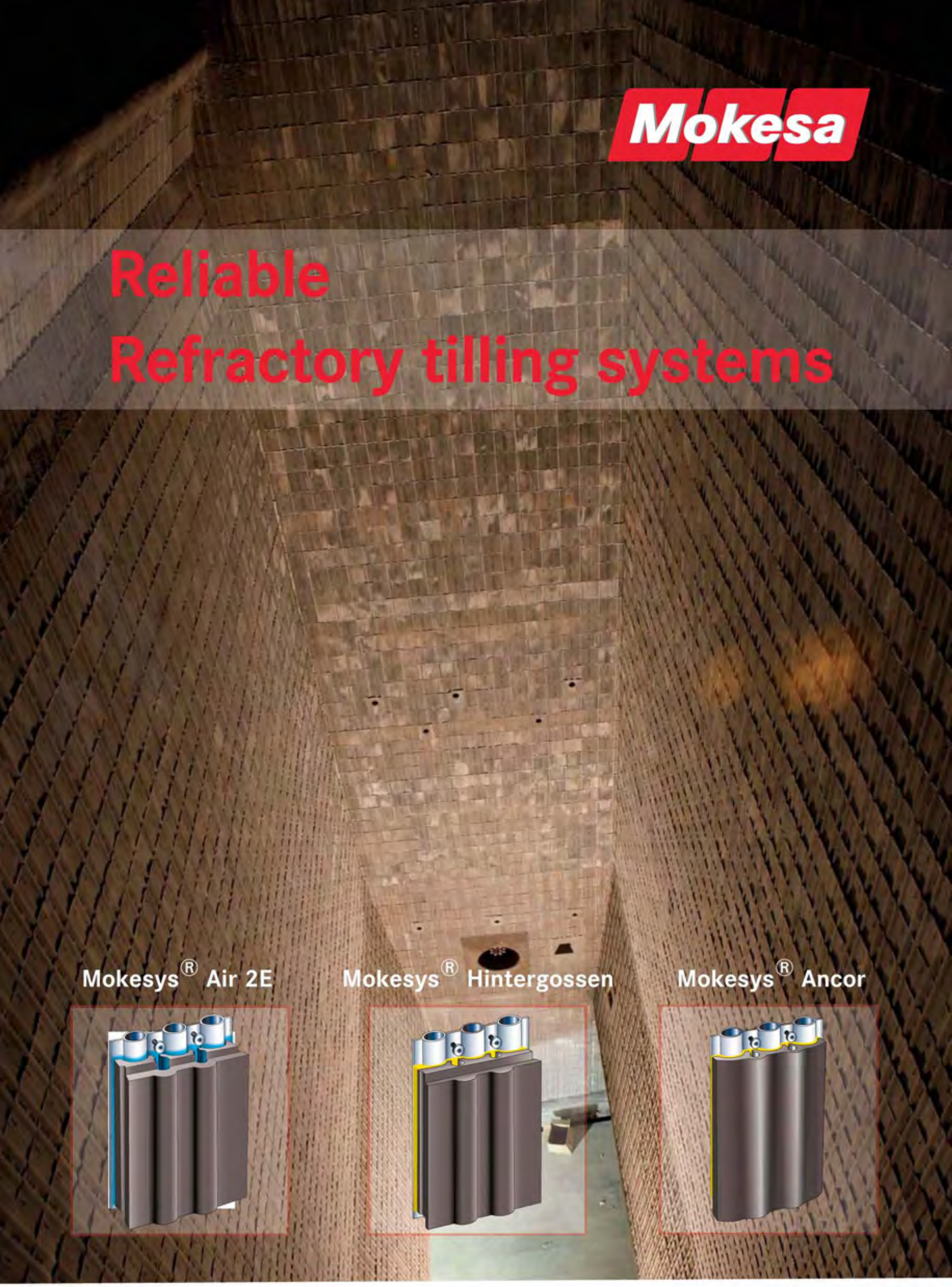

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Optimization and Designing of Modern Waste-to-Energy Plants

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The oldest waste-to-energy plants were constructed more than 100 years ago.

About 400 waste incineration boilers with a total incineration capacity of approx. 45,000 tons of waste per hour exist in Germany today.

Germany is well provided with waste-to-energy plants, there is no demand for further expansion currently. The same applies to RDF-(refuse-derived-fuel) plants: the incineration capacity to utilize RDF is sufficient for its production in Germany.

There is a very different situation in many other countries in the world. Even today there is a focus on waste disposal and treatment by landfill. However, there are many different reasons for taking another new direction.

- Changes in legislation, for example in the new EU accession countries.
  (The European law about waste 2008/98/EG defines that all EU Member States have to effort to professional refuse utilization. On 31/12/2014 the Commission responsible checks the progress and concepts of the Member States. Having waited and postponed necessary decisions put many countries under pressure today.)
- Catastrophic environmental problems by unprofessional realization of landfill
- Acceptance problems in population (e.g. in Vietnam, in Brazil and others)
- Landfills and their impact as disturbing argument for tourism

In many countries the waste amounts are considerable (see diagram) and, even setting for example 35 % of the utilizing waste amounts as target value, there still remains open a high potential for power generation.

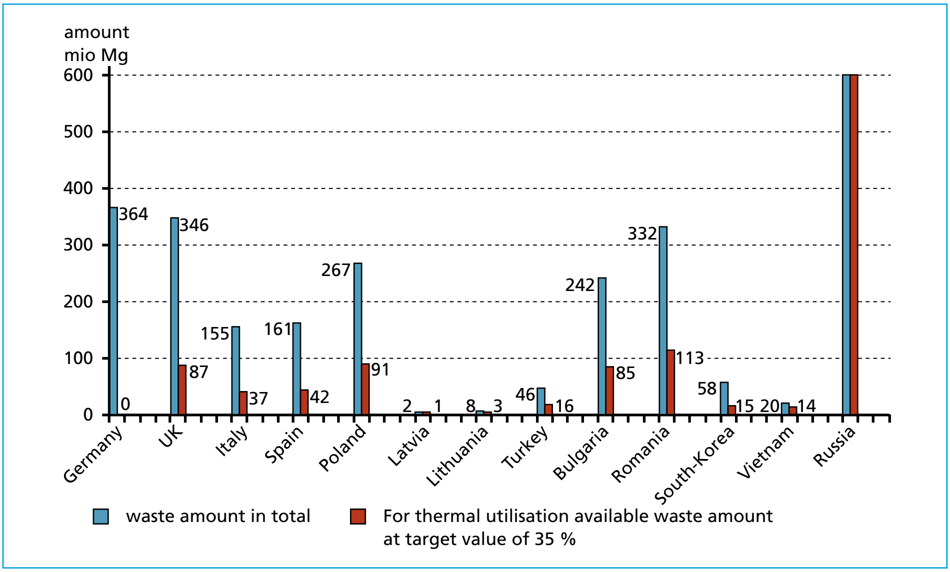

Figure 1: Amount of waste in different countries

Referring to a hypothetic thermal plant capacity of 100 MW with waste quantity of 32 tons per hour, there is a substantial rate of realizable waste-to-energy plants, which is illustrated in the diagram below.

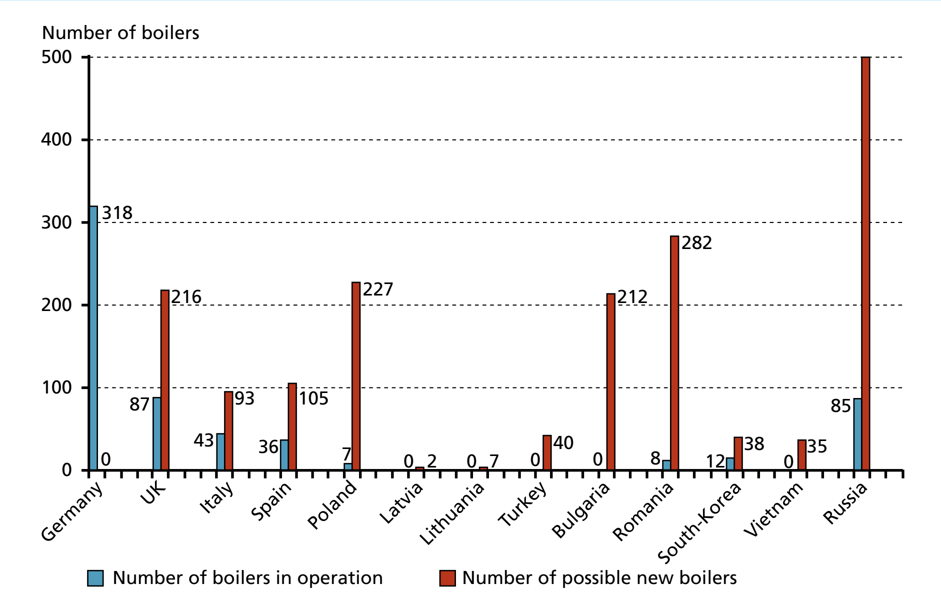

Figure 2: Potential of waste to energy boiler plants

Taking this huge potential and these many different reasons to think about new methods of waste treatment and utilization, there are as many different approaches to design and optimize such plants and systems.

Experience bases on a huge number of incineration plants with quite different fuels, starting with biomass and going on to waste and RDF. Also the requirements for the incineration plants vary greatly:

- Some waste incineration plants are only waste fired. Durability and lifetime are required with lower efficiencies referring to electrical power generation.
- Other substitute fuel plants are working with energy-optimized concepts.
- Some biomass plants have become real high-tech products.

There will be significant developments in waste incineration. The first aim won't be only the waste disposal by thermal utilization but also an increase of energy efficiency and total economic efficiency of such plants.

Why should not these ideas be developed further, which are already prepared and tested for other fuels?

The basic boiler concepts are quite similar and comparable, or the concepts can be adapted at least.

Therefore different development concepts or special features in the boiler and plant design shall be presented thereof many are not used in the classic waste incineration.

The basic plant design considers a waste fired boiler with 40 bars, 400 °C steam parameters and a lower calorific value of 11 MJ/kg.

As mentioned, these live steam parameters were not chosen because of energetic reasons, but exclusively to prevent damages – especially corrosion damage – and to ensure long-term operation.

The variations to this basic design are described together with:

- Change of boiler and plant concept
- Required effort and cost assessment
- Risks from this change
- Advantage of the concept

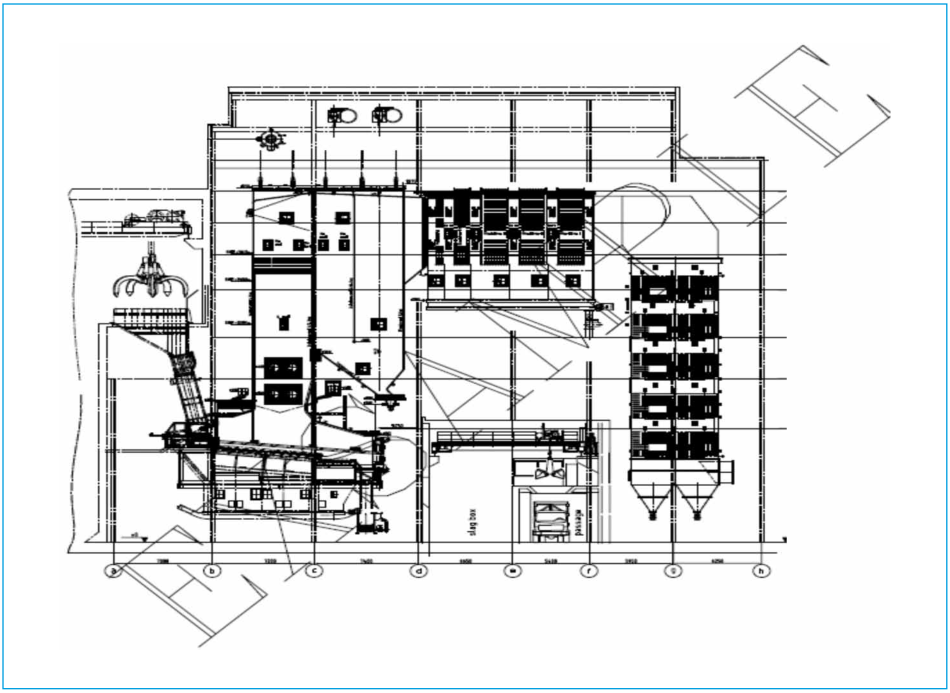

Figure 3: The basic design

It is a standing boiler with 3 vertical passes, a 4th pass for the super-heater and a 5th pass for the economizer. The steam parameters of 40 bars and 400 °C are chosen very conservatively.

The grate furnace is based on an air cooled grate system. The capacity is set on a value of 60 MW thermal capacity, which corresponds to approximately 20 tons per hour fuel quantity.

The incineration air is not preheated. The feed water temperature is 130 °C. The flue gas temperature downstream the economizer is 180 °C.

In a common condensing turbine with air cooled condenser at 20 °C outside temperature the result is a brut electrical output of 15.2 MW at the generator.

Table 1: Data of the basic design

summary	unit	basic variant
Thermal capacity	MW	60
Steam flow	to/h	69
Steam pressure	bar	40
Steam temperature	°C	400
Steam capacity	MW	51
Electrical capacity	MWe	15.2
Electr. Output/fuel-Input	%	25.3

To hold a reference point the thermal capacity is kept constant for all of the following cases.

The variations to the basic concept are:

- Increasing the live steam parameters
- Increasing the temperature of feed water and incineration air.
- Installation of an external super-heater
- Re-heating

Case 1) Increasing the live steam parameters

A moderate increase of the steam parameters for example to 430 °C live steam temperature raises the corrosion risk not significantly. By the use of suitable pipe materials and brick linings in the 1st boiler pass an additional protection of pipes and membrane walls can be achieved. The transition zone after brick linings and also the first part of the hot super-heater section are supplied with cladding and/or protective shells.

Table 2: Data of case 1

summary	unit	case 1: increased steam parameters
Thermal capacity	MW	60
Steam flow	to/h	67.5
Steam pressure	bar	45
Steam temperature	°C	430
Steam capacity	MW	51.1
electrical capacity	MWe	15.7
electr. Output/fuel-Input	%	26.2
additional plant costs	EUR	40,000
increase electr. Output to basis	MWh/anno	4,000

The live steam pressure is based on an optimized working point of the steam turbine at the mentioned temperature. As only a trend of efficiency changing and the relative level of the change shall be considered, 45 bar steam pressure for the new working point is supposed.

There is only a low risk with this change, mainly because possible deteriorations are safely controllable with little effort on material site.

The values change as shown in Table 2.

Case 2) Increasing the temperature of feed water and incineration air

In many biomass plants usually the plant is operating with significantly higher temperature of feed water and incineration air. The main reason is the high costs for the fuel, which accounts for efficiency-optimized operation of the plant.

A feed water temperature of 180 °C and combustion air temperatures of 160 °C are considered in this design case.

For the further exchange of the flue gas temperature downstream to eco, one eco-package can be installed downstream the flue gas cleaning system to preheat the condensate or alternatively a air-pre-heating.

Preheating of the incineration air and also heating of the feed water takes place with tap steam from the steam turbine.

Table 3: Data of case 2

summary	unit	case 2: higher process temperatures
Firing capacity	MW	60
Feed water temperature	°C	150
Combustion air temperature	°C	150
Steam flow	to/h	75.8
Live steam pressure	bar	45
Live steam temperature	°C	430
Steam capacity	MW	55.6
electric capacity	MWe	16.1
electr. Output/fuel-Input	%	26.8
additional plant costs	EUR	220,000
increase electr. Output to basis	MWh/anno	7,200

This measure means no additional technical risk for operation or the life cycle of the plant. The additional investment costs are fairly low referring to the total investment.

The values change as shown in Table 3.

Case 3) Installation of an external super heater

The reason for the additional superheating of the live steam inside an external super heater instead of inside the boiler is the prevention of corrosion damage by chlorine or high temperature. Such an external super heater can be fired with many different fuels: beginning with natural gas or fuel oil, but also with waste oil, landfill gas or gas from purification plants and high-caloric exhaust air. (In Scandinavia separate straw incineration plants operate with a downstream wood chips fired biomass boiler to superheat the generated steam.)

Additional required parts of the plant are an external super heater with burner system, which is suitable for the used fuel. It is possible to re-circulate the hot flue gas directly to the grate firing system or to the first boiler pass. That way the flue gas from the external super-heater is led through the whole boiler and terms like 2 seconds retention time in the 1st boiler pass and integration into the flue gas cleaning device are assured.

As it is possible based on this concept to increase the live steam temperatures significantly it is useful to increase also the live steam pressure under the aspect of optimized working point of the steam turbine.

Table 4: Data of case 3

summary	unit	case 3: external super heater
Firing capacity	MW	60 + 3
Steam flow	to/h	69
Live steam pressure	bar	65
Live steam temperature	°C	480
Steam capacity	MW	54
Electric capacity	MWe	17.9
electr. Output/fuel-Input	%	28.2
additional plant costs	EUR	850,000
increase electr. Output to basis	MWh/anno	21,600

Here we choose a live steam temperature of 480 °C and a pressure of 65 bars.

The investment costs for an external super heater system are with approx. 0.65 Mio Euro higher than the previous variants. At the same time the risk of corrosion is reduced because of the low steam temperatures in the main boiler. Besides such an external super heater can be controlled very well and from the technical point of view it is a relatively simple boiler system.

The values change as shown in Table 4.

Case 4) Reheat

A special solution the reheat, which was only a common practice in big industrial power plants until a few years ago, is today more and more practiced also in grate firing plants in medium capacity ranges.

The cause of this technical solution is the requirement for a significant increase of the electrical efficiency. There can be different reasons: for example in England the high remuneration rates for electricity from biomass depending on the efficiency or in Spain the higher prices for the fuel wood.

This system works also with lower steam temperatures than the system with external super-heater. There is an energetic advantage because the steam is superheated again after a working step in the first part of the turbine. The higher enthalpy from the hot reheat steam is used in the process for generation of electric power.

Table 5: Data of case 4

summary	unit	case 4: re-heating
Firing capacity	MW	60
Steam flow	to/h	66
Live steam pressure	bar	65
Live steam temperature	°C	450
Steam capacity	MW	55.2
Electric capacity	MWe	18
electr. output/fuel-Input	%	30
additional plant costs	EUR	1,500,000
increase electr. output to basis	MWh/anno	22,400

Additional investments are located especially in the steam turbine and the water-steam cycle. The steam turbine consists mainly of 2 turbines which are connected in series, so that there is an extra effort of piping steam side. Inside the boiler the effort of cladding has to be increased.

A disadvantage of this variant certainly is the significant financial additional effort. However it is possible to realize such improvements of the electrical efficiency only by reheat and with comparatively low steam parameters (here 65 bars, 450 °C)

The values change shown in Table 5.

Summary

As shown, the electrical efficiency values are improved and the electrical power generation is increased by all of the individual measures.

Table 6: Data by comparison

Results	unit	basis	case 1	case 2	case 3	case 4
electr. output increase	MWh/a	0	5,640	7,200	21,600	22,400
additional costs	EUR	0	40,000	220,000	850,000	1,500,000
capital reflow	years (with 0.1 EUR/kWh)	0	< 1	3	3.9	6.7

Surely it is possible to combine different concept changes, whereas every individual case and fuel have to be checked in terms of advantages and disadvantages.

As shown above, there are various approaches to optimize and design incineration plants. Basically many optimization steps were already shown in biomass plants. Caused by higher fuel costs (instead of the gate-fees of waste incineration) biomass plants were always forced to attach more importance to high-quality energetic utilization. Also the legislation and financial incentives for electricity input considering criteria like efficiency have contributed to this development.

However, also completely other approaches have a potential for a plant optimizing.

Example 1:

It is possible to reduce the pressure loss by changing the boiler geometry for example at transitions with different physical dimensions or reversing chambers. Also the choice of the tube spacing referring to pollution during operation is very important. A typical value for pressure loss of the whole boiler including economizer and the flue gas treatment is about 40 mbar. This negative pressure has to be generated by the ID-fan to ensure a low pressure in the combustion zone. Flow optimization by furnace-simulations in CFD-models and using the experience of many realized plants could mean reducing the pressure losses of the boiler by up top to 6 mbar. Producing a flue gas volume about 220,000 m^3/h this reduction results in reducing the required drive power of the ID fan by 50 kW. Referring to an operating time of 8,000 h/a and an electricity price of 0.1 EUR/kWh this results also in savings of 40,000 EUR/a.

Example 2:

As already stated at the beginning, most of the waste-to-energy plants are already built and the markets for these technologies move to quite different countries. Associated with this the waste is not comparable with typical domestic refuse in Germany.

In many regions of the world the interest in waste incineration increases. Many times there is a fuel waste, which contains a high proportion of organics, which means also water.

In case, a waste with lower calorific values for example of 7 MJ/kg must be considered for feeding and incineration, huge efforts in air preheating, fuel transport and so on have to be considered.

The alternative and optimization could be to make a small effort in pre-sorting of the fuel with partial drying of the organic content. As a result not only valuable material is gained and foreign material is sorted out, but also the lower calorific value of the organic fraction is increased. Left is a mixed fuel consisting of substitute fuel and pre-dried organic fraction which not only has a higher calorific value but also can be handled and incinerated much easier due to the waste homogenization and sorting out the foreign material.

However, the main energetic advantage is, that there is no need for waste energy for heating and evaporating the moisture of the fuel inside the boiler because of the pre-drying. Usable for the pre-drying is for example exhaust air from the air condenser or sub-quantities of the cleaned flue gas, so that no valuable energy is lost.