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Optimization of Plant Operation by Means of Technical Service

Michael Mück

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1. Situation of Waste-to-Energy plants in Europe and worldwide

The worldwide Waste-to-Energy-Market is still on a high level was a keynote mentioned by EUWID in an article from 23.11.2016 [4]. And it is still in this way. In 2015 and 2016 128 plants started their operation, mainly in Asia. At the end of 2015 worldwide 2150 units are in operation with a capacity of 300,000,000 t/year.

Since 2010 the additional capacity increased about 12,000,000 t/year, only in China. Other parts of the world, for example Europa, added only a capacity of about 2,000,000 to 3,000,000 t/year. In the boom-years between 2008 and 2010 it was more than 4,000,000 t/year. But after a silent period the market in Europe started to create some new projects in the last years and now starts to come back to life slowly.

The focus of this article is not as much on new plants, it is rather giving a look to the possibilities of optimization and development of existing plants.

Please remember: 2150 plants are in operation and the average age is between 18 and 26 years, which is as well shown in the following diagram (Figure 1).

More than 300 units are in an age older than 25 years.

The average age is country-specific and depends, inter alia, on political and environmental decisions.

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Figure 1: Average age of plants in Asia, Central Europe and North America

Sources:
ecoprog GmbH: Market Study Waste to Energy 2016/2017

Figure 2: Number of units related to the age of the plant in Central Europe

Sources:
ecoprog GmbH: Market Study Waste to Energy 2016/2017
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Figure 3: Average age of the boilers in Central Europe

Sources:
- ecoprog GmbH: Market Study Waste to Energy 2016/2017

Like in every industry, changes are taking place, environmental directives are tightened, the waste quality and amount changes, as well as the challenges are changing. The result: most of the plants are not operated in the way they are designed for.

2. Status of the plants

Usually when a plant is built, it fulfils the current environmental requirements. It corresponds to the state of technology at that time with improved and latest technologies. But we should not forget: high price pressure and the marked situation lead to the fact, that new built plants are created under a high economical pressure and the given environmental and economic framework conditions [1, 6].

After the first years of operation the existing experience and change in boundary conditions cause more or less continuous modification of the most plants [2, 9, 10, 11]. In our industry, it is like Rudolf von Bennigsen-Foerder, a German top manager and chairman of Veba AG stated: Stagnation means regression.

Following this statement, it has to be the goal of every plant operator to create a mechanism of continuous development, optimization and modernization. But unfortunately, plant staff usually suffer as well under economical pressure, so that often the time is just
calculated to operate the plant and to do small repair works. Large evaluation of the processes and the development of ideas are often not possible in the necessary depth. But not only the time for developing single components is missing, there is as well a lack of experience e.g. from other plants. Of course, single solutions can be discussed with suppliers or individual solutions can be created like e.g. in the case of cladding in the radiation passes. But is this the right solution for an overall view to the plant?

3. Involved partners

Let us have a rough look to the benefits of each party involved in the optimization process of a plant:

The main players are:

- **Operational personal of the plant:** Operators as well as maintenance staff have a very detailed knowledge about the behaviour of the plant. They know the bottle necks and specific themes like waste supplier, development of specific values, fouling behaviour and corrosion risk [10, 12].

- **Supplier/Producer:** Supplier and producer have a detailed knowledge about the single components, its fabrication and the background of different applications [6].

- **Specialists:** Often specialists are used to evaluate specific topics like corrosion behaviour, emission values, residence time, etc. [5, 6, 13].

- **Maintenance companies:** For revision and repair work maintenance companies are specialized in realizing the work in short time to reduce outage time.

![Synergy model for optimized revamping project](image-url)
- **Plant engineering company**: Based on the specific knowledge of the core components of a plant they are also familiar with ancillary facilities, planning, engineering, layout, procurement assembly works and commissioning. They have mostly gain a lot of experience about realised plants and solutions [11].

In addition to the shown main players there are some more possible participants like consultants, central staff offices and others.

An optimized synergy model depending on the project could create a connection between the players and enhancing the strength of all to realise best synergies and success.

### 4. Education, tools and structure

Well educated employees and a long-term experience is the right approach to realize successful optimization projects. The view to the whole picture and to look behind the plate is the next requirement, a partner should fulfil. The willingness and strength to develop new ideas and solutions are the next essential prerequisite to reach the goal.

To create a high efficient service project, it is important to have a slim structure. Due to the wide range of different projects a large number of experts is needed. A possible solution is a core team responsible to organize and lead the project. Whenever necessary the different experts support the project. As well external specialists and local companies can be included in the team, to work out the best solutions for and with the customer.


The benefit of this structure like shown in the figure above, is the feedback and experience from the plants for developing better solutions and the implementation of continues development.
But not only process engineering and design work is necessary, the evaluation of the current situation as well as possible reasons for optimization are a second important basis for developing solutions. The following tools are the second part of evaluation the basis and checking the success of optimisation steps:

- Analysis of process data,
- Temperature measurement in flue gas path,
- Thermal recalculation,
- Laser scan and layout planning,
- CFD analysis,
- Anchor load measurement,
- Analysis of vibrations and bearings,
- Thermographic analysis,
- Endoscopy analysis.

Figure 6: Necessary tools for optimized service projects

5. Steps for improvement

To realise a successful project, it is basically important to do the right steps at the right time.

Make sure that you follow the guidance and find answers:

- What are the needs, what is the status?
- What is the goal, the necessaries, the costs and the benefit?
- Develop a concept and evaluate the costs and the benefit
- In which way can you manage the interplay of experiences, goals and tools?
In a practical way, this means to start a project in the first step with a basic analysis of the current plant situation. The mentioned synergy effects become an important meaning. All involved partners can bring in their experience and knowledge to develop ideas and solutions. Based on this analysis optimization concepts are created and a cost and time frame evaluation takes place, as well a analysis of the return of invest. Now a priority list of projects can be created.

![Figure 7: Priority model to evaluate realistic and profitable optimization projects](image)

![Figure 8: Life cycle model for optimized revamping projects](image)
Michael Mück

Waste Incineration

Figure 7 shows a priority model to evaluate the most realistic and profitable projects (A, B, C).

After pointing out the projects the second step is a detailed engineering. The goal is to specify the scope in such a particularly way, that material and components can be ordered. Dismantling and erection is the next step, commissioning finalizes the project. To find optimized results the life cycle model shows the main idea for optimized revamping projects. After the first commissioning, the optimization takes place as long as a continues result is reached.

6. Customer satisfaction and expectations

To fulfil the expectations of the customer it is necessary to have a weight service portfolio managed by a core service team.

To underline all these theoretical ideas in the following chapter a number of plants are shown where a long-term partnership is the basis for the technical support in different optimization projects, from basic studies up to the realisation on site.

![Service portfolio and expectations of a cooperative partnership](image)

7. Examples of realised projects and partnerships with plant operators

7.1. Example I: A plant in Italy (3 x 113.3 MWth)

Plant designed for RDF, high heat value, steam parameter chosen because of financial benefit for high efficiency. Changes in the meantime:

- Waste quality (LHV decrease),
- Slag amount increases,
- Corrosion risk increases,
• Fouling behaviour increases,
• Residence time change by waste quality and modified refractory,
• Due point problems in the bag house filter,
• Vibration problems with fans,
• Noise problems in air preheater.

Based on a long-term agreement for engineering support a large number of single optimization projects over a five years period was started.

a) Caused by the change of the fuel and its quality a number of modifications have been realised in cooperation with operating experienced staff and the plant supplier. The combustion control was adapted to the changed waste quality to realise a stable combustion, steam flow and burn out quality.

b) The deslagger was medicated to become able to handle the much higher amount of slag in the household waste instead of the low amount in RDF.

c) The changed waste quality leads in combination with the high steam parameter to an unexpected high corrosion rate. Together with experts for analysing the corrosion behaviour and its mechanism, a concept was developed to protect the affected areas by cladding and refractory to increase live time and reduce maintenance costs.

d) To improve the drying phase of the waste and stabilise the burn out quality a steam supported air preheater was retrofitted.

e) The modified heat value of the fuel in combination with the optimized combustion control and the changed wall protection caused changes in the residence time. Together with experts from a measuring institute, the support from a university and the experience of operator and supplier, the calculated characteristics where evaluated and adapted.

f) Vibration in fans and noise problems in the air preheater where analysed with special tools, verified with theoretical calculations and concepts to solve these matters where developed and realised.

g) Caused by different circumstances due point problems in parts of the flue gas system could be solved by a thermographic scan to locate damages in the insulation.

h) Mainly influenced by the waste quality and the need for realising the superheater in a high temperature area, the higher corrosion risk leads to high maintenance costs. With a detailed analysis of the process data, a recalculation of the boiler, combined with ideas of the plant staff a modified superheater concept was developed and realised by a local supplier.

i) Is the combustion system able to fulfil requirements by lower heat values and higher waste flow? To underline this an analysis of the current situation and ash quality was done.

j) To update the operator manual all realized changes where updated.
k) Mistakes in the calculation of the drum level were analyzed and a revised calculation was implemented.

l) Monitoring tool: To calculate the efficiency of different heat surface parts of the boiler and a more aimed use of the soot blower a monitoring system was created (Figure 10 and 11).

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**Figure 10:** Principle structure of advanced monitoring tool


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**Figure 11:** Example: Calculation of fouling value for the economizer
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7.2. Example II: A plant in Northern Germany (2 x 22 MWth)

The technical support phase started with a basic analysis of the current situation of the plant. This analysis was supported by specialist for checking all relevant measurements and the flue gas distribution in the first pass. An evaluation of all mass- and energy flows as well as recalculation of the boiler and flue gas cleaning was the basis for the development of several projects.

a) How much refractory is necessary?

b) Increasing of plant efficiency by saving primary fuel for flue gas reheating, support by a consulting company to create an idea. The influence on the boilers and its temperature and heat balance was evaluated in a pre-study. In a second step, the reheating of the flue gas by gas burners was changed into a drum steam supported heat exchanger.

c) Optimizing process by constant thermal load to increase waste throughput and reducing thermals peaks, by implementation of an optimized combustion control.

d) Change in fuel quality leads to fouling problems in the first pass, reduced live time of refractory and grate. Development of measures to reduce thermal stress.

e) Increasing efficiency of power units lead to a reduced electrical consumption. But what is the return of invest? To evaluate this mater, all large consumers where checked and a list of sense full optimization matters was created.

f) Flue gas condensation and reuse of heat out of the flue gas system can achieve a big step forward according the efficiency of the plant. Pointing out possibilities with focus on the function of the complex flue gas cleaning system was goal of a realised evaluation study.

Figure 12:
Support of concept development by CFD study
Figure 13: Erecting of steam supported heat exchanger upstream DeNOx reactor

Figure 14: Detailed analysis of necessary refractory surface and influence to the residence time

7.3. Example III: A plant in Eastern Germany (1 x 114 MWth)

After the first wave of plants were built for RDF combined with high steam parameter and efficiency some years of operation was needed to point out the real operating conditions. Falling electrical revenues and high maintenance costs caused by the special fuel lead to a rethinking. This was the start for a long-term partnership to analyse the different challenges, to develop ideas and concepts and to realize it.
a) Waste to Energy plants are dependent on the available fuel and its costs or revenues. On the other hand, different fuels are design relevant. To enlarge the spectrum of fuel it was necessary to evaluate the influence of the fuel to the combustion system, the boiler and the flue gas treatment. Based on this evaluation the possible limits related to the fuel inside the existing design where pointed out.

b) Lower heat values and higher water content lead to the necessity of preheated primary air. A concept to integrate an air preheater in the existing primary air system as well as in the steam and condensate system was developed in close adjustment with the customer. This system is prepared for realisation.

c) Due to the condition of the flue gas in combination with the high parameter continuously different analysis and evaluation have been done in a partnership between specialists for corrosion analysis, operator and SBENG. The goal was to evaluate the dependencies and possibilities to reduce corrosion risk by using the available technologies according to:
   • refractory
   • protecting layers and material (e.g. cladding)
   • modification in the superheater flow

d) To reduce the gap between grate and boiler a new concept was developed, that reduces the thermal and mechanical stress for the compensator.

e) The reduction of NO\textsubscript{x} emissions is a goal to achieve future emission levels. The first step in partnership with the operator and by running several tests, was to evaluate possibilities and limits in the combustion system. Temperature level, temperature gradient as well as temperature distribution where the main focus and basis for further steps. The selection of the right technology and the development of an optimized functional description was the second step. And finally, the concepts were installed and successful commissioned.

f) The availability of the plant, its safety and finally the cost for insurance policies are the driver to develop a new emergency power concept.

All this steps where supported by measurements, analysis of process data and thermal calculations.
7.4. Example IV: A plant in Western Germany (1 x 76.4 MW<sub>th</sub>)

Plant with roller grate technologies are designed for a small range of heat value changes. Changes on the waste marked led to increased heat values and as a consequence to higher thermal stress for the refractory in the combustion chamber. An increase in maintenance costs was the result.

a) Based on operation and maintenance experience a new refractory concept considering the as built thermal calculation as well as the new concept and its consequences according the temperature distribution, wall temperature and residence time was realized in the annual revision.

b) A clear structure in combustion control with the view to load stabilization and fire position is the next step to optimize thermal stress for the combustion chamber and its components and the boiler itself. In the meantime, this measure is successful realized.

c) By operating the plant in island-mode different circumstances caused a malfunction of a turbine and subsequently a loss of other turbines and blackout of the plant. All available process data where analysed and recalculated in models. A concept to solve the problem was developed.

Figure 16:
New developed refractory concept
Optimization of Plant Operation by Means of Technical Service

Figure 17: Balance of the complete water steam cycle

Figure 18: Analysis of process data
7.5. Example V: A plant in Western Germany (1 x 35 MW\textsubscript{th}, 3 x 40 MW\textsubscript{th}, 2 x 45 MW\textsubscript{th})

A way to increase the efficiency of a plant is to rise the live steam parameter. This was planned together with the change of an old boiler and the concept for a new turbine. One question, that has to be answered: What are the consequences for the existing boilers?

a) To evaluate the influences on the existing process, thermal calculation with new parameter were done to point out the consequences.

b) A plant in close neighbourhood to residential buildings has a certain view to noise protection. To increase the acceptance in the neighbourhood and to lower the noise emission a new concept for the silencer of the blow down tank was developed.

c) Changing of waste quality in a changing market led to problems with the combustion quality. The layout possibilities in an existing plant are very limited. To improve the combustion quality and the burn out results we started to develop a concept to realise an additional primary air preheater. The specific challenge is to combine process needs and given layout possibilities.

7.6. Example VI: A plant in the Netherlands (2 x 60 MW\textsubscript{th})

The general view on a newly built facility assumes that it is state-of-the-art and free from defects. But what happens, if the plant builder gets into insolvency and the plant is not yet fully optimized?

In a partnership of involved experts from different companies and based on a fundamental knowledge about the design, the time after commissioning was used to start the optimization work and the development of new concepts.

a) As a basis for further steps the basic study was done to point out all bottle necks and the current situation as well as the potential of the plant.

b) Damages caused by a blackout has been analyzed and reported as support for further insurance discussions.
c) Based on the basic study the possible load increase was evaluated in a second step. The limitation in some components, as well as the necessary improvements for safety related components and optimization of control loops were listed and the consequences for the boiler were shown.

d) Temperature distribution in the 1st pass and the reduction of peaks, which lead to a higher corrosion risk, was combined with the optimization of the combustion control.

e) A possible step to increase the overall efficiency of the water steam cycle is to rise the live steam parameter. But not only the process side of the boiler must be able to fulfill this, as well the pressure part has to be able to work with the new parameters. Based on several thermal calculations the maximum stress was evaluated and all headers and pipes as well as the pressure parts of the boiler were checked.

Figure 20: Evaluation of the reason for deformation of an evaporator wall
Whenever you can use heat out of the water-steam-system on a very low level without condensing losses, you can use this benefit to increase plant efficiency. Heat directly from waste! Supporting a customer with warm water to heat up a water cycle for production was the goal of a concept development. Before it was necessary to check the influence of this to the existing boiler one and to and to the boiler under construction in line 3. Especially the drum heat exchanger reaches its limits, but with modified bypass of the economizers the boilers are operable.

7.7. Example VII: A plant in Finland (1 x 53 MW\textsubscript{th}, 1 x 36 MW)

In the most plants, single components are delivered in a standard way related to the project budget and under competitive pressure. After some years of operation, the operating company starts to develop solutions with a longer life time and lower maintenance costs. Changes in fuel quality as well as possible reductions of operating costs are the basis for different optimization projects realised in the meantime.

a) A optimized fuel chute concept and modification at the grate reduced maintenance costs and the number of unplanned outages.

b) To find the right temperature profile for SNCR a check of the unnecessariness of refractory in the upper part of the 1st pass was the goal for a detailed process data analysis compared with temperature measurements and a measurement program with different combustion air distributions. In a second step, the SNCR process was modified to reduce operating costs. Refractory height could be reduced and changed to a maintenance friendly system.

7.8. Example VIII: A plant in Western Germany

(1 x 33 MW\textsubscript{th}, 1x 18 MW\textsubscript{th}, 1 x 6 MW\textsubscript{th}, 1 x 3,5 MW\textsubscript{th})

Hazardous waste plants are very specific and the operating staff has a lot of experience with the combination of fuel and its influence to fouling and wearing. On the other hand, in times of reduced personal and the focus on economic aspects unplanned outages are increasing and the pressure on optimization solutions becomes higher. Related to the different parts of the plant a large number of projects where started.

a) A first step was the development of a boiler diary with the aim to show the complete history of the done repair works and modifications. The status of the different parts where evaluated, measured and documented. Similar activities where done on the process side.

b) Based on the above-mentioned status analysis and a customer developed concept for a change in fuel types a new concept for the oven hood was developed and constructed in detail. CFD analysis and the experience of the operating staff was part of the developed solution.

c) To check the influence of different water content in sludge test periods were analysed and the consequences for the boiler where pointed out.
d) The development and support of an *energy management system* was and still is a close working relationship between customer and SBENG to optimize energy consumption in the process line. Based on balances and detailed analyses the goal is to identify implausible measurements, to check not properly working components and to implement an PDMA-cycle. In the meantime, a successful audit attests the good work.

e) Refractory in the combustion part and in the pre-combustion chamber is a high costly maintenance item. Expert analysis and concept developments in combination with supplier and customer led to an optimized system.

f) To reduce unplanned outages in the flue gas cleaning caused by the quench header, new materials where checked and realisation is under progress.

7.9. Example IX: A plant in Western Germany (2 x 27 MW, 1 x 36 MW)

Related to the age of existing boiler and grate improvement in this three-line plant is clearly needed. After a complete revamping of the flue gas treatment in the year 1996 caused by the environmental regulations, the combustion system a boiler is main focus now.

The goal was mainly:
- increasing efficiency,
- reducing maintenance time and costs,
- creating solutions for fouling problems in the radiation pass of the boiler,
- improvement of the existing combustion control.

Based on operator experience and process data the evaluation of the current status and the development of the necessary modifications was done in the following steps:

a) In a basic study, the current situation of the combustion units and boiler where analysed. Thermal recalculation of the different load cases, fouling stages and heat values took place as well as a check of all necessary components. Possible solutions to reach the above-mentioned goal were developed:
- modification of the grate system,
- modification of the combustion chamber and refractory,
- combustion air distribution and O₂-content,
- cleaning systems for the radiation pass,
- modification in heat surface cycle,
- additional economizer to reduce flue gas outlet temperature.

b) In a second step, the discussed and agreed solutions where detailed in the basic engineering phase with the following results:
- detailed description of the planed measure,
- bill of quantity of the measure,
- time schedule for realisation: engineering, production, dismantling, erecting and commissioning,
• specification for components,
• influence on the existing system,
• pointing out of benefits,
• cost estimation.

c) In the meantime, the combustion control was optimized for all three lines as the measure with the shortest time to realize without a plant outage.

Figure 21: Concept for an evaporator cooled combustion chamber side wall

7.10. Example X: A plant in Western Germany (90 MWth)

Figure 22: Repeated leakage – analysis, concept development, realisation
A coal and reject fired boiler supports a paper producing process. High availability and flexible operation is the goal. After several unplanned outages caused by a leakage of an evaporator wall in the hopper below 2nd and 3rd pass, the customer asks for support. He knew that different small project where realised before, the reason for damages was analysed and a solution was created. In the meantime, the following projects where realised:

a) Development of a concept for sidewall cooling for the reject grate.

b) Analysis of reason for leakages in the evaporator wall. As a reason, a structural mistake in the water circulating system could be identified.

c) Development and detail engineering for solution to solve the leakage problems.

d) Realisation of the modification.

8. Summary and outlook

_The who sticks his head in the sand today, has grit in his teeth tomorrow_. There is no reason to designate. The large number of successful realized project shows that a trustful partnership between plant operator and owner and right skilled partners is the right foundation for the implementation of optimization and development projects. The success speaks for itself.

Do not _stew in your own juice_, work together with competent partners! And avoid to stand still in your development, try a continues development instead, better step by step than with big jumps.

9. Literature


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