Biomass use in the Dutch cement industry
ENCI, Maastricht, The Netherlands

ENCI Maastricht is the largest cement factory in the Netherlands. In 2007, ENCI Maastricht produced almost 1.4 million tonnes of cement, and about 900,000 tonnes clinker (which are largely used internally for cement production). It has been strongly increasing its use of biomass waste streams from 0% in 1996 to 44% in 2007, leading to an overall GHG emission reduction of 28% compared to 1990. Sewage sludge is the principal biomass source, other biomass feedstocks being still significant quantities of bone meal, paper sludge and plastic-paper derived fuel.

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Introduction

Based in the Netherlands, ENCI is a division of HeidelbergCement active in the Benelux countries. It possesses three main production facilities in the Netherlands, of which the biggest is the integrated production plant in Maastricht. ENCI has been generating cement from Maastricht since 1926, and directly employs 212 people. There, the full cement production process is realised, as limestone is extracted from the 135-hectare quarry and burnt in a kiln to make clinker, which is then ground into cement. ENCI has two further sites in the west of the Netherlands- in IJmuiden and Rotterdam - both of which are grinding plants, where clinker is supplied rather than produced. In the integrated site in Maastricht, mainly Portland cement is produced, while the two grinding plants in the west of the country are solely focused on blast furnace cement.

Producing cement is a very energy-intensive process, and ENCI Maastricht alone consumes annually about 3.1 PJ primary energy, which is a little less than 1% of the total primary energy demand of the Netherlands.

Energy consuming production process

Cement is produced in two steps: first, clinker is produced from raw materials by heating limestone with small quantities of other materials (such as clay) to 1450°C in a kiln. Then, in the second step the resulting hard substance, called ‘clinker’, is ground into a fine powder. The raw materials are delivered in bulk, crushed and homogenised, preheated and then fed into a rotary kiln which reaches flame temperatures of up to 2000°C. The inclination of the kiln allows the materials to slowly reach the other end, where it is quickly cooled to 100-200°C. Hot flue gases from the kiln are used for preheating of the homogenised raw material before it enters to the kiln. Carbonates of limestone react with the heat by forming calcium oxide CaO (also called burnt lime) and carbon dioxide CO_2. The high temperature of the kiln melts the CaO powder. New compounds - silicates, aluminates and ferrites of calcium are formed. When mixing the ready cement powder with water, the hardening happens thanks to these compounds. The final product of this phase is called “clinker”. After cooling, these solid grains are then stored in silos.

Fig. 1: Overview of the cement manufacturing process at the ENCI Maastricht plant.

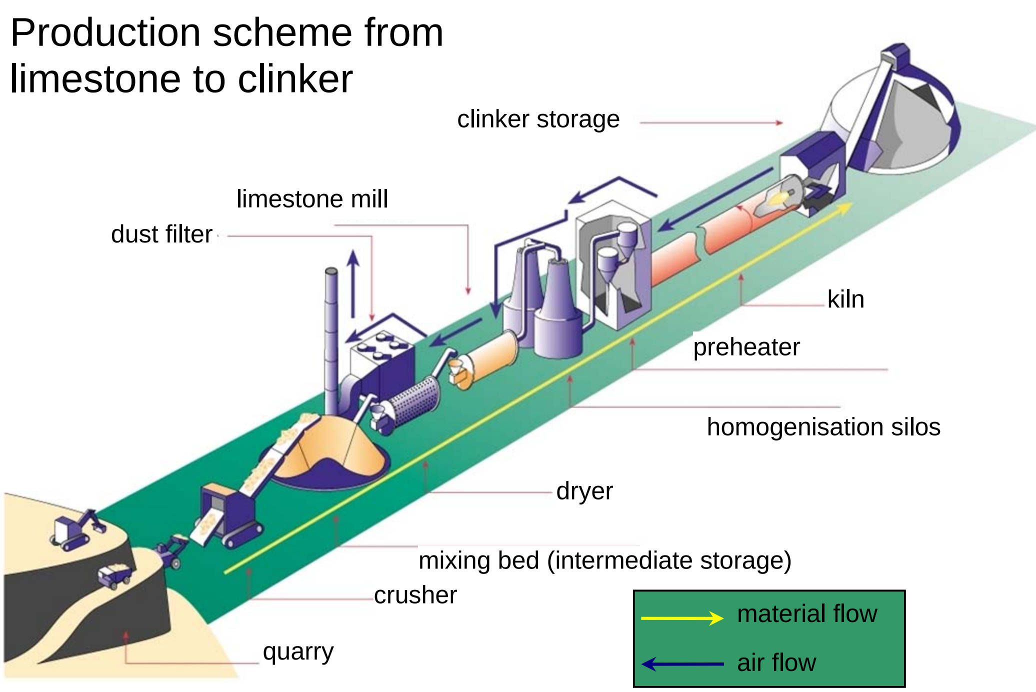

Table 1. Overall and biomass fuel use at the ENCI Maastricht plant in 2006. Adapted from Anonymous (2007)

	Total fuel (kt/y)	GJ/t clinker	Biomass (%)	Biomass (kt/y)	Total fuel (TJ/y)	Biomass use (TJ/y)
Finecokes	5,3	0,22	0	0	176	0
PPDF	10,8	0,31	0,6	6,48	248	148,8
PPDF 90	6,3	0,13	0,8	5,04	104	83,2
paper sludge	1,2	0,01	1	1,2	8	8
anode dust	25,8	1,01	0	0	808	0
Glycolbottom	11,8	0,23	0	0	184	0
Natural gas	0,2	0,01	0	0	8	0
Lignite	10,3	0,29	0	0	232	0
animal meal	13	0,31	1	13	248	248
sewage sludge biomill	73,4	1,2	1	73,4	960	960
paper sludge sappi	6,2	0,05	1	6,2	40	40
natural gas	0,9	0,04	0	0	32	0
Lignite	2,5	0,07	0	0	56	0
Total	**167,7**			**105,32**	**3104**	**1,488**

Use of biomass

ENCI uses a mix of fossil fuels, biomass fuels and other alternative fuels. In 2007, this contribution was 14% fossil fuels, 44% biomass and 42% other alternative fuels (e.g. anode dust or glycolbottom). The share of biomass in the fuel mix of the ENCI Maastricht plant has been increasing steadily from 0% in 1996 to 44% in 2007 (see also fig. 1). The fuel is used for the cement production process, where it produces the required heat to reduce CaCO3 to CaO.

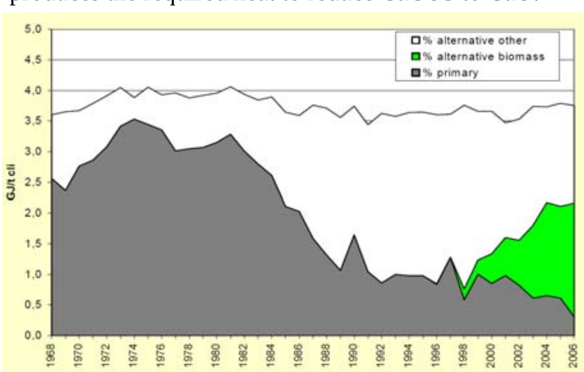

Fig. 1. Overview of the fuel use in the ENCI kiln 8 in GJ/tonne clinker from 1968-2006. (Anonymous, 2007).

ENCI uses a variety of biomass fuels, which are either 100% organic materials (such as sewage or paper sludge and animal meal) or sources mixed with fossil-derived materials (such as paper and plastics-derived fuels, PPDF). Table 1 provides the total fuel use and biomass fuel use of ENCI Maastricht in 2006. The various biomass streams are all sourced externally, i.e. no biomass is used from internal production.

The biomass fuels consisted out of sewage sludge animal meal, and (partially) PPDF pellets (a mixture of paper and plastic, the paper fraction constitutes the biomass part).

By far the most dominant biomass fuel used is sewage sludge (73,400 tonnes in 2006, in 2007 about 78,000 tonnes). Dewatered (i.e. a moisture content of 75%) the heating value is only 1.5 to 2 GJ/tonne. In dried form (i.e. a moisture content of 10-15%) the heating value is approximately 12 GJ/tonne (Mathieu, 2009), so it is essential to dry the sludge before transportation. About 35,000 tonnes of sewage sludge is transported from several locations in the Netherlands to Maastricht: from Venlo, Susteren and Hoensbroek, all in Limburg province (weighed average distance about 55 km), supplied by the Waterschapsbedrijf Limburg (WBL). The remainder is sourced from the vicinity of Amsterdam (distance about 200 km), and from the two most northern provinces of the Netherlands Friesland and Groningen (about 350 km transport distance, see also Figure 2). In all cases, the sewage sludge is dried (using natural gas) to a dry matter content of at least 90%, after which it is transported by truck to the Maastricht cement plant.

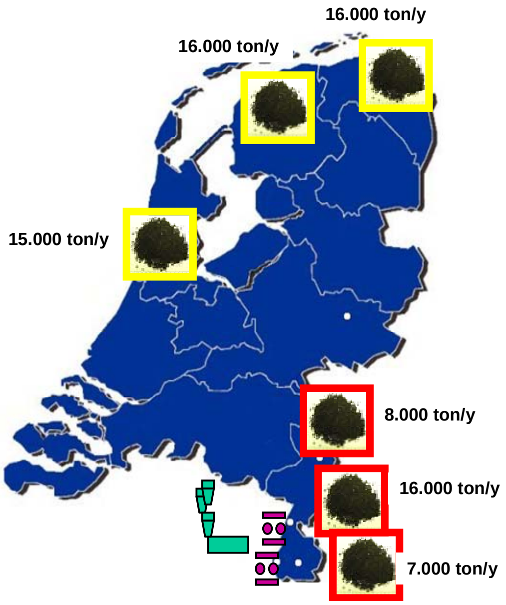

Fig. 2 Overview of sewage sludge origin for use in the ENCI Maastricht kiln. Source: Theulen (2009).

Paper sludge is sourced from the Sappi paper plant located nearby Maastricht (10 km distance). Animal meal is transported from the Rendac plant in Son (Brabant, about 100 km distance). Finally, PPDF is mainly imported from North Rhein Westphalia, Germany, about 100 km away from the Maastricht cement plant.

In the past, also shredded car tyres were used. Car tyres contain biogenic carbon (about 27 % due to the content of natural rubber) thus leading to a direct reduction of fossil fuel related CO_2. As the tyres have to be shredded to make them suitable as fuel for the ENCI Maastricht plant, the total price is getting too high. Other cement plants of HeidelbergCement (mother company ENCI) in Europe are capable of using entire tyres without shredding. In this case, use of tyres can still be affordable.

Dedicated investments for bioenergy

In order to be able to process dried sewage sludge in its kiln, the sewage sludge has to be grinded first. Therefore, ENCI Maastricht has invested into two mills to crush the sewage sludge. First trials with sewage sludge started in 1996. During these trials, sewage sludge and cokes mixture were ground in ball mill at a low O_2-content. These trials led to the construction of a “BioMill” a vertical roller mill for grinding Sewage Sludge. The first Biomill was commissioned in February 2000 as a joint venture of ENCI and Waterschapsbedrijf Limburg (WBL). Since then, sewage sludge consumption has steadily increased from less than 1 tonne per hour (tph) in 1997 to 3.5 tph using the BioMill 1, and to over 6 tph in 2004 with the commissioning of a second BioMill. In 2007, the annual sewage sludge had reached 11 tph.

The biomills are supplied by ambient air and consist of five large grinding balls which revolve around a grinding table that is less than 2 meter in diameter. Energy consumption of the mill is approximately 40 kWh/t (Bell, 2007).

The high ash content (30-40%), which causes problems for power plants, is used to replace natural raw materials for the clinker formation. The mercury and chlorine contents and the impact of the sludge’s P_2O_5 on early strength levels limits the sewage sludge utilization.

CO_2 Emissions

The production of cement is a rather energy-intensive process. The total annual CO_2-emission of the Netherlands amounts to approximately 212 million tonnes CO_2 equivalents. ENCI is responsible for roughly 0.3% of this emission.

It is important to recognize that CO_2 emissions during the clinker/cement production process are from two different sources. The first one is caused by the chemical reaction where limestone ($CaCO_3$) is transformed in the kiln under intense heat into calcium oxide (CaO) and carbon dioxide (CO_2). More than 60% of the total CO_2-emission during the production of cement is caused by this process. It is important to point out that this emission is fixed, and cannot be lowered.

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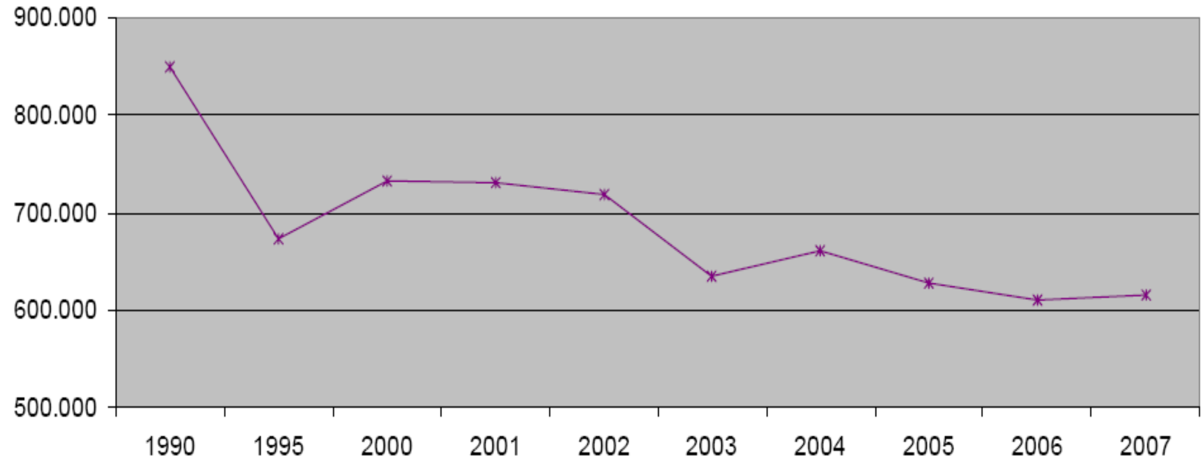

Fig. 3. Evolution of direct CO_2 emissions at the ENCI Maastricht plant in tonnes/year. (Source: Erens, 2008)

The remainder of CO_2 emissions is caused by the fuel use. By reducing the amount of fossil fuels, and replacing them by renewable biomass, the net emission of GHG can be limited.

The increasing use of biomass and the implementation of energy efficiency improvement programs have led to a substantial lowering of CO_2 emission over the past two decades. Since 1990, ENCI was able to reduce its direct CO_2 emissions per tonne cement with 28% (See also fig. 3). On a global level, ENCI Maastricht is in this respect one of the frontrunners, and belongs to the group of factories with the lowest CO_2 emissions per tonne cement worldwide (ENCI, 2008). Compared to the EU-Kyoto target of reducing GHG emission by 20% in 2020 compared to 1990, this is a major reduction.

Other emissions

Next to GHG emissions, the ENCI Maastricht plant emits also other substances, as shown in table 2.

Table 2. Emission of the ENCI plant in 2008. Source: Erens (2009).

Substance / emission	Permitted emission (mg/Nm^3)	Values in 2008
Dust	15	9.2
HCl	10	4.1
HF	1	0.06
SO_2	250	133
NOx	800	681
Hg	0.05	0.01
Cd & Tl	0.05	>0.003
Sum of all other heavy metals	0.5	0.011
CxHy	40	22
PAC	0.3	0.19
PCDD/PCDF (ng TEQ/Nm^3)	0.1	<0.01

These emissions are carefully monitored and controlled by the plant and by the authorities. The method that ENCI has developed to avoid increasing mercury emissions at rising input rates, has been adopted by many other cement plants worldwide and is accepted as a Best Available Technology (BAT) (see also Clarke, 2009, for a discussion of the mercury issue).

Moreover, it is also important to consider what alternative methods of processing biomass waste streams would be, and what emission would result form these processes.

For many waste streams used in a cement kiln, alternative processing methods would be combustion in a waste incineration plant. A LCA study carried out by TNO (de Vos, 2007) for Febelcem (2007) pointed out that for the vast majority of environmental impacts that using industrial wastes as alternative fuel in cement production is better for the environment than treating them in waste incinerators. For both treatment options the use of a ton of waste generates energy which would otherwise have been provided by other sources, including fossil fuels that contribute to global warming. These statements are supported by two facts:

- Waste and fossil fuels contain a certain amount of energy (expressed in mega joules or MJ). In the case of cement kilns, burning 1 MJ of waste is as efficient as burning 1MJ of fossil fuel. Waste incinerators however are far less energy efficient than fossil fuel power plants when it comes to producing electricity and steam, because only a small part of the energy is recovered. As a result, more fossil fuels are spared when using the waste as an alternative fuel in cement production.
- The burning of waste generally leaves behind ashes. In cement production these ashes are incorporated in the final product, in effect replacing some of the raw materials that would otherwise have been added to the product. In the case of incineration, the leftover ash is disposed of in landfills.

Summary and conclusions

In the past decade, ENCI Maastricht has seen a strong increase in biomass utilization and a corresponding impressive decline in CO_2 emissions. The plant is currently one of the biggest users of biomass waste streams for energy use in the Netherlands. A possible point of attention for further improvements may be the efficient drying and transport of sewage sludge. Combined with the additional advantages of the process (processing partially hazardous materials without any waste products), the ENCI cement plant in Maastricht is in our eyes clearly a success story of increased biomass utilization.

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Additional information

EUBIONETIII Dutch country representative
Martin Junginger (Main author of this leaflet) and Jinke van Dam
Utrecht University
Tel: +31-302537613
Email:H.M.Junginger@uu.nl

EUBIONETIII coordination
Eija Alakangas and Kati Veijonen, VTT, Finland
Email: eija.alakangas@vtt.fi

ENCI Maastricht - HeidelbergCement:
Jan Theulen
Tel: +31 6 2909 7354
jan.theulen@heidelbergcement.com

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