Use of Solid Recovered Fuels in the Cement Industry

Roland Pomberger and Renato Sarc

This contribution describes the legal, material, plant and economic developments and properties as well as the quality and quality assurance of Solid Recovered Fuels (SRF) that are increasingly used in a wide range of co-incineration plants. In Austria, the quality criteria for waste fuels burnt in co-incineration plants are defined in the *Guideline for Waste Fuels* and the *Waste Incineration Directive*, where limits are given for the heavy metals content which are related to the heating value. The statistics about commercial and industrial amount of waste which is used for manufacturing of SRF, together with the statistics about treatment plants – Mechanical Biological Treatment plant (MBT) – and SRF-application plants – Cement Production Plants (CPP) – as well as the trends on SRF – substitution rates in Austria, Germany, EU 27 and Global are described. Additionally, the challenges of SRF developments and properties in modern waste management and its impacts on the resulting waste quality and waste processing technology are presented by reporting comprehensive examples. Another focus is the description of technical developments that will allow a one hundred percent substitution of primary fuels by secondary fuels produced out of different waste types.

Also, the interdependencies between primary and secondary raw material markets and economic relevance by substituting primary material through different waste fuels are discussed on the basis of capacity model. Since first of January 2012, the quality assurance incl. waste information, sampling procedure, analysis etc. in SRF preparation plants (supplier) or cement production plants (user) has to be executed. Based on CEN/TS-guidelines for SRF as well as national norms (ÖNORM), two common approaches for monitoring of SRF are presented.

1. Introduction

The European Union Directive 2000/76/EC on the Incineration of Waste [9] limits emissions to air, only, however, so far there are still no limits considering the levels of pollutants in the fuels, residues or products themselves when waste fuels are burnt in co-incineration plants,. To overcome this shortage, the Guideline for Waste Fuels [4] and the Waste Incineration Directive [5], which define quality criteria for waste fuels burnt in co-incineration plants, have been issued in Austria. [13]

According to this legal framework, *waste fuels* are waste that is used entirely or to a relevant extent for the purpose of energy generation and which satisfies the quality criteria laid down in the *Waste Incineration Directive* [5].

Thus, the composition of waste fuels is restricted by limit values – i.e. pollutant content per net calorific value (mg MJ_{DM}^{-1}) – for Sb, As, Pb, Cd, Cr, Co, Ni, Hg and a distinction is made for three different types of co-incineration plants, namely cement kilns, power stations and other facilities. Before waste becomes a waste fuel that can be used in a co-incineration plant, it usually undergoes treatment by preparation and manufacturing. Preparation of waste fuels includes classifying, sorting and separation of ferrous and non-ferrous metals as well as heavyweight inert materials. Manufacturing, which includes crushing, drying and pelletizing, is the treatment of waste fuels to improve its feeding and incineration properties. Waste fuels having a low level of pollutants (i.e. after multiple preparation steps) may become a 'substitute fuel product' which can be released out of the waste regime. Solid recovered fuel (SRF) is a waste fuel, having a net calorific value (LHV) between about 11 and 25 MJ kg_{OS}^{-1} and a particle size (d_{95}) range from five millimetres to smaller than 300 millimetres, which is normally prepared from high calorific fractions of municipal, commercial or industrial waste materials that satisfies certain fuel quality criteria laid down as limit values in legal regulations, guidelines or specifications. [13]

This paper sets its main focus on SRF production and usage in cement industry. Co-incineration of SRF in clinker kiln (cement plants) already has a long tradition in Austria, with more than 65.3 percent in 2011 [14] and even 72.36 percent in 2013 [15] substitution of primary energy. In the meantime, emission trading (Directive 2003/87 EC [10]) has opened a new scope for use of SRF, because due to its relative high biomass content (between 30 and 55 percent, depending on calorific value), emission certificates can be saved by co-incineration plants when using SRF. Even higher biogenic portions may be achieved for specific commercial and industrial waste and SRF specifically processed in order to gain higher biogenic content [16, 17]. There is also a great opportunity for SRF in developing countries where huge amounts of high calorific waste fractions are still deposited in landfills or at dumping sites [8].

Three fundamental conditions must be fulfilled before a plant operator is ready to opt for co-incineration of SRF (which requires considerable investments). The conditions are:

- Legal compliance but also legal certainty,
- Security of supply,
- Assured quality. [13]

Usage of SRF, although usually burning of waste, is largely accepted by the society in Austria and some middle- and northeuropean countries (e.g. Germany, Switzerland, Belgium and Scandinavian countries). This is also reflected by the fact that approval processes for the use of SRF have not initiated specific resistance of the people or the media in recent years. The pioneer phase of waste to energy is over and nowadays the technology of co-incineration is optimized and improved to increase the substitution rate and expand the fields of SRF application.

2. Current state of Solid Recovered Fuels (SRF)

According to the Federal Waste Management Plan [3], 1.532 million t a^{-1} waste was treated in Austrian thermal plants in 2012, namely:

- 1,041,400 t a^{-1}: residual and bulky waste,
- 152,600 t a^{-1}: high-calorific fraction from waste sorting or residual waste splitting,
- 321,800 t a^{-1}: energetically usable residues from sorting of separately collected waste.

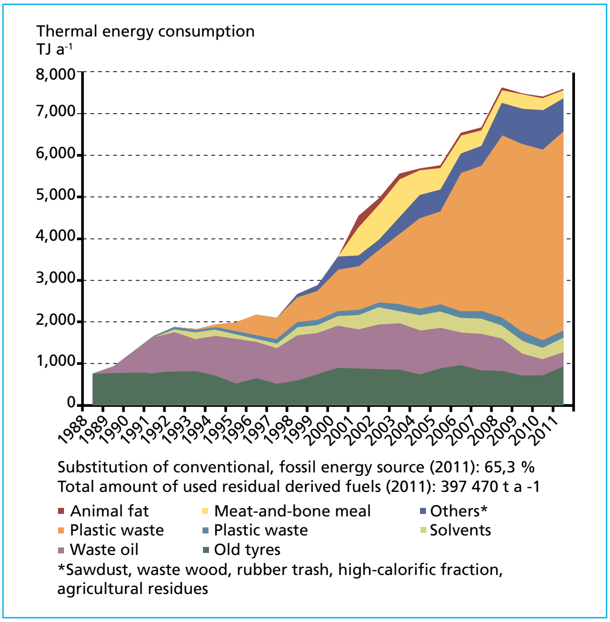

Figure 1:

Input of RDF in Austrian cement production plants (time period: 1988-2011)

Source: Mauschitz, G.; 2012: Emissionen aus Anlagen der österreichischen Zementindustrie; Berichtsjahr 2011 [Emissions from plants of the Austrian cement industry]. TU Wien, Wien, Austria

In Austria, 11 cement production plants, with a total plant capacity of 5,086,900 t a^{-1} (VÖZ, figures for year 2011) are in operation, and 4,426,944 t a^{-1} cement products (clinker factor 0.717 t_{cl} t_{ce}^{-1}) were produced. Time related developments in application of SRF, especially made out of treated plastic waste, in cement production plant is shown in Figure 1.

As mentioned before, utilization of SRF in cement industry has a long tradition in Austria. Figure 2 shows the substitution rate and trends in utilization of different SRF in cement production plants worldwide. Austria (2011: 65.3 percent substitution [14]) and Germany (2011: 61.1 percent substitution [22]) are clear over the EU 27 average, as well as over the Global (data for 2006: EU: 18 percent, North America: eleven percent, Japan: eleven percent, Australia: eleven percent and Asia: four percent [23]) average. It can be expected that the EU 27, as well as Global substitution rate for primary energy consumption will be increased in future.

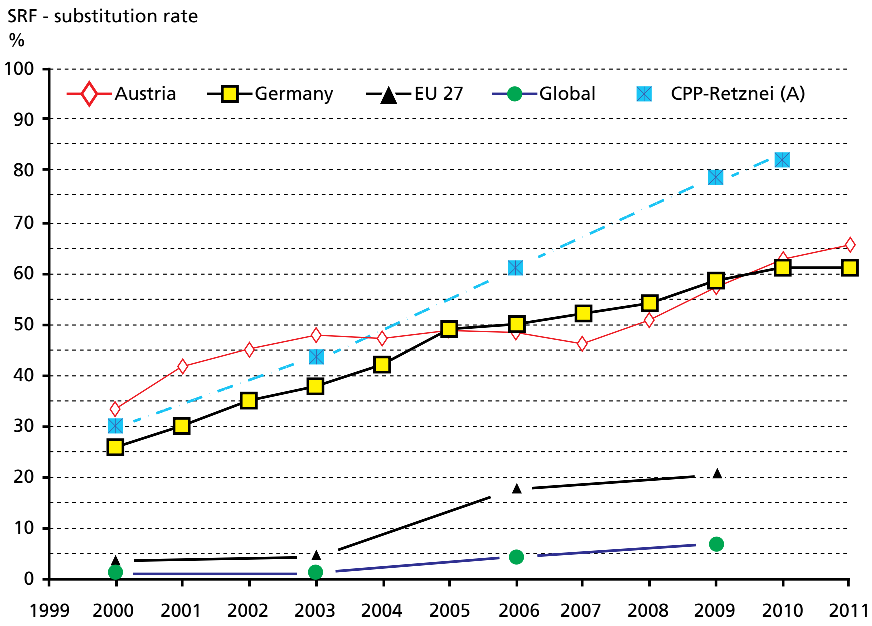

Figure 2: SRF – Substitution rate in cement industry (time period: 2000-2011) Note: CPP: Cement Production Plant

Sources:

Pomberger, R. & Curtis, A.; 2012: Neue Entwicklungen bei der Produktion und Verwertung von Ersatzbrennstoffen in Österreich [New developments in production and application of Solid Recovered Fuels in Austria]. In: Energie aus Abfall 2012. Proceedings of the 9th International Conference on Energy from Waste (eds. K.J. Thomé-Kozmiensky, et al.), Berlin, Germany, pp. 721-739. Berlin, Germany: Verlag TK Verlag Karl Thomé-Kozmiensky.

VDZ; 2012: Web query: http://www.vdz-online.de/vdz.html queried on internet in August 2012.

VÖZ; 2012: Web query: http://www.zement.at/ queried on internet in August 2012.

3. SRF Developments

Modern production, marketing, application and quality assurance of SRF are intensive processes which are directly connected with certain legal, material, plant and economic developments and properties (compare Figure 3).

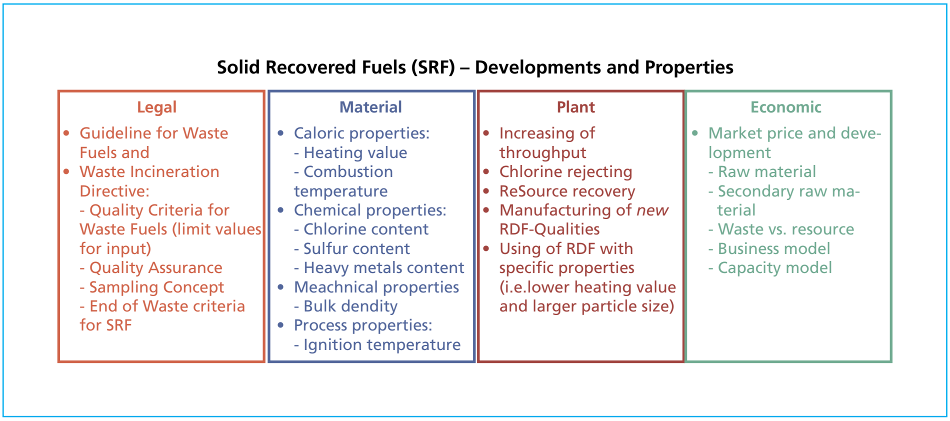

Figure 3: Legal, material, plant and economic developments and properties of SRF

3.1. Legal developments

In 2008, after extensive discussions, a technical Guideline for Waste Fuels was issued by Austrian BMLFUW [4]. The production and use of SRF is regulated and controlled by this Guideline. At the beginning, it was not legally binding, but the state of the art was defined by it and the licensing processes were using it as reference. In 2010 the contents of the Guideline including important regulations for *end-of-waste* declaration (products of Residual Derived Fuels) were implemented in the already existing Waste Incineration Directive [5].

The Waste Incineration Directive [5] among others defines the input quality criteria (specified limit values) for SRF burnt in co-incineration plants (distinction is made for three different types of plants, namely cement production plants, power stations and other co-incineration plants). Waste fuel can only be used if the co-incineration plant owner has the valid quality assessment certificate. This certificate contains information about origin of waste, used treatment procedures, sampling data, analysis data and evaluation of waste quality. If all limit values are observed and technical requirements are fulfilled, waste fuel can be used for co-incineration.

The composition of waste fuels is restricted by limit values (i.e. pollutant content per net calorific value (mg $MJDM^{-1}$) but not anymore pollutant content per mass fraction (i.e. mg kg^{-1}) for As, Pb, Cd, Cr, Co, Ni, Hg and Sb. Additionally, statistic methods (i.e. median and 80 percentile) for the determination and the compliance of parameters with the limit value are given. At least ten parallel analysis results are needed for statistical evaluation and assessment of waste fuel quality.

Waste fuel must fulfill all requirements defined in Waste Incineration Directive [5]. If SRF has a similar material and chemical composition and quality as the conventional, fossil fuel, the waste owner has the possibility to declare the so called *End-of-waste* status for this waste. When the declaration process is finished and all requirements are fulfilled and accepted by authorities, the waste fuel is classified as *SRF-product* and can be used in specified process.

3.2. Material developments

Material properties and quality of SRF can be described through calorific, chemical, mechanical and process parameters, which are also used for the clasification of different waste fuel types. By the use of SRF, the amount of conventional, fossile fuels can be reduced. If the substitution rate is low, a lower quality of SRF can be compensated by higher quality of other fuels. The greater the substitution rate, the greater are the quality requirements for waste fuels including the material handling technologies.

The challenge and development of modern waste management in respect of waste quality may be described as follow [19]:

- **Decreasing of heating values:** Reasons for decreasing of SRF heating values in recent yerars are increasing demand and higher prices for plastics, used in material recycling processes. In last years, material recycling of high quality plastics has become an attractive waste management option. The content of plastics with high heating values in the SRF-waste fraction is decreasing, but the biological portion is increasing. Main reason for reported changes is, that waste streams from Mechanical Biological Treatment plants (MBT), which usually process household waste with high biological content, have been risen.
- **Increasing of chlorine problems:** Increasing usage of packagings which contain chlorine (i.e. PVC-packagings) leads to quality degradation. Because of different consumer behaviour in different countries and waste imports from this countries, the SRF quality has been changed. Increasing of chlorine content has to be compensated and limited by using modern automatic sorting systems and applying sampling concepts including chemical analysis.
- **Heavy metal contents in metal fraction:** Despite multiple metal sorting procedures (magnetic separator for FE and eddy-current separator for NON-FE), the presence of metal (metall, heavy metal or heavy metall bounded on the surface of metal) still is a problem of high quality SRF. Depending on the element, different percentage of heavy metals are bounded to the metalic fraction.
- **Solid hazardous waste:** Waste oil and solvents have been used in cement production plants as waste fuel for extended period of time. Solid waste, which is contaminated with waste oil and solvents, was, according to the Austrian law, marked as *hazardous* because of its harmful properties, and could not be used as waste fuel. Due proper mechanical treatment of e.g. hazardous car worhshop waste, quality SRF for use in cement production plant can be manufactured nowadays.

Modern waste management is a system of elements with mutual dependencies. A large waste management company requires a combination of different plant types. The individual systems are interrelated and interdependent. The plants are both elements but also subsystems of the overall system *Thermal utilization of wastes*. The connections between the systems are material- and freight-flows. In Figure 4, the system *Thermal utilization of waste* is depicted by the example of an Austrian waste management company. The assignment of waste streams to the appropriate plant types is made according to the quality of wastes. [18]

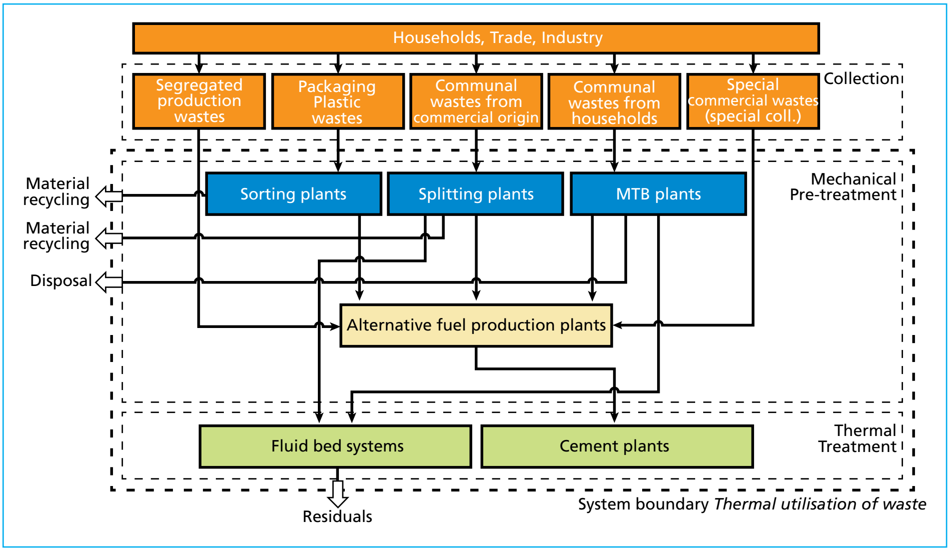

Figure 4: System overview *Thermal utilization of wastes*

Source: Pomberger, R.; 2004: Umsetzung der Deponie-VO-Kombination von Anlagen für Splitting, Ersatzbrennstoffproduktion und thermische Verwertung [Implementation of the Landfill Regulation - Combination of plants for splitting, RDF-production and thermal treatment]. In: DepoTech 2004. Proceedings of the 7th International Conference on Waste Management (eds. KE Lorber, et al.), Leoben, 24-26 November, pp. 443-450. Essen, Germany: Verlag Glückauf GmbH.

Splitting plants treat mixed commercial waste and operate on the principle of qualitative splitting. They produce a furnace-ready, medium-calorific SRF for fluidized bed systems, as well as a high-calorific light fraction for the subsequent SRF-production for the primary burner of a clinker rotary kiln. The waste delivered to the splitting plant is mixed commercial waste originating from commercial and industrial sources. The accepted waste can be described by the following properties: low moisture, low organic fraction, good processability, high heating value. Determining sub-fractions are plastics, paper, cardboard, wood, metals and mineral shares.

3.3. Classification of SRF

There are different ways of classifying the different types and quality classes of SRF used for co-incineration in various industrial sectors (e.g. CEN/TR15508 [6] or CENprEN 15359 [7]). For practical reasons, the classification systems are shown in Table 1, which is based on the net calorific value and particle size as the main criteria.

Table 1: Classification of different SRF-qualities used for co-incineration in different industrial sectors

Parameter for Classification	SRF-Specifications							
	Unit	Coalfired Power Station	Calciner	Grate Firing (Utility boilers)	Fluidized Bed (Utility boilers)	HOT DISC Cement Kiln (HDF)	Primary Burner Cement Kiln (PBF)	Blast Furnace (Steel Plant)
Net Calorific Value	MJ kgOS-1	11 - 15	11 - 18	11 - 16	11 - 16	14 - 16	20 - 25	> 25
Particle Size	mm	< 50	< 50 - 80	< 300	< 20 - 100	< 120	< 10 - 30	< 10
Oversize	%	0	< 1	< 3	< 2	*	< 1	0
Impurities (extraneous material)	w%DM	< 1	0	< 3	< 1 - 2	*	< 1	0
Chlorine	w%DM	< 1.5	< 0.8	< 1.0 - 0.8	< 1.0 - 0.8	0.8 - 0.6	< 1.0 - 0.8	< 2
Ash	w%DM	< 35	*	*	< 20	20 - 30	< 10	< 10

*: no distinct limitation, depending on feeding system or ash discharge

Source: Lorber, K.E., Sarc, R. and Pomberger, R.; 2011: Production and application of refuse derived fuels. In: Waste-to-Resources 2011, 4. Internationale Tagung MBA und Sortieranlagen (ed. M Kuhle-Weidemeier). Göttingen, Germany: Cuvillier Verlag.

3.4. Production plant developments

The SRF properties can be influenced by two different ways, namely by:

- the selection of waste streams, which perhaps contain high calorific components (e.g. paper, plastics, wood), or
- using specialized mechanical treatment techniques, which are designed for selective removing of unwanted fractions (e.g. PVC-plastics) or wanted recyclable material (e.g. PET-plastics).

Modern specialized mechanical treatment techniques are responsible for different developments in waste management [19]:

- **Increasing of throughput:** The ongoing increases in production and expansion of production amounts are a result of increased modern industrialization. This can be shown by the ThermoTeam SRF-production plant. Since its opening (2003), the plant was optimized, more efficient equipment was installed and the production amounts to about 95,000 t a^{-1} (2011).
- **Chlorine rejecting:** By application of modern sensor-based sorting technologies – near infrared technology (NIR-Plant) –, the fractions with higher rate of chlorine (e.g. PVC) can be removed out of processed waste stream. Through the removal of chlorine fraction, the output quality of SRF production plant is stabilized and simultaneously increased.

- **Resource recovery from SRF:** Waste is simultaneously the resource for material recycling. Investigations have shown that considerable amounts of plastics (e.g. PET) and aluminum are contained in ThermoTeam SRF-material. About two to three percent PET and about 0.1-0.15 percent aluminum are found in SRF, which is currently burnt in cement production plant. These materials are valuable resources and could (should) be used in material recovery processes.
- **Production of SRF for the secondary firing (calciner):** Another possibility to increase the substitution rate of SRF in cement production plant is the use of SRF in secondary firing. The development of specifically designed calciner burners and combustion chambers (e.g. HOT DISC-technology) enables use of middle-calorific-SRF with relative low quality requirements (i.e. particle size and heating value) but still higher heating value in comparison to the SRF-type used in fluidized bed incineration plants.
- Other important plant developments are in **logistics**; e.g. compression plant for better truck loading factor (use of maximum load capacity, about 23 t); and **fire prevention technology**; e.g. determination of self-ignition temperature and installing of required equipment.

3.4.1. Increased use of pre-combustion chambers

At relatively low substitution rates and still less developed waste management collection and treatment systems, a flexible combustion technology is of essential importance. Waste types and qualities can change rapidly, the quality of collection and pre-treatment has yet to be developed. Countries without separate collection are also characterized by high biogenic content in municipal waste, this leads to rather lower heating values in the produced SRF. Pre-combustion chambers (for example HOTDISC or PREPOL) allow the use of inhomogeneous SRF with higher grain sizes and lower heating values. The qualitative requirements and their tolerance of hard impurities form a good basis for use in countries with waste management systems, which are on the way to be developed or implemented.

The following Figure 5 describes the technological development and the use of HOTDISC system in the cement industry. For the first time, this technology was implemented industrially for alternative fuels in cement plant Rohožnik (Slovakia) of Holcim Ltd.. In order to increase the substitution rate in cement plants, a higher energy input from alternative fuels on the secondary firing part of the kiln must be developed [19]. HOTDISC technology offers the possibility of using less recycled waste, i.e. the material-specific requirements (in particular heating value and grain size) can be met with a few processing steps. In simple terms, the demands on the quality of fuel in the secondary combustion is lower than in the primary firing, which requires higher heating value (i.e. Hu > 18 MJ/kg_{OS}) and smaller grain size (i.e. d_{95} < 30 mm). The HOTDISC is a pre-combustion chamber in the region of the cyclone heat exchanger of a rotary kiln. SRF is loaded via a damper system and the combustion takes place on a refractory lined rotary plate which is passed by a stream of the furnace exhaust gases. Combustion exhaust gas is preheating the raw meal and supports calcining process. [12]

The Holcim Ltd. cement production plant located in Rohožnik (Slovakia), which has implemented the HOT DISC-technology for incineration of middle calorific SRF with larger particle size (d_{95} > 80 mm) is already playing a certain role in Slovakian and Austrian waste management.

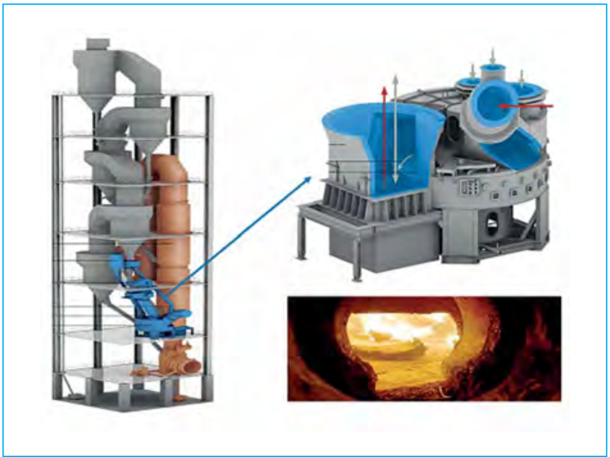

Figure 5:

Location and detail of pre-combustion chamber, system HOTDISC

Source: FLSMIDT: HOTDISC cobustion device

3.4.2. Target of one hundred percent substitution rate

As already mentioned, Austrian average substitution rate in the cement industry achieved 72.4 percent in 2013, some plants e.g. the cement plant in Retznei of Lafarge Perlmooser AG reached a substitution rate over eighty percent in 2010. As part of an experimental operation, all primary energy sources were replaced by a mix of liquid and solid waste fuels to one hundred percent in this cement plant in 2010 for one week. Key findings in terms of technical problems (fuel mix, fuel control, caking) can be summarized as following. A significant, positive aspect of this *hundred percent – rate of substitution* was that no change of clinker quality could be observed [19]. Results of this experiment are used, inter alia, as basis for the implementation of a project at the Chair of Waste Processing Technology and Waste Management (Montanuniversitaet Leoben) which is concerned with the quality assurance of substitute fuels. The data of produced fuel quality by Thermo Team plant – producer of SRF, which is used for example in the cement plant Retznei – are then used in a cement plant for balancing the clinker process and optimization of the technology.

In the future, one hundred percent substitution rate of SRF in cement production plant seems to be a realistic target. In Retznei (A), the total thermal energy supply for a cement production plant only by using of solid and liquid waste fuels was successful tested for some times. It is expected, that substitution rate will reach ninety percent in 2014.

3.4.3. Technical challenges in order to increase the substitution rate

To reach the last twenty percent of the substitution, places particularly high demands on SRF producers and cement plants. The hundred percent target is a technical challenge, which depends on the type of RDF used and the individual circumstances of the furnace system. From an economic perspective, it may also be reasonable to accept a lower substitution rate since the last percent require more costly treatment steps. The following activities support the goal of complete replacement.

Drying of waste

Demand for high-calorific, quality-assured waste fuels on the Austrian market is larger than the actual offer. The demand for middle calorific substitute fuels (heating value of 11 to 18 MJ/kg) will rise in the future and thus gain considerations for the drying of low calorific wastes (e.g. rejects from paper industry, materials from the mechanical-biological waste treatment plants, etc. with a calorific value smaller than 11 MJ/kg_{OS}) of significance. The drying increases the heating value and allows the use of SRF in the cement rotary kiln (*refinement*). Waste that is presently used as a medium-calorific SRF, could even reach the qualities of high-calorific substitute fuels (heating value > 18 MJ/kg_{OS}) after drying (= increasing of the heating value). This assumption still requires further research.

At constant composition of waste there are several approaches to dry the waste. On one hand, waste heat can be used for the drying of medium and high-calorific substitute fuels from industry (e.g. cement and paper industry). On the other hand, there is the possibility for drying of waste through the conversion of ordinary mechanical-biological waste treatment plants (prior to landfilling) towards mechanical - biological stabilization (MBS) and mechanical – physical stabilization (MPS). This could be the biologically stabilized fraction (MBT material), which currently lands on landfills after the rotting process, to be used in waste incinerators. On the other hand middle-calorific wastes that are currently used in municipal waste incinerators could be used to increase the substitution rate in the cement industry at the secondary firing systems. This would make a significant contribution to the relief of landfills, reducing landfill aftercare and conservation of landfill space. This change would lead to the expansion of the waste management *value chain*, but implementation should be studied scientifically and technically in more detail.

Fine materials

An increase in the amount used at the main burner can be achieved by improved burnout of the SRF in the flame. The size reduction to about 5 mm need not be done in the SRF production plant, usually producing for several customers, but could be carried out immediately prior to the furnace by the individual cement plant itself. As already crushed, impurity and metal liberated SRF was delivered, a cutting-shredding can be integrated as an isolated additional process step. The cement plant then adjusts and optimizes the grain size itself.

Chlorine reduction in material

Another objective of the above-mentioned project *hundred percent substitution rate* is the discharge of chlorine-rich fractions (e.g. PVC-containing products such as soils) from the produced alternative fuel. Some mechanical treatment plants and SRF production plants have installed such aggregates, which are to improve the quality of EBS or at least keep constant. The chlorine problem is a known issue in the cement industry and the higher the substitution rate is increased, the better must be the quality of the material used, i.e. the less must be the chlorine loading (i.e. Cl < 0.6 %).

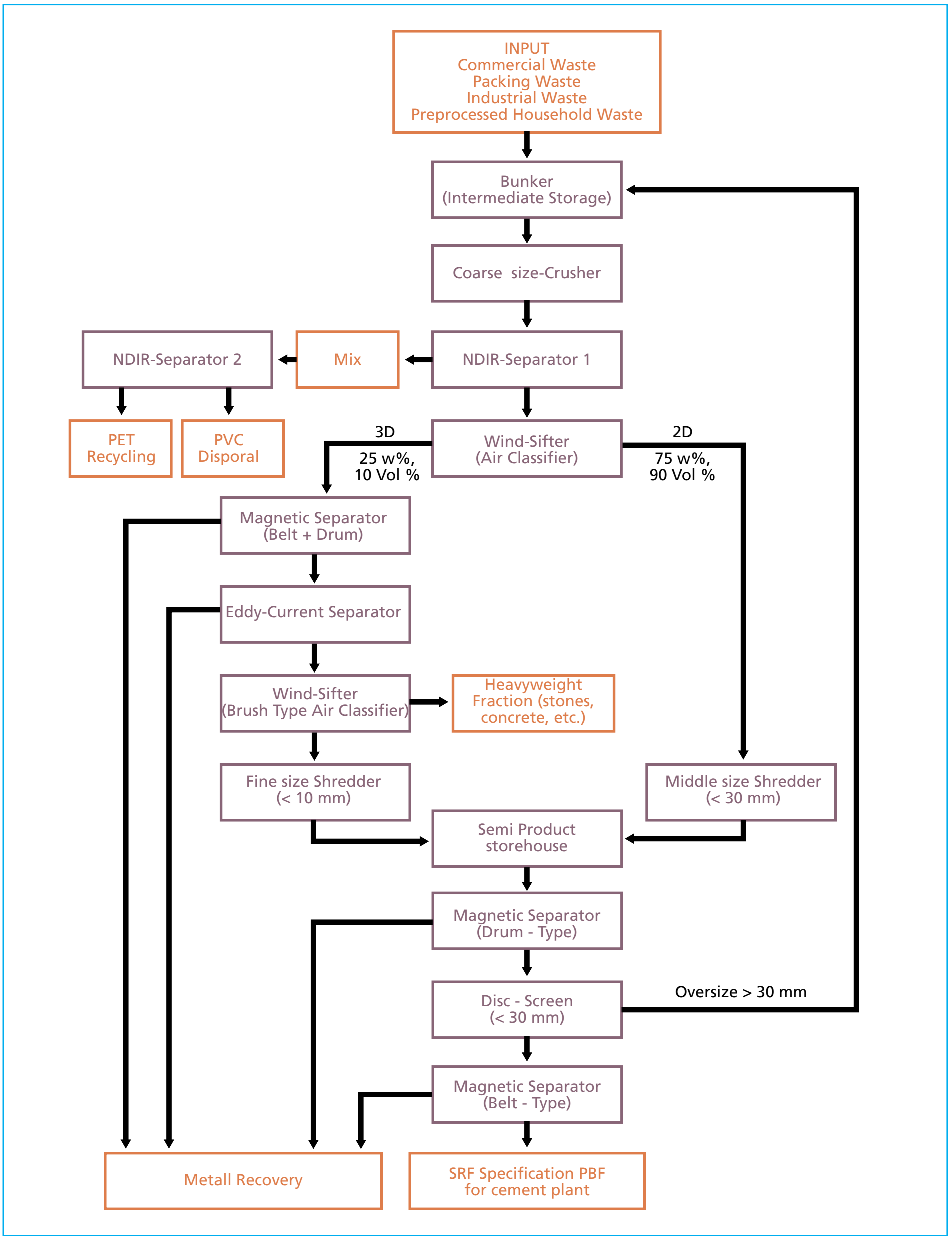

Figure 6: Simplified flow scheme of the SRF production plant Thermo Team

Source: Lorber, K.E., Sarc, R. and Aldrian, A.; 2012: Design and quality assurance for solid recovered fuel. In: Waste Management & Research Special Issue 30(4).

In Austria's largest SRF-production line Thermo Team, the treatment process is designed to ensure that the chlorine load is lowered or that a maximum chlorine content of 0.6 percent is limited. NIR sorting technology has been extended to other units (Figure 6) [19].

The plant has been commissioned in the summer 2012 in operation and the associated project is accompanied by Montanuniversitaet Leoben under cooperation of Thermo Team and Lafarge.

Optimizing waste mix

High substitution rates can only be achieved through the use of various waste streams (RDF). Liquid hazardous waste such as waste oil and solvents also play an important role. By selecting appropriate RDF and allocation of waste types to the appropriate feeding place an optimized furnace system for the waste mix can be adjusted. Unfortunately, the availability of particularly suitable liquid wastes is limited and due to high competition and growing economic reasons these materials are becoming unattractive.

Oxygen feeding into the furnace

With declining calorific values on the main burner, the addition of oxygen to the combustion air can improve the burnout and increase the flame temperatures. Even by this measure, the substitution rate can be improved at the main burner.

3.5. Economic developments

Secondary raw materials obtain their economic relevance by substituting primary resources and thus cutting costs. Regarding the latter, not only the European economies and industries are especially interested in. This results in a demand for comparatively inexpensive raw materials. It is the waste industry that needs to deliver such raw materials made from wastes in different quantities and qualities. To be able to fulfill these requirements, companies need an appropriate model that depicts the development of individual secondary raw materials from waste and allows statements concerning their future trends reaching from waste to the resource market. Such system would enable companies to assess and plan the required capacities to be installed for the secondary raw materials in need. [11]

Capacity Model

The so called Capacity Model is the basis for generating hypotheses regarding the interdependencies between primary and secondary raw material markets, combining conclusions to be drawn from the so called *S-curve* (Figure 5) and Life Cycle Models applied.

In support of the Life-Cycle-Concept, the Capacity Model establishes an explanatory approach for the interdependencies between primary and secondary raw material markets alongside the life cycle of different waste fractions (Figure 7). Depending on plant capacity and waste amount, the price for waste is either determined by the disposal market or the energy and raw material market. Consequently, the price is geared towards the disposal and treatment costs or towards the substituted primary raw material's price. [11]

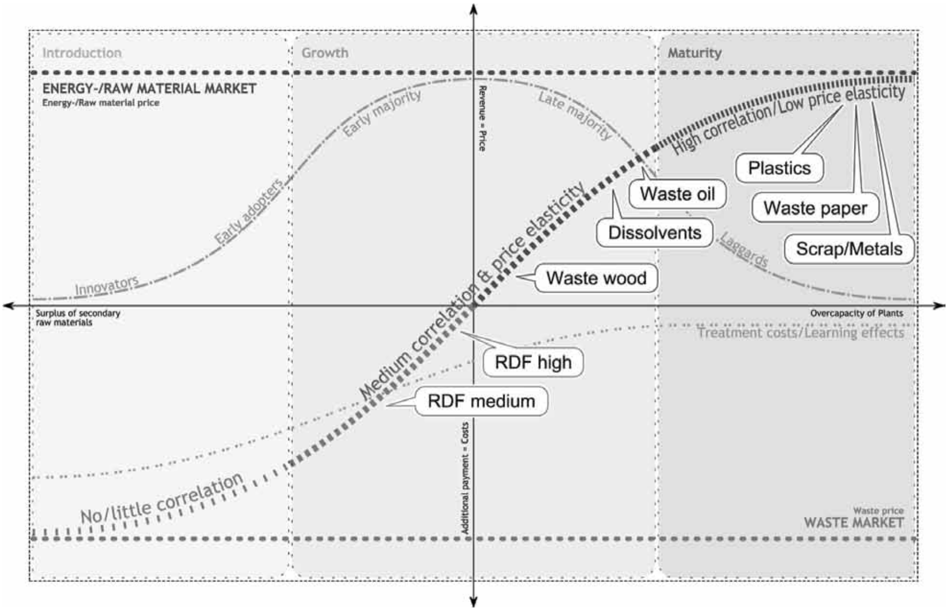

Figure 7: Capacity Model (Situation Austria 2007)

Source: Klampfl-Pernold, H., Pomberger, R. and Schmidt, G.; 2011: Decoding interdependencies between primary and secondary raw material markets by means of the Capacity Model. In: Waste-to-Resources 2011, 4. Internationale Tagung MBA und Sortieranlagen (ed. M Kuhle-Weidemeier). Göttingen, Germany: Cuvillier Verlag.

4. Importance of SRF-quality assurance

As mentioned before, the legal framework for the application of SRF in Austria is laid down in the regulations issued by the Ministry of Environment [4, 5] and by the norms and standards (ONORM) published by the Austrian Standards Institute (ASI) (e.g. ONORM EN 15442 [1] and ONORM EN 15443 [2]). By definition, waste fuels are waste that is used entirely or to a relevant extent for the purpose of energy generation and which satisfies the defined quality criteria [4].

Apart from legal requirements, additional fuel specifications are usually fixed in the contract between SRF supplier and user, which normally contain:

Particle size (d_{95}) or (d_{90}), net calorific value (MJ kg_{OS}^{-1}), chlorine content (w $\%_{DM}$), sulfur content (w$\%_{DM}$), biogenic carbon content (%), ash content (w $\%_{DM}$), water content (w $\%_{OS}$), as well as restrictions (mg kg_{DM}^{-1}) for the heavy metals (As, Sb, Pb, Cd, Cr, Co, Cu, Zn, Ni, Hg, Tl, V, Sn, Mn). [13]

Ensuring the necessary legal compliance with the limit values and specifications given in the supply contract requires proper monitoring of SRF. For this, two different approaches are common [13]:

- Supplier control. External quality control of SRF for legal compliance is done by the suppliers, who pass down all the relevant information to the consumer. In this case, the suppliers have to elaborate a sampling plan and conduct all required analytical measurements, and the consumer (i.e. the co-incineration plant) has to take randomly samples of the incoming SRF in order to check the identity of the material. These identity checks have to be carried out at least once a year. If a contamination of the waste fuel is suspected in the course of a visual check or if the waste fuel does not seem to comply with regulations, samples have to be taken and examined. For the identity check, the analytical examination (lot size) refers to an amount of 150 t or – in case of waste streams larger than 40,000 t year^{-1} – to an average daily amount.
- Consumer control. The incoming SRF delivered by different suppliers is examined by the co-incineration plant itself. Therefore, sampling plans as well as a sample preparation concept have to be established according to norms, standards and guidelines given or recommended by the authorities [e.g. 1, 2, 4 etc.]. The volume and intensity of investigations to be performed for quality assurance depend strongly on the amount and frequency of SRF-deliveries to the plant. A sampling plan is to be set up according to CEN/TS 15442 [1] for every type and origin of SRF separately. For this, a distinction is made between the amounts of the incoming SRF, i.e.: waste streams larger than 40,000 t year^{-1} and waste streams smaller than 40,000 t year^{-1}.

5. Summary

SRF production and utilization show a strong positive development in Austria and some other middle and north European countries. It has become state of the art in cement industry and from the economic point of view it is hardly impossible to run a cement kiln without utilization of SRF for substitution of conventional fossil fuels. Co-incineration is now a necessary and generally accepted part of waste management in Austria and other European countries.

Although there are still problems in developing countries (e.g. CEE) with public acceptance of SRF, but an increase of the substitution rate can be expected in near future. It is a social process rather than a technical one to accept these innovative developments and changes in waste management.

Some countries still have to provide fundamental requirements and to set the stage for production and utilization of SRF. Suitable waste streams have to be generated, collection and separation systems must be built up and financing has to be solved. SRF production and utilization is part of a complex waste management system which is currently in different development stages depending on the type of country, market and sector.

There are different ways to increase the substitution rate. To achieve the goal of one hundred percent, several technical improvements (e.g. drying, finer shredding, chlorine reduction) are possible. An ongoing research project investigates the impact and shows the realistic implementation. Another development is the increased use of medium calorific SRF and the use of pre-combustion chambers.

The availability of appropriate waste streams is/will be a main challenge in the future. It is a paradox, but waste is a *scarce good*. Demand is still increasing and as a result of it, the competition for capable waste streams will be greater in future. This also puts the principle and strategy of *waste prevention* under question.

But there is no doubt, SRF utilization worldwide will increase, it will be more and more accepted, it will be an important part of forward-looking waste management systems and it will contribute to higher energy efficiency in industry.

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