

Thermal Utilization of Solid Recovered Fuels in Pulverized Coal Power Plants and Industrial Furnaces as Part of an Integrated Waste Management Concept

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Abstract Solid Recovered Fuels (SRF) are highly heterogeneous mixtures generated from high calorific fractions of non-hazardous waste materials intended to be fired in existing coal power plants and industrial furnaces (CEN/TC 343 2003). They are composed of a variety of materials of which some although recyclable in theory, may have become in forms that made their recycling an unsound option. Their use is regulated under EU regulations and requires specification for commercial and regulatory purposes. The use of waste as a source of energy in itself is an integral part of waste management, as such within the framework of the European Community's policy-objectives related to renewable energy, an approach to the effective use of wastes as fuel sources and energy recovery from wastes is outlined in documents such as the European Waste Strategy.

This work involves a characterization step for SRF especially for co-firing in pulverized coal power plants for the purpose of generating heat and electricity. The nature of SRF requires a thorough understanding of their combustion properties before optimal energy recovery can be realized. The characterization process involves among other things lab-scale experiments that critically examine the fuel concerning their physical and chemical properties. The de-volatilization, ignition and combustion processes associated with different types of SRF are also studied using a thermo-gravimetric analyzer (TGA). Based on these experiments, suggestions are made for a successful application of SRF in power plants and industrial furnaces. Finally, an overview of the potentials of waste materials as fuel and a source of energy is discussed.

Keywords Solid recovered fuels (SRF) • municipal solid waste (MSW) • integrated waste management concept • co-combustion/co-firing • thermo-gravimetric analysis

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1 Introduction

The production and thermal utilization (energy recovery) of Solid Recovered Fuels (SRF) from bio-waste, residues, mixed- and mono waste streams is fast becoming a key element in an integrated waste management concept, as the deposition of untreated waste stream in landfills is not an option in the future as outlined in the European Landfill directive (1999/31/EC). The key elements of such waste management concept would be recycling/reuses, mechanical- and biological processes (M/B), solid recovered fuel production and municipal/hazardous waste incineration (MSWI). The targeted hierarchy (Fig. 1) within this concept would be material recovery, energy recovery and final disposal according to the directive (1999/31/EC).

The implementation of solid recovered fuel production in an integrated waste management concept demands a potential market for the products, which can be found in the energy sector, and in product-oriented sectors such as cement or lime industries by substituting fossil fuels. Figure 2 illustrate the process scheme for SRF utilisation in industrial processes and power plants (Gawlik and Ciceri 2005).

By definition, Solid Recovered Fuels are highly heterogeneous mixtures generated from high calorific fractions of non-hazardous waste materials intended to be

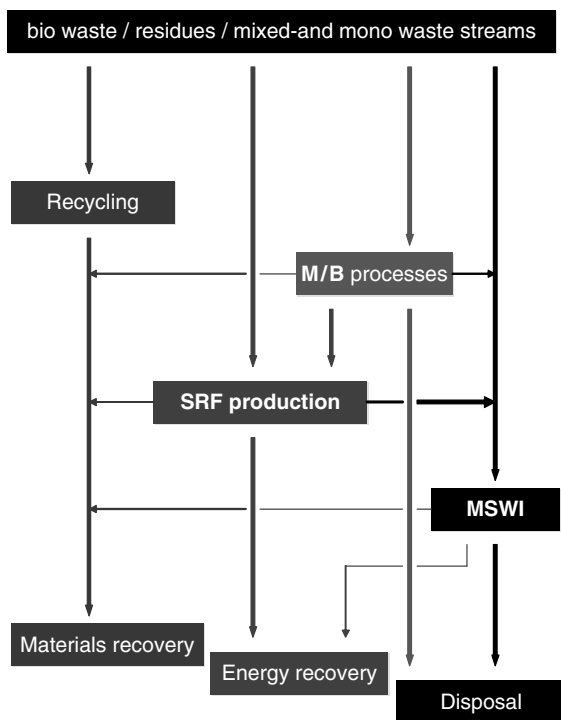


Fig. 1 The targeted hierarchy within the waste management concept

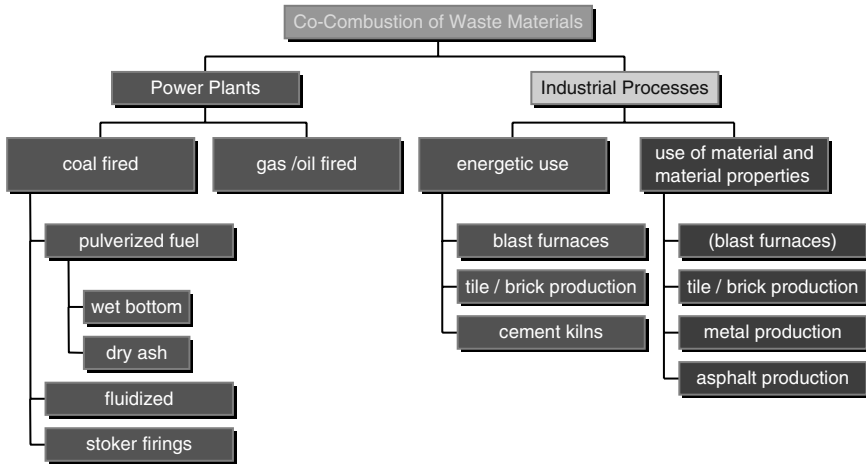


Fig. 2 Process scheme for SRF utilisation

fired in existing coal power plants and industrial furnaces (CEN/TC 343 2003). They are composed of a variety of materials of which some although recyclable in theory, may have become in forms that made their recycling an unsound option. Their use is regulated under EU regulations and requires specification for commercial and regulatory purposes. Figures 3a, b below shows a type of SRF called *Substitutbrennstoff aus Siedlungsabfaellen* (SBS®) –high calorific fraction generated from municipal solid waste (MSW)– and its percentage composition (Dunnu et al. 2006).

Co-combustion of SRF such as SBS® in existing coal fired utilities can have a huge impact on a power plant performance. Due to different physical and chemical properties of these fuels in comparison with coal, a number of processes including milling, feeding, combustion, heat transfer, and steam production can be affected. With the current knowledge of co-combustion, it is not possible to predict the impact of a single SRF or their mixtures on a power plant performance. With the knowledge of the physical, chemical and biogenic characteristics of the SRF, some of the negative impacts of co-combustion on the performance of power plants can be avoided and subsequently, carrying out expensive large-scale tests and trials in order to determine the suitability of a solid recovered fuel at certain plants can be minimized. Characterization of SRF is therefore essential for the purpose of quality assurance and quality management system for the smooth operation of plants and other industrial furnaces.

2 Waste-to-Energy a Better Option

Waste disposal and the availability of cleaner energy sources are two major issues facing Europe and the rest of the world. Both landfills and the emission of greenhouse gases present serious health and environmental threats. Finding solutions to

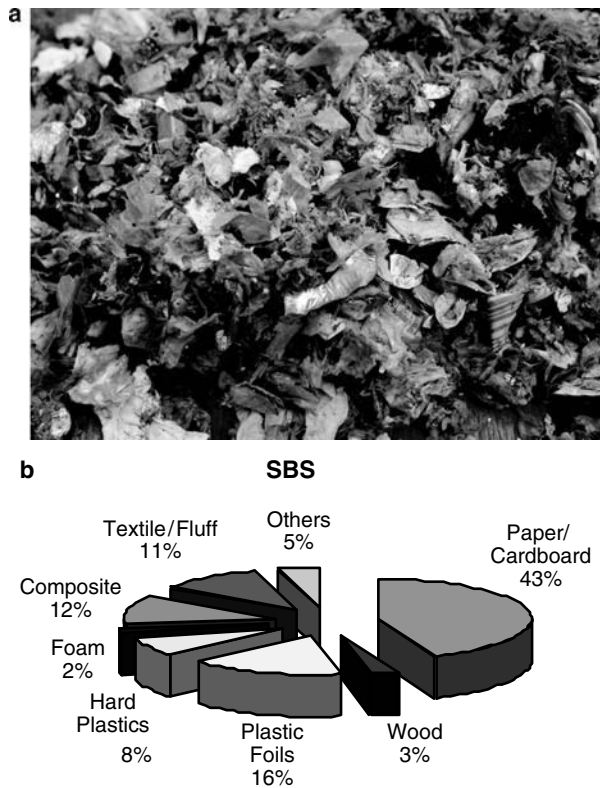


Fig. 3 (a) Solid recovered fuel (SBS[®]); (b) Composition of SBS[®]

these threats therefore advance waste-to-energy (WTE) concept as a potential option that should not be overlooked. The production of SRF from non-hazardous bio-waste, residues and other mixed- and mono waste streams represents a potential solution to both cleaner burning fuels compared to fossil fuels and waste materials that are currently disposed of in landfills.

2.1 Environmental Benefits

Using waste as an energy source would reduce the amount of fossil fuels used. Under normal conditions, 1 t of waste can generate 3.5 MW of energy, as much energy as contained in 300 kg of fuel oil (Fitze 2002). If this kind of energy is recognized as partially renewable resources, then fossil fuels can to some extent

be substituted. The environmental benefits would be enormous if municipal solid wastes (MSW) now going to landfills are turned into SRF and subsequently combusted in thermally efficient Waste-to energy facilities. Approximately 1.4 billion tonnes of MSW worldwide are disposed in landfills, deep enough to generate biogas of approximately 50% methane and 50% CO₂. The annual generation of methane is estimated at 62 million tonnes, of which less than 10% is recovered in controlled landfill equipped to capture biogas (Themelis 2006). As a matter of fact, methane is 20 times more potent as a greenhouse gas than carbon dioxide (Veltzé 2005). As a result, if the contribution of landfill non-captured methane to greenhouse gas emission is considered, it will be clear that a gradual move from landfill to WTE is one of the low-hanging fruits in reducing global emission of greenhouse gases.

Figure 4 shows the projected situation of the German waste market 2006 with an expected capacity deficit of approximately 4.5 Mt. Co-firing SRF in energy production throughout Europe, even in small thermal shares, offers enormous potential as a sustainable, efficient and environmentally friendly waste-to-energy technology. The specific CO₂ emission based on initial SRF quality (BGS® quality 2, LHV 13.5MJ, 0.4 wt% Cl_{th}) with a biogenic fraction of 50 wt% is 0.04kg CO₂/MJ, compared to 0.12kg CO₂/MJ for brown coal (Kronberger 2001).

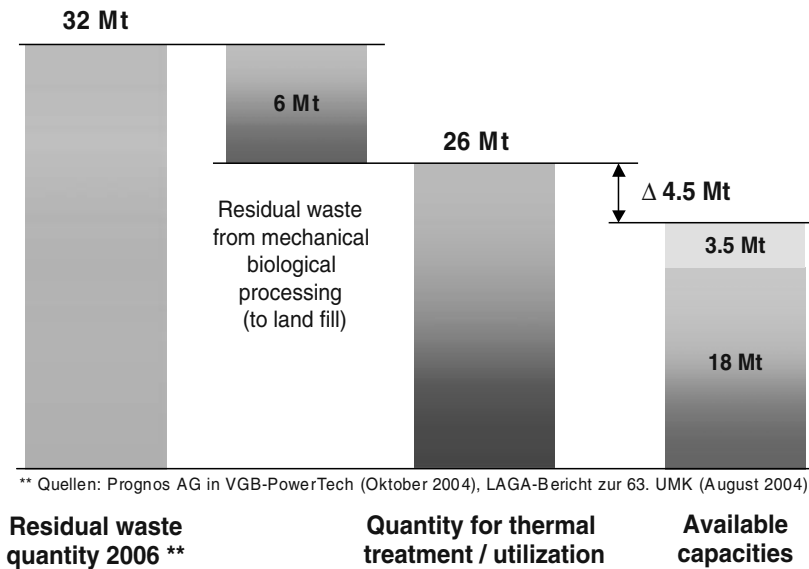


Fig. 4 Projected situation ion of Germany waste market 2006 (PROGNOS 2004)

3 Experiments

3.1 Fuel Analysis

Particle size and reactive surface area of fuel have the largest influence on a combustion process, as all matter and energy transport take place (Kock 2002). Both renewable and fossil fuels consist of a combustible organic fraction and an inert inorganic part (mineral matter). The main elements in most solid fuels are carbon (C), hydrogen (H), oxygen (O), sulphur (S) and nitrogen (N). Besides, there exist minor constituents like chlorine (Cl), potassium (K), and sodium (Na). The share of these elements in solid fuels varies, influencing the pyrolysis and combustion characteristics. Particularly the share and nature of the inorganic compounds and trace metals affect the fuel reactivity (Jenkins et al. 1998). Fuels suitable for co-firing with coal include not only typical biomass fuels like wood and straw, but also waste streams from agriculture, industrial and municipal sources.

The characterization of SRF involves the determination of the physical/mechanical, chemical and biological components of a given fuel. While it is important to determine the biogenic characteristics of SRF because it enable the calculation of the CO₂ emission savings, this work is limited only to characterizing SRF based on their physical/mechanical properties, and major chemical elements.

The SRF used for the characterization were milled down to particle size 1 mm with a rotor-sieve cutter. Because of the heterogeneous nature of this type of fuel, a representative sample can easily be achieved with a finer particle size distribution and furthermore minimise the heat and mass transport resistances in the boundary layer and within the particles. The proximate and ultimate analyses of different fuels were conducted. The fuels included SBS, shredded rubber tyre, paper/plastic mixture, and demolition wood. In addition, base line analyses of lignite and hard coal as referenced fuels were also included.

3.2 Thermo-Gravimetric Investigation

The behaviour and release of volatile components of SRF and the referenced fuels were investigated by thermo-gravimetric analysis (TGA). With the standardised methods according to DIN51718-DIN51720, the mass fractions of water, volatiles, fixed-carbon and ash were determined. For the combustion behaviour the temperature range in which the volatiles are released are of interest. The TGA analyzer was charged with SRF test portions each of about 1 ± 0.1 g. With a heating rate of 5 °C/min, the test portions were heated up to a temperature of 900 °C under a reducing atmosphere (N₂). At 106 °C the temperature was kept constant to evaporate the moisture content of the fuel, the heating continues when the mass deviation of the samples was less than 0.1%. The weight loss curve of the heat-up ramp from 106 °C to 900 °C with Nitrogen atmosphere gives information about the release of the volatile matter which is composed mainly of hydrocarbon groups.

4 Results

The results from the proximate and ultimate analysis presented in Table 1 shows that demolition wood has the largest percent of volatile matter followed by SBS, shredded tyre, lignite, and hard coal in the respective order. The de-volatilization behaviour of the respective fuels investigated with a thermo-gravimetric analyzer is also presented in Figure 5.

Table 1 Fuel analysis

	SBS	Wood	Shredded tyre	Lignite (DE)	Hard coal (SA)
Proximate analysis, % (as received)					
Moisture, 106°C, %	1.7	5.7	0.62	10.2	3.6
Volatile matter, %	77.8	77.9	52.8	48.6	21.6
Fixed carbon, %	13.1	0.022	22.7	36.6	56.2
Ash, 550°C (SRF); 815°C (coal), %	7.3	16.1	23.8	4.6	18.6
Ultimate analysis, % (as received)					
C, %	52.7	48.2	83.3*	57.5	65.3
H, %	8.1	6.5	6.9*	5	3.9
N, %	0.6	<0.3	<0.3*	0.52	3.5
S, %	<0.3	<0.3	2.7*	<0.3	1.3
Cl, % LHV, J/g	25,053	18,780	29,095	22,350	24,931

*Without metal constituent.

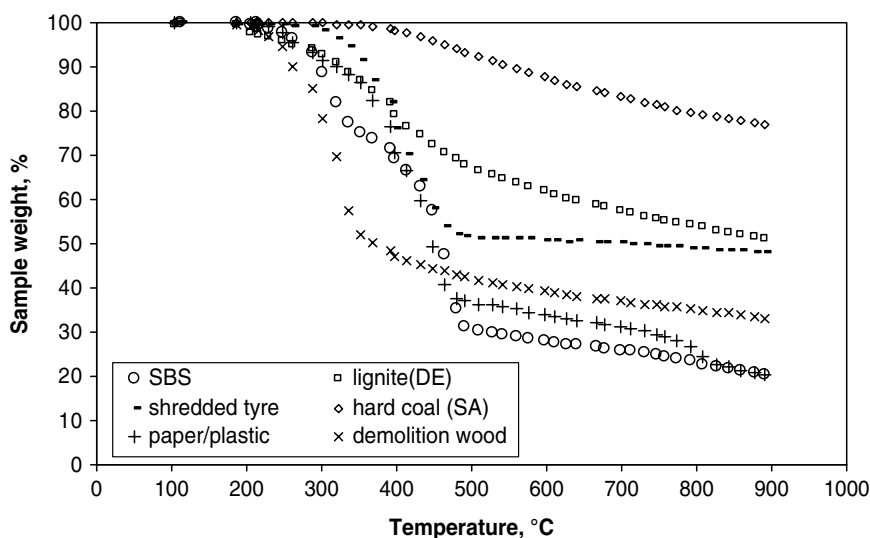


Fig. 5 TGA curves of different SRF and coal comparing weight loss due to devolatilization

The TGA curves shows that the temperature at the onset of primary de-volatilization for all the SRF is around 220 °C and ends at about 490 °C. Large percentage of the volatile matter is released at much lower temperature as compared to the primary fuels, lignite and hard coal, and it occurs within a narrow temperature range. Demolition wood exhibited maximum primary weight loss at 350 °C whereas that of paper/plastic, SBS, and shredded tyre occurred at 490 °C. Volatiles released at low temperatures favours particle ignition and improve stable flame conditions, therefore the release of large amounts of combustible matter at low temperatures show that a good ignition can be expected for all the SRF tested.

5 Conclusion

- The concept of using waste as a source of fuel to be co-fired as part of an integrated waste management concept with the aim of energy recovery and not disposal is an effective way to reduce the amount of landfill un-captured methane emission which is more potent a greenhouse gas than CO₂ (combustion product).
- The biogenic fraction of SRF makes it partially renewable and partially CO₂ neutral.
- The thermo-gravimetric analysis performed on the SRF is an essential tool to determine the suitability of fuel to be co-fired in power plants or industrial furnaces, however, it is not a blue print since other factors such as slagging, fouling, sintering, and corrosion potential also contribute significantly as to whether a particular SRF can successfully be used. Notwithstanding this, the TGA provided very useful information concerning the de-volatilization of the SRF. All the waste fuels investigated showed an early de-volatilization and this occurs at relatively low temperatures. This phenomenon substantially predicts a good ignition if such SRF are to be co-fired with coal in power plants and industrial furnaces.

In sum, it should be clearly stated that the number one objective remains the removal of waste in an environmentally correct manner, without forgetting that energy recovery can take the place of other fossil energies, and in doing so reduce the impact of vhuman activity on the environment.

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