BREF „Waste Treatment“
Solid Recovered Fuels

European Recovered Fuel Organisation

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1. Introduction

The history of SRF is going back to the oil crisis of 30 years ago. Then RDF (refuse derived fuel) was promoted as a substitute low cost fuel. But the fuel was not accepted by the market. However, since more than 10 years there is a growing interest within the cement, lime, steel and energy industry in fuels derived from waste for economic reasons. The European energy policy targets and waste management policy gave an impetus to the usage of waste derived fuels based on non hazardous wastes. These fuels, having an average content of 50 - 60% on biogenics, may contribute considerably to the reduction of CO_2 emission and the doubling of the share of renewable energy. Moreover, due to liberalisation and need for cost reduction, industry is interested in less expensive homogenous substitute fuels of a specified quality. At present the main end-users are the cement and lime industry. However the market chances in the potential bigger market of the power generating sector are increasing.

The waste management policy aiming at the reduction of landfill disposal initiated the development of facilities for the production of secondary fuels. Also the (high) tax system on landfilling is a major driving force in some Memberstates. Contrary to the situation 30 years ago the producers of these fuels took the initiative for a quality system that should guarantee the properties of the Solid Recovered Fuel (SRF) out of non hazardous waste. Quality systems exist in several Member States now. CEN was given a mandate by the Commission to develop standards for SRF based on non hazardous wastes.

2. The Market of secondary fuels from non hazardous waste

The main outlets of SRF are found in the cement industry and the lime industry. The coal fired power stations could be assessed as an emerging sector with a huge potentiality. Steel mills use SRF as a carbon-substitute. The nordic countries burn SRF for district heating.

The production of cement in the EU was 172 Mt in 1995. The break down of the fuel consumption is given in Table 1.

Table 1: Fuel consumption by the European cement industry /1/

Fuel	%
Pet. coke	39
Hard coal	36
Fuel oil	7
Lignite	6
Gas	2
Waste	10

The specific energy consumption is 3 – 4 MJ/kg clinker. Assuming 0,75 kg clinker/kg cement, a substitution rate of fuel of 30 - 50% and a LHV of SRF of 19 MJ/kg this means a potential of 6 – 11 Mt SRF/a. Assuming an energy consumption of 4 MJ/kg lime, at the same substitution rate as for cement kilns, this means a potential of 1 – 2 Mt SRF/a at an annual production of 20 Mio tonnes lime.

The consumption of hard coal and lignite for power production in the EU was 145 Mtoe/a in 1999 (European Commission 1999 Annual Energy Review). The substitution rate is estimated at a minimum of 5 - 10% of the fuel on a heat basis. So the potential may be 14 – 29 Mt SRF/a. The total potential market for SRF may be 21 – 42 Mt/a, which is a substantial amount of the SRF that could be produced from MSW and other combustible waste. There are big differences between countries. Germany has still a lot of lignite and coal fired power plants. France, as they have chosen for nuclear power plants, do only have few coal fired power plants. In “CEN report Solid Recovered Fuels” /2/ a potential of SRF is indicated of between 33 and

50 Mt/a. The conclusion is that the SRF production may become an essential link in the waste management system.

The current best estimate of the quantity of solid recovered fuels produced and consumed in Europe is about 1.4 Mt/a, as set out in Table 2 below.

Table 2: Summary of European Solid Recovered Fuels market in 2000 (2002) /2/ /3/

State	Production		Consumption		- Export / Import +		Note
	kt/a	toe/a	kt/a	toe/a	kt/a	toe/a	% CK
Austria	100	50.000	100	50.000			7
Belgium	<100	<50.000	<100	<50.000	n.a.	n.a.	(100)
Denmark	0	0	0	0			
Finland	170	58.000	170	58.000	n.a.	n.a.	0
France	0	0	0	0			
Germany	500 (650)	250.000 (325.000)	500 (650)	250.000 (325.000)	n.a.	n.a.	85
Greece	0	0	0	0			
Iceland	0	0	0	0			
Ireland	0	0	0	0			
Italy	<200 (250)	<100.000 (125.000)	<200 (250)	<100.000 (125.000)	n.a.	n.a.	
Luxembourg	0	0	0	0			
Netherlands	250 (350)	100.000	15	6.000	-145	60.000	20
Norway	1)		1)				
Portugal	0	0	0	0			
Spain	n.a.	n.a.	n.a.	n.a.			
Sweden	1)		1)		+500 2)		
Switzerland							
United Kingdom	60 (100)	30.000 (50.000)	60 (100)	30.000 (50.000)	n.a.	n.a.	
Total	**1.380**						

Notes: kt/a = 1000 tonnes per year;

toe/a = tonnes oil equivalent per year (It is assumed that solid recovered fuel has a calorific value of 21 MJ/kg, although it is lower in Finland and the Netherlands, and oil has a calorific value of 42 MJ/kg)

% CK = % of consumption that occurs in cement kilns

The figures in this table are only indicative as they do not correspond to the same harmonised definition throughout the European Union

1) There is no overall statistic for Sweden or Norway because this fuel is used in ordinary heat/power plants and in waste incinerators without a demand for detailed specifications. Data for Sweden (2001) are: waste incineration plants for district heating 856.000 t/a and power plants for district heating 455.000 t/a.

[2)] No exact figures exist, but approximate figures give 500 kt of waste which was imported in 1999. 90% consisted of wood, paper, plastic and rubber.

Industry's best estimate of solid recovered fuel production in 2005 is about 13 Mt/a (cf. Table 3).

Table 3: Forecast / potential for European Solid Recovered Fuels market in 2005 /2/ /3/

Member State	Production		Consumption		- Export / Import +		Δ 2000 %
	kt/a	toe/a	kt/a	toe/a	kt/a	toe/a	
Austria	500	250.000	500	250.000	n.a.	n.a.	400
Belgium	100	50.000	100	50.000	n.a.	n.a.	0
Denmark	0		0				
Finland	350	120.000	350	120.000	n.a.	n.a.	100
France	1.000	500.000	0	0	-1.000	-500.000	
Germany	3.000	1.500.000	4000	2.000.000	+1.000	+500.000	
Greece	500	250.000	500	250.000	n.a.	n.a.	
Iceland	0		0				
Ireland	500	250.000	500	250.000	n.a.	n.a.	
Italy	1000	500.000	1000	500.000	n.a.	n.a.	
Luxembourg	50	25.000	50	25.000	n.a.	n.a.	
Netherlands	1.000	400.000	600	240.000	-400	-160.000	
Norway	150	75.000	150	75.000	n.a.	n.a.	
Portugal	500	250.000	500	250.000	n.a.	n.a.	
Spain	1000	500.000	1.000	500.000	n.a.	n.a.	
Sweden	500	250.000	1000	4.500.000	+500	+200.000	
Switzerland	0	0	0	0			
United Kingdom	600	300.000	600	300.000	n.a.	n.a.	
Total	**10.750**	**5.220.000**					

Notes: kt/a = 1000 tonnes per year;
toe/a = tonnes oil equivalent per year (It is assumed that solid recovered fuel has a calorific value of 21 MJ/kg, although it is lower in Finland and the Netherlands, and oil has a calorific value of 42 MJ/kg)
Δ 2000 = Difference from year 2000
It is assumed that no Solid Recovered Fuel is exported outside the European Union.
The figures in this table are only indicative as they do not correspond to the same harmonised definition throughout the European Union

It is interesting to note that the consumption of hard coal and lignite for power production in the EU was 145 Mtoe/a in 1999 (European Commission 1999 Annual Energy Review). The total production of solid recovered fuel forecast in Table 3 for 2005 (more than 5 Mtoe/a) represents a substitution rate of 3.5%.

3. Applied process and techniques for secondary fuel production

3.1. Introduction

Secondary fuels are used for several purposes. Depending on the application there are different requirements for secondary fuels. This BREF only handles secondary fuels derived from solid non hazardous waste. In the following report they are called refuse derived fuel (RDF) and solid recovered fuel (SRF). The difference is that the last type of waste derived fuel meets certain standards /3/.

Figure 1 presents an overview about common process units, which can be applied for SRF production. The number and the kind of processing steps correlate to the waste compositions and the desired product qualities /4/.

It is very important to keep in mind that waste is an inhomogeneous mixture of materials especially municipal solid waste (MSW). So it is a challenging task of the SRF producer to reduce inhomogeneities by technology and adapted processing. The circumstances (location) and parameters (kind of used wastes) differ by each SRF producer. As a result the producers follow up their own strategy concerning how to produce the SRF. Depending on what quality should be reached different processing steps must be applied.

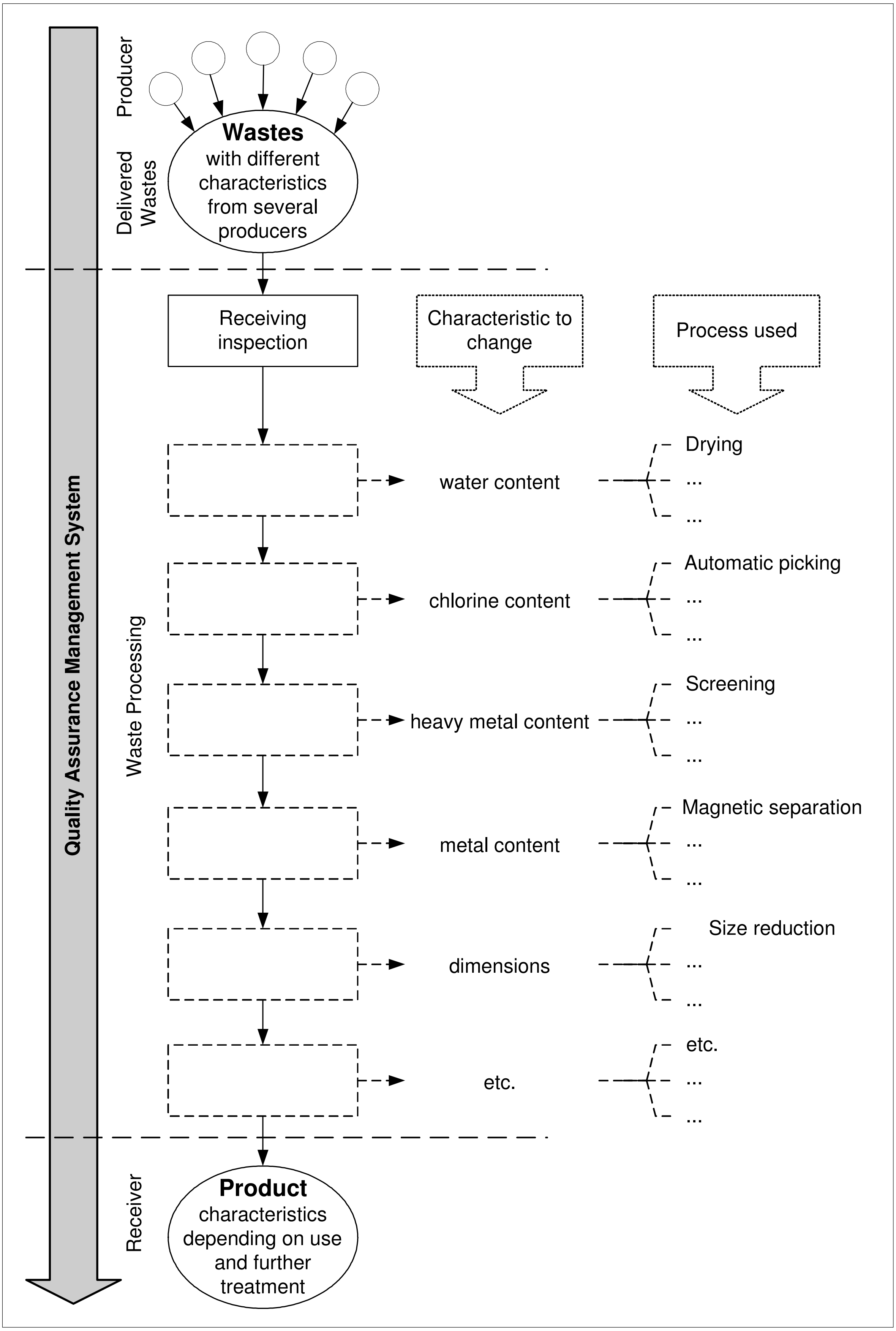
Quality Assurance Management System
Producer
Delivered Wastes
Wastes with different characteristics from several producers
Waste Processing
Receiving inspection
Characteristic to change
Process used
water content
Drying
...
...
chlorine content
Automatic picking
...
...
heavy metal content
Screening
...
...
metal content
Magnetic separation
...
...
dimensions
Size reduction
...
...
etc.
etc.
...
...
Receiver
Product characteristics depending on use and further treatment

Figure 1: Process scheme

Source selection may be the first action to take into account for monostreams. Pre-selection may also be incorporated in the collection system for mixed commercial wastes. The waste receiving area as the first important facility with regard to the quality assurance management system is the receiving inspection. All kinds of disturbance materials, which might cause operation or quality problems, have to be sorted out.

All following processing steps are modules depending on what product quality is requested. If the water content has to be reduced to increase the calorific value a drying process step is necessary, implemented as thermal or biological drying step. In the case of mechanical biological treatment the process of SRF production is a kind of mechanical upstream facility, because the high calorific wastes are separated before the rest of the material is fed into the biological degradation step to lower the organic content. In some cases the biological degradation step is part of the SRF production, with the main focus on lowering the water content. In other cases the biological degradation step is also arranged in a SRF production, but with the main focus on lowering the organic content to keep the respective disposal criteria for the material which is not part of the SRF product and need to be disposed. In dependence of the applied process different regulations for emissions can obtain.

A very important processing step is the screening step, before and after grinding. Screens are applied for mass and volume division by particle size. It is noticeable that in small particle size mixtures the content of hazardous substances accumulates in comparison to the screen overflow. As recorded in several studies the main part of the heavy metals was found in the fine fraction. Depending on the waste composition the product quality increases by discharging the fine fraction with suitable screen openings.

But, screening is not suitable to lower the content of chlorine. High chlorine contents entail better technical processing equipment for flue gas cleaning. PVC in wastes is mainly responsible for the chlorine content. PVC appears in a wide range of particle sizes, so screening processes are not suitable to discharge PVC, neither do air classifiers or other sorting aggregates, which separate by density. But, it can be discharged by automatic sorting.

Sorting the metals with magnetic separation and eddy current separator has positive effects on the product quality of the SRF and protects the machinery against damages. And with regard to closed loop recycling management, metal is a potential recyclable.

In dependence of the extend of proceeding and the desired quality of the SRF the amount of materials sent to landfill varies in a wide range. Therefore, it is substantial to distinguish between two different processing strategies: positive and negative sorting. Positive sorting means that only the desired materials with high calorific values and low contents of harmful substances are sorted out of the material flow. This strategy leads to a higher amount of landfill material and probably to a higher quality of the produced SRF. Negative sorting strategies only separate the materials which are disliked in the product e.g. PVC because of the content of chlorine. With this strategy the amount of landfill material might be less because other materials which might contain a higher content of harmful substances end up in product. Other strategies just separate the inert material and metal fraction and lower the organic and water contents. The rest ends up in the product what automatically lowers the amount of the landfill material. Regarding economic aspects about positive and negative sorting, it is not possible to make a general statement. Depending on the required quality negative or positive sorting is applied. If a high grade material flow is requested, negative sorting is advisable and the revenue for the product is higher than for positive sorting but the amount of product is less. Nevertheless, some contaminants cannot be sorted out, because they are kept or hidden in the material, so scanning devices cannot recognize them.

After the final processing step a product is obtained. In some cases additional processing steps to design the product for the consumers' desires are required, e.g. compacting or further size reduction /5/. Table 4 shows the correlation between the fuel preparation processes and the application for different purposes.

Table 4: Additional processing steps /6/

Fuel preparation process		Co-combustion process			
	Prepared fuel in form of	Cement kiln	Circulated fluidised bed	Pulverised coal power plant	Gasification & pulverised coal power plant
FP 1	Bales	Shredding (fluff), covered storage	Shredding (fluff), covered storage	Pelletising, storage, pulverisation	Shredding (fluff), covered storage
FP 2	Soft pellets	Covered storage	Covered storage	Covered storage	Covered storage
FP 3	Hard pellets	Covered storage, simple crushing	Covered storage	Covered storage, pulverisation	Covered storage
FP 4	Chips				
FP 5	Powder				

3.2. Wastes used and products

3.2.1. Wastes used

In general the input material of SRF processing plants is a mixture of different wastes generated under different basic conditions. The consequence is a wide range of each characteristic listed in Figure 1 (cf. page 14) including the water content.

3.2.1.1. Wastes used for SRF

Non-hazardous solid wastes include production specific wastes and high calorific fractions of MSW (i.e. household and commercial solid wastes, packaging wastes). In Germany, the Bundesgütegemeinschaft für Sekundärbrennstoffe e.V. has established a positive list of waste suitable for the production of SRF within the quality management system (cf. chapter 5.2.1.). The complete list is attached in Annex I of this document.

3.2.1.2. Practical examples for products

In Germany RWE Umwelt AG provides two different kinds of SRF. SBS® (Substitutbrennstoff) and BPG® (Brennstoffe aus produktionsspezifischen

Gewerbeabfällen) are based on non-hazardous wastes. SBS® is made in different quality categories from high calorific fractions of MSW (i.e. household and commercial solid wastes, pre-sorted packaging wastes).

BPG® is made in different quality categories from non-hazardous production specific commercial wastes with a high calorific value /7/.

Herhof Umwelttechnik GmbH produces a SRF which is called TROCKENSTABILAT® and is derived from household wastes. It concerns a high calorific fraction, which is produced with simple processing techniques like magnetic separation, eddy current, comminution, screening etc /8/. In this process a biological degradation step for the main purpose of lowering the water content is applied.

In the Netherlands the company Kappa Roermond Papier produces a SRF which is called ROFIRE®. It is derived from non hazardous recycled paper and from non hazardous production rejects /9/.

Other companies have their own specific quality, but did not register the SRF under a trade name.

3.2.2. Products and by-products

3.2.2.1. Products

SRF are sold as different forms of appearance. Table 1 gives an overview of the different terms for products; special trademarks with certain characteristics are presented in chapter 3.2.1.

Table 5: Overview of the different products

Product	Physical and chemical characterisation
Fluffy secondary fuels	Particle size, bulk density, moisture content, net calorific value, ash content, chemical composition
Soft pellets	
Hard pellets	
Chips	
Powder	

The requirements on the side of the users can define the product quality and their characterisation. Power plants, cement and lime works, gasification plants, multi fuel boilers etc. have different standards for the use of SRF dependent on their technology, waste gas treatment and product specification.

3.2.2.2. By Products

In dependence of the processing method there will be some by-products generated. According to the quality of the produced by-products they might be recycled directly or treated after a further processing. The current by-products are ferrous and non-ferrous metals and an inert fraction. The quality of the ferrous and non-ferrous metal product depends on the waste content and the processing method. Higher quality products are applicable for material recycling.

The inert fraction could be used, if in accordance with the local regulations, as construction materials e.g. road construction material or for landfill. In rare cases a recycling material is produced which is used as raw material e.g. some kinds of plastics and glasses. Furthermore by application of an air separator a heavyweight fraction can accrue which is applied for energetic utilisation, too.

3.3. Production process

The production of SRF can be divided into the following steps. However, it should be mentioned that the processing of SRF is not a standardised process. The extend of processing is connected to the type of waste at the input and to the following application of SRF. The functional units listed below present only an overview about possible techniques; they are not necessarily part of each process.

Receiving area / bunker

Pre-sorting / contaminants selection

Feeding equipment

Size reduction

Metal separation

Classification

Air classification

Near Infrared Spectroscopy

Automatic picking

Compacting / pelletising

Storage / storage area / hopper

Biological degradation / thermal drying

Exhaust gas collection and cleaning

Waste water treatment

Loading and transportation

3.3.1. Receiving area / bunker

The first part of the receiving area is the check-point including the weighing bridge. The receiving area must offer the opportunity to take samples and to pre-sort the waste from unwanted items.

Depending on the delivered wastes the receiving area / bunker can be equipped with technical installations to fight fires, because some wastes tend to auto-ignition especially wastes with a high organic content. Biological degradation may cause high temperatures and in some cases this can cause fire. Moreover, the disposed wastes can already contain glowing particles e.g. incomplete burned coal. The receiving area is normally covered and the gates are often closed because of odour, dust and noise emissions. The receiving area or bunker has an air ventilation installation which collects the exhaust air. However, this is not needed for production specific wastes and certain high calorific fractions. The air might be loaded with dust and odours which should be cleaned to comply with immission standards. To prevent leaking air from the inside some plants are equipped with an air ventilation system which creates a negative pressure in the receiving area or bunker. The bunker or the equipment to feed the process should allow a constant feeding to abate overloads of machines.

3.3.2. Pre-sorting / selection of disturbance materials and contaminants

The feeding process is very important because it has a big influence on the product qualities. An effectual homogenisation has to be guaranteed and high contaminated loads should be barred from SRF processing because they might downgrade the product qualities. So, a strict delivery control is advantageous. This can be aimed by taking samples when there is no information about the delivered wastes or by a logistic effort, which offers the opportunity to exclude heavily contaminated wastes from processing. Nevertheless, it might happen that delivered wastes might cause problems, so it is advantageous if the persons in charge are alert on problematic wastes. However, these people should be aware of all materials which might cause problems during processing. In dependence of the applied machines these might be large bulky parts or other components like metals. If these persons are highly alert an almost continuously processing with a small range of quality fluctuations might be guaranteed. Some plants have separated bunkers for different kinds of waste e.g. household wastes / commercial wastes similar to household wastes and production specific commercial wastes.

3.3.3. Feeding equipment

Wheel loaders or cranes are usually applied for the feeding of the process. These facilities have an overpressure cabin to comply with occupational health and safety regulations.

3.3.4. Comminution

Comminution in processing is the step to downsize the particle sizes. The aim of comminution depends on the following processing steps or on the application of the down sized products. The comminution can be differentiated into the following impacts:

Comminution for disintegrating of composite materials: A further processing does only make sense, if the different materials are separated by comminution. Then a desired concentration is possible.

Production of fractions with a defined maximum particle size or a certain size range to convert materials for sorting or classifying: For optimal separation results in further processing steps it is necessary to accomplish specific requirements concerning the upper or lower particle size and the size range respectively.

Comminution processes can be classified as rough, middle and fine comminution. Rough comminution is called crushing and fine comminution (< 1 mm) is called grinding. In SRF plants rough comminution is principally used.

3.3.4.1. Hammer mill

Hammer mills are used for the comminution of brittle-rigid materials and of relative thin-walled scrap from electric appliances. Hammer mills have a steel panel and at least one fast moving rotor with oscillating bedded hammers or brass knuckles. The hammers align radial as a result of the circulating rotor. Serious damages are avoided because of the flexible bedded hammers. The feeding material is hit by the hammers and so it is reduced to small pieces. The strain depends on the kind of material. Brittle-rigid wastes are reduced to small pieces by collision and impact.

The discharge of the hackled material runs through a grid located at the bottom. The shapes and the range of the grid openings give an impact to the upper particle size of the comminution product. The smaller the grid openings are, the lower the throughput is, which is of course also dependent on the kind of material to comminuted. Brittle-rigid materials are not as much influenced by the grid opening as ductile materials.

In general the internal space of hammer crushers is equipped with steel panels to protect against abrasion. The hammers can be reversed before they must be exchanged because of abrasion. The operator can vary some parameters between certain limits to influence the result of comminution. The parameters are: Circumferential velocity, grid openings, shape of hammers, condition of abrasion, distance between hammers and grid or housing elements, installed power of the driving motor and the temperature of the feed material.

3.3.4.2. Shear shredders

Shear shredders are principally used in SRF processing plants. The universal possibility for applications of shear shredders was approved with a variety of solid waste materials among other things household wastes, bulky refuse and commercial solid wastes etc.

Shear shredders are equipped with two slow turning shafts (approx. 10 – 30 rpm) in the interior. On each shaft several toothed cutting plates are fixed. Each toothed cutting plate turns between two cutting plates of the other shaft. The cogs can welded on of plates against abrasion. The feed material is strained lengthwise and also in transverse direction. The particle size depends on the distance of the toothed cutting plates and the number of cogs. The material strain in shear shredders is very complex. Besides cutting strain there is tension and tear strain which often has positive impact on the result of comminution. The feeding works automatically as long as the feed material is not too bulky or voluminous. In that case a hydraulic plunger is applied to assist the feeding.

In case of an overload caused by disturbance components the drive motors of shear shredders stop and reverse their running direction. If after a certain number of reverse rotations the shear shredder does not work without faults the drive motor stops completely and the disturbance components have to be removed manually. In some cases hydraulic pre-stressed shafts can extend there distance and the disturbance components can pass the shear shredder.

3.3.4.3. Single shaft shredders

Single shaft shredders can be applied as universal as shear shredders. The principal difference to shear shredders is that there is only one rotating shaft which has a higher number of revolutions (approx. 90 – 160 rpm). The geometry of the cutters fixed on the shaft is different to the of shear shredders. This leads to a different application range. Single shaft shredders are applicative for the comminution of

Electric / electronic scrap,

Cables,

Plastics of cars,

Plastic packaging wastes,

Carpets, textiles and

Wood.

The housing consists of steel panels and in the interior there is a massive rotor equipped with cutters and a screen for discharge. The screen encloses the rotor approx. 180°. Furthermore there are stator cutters fixed to the housing with a distance of approx. 0,1 mm to the rotary cutters. In most cases they are equipped with a hydraulic plunger for the feeding. The plunger is controlled automatically and presses the material against the rotor. It is controlled by demand to avoid peaks. After the plunger has reached the predetermined position it is retracted and another cycle starts. The material is reduced to small pieces between the cutters fixed to the rotor and the stator cutters fixed to the housing by cutting strain. The upper particle size is appointed to the discharge screen. Smaller screen openings lower the flow rate because of the rising dwell time. The material discharge is often designed as integrated screw conveyor. Disturbance components in the feed material can lead into broken cutters. To protect the equipment hydro clutches are applied to lower the stator cutters and the screen is also lowered hydraulically. Another possible reason for a lowered flow rate is the abrasion of the cutters. Then the cutters should be exchanged. In most cases it is possible to reverse the cutters before a change. From time to time a change of the stator cutters is also necessary.

3.3.4.4. Rotary cutters

Rotary cutters are counted among the fast rotating comminution machines because they are operating with number of revolutions of approx. 400 – 600 rpm. They are applied for all materials which can be strained by cutting but they are markedly damageable by disturbance materials e.g. ferrous. In SRF processing rotary cutters are applied for:

All kinds of plastics

Leather,

Rubber and

Other tough elastic materials.

The housing is stable and can be opened. The interior is equipped with a rotor with several cutters. In most cases the cutters are very short; this is an advantage because it offers the opportunity to change only the cutter which is damaged by disturbance materials. Similar to the single shaft shredder there are stator cutters fixed to the housing which can be adjusted. The distance between rotor cutters and stator cutters is approx. 0,1 mm. A screen to discharge the material and to convert the upper particle size is located at the bottom of the housing. The feeding is cuneiform so that particles which are to big can not pass and damage the cutters. If the cutters are not acute the energy demand rises because the strain turns from cutting strain to tearing and breaking strain. For that reason the cutters are made of hardened steel followed by the disadvantage of breaking out when strained by hard disturbance materials. Worn cutters should be changed as soon as possible. The worn cutters can be grinded and reused. The rectangular shaped stator cutters can be reversed up to three times. The material discharge is operating with pneumatic assistance and offers some advantages:

The unwanted content of extremely fine-grained material in the end-product is reduced,

The rotor including the cutters and the housing are cooled down,

The energy demand is reduced and

The transportation of material is assisted.

3.3.4.5. Cam shaft shredder

Cam shaft shredders can be applied for the comminution of complex waste mixtures like household wastes, bulky wastes, wood wastes. Cam shaft shredders are counted among slow rotating machines with a circumferential velocity of approx. 1 m/s. The principal strains are tension and tear. Machines which are applied for the after comminution are working with a circumferential velocity of approx. 12 m/s. Cam shaft shredders can designed with one or two shafts. The rotors are toothed. The shape of the cogs depends on the comminution problem. The cogs grip through a hydraulic pre-stressed cam. The cogs ensure the material feed. A cam shaft shredder does not work well with tough elastic plastics so a selective comminution of a material mixture takes place. That can be useful if the further processing step separates the material because of their different particle sizes. Massive disturbance materials can be discharged by hydraulic cylinders moving the cam. Rotor and cogs are made of hardened steel and in most cases they can be changed quickly.

3.3.4.6. Cascade Mill

The cascade mill is a tumbling mill with diameter approximately 3 times its cylindrical length. The body of the mill is a rotating cylinder with tapered ends.

The cascade mill operates using hard substances of the waste itself as the grinding medium (metals etc.). To support the size reduction steel balls are normally added.

The comminution takes place by rubbing and rolling effects. These strains can evoke a cleaning of the surface of materials. The treatment of waste by cascade mills can evoke as well a selective comminution of inert substances and organic waste.

Because of the high attrition the inner side of the mill is lined with steel plates and from time to time it is necessary to add steel balls.

3.3.5. Metal separation

To separate for instance ferrous metals out from solid waste, it is possible to use different properties of the material. The most important characteristics in waste treatment are density, shape, the magnetic susceptibility and the electric conductivity. But in most technical processes the quality of separation is strongly affected by the different particle sizes and masses. In addition, there are several kinds of beverage cartons on the market, which are made of composite materials. Classifying and crushing is substantial for achieving satisfying sorting results.

Nevertheless, the efficiency of separation is influenced by grain size and grain shape with the consequence that most sorting units have to be combined with additional crushers, classifiers and separation units to achieve the requested results.

3.3.5.1. Separation of ferrous metals

Magnetic separators extract ferrous metals from a mixture of materials. The flow of material passes through a high magnetic field, so that magnetisable pieces will be deflected and sorted separately. The use of magnetic separators is integrated in most processes of waste treatment. On the one hand magnetic separators extract iron and steel as a resource, e.g. extracting tinplate cans from lightweight packaging. On the other hand it is essential to remove any ferrous metals in order to avoid operating trouble and to improve the product quality, e.g. magnetic separators are used in cable recycling processes to protect the knifes of rotary cutters and for the subsequent cleaning of the copper product. But, it must be pointed out that the usual magnetic separators cannot extract stainless steel. This is due to the fact that stainless steel is not or slightly magnetisable. The three most important types of magnetic separators are explained in the following subchapters.

3.3.5.2. Overband magnetic separator

Overband magnetic separators are applied in processes to separate continuously bigger iron and steel parts out from the material flow. They consist of a magnet system which is installed in a short axe distanced belt conveyor. All parts are carried by a strong steel frame. Overband magnetic separators are always placed above a conveyor (mostly belt conveyor) on which the material passes the magnetic field. Ferrous material will be extracted out from the flow upwards to the revolving conveyor belt. The conveyor belt transports the ferrous material continuously and discharges it after leaving the magnetic field. The total construction of the overband magnetic separator has to be made of non magnetic materials like stainless steel to avoid field deformation, which could lead to bad sorting results and could block the process.

The most important positions to install an overband magnetic separator in combination with conveyors belts is crossbelt, across the conveyor belt and inline, lengthwise to the belt, right above the trajectory of the material. The latter way of installation (lengthwise) has to be preferred, because the separation of the loosen material out from the trajectory is more effective. If the magnet is aligned transversally to the material, the power of the magnet must be several times higher than in lengthwise alignment, because sometimes non magnetic objects are situated onto ferrous items, which the magnet has to extract from.

Overband magnetic separators work with distances up to 400 mm to the conveyor belt. Therefore they need a long distance magnetic field to extract heavy ferrous items, too. The magnets can be made of electromagnets or, by using middle and small range separators, also permanent magnets. Nevertheless, it is indispensable to re-sort the material with a magnetic drum separator or with a magnetic pulley, because small ferrous particles could still remain under a non magnetic layer.

By sorting municipal solid waste (MSW) with a certain content of plastics with a large surface, overband magnetic separators will extract inevitably these plastics together with the ferrous items. To minimize this discharge it is recommended to increase the belt conveyor’s velocity gaining a low level of the material. Generally, the realized result you can achieve with overband magnetic separators is very high, up to 98 weight % iron output.

3.3.5.3. Magnetic drum separator

Magnetic drum separators are used for separation of small to medium sized ferrous pieces up to a grain size of 150 mm. They are made of a static magnetic system and a non abrasive (robust) drum shell. The drum shell, which turns around the magnetic system, is made of a non magnetisable steel ejection strips. The magnetic field is caused by electric or permanent magnets. The magnetic systems are divided in axial pole and vertical pole. This leads to a continuous or a changing magnetic field polarity in its sense of direction. Axial poles are used if a high recovery of fine-grained ferrous particles is requested, whereas vertical poles guarantee a higher purity of the iron product. The latter results from the relative movement of the ferrous items on the drum shell, when the polarity changes and the adhered not magnetisable material will be released. The magnet system is fixed on the drum axle and is adjustable to the direction and kind of feeding.

The mode of operation how the material could be fed is divided in an overfed layout and in an underfed layout. In an overfed layout the material is charged onto the drum, right before the crest, by using a vibrating chute. In this case, only magnetisable items are held on the drum shell until they reach the limit of the magnetic field at which point the material falls off the drum and will be collected behind a non magnetisable separating plate. The advantage of the overfed layout is that ferrous parts get directly in contact with the strongest magnetic field, and as a consequence fine-grained and slightly magnetisable items can be well separated.

In an underfed layout the drum shell attracts ferrous metals through the air gap and drops them – similar to an overband magnetic separator – not before leaving the magnetic field. Concerning a homogenous feeding it is indispensable to use vibrating chutes.

Normally, in waste processing the underfed operation is only relevant for special applications, e.g. in shredder scrap processing. The approach pole of this drum causes a strong and far-reaching magnetic field to extract securely the shredded and compacted scrap. The transport of the ferrous material till the dropping line will be done by additional weak poles. Because of the strong abrasion during scrap sorting the drum shell is manufactured with 8 mm thick plate made from hard manganese steel.

3.3.5.4. Magnetic pulley

The design of a magnetic pulley is similar to the magnetic drums. The main difference is the way of feeding, which is indirect. This means that magnetic pulleys are installed in conveyor belts instead of the standard drive. The feeding of the material is always from above. To compensate the conveyor belt the magnet system must be stronger in comparison to magnetic drums to realize the same retention force. The magnet system operates completely within the perimeter of the drum and rotates synchronously with the drum shell.

The magnetic field, caused by permanent or electric magnets, keeps the magnetisable material on the belt till it will be dropped behind the crest, the rest material falls with the normal trajectory. The design of the magnetic fields can be varied in a way that their position to the conveyor drum is axially parallel or vertical.

This leads to similar effects of the radial or axial pole position in magnetic drums. It is very common to use magnetic pulleys in plants, where the space is limited, where a drive drum is changed by a magnetic one or where a high output with a low ferrous content must be treated.

3.3.5.5. Separation of non-ferrous metals with Eddy Current separator

Eddy current separators or non-ferrous metal separators are units specially designed for the use in recycling plants to separate selectively non-ferrous metals. The principle of eddy current is that only good electro conductive pieces produce a voltage in an alternating magnetic field. This leads in circuits to a current flow, so called eddy current. The current produces in turn a magnetic field, which is contrary to the external field. This leads to a rejection of the non ferrous metals out from the rest of the material. The force of the rejection depends from the following parameters:

The grain size of the non ferrous elements should be between 3 and 150 mm. The separation result will be improved, if a classification is chosen before. It is difficult to separate longish and plane components, like aluminium foil and copper wires, because of the weak eddy current in these materials.

The electric resistance and the consistency have a big influence on the eddy current. For instance, it is easier to repel aluminium than brass. But the conclusion to separate different non ferrous materials from each other cannot be drawn, because of the big influence of grain size and shape in comparison to its repulsive force.

The strength and the range of the alternating magnetic field are increasing linear to the square of its distance to the material.

The higher the frequency of the alternating magnetic field the better fine-grained non ferrous items can be separated.

Generally, eddy current separators have a fast rotating magnet wheel, which is built in the drum shell made of fibre reinforced plastic. The magnet wheel is made of permanent magnets with alternating polarity, which cause in the rejecting zone a variable magnetic field with a frequency up to 1000 Hz. The use of permanent magnets with a high remanence, mostly neodymium steel boron magnets, and their arrangement in the magnet wheel guarantee a far reaching field. The magnetic pole system is positioned either eccentric or centric. Centric pole systems suffer from small iron particles, which find a way between the conveyor belt and the drum shell. These particles are attracted along the whole perimeter of the drum, become hot and finally could damage the plastic drum. Additionally, the position of the magnetic pole system in eccentric systems is variable in a way that the strongest field is directed to the rejection zone.

To achieve good sorting results, a single grain layer is essential, which is realizable with vibrating chutes. Additionally, it is advisable to separate fine-grained ferrous particles with a magnetic drum in an overfed layout before feeding the eddy current.

3.3.5.6. All-metal separators

All-metal separators are applied for auto separation of ferrous and non-ferrous metals. These aggregates are applied if the content of metal in the feed material is quite less, other metal separation operations do not work efficiently enough because of very high demands on the product qualities or downstream aggregates have to be protected e.g. rotary cutters. In SRF-processing they are mainly applied for plastics processing. High throughputs can be realised if the material is diversified before auto recognition. Normally, all-metal separators operate with a detection coil which is placed transverse to the direction of transport and cut into single segments. If a metal particle enters the high frequent alternating magnetic field of the coil it influences the field. This information is handled by an electronic controlled microprocessor which is able to identify the coil segment close to the metal particle. This particle is separated by one or more air jets located close to the detection coils. The metals are separated by a partition plate. Detection coils are able to detect metal particle sizes of approx. 1 mm and larger. The shape and the mass are not important for the separation process.

3.3.6. Classification

A classification with sieves is applied in SRF processing when:

Products of up streamed processing should be converted for further processing steps, i.e. a separation into defined size fractions.

A separation of coarse or fine particle sizes is required.

A comminution product has already a high content of particles with the final particle size and only oversized particles should be reduced in size again.

Certain materials should be concentrated. In that case it is called sorting classification. This also includes the separation of the small size fraction which often contains a high content of heavy metals substances.

3.3.6.1. Drum screens

Drum screens are preferably applied to waste mixtures with a high content of large surface particles e.g. separation of packaging wastes, household wastes or commercial solid wastes. Advantages are the operation free of vibrations, the homogenisation and the cleaning of surfaces of adhering small particles which often contain a high content of heavy metals substances. Drum screens consist of cylindrical screen decks. The drive is operating with a disk where the cylinder is supported on. The cylinder is inducted from axial and the feeding material is transported via friction and centrifugal forces along the screen walls to a certain point which mainly depends on the number of revolutions.

In dependence of the velocity of the drum different operating modes arise: cascade or cataract mode.

The cascade effect develops by operating with slow revolution. During the cascade mode the material is rolling off and sliding over itself. By increasing the rotational speed the cataract effect develops. The material is transported higher and when falling down the whole screen area will be effective. Figure 2 and figure 3 show the different operating modes.

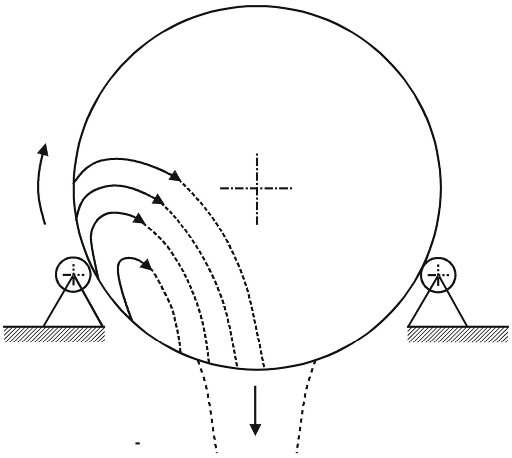

Figure 2: Cascade mode

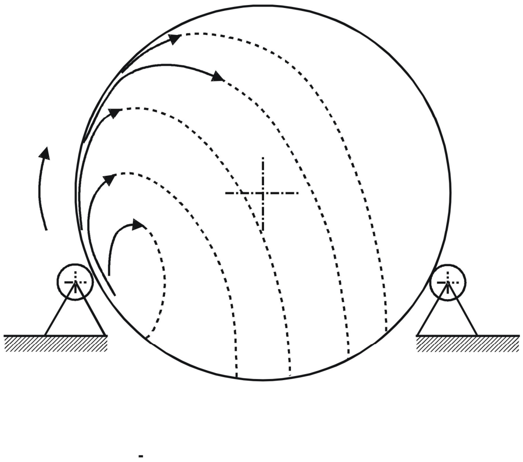

Figure 3: Cataract mode

The drum screen gives the best results at a rotational speed of 70 % of critical in the cataract mode. The disadvantage of the cascade mode is that the screen will create lumps. Fines will not be well liberated.

The material in transport direction slides down and in connection with the inclined screen cylinder (approx. 3° - 5°) it is transported through the screen drum. This procedure is repeated until the discharge. Because of the revolution of the material the particles smaller than the screen openings have the opportunity to get into the underflow. The transportation speed depends in principal on the angle and the number of revolutions of the screen. To increase the efficiency lifters are fixed inside the screen to pick up the material and to carry it higher, so that the material falls down on free area. Feeding material with a high content of coarse particles (approx. 100 – 250 mm) often causes problems with blocking of the screen what is followed by the decrease of efficiency because of a high content of large particles in the overflow. To protect the screen against blocking bushings which are welded on have proved well. Drum screens can be applied for multiple-stage screenings then the screen openings close to the feeding area are smaller than the openings located close to the discharge. By use of separating plates several screening products can be produced.

3.3.6.2. Linear and circular oscillating screens

There several different models of oscillating screens existing. The common characteristic is the mechanical activated screen which is lying in a stable framework. The material lying on the screen is loosened and transported by oscillating movements. Both effects make sure that particles smaller than the screen openings can get into the underflow.

In dependence on the kind of pulsation, the manner of drive and the movement of the material oscillating screens can be divided into different types of construction. The two most important models are linear oscillating screens and circular oscillating screens.

The excitation of linear oscillating screens is caused by two counter rotating unbalances. In small models they can be designed as unbalances motors or they can be driven by electric motors with a cardan shaft. The oscillation is almost equal to the direction of transport so that the material flow all over the screen deck works well, i.e. that the transportation can take place even if the screen ascends a little. The circular oscillating screen is activated with an unbalance located in the centre of gravity. The circular pulsation stops material transport so that the screen has to be declined (approx. 12° - 20°). Both types of construction can be applied in dry and wet screenings. Oscillating screens can be designed as one stage or multiple stage screens. In case of multiple screens the screen decks are located among themselves. The characteristics water content, grain shape and particle size distribution affect the efficiency of the screening. But basically the length of the screen deck is responsible for the efficiency and the width of the feeding area is directly proportional to the maximum throughput.

3.3.6.3. Flip-flop screens

A sieve with specific applications in recycling processes for particle sizes between 1 and 30 mm is a flip-flop screen. They are applied for materials which are difficult to screen caused by e.g. humidity or irregular shaped particles which tend to stick to the screen deck or cause blockings. There are two frameworks driven in the opposite direction with an eccentric. In the framework cross beams are fixed. Rubber screen mats are fixed to the cross beams so that one rubber mat side is connected with one framework and the other side is connected to the other framework. Caused by the reverse drive each mat is stretched and unbent like a trampoline which causes high accelerations and loosening to the material. Furthermore the screen mats are hyper tensed when they are stretched so that the screen mats are cleaned from adherences and obstructions. Because of the strong vertical accelerations it is necessary to cover flip-flop screens to prevent the loss of material. The material flow is ensured by the inclined screen.

3.3.6.4. Flat screens and tumbler screens

Flat and tumbler screen machines are characterized by a specific kind of oscillation. The screen deck oscillates in the same direction as the screens framework. Longish particles do not pass the screen deck even if the transverse extension is smaller than the screen openings. The framework is inclined (approx. 5°) and bedded on a suspension strut. The declination ensures the material transport. They are driven with a vertical shaft with an eccentric at the top of the shaft located under the framework. The feeding material is sliding along the screen deck so that oblong particles do not erect and do not pass the screen openings. Multiple stage screening is possible to about 4 screen decks which are located among themselves. It is possible to use rapping equipments to avoid blockings. Then balls made of rubber are lying between the screen decks to rap on the screen decks. The screens can be covered for an application without any dust emissions. Applications of flat screens in recycling processes are limited because of the very soft strains with accelerations only caused by gravitation.

In tumbler screens the horizontal oscillation is superposed by vertical forces what causes a tumbling movement of the screen. Tumbler screens are applied for fine grain screenings. All operations between a circular oscillation and a tumbler oscillation are adjustable by adjusting the unbalances. Tumbler screens are applied for dry and wet classifications.

3.3.6.5. Moving grates

The term moving grates summarizes rod shaped oscillating screens and rolling grates where the screen area consists of shafts and discs which turn in the same direction. Grates are applied for pre-screenings to separate large particles or for screenings of adhesive materials. Each screen deck consists of several parallel cross beams located one after each other and fixed only on one side. Distance and declination can be adjusted for each rod. Often it is advantageous to have different declinations at two adjoining rods what causes an opening in direction of transport and an operation without blockings.

If the screen oscillates with directed vibrations because of eccentric drives the rods also start to vibrate. The amplitude and the frequencies depend on the thickness and length of the rods. The separation size is defined by the rod distance but it does not exclude oblong particles from passing the grate. It is an advantage that the material is revolutionized because of the steps between grate decks followed by material loosening in combination with an increasing screening result.

Rolling grates are constructed as different types which principally differ in shapes and dimensions of the discs. They all have in common that they consist of several parallel shafts located next to each other with the same distance with round, polygon-shaped or star-shaped discs or cylinders. That principle causes rectangular or quadrate grate openings. The distances between the shafts take influence on the grate openings. Rolling grates can be inclined and particles which do not pass the grate are transported to the discharge side. Rolling grates are characterized by a smooth operation without vibrations and can be applied for separation sizes between approx. 8 to 80 mm. The application of moving grates in the SRF-processing is as limited as the application of flat screens.

3.3.7. Air classification

3.3.7.1. Air classifier

Air classification can separate dry solid materials depending on their specific density, particle size and shape. These characteristics often overlap, so pre-treatment of the feed material is necessary to ensure that one separation characteristic is more distinct. This can be aimed by a pre-screening to concentrate plane particles in one screening product. Only if the ratio of the overflow to the underflow is 3:1 a satisfying separation is ensured.

The field of main application in waste processing or SRF processing is the sorting of mixtures containing light parts of plastics, paper, expanded materials or the like.

Typical field of application in SRF processing is the separation of high calorific products from pre-classified wastes generated from households or other mixed wastes. The functional principle of air classifiers is based on a material mixture which is inserted in a duct which again is flown through by air with a defined velocity. Light particles which can be picked up by the air are twisted out and separated from particles with a higher specific density. Air classifiers are categorised by the direction of the air flow in the classifier duct in: Upstream and transverse stream air classifiers. In the upstream air classifier the air streams from the bottom to the top. The feeding material is fed into the heeling by a belt conveyor. In contact with the reverse streaming air the light particles are lifted along the stream while the heavy fall. The lightweight material is pneumatically transported to the separation chamber by a duct. For this purpose cyclone separators are often applied. Cyclone separators consist of a cylindrical sheet metal bin which bottom part is conic. The air intake is tangential. The solids describe a helical movement down and they are discharged by a rotary valve which prevents inleaked air. The air flows out via an immersion pipe which is connected to the suction side of a ventilator. Approx. 30 % of the air of the circular flow is discharged on the pressure side of the ventilator and cleaned by a dust filter. This operation offers the following advantages:

The filter to separate the dust can be designed much smaller because the air which has to be cleaned is less than 1/3 of the conventional operation.

No air loaded with dust is discharged at the loopholes for the feeding conveyor or the heavyweight discharge.

The circulating air does not concentrate dust particles or moisture.

The air velocity at the separation zone can be exactly adjusted by butterfly valves.

The air velocity for dry papers, thin-walled plastics and plastic films for example is approx. 11-12 m/s. The minimum recovery of this high calorific lightweight material amounts 70 %. The amount of air consumed for air classifiers depends on the geometry of the classification duct. The throughput rate of air classifiers is limited by the specific load which maximum capacity can be 0,35 kg solids/(m^3air * h).

For applications in recycling processes not all available air classifiers can be applied. In most cases the applied aggregates are special designs because they have to treat large particles.

3.3.7.2. Aeroherd

In few cases aeroherds are applied in SRF processing. Aeroherds can be described as air passed inclined oscillating screens. There are two types of construction: One which is only inclined in longitudinal direction and the others with a cross inclination. The first type sorts by density into two products. With the second type it is possible to get a lightweight and a heavyweight product and also different products with average densities which are often not liberated composite materials. Aeroherds are equipped with a hood. In the middle of the hood there is a pipe to collect the air which also contains dust particles. Comparable to the air classifier there is a ventilator which discharges approx. 15 % of the total air volume via a filter. This operation offers the same advantages like the air circulating system of the air classifier. The air passes the screen deck from the bottom to the top and fluidises the material so that there are different layers as a result of different densities. The heaviest particles have friction contact with the screen and are transported to the discharge because of the screens oscillation. The lightweight particles which are much more fluidised are transported downwards and discharged via a weir. Aeroherds normally operate with a better selectivity. The following parameters take influence on the separation result:

The range of particles sizes of the feeding material: The range of upper and lower grain size should be less than 3:1 and the upper grain size is approx. 40 mm.

The differences in density of the solids: If the content of heavy particles is to low the separation might be difficult and causes a yield loss of light material.

The grain shape of input material: Significant differences degrade the separation. Only in exceptions e.g. sorting of plastic films this can be an advantage.

The air velocity on the up side of the screen deck: The air velocity can be adjusted continuously variable with butterfly valves.

Direction of the streaming air: With the choice of the exchangeable screen decks the direction of the air stream can be influenced, e.g. with the application of nostril shaped openings a targeted streaming can be reached.

The amplitude and the frequency of oscillation: The range of oscillation wide is adjustable in narrow confines while standstill.

The longitudinal inclination of the screen: If there is a lot of spherical material the longitudinal inclination can be adjusted while standstill.

The charging of the aeroherd: A volumetric metering of the feed material is essential for an optimal operation.

Aeroherds which also have an inclination transverse to the direction of transport, can produce several products. The quality control is easy because the separation process is observable and adjustable by partition plates for each discharge opening. The basic parameters for the quality of separation are principally as like as the parameters of the two-product aeroherds. Additional possibilities are the adjustment of partition plates and the alterable transverse inclination.

3.3.8. Near Infrared Spectroscopy

Near infrared spectroscopy (NIR Spectroscopy) is applicable for auto recognition of beverage cartons, pulps and plastics. Several processes were developed during the last years. The material which has to be separated is often feed on a belt conveyor. The conveyor is operating with fast velocities so that its function is like an isolating device. Two with halogen lamps equipped light lifters and the detector are installed above the belt conveyor. The detector consists of a NIR sensor which scans the whole width of the belt conveyor and transmits characteristic spectrums of the different materials to a data processor. The signals are compared with a database. The analysis contains the calculation of the actual position on the belt conveyor and the knowledge of measurements in only a split second. The real sorting is operating with an air jet batten in front of the discharge end. The air jet lifter is equipped with several single air jets with a distance of about 30 mm. Each air jet is fed by a pressure reservoir and is steered by magnetic valves. The data processor transmits a signal if the detection of a particle is positive and the air jet blows it out. Here one or more air jets can be activated. The pressure surge blows out the particle which is then separated of the material flow by a partition plate. Auto recognition devices can sort particle sizes between approx. 30 to 300 mm. The application is the selective separation of beverage cartons, paper, cardboard, mixed plastics like PE, PP, PS, PET and PVC. The operation width of the belt conveyors vary between 500 to 1.400 mm. The throughput of pre-classified light packaging with particle sizes between 50 and 200 mm amounts between 1 and 6 t/h. The separation of dark brown and black materials is impossible because the NIR light is almost completely absorbed so no irradiation is reflected to the sensor. The recovery of potential recyclables is in dependence on the waste qualities approx. 80 to 90 %. The reachable product qualities are 90 to 97 %. Important for the separation result is the kind of feeding because it is necessary to singularise the material on the belt conveyor.

3.3.9. Automatic picking

Automatic picking gains more and more recognition in the waste treatment sector, especially, if a product with certain specifications is required. The material passes a vibrating chute which feeds a conveyor belt. A metal detector is located under the conveyor belt, which sends specific data of each particle to the computer unit. Additionally, a colour camera located above the conveyor belt processes particle information to the computer unit. Both information lines will be analysed by special software, before the computer unit transmits impulses, instructing the nozzles to blow out the single particle or allow it to pass (positive or negative sorting). Both the accepted and the rejected products are then transported by single belts to further treatment or storage.

Actual top automatic picking systems combine special characteristics of multi sensor systems. They incorporate a high speed camera with 1 billion colours with e.g. a special conductivity sensor which permits the separation of various materials. With a belt width of 1200 mm and depending on the feed material it is possible to handle a throughput of 2 – 8 t/h, a grain size of 3 – 250 mm. Within this range an acquisition and evaluation up to 10.000 particles per second is possible. The discharge system used for is based on compressed air supported by air jets with a circuit time of just 1 msec /10/.

3.3.10. Compacting / pelletising

Compacting is the aggregation of particles with different grain sizes to bigger agglomerates. The principle aim is to arise density by agglomeration or by sintering (Heating of surface till boiling point with particle bond).

Pelletising is the production of mainly cylindrical grains from unformed bulk materials by conditioning, compression-mould (flatbedpresses or ringdiepresses) and cooling (belt coolers or counter current coolers).

Granulation is the production of granulate. In comparison to pelletising the material matrix melts completely. There are several kinds of granulators applied (e.g. disc-agglomerators). Most of them operate discontinuous.

The advantage of compacting and pelletising is based on the reduction of volume, the improvement of flow and dosage characteristics and the binding of dust. During compression the temperature arises so it is necessary to install a cooling operation downstream. For specific requirements to the final product concerning the size screens are often installed downstream. These screens can operate as cooler if there is an air stream installed which can blow from the bottom to the top or from the counter current flow.

Pelletising is the main operation in SRF processing if the SRF product is agglomerated. This results from the advantage of superficial melting because the SRF-pellets keep their shapes during loading, transport and reloading. This does apply to granulates as well but the production of granulates is more energy-intensive because of the complete melting of the matrix. Before pelletisers are applicable an efficient disturbance materials separation has to take place to protect the aggregates from exceeding attrition.

3.3.10.1. Flatbedpresses

Flatbedpresses consist of a cylindrical housing with a round transverse steel plate in the inside of the cylinder. The steel plate operates as die plate and has plenty of openings with an equal diameter. The opening wide determines the diameter of the pellets. The material is charged from the top. The material falls down on the die plate and one or more slow revolving rollers roll with a circular orbit across the material and presses it through the die plate openings. Because of the high pressure the temperature arises and the material surface begins to melt. Below the die plate a cutter is installed. The cutter cuts the pellets and the distance between cutter and die plate appoints the pellet length and is adjustable. The quality of the pellets decreases with a higher throughput. For compensation the duct length can be lengthened. The moisture of the material affects the pelletising operation, the pellet quality respectively.

3.3.10.2. Ringdiepresses

Ringdiepresses operate similar to flatbedpresses. The main difference is that the die is a ring instead of a flat plate. The ringdie stands upright or lies horizontally. The rollers are arranged horizontal and the rollers and the ringdie are rotating. One or more cutters are located on the outside of the ringdie to cut the pellets into the desired length. The parameters length and diameter of the pellets are adjustable in the same manner as by flatbedpresses. Ringdiepresses are fed with an inclined chute from the top which leads the material to the inner side of the ringdie. The pellets quality is also affected by moisture content and throughput, length, diameter and form of the holes in the die. There also exists one type of ringdie press, which has been established as a comminution aggregate.

3.3.10.3. Disc-agglomerators

Disc-agglomerators consist of a metal housing with one or more discs inside. The inner side of the reactor is filled with material discontinuous. The discs which have superstructures to stir the material much better start to rotate. The friction energy is converted into frictional heat. The material is homogenised by stirring and begins to melt. At the moment the material is plasticising the energy consumption rises and can give the signal to empty the reactor. Because of the complete melting the energy consumption for this process is much higher than for pelletising. Depending on the equipment for discharge the material can be granulated. After process the material has to be cooled down.

3.3.11. Storage / storage area

The storage area or the hopper should be equipped with fire protection facilities. Organic matters and also the high temperatures of pellets can still cause fires. In some cases the pellets can stick together because of a bad cooling operation. In these cases technical equipment to support the discharge might be advantageous. If the pellets are not stored in a closed hopper with exhaust air collection the storage area can have an exhaust air collection system because the pellets often release odorous air because of the foregoing warming.

3.3.12. Biological degradation / drying system

The biological treatment process is applied in mechanical – biological waste treatment plants. The biological degradation system has mainly two functions. First the content of organic matter is reduced by micro organisms and then the water content is lowered to improve the material characteristics for the down stream processing and to increase the calorific value. According to the applied process the degradation is more or less distinct; sometimes the focus is on the drying. Depending on the system incidental process water during the biological degradation has to be cleaned before releasing to the canalisation. To keep biological activity the system is fed with air. The exhaust air is collected and has to be cleaned as well.

The biological degradation system is not handled in this part of the BREF because it will be mentioned in the part for mechanic-biological waste treatment plants but the manufacturers` instructions of SRF-processing with mechanic-biological treatment in chapter 4 include these emissions from the decomposing system.

3.3.13. Thermal drying

In some plants the waste material will be dried in a specific processing step to increase the calorific value and reduce the weight. Moreover, fines may be removed after drying. In this case the waste will be fed to a continuously operating rotary kiln. The size of the material should be less than 100-200 mm to avoid clogging of the feeding and discharge units of the kiln. The rotary kiln is heated indirectly to avoid fires. The maximum temperature in the kiln should not be higher than 80 °C to avoid fouling of the wall by melting plastics. The heated air can be introduced to the rotary kiln with transfer direction or counter current.

3.3.14. Exhaust gas collection and cleaning

Facilities which discharge odours and dust maybe enclosed to prevent emissions and to reduce the amount of contaminated air which has to be cleaned afterwards. A well operating exhaust air collection system ensures a minimum of germs, fungi, spores, odours and dust particles. This is supposed to have positive effects on the physical health of the employees and reduces times absent. The side effect is the reduction of noise emissions to the employees.

In dependence of the exhaust air loads several different waste gas cleaning techniques are applied:

Dust separation:

Cyclone

Bag filters

Electrostatic precipitators (ESP)

Lamella separators

Odours treatment:

Bio filters

Bio scrubbers

Activated carbon adsorption

Thermal exhaust air decontamination

Regenerative thermal oxidation

3.3.14.1. Cyclone

Centrifugal force separates solid particles or liquid droplets from the flue gases. Cyclone filters are used to remove heavier particulates which 'fall out' as the flue gases are forced into a rotating motion before they leave the separator again. Exist in the form of a cyclone or multi-cyclone which separate finer dusts.

3.3.14.2. Bag filter

The creation of a barrier separates the dust from the flue gases. In-situ cleaning by air pulse, counter flow air or mechanic tapping and therefore need to work in pairs. Reliability depends highly on filter material.

3.3.14.3. Electrostatic precipitators (ESP)

Electrostatic precipitators use high voltages to attract and remove particulate matter from the flue gases. There are two different kinds of operation.

Dry: Collection of dust on electrodes, under influence of electric field.

Wet: Same as above, except the electrodes are cleaned to increase effectiveness. Flue gases are saturated with vapour before entering the ESP.

3.3.14.4. Lamella separators

Lamella separators are only applied for separation of rough dust particles. The air stream flows through several parallel plates with hooked bumps. The air stream is forced to change its direction. Because of the inertia of the particles they are separated in the dust trap and split from the air stream.

3.3.14.5. Bio filter

Bio filters are applied for great volumes of exhaust gas streams with low organic loads in particular exhaust gases with intensive odours. The bio filter consists of an apparatus filled with decomposable material like compost, bark or a mixture of turf and heather etc. On the material micro organisms (fungi, bacteria, viruses and algae) are resident. The exhaust air flows through the material while the micro organisms decompose the harmful substances. Water and air transport normally runs in a counter current flow. A bio filter is not a filter in the mechanical view (separation of particles), it is a reactor where a certain range of harmful substances is metabolised to harmless substances.

3.3.14.6. Bio scrubber

In comparison to the bio filter the micro organisms are not fixed in the bio scrubber on organic materials. The biomass swims quasi free in the suspension which is sprayed on the exhaust gas in counter current flow. The principal difference is that the absorption of the harmful substances is local separated from the metabolism.

3.3.14.7. Activated carbon adsorption

Activated carbon has a large volume of very small pores which create a large surface area. Typical activated carbons have surface areas from 600 to 1,200 m^2/g. Activated carbon is applied for purification and removal of trace organic contaminants from liquid and vapour streams. There are several different applications for activated carbon. The exhaust gas can be purified by an activated carbon fill or by an injection of activated carbon into the air stream with a downstream separation by a textile filter. If an activated carbon filter is applied the exhaust air hast to be purified of dust first because the dust can cause clogging followed by an increasing pressure gradient.

3.3.14.8. Thermal exhaust air decontamination

In the thermal exhaust air decontamination process step the exhaust air is treated in a combustion chamber with temperatures up to 850 °C and a minimum remaining time of 2 seconds. Within this space of time the harmful substances will be oxidised totally and the cleaned gas can be released.

3.3.14.9. Regenerative thermal oxidation

Similar to the thermal exhaust air decontamination the hydrocarbons are oxidised in a combustion chamber, but the ratio of the heat recovery is higher. The air passes through a ceramic heat exchanger and is heated. Then in the combustion chamber the oxidation takes place by a burner. The heated air whose organic substances will be oxidised quantitatively heat the second heat exchanger. After short period of time the stored heat of the first heat exchanger is depleted while the second ceramic heat exchanger is hot. By cyclic switch of the heat exchangers continuous operation is ensured.

3.3.15. Waste water treatment

An example for waste water treatment is given in the German Annex 23 of the Waste Water Ordinance (AbwV) is applied to wastewater whose pollutant load originates mainly from facilities for biological treatment of waste from human settlements and for other waste that is to be treated like waste from human settlements, and the precipitation water contaminated, through operations, within such facilities.

According to this annex the stream volume and pollutant load of wastewater from facilities shall be kept as small as possible by means of the following measures:

Extensive recycling and multiple use of process water,

- Prevention of entry of precipitation water into waste-storage and waste-treatment areas, by means of enclosures, roofs or covers.

The wastewater may be discharged into water bodies only insofar as process water from process and waste-air treatment in mechanical-aerobic-biological treatment facilities cannot be used completely in internal processes. In such cases, the requirements pursuant to Table 3 shall apply.

Table 6: Requirements pertaining to wastewater for the point of discharge /11/

	Qualified random sample or 2-hour mixed sample	
Chemical oxygen requirement (CSB)	200	mg/l
Biochemical oxygen requirement in 5 days (BOD_5)	20	mg/l
Total nitrogen, as sum of ammonium, nitrite and nitrate nitrogen (N_{total})[*1]	70	mg/l
Total phosphorous	3	mg/l
Total carbon[*2]	10	mg/l
Fish toxicity T_F	2	

[*1] The requirement for total carbon refers to the random sample

[*2] A standard defined for total nitrogen shall be considered complied with if the standard is measured and complied with as "total bound nitrogen (TN_b)"

According to the ordinance the generated wastewater is often used for waste gas cleaning process e.g. for humidification of the bio filter or for the operation of the bio scrubber. In some cases it is applied for cooling processes with an open evaporation. Because of the small volume of wastewater filter techniques are the main applied operations.

3.3.16. Shipping and transportation

The solid SRF products are stored on heaps, in containers or hoppers. The storage in containers or hoppers causes less emission because the loading process can take place with only one lorry. In case of a heap storage another wheel loader is necessary to load the lorries. The containers have to be covered if there is the chance that the goods can emit dust during transport and to preventing loss and getting wet.

4. Actual Values of emission to air, water and soil by plants for the production of secondary fuels, energy consumption and auxiliary materials

4.1. Methodology

For the sake of this BREF several plants were visited to find out the actual applied techniques for solid SRF processing. Solid SRF producers were asked to fill in a questionnaire. The questionnaire in German is attached in Annex II and in English is attached in Annex III of this document. In total 47 SRF producers were addressed (30 from Germany, 7 from the Netherlands and 10 to ERFO members from Belgium, Finland, France, Great Britain and the Netherlands). The response amounts 19 % which means 9 questionnaires sent back, six from Germany. Two of them run a mechanical biological waste treatment plant for waste from MSW. Four run a processing plant for SRF production from MSW, but without biological degradation system. The remaining two plants produce SRF from production specific commercial solid wastes. For the sake of completeness it is mentioned that the high calorific product of one mechanical biological waste treatment plant is used as input material for the purpose of further processing in one of the mentioned four MSW processing plants without biological degradation system. The following table gives an overview of the investigated plants.

The flowchart and the process scheme of the investigated plants are attached in Annex IV and Annex V of this document. Both represent processing plants for commercial waste.

Table 7: Overview plants of received questionnaires

Plant number	Type of plant	Capacity [t/a]	Kind of SRF production	Operation since
1	Mechanical-biological waste treatment	110.000	High calorific fraction in bales	2002
2	Mechanical-biological waste treatment	100.000	Fluff	2000
3	MSW processing without biological decomposition step	840.000	Fluff	1996
4	MSW processing without biological decomposition step	23.000	Fluff	1997
5	MSW processing without biological decomposition step	80.000	n.s.	2002
6	High calorific fraction from MSW processing and commercial waste processing plant	100.000	Soft pellets, fluff	1996
7	Commercial waste processing plants	100.000	Soft pellets, fluff	1996
8	Commercial waste processing plants	65.000	Soft pellets, fluff	1997
9	Commercial waste processing plants	40.000	Soft / hard pellets	2000

The returned data refer mainly to the basic year 2001. Because of the limited knowledge of energy consumption figures (c.f. Table 12) the GUA (Cost Benefit Analysis) study was applied for calculations of CO_2 equivalents. Relevant emissions like CO_2 and CH_4 could be reduced significantly by the use of SRF. This refers to the different scenarios in the study which regards landfilling and energy production by incineration of fossil fuels.

4.2. Emission to air

SRF processing plants are within the scope of waste treatment and have to comply with local immission regulation.

Unloading platforms, bunkers or other facilities for the purpose of delivery, transport and storage of ingredients can be built in closed buildings equipped with air lock gates with negative air pressure. However, air lock gates are not necessary for production specific wastes and high calorific fractions of MSW, because of their negligible odour and dust emissions. Machines, apparatus or other facilities for mechanical processing or physical separation of materials or accruing wastes have to be encapsulated. As soon as an air tight construction in particular at the facilities for feeding, discharge or transfer is not possible, the exhaust gas streams have to be removed by suction.

Accruing exhaust gas streams have to be channelled so that the transport takes place untroubled in the free air stream. The air has to be diverted via stacks.

4.2.1. Amount of treated waste, products in correlation to the exhaust gas

Table 8 shows the amount of treated waste and the SRF production in tonnes per year. Depending on the type of plant (cf. Table 7) there is a big difference in ratio between the treated waste and the SRF products. This is explained by the fact that some plants treat commercial waste and other plants MSW. Additionally, the producers follow different ways to produce their SRF. For instance, if the fine material is added to the SRF product and not disposed in a landfill, the amount increases but the quality decreases significantly. Other plants are building up their capacities by modifications or produce SRF in a combined production with MSW processing plants.

Table 8: Amount of treated waste, products in correlation to the exhaust gas

Plant number	Amount of treated waste [t/a]	Amount of SRF products [t/a]	Amount of exhaust gas [m³/h]
1	110.000	19.500	120.000
2	63.100	30.700	45.000
3	780.000	90.000.	90.000
4	22.700	17.400	not specified (n.s.)
5	19.400	16.300	n.s.
6	10.000	9.000	48.000
7	30.000	27.000	48.000
8	32.000	31.700	48.000
9	22.000	15.300	18.000

4.2.2. Dust

Table 9: Dust emissions

Plant number	Dust [kg/year]
1, 3 - 9	n.s.
2	394

4.2.3. Odours

Table 10: Odours emissions

Plant number	Odour units [OU/m³]
1	406
2	220
3 – 9	n.s.

4.2.4. Noise

Table 11 shows the received noise emissions of the plants. The declared values are taken from the technical approval. The difference in the wide range of the values can be explained by the location of the processing plants, different input materials and operating times, e.g. one, two or three shift operation.

Table 11: Noise emissions

Plant number	Distance to the location of immission [m]	Acoustic pressure level day / night as technical approval [dB (A)]
1	200	50 / 39
2	n.s.	n.s.
3	650	38 / 37,5
4	n.s.	n.s.
5	n.s.	n.s.
6	1.000	< 50 / < 35
7	1.000	< 50 / < 35
8	10	< 70 / 70
9	n.s.	< 40 / < 40

4.3. Energy consumption

4.3.1. Power

The following table depicts the power consumption. The big difference of energy consumption in relation to the amount of input material is caused by the kind of processing plant and the type of generated SRF; for instance, if drying facilities are installed or the generated SRF is made in different grain sizes and shapes (cf. Table 7). This as a consequence makes a fair evaluation or comparison of these data impossible.

Table 12: Energy consumption

Plant number	Energy consumption [MWh/a]	Energy consumption [kWh/t input material]
1	1.870	17
2	5.800	92
3	23.650	30
4	n.s.	-
5	781	40
6	315 – 405	32 – 41
7	1.080 – 1.620	36 – 54
8	1.268 – 1.902	40 – 59
9	2.400	109

4.3.2. Fuel

Except for thermal drying processes as mentioned in chapter 3.3.13 fuel is not required for SRF production; fuel is only necessary to run the vehicle at the process area like forklifts or wheel loaders. These consumptions were not specified in the returned questionnaires apart from one producer with thermal drying, whose gas consumption is about 21.250.000 MJ per annum. The specific consumption amounts to 1.390 MJ/t input material.

4.4. Wastes

With reference to Table 8 the difference between the amount of input and product output must be adjusted with the amount of potential recyclables like e.g. ferrous and non-ferrous metals is the amount of waste, which has to be disposed. The content of potential recyclables depends on each waste composition, which varies in a wide range. Therefore, further specifications are not given in this document.

Furthermore residues may accrue during waste gas cleaning process.

4.5. Use of further ingredients

In general no further ingredients besides waste are deployed which end up in product.

4.6. Use of auxiliary materials

To ensure failure-free operation the process and material handling equipment have to be lubricated. Several detergents are applied.

Furthermore there are auxiliary materials applied to support the exhaust gas cleaning process. These figures are shown in Table 13:

Table 13: Auxiliary materials

Plant number	Sodium hydroxide [t/a]	Phosphate [t/a]
1, 3 - 9	n.s.	n.s.
2	1,8	0,3

4.7. Plant safety

Emissions are caused by normal operation. But emissions accrue through uncontrolled fires what happened several times in recent years.

4.7.1. Hazardous situations

Biological degradation processes may cause self heating and auto-ignition. Thereof affected is not only the biological treatment system. Auto-ignition may also happen in the bunker. And in some cases fires appeared in the product storage area. A second reason for fires in SRF processing plants are still glowing particles.

4.7.2. Technical constructions for prevention hazardous occasions

In some plants smoke detection systems, sprinklers and water spray fire-extinguishing systems are installed for fire prevention.

4.7.3. Organisational arrangements for prevention

To prevent fires and to alert the staffs they can be instructed by a safety inspector. Further arrangements can be planned with the responsible institutions.

5. Characterisation of secondary fuels and quality assurance systems

5.1. Introduction

There are several initiatives to characterise and to install quality assurance systems for SRF. It can be divided into initiatives on European levels and into national levels.

5.2. Quality assurance systems

One part of the description of the best available technique is the logistical organisation of SRF processing. By choosing and using specific waste materials SRF producers set a kind of quality assurance themselves. Quality assurance systems already exist and further regulations are in the development phase.

In the past, SRF was mainly produced from process related wastes as mono-batches which were easier to handle because of their constant qualities. Nowadays high calorific fractions of municipal solid wastes and of other mixed wastes are in the picture as source for the production of SRF, which makes the need for a quality assurance system more urgent. The aim of a quality assurance system for SRF is to attain and ensure constant qualities to increase acceptance by end users and permitting authorities. The requirements mainly concern product quality. The following sections present a survey about the existing quality assurance systems and the actual developments.

5.2.1. RAL

Early 1999 the German Bundesgütegemeinschaft für Sekundärbrennstoffe e.V. (BGS e.V.) started its endeavours to install the quality label GZ 724. The label is awarded to SRF producers which comply to the requirements by guaranteeing constant qualities. The standards firstly relate to cement industry and power stations. Accordingly SRF have to fulfil the criteria given in annexes 1 and 2 of the GZ 724. Annex 1 contains a list with all allowed wastes which are applicable as a basic principle. In annex 2 values are given which have to be met. These values are shown in Table 14. The inspections in the acknowledging as well as in the supervision procedure occur in two phases.

Level 1:

The three samples, taken by the independent supervisor, and seven samples out of the pool of the self monitoring are analysed according to table 1 of the annex 2. For the heavy metal contents occurs:

(a) The median value of the results of the analysis of the ten samples must not exceed the allowed median values given in Table 14, and (b) the “80. percentile” values in table 4 must not be exceeded by eight out of ten samples (Application of the “4 out of 5-Regulation”).

Level 2:

If, within level 1, the median or the “4 out of 5-Regulation” could not comply, another ten samples will be chosen out of the sample pool of the self monitoring and be examined for the parameter(s) that did not comply. The analysis occurs similar to level 1:

(c) The median values of the results of the analysis of the 20 samples must not exceed the allowed median values given in table 4, and (d) the “80. percentile” values of table 4 must not be exceeded by 16 out of 20 samples (Application of the “4 out of 5-Regulation”).

Further parameters need to be documented as follows:

- the calorific value,
- the humidity,
- the ash content, and
- the chlorine content /12/.

These values should not be regarded as strict thresholds. The conditions are kept if four of five outlier still keeps the 80% percentile. Outliers often appear in waste analysis and this regulation is specific to the character of wastes. The guideline value is determined as median because of the obvious low concentration emphasis in waste and environmental analysis. Heavy metal contents are established applying the DIN or DIN EN ISO test methods. As digestion method is applied aqua regia in a closed microwave system.

Table 14: Heavy metal contents which have to be complied according to BGS /12/

Parameter	Content of heavy metals[4)]	
	Median [mg/kg$_{Dm}$]	80-percentile [mg/kg$_{Dm}$]
Cadmium	4	9
Mercury	0,6	1,2
Thallium	1	2
Arsenic	5	13
Cobalt	6	12
Nickel	25[1)] 80[2)]	50[1)] 160[2)]
Selenium	3	5
Tellurium	3	5
Antimony	25	60
Lead	70[1)] 190[2)]	200[1)] -[3)]
Chromium	40[1)] 125[2)]	120[1)] 250[2)]
Copper	120[1)] 350[2)]	-[3)] -[3)]
Manganese	50[1)] 250[2)]	100[1)] 500[2)]
Vanadium	10	25
Tin	30	70
Beryllium	0,5	2

1) For solid recovered fuel from production specific waste

2) For solid recovered fuel from the high calorific fractions from municipal waste

3) Restriction not until a secured database is given by the fuel processing

4) The above-mentioned heavy metal contents are valid up to a calorific value NCV_{Dm} of ≥ 16 MJ/kg for the high calorific fractions from municipal waste and up to a calorific value NCV_{Dm} of ≥ 20 MJ/kg for production specific waste. For calorific values falling below, the above-mentioned values need to be lowered accordingly, an increase is not allowed.

Furthermore the BGS e.V. demands for an acknowledging procedure (first inspection) and a monitoring proceeding which also is cut into self-monitoring and independent supervision. A re-inspection is also scheduled.

Moreover annex 2 defines sampling instructions including the analytical examination extent and analyses regulations for all different surveillances.

5.2.1.1. Acknowledging procedure (first inspection)

To attain the quality label the applicant has to absolve the acknowledging procedure. This first inspection is conducted by a neutral inspection institute which investigates the applied techniques and the employees situation. The SRF have to keep the regulations in annex 2. Furthermore the applicant has to verify his practice and expert knowledge, reliability and the official permission for operation of the plant. On top of that he has to give evidence that he is able to conduct a continue self-monitoring system. Parts of the self-monitoring can be carried out by a neutral inspection institute in arrangement with the BGS e.V. But this inspection institute is not allowed to carry out the independent supervision at the same time.

5.2.1.2. Self-monitoring

The self-monitoring concerns the control of the production process and is carried out by the enterprise itself. Exceptions were explained above. In this connection the input material has to be documented in form of a mass balance with documentation of the European Waste Catalogue Code (EWC), mass, derivation, chemical-physical parameters and the output as produced SRF. The produced SRF have to be approved concerning the requirements from annex 2.

5.2.1.3. Independent supervision

The independent supervision is conducted by a dedicated inspection institute which is nominated by the BGS e.V. The quality of the produced SRF is controlled and the completeness and the plausibility of the self-monitoring documentation are reviewed. The ascertained personal situation from the approval proceeding is appraised. The monitoring intervals depend on the yearly produced amount of SRF.

5.2.1.4. Re-inspection

A re-inspection is carried out within a period of four weeks if in the framework of the independent supervision the supervisor detects any faults in the quality assurance. If the re-inspection fails, the independent supervision is considered as failed as a whole. The further action is laid down in the implementation instructions for awarding and using the quality label of the BGS e.V.

The BGS e.V. can decree penalties depending on the irregularity. This can be an admonishment or the cancellation of the label.

5.2.2. SFS 5875

The Finnish waste disposal system is based on a separate collection of wastes for the recycling and for SRF production. Different solid wastes and Finnish boilers with a high technical standard are applied for a high efficient energy production followed by low emission levels. The application of SRF in the Finnish multi fuel boiler is estimated as “well suited”. The regulations concern separate collected, dry solid, high calorific fractions or for dry, high calorific fractions derived from household wastes. The regulation defines operations and demands to control the SRF production. The regulation refers to the complete waste management chain, from the waste recovered paper source up to the disposal. For each part of the disposal chain the standard requires a person in charge who monitors the technical and quality requirements /13/.

Analogical to the BGS e.V. standard the annexes of the Finnish standard define concrete requirements concerning thresholds for heavy metals as well as for the framework of analysis, sampling etc. Predefined are the thresholds which have to be kept as well as regulations as regard to the matter of contracts.

5.2.2.1. Supervision operation

The compliance with standard is guaranteed by contracts and stipulated delivery specifications between the respective groups within the disposal string. Regulations concerning self-monitoring, independent supervision or acknowledging procedures are not new defined in this standard. Therefore the regulations of the standardisation institute have to be obeyed.

5.2.2.2. Quality requirements and quality classes

In comparison to the BGS e.V. standard the Finnish standard divides into three quality classes. For categorisation of SRF in Finland seven elements contents are analysed. Limiting values for heavy metals are given for cadmium and mercury.

Furthermore the classification into one class requires an analysis for the contents of chlorine, sulphur, nitrogen, potassium and sodium. Table 15 presents the criteria for the classification into quality classes. Metallic aluminium is not allowed for quality class I ([1)]) but is abided within the accuracy (two decimal places). The metallic aluminium content of SRF of quality class II ([2)]) is already reduced by sorting and further processing steps. For SRF of quality class III ([3)]) it is necessary to acquiesce to the content of metallic aluminium separately. The given thresholds refer to a volume of SRF of ≤ 1.000 m³ or to the volume which is produced or delivered during one month.

Table 15: Quality classes according to SFS 5875 /13/

Parameter	Unit	Quality classes		
		I	II	III
Chlorine	weight -%	< 0,15	< 0, 5	< 1,5
Sulphur	weight -%	< 0,2	< 0,3	< 0,5
Nitrogen	weight -%	< 1,0	< 1,5	< 2,5
Potassium and Sodium	weight -%	< 0,2	< 0,4	< 0,5
Aluminium (metallic)	weight -%	- [1)]	- [2)]	- [3)]
Mercury	mg/kg	< 0,1	< 0,2	< 0,5
Cadmium	mg/kg	< 1,0	< 4,0	< 5,0

1) Metallic aluminium is not allowed, but is accepted within the limits of reporting precision.
2) Metallic aluminium is minimized by source-separation and by the fuel production process.
3) Metallic aluminium content is agreed separately.

In principle the SRF quality is specified by means of the table above. A second possibility for an arrangement about the characteristics of SRF is the possibility to attune to the content and amount of parameters. The amount of parameters can comprehend further thresholds and characters in extend to the defined quality classes. Concerning the analysis of the chemical and physical parameters the respective ISO standards apply.

5.2.3. CEN/BT/TF 118

The CEN Task Force 118 "Solid Recovered Fuels" was established in April 2000. The Task was to prepare a technical report about the production and the application of SRF within the EU as well as the development of a work programme as basis for an European standard in the future. The European classification model should be based on SRF characteristics, source material and origin. The letter "X" in Figure 4 stands for chemical and physical SRF characteristics. "Y" stands for the specifications which are arranged between producers and recyclers. Thresholds and requirements intend to be added here in future. The source material (mono-batches, mixtures), origin (production specific, household) as well as composition are indicated "Z" /14/.

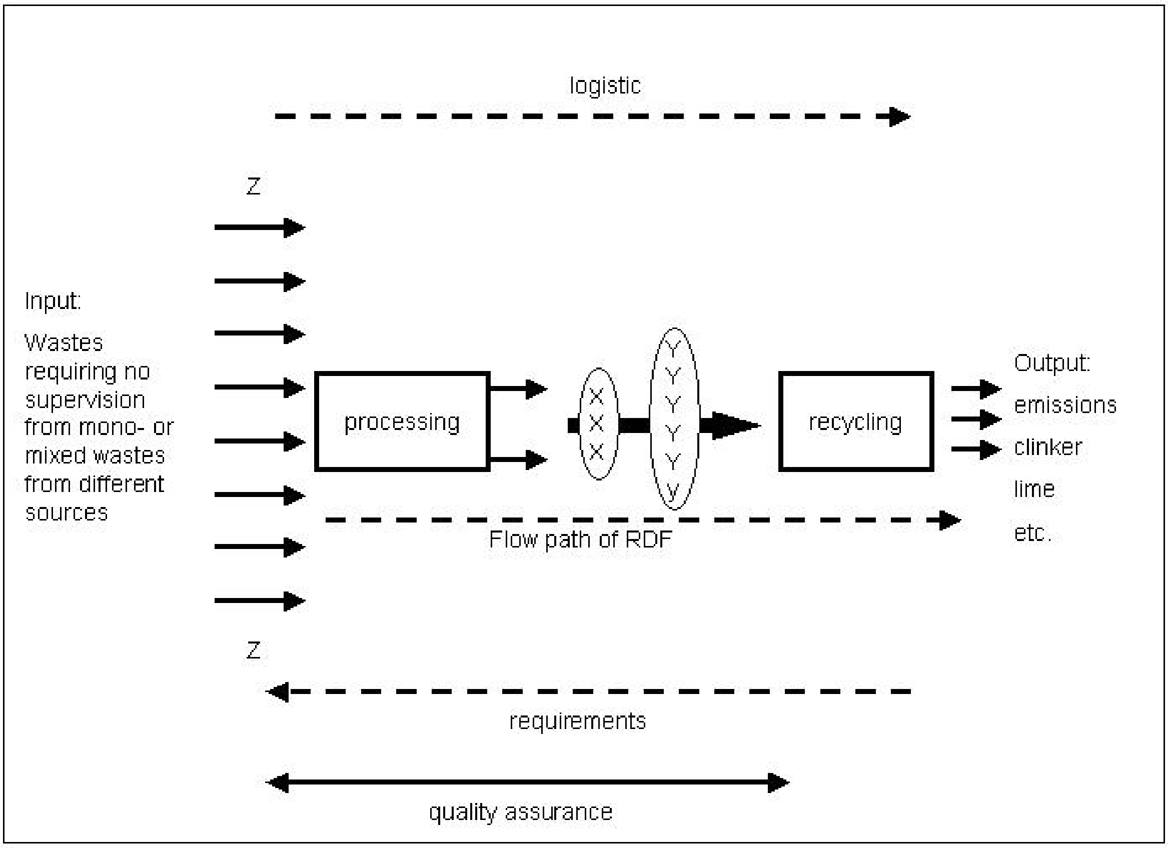

Figure 4: Suggestion to standardisation of the SRF production and application /14/

The report concludes that it is necessary to develop a European standard. CEN is given the mandate to develop, as a first step, a set of Technical Specification concerning the use of SRF for energy recovery in waste incineration or co-incineration plants. As a second step, CEN is given a mandate to transform this set of Technical Specification into European Standards /15/.

5.2.4. ÖG SET

Within a joint project of the “Östereichische Gütegemeinschaft für Sekundärenergieträger (ÖG SET)” a quality assurance concept is worked out. The work commenced in May 2001 and it should be finished by May 2003. The result ought to be a base for a label alike the one generated by the BGS e.V.

5.2.5. Other

There are internal quality assurance systems existing e.g. the generated quality assurance system by Trienekens AG whose successor is RWE Umwelt AG. Table 16 gives an overview about the system.

Table 16: Quality assurance system of RWE Umwelt AG /16/

Process step	Measures	Supplementary measures
Origin (waste producer, sorting plant, mechanical biological processing)	Collection of wastes Avoidance of impurities Contractual arrangements about allowed qualities of wastes Declaration analysis Documentation of disposed amounts	Instruction courses for waste producers Periodic controls of the waste producing company by the disposer
Processing plant (delivery)	(regular) sampling and analysis Reserve samples Documentation of input and processed amounts	Regular sampling and analysis of the outgoing materials by a external official expert
Processing plant (output)	Regular sampling and analysis Reserve samples Documentation of the delivered amounts	
Cement and lime kilns, power plants	Regular sampling and analysis Reserve samples Documentation of the input amounts	

5.2.6. Comparison of quality assurance systems

The regulations of the German Bundesgütegemeinschaft für Sekundärbrennstoffe e.V. should complement internal quality assurance systems. The regulations according to RAL-GZ 724 are a completion of ISO 9000 and are specified for SRF. The Finnish regulation aims an incorporation into existing systems which allows the possibility to make an agreement concerning the SRF quality between the producer and the consumer. The BGS e.V. defines actually two classes whereas the Finnish separates into three different quality classes. It is already decided that the quality classes will be expanded /27/. The result may be a classification system as shown in Table 17 and additional parameters with respect to fuel technology and process engineering /27/.

Table 17: Classification system /27/

		Codification of the columns				
Parameter	Unit	A	B	C	.....	X
NCV	MJ/kg					
H_2O	% o.s.					
Chlorine	% o.s.					
Ash	% o.s.					
Hg	mg/MJ					
Cd	mg/MJ					
Sum of As, Co, Cr, Cu, Mn, Ni, Pb, Sb, V	mg/MJ					
Biogenic part	% o.s.					

The BGS e.V. standard demands the documentation of the chlorine content whereas the Finnish defines thresholds for each quality class.

The implementation of the Finnish standard into practice seems not as applicable as the German quality label GZ 724. The approach of the Finnish standard is quite different in comparison to the German quality label. The German system is based upon an extensive data basis and considers the complete process chain. The Finnish standard regulates high calorific fractions derived from separate collected wastes and defines procedures and requirements for SRF quality control.

6. Tools to assess the suitability of secondary fuels in typical co-incineration plants

6.1. Environmental aspects

6.1.1. Use of transfer factors

The material flow analysis (MFA) was developed by Baccini and Brunner as a model for the material input and output flows of well defined systems /17/. Transfer coefficients (TF's) were introduced in 1999 by Fehringer, Rechberger and Brunner /18/. These coefficients reflect the share of the input of a system that ends in a defined output. TF's are increasingly adopted in the assessment of mechanical treatment and thermal processes /19/.

6.1.2. Use of material flow analysis (Example North Rhine Westphalia)

The MFA was introduced in NRW as an instrument for the assessment of the effects of waste derived fuels e.g. SRF in co-combustion. The method was introduced with a decree in October 2000 /20/.

Aim of the decree is to assess the suitability of defined recovery processes for waste derived fuels with a well-known composition. Therefore the concentration of the parameters mentioned in the German decree 17th BImSch are calculated and compared with the standards for incineration plants according to this decree.

An overview of the results descending from the practice of SFA is given in /21/.

The results show that industrial co-combustion may be a meaningful option, certainly for those waste derived fuels that meet the quality standards of RAL-GZ 724.

6.1.3. Possibilities and borderlines of such tools

The MFA offers the possibility to determine sensitive parameters. Mercury may be mentioned that needs special attention in co-combustion processes concerning air-bound emissions due to its high volatility.

The rather conservative approach applied in reference /21/ is disputed, as 90 percentile values regarding the composition of wastes and SRF are compared with mean values of coals. Therefore, the conclusion drawn that co-combustion would mean higher emissions is not confirmed in practice. Actual investigations show that fuels derived from wastes should be characterised by their median values /22/. The compliance with the daily mean values (emission standards) should be considered using mean realistic TF's. Recent research /22/ shows that TF's could vary substantially at a plant for a defined parameter. This means that the power plants cannot be sufficiently described with a single TF for each parameter. Therefore TF's were established for technical configurations specified by their firing and waste gas treatment systems /23/. However, the data base for some parameters is still poor for specific configurations.

In a consistent conversion of the Waste Incineration Directive (WID) in national law of the Member States the MFA may became superfluous as an instrument for directing the waste stream, as the WID guarantees a considerable equalisation of co-combustion and mono-combustion concerning the level of emission standards.

However, the MFA may contribute to an improved transparency and acceptance of e.g. SRF.

6.2. Economics

In the GUA report for the European Commission "Waste to Recovered Fuel Cost – Benefit Analysis" several scenarios were assessed. Five principal scenarios are selected for presentation here. Data for the baseline, landfill and incineration scenarios as well as for primary processes are derived from the GUA data bank. Data for the fuel recovery scenarios, low, medium and high yield (assumption: constant quality, cf. 4.2.1), are acquired from the operations of Essent Milieu VAM in the Netherlands, Trienekens AG (now RWE Umwelt AG) in Germany and Ewapower in Finland respectively.

The mass balances (cf. Figure 5) show the diversion of combustible waste from landfill. For the scenarios involving incineration only process ashes are landfilled. The high yield fuel preparation, combined with organic recovery of biowaste, and consequent landfilling of rejects, meets the Landfill Directive targets.

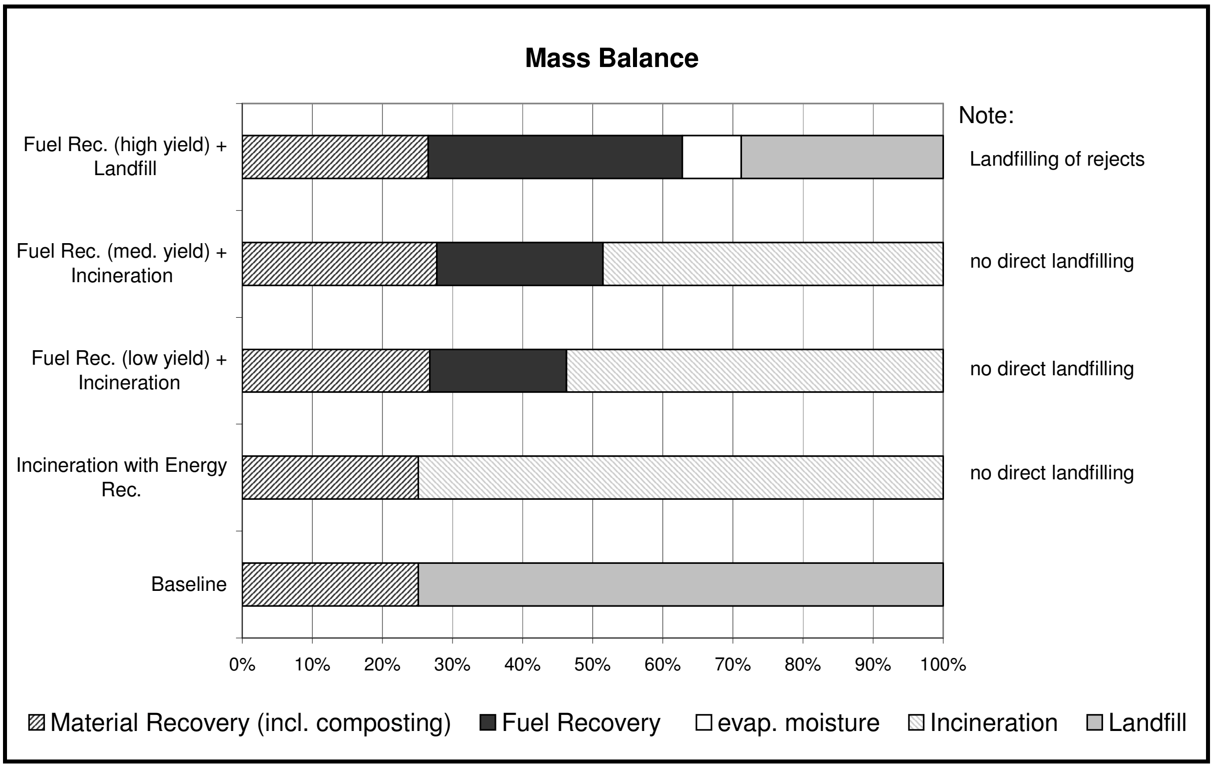

Figure 5: Mass balances of selected scenarios

The final macro economic benefit (cf. Figure 6) is highly influenced by the total amount of energy produced. The model does not distinguish between the production of electricity and heat. Most favourable is the substitution of coal. Condensing power (electricity only) from dedicated MSW incineration, which substitutes electricity from fossil gas, does not give a macro economic benefit.

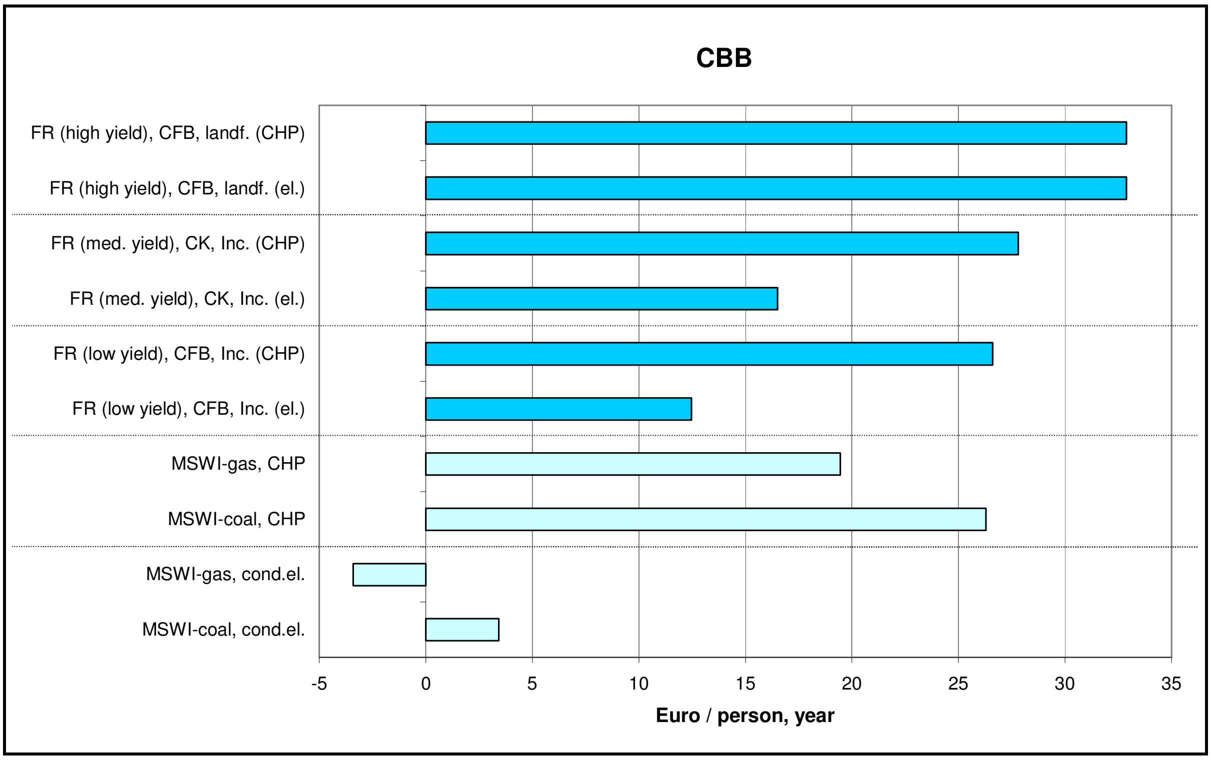

Figure 6: Cost-Benefit Balance of selected scenarios compared to landfill

The study shows clearly that the internal costs of direct landfilling are lower than the internal costs of any recovery operation. However, when including external costs the results change, and both Energy Recovery and Fuel Recovery show a benefit for the Society in the order of 5 – 30 Euro per person and year. This is mainly due to averting costs for emissions from landfill and to averting costs for fossil CO_2 emissions, saved through energy and fuel recovery. 50 % of the combustibles in MSW is considered to be of biogenic origin.

The study shows even better results for high yield fuel preparation for co-combustion in pulverised coal power plant. However, the economy of fuel pulverisation technology is not yet proven for recovered fuels in general, so these results are not as valid as those for cement kiln and fluidised bed combustion.

6.3. Contribution to CO_2 reduction

The energy related C-share and by that the energy related CO_2 emissions turn out significantly better using waste derived fuels like BPG® and SBS® . Regarding these emissions the waste derived fuels are more similar to fuel oil than lignite and hard coal (c.f. Figure 7).

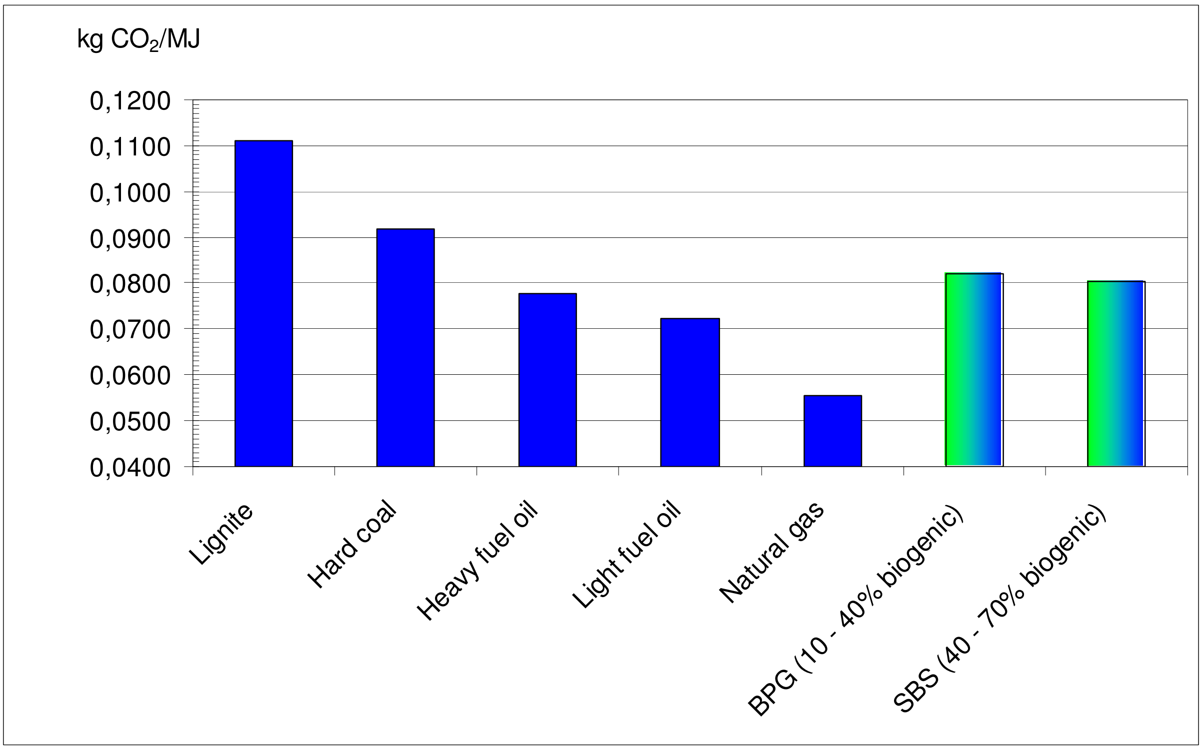

Figure 7: Energy related specific CO_2-emissions of different fuels /24/

Substitution of primary fuels by waste derived fuels like SRF may gain in importance to a substantial and continuous contribution to national and global CO_2 reduction, because of lower energy specific CO_2-emisssions the regenerative (biogenic) share (Figures 7 till 9 /25/) and the use in high efficient processes.

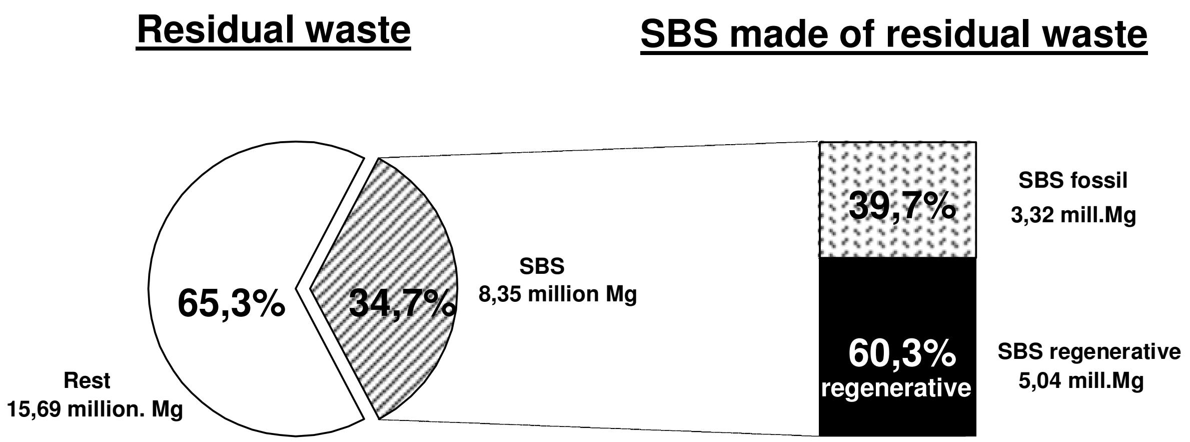

Figure 8: Regenerative share in SBS (related to mass, data for Germany)

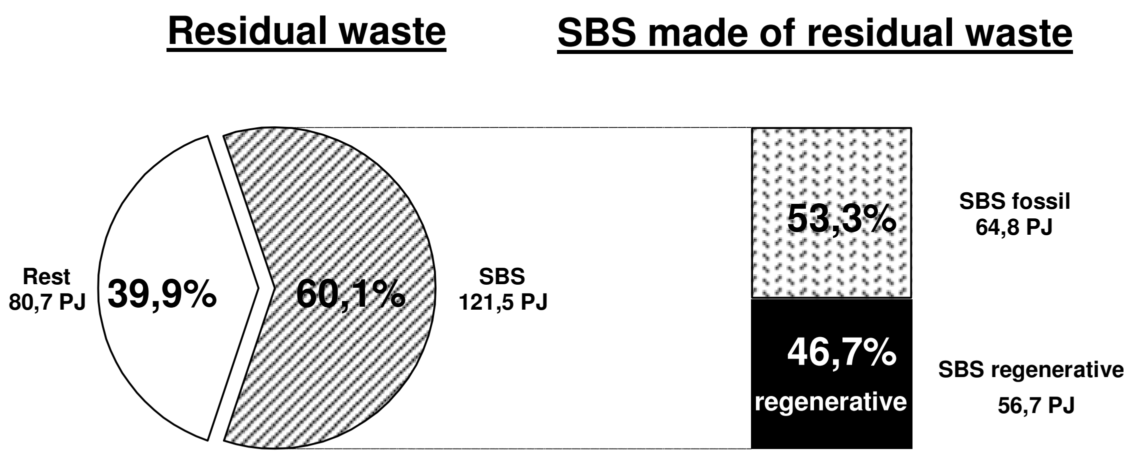

Figure 9: Regenerative share in SBS (energy related, data for Germany)

As long as wastes are disposed at a landfill, which is the dominant method in the EU, the heavy climate influencing CH_4 will be emitted. In this situation the reduction potential is substantially larger. At present an integrated recovery and waste management scenario compared to the landfill scenario could result in a reduction of about 1t CO_2/t residual waste /6/. An optimised combination of waste incineration and co-combustion even allows a reduction up to 1,25t CO_2/t residual waste.

In the near future landfill as disposal option for untreated wastes will become obsolete as Memberstates have to comply with the Landfill Directive. In that case the energy specific CO_2 emissions and the regenerative share are important. Therefore the determination of the biogenic share is gaining importance. Methods should be developed and included in international and national standardisation activities /26/ /27/. The biogenic share is regarded as a parameter to be covered in the specification list by CEN/TC 343 Solid Recovered Fuels.

Annexes

Annex I: Positive List BGS

Annex II: Questionnaire for BREF “Solid Recovered Fuels” in German

Annex III: Questionnaire for BREF “Solid Recovered Fuels” in English

Annex IV: Process scheme of a commercial waste processing plant

Annex V: Flow chart of a commercial waste processing plant

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