Use of LCI for the decision-making of a Belgian cement producer : a common methodology for accounting CO_2 emissions related to the cement life cycle

Ph. Teller, University of Liège, Belgium

S. Denis, R. Renzoni and A. Germain
Industrial Chemistry Department, University of Liège
Allée de la Chimie B6, 4000 Sart Tilman (Liège), Belgium
Tel : + 32 4 366 35 80 ; Fax : + 32 4 366 44 35 ; E-mail : Ph.Teller@ulg.ac.be

Ph. Delaisse, H. d' Inverno
CBR Cement Belgium
Chaussée de la Hulpe 185, 1170 Bruxelles, Belgium
Tel : + 32 2 678 35 72 ; Fax : + 32 2 678 37 48 ; E-mail : mayke.vandeputte@cbr.be

Abstract

The very first consciousness of the potential risks associated with the greenhouse gas emissions began in the eighties. The UNEP brought this discussion to an international level and in 1997, most industrialized countries agreed to decrease their greenhouse gas emissions for 2008-2012 (The Kyoto Protocol, 1997). Aware of its part of responsibility, CBR Cement Belgium decided to estimate the CO_2 emissions associated with the cement life cycle from gate-to-gate (from the transport of raw materials to the final cement production), mainly for three distinct years : 1990 (as a reference), 1998 (corresponding to the situation nowadays) and 2002 (as a prospective situation needed for further decision-making). This study only refers to a small part of a complete LCA : one effect is assessed (the greenhouse effect), one substance is taken into account (the carbon dioxide) and only a part of the total life cycle is studied. But the results obtained for the different production plants (which correspond to different characteristics) allowed to achieve very interesting results concerning what has been done so far, and what can still be done to improve the efficiency of the cement production processes at different levels (type of kiln, amount of waste used as substitute, type and quality of cement produced…). The most relevant result to be noticed is a decrease of 11% for the specific CO_2 emissions (expressed in kg CO_2/t cement), when comparing 1998 to the reference.

Introduction

Carbon dioxide (CO_2)

The concentration of carbon dioxide in the atmosphere is estimated at 357 ppm, i.e. approximately 0.03% of the volume of the atmosphere. This level has gradually been increasing since the 19^{th} century. Therefore, measurements of the concentration of carbon dioxide in the atmosphere taken since 1958 at Mauna Loa (Hawaii), show an annual increase of approximately 1.5 ppmv/year, which corresponds to an annual increase of 3.1 GtC in the atmosphere. According to scientists, carbon dioxide is currently responsible for 60% of the increase in the greenhouse effect. Despite the fact that the balance of carbon flows can only be established as an approximate, there is at least one thing that is certain : the consumption of fossil fuels will continue to increase the amount of carbon dioxide in the atmosphere.

The Kyoto Protocol (1997)

The Kyoto Protocol, adopted in December 1997 specifies the commitments made by the developed countries. The agreement was to limit their emissions of the principal greenhouse gases to 5% below their 1990 levels by 2008-2012. This reduction is not evenly shared among the various countries. Belgium was involved in the negotiations within the European Union. The result is that between now and 2008-2012, Belgium must reduce its greenhouse gas emissions to 7.5% below the 1990 levels.

Life Cycle Inventory

The evaluation of carbon dioxide emissions associated with the activities of CBR Cement Belgium requires a practical tool for allowing the different sources to be identified and calculated. This tool is the Life Cycle Inventory (LCI) which allows all the emissions associated with a given activity to be listed and quantified.

Emissions considered

This study covers all the activities of CBR Cement Belgium. The calculated CO_2 emissions include each stage of the process from transport of the supplies (raw materials, fuels and electricity) at one end to production of the cement at the other. This approach corresponds to an inventory from gate-to-gate as neither the cradle (extraction of raw materials and fuels), nor the grave (use phase and end of life of the cement produced) of the life cycle are considered.

The carbon dioxide associated with the cement production comes from three sources. These are, in decreasing order of importance :

1. Burning of clinker : 95% of the emissions are due to decarbonation (reaction releasing the CO_2 contained in limestone raw materials) and the use of fossil fuels. The remaining 5% are due to points 2 and 3.
2. Production of electricity needed (grinding of cement, fuels and raw materials, preparation of the powder, the slurry, and the fuels, but also use of dryers, kilns, fans, coolers, etc.).
3. Transport of raw materials and fuels.

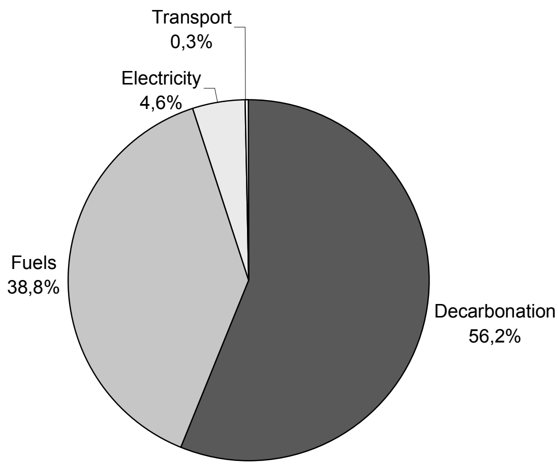

Figure 1 – Sources of CO_2 emissions.

It must be noticed that emissions associated with the use of alternative fuels, which replace a part of the non-renewable fossil fuels, are considered as nil. Indeed, if they weren't used in cement kilns, they would be destroyed (incinerated, for example) anyway. So, when not specified, it must be considered that the results are obtained by calculating a CO_2 emission lower than the real one measured at the chimney.

However, in order to provide useful data concerning the emission of CO_2 related to the production of cement, some global results (for which all the fuel burned is supposed to be coal) are given for different assumptions at the end of this paper.

Detailed inventory of CO_2 emissions in 1998

In 1998, CBR Cement Belgium emitted 2.5 million tonnes of CO_2 (i.e. 8.2% less than in 1990). At the same time, 2.7 million tonnes of clinker and 2.9 million tonnes of cement were produced by CBR Cement Belgium. Most of these emissions were due to clinker production (97%). The transformation of clinker into cement generates only a tiny part of these emissions (3%). Without the implementation of measures to reduce them, these emissions would equal 5.2 million tonnes of CO_2.

From this study, it is easy to notice that essentially, cement producers have three possible means of reducing CO_2 emissions :

Use of more efficient technologies

CBR currently uses two different clinker production processes : the wet process (WP) for chalk that is naturally rich in water, and the dry process (DP) for limestone having a water content of less than 16%. The dry process requires less energy to produce a given amount of clinker. On average, for an equal volume of production, wet process kilns emit 30% more than dry process kilns (this result is obtained by considering that the kilns are burning only coal).

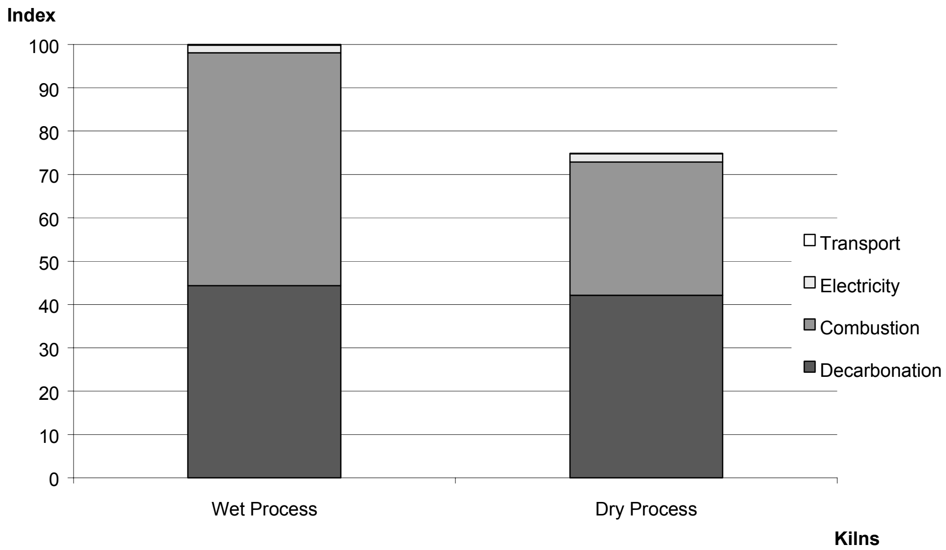

Figure 2 – Comparison of specific emissions of CO_2 by type of kiln.

Substitution of fuels

CO_2 emissions depend not only on the amount of fossil energy used, but also on the relative abundance of carbon and hydrogen they contain. Therefore, replacing the coal burned by CBR (which corresponds to an emission of 107 kg CO_2/GJ) with other fossil fuels of lower specific CO_2 emission value such as natural gas (which corresponds to an emission of 56 kg CO_2/GJ) or with alternative fuels (whose CO_2 emissions are considered to be nil) has allowed CBR Cement Belgium to reduce the emissions of CO_2 in the atmosphere.

Modification of product composition

The specific emissions of CO_2 (expressed in kg CO_2/ ton cement) resulting from the production of Blast Furnace Slag Cement (BFSC) are approximately half of those resulting from the production of Portland Cement (PC). Indeed, thanks to the use of alternative raw materials, BFSC contains a lesser proportion of clinker, which is the main source of CO_2 emissions.

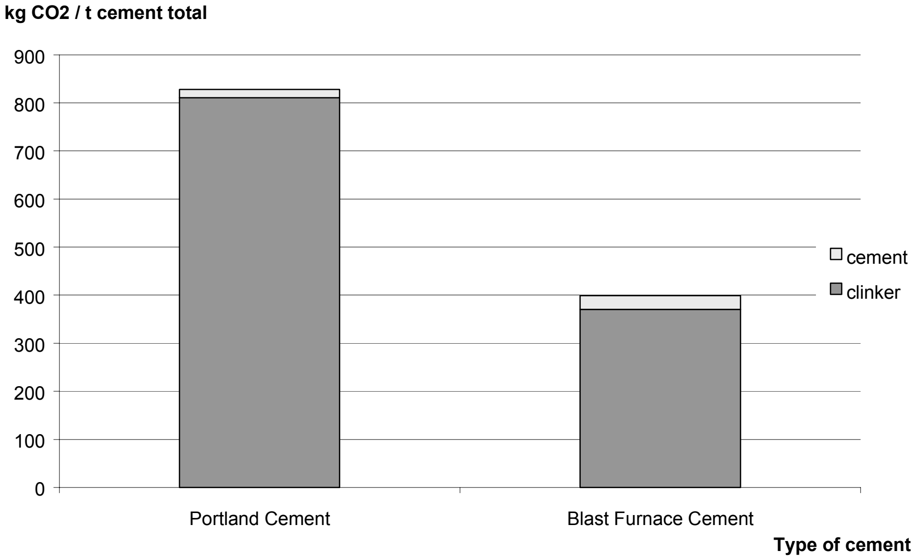

Figure 3 – Comparison of specific emissions of CO_2 by type of cement.

Overall effect

In the absence of any policy for reducing emissions, the activities of CBR Cement Belgium would have resulted in the emission of 1182 kg CO_2/t cement instead of the 567 kg/t actually achieved. The absence of any policy for reducing emissions corresponds to a situation in which CBR Cement Belgium were to produce only Portland Cement using only wet process technology and coal as its only fuel.

It must be noticed that if the emissions associated with the use of alternative fuels were taken into account, it would increase the value of the specific emission to 617 kg/t instead of 567 kg/t.

Evolution of CO_2 emissions

The same methodology has been applied to three distinct years :

1. 1990 : which is considered as the year of reference according to the Kyoto Protocol
2. 1998 : which corresponds to the situation of CBR Cement Belgium nowadays
3. 2002 : which corresponds to a prospective situation needed for further decision-making

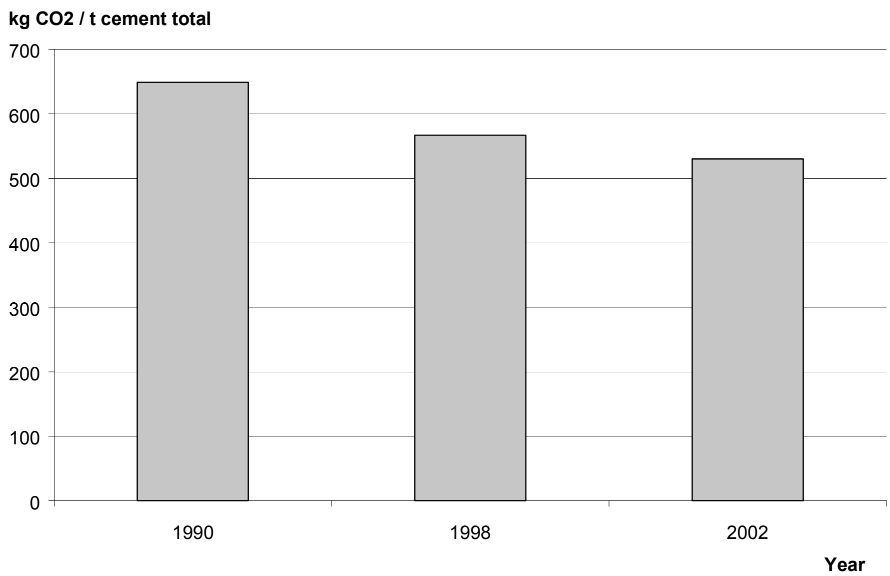

Figure 4 – Evolution of specific CO_2 emissions since 1990.

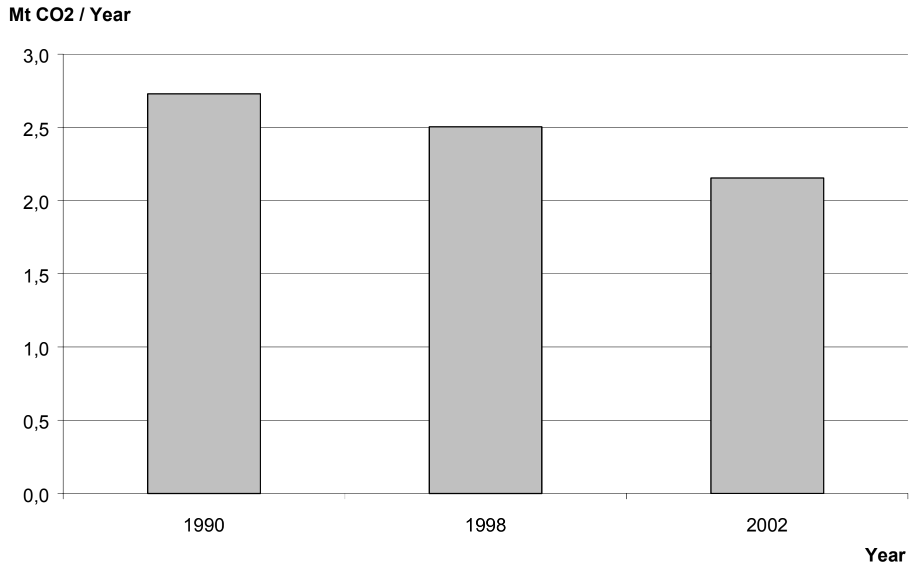

Figure 5 – Evolution of global CO_2 emissions since 1990.

Figures 4 and 5 both show that :

- The amount of CO_2 emitted in 1998 is lower than in 1990. This decrease can be explained by the increasing use of alternative fuels and the rapid expansion of Blast Furnace Slag Cement.

- The amount of CO_2 emitted in 2002 is expected to be even lower than in 1998. Two main lines of action can explain this reduction : the shutting down of a wet process kiln (which corresponds to the transfer of a part of its capacity to a dry process kiln) and the shutting down of a cement grinding plant (which is compensated by the increasing production of cement at a more efficient plant).

Conclusions

- The policy of reduction of emissions of CBR Cement Belgium is a threefold policy based on technology, energy and products.

- This policy will result, by the year 2002, in a reduction of total carbon dioxide emissions of 20% compared to the base year of 1990. This target greatly exceeds the 7.5% reduction of greenhouse gases that Belgium has undertaken to achieve under the Kyoto Protocol.

- This Life Cycle Inventory has been used as a basis to develop a common methodology accepted by all the Belgian cement producers. This new methodology allows to compare their past, present and future policies of reduction of CO_2 emissions.

- The resulting inventory can also be easily used to assess the efficiency of the policy of rational energy use. However, it must be noticed that a part of the global CO_2 emissions results from the decarbonation and not from the burning of fuels.

Useful data

	Decarbonation (kg CO_2/t clin)	Fuel (coal) (kg CO_2/t clin)	Electricity (kg CO_2/t clin)	Transport (kg CO_2/t clin)	Total (kg CO_2/t clin)
Clinker production (Raw mat. → Clinker) Wet proc., coal	540	670	21	3	1234
Clinker production (Raw mat. → Clinker) Dry proc., coal	515	385	23	2	925

Table 1 – Average data of clinker production (CBR, 1998).

	Decarbonation (kg CO_2/t cem)	Fuels (kg CO_2/t cem)	Electricity (kg CO_2/t cem)	Transport (kg CO_2/t cem)	Total (kg CO_2/t cem)
Cement production (Clinker → Cement) Portland Cement	--	0.2	16.9	1.2	18.3
Cement production (Clinker → Cement) BFSC	--	7.8	19.6	1.5	28.9

Table 2 – Average data of cement production (CBR, 1998).

If the ratio « kg clinker incorporated / kg cement produced » (between 0.8-0.9 for PC and 0.4-0.5 for BFSC) is known, the global specific emission of CO_2 related to the production of 1 ton of cement can be easily calculated.

For example, in the particular case of a clinker produced in a dry kiln (fed with coal) and then incorporated in BFSC (Blast Furnace Slag Cement), the global specific emission of CO_2 is :

$$Emission_{CO2} \approx \underset{\text{kg } CO_2\text{/t clin}}{925} \times \underset{\text{t clin/t cem}_{BFSC}}{0.45} + \underset{\text{kg } CO_2\text{/t cem}_{BFSC}}{28.9} = 445.2 \text{ kg } CO_2\text{/t cem}_{BFSC}$$

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