CO_2 REDUCTION IN THE CEMENT INDUSTRY

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Introduction

The extent to which climate changes are actually attributable to anthropogenically caused greenhouse gas emissions is almost impossible to prove scientifically. Nonetheless, the political and social consensus today, and this can be seen throughout the world, is that the emissions of gases affecting the climate must be reduced world-wide. As by far the greatest part of the CO_2 emissions throughout the world is attributable to the burning of fossil fuels, a reduction in the use of fossil energy sources is necessary, which would also be consistent with the sustainable management of our planet.

What then is the role of the cement industry in this? Figure 1 shows the CO_2 emissions emitted throughout the world in 1997 (more recent data are unfortunately not available), subdivided on the basis of the different regions of the world, which were published by the OECD /1/.

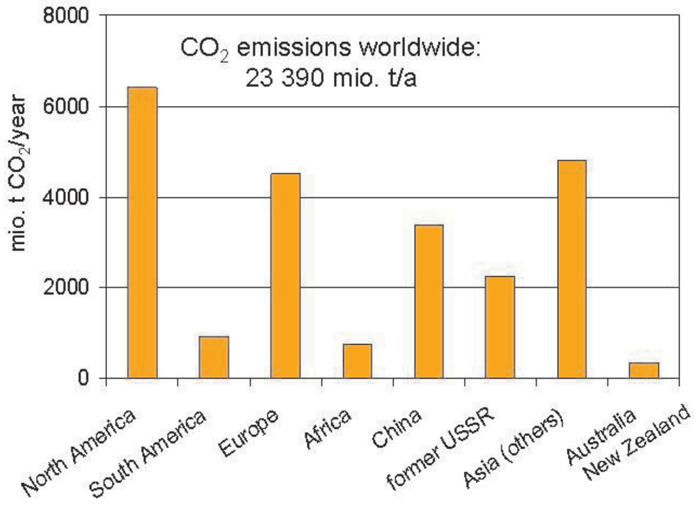

Figure 1: Wordwide CO_2 emissions devided into regions /1/

Figure 2 shows the world emissions of CO_2 subdivided on the basis of the different sectors and then compared with the total emissions. The percentage due to process-related emissions (the emitter is practically exclusively industry) is very low at approx. 3.5 %, but to a large extent results from the calcining of limestone in cement and lime production. It is interesting that throughout the world, as also in Europe, the emissions from traffic in particular are rising markedly, whereas industrial emissions (excluding energy conversion) are almost constant.

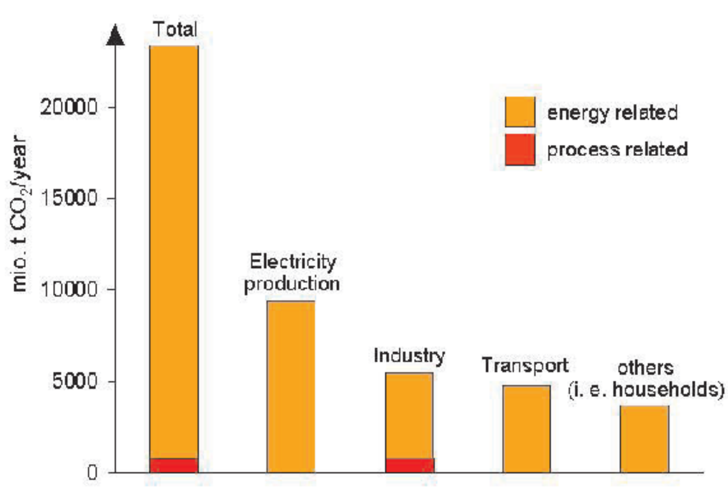

Figure 2: Wordwide CO_2 emissions devided into sectors /1/

Attempts to estimate world-wide CO_2 emissions by the cement industry have been made in many places. No concrete numbers for this are available, however. As a rule, the extrapolations are based on specific values, multiplied by the annual production. While the raw material-derived emissions from clinker production can be estimated relatively exactly (about 0.5 t CO_2/ t clinker), the fuel-derived CO_2 emissions to produce one tonne of cement are essentially determined by the specific fuel energy consumption for clinker production, the carbon content and thermal value of the fuels used and the clinker content in the cement. Assuming a fuel energy consumption of 3500 MJ/t clinker and hard coal with a thermal value of 25 MJ/kg, this corresponds to a specific CO_2 emission of just 0.35 t CO_2/t clinker. This gives a total of 0.85 t CO_2 per tonne of clinker or about 0.78 t CO_2 per tonne of Portland cement, approx. 60 % of this deriving from the calcining of the limestone.

The indirect emissions, which are associated with the consumption of electric power, are not included in this. Throughout the world, the trend nowadays is to attribute these indirect CO_2 emissions not to the consuming industry, but rather to the power generating industry. A comparison between different countries is often difficult, as the energy mix of power generation can be very different. For example, the comparison between France, where power is almost exclusively generated by atomic power stations, and Germany with its essentially fossil energy source-based power generation may be mentioned.

On the basis of the above figures and a world-wide cement production figure for 1997 of 1.54 billion tonnes quoted by the CEMBUREAU, the CO_2 emission of the cement industry world-wide can be estimated at approx. 1.2 billion tonnes per year, corresponding to approx. 5 % of the global CO_2 emissions. This corresponds to about 3 % of all green house gases emitted world-wide /2/.

Reduction of Climatically Relevant Emissions

Potentials

Among the climatically relevant gases named in the Kyoto Protocol, only carbon dioxide (CO_2) is relevant in cement production. Methane arises as a trace component in the exhaust gas from rotary kilns in the cement industry. It is formed from organic components which are contained in the raw materials. Even taking account of the CO_2 equivalence factor of methane, however, a contribution to the total emissions of greenhouse gases of only approx. 0.1 % is obtained. N_2O can be formed in combustion processes in a temperature range between 800 and 900° C, if certain reaction conditions arise. However, measurements by the Research Institute of the Cement Industry have shown emissions concentrations of 1 to 5 mg/m^3 N_2O in the exhaust gas from rotary kiln cement which is just about the detection limit of the measurement procedure. The other so-called Kyoto gases are also not relevant in cement production.

The efforts of the cement industry to reduce climatically relevant emissions are thus confined to carbon dioxide. By way of example, Figure 3 shows the specific CO_2 emissions from the German cement industry in the period from 1990 to 2001, subdivided into direct emissions (from fossil fuels and limestone calcination) and indirect emissions due to power consumption. Secondary fuels are not taken into account in this, and this will be discussed in detail later. The figure shows that the indirect emissions due to power consumption in the period in question could scarcely be reduced. On the other hand, the CO_2 emissions due to fossil fuels fell markedly, while the emissions from the calcination of limestone could only be slightly reduced in recent years.

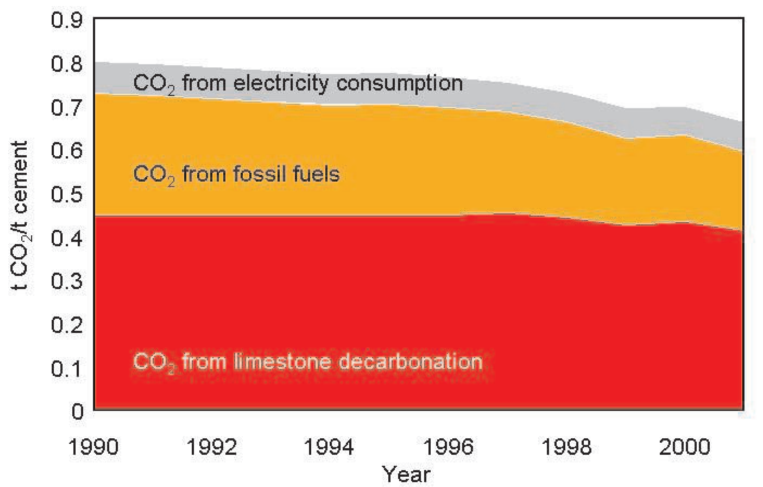

Figure 3: Specific CO_2 emissions in the German cement industry

The numbers presented are the base for the voluntary agreement of the German cement industry on climatic protection /3/. In this agreement the cement industry has committed itself to a reduction in energy-related CO_2 emissions (excluding secondary fuels) of 28 % in the period from 1990 to 2012. Including raw material-derived emissions, this corresponds to a reduction by approx. 16 %. The next figure, Figure 4 shows how this commitment is to be implemented. From the figure, it is clear that the greatest potential (24 %) lies in the substitution of fossil fuels by waste fuels. Including the optimisation of the kiln installations (7 %) and the increased use of granulated slag, limestone fines and pozzolans as main cement constituents (5 %), a total reduction of fuel-derived CO_2 emissions of 36 % should be attained. This is necessary in order to attain the promised –28 %, based on the total energy-related CO_2 emissions. Thus in the future, fuel substitution in particular will be of outstanding importance.

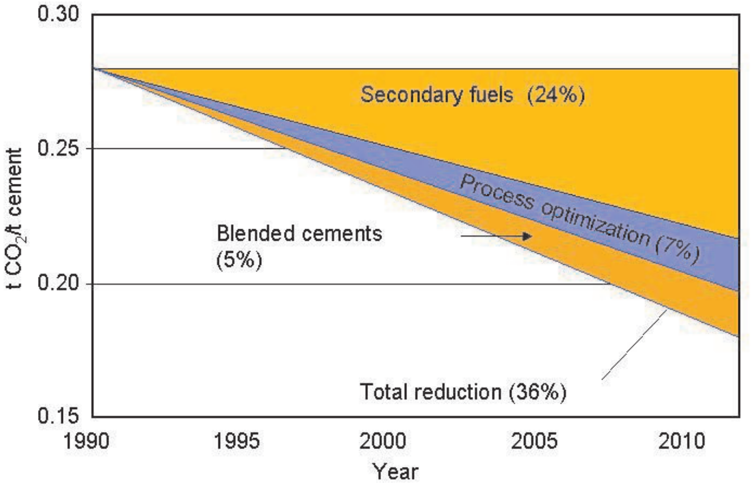

Figure 4: Reduction of fuel-related CO_2 emissions in the German cement industry (extrapolation 1990 – 2012)

Combustion Process

The potential for the reduction of fuel energy consumption by process technology optimisation or the replacement of existing installations by new ones is certainly very different across the world /4/. An evaluation for the German cement works showed that even with the replacement of all existing installations with new installations, a reduction in fuel energy consumption of only 9 % could be achieved.

Apart from process technology optimisation, a reduction in the CO_2 emissions from the combustion process is only possible by a change to lower-carbon fuels and the substitution of natural limestone by already calcined or calcium-containing industrial recycled materials as secondary raw materials. The so-called “fuel switch” is not nowadays practicable with the current cost situation in Europe. Raw material substitution certainly still offers a very small potential, because the available materials are quantity-limited. The possibilities for the use of granulated slag as a raw material component and the possible CO_2 reductions are reported in /5/.

Cements with Several Constituents

Essentially, national and European cement standards allow the partial replacement of cement clinker by other substances. Of particular significance throughout the world are granulated slag from the production of pig iron and fly ash and uncalcined limestone. In addition, regionally there is a growing number of mineral substances which are coming into use as cement constituents. In Germany, granulated slag, limestone and to a lesser extent trass and burnt oil shale are of particular economic significance. In the evaluation of the potential represented by these, the different properties and the performance of the cement types produced from them have to be taken into account.

The degree of substitution can be characterised by the clinker-cement factor, which for Portland cement is between 0.9 and 0.95. The lower the clinker-cement factor, the higher is the degree of substitution of the clinker by other main cement constituents. In Germany, the average clinker-cement factor is at present 0.78.

Figure 5 shows the effect of the substitution of clinker by granulated slag for a CEM II/B-S 32.5 with 35 % granulated slag. The calculations are based on an average fuel energy consumption of 3500 MJ/t clinker, the use of hard coal as fuel and a CO_2 emission factor for electricity generation of 0.67 t CO_2/MWh, typical for Germany. Under these conditions, the production of one tonne of Portland cement, which was produced using 5 % sulphates and 5 % minor additional constituents is associated with a total CO_2 emission (including that for the electricity) of 0.88 t CO_2/t cement. As a result of clinker substitution with 35 % granulated slag, a reduction in the specific fuel-derived CO_2 emissions of approx. 0.11 t CO_2/ t would be attained. Additional thermal energy is, however, necessary for the drying of the granulated slag (ca. 0.02 t CO_2/ t cement) and if necessary for the transport from the steel works to the cement works (not taken into account here). The effect of the electricity-related CO_2 emissions is also negligible, given the relatively high German emission factor for electricity generation. Power saving by clinker substitution and higher power consumption because of the finer grinding of the CEM-II cement balance one another out. By far the greatest saving effect is produced by the reduction of the raw material-related CO_2 emissions from the limestone, with just 0.19 t CO_2/ t cement. In total, a reduction of approx. 0.27 t CO_2/ t cement or 23 % is obtained.

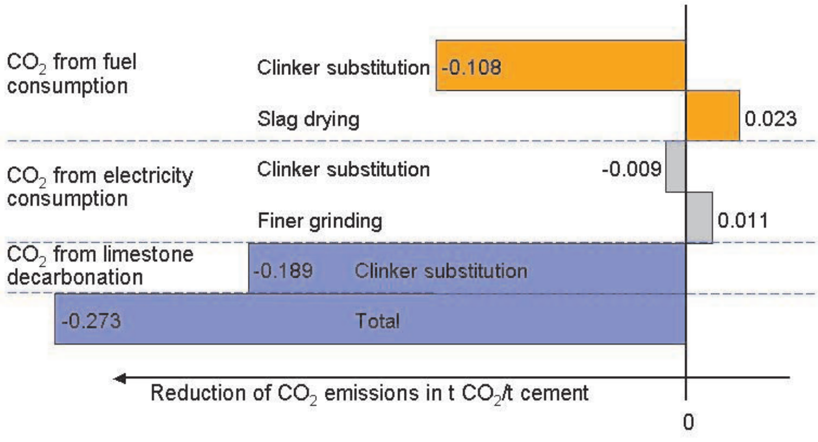

Figure 5: CO_2 reduction from the production of blended cements

Figure 6 below shows the raw material-related and energy-related CO_2 emissions in the production of composite cements as a function of the content of other main cement constituents. The calculations are based on the same boundary conditions as stated previously. The diagram applies for cements of the strength class 32.5 N/mm². It is clear that the CO_2 emission decreases approximately linearly with the content of the other main constituents. Based on the energy-related specific CO_2 emissions, a saving of only approx. 54 % can be achieved by an 80 % replacement of the clinker with granulated slag. The main reasons for this are the need to dry the granulated slag and the need for finer grinding of the CEM III cement. On the other hand, if the raw material-derived CO_2 emissions are also included, the possible saving is 72 %.

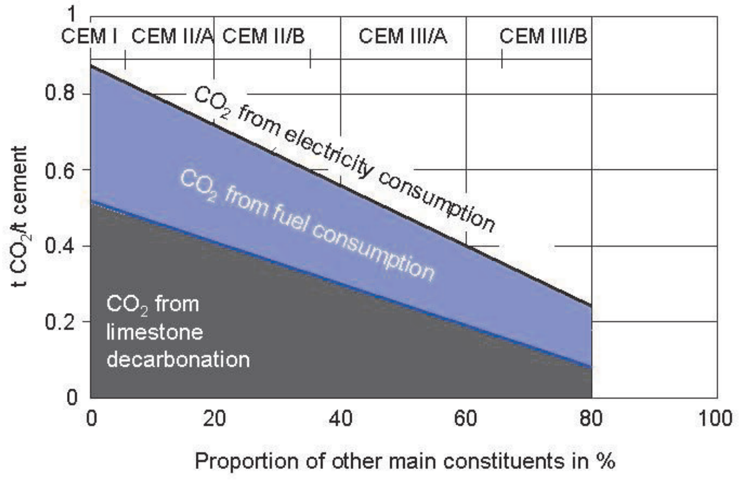

Figure 6: CO_2 emissions from the production of blended cements

In past years, the German cement industry has intensified its efforts to increase the percentage of cements in the total cement production volume, which contain several main constituents. Figure 7 shows the change in the past 10 years. From this it can clearly be seen that above all the percentage of granulated slag- and limestone containing cements has been markedly increased in previous years. In order to achieve this, corresponding activity had to be deployed in the market, so as to create acceptance of these cement types for new construction applications and to promote sales.

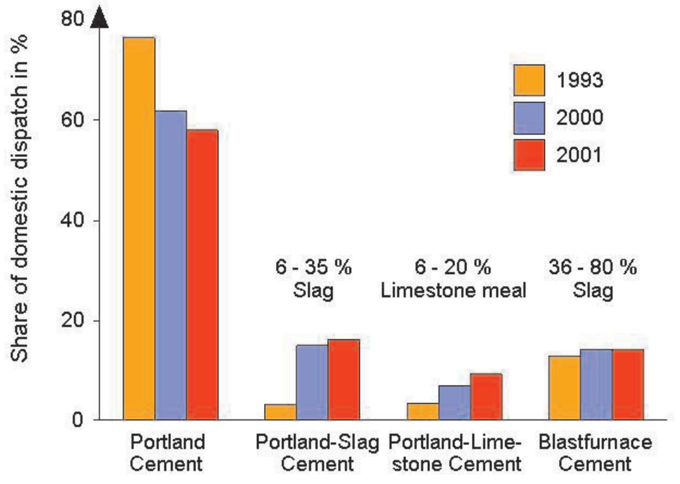

Figure 7: The cement types produced by the German cement industry

Substitution of Fossil Fuels by Waste Fuels

In the European cement industry, coal (hard coal or lignite) or coal-like fuels (e.g. petroleum coke) are the most commonly used fuels. For economic reasons, the substitution of coal by lower-carbon fuels is not a realistic option for significant saving of CO_2 emissions. In particular, natural gas, which is gaining ground in electricity generation and in many process firing applications, is not an option in Europe in view of the existing energy prices. Under these circumstances, the substitution of fossil fuels by secondary fuels prepared from wastes is gaining increasing significance.

The question as to how this type of "fuel switch" is to be assessed with regard to CO_2 relevance is to this day mainly decided from political rather than scientific viewpoints. Thus it is that in many countries, such as for example Switzerland, the use of wastes as a secondary fuel is assessed by a zero-CO_2 emission factor. This applies also to the voluntary agreement of the German cement industry for climatic protection or the voluntary agreement between the French cement industry and government dating from 1998.

The European Directive for a CO_2 emissions trading system does not cover dedicated waste incineration plants. On the other hand, CO_2 emissions from cement works and other co-incineration plants are not attributed a zero-emission factor. However, the European cement industry arguing for a equal treatment of incineration and co-incineration. This could be achieved by providing co-incineration plants with zero-cost certificates not being subject to a cap.

The cement industry makes a considerable contribution to the reduction of CO_2 emissions through the utilisation of wastes. This is due to the fact that these substances would otherwise have to be dumped or incinerated at another site, where they would release their carbon content mainly as CO_2 or as methane. As a rule, the biogenic component of the waste substances, such as for example wood wastes, sewage sludge or animal meal which is attributed a zero-CO_2-emission-factor. Scientifically considered, the determination of the "actual" degree of reduction is very complex, and only possible by means of life cycle analysis considerations. Several of these studies, some of which gained input from Research Institute of the Cement Industry, demonstrate the marked ecological benefit of the utilisation of wastes in cement works. However, the life cycle analyses also show that the actual reduction levels depend quite considerably on the comparison procedure as well as on the composition of the wastes looked at. In practice, this means that the current situation in the province or the region in which the waste is utilised must also be taken into account. Thus it is for example significant whether wastes, if they are not utilised in the cement works, would otherwise be dumped or incinerated. By way of example this will be illustrated for the case of plastic fractions from packaging materials /6/.

In Germany, packaging materials are mainly collected separately, processed and passed into various recovery paths. The packaging materials are made up of varying proportions of plastic sheets and bottles, mixed plastics and a sorting residue. In the recovery scenario shown in Figure 8 below, both plastic bottles and plastic sheets and also mixed plastics are utilised in the cement works. The sorting residues are dumped (scenario 1).

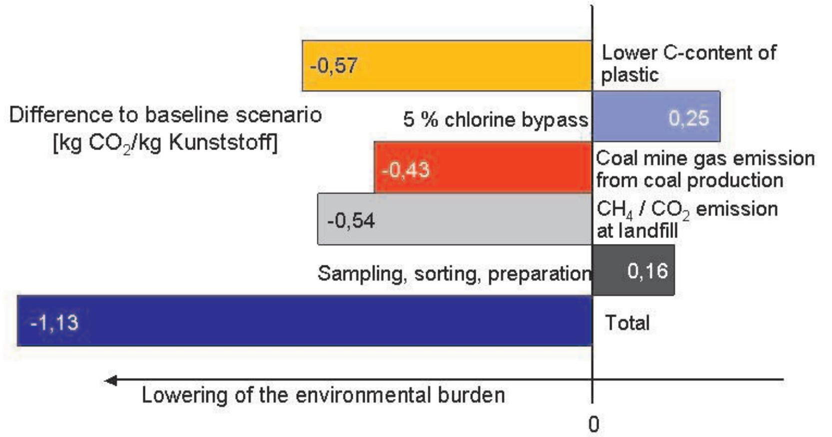

Figure 8: Reduction of greenhouse gas emissions by the use of plastic waste in a cement plant

The dumping of the whole of the wastes is taken as the reference scenario. The figure presented above shows that on recovery in the cement works, the lower carbon content of the plastics compared to coal, avoidance of mining gas emissions during coal production and the avoidance of methane and CO_2 release from the dump have a favourable effect on the CO_2 emissions. On the other hand, the chlorine input into the kiln installation via the plastics wastes is higher than via the replaced coal. Hence it was assumed that the kiln installation must be operated with a 5 % gas-bypass. In addition, the energy expenditure necessary for the collection, sorting and preparation of the wastes results in a further emission contribution. In total, a reduction of 1.13 kg CO_2/kg plastic is found for this scenario.

The next figure, Figure 9, shows the magnitude of the CO_2 reduction relative to the actual CO_2 emissions of the cement works for the case where hard coal or lignite are substituted there. In addition, the manner in which various recovery scenarios affect the total CO_2 emissions was investigated. For this, one further scenario compared to that described above was considered: in scenario 2, the whole of the processed packaging plastics are used in the cement works. Moreover, the substitution of lignite and hard coal are considered. As a further variation, the utilisation of the plastics wastes in the cement works are shown in comparison to their incineration together with the residual waste in a dedicated incineration plant. For this, an incineration plant typical for Germany with decoupling of heat to a remote heating system was assumed.

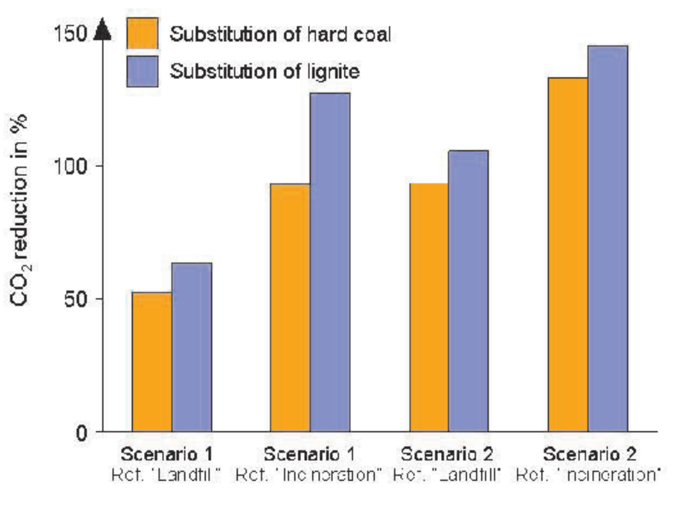

Figure 9: CO_2 reduction by the use of plastic waste in a cement plant

The saving of 1.13 kg CO_2/ kg plastic achieved in scenario 1 results in a percentage reduction of 52.5 % overall. The diagram shows that scenario 2, i.e. the complete utilisation of the wastes in the cement works, leads to almost a 100 % CO_2 reduction, when hard coal is replaced. If lignite is replaced in the cement works, this reduction rate even comes to more than 105 %.

Markedly more than 100 % saving is achieved if incineration in a dedicated incineration plant is assumed as the reference scenario.

This means that, depending on the composition of the wastes and on the emissions avoided, the reduction rates can be more or less than 100 %. Particularly when CH_4 or N_2O emissions are avoided, markedly more than 100 % can be reached because of the high CO_2 equivalence factor of these gases. This also applies for the case when carbon-rich fuels, such as for example petroleum coke, are substituted. Since in practice it is not possible to carry out an appropriate environmental life cycle analysis for each individual waste and each cement works which uses secondary fuels, a provisional reduction rate of 100 % has been agreed upon in various European countries.

Summary and Outlook

The cement industry is aware of its responsibility for climatic protection in terms of sustainable cement production. This is shown by a range of voluntary measures that have been taken in previous years at the company or sector level. Since cement production is an energy-intensive, high temperature process, the process technology options for CO_2 reduction are limited. Hence in the future the focus of efforts will in industrialised countries lie mainly in the further development of composite cements, i.e. in the reduction of the clinker content in the cement, and in the further substitution of fossil fuels by waste fuels. Efforts are therefore being made on the one hand to increase market acceptance of these cement types with several main constituents and on the other hand to increase the political acceptance of the substitution of fossil fuels by secondary fuels. Only if these efforts are successful can the objective of sustainable cement production be achieved.

References

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