Influence of Waste Fuels on the Heat Consumption and on the CO_2 Emission (Situation in Germany)

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Josef Waltisberg
dipl.Ing. ETH
Eichhaldenweg 23
CH-5113 Holderbank / Switzerland
josef@waltisberg.com

Heat Consumption

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Theoretical Heat for Clinker Formation

Reaction	**Heat [MJ/kg Clinker]**
Evaporation of residual Formation of Oxides (Calcination)	+ 2.215
Formation of Intermediates «CA»; «C_2F» «ß-C_2S»	- 0.505
Sintering Reaction Formation of «C_4AF», «C_3A», «C_3S»	+0.040
Overall Reaction	**+ 1’750**

Spelling cement
C : CaO A: Al_2O_3 F: Fe_2O_3 S: SiO_2

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Heat Consumption of a modern Kiln

- A modern kiln system with precalcination, which is operated with coal, has about the following heat losses.

Reaction	**Heat Loss [MJ/kg Clinker]**
Radiation of Preheater	0.05 – 0.10
Radiation Rotary Kiln	0.20 – 0.25
Clinker Cooler - Heat of Clinker - Exhaust air	 0.05 – 0.15 0.40 – 0.50
Conditioning tower, raw mill, exhaust gas	0.60 – 0.80
TOTAL	**1.30 – 1.80**

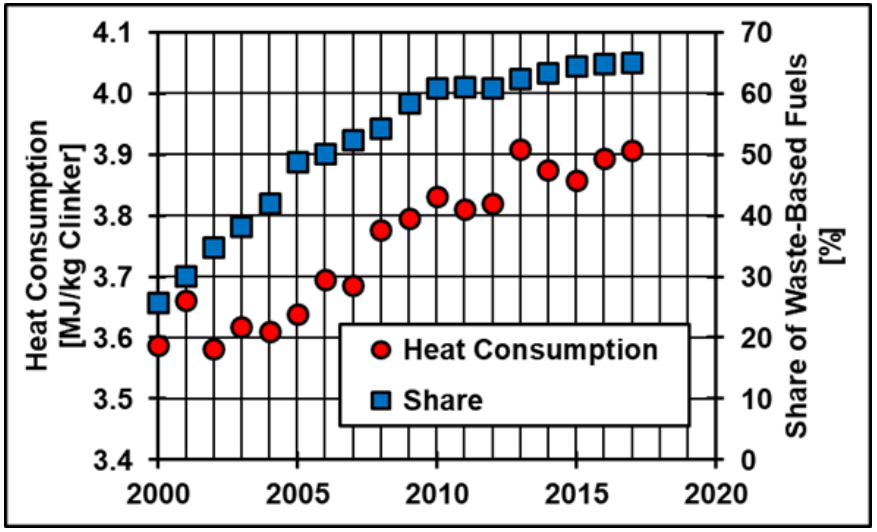
- Therefore such a kiln would have a heat consumption between **3.0 and 3.5 [MJ / kg clinker].**

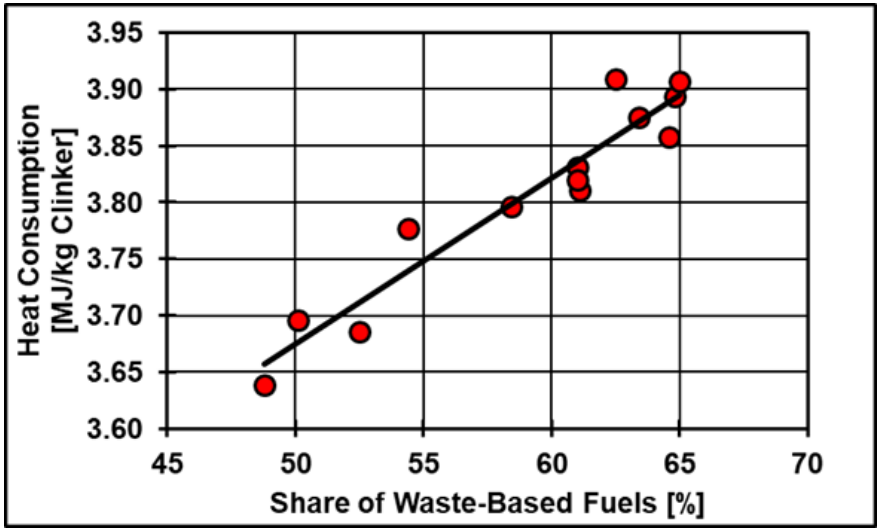
German Cement Kilns (2017)

- The average heat consumption of the German cement kilns is higher than the heat requirement of an optimal modern kiln. (2017: 3.91 [MJ/kg Clinker]
- Different German kilns do not yet have the assumed standard of a modern pre-calcined kilns. For example, they have no pre-calcination, only four heat exchanger stages, etc. In addition, there is still a factory that uses Lepol kilns with higher heat demand.

An important influence on the heat consumption is the use of waste!

Heat Consumption between 2005 and 2017





- **Increase of heat consumption increasing proportion of waste fuels.**
- Waste fuels have on average a significantly lower calorific value than fossil fuels. This is a consequence of a higher ash content, higher humidity, etc. In addition, parts of these fuels have to be blown into the kiln system with additional air.


Carbon Dioxide
CO_2

EU System and Commitment with Authorities

- **Commitment with the German Authorities:**
  The commitment of the cement industry included indirect emissions from electrical energy consumption. The CO_2 emissions from waste fuels were here not taken into account as they replace fossil fuels and thus lead to a reduction of CO_2 elsewhere.
  The raw material-related CO_2 emissions from the calcination of the limestone are not subject to the commitment of the cement industry, but are also reported as part of the monitoring.

- **European Union:**
  On 01.01.2005 a trading system for CO_2 emissions was introduced in the EU. Emissions trading covers the direct CO_2 emissions from the combustion of all fuels (excluding biogenic components) and the calcination of the limestone.

- **2 different Reporting Systems:**
  Since the emissions trading continues to refer only to the clinker burning process, but the commitment to the entire cement production, different emission levels result in the corresponding reporting systems.

Calculation of CO_2 Emissions according to the Commitment with the Authorities

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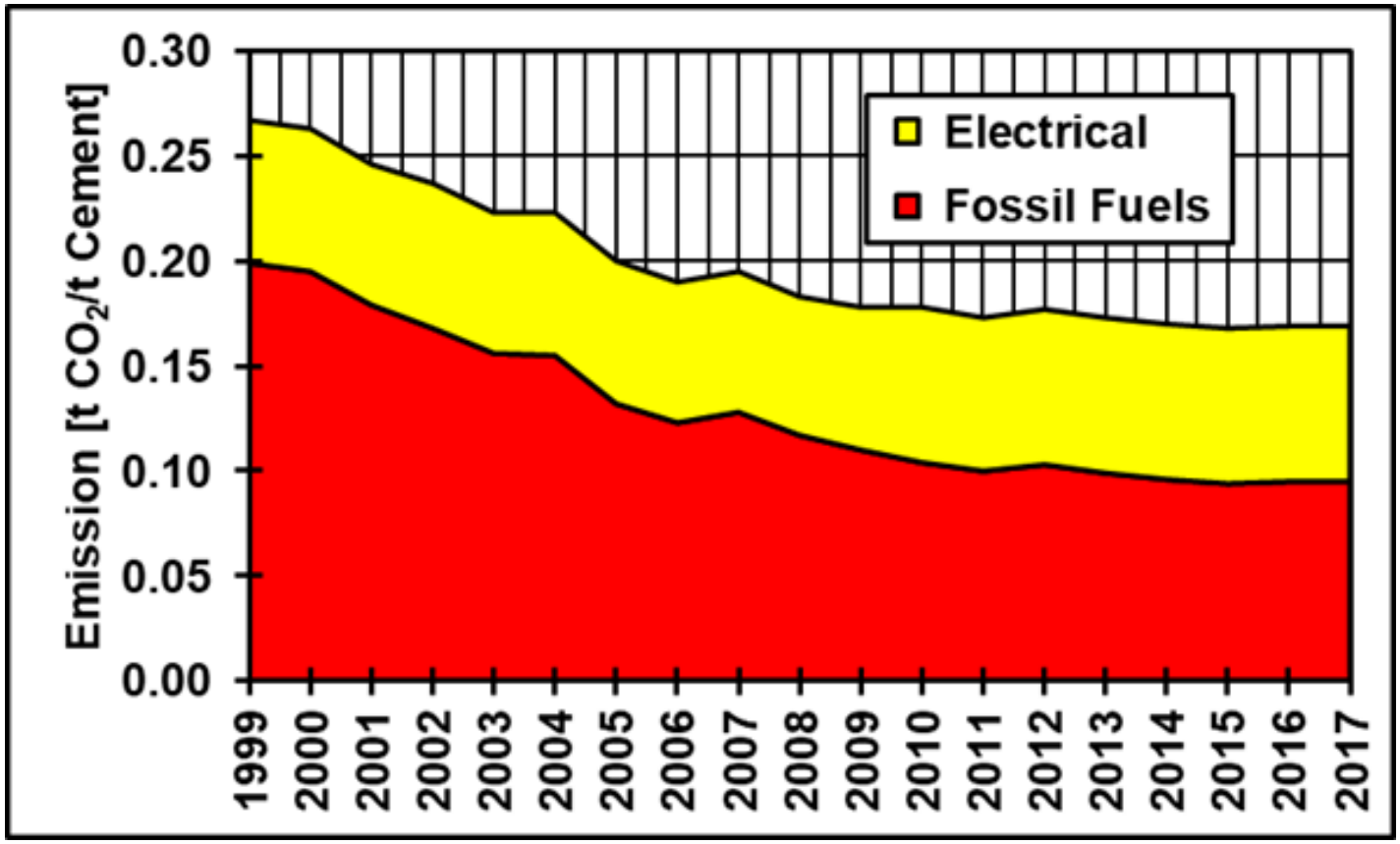
CO_2-Emission - Official Values



Remark: The emission of fuels covers only the emission of the fossil fuels

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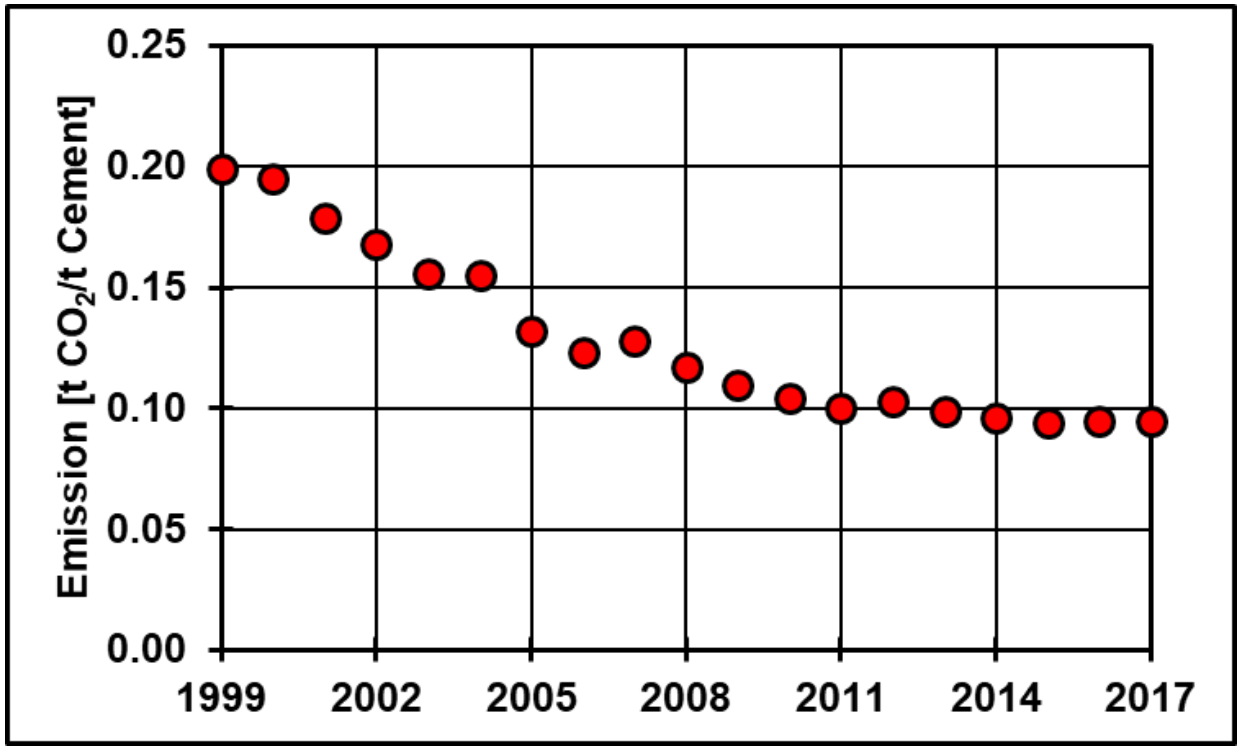
CO_2-Emission and Reduction via Fuels

Fossil fuels (mainly coal) replaced by waste fuels

Used tires, waste oil, fractions from industry/trade (Pulp/paper/cardboard, packaging, waste from textile industries, …), animal meal and fat, fractions from municipal waste, wood, solvent, sewage sludge, oil sludge, distillation residues, …



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Reduction acc. Commitment

The first commitment was completed in 1995.

→ Reduction of fuel specific energy demand from 1987 to 2005 by 20 [%]. → Fulfilled

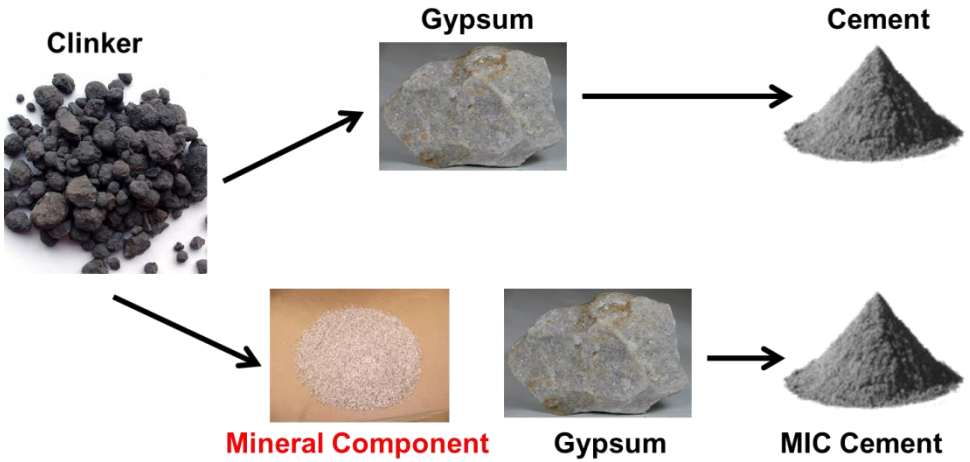
Further development in November 2000:

→ Reduction of energy-related specific CO_2 emissions (fuels and electricity) by 28% between 1990 and 2008/2012. → Fulfilled

Further commitments: unknown

→ Problem: In recent years, energy-related CO2 emissions have remained more or less constant

Reduction via Mineral Components

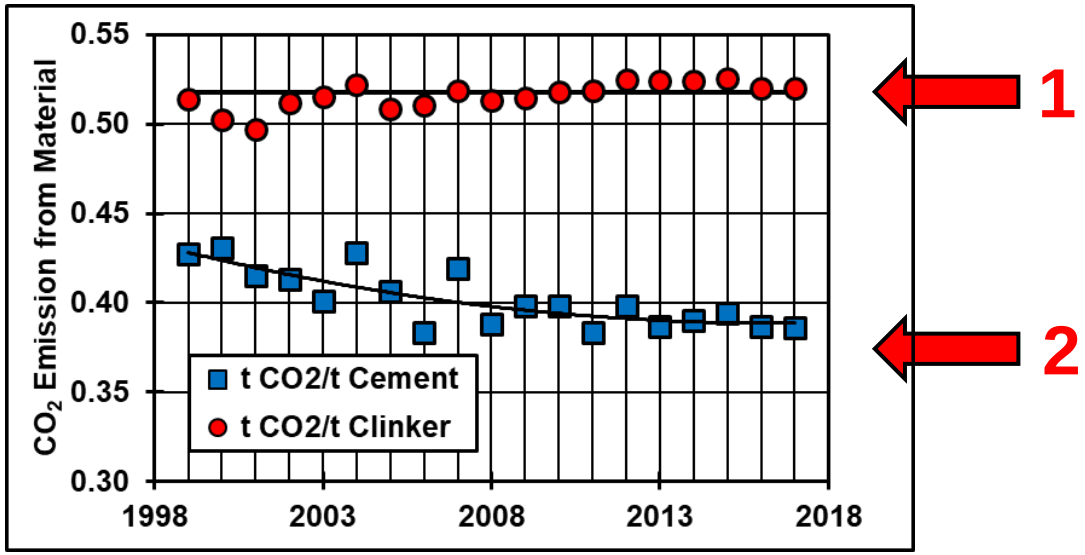


1: Clinker or Ordinary Portland Cement
(Gypsum < 5 [%])
0.52 [tCO_2/tClinker]

2: Cement with Mineral Components

Reduction of CO_2-emission per ton of cement by adding mineral components

e.g. blast furnace slag, fly ash, silica fume, natural Pozzolan, limestone, …



Influence of fuels not considered

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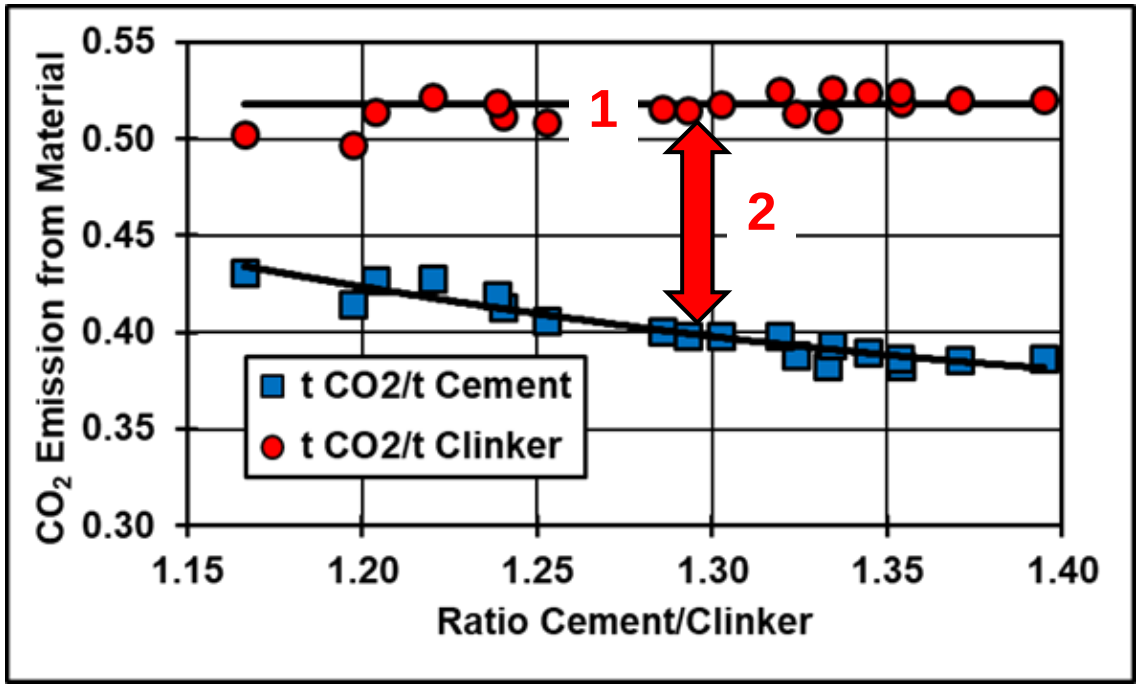
Reduction via Mineral Components

1. Emission from the Calcination of the Raw Material
   $CaCO_3$ → CaO + CO_2 → **0.52 [kg CO_2/ kg Clinker]**
2. Addition of mineral components to clinker → MIC cements (composite cements) → **Material without CO_2 emission**



Influence of fuels not considered

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Calculation of CO_2 Emissions according to the European Trading System

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Definition: Biogenic Fraction of CO_2

For the EU cement plants (including EEA), on 21 June 2012, Regulation No 601/2012 was adopted.
Article 3 of that regulation defines the terms «fossil» and «biomass» fraction

- The fossil fraction is the ratio of fossil carbon to the total carbon of a fuel or material expressed as a fraction.
- The biomass fraction (or biogenic fraction) is the ratio of the biomass-derived carbon of a fuel or material, expressed as a fraction.

73 [%] Fossil → Fossil CO_2 → Climate relevant

27 [%] Biogenic → Biogenic CO_2 → Not climate relevant
(natural rubber, fibers, …)

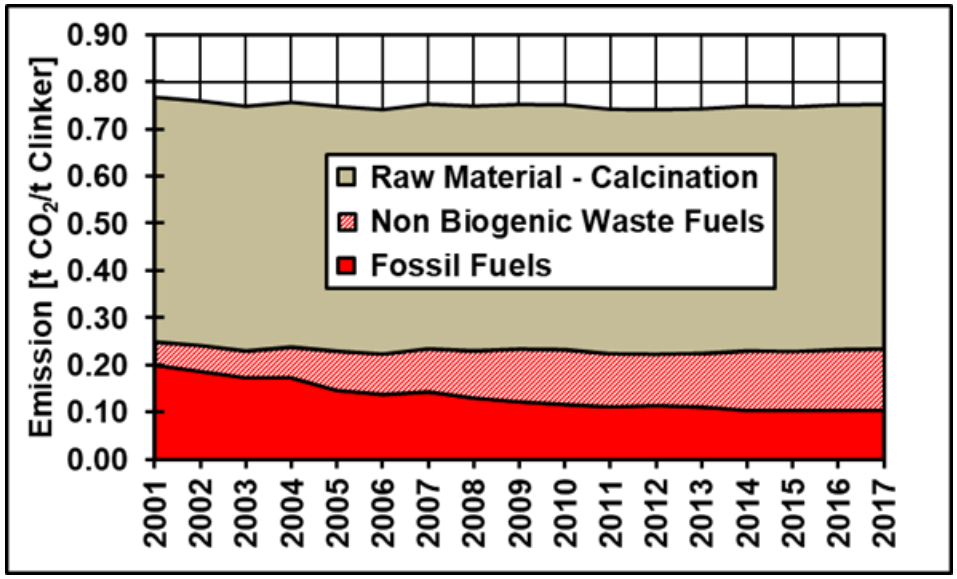
Biogenic Fraction of a Waste Fuels

	Emission Factor [kg CO_2/TJ]	Biogenic [%]
Used tires	97.3	27
Waste oil	78.7	0
Fraction from industry/trade		
- Pulp/paper/cardboard	64.9	91
- Plastic	83.5	0
- Packaging	56.9	40
- Waste from textile industries	63.3	70
- Other	68.1	0
Animal meal and fat	74.9	100
Fractions from municipal waste	59.8	55
Old wood	95.1	100
Solvent	71.1	0
Fuller's earth		
Sewage sludge	95.1	100
Miscellaneous		
- Oil sludge, distillation residues	84.0	0

Non Biogenic CO_2 Emission

The non-biogenic, climate-relevant CO_2 emission remains since 2001 approximately constant

- Clinker production did not change significantly from 2001 to 2017 (Average: 24.5 [Mio.t], Maximum: 27.0 [Mio.t]; Minimum: 23.0 [Mio.t])
- Calcination: 0.52 [t CO_2/t Clinker] (constant)
- Fossil fuels (coal, oil) partly replaced by waste fuels



- Combustion of all fuels (excluding biogenic components)
- Calcination of the limestone.

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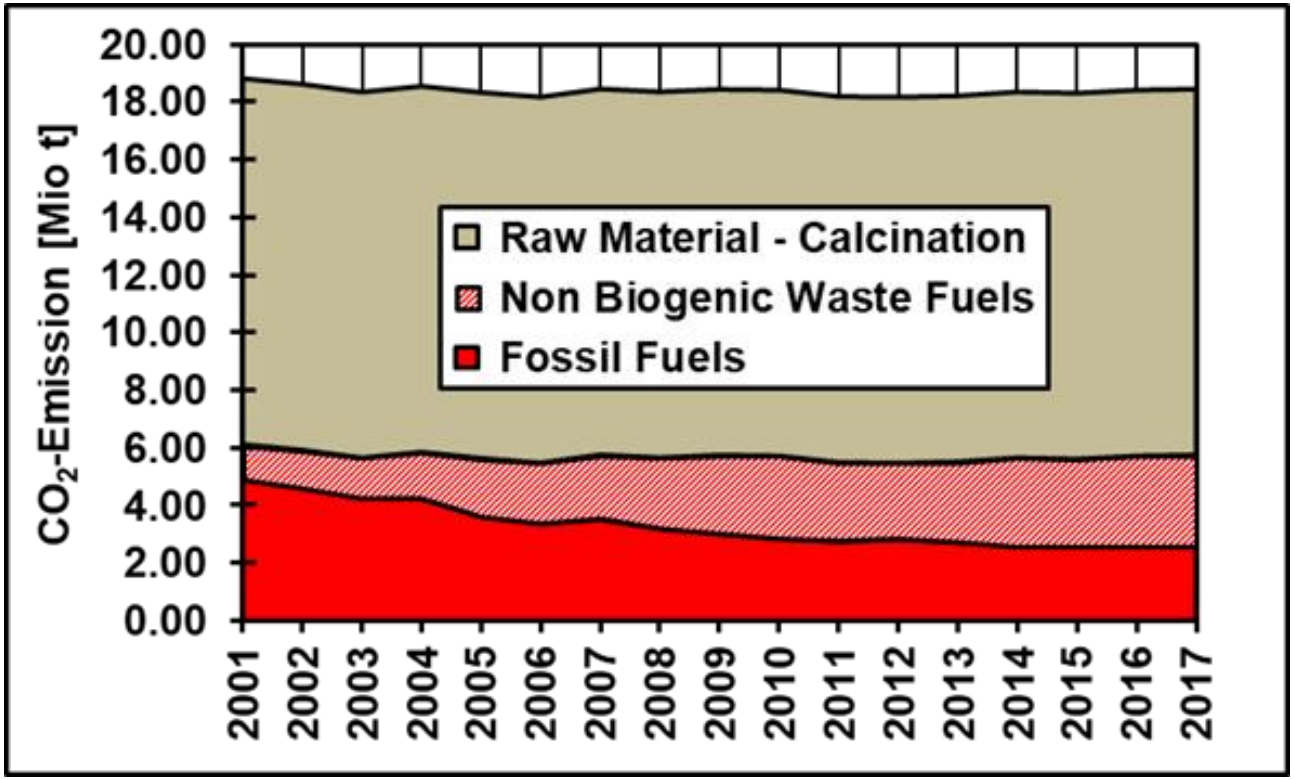
Non Biogenic CO_2 Emission – Absolute Values

Emissions trading covers the direct CO_2 emissions from the combustion of all fuels (excluding biogenic components) and the calcination of the limestone.



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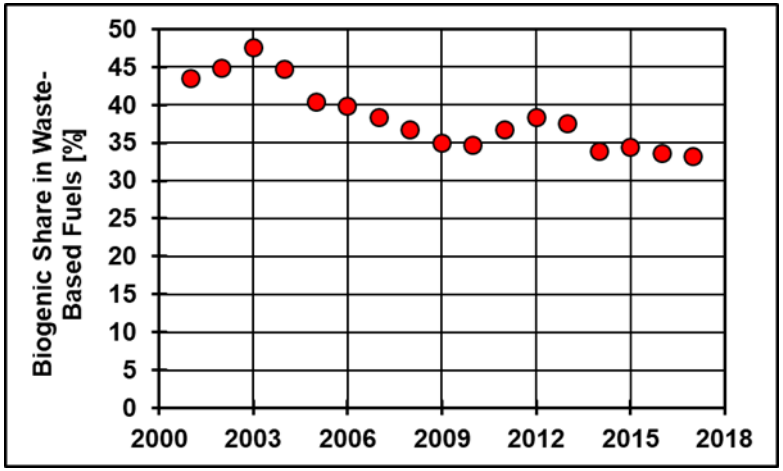
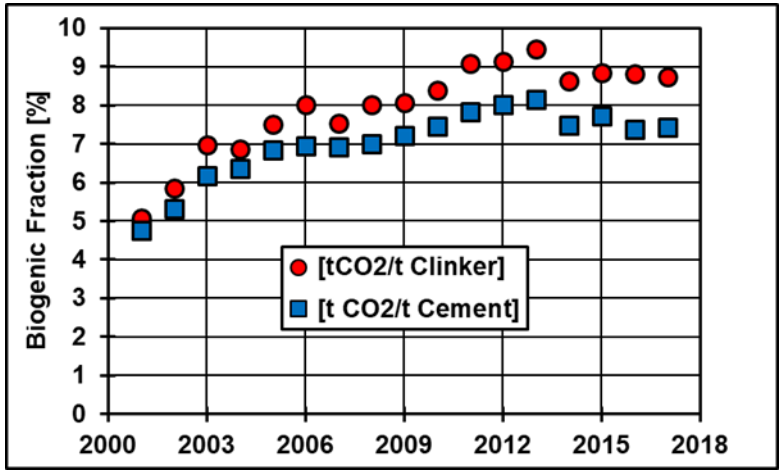
Biogenic Fractions

Biogenic fraction related to the fuel emission or to the total emission





Biogenic fraction of the emission related to clinker or to cement production

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07: REGULATION (EU) No 601/2012of 21 June 2012on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council (Text with EEA relevance)