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SUMMARY

The use of waste materials as alternative fuels in cement production represents an important contribution to environmental protection, especially for developing countries. MVW Lechtenberg has developed a 3-stage plan by which a cement works that plans to use alternative fuels, i.e. refuse derived fuels (RDF), produced from solid domestic waste or biomass, can be advised with the necessary level of certainty. The first phase, which provides for the verification and classification of the available quantities of waste materials and investigation of the relevant legal requirements, is followed by the second phase, which deals with the selection of suitable equipment and development of the project. The specific support during the implementation of the project, which also includes carrying out monitoring and quality management measures, then takes place in the third phase. The alternative fuels from biomass that are used in developing countries normally range from rice husks to wood chips. Apart from the use of old tyres the fuels obtained from solid domestic waste materials are usually composed of paper and plastic waste. Dried and processed domestic waste can reach a net calorific value of 4500 kcal/kg. Detailed examination of the costs, which is based on the prices prevailing in February 2009, confirms that even under the present conditions of financial crisis it pays dividends to replace coal by, for example, rice husks. It is not the clinker output that is generally the decisive criterion for a cement works but the level of the production costs, so it continues to be worthwhile to use alternative fuels in cement production. Valuable advice is given on the handling of alternative fuels, in particular also the cost the equipment, which can be many times higher when investing in state of the art technology. Finally, a long section deals with the possible effects of alternative fuels on the stability of the production process, the clinker output and the clinker quality.

ZUSAMMENFASSUNG

Die Verwertung von Abfallstoffen als alternative Brennstoffe bei der Zementherstellung stellt besonders für Entwicklungsländer einen wichtigen Beitrag zum Umweltschutz dar. MVW Lechtenberg hat einen Dreistufenplan entwickelt, nach dem ein Zementwerk mit der notwendigen Sicherheit beraten werden kann, das den Einsatz von alternativen Brennstoffen, d.h. von so genannten Refuse Derived Fuels (RDF), hergestellt aus festen Haushaltsabfällen oder Biomassen, plant. Nach der ersten Phase, die die Verifikation und Klassifizierung der vorhandenen Abfallstoffe in ihren verfügbaren Mengen bis hin zu den jeweiligen gesetzlichen Erfordernissen untersucht, folgt die zweite Phase, die sich schon mit der Auswahl des geeigneten Equipments und der Projektentwicklung befasst, während in der dritten Phase dann die konkrete Unterstützung bei der Realisierung des Projekts erfolgt, die auch die Durchführung von Maßnahmen zu Überwachung und Qualitätsmanagement einschließt. Die zum Einsatz gelangenden alternativen Brennstoffe aus Biomassen reichen dabei in den Entwicklungsländern in der Regel von Reisschalen bis hin zu Holzchips. Neben der Verwertung von Altreifen setzen sich die aus festen Haushaltsabfällen gewonnenen Brennstoffe gewöhnlich aus Papier- und Plastikabfällen zusammen. Dabei kann ein aufbereiteter und trockener Haushaltsabfall immerhin einen unteren Heizwert von 4#500 kcal/kg erreichen. Detaillierte Kostenbetrachtungen, die auf den aktuellen Preisen von Februar 2009 basieren, belegen, dass sich auch unter den gegenwärtigen Bedingungen der Finanzkrise die Substitution von Kohle durch z.B. Reisschalen bezahlt macht. Da nicht der Klinkerausstoß, sondern die Höhe der Produktionskosten im Allgemeinen das entscheidende Kriterium für ein Zementwerk darstellt, ist die Verwertung von alternativen Brennstoffen bei der Zementherstellung nach wie vor lohnend. Schließlich werden auch wertvolle Hinweise zum Handling von alternativen Brennstoffen gegeben, insbesondere auch zu den Kosten des Equipments, die bei der Investition in eine „state of the art" Technologie um ein Mehrfaches höher liegen können. Schließlich beschäftigt sich ein langer Abschnitt mit den möglichen Einflüssen von alternativen Brennstoffen auf die Stabilität des Produktionsprozesses, auf Klinkerdurchsatz und Klinkerqualität.

(English text supplied by the author)

The use of alternative fuels in the cement industries of developing countries - an opportunity to reduce production costs?

Nutzung von Alternativbrennstoffen in der Zementindustrie von Entwicklungsländern – eine Möglichkeit zur Kostenreduzierung?

1 Introduction

The excellent market situation in the cement industry in previous years has meant that most companies have focused on increasing production and market shares while at the same time taking over competitors and developing greater capacity. Many of the market participants have grown without any optimization of the organization or production. The cement industry worldwide is now suffering from the financial crisis so that in the current situation it is very important to achieve the lowest possible clinker production costs. Multinational groups like Holcim, HeidelbergCement and Lafarge have had long-term experience with the use of alternative fuels and raw materials and have developed their internal organizations to focus on these materials. However, even these huge organizations are now being overwhelmed by the changed market conditions.

2 The use of alternative fuels

It is well known that alternative fuels can have a significant cost-reduction value if the fossil fuel prices are high. ◗ Tables 1 and 2 show the cost reduction that is achieved by replacing 25 % of the fuel with rice husks under the market conditions in September 2008 and in the current situation in February 2009 with lower fossil fuel prices.

The above shown calculation was made for a "standard" 1.0 million tonnes clinker production plant equipped with a calciner, calculated without thermal losses and with a rice husk purchase price of US$ 20 at the flame. Values for CO_2-emission reduction were not included in the calculation.

Even with the lower fossil fuel prices the use of alternative fuels can significantly reduce the costs. Most developing countries have now established a collection and disposal infrastructure for waste materials, such as agricultural or municipal solid wastes. A system for collecting, and possibly processing, the materials therefore has to be developed by the cement plants or contractors. Collection and use of biomass wastes, such as rice husks or coconut shells, is easier to implement as no processing is needed and it is possible to use the available cement transport trucks. ◗ Table 3 lists the calorific values of biomass wastes.

Table 1: Kiln production figures

Designation	Unit	Value
Clinker throughput	t/d	3300
Spec. heat consumption	kcal/kg	850
Fuel distribution		
Calciner	%	59
Kiln	%	41
Net calorific value		
Coal	kcal/kg	6000
Rice husk	kcal/kg	3500
Fuel costs		
Coal	US$/t	65
Rice husk	US$/t	20

The use of alternative fuels is well known in the cement industry, but even in the current market situation it is not the core business of a cement plant and often fails because of the following constrains:

- lack of experience by employees
- authorization problems
- no human resources for development
- entrenched opinions (We have always used pulverized coal and now we are being asked to use waste materials?)
- arguments that are being advanced, such as the opinion that only clean wastes should be used in Europe
- communication failure with communities
- incorrect cost figures and the assumption that storage, metering and feeding to "German Standards" involves high investment costs

3 MVW Lechtenberg's 3-stage plan

MVW Lechtenberg has developed a 3-stage plan that allows the cement plants to have an adequate safety margin when starting to use alternative fuels. The company works with the following three phases when implementing turnkey projects:

Table 2: Rice husk substitution

Substitution rate [%]	Burner	Total line	Using RDF			Using coal	
			[t/h]	[t/a]	[US$/t]	[t/a]	[US$/t]
Calciner	36	21.2	7.1	52769	1055385	30782	2000835
Kiln burner	10	4.1	1.4	10186	203723	5942	386225
All burners*)		25.3	8.5	62955	1259108	36724	2387060

*) Savings from substitution with RDF (refuse-derived fuel): 1127952 US$/a

Table 3: Calorific values of some alternative fuels and biomasses

Alternative fuel/biomass	Approx. calorific value [kcal/kg]	
	Natural	Dry
Wood	1500	3500
Cattle dung	1000	3700
Bagasse	2200	4400
Wheat and rice straw	2400	2500
Cane trash, rice husk, leaves and vegetable wastes	3000	3000
Coconut husks, dry grass and crop residues	3500	3500
Groundnut shells	4000	4000
Coffee and oil palm husks	4200	4200
Cotton husks	4400	4400
Refused Derived Fuels (RDF) from municipal solid wastes	4000	4500

Figure 1: Public presentation on the use of alternative fuels by MVW Lechtenberg to the authorities in the Philippines

Phase 1

- Verification and classification of existing types of waste available at source
- Suitability of available wastes as alternative fuels, and recommended feed points
- Quality requirements of alternative fuels
- Impact of the use of alternative fuels on the clinker chemistry and production process
- Impact on air quality (emissions)
- Thermal energy substitution and economic benefits
- Possible greenhouse gas emission savings (CO_2 calculation)
- Legal requirements
- Project capital investment cost evaluation and return on investment

Communication with the local society and with the authorities is very important at this stage. The authorities impose many constraints on the use of alternative fuels, especially in developing countries, as it is considered as "waste incineration". There are often local arguments, e.g. in the emirates, against the use of alternative fuels by foreign multinational cement groups. Communication, explanation and lobbying on behalf of alternative fuels is therefore one of MVW Lechtenberg's important activities (◗ Fig. 1).

Figure 2: Coconut shells, tyres, wood chips and rice husks are used as alternative fuels in cement works

This article only focuses on the development of Phase I, but a short overview is given of the subsequent working stages.

Phase II

- MVW assists the cement plant in choosing, obtaining and checking the equipment
- Provides support in negotiation contracts with waste suppliers
- Authorization issues
- Development of "turnkey-projects", including design engineering and drawings for imported and locally manufactured equipment

Phase III

- Support in the implementation of the alternative fuels project, including ongoing monitoring and quality management

The procedure for the use of alternative fuels and the development of such a project is always standardized in spite of local or technical differences. Each kiln responds differently to the substitution of alternative fuels, and there are always different types of waste available in the vicinity of cement plants (◗ Fig. 2). The alternative fuels used by most cement plants are governed by chance, based on the waste materials that are available.

The basic principles for the use of alternative fuels are as follows:

- The chemical quality of the fuel has to meet regulatory standards to ensure environmental protection.
- The calorific value of the fuel must be stable enough to allow control of the supply of energy to the kiln for the production of a homogeneous clinker.
- The physical form of the fuel has to permit easy handling of the material for transportation and a controlled flow into the kiln.
- The fuels must not introduce any chemical compounds into the clinker production process that might be deleterious to the stability of the process or the performance of the product.

Depending on their origins, agriculture wastes, such as rice husks (◗ Table 4), coconut shells or bagasse, are associated with considerable variation in moisture content, silicates and other constituents. Detailed analyses are therefore needed.

Detailed studies of the effects of co-firing these fuels then have to be carried out on the basis of these analyses. MVW Lechtenberg has developed a tool to calculate these effects on a theo-

Table 4: Typical chemical analysis of rice husks

Chemical composition	Unit	Value
Calorific value	kcal/kg	3371.30
H_2O	%	10.00
Volatiles	%	61.40
C	%	39.00
H		2.97
S		0.07
N		0.49
Ash	%	> 25.00
SiO_2		89.12
Ai_2O_3		3.08
Fe_2O_3		0.80
CaO		2.50
MgO		0.74

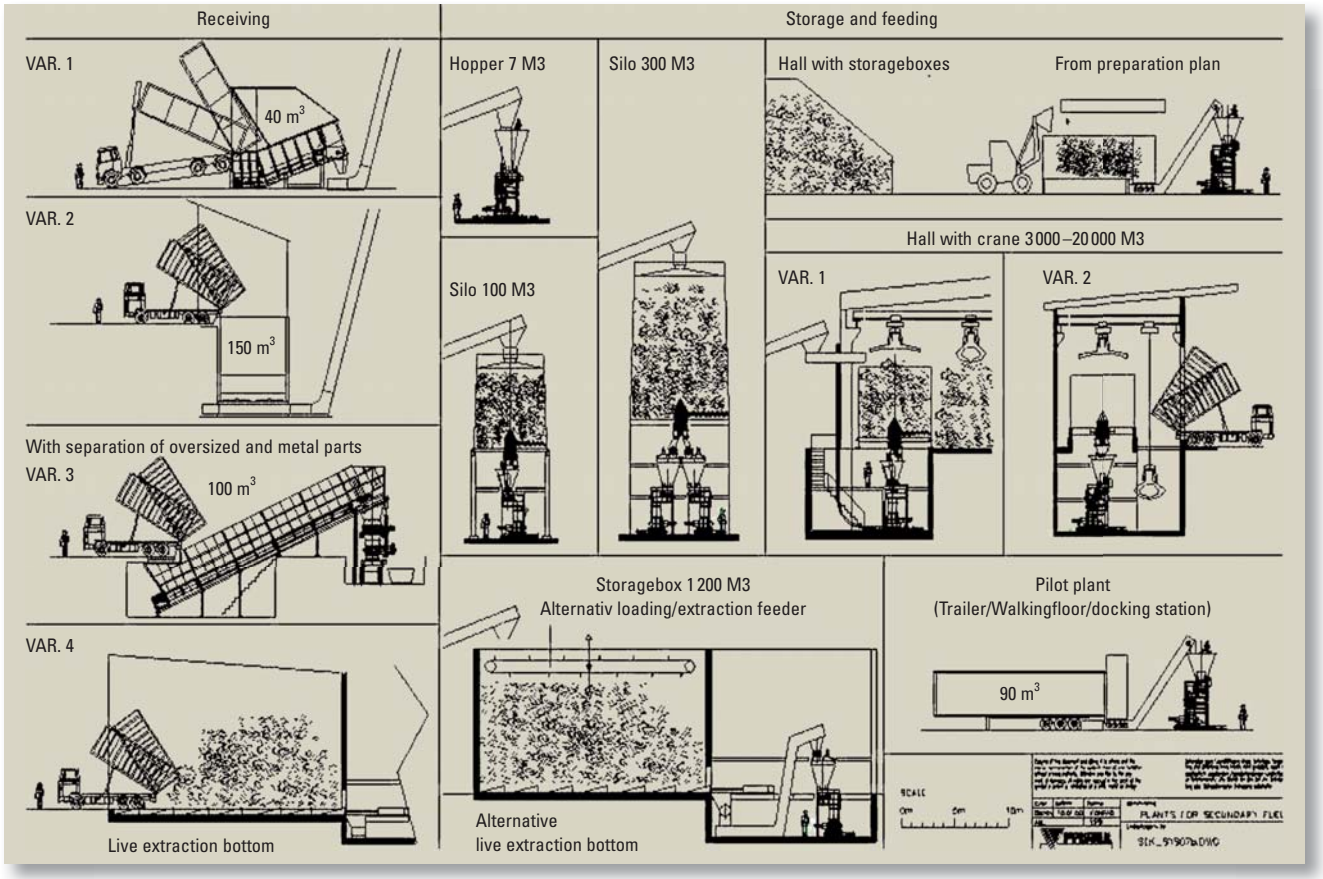

Figure 3: Examples of different systems for feeding alternative fuels

retical basis, which will give the cement plant a detailed summary of such effects and guidelines and recommendations for fuel substitution.

4 Carbon Credits

The Kyoto Protocol to the United Nations Framework Convention on Climate Change has strengthened the international response to climate change. The developed countries have committed themselves to reducing their collective emissions of six key greenhouse gases by at least 5 %.

Under the Kyoto Protocol, the EU committed itself to reducing its greenhouse gases emissions by 8 % during the first commitment period from 2008 to 2012. This target is shared between the Member States under a legally binding burden-sharing agreement, which sets individual emissions targets for each Member State. Under the EU emissions trading scheme, which is mandatory, the EU Member States will cap direct CO2 emissions from energy-intensive companies (steel, power plants, oil refineries, paper mills, glass and cement installations) by issuing allowances as to how much CO2 these companies are allowed to emit. Reductions below the limits will be tradable. Companies that achieve reductions can sell them to companies that have problems staying within their limits or for which emission reduction measures are too expensive in comparison with the cost of the allowances. Any company may also increase its emissions above the level of allowances that it has been issued by acquiring additional allowances from the market.

On 23rd July 2003 the Commission adopted a proposal that links credits from Joint Implementation (JI) and Clean Development Mechanism (CDM) projects with the emissions trading system. Indeed, under the Kyoto Protocol, (JI) and (CDM) will allow industrialised countries to achieve part of their emission reduction commitments by conducting emission-reducing projects abroad and counting the reductions achieved toward their own commitments. Under this proposal, companies and governments will be allowed to convert credits from JI and CDM projects for use towards meeting their commitments. JI and CDM allow for the creation, acquisition and transfer of "Emission Reduction Units" (ERUs) and "Certified Emissions Reductions" (CERs) respectively.

Projects for cement plants that are intending to use alternative fuels, such as biomass or refuse derived fuels with a certain biogenic (renewable) content, can obtain "Certified Emission Reductions" (CER`s) in order to finance their alternative fuel projects because the fossil CO_2 emissions are being reduced.

There are two ways of saving "Green House Gas" emissions:

- reduction of landfill gas (methane) if RDF from municipal solid wastes is used
- reduction of fossil fuel emissions in the kiln.

MVW Lechtenberg calculates the possible CO_2 emission savings and develops the procedures to needed to obtain the Certified Emission Reductions (CER`s).

5 Storage, metering and feeding systems

There is a huge variety of technical equipment for storage, metering and feeding of alternative fuels available on the market. As there is no "standard" utilization it is advisable to start with simple technical equipment in order to gather some experience before investing in state of the art tech-

Figure 4: Screening municipal solid wastes

nology. These days, lowering the capital cost is a major key to successful alternative fuel implementation.

As an example, a state of the art storage, metering and feeding system for handling 10 tonnes rice husks is available on the market for a capital cost of € 5 Million, but this can also be achieved for less then € 500 000.

Such a system consists of a receiving area from where a hopper is fed by a wheel loader, volumetric or gravimetric metering, and pneumatic transport. ❱ Fig. 3 provides examples of different feed systems. The flexibility of the system is very important for such capital investments. This flexibility is needed to achieve independence in the purchase of various alternative fuels. If, for example, the rice farmers demand excessively high prices for the rice husks, then the cement plant can switch to olive kernels or other available materials. This is also important for using Refuse Derived Fuels (RDF), consisting of paper, plastics fractions, etc. The use of RDF made from industrial wastes or municipal solid wastes is common practice in the European and some Asian cement plants where a waste collection and disposal infrastructure exists.

6 Economics in the clinker production process

Depending on the local energy and labour cost, the total production costs for RDF are 25 to 30 €/t. In most developing countries the use of alternative fuels made from industrial wastes or municipal solid wastes is therefore not cost-effective in view of the current low cost of fossil fuel.

Coal with a calorific value of 6 000 kcal/kg and prices above 55 €/t marks the baseline for cost-effective use of RDF for a cement plant. MVW Lechtenberg has developed a calculation tool for assessing different waste types, separation values (❱ Fig. 4), transport distances, gate fees (or input costs) and production costs on a local basis.

Wear and spare part costs, based on working experience with different waste materials and different equipment suppliers, are integrated into the modular system. Typical production costs (maintenance, energy, wearing parts, spare parts) for RDF from mixed industrial wastes start at 15 €/t plus labour and depreciation costs.

Due to the current situation of low fossil fuel prices the production of RDF made from municipal solid waste is not feasible. But it is predicted that fossil fuel prices will increase soon again after recovery from the financial crisis.

MVW Lechtenberg has developed a "low-cost start-up package" for cement plants that are intending to use alternative fuels made from municipal solid wastes and other available biomass wastes. This start-up package consists of equipment from well known European equipment suppliers for the production, metering and feeding of such fuels to the kiln and includes the necessary feasibility studies, environmental impact assessment and training for the start-up period.

The use of RDF has a direct impact on the clinker production process and production capacity. The presence of chlorine is the most critical factor in the thermal process. Chlorine may react with calcium. In that case it will end up as $CaCl_2$ in the clinker. But most of it will react with sodium or potassium to form NaCl or KCl. These salts sublimate in the calcining zone and recrystallize in the decarbonization zone, which results in an internal chloride cycle. As the chloride concentration increases this may lead to blockages in the cyclone pipes, resulting in kiln shutdowns. To prevent this the chlorine content of the substitute fuel must be monitored carefully. If the substitute fuel has a high chlorine content the input of that fuel must be reduced or else a special bypass will be needed to clean the NaCl and KCl from the gases.

At the same time the presence of alkalis, and also of sulphur, has to be monitored carefully. Any imbalance in the system will cause the formation of rings in the kiln and build-up at the kiln inlet and in the lower stages of the cyclone preheater.

Any moisture introduced with the fuels will reduce the available gas volume. More oxygen will be needed for complete incineration of larger pieces of RDF, which will mean the need for increased fan capacities. As a result, the loss of thermal efficiency will be at least 10 % of the level of RDF introduced.

A loss of clinker production may occur, depending on the following circumstances:

- humidity and/or quality of RDF
- quantity of RDF introduced
- kiln performance.

Experience has shown that a substitution of up to 20 % (in calorific value) can be made without any loss of clinker production. Higher substitution rates can be achieved with certain modifications.

As stated before, the production costs per tonne of clinker are currently more important than the production rate. The German cement Industry with an average alternative fuel substitution rate of almost 60 % in 2008 has shown that the production losses are only 5 to 10 % of the designed kiln capacity. These high substitution rates of alternative fuels mean that the clinker production costs can be reduced by up to 10 €/t of clinker.

7 Final remarks

These figures can be optimized through possible "gate fees" for hazardous wastes. Developing countries, in particular, do not normally have a system for disposal of hazardous wastes such as solvents, oils, refinery sludge, pesticides and others, so the cement industry can take a significant role in the environmental friendly disposal and use of such wastes. ❰