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Refuse-based fuels in power stations: Solution or illusion?

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Abstract

After failed attempts in Germany in the 1980's to create fuel from refuse and to incinerate it as an alternative fuel in conventional furnaces with a low flue-gas cleaning standard, the waste policy currently pursued in Germany and Europe has given rise to renewed lively discussion concerning plans to utilize waste for the recovery of energy or material in industrial plants.

The same applies to municipal residual waste, the disposal of which comes under the responsibility of the regional administrative bodies subject to public law. For some time now, there have been fresh attempts here too to make alternative fuels from such residual waste and to utilize the energy or material in industrial plants.

This paper deals with the parameters that have to be taken into account and the questions that have to be raised in terms of process engineering for the creation and use of alternative fuels from commercial and industrial waste.

When discussing and implementing the use of waste in industrial thermal processes in general and in power stations in particular, it is essential to keep a sharp focus on the fact that expertise and experience in the handling of waste are of utmost importance as far as the treatment processes are concerned. This is nothing new for insiders, but nevertheless it would seem appropriate to stress this point if every aspect - technical, ecological, administrative and economic – is to be discussed and evaluated in the debate for the recovery of energy from waste in industrial furnaces.

It must be ascertained that the use of high caloric fractions from municipal residual waste as an alternative fuel for incineration in industrial thermal processes has not become an established practice as yet, and in so far there can be no description of "state of the art" technology where the incineration of alternative fuels from municipal residual waste is concerned.

Refuse-based fuels in power stations:

Solution or illusion?

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In this paper, I will be dealing with the parameters that have to be taken into account and the questions that have to be raised in terms of process engineering when producing and incinerating refuse-based fuels. I will also be giving due consideration to the legal and economic constraints.

Where the treatment and handling of waste in thermal processes are concerned, experience has shown that a particularly high level of engineering expertise and know-how are required.

- **Energetic utilization of refuse-based fuels**
- **Legal and waste-economic constraints**
- **Qualities of refuse-based fuels**
- **Co-incineration of refuse-based fuels in power stations – requirements to be met and experience gained**
- **Conclusion**

I shall commence by commenting generally on the energetic utilization of refuse-based fuels, and the legal and waste-economic constraints in Germany and Europe, and will then move on to discuss a number of aspects regarding the qualities of refuse-based fuels.

Using two cases as an example, I will outline the requirements to be met for the co-incineration of refuse-based fuels in power stations, and describe the experience that has been gained in this field.

Terms

- Solid recovered fuel
- Alternative fuel (EBS)
- Substitute fuel (SBS®)
- Fuel recovered from production-specific commercial waste (BPG®)

In the German language there are a number of different terms in use to describe refuse-based fuels of varying definitions.

In my paper I will be using the English terms

“Refuse-derived fuels” (RDF) or

“Solid Recovered Fuels”.

- **Energetic utilization of refuse-based fuels**
- Legal and waste-economic constraints
- Qualities of refuse-based fuels
- Co-incineration of refuse-based fuels in power stations – requirements to be met and experience gained
- Conclusion

Let me start by referring to a number of aspects on the energetic utilization of refuse-derived fuels in various thermal processes.

Refuse-based fuels in power stations

Utilization of heat produced in various types of plants	
Type of plant:	**Utilization of heat for:**
Cement works	**Calcination of calcium carbonate to calcium oxide and carbon dioxide [$CaCO_3$ à $CaO + CO_2$].**
Blast furnace	**1. Reduction of iron oxides to elemental iron including melting of pig iron** **2. Utilization of chemical energy for heating or process purposes or conversion into electricity**
Power station /heating station	**Production of steam for generation of electricity and/or pipeline-bound heat**
Waste incineration plant	**1. Thermal treatment of waste for disposal** **2. Generation of electricity and/or heat**

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The criterion for energetic utilization of refuse-derived fuel is that the **"released heat is utilized for own direct use or is sold to outside party"** .

In a cement works for example, the heat in the process is used solely to cover the energy required for the material conversion process.

In a blast furnace for the production of pig iron, the heat in the process is used for material conversion in the reduction of iron oxides.

In a power or heating station, the heat released in the process is used for the production of steam for the generation of electricity and/or heat to be sold to an outside party.

This table gives an overview of these possibilities of utilizing heat. Utilization of heat in a waste incineration plant is also included and taken into account in the overview.

- Energetic utilization of refuse-based fuels
- **Waste-economic and legal constraints**
- Qualities of refuse-based fuels
- Co-incineration of refuse-based fuels in power stations – requirements to be met and experience gained
- Conclusion

I would now like to turn to the legal and waste-economic constraints that have to be taken into due consideration in the production and use of refuse-derived fuels.

Sources of refuse-derived fuels - municipal waste and production-specific waste

- Mechanical-biological treatment or stabilization of municipal waste
- Grading of constructional and commercial waste
- Sewage sludge
- Used oil
- Paper industry rejects
- Animal meal and tallow

This is a list of sources for refuse-based fuels derived from municipal waste and production-specific waste.

In this paper I would like to focus on the category of refuse-based fuels derived from municipal waste and from the grading of constructional and commercial waste.

Refuse-based fuels in power stations

Predicted quantities of RDF from municipal waste, and corresponding capacities for co-incineration in industrial furnaces in Mg/a

PROGNOS 2003

	2006	2012
Amount	2.9	3.5
Capacities	2.6	3.6

Not taking into account the quantities and capacities for refuse-based fuels from production-specific waste (such as old tyres, used oil, rejects, animal meal and suchlike).

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In a current study, the available capacities in co-incineration plants indicated for the years 2006 and 2012, correspond to the amount of refuse-derived fuel to be expected.

It is questionable, however, whether it will actually be possible to utilize these theoretical capacities in the future, in view of the conditions of the developing market and taking into consideration the operational experience gained in the various plants.

Recently, in an issue of the German journal “Müll und Abfall”, the experts Alwast, Hoffmeister and Paschlau quite rightly questioned whether the co-incineration of RDF from municipal waste will in fact dispose of a significant proportion of this waste.

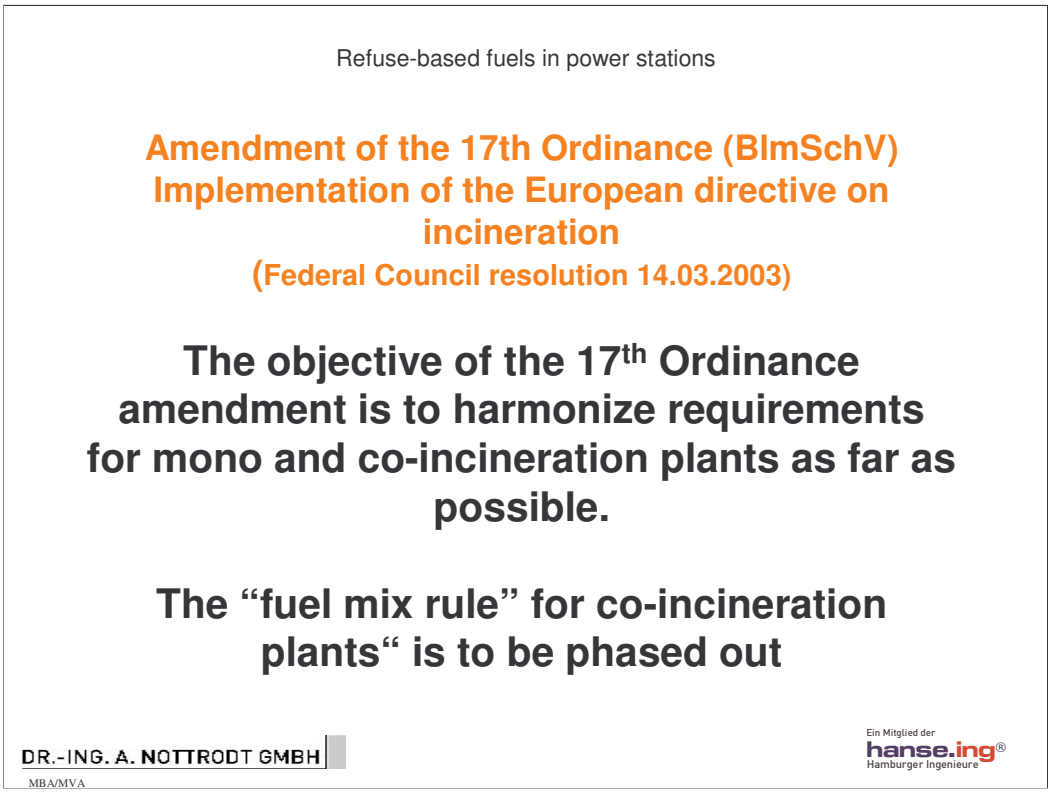
EU-provisions for recovery of energy in compliance with the European Court of Justice

- **Incineration with excess heat**
- **Utilization of the excess heat**
- **Substitution of primary energy sources**
- **Case-by-case examination by authorities**

A new ruling was reached by the European Court of Justice in the legal matter of the Commission of European Communities versus the Federal Republic of Germany with regard to the export of waste from the Federal Republic of Germany to cement works in Belgium. This ruling systematically defines the provisions for the recovery of energy from waste in Europe.

In accordance with this, there must be utilization of the excess heat released during incineration, and at the same time primary energy sources must be substituted.

The competent authorities have to examine the situation on a case-by-case basis.



For the authorization of plants within the European community, the European directive on incineration is applicable. This is currently being implemented in Germany by the amendment of the 17th ordinance (17. BImSchV).

The objective of this new German ordinance is to harmonize the requirements to be met by mono and co-incineration plants.

Amendment of the 17th Ordinance (BImSchV) Implementation of the European directive on incineration

(Federal Council resolution 14.03.2003)

Where more than
25 percent of the thermal output is produced using co-incineration substances in an incineration plant, the emission limits defined in
Article 5 para. 1 shall apply for incineration plants (mono incineration).

If the 25% limit of thermal capacity is not reached, then the “mix limits“ apply for a number of pollutants for the co-incineration of waste, with lesser requirements.

Refuse-based fuels in power stations

Amendment of the 17th Ordinance (BImSchV)
Implementation of the European directive on incineration
(Federal Council resolution of 14.03.2003)

Type of plant	Proportion of waste in the thermal output	Requirements
Mono incineration	Any	Article 5, para. 3
Cement and Lime industry	< 60 %	Appendix II.1
	> 60 %	As for mono incineration
Firing plants (such as power stations)	< 25 %	Appendix II.2
	> 25 %	As for mono incineration
Other plants	< 25 %	Appendix II.3
	> 25 %	As for mono incineration

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This table shows the system used to govern the limits in the 17th BImSchV Ordinance for mono-incineration and the groups of co-incineration plants taking into consideration the proportion of waste in the thermal output.

You can see that while the 25 % rule applies for power stations, the figure is 60% for plants in the cement and lime industry.

Refuse-based fuels in power stations

Amendment of the 17th Ordinance (BImSchV)
Implementation of the European directive on incineration
(Federal Council resolution of 14.03.2003)

Emission limits for mono incineration and co-incineration in firing plants for sold fuels (100 to 300 MW_{th}) for a waste thermal output < 25 % **Daily average / half-hourly average in mg/m^3**		
	Mono incineration	**Co-incineration**
HCL	10 / 60	10 / 60
HF	1 / 4	1 / 4
SO_x	50 / 200	Mix rule
NO_x	200 / 400	Mix rule
CO	50 / 100	Mix rule
TOC	10 / 20	10 / 20
Ash	10 / 30	10 / 30

It is evident from this comparison that the limits for gaseous pollutants and ash have already been harmonized for mono incineration and co-incineration to a large extent.

The mix rule is only still applicable for NO_x, SO_x and ash.

Refuse-based fuels in power stations

Amendment of the 17th Ordinance (BImSchV)
Implementation of the European directive on incineration
(Federal Council resolution of 14.03.2003

Identical emission limits for mono incineration and co-incineration	
PCCD/PCDF	O.1 ng TE/m³
Mercury	0.03 mg/m³ 0.05 mg/m³
∑ (Cadmium and Thallium)	0.05 mg/m³
∑ Heavy metals	0.5 mg/m³
∑ (As, Benzo(a)pyrene, Cd, Co, Cr)	0.05 mg/m³

This harmonization is even more evident in this table which shows the emission requirements for organic and inorganic pollutants.

Refuse-based fuels in power stations

- Energetic utilization of refuse-based fuels
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I would now like to turn to the actual properties and qualities required of refuse-derived fuels.

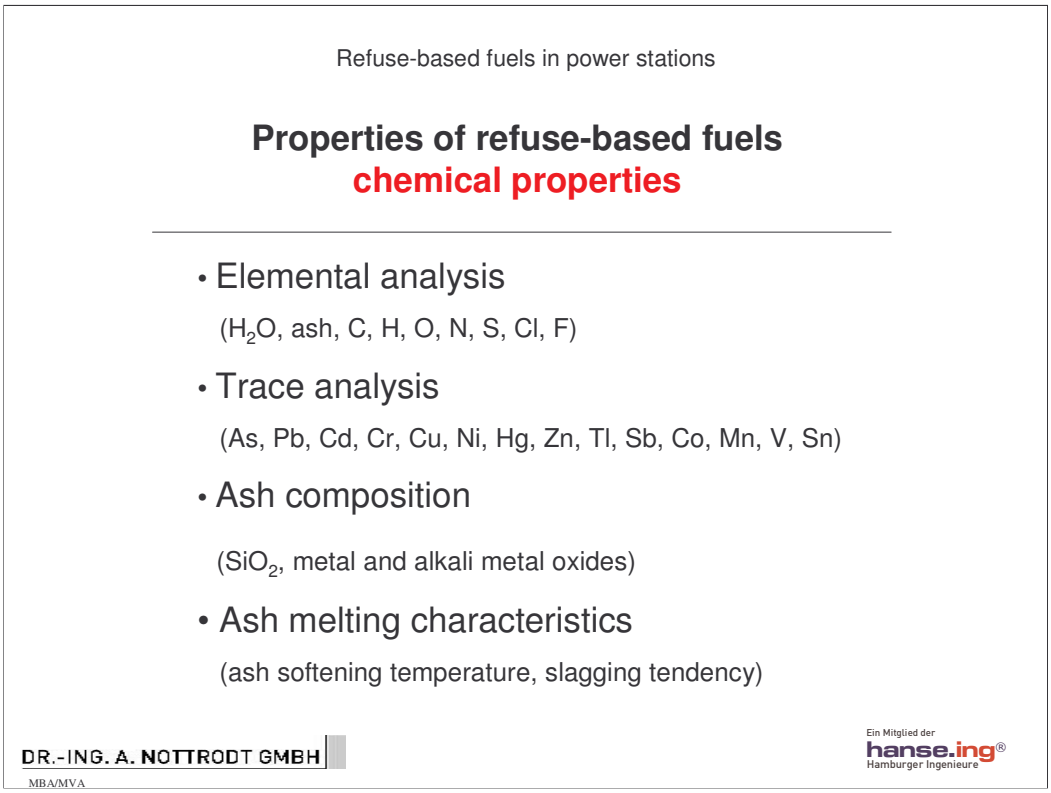
Qualities of refuse-based fuels

- chemical properties
- mechanical properties
- calorific properties
- reaction properties

Scholz and Beckmann

It is quite remarkable that in quality standards currently in existence or preparation, emphasis is given to the chemical properties of the refuse-based fuels, in particular their pollutant contents.

However it is the mechanical, calorific and reaction properties that are of crucial importance for successful co-incineration of refuse-derived fuels. Every plant operator knows that it is these very properties that are decisive in the success of co-incineration.



The parameters of the elemental analysis and trace analysis characterize on the one hand the pollutant potential. On the other hand, the elemental analysis parameters calculate the calorific value and the specific minimum air required.

The ash composition and the ash melting characteristics for example determine the amount of deposits on the heat exchanger surfaces on the flue-gas side of the steam generator.

Properties of refuse-based fuels
Mechanical properties

- Density

  (Density of the inert substances, density of the fuel

- Bulk properties

  (Bulk density, etc.)

- Handling qualities

  (grindability, distribution of grain size, storability)

- Fuel input

  (Preparation etc.)

The mechanical properties of refuse-based fuels frequently decide whether co-incineration will be successful or not.

Operational experience and knowledge gained so far are not yet suitable for a systematic structure and evaluation.

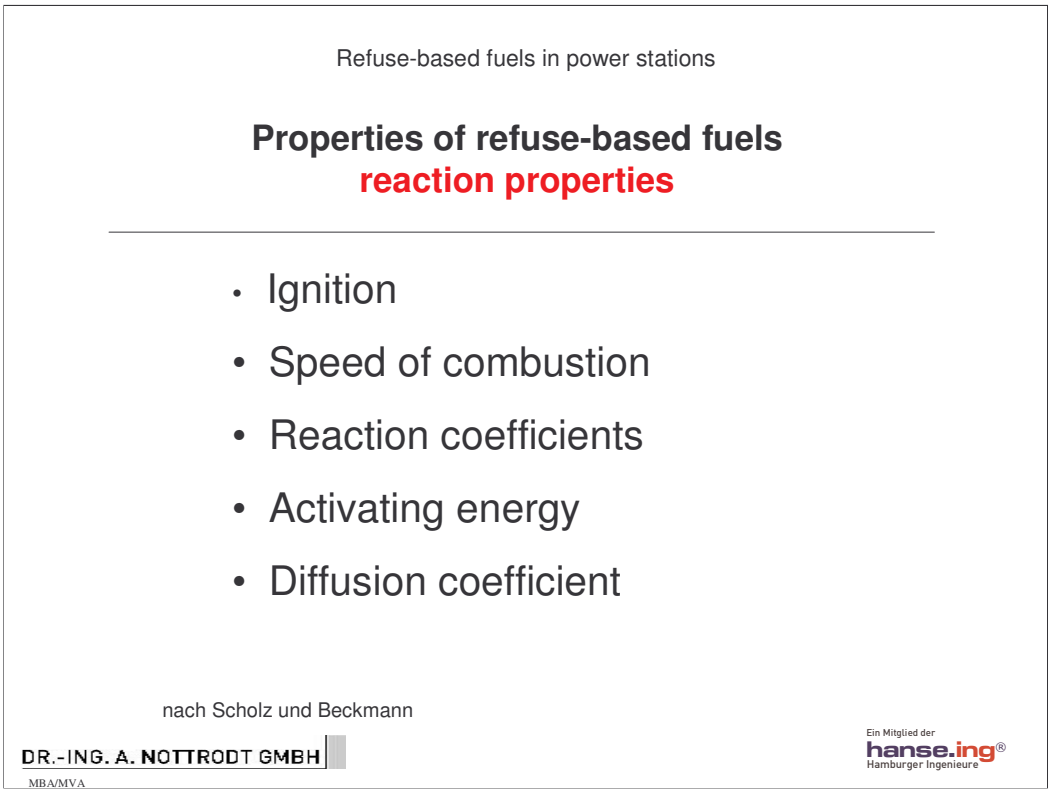
The properties must be first be examined from case to case, and the conditions adapted accordingly, if necessary.

Properties of refuse-based fuels
calorific properties

- Calorific value and gross calorific value
- specific minimum air requirement
- specific minimum flue gas amount
- Thermal conductivity
- Thermal capacity
- Adiabatic incineration temperature

As regards the calorific properties of refuse-based fuels, the usual figures for standard fuels can be applied.

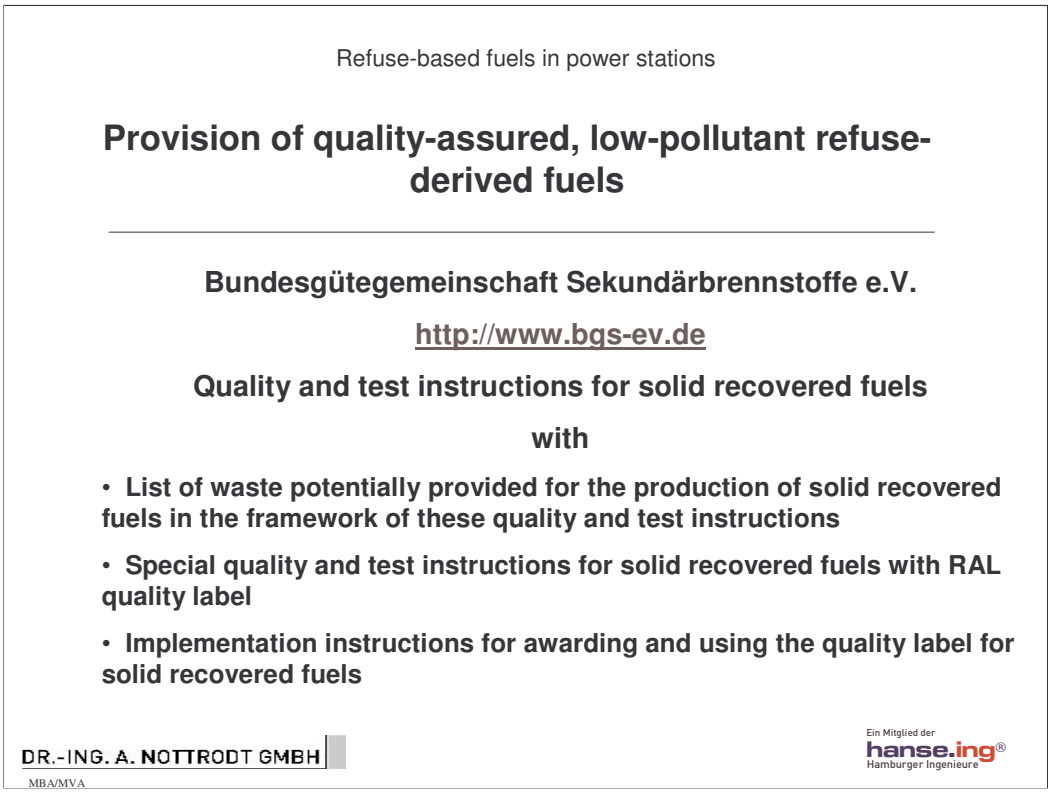
These calorific properties are of course crucially important for the energetic utilization of the released heat and the substitution of standard fuels (primary fuels).



These are the properties of kinetic reaction. They are dependent on the chemical, mechanical and calorific properties.

For their description, Scholz and Beckmann refer for example to experimental examinations and mathematic model approaches.

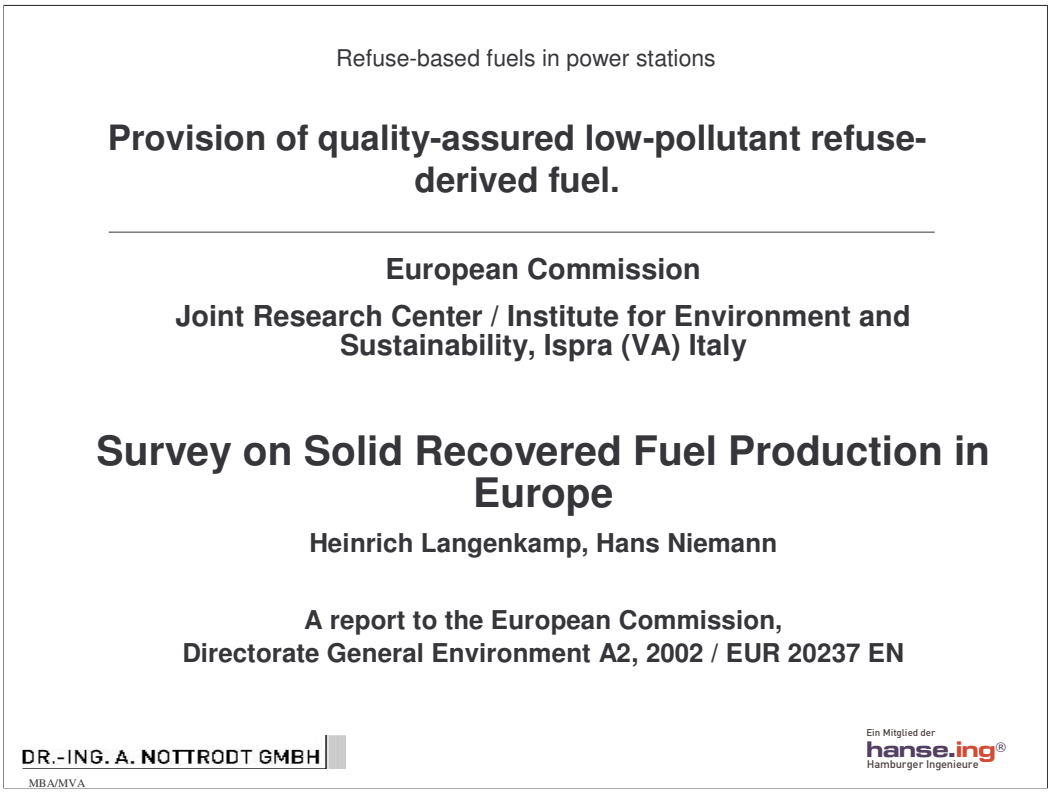
With refuse-derived fuels, there is a greater fluctuation in composition as compared with the standard fuels, and therefore only simplified models approaches can be used to describe the combustion



These last pictures have shown how varied and complex the properties of refuse-based fuels are.

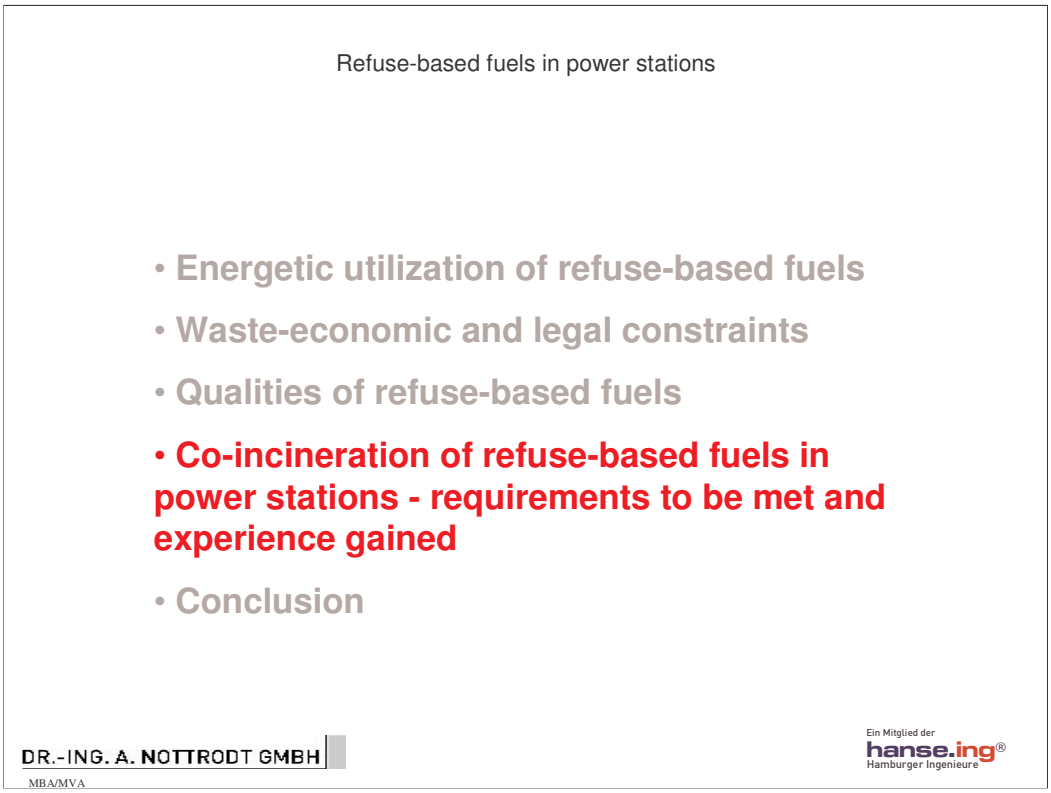
At this point I would like to make two references to Standards for the provision of quality-assured refuse-based fuels in Germany and in the European Community.

The Bundesgütegemeinschaft Sekundärbrennstoffe e.V. (Federal Quality Assurance Association for Solid Recovered Fuels) has prepared corresponding quality and test instructions. Moreover, in Germany there are special quality and test instructions for solid recovered fuels with RAL quality label.



This technical report was issued on behalf of DG Environment Unit 2 as an additional report on refuse-derived fuel (RDF), produced from selected, non-hazardous, mono- and mixed-wastes. The report is based on data supplied by RDF-producers in Europe. To collect the data a documentation sheet was sent to the RDF producers with questions about input waste, plant specifications, sampling-, digestion- and analytical methods and quality of RDF.

It is recommended to give this mandate to the EUROPEAN COMMITTEE FOR STANDARDISATION (CEN) for drafting a standard for the use of waste as a fuel in form of **Refuse Derived Fuels** in conformity with the **European Directive on Incineration of Waste** and the **European waste list**.



Now that I have dealt with a number of aspects of the energetic utilization of refuse-based fuels, also touching on the economic and legal parameters and the qualities of RDF, I would now like to report on two concrete examples to demonstrate the requirements and experience gained with RDF in power stations.

Refuse-based fuels in power stations

Examples

•Gersteinwerk power station of the RWE Power AG in Werne: Use of refuse-derived fuels in continuous operation from the beginning of 2004 (Schulz 2003)

• Wedel heating power station of the HEW AG: Experiments with the co-incineration of refuse-derived fuel (high-calorific light fraction (Kimmich 2002)

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The REW Power AG recently made a report on the use of refuse-derived fuels in continuous operation for the Gersteinwerk power station in Werne.

And the HEW AG carried out experiments in the Wedel heating station for the co-incineration of refuse-derived fuel.

Refuse-based fuels in power stations

Gersteinwerk power stationof the RWE Power AG in Werne

Standard fuel of steam generator:	hard coal
Thermal output :	1.500 MW
Steam turbine power:	658 MW
Use of RDF:	
Thermal output RDF:	150 MW
Share of RDF in the overall power:	10 %
Average calorific value RDF:	17 MJ/kg
max. throughput capacity RDF:	32 Mg/h
RDF-throughput per year:	240.000 Mg/a
2-year preliminary tests/ approval	July 2002
Operation of power station with RDF	Beginning of 2004

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In this table you can see the main data for the approved co-incineration of refuse-derived fuels in preparation for the Gersteinwerk power station.

Refuse-based fuels in power stations

Gersteinwerk power station of the RWE Power AG in Werne
Use of high-quality, quality-assured refuse-derived fuels:

- Grain size < 20 mm.
- Bulk density as low as possible (approx.) 250 kg/m^3).
- Avoidance of undesirable substances (metals, hard plastics, wood, Styrofoam.
- Low contents of water and ash to permit pneumatic transport.
- Calorific value as high as possible.
- Low contents of heavy metal and chlorine.
- Restriction of waste categories and pollutant content through comprehensive quality assurance measures.

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It is very clearly emphasized that the use of RDF must be restricted to high-quality and quality-assured waste in order to guarantee trouble-free operation for co-incineration.

This list shows the most important requirements that need to be met in terms of fuel qualities.

Refuse-based fuels in power stations

Gersteinwerk power station of the RWE Power AG in Werne
Expected results in operation:

No impact on the emissions of the power station (achieved by refurbishing the flue gas cleaning system).

No pollutant concentration in the residual substances (fly-ash, gypsum,waste water).

No chlorine corrosion on the evaporator heating surfaces provided the consistency of RDF qualities can be ensured in the long term.

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After carrying out preliminary tests for a number of years, the operator of the power station does not expect any impact on the emission levels and the pollutant loads of the residual substances. Nor do they expect any chlorine corrosion on the evaporator heating surfaces, provided the consistency of RDF qualities is ensured in the long term.

Refuse-based fuels in power stations

Wedel heating station of the HEW AG - tests for the co-incineration of refuse-derived fuels in a block power station :

Steam generator fired by hard coal and with dry ash removal;

Input of hard coal at full load:	40 $Mg_{hard\ coal}$/ h
Live steam mass flow rate:	430 Mg / h
Steam parameters:	176 bar / 540 ° C
Max. RDF input:	4 Mg_{ESB} / h

Corresponding to approx. 7 % of the thermal output

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The heating station in Wedel is operated primarily to cover needs for district heating in Hamburg. The two block plants of the heating station can be used variably, in accordance with electricity and heat requirements.

Here you can see the main data achieved during tests for the co-incineration of refuse-derived fuels.

Refuse-based fuels in power stations

Wedel heating station of the HEW AG
Tests for the co-incineration of RDF
RDF quality :

High calorific fraction (fluff);

Treated and prepared commercial waste;

Supplied by a certified waste management companies;

Description: Substitute fuel (RDF)

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For the trial operation, the high-calorific fraction, referred to as fluff, from municipal waste as well as treated and prepared commercial waste was supplied by a certified waste management company.

Refuse-based fuels in power stations

Wedel heating station of the HEW AG
Tests for the co-incineration of RDF

Objectives of the tests:

Compliance with emission limits?

Compliance with approval limits for water?

Compliance with quality requirements to be met for slag, fly-ash and gypsum?

Guarantee of a trouble-free operation of the plant (fuel handling, pollution, corrosion)?

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The objectives of the co-incineration tests were to determine compliance with the pollutant limits for emissions, waste-water and residual substances, and to determine whether trouble-free operation can be guaranteed for the co-incineration of refuse-derived fuels.

Refuse-based fuels in power stations

Wedel heating station of the HEW AG
Tests for the co-incineration of RDF

Results:

- Owing to the content of undesirable substances, it was not possible to carry out uninterrupted trial operation for more than 8 hours at a time.
- The impact on the quality of the fly ash and the flue gas emissions is controllable, although in the case of Hg, the limit was in fact exceeded.
- Significant deterioration in quality of slag and waste water.
- No proof of guaranteed trouble-free continuous operation (fuel handling, pollution, corrosion).

Owing to the content of undesirable substances in the RDF supplied, it was not possible to carry out uninterrupted trial operation for more than 8 hours at a time

The impact on emissions can be described as controllable, although it was observed that there was a significant deterioration in the quality of slag and waste water.

Trouble-free continuous operation could not be affirmed. There are no further plans for the co-incineration of refuse-derived fuels in the Wedel heating station.

Refuse-based fuels in power stations

- Energetic utilization of refuse-based fuels
- Waste-economic and legal constraints
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- **Conclusion**

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I would now like to come to my conclusion!

Conclusion

- Quality assurance is essential for every property of fuel.
- Insufficient experience with successful quality assurance of large RDF quantities in the long term.
- Insufficient operational experience in power stations in the longer term.
- Assessment of successful operation must be reserved for individual cases.

The extent of long-term experience in the field of quality assurance for RDF from municipal waste is still lacking and incomplete.

The same applies to operational experience with continuous operation in power stations.

No general statement can be made as regards successful operation. Such statements can only be made from case to case, with reference to a particular power station.

Refuse-based fuels in power stations:

Solution or illusion?

Not a solution in any event!

But nor is it an illusion in certain cases in the future

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