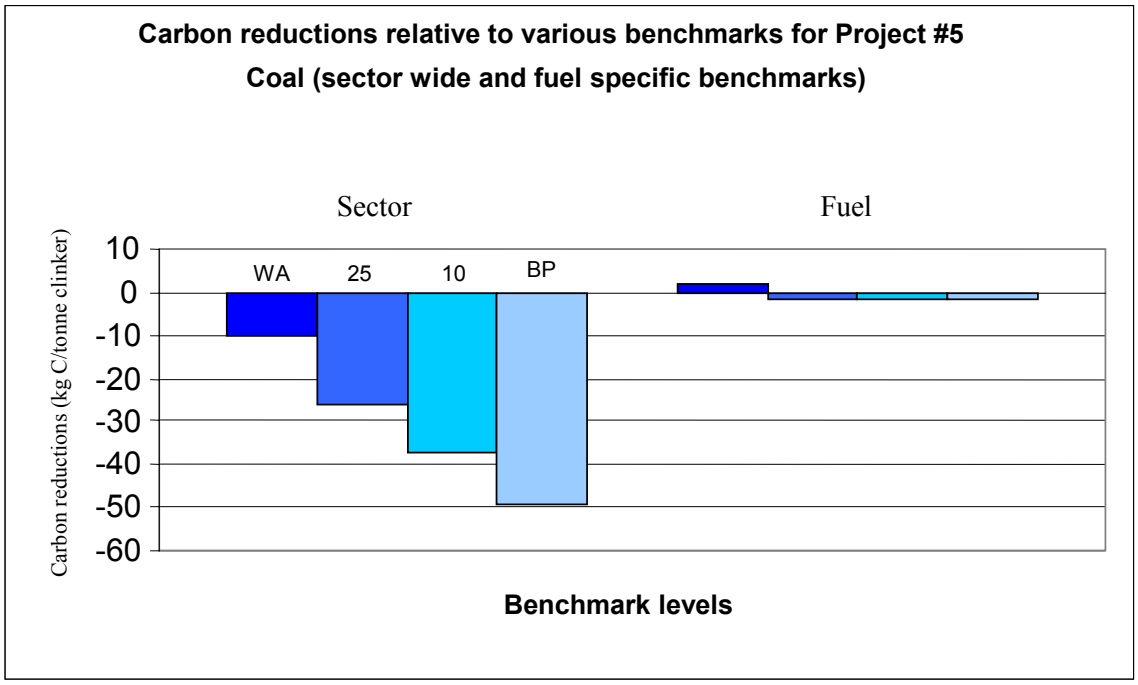

Figure 9. Carbon reductions for CDM-candidate cement manufacture Project #5 against fuel-specific and sector-wide multi-project baselines

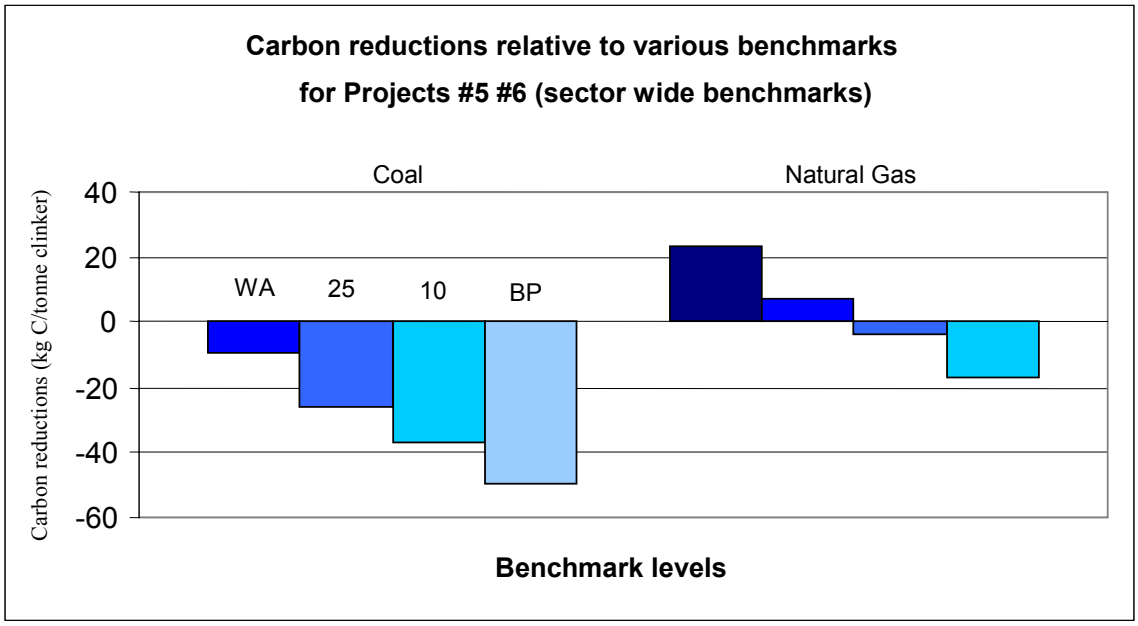

Figure 10. Carbon reductions for CDM-candidate cement manufacture Projects #5 and #6 against sector-wide multi-project baselines

8. Final discussion

Potential CDM project types in the cement sector can be divided into the broad categories of energy related and non-energy related categories. Energy-related CDM cement projects, which were the focus of this paper, include increasing the energy efficiency of cement manufacture,

changes in the production process, and changing the input fuels to less carbon-intensive energy carriers (including less-carbon-intensive carriers for electricity production).

Non-energy related cement projects include process CO_2 emissions, which can also be significantly reduced with the blending of clinker with increasing proportions of other products. This possibility, which was not examined here either but that could also be accounted for using this same methodology and the multi-project baseline model, should be also pursued in future research efforts.

Baselines were set from fourteen relatively new existing cement plants in the country. These plants were chosen because they are both the most recently built and the most modern ones, and also because data on plants under construction and/or planned are not currently available in Brazil. A baseline that included all plants, including older plants, would certainly differ from the one presented here, but the difference would not be substantial: the SEC for clinker production averaged 3.30 MJ/kg clinker for our baseline while the SEC for clinker production would average 3.60 MJ/kg clinker for a baseline constructed considering all the dry process plants in operation in Brazil.

Interestingly enough, the widespread potential availability of low-or-zero net carbon emissions alternative fuels in most regions of the country (charcoal and sugarcane bagasse mainly) make fuel switching, rather than energy-efficiency improvements, the most effective carbon-savings option for energy-related CDM cement projects in Brazil. While increasing the energy efficiency of cement manufacture plants in Brazil can reduce, in theory, on average, carbon emissions from cement production by less than 20% at most (assuming an average SEC for clinker production of 3.6 MJ/kg clinker in the country and a "best-of-all" plant with a SEC for clinker production of 2.88 MJ/kg of clinker), fuel switching can reduce carbon emissions by up to 100% (in the case of new cement plants fueled with 100%-renewable biomass, such as increasingly-renewable charcoal and already zero-net-carbon emissions sugarcane bagasse).

One question that comes up often regarding multi-project baselines is how difficult is to get the data for different plants. In the case of Brazil, the most recent data on energy consumption for cement production are for 1995 and even so these data are not complete: no electricity consumption data on a plant-by-plant basis are available. Even so, the data available are good enough for setting the most appropriate multi-project baselines and reference values for MPEFs for the cement industry in Brazil as an alternative to project-specific baselines for purposes of CDM projects. Also, although the use of kiln-specific data vs. plant-specific data might be preferable in some cases, in Brazil there are no significant differences in energy efficiency between kilns at the same plant.

The discussion presented leads us to conclude that, in principle, the "best plant" approach seem to be the best model for future CDM-candidate cement plants in Brazil. That approach, as we have shown, would not be too restrictive and, as such, would help reduce carbon emissions from energy use in the cement industry to a minimum, and, at the same time, help Brazil to get access to the most modern technology in the sector, with possible spill-outs to other industrial sectors as well. We have to recognize, however, that in some very few situations the "best-plant multi-project-baseline approach" may be too restrictive, perhaps even de-stimulating potential investors-to-be on CDM-cement projects in Brazil.

In any case, results clearly show that different criteria for establishing multi-project baselines may have substantial impacts on the amounts of carbon credits to be obtained from CDM-cement projects in Brazil. When all fuels are included in the multi-project baselines, fossil-fueled projects

do not look good in sector-wide analyses (never beating "best plant" or 10th-percentile multi-project baselines).

Because of the wide availability of renewable biomass as input fuels for the cement industry in Brazil, even energy-efficient natural-gas-fueled plants do not perform well at the "best plant" and 10th-percentile levels sector-wide. Energy-efficient fuel-oil- and coal-fueled cement manufacture plants can only perform well compared to fuel-specific plants.

Although electricity consumption data for grinding are not easily available on a plant-by-plant basis in Brazil (it is considered a "commercial secret" by the domestic cement industry), because more than 95% of all electricity consumed in the country is hydro-based electricity–efficiency gains in grinding would only have minor impacts on carbon credits for future CDM-candidate cement plants.

In summary, the results presented here support our argument that, for the cement industry in Brazil at least, multi-project baselines based on "10th percentile" or "best plant" seem to be the most appropriate criteria for setting up future CDM baselines, by no means being too restrictive.

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