Experiences with the preparation and utilization of refuse derived fuel from commercial waste for heat production in Flensburg/Germany

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Erfahrungen mit der Aufbereitung und Verwertung von Ersatzbrennstoffen aus Gewerbeabfällen

Abstract

"Stadtwerke Flensburg" operate three hard coal-fired fluidized bed boilers for long-distance heating production, which are renewed and extended for the Co-Combustion of Refuse derived Fuels. Additionally in the year 2006 with three privatly owned waste-management companies a plant was realized to produce a furnace-finished, chlorine-depleted RdF from commercial waste. The contribution describes the plant and the first operational experiences.

Keywords

Refuse derived Fuel, commercial waste, Near-infrared-Sorting, fluidized bed combustion, facility design, plant operation

1 Introduction

Since the end of 2006, the limited company Mittelständische Entsorgungsinitiative Schleswig-Holstein (MEISH) has operated a plant for the production of refuse-derived fuels (RDF) from different commercial wastes. The project was triggered by the 2003 concept for the optimisation of the power plant of the utility company Stadtwerke Flensburg (SWF) for the compliance with stricter emission standards. This concept comprises actions for co-combustion of refuse-derived fuels (Project KWK^{plus} [CHP^{plus}]). The RDF produced in the MEISH plant are co-combusted in the three, so far, exclusively hard coal-fired fluidized bed boilers of the Stadtwerke. Since the boilers are operated in a heat-oriented manner, the RDF contained energy is used with a high degree of efficiency and, because of the share of renewable raw materials contained in the RDF, contributes to the reduction of the carbon dioxide balance of the power plant. In the following, essential aspects of this project are described.

2 General concept KWK^{plus}

Triggered by the amendment of the 13th BImSchV (German federal immission control regulation), the Stadtwerke Flensburg started to plan the retrofitting of the previous electrostatic dust filters in 2003. The retrofitting project was expanded by a subproject for the co-combustion of secondary fuels (RDF from waste with a high calorific value; old wood and sewage sludge), because the basic load of district heating for the town of Flensburg (ca. 98% of connection to district heating) was generated by three fluidized bed boilers, which really work well for the co-combustion and amongst others due to possible recovery shortages arising from the waste storage prohibition in force as of 2005 for selected waste fractions.

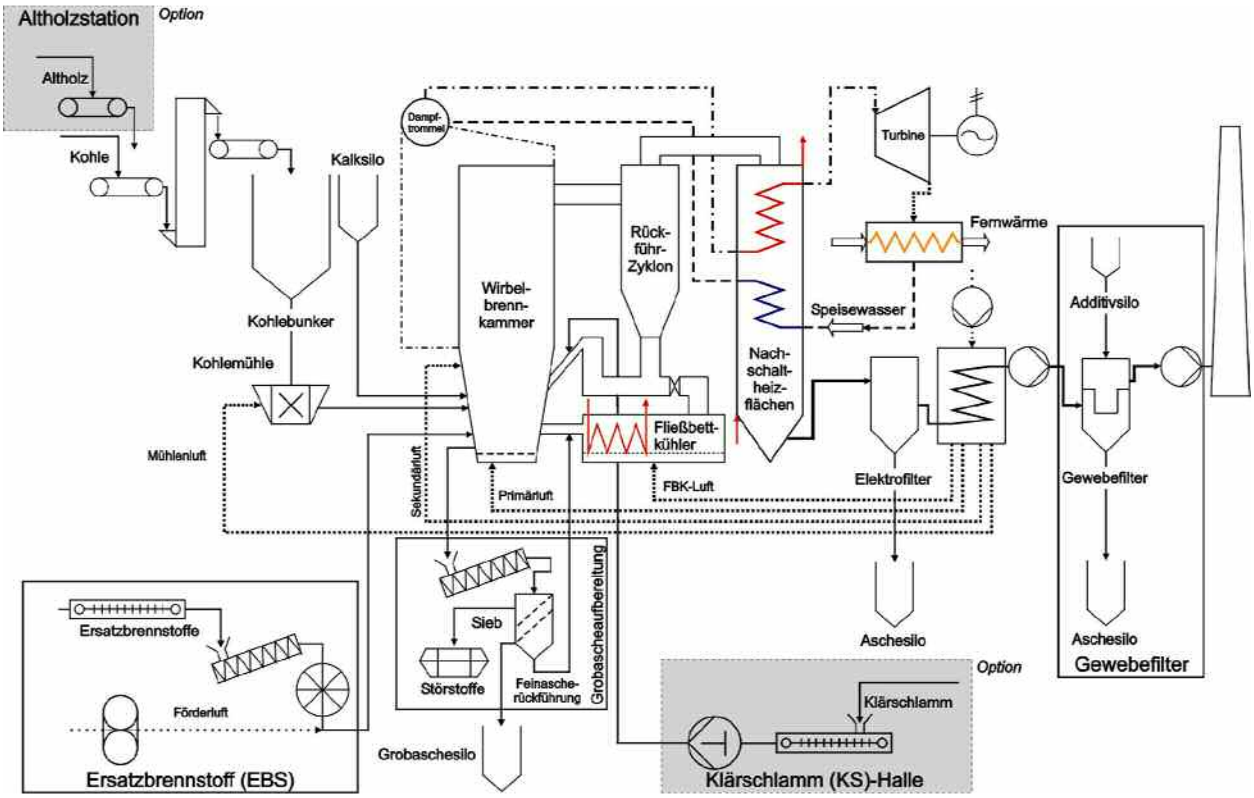
The legal immission protection authorisation process for co-combustion took 1.5 years to be approved by the environment office Staatliches Umweltamt Schleswig (STUA) and after the conclusion of the authorisation, in the course of the year 2006 a considerable part of the construction programme was implemented at the power plant (e.g. new fabric filters, additive dosing, induced draught fan, collection point for RDF, EICA-technology).

Originally, the idea was to exclusively acquire refuse-derived fuels on the market. However, in the course of 2005 there was the opportunity to erect a plant for RDF treatment, jointly with three private partners, on the premises of the waste management company Abfallwirtschaftszentrum Flensburg, in order to self-sufficiently produce an essential part of the necessary amount of fuels. The Abfallwirtschaftszentrum goes back to the construction of a waste compost plant in 1974. The plant's technical equipment and facilities have constantly been adapted to sharpening waste management constraints. While today the bunker area is used for waste shifting and the composting hall that was taken into operation in 1994 is used for biowaste composting, further buildings are used for the RDF-treatment.

Currently, the building operations for the first of the three fluidized bed boilers are finished. The remaining boilers will be constructed in the course of this year. In conformity with the authorisation these three boilers (with a thermal output of 118 MW each) can account for up to 25% of the thermal output using RDF. With regard to RDF, a maximum of 8.75 Mg/h per boiler may be applied. The compliance of the limiting factors is to be monitored continuously in such a way that in case of an excess the RDF-input is reduced.

For the Stadtwerke Flensburg the refuse-derived fuel treatment facility is not only a consolidation of the value-added chain but also the opportunity to co-design the requirements of the quality of fuels. By pooling the waste quantities of the three partners, additional degression effects can be made use of.

Ahead of schedule in October 2006, the break-in operation of the treatment facility began. Since January 2007, RDF have been co-combusted in the exclusively hard coal fired boiler and the operation regime has been adjusted to the new tasks.



Altholzstation Option	*Used wood collection point - Option*	*Speisewasser*	*Feed water*
Altholz	*Used wood*	*Elektrofilter*	*Electrostatic precipitator*
Kohle	*Hard-coal*	*Fernwärme*	*District heating*
Kalksilo	*Lime silo*	*Additivsilo*	*Additive silo*
Kohlebunker	*Coal bunker*	*Gewebefilter*	*Fabric filter*
Kohlemühle	*Coal mill*	*Aschesilo*	*Ash silo*
Mühlenluft	*Air of the mill*	*Klärschlamm (KS)-Halle Option*	*Sewage sludge (sewage sludge hall – option)*
Wirbelbrennkammer	*Circulation combustion chamber*	*Grobaschesilo*	*Coarse ash silo*
Dampftrommel	*Steam drum*	*Grobascheaufbereitung*	*Coarse ash treatment*
Primärluft	*Primary air*	*Feinascherückführung*	*Fine ashes recovery system*
Sekundärluft	*Secondary air*	*Sieb*	*Sieve*
Rückführzyklon	*Recovery cyclone*	*Störstoffe*	*Foreign material*
Fließbettkühler	*Moving bed cooler*	*Ersatzbrennstoff (EBS)*	*Refuse-derived fuel (RDF)*
FBK-Luft	*Moving bed cooler air*	*Förderluft*	*Conveying air*
Nachschaltheizflächen	*Heat recovery adjuncts*	*Ersatzbrennstoffe*	*Refuse-derived fuels*
Turbine	*Turbine*		

Figure 1 Scope of project KWK plus (Source: Stadtwerke Flensburg)

3 Refuse-derived fuel quality requirements

The co-combustion is subject to the provisions of the 17th BImSchV, the limiting values of which are to be adhered to by the means of respective flue gas cleaning actions based on state-of-the-art technology. By the standards of imission protection, a limitation of the RDF components would not be necessary. However, the RDF components indeed influence a power plant's constant output streams which are generally utilised.

Further, chlorine, for instance, can have a negative impact on economically relevant factors (e.g. availability) on account of its contribution to corrosion.

Therefore, binding quality requirements were elaborated in the planning process. Amongst others, the basis of investigations/research were transfer coefficients with which the distribution of materials (e.g. heavy metals) that are fed into the plant via various input flows (e.g. raw-materials, fuels) are depicted on the particular output flows (e.g. filter ashes, discharged air). For the employed fluidized bed furnaces literature values (UMWELTBUNDESAMT 2004 [federal environment agency]) were applied, unless own appropriate operation data was available. As a result of the authorisation process the quality requirements, which are shown in extracts in table 1 and reduced, compared to the authorisation application, were determined. Through a sophisticated quality management system the compliance with these requirements can be autonomously monitored at the RDF producer and the power plant.

Table 1 RDF-quality requirements (excerpt of the authorisation notification)

Parameters	**Unit**	**Values**	
Ashes DIN 51719	m.-% raw, humid	< 30	
Chlorine content DIN 51727	m.-% raw, humid	< 1	
Fluorine content DIN 51723	m.-% raw, humid	< 0,08	
Calorific value DIN 51900	kJ/kg raw humid	> 11.000 – 24.000	
Aluminuim content	m.-% raw, humid	< 1	
Sulphur	m.-% TS	< 2	
Trace elements 17th BImSchV		**80 % percentile**	**MAX (sing. values)**
Cadmium	mg/ kg DS	9	16
Lead	mg/ kg DS	400	800
Chromium	mg/ kg DS	250	750
Copper	mg/ kg DS	750	1200
Mercury	mg/ kg DS	1,2	4
Physical properties			
Grain size distribution			
Pieces with edge length a, b, c	mm	< 50	
Pieces with edge length a + b + c	mm	< 150	

The specifications of supply of the Stadtwerke Flensburg additionally contain further parameters (share of metal) as well as partially lower quality parameters (concentration of chlorine < 0.6 %).

4 Concept of the treatment plant

4.1 Input materials

The central treatment facility is fed with material flows of three differently configured sorting plants:

- Pre-crushed sorting remainders of a commercial waste processing plant put into service in 2006. In recyclable material oriented processing of commercial waste, supported by automatic sorting, a grain fraction in the size range of 15 to 50 mm comes up as RDF pre-product, as well as a sorting overflow of > 50 mm.
- Uncrushed sorting remainders of a simple sorting plant for commercial and construction waste.
- Sorting remainders from the processing of metals and white goods in the fine and medium sized grain range.

4.2 Concept of processing

The goal of the processing is metal removal to a large extent, diminishing the concentration of PVC from the RDF-part stream, crushing to a final grain size of ca. 50 mm and the optimisation of the fuel yield, the latter especially in compliance with the quality parameters. Since at the point of planning, the properties of the input materials could only be analysed in a limited way, corresponding reserves had to be included in the design as experience has shown (cf. OETJEN-DEHNE 2003).

Sorting remainders suitable for fuel production and residues are delivered in containers or on walking-floor lorries, received in a retrofitted hall of the Abfallwirtschaftszentrum Flensburg and intermediately stored until processing (cf. figure 2).

With the aid of an orange-peel bucket and a wheel loader, the material is passed directly to the pre-crusher, which also has to well dose the material flow for the downstream units in order to prevent a pulsation of the material flow. Faulty material detected through a visual inspection, e.g. larger parts of metal or PVC, are removed or sorted out beforehand.

Metals and plastics containing chlorine have to be extracted from the pre-crushed materials, now having a grain size of ca. 200 mm and afterwards they are crushed to their final size.

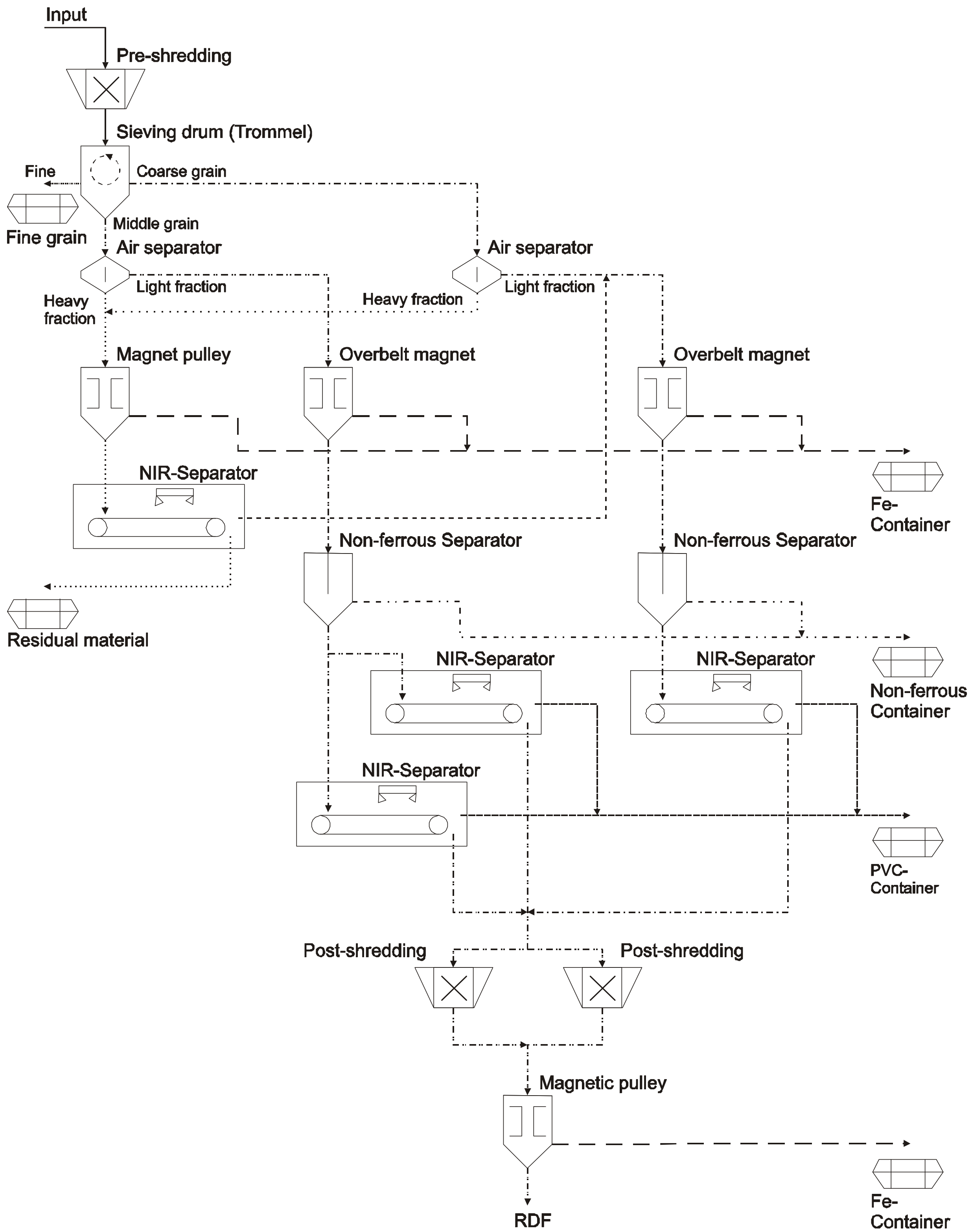


Figure 2 Simplified flow diagram of the processing plant

Firstly, three grain fractions are produced in a polygon sieve drum. While the fine grain fraction, produced to relieve the following sifting technology, depending on the result of the quality check is either utilised as RDF or disposed of, the medium grain and the coarse grain fractions have to be further processed.

The two fractions then first proceed to wind sieves that separate the respective material flow into a heavy and a light fraction. This way, the combustible components (paper, plastic, compounds etc.) are accumulated in the light fraction and the non-combustible components (stones, ceramics, metal parts) in the heavy fraction.

Then, from the medium and coarser light fractions ferrous and non-ferrous metals are extracted before PVC components are detected by means of an automated detection unit working on the basis of NIR spectroscopy and subsequently are removed from the material flow by compressed air (negative sorting).

The portions of heavy lift from the wind sieves are gathered in order to also be, after completing metal separation, automatically separated with a NIR device (positive sorting) from the fuels still contained (e.g. hard plastics, wood). While the mainly mineral remainders are deposited, the fuels proceed to the processing line for the coarse light fraction. The mingling is carried out prior to proceeding to NIR separator, so that the share of fuel in the heavy lift again is negatively sorted for PVC.

Figure 3 Plant floor with 3 of 4 NIR separators

In the last processing step, the fuel is crushed again to a grain size of < 50 mm and the now extracted residual metals are separated by a neodymium magnet. The subsequently crushed fuel is conveyed to the RDF storehouse and from there loaded by a wheel loader onto ready lorries, which then transport the RDF to the power plant of the Stadtwerke Flensburg.

By order of the MEISH, the realisation of the facility was significantly supported by the u.e.c. Berlin office. As a result of a restricted call for tenders, the limited company IMRO GmbH was in charge of the execution of the M+E part as general contractor.

Within a period of about 5 months of construction and assembly, 15 processing units and about 370 m of conveyor belts were installed. A modern process control system for controlling the facility, a unit for exhaust gas collection and dust extraction, extensive fire precautions and a sophisticated quality assurance concept top the facility off.

5 First operational experiences

5.1 Facility operation

Within a short period of time, the facility was able to achieve the demanded throughput (ca. 20 Mg/h) and to optimise the passing, especially to the vibro conveyors and the NIR separators. Subsequently, the measures for dust extraction were adjusted to the operating situation and the separation behaviour of the single units was synchronized. In November 2007, a test run and the acceptance test took place. Apart from a necessary constructive modification of two follow-up crushers, the commissioning proceeded without any failures. Since December 2006, the facility operates under the responsibility of the MEISH GmbH. The current focus is placed on the further training of the facility personnel and on the sophistication of the quality assurance concept.

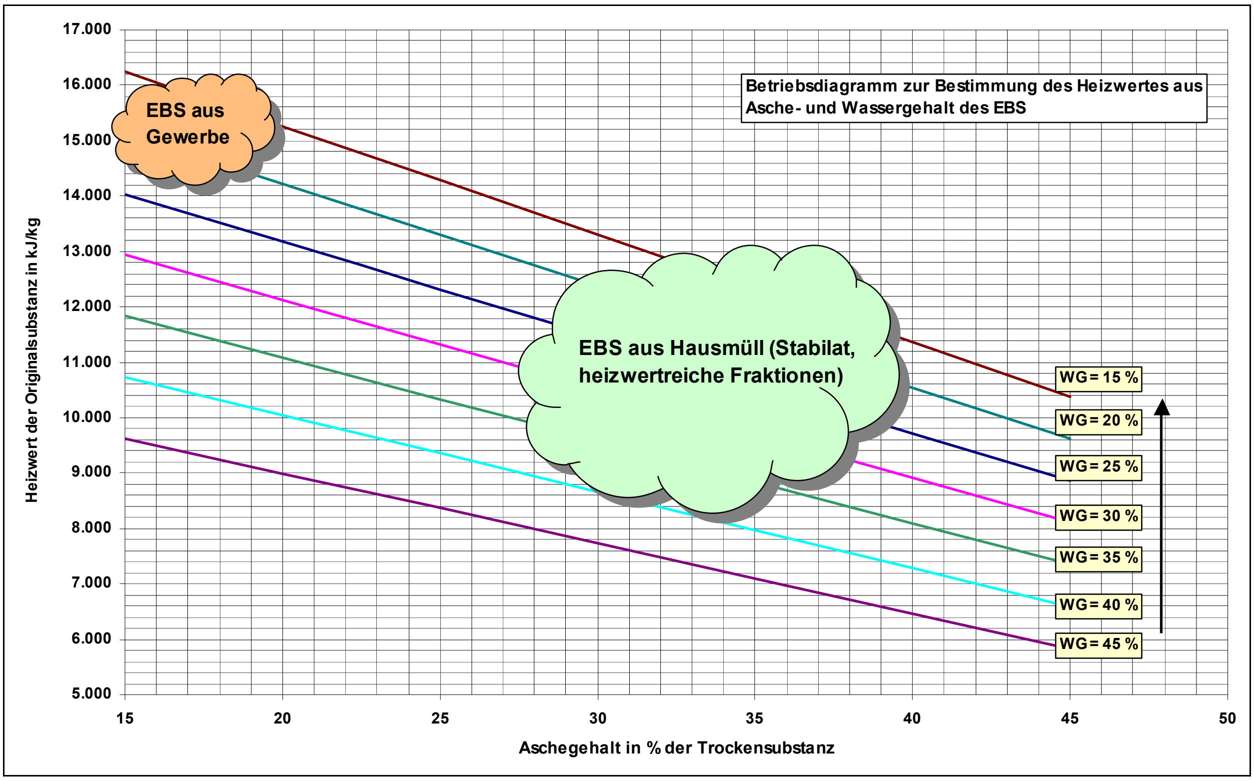
5.2 Material flows

5.2.1 Mass flows

The material flow distribution to the facility depends to a great extent on the mass distribution of the waste input to the different suppliers. Relating to the planned input allocation, around 3 m.-% Fe metals, 0.5 m.-% non-Fe metals, 2.6 m.-% PVC und 6.3 m.-% of heavy lift material are extracted. Though the fine grain fraction (ca. 14 %) contains a higher share of mineral fine materials, these do not disturb the fluidized-bed incineration. With ca. 74 m.-% of RDF, the original assumptions prove to be right.

5.2.2 Refuse-derived fuel

With a mean water content of 18 m.-% and an ash content of < 20 % the RDF has a mean calorific value of 15 MJ/kg, raw, being equal to 80% percentile 18 MJ/kg, raw. Compared to RDF from domestic refuse (stabilate and/or high calorific fractions) the RDF from commercial waste shows much less fluctuations in calorific value. Nevertheless, it makes sense to mix the daily batches in the future in the RDF storehouse at the power plant in order to balance out fluctuations in calorific value.



Heizwert der Originalsubstanz in kJ/kg	*Calorific value of the original substance in kJ/kg*
Betriebsdiagramm zur Bestimmung des Heizwertes aus Asche- und Wassergehalt des EBS	*Operation diagram for determination of calorific value from the content of ashes and water of the RDF*
Aschegehalt in % der Trockesubstanz	*Content of ashes in % of the dry matter*
EBS aus Gewerbe	*RDF from commercial waste*
EBS aus Hausmüll (Stabilat, heizwertreiche Fraktion)	*RDF from domestic refuse (stabilate, fraction with high calorific value)*

Figure 4 Experienced values for ash contents, water contents and calorific value of RDF

Initially, the produced RDF fraction had a mean chlorine content of 0.7 m.-%, DS (n= 23). Part of the chlorine is allotted to inorganic Cl which is not possible to be separated by a NIR device. By means of analyses specific to chemical groups or compounds, this concentration of chlorine can be estimated to 0.3 to 0.5 m.-% Cl of the DS. Additional shares of chlorine chiefly stem from PVC containing components, the extraction of which towards NIR depends on a variety of factors (above all the degree of isolation; colour; chunk size and weight). First balances demonstrate that the PVC output with chunks weighing > 10 g is ranges around 70 %; this output decreases with reduced chunk weights and/or grain sizes. In order to achieve the target value of chlorine of 0.6

m.-% in the RDF, further optimisation actions on the basis of respective material flow analyses are implemented in order to increase the output rate.

Except of isolated to high concentrations of copper and antimony of the time of commencement of the operation the remaining quality parameters (heavy metals, organic pollutants) are uncritical; in this context, also the approving authorities might reflect in due time if the extent of analysis could be adapted to the reality.

5.2.3 Metals

The purity of the separated Fe-metal fraction is only between 85 and 92 m.-% and therefore needs additional processing. The reason for this particularly lies in the configuration of the separation equipment aiming at a maximum yield. The NE-metal fraction generated by the eddy current separator depending on the system has a purity of between 60 and 80 m.-%, however, in this case the focus was placed on a very high yield.

During the test run, another separator in the make of a NEODYM-drum in the RDF conveyor belt was installed after the follow-up crushers allowing the separation of magnetisable steels. A better protection was achieved for the subsequent units in the incineration facility. First analyses of the incineration residues demonstrate that the remaining metal content in the RDF is about 0.01 m.-%.

5.2.4 Heavy material

The mainly mineral heavy material fraction still contains ca. 10 m.-% NF-metals, the recovery of which is currently still deferred. The share of PVC of about 7 m.-% notably contributes to the recovery of PVC from the RDF.

5.2.5 Outlook

The benchmarks set forth by the power plant for the purity of the RDF with regard to ferrous and non-ferrous metals are complied with due to facility concept. In spite of the well functioning iron and heavy material separation, however, in the per mille range non-magnetisable metals (copper wires and sheets, stainless steels) still are detected in the RDF. Due to the geometry these cause a high degree of wear in the units in the discharge of the ashes in the power plant. In the fuel treatment various methods for refraining longish metal remainders are tested.

Another focus is placed on the optimisation of the PVC recovery in the process as well as the reduction of the PVC share directly at the delivering units.

5.3 Expenses

The project budget of 4.9m EUR for the main items M+E, mobile equipment, construction, fire protection, original equipment of the plant and ancillary construction expenses was exceeded by 1.7 % by March 2007. In view of conversions in existing buildings and the related imponderables this is an outstanding project result. Relating to the three-shift operation in the final project stage with 100,000 Mg input material the specific investments of 50 Euro/Mg installed annual throughput are reasonable, too.

Apart from the costs of capital (ca. 8 Euro/Mg), main expenditures incur for service and maintenance, energy (ca. 47 kWh/Mg) and personnel (4-5 persons each shift) and manufacturing costs. Due to the short operation time of the facility no reliable data can be given.

5.4 State of the co-combustion

Especially for the adjustment of the control and regulation technology, the co-combustion started in January 2007 envisages a slowly increasing feeding curve. At the time of the report about 3 Mg RDF/h are co-combusted. The continued planning includes decoupling the acceptance and feed of RDF into a warehouse; currently this is put out to tender.

Figure 5 Walking-floor unloading and compact collection point at the power plant Flensburg

6 Summary

Since 2003, the Stadtwerke Flensburg has been implementing an extensive modernisation programme. Part of the KWKplus-concept is not only the originally necessary retrofitting of a filter unit for the reduction of the dust emissions of the fluidized bed boilers for heat generation, but also the co-combustion of secondary fuels. Additionally, the Stadtwerke participated in operating a facility for the production of RDF from commercial waste which can process up to 100,000 Mg of input material in a three-shift operation. Within five months, the facility was realised under aggravated assembly conditions in existing buildings of a former waste composting plant. The total investment amounts to ca. 5m Euro.

Since the mixed collected commercial wastes on the one hand have a comparably high content of PVC and on the other hand the feed of chlorine into the incineration needs limitation, the processing facility was equipped with four NIR separators. While the PVC components from the light fraction are subject to negative sorting, positive sorting for fuel components is carried out with the heavy fraction. Due to these measures, it was possible to reduce the chlorine concentration in the RDF already in the initial phase of the start-up to 0.7 m.-%.

Due to a multiple-step metal extraction procedure and a two-step crushing procedure, a furnace-ready fuel is generated, which is co-combusted together with hard coal since January 2007 in the first of the three retrofitted fluidized bed boilers. Since the boilers are used for district heating generation, the energy content of the RDF is well made use of with an efficiency factor of ca. 80%. Additionally, due to the share of renewable energy contained in the RDF, the co-combustion has a positive impact on the CO_2 balance of the power plant.

7 Literature

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