Highly Efficient Energy-from-Waste Plants in the Netherlands

Innovative Concepts for Highly Efficient Energy-from-Waste Plants in the Netherlands

Gerhard Lohe and Kees Sinke

1. Introduction
In 2008 AE&E Lentjes GmbH received the order for the turnkey supply of the incineration unit REC Harlingen (REC=ReststoffenEnergieCentrale). In this plant the high calorific portion of pre-treated municipal solid waste is thermally treated.

In the following it will be reported about the conceptual particularities of this plant as well as about first operational results.

2. Remarks about the Waste Disposal in the Netherlands
In the Netherlands 16.3 Mio. inhabitants annually produce about 60 Mio. tons of waste; with some 450 inhabitants per m² the Netherlands belong to the countries with the highest population density within Europe. The mostly rather flat land has a well developed system of streets as well as water ways resulting in rather low transport cost.

467 communities in 12 provinces are obliged to find a solution for the disposal of their household waste. The waste collection usually takes place on a weekly basis, the financing of the disposal system is based on a waste specific tax system. The provinces have the responsibility for the licensing of plants as well as the control of regulations. The state itself is responsible for legislation and for the set-up of a national waste plan.

Thermal waste treatment has a long tradition in the Netherlands, so that the portion of untreated waste which is landfilled is rather small. In 2009 (as of December 31st) there were in total 11 EfW plants with a permitted capacity of 6.888 Mio. t/y in operation (this does not include the hospital waste incineration plant ZAVIN). The extension of capacities (new
plants as well as plant extensions) in the provinces of Groningen, South Holland, North Brabant and North Friesland but also considering the shut down of the plant in Rotterdam there are today (as of July 2011) in total 12 plants with the capacity of 7.406 Mio. t/y. The EfW plant Coevorden is not included in this balance.

The further installation of additional capacities in the Netherlands is not to be expected. Since the end of 2009 there is a consensus between the involved parties that there will be no further initiatives for the extension of capacities. Ministries will engage themselves for an accelerated assignment of the R1-status for the existing plants.

In accordance with the SDE-Program the plant operators in the Netherlands receive since 2003 subsidies for the produced energy depending on the plant efficiency [1]. The calculation of subsidies takes place on a theoretical efficiency value that includes 2/3 of the produced heat and 1/3 of the produced electricity.

Mechanical biological treatment plants were considered only as transitional solution at an early point of time and not as a replacement for EfW plants. The market for MBT plants in the Netherlands is thus limited.

The average total capacity per plant is about 620,000 t/y. Though comparably high technological efforts in particular with regard to the gas cleaning system are applied the gate fees are still on a moderate level, the range is between 80 and 125 EUR per ton. With regard to the thermal capacity there is a high degree of utilisation of the plants; the difference between the theoretical possible throughput and the actual throughput is related to the increased heating value that has taken place since the original design phase.

A detailed analysis of the status of waste treatment in the Netherlands is given in [2] and [3].

3. The REC Harlingen Project

The public association Afvalsturing Friesland N.V., acting under the trade name Omrin is engaged in the disposal of municipal solid waste coming from the 31 communities within the province of Friesland. Omrin is a regionally active waste management company in the North of the Netherlands and treats more than 750,000 t of waste per year. Some 500 employees generate an annual turnover of 110 Mio. EUR.

Omrin is active along the entire chain of waste disposal. In the past Omrin had concentrated exclusively on the mechanical waste treatment. These activities were to be extended by the construction and operation of an EfW plant which was to be specially designed for the conditions prevailing in the North of the Netherlands.

In the past the waste was collected, transported and either mechanically treated at the Ecopark De Wierde close to Oudehaske (separation of valuable materials) and/or finally treated in the surrounding EfW plants. The overall concept also included adequate recycling activities within the area of the province.

A mechanical waste treatment plant as well as an anaerobic biological treatment plant (SBI) was taken into operation by the end of 2002. These plants are operated by Omrin as well. The treatment capacity is in the range of 228,000 t per year, whereas 55-60 % RDF, 40-45 % of wet organic fraction as well 2-3 % metals are separated from this stream. This concept included that the final treatment of the combustible fraction (RDF and a paper/plastic mixture) should be taken over by external parties.

The dependency on a treatment capacity beyond own control as well as the relatively limited treatment capacities in the surrounding incineration plants – in connection with increasing
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disposal prices – resulted in first thoughts at the beginning of the new century to build up own treatment capacities and thus to build an EfW plant within the contracted disposal area.

An analysis of the waste streams showed that from the approx. 600,000 t per year of waste arising in the province following pre-treatment and separation of valuable materials an amount of approx. 228,000 t per year was available for a thermal waste treatment plant. The heating value of the waste was determined to be approx. 13 MJ/kg so that a thermal capacity approx. 100 MW was taken as a basis for further planning.

As already outlined the average plant capacity in the Netherlands is about 620,000 t/y. The recovery of energy is strongly related to the generation of electricity. Considering the huge plant capacity the production of heat in particular in the Netherlands seems to be difficult and applications are limited.

Omrin clearly recognized the disadvantage of this large scale philosophy and looked for alternative solutions.

Finally with the company ESCO/Frisia Zout BV in Harlingen the site was identified that in an optimum way fit into the own planning to build a plant with a maximum efficiency (Figure 1). The generated steam is used in a process to produce about 1 Mio. t/y of salt as well as in a 15 MW turbine for the generation of electricity for the site and to cover the parasitic consumption of the new EfW plant (Figure 2). This combination resulted in a total efficiency of about 80 %, a value which is the highest for EfW plants in the Netherlands.

ESCO was looking for a reduction of the primary energy cost by substituting LNG at their Harlingen site. The fast price increase for fossil fuels in the past years would have further

Figure 1: Plant Site Harlingen/NL
increased the anyway high energy cost of the saline plant. Thus an integral part of the energy concept for the Harlingen site was the integration of the Frisia power plant within a contracting model by Omrin. Omrin was to use the primary steam from the EfW plant for the production of electricity as well.

In consideration of the already existing pre-treatment and the relatively high heating value first planning activities included the possibility to incinerate the waste in a fluidized bed system. That would have been a meaningful application under consideration of purely economic aspects. A missing experience with this technology as well as the high dependency of the operational security and the disposal security from the degree of pre-treatment of waste finally resulted in the decision to apply the well known grate technology.

Further investigations as well as visits of various EfW plants in Europe finally supported the decision in favour of a grate bases combustion system. It was considered as a further advantage that a necessary pre-treatment of waste was limited and that there are several references for this technology for the incineration of municipal solid waste.

Thus thoughts to apply the fluidized bed technology instead of the grate based technology were rejected pretty soon, so that the grate based process should again represent the state of art for EfW plants.

The realization of the Harlingen project eventually started in 2006. In a first step Omrin engaged the engineering and consultancy company MAKE. This company had at its disposal a vast experience with regard to the technology as well as with regard to the necessary project management to realize an EfW plant in the Netherlands. Thus this company had the task to realise the project Harlingen regarding both technical as well as organisational aspects.

Omrin’s 31 shareholders were engaged for the project and internally gave their full support for this.

The project financing was done in cooperation with two Dutch banks (RABO and BNG). In addition to the SDE subsidies being granted over a period of 15 years there was an additional state subsidy of approx. 6 Mio. EUR.

The REC Harlingen plant was planned and built in accordance with the one-line-principle. The installation of 2 incineration lines was only considered to be economic beyond a capacity of 400,000 t/y. Such waste amounts were not available at the site and would have meant an additional import of waste from abroad.
In September 2006 the four lots (lot 1: grate/boiler/BOP, lot 2: flue gas cleaning, lot 3: E/I&C, lot 5: civils) were published in the EU-Journal. In parallel planning permission was applied for. Already in May 2007 the selection of the successful bidders took place as well as the final approval of the project by the shareholders of Omrin. In November 2007 AE&E Lentjes GmbH received the contract for a FEED study followed by the award of the supply contract in October 2008. Provisional transfer of the plant took place on time and in accordance with planning on May 31, 2011.

The throughput of the plant in the design point is 27.7 t/h at a heating value of 13 MJ/kg corresponding to a thermal heat capacity of 100 MW (Figure 3). The range of heating value is between 9 and 15 MJ/kg. The minimum heat input is 80 MWth. The well advanced Lentjes 2-track-reciprocating-grate technology is applied including water cooled grate bars (Figure 4). The grate width is approx. 11 m (Figure 5).

![Combustion Diagram](image)

![Water Cooled Grate Bar](image)
The boiler is of a 5-path type where the first three empty paths followed by a horizontal and finally entering a vertical fifth path (Figure 6).
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Integrated directly heated superheater

Today’s waste fired steam generators are usually operated at 40-45 bar and a steam temperature of up to 420 °C. Higher operating pressures as well as higher steam temperatures are usually avoided in view of the increased risk of corrosion of the superheater surfaces, or alternatively higher exchange rates for the superheater tubes including longer revision and shut-down times are considered.

Tube temperatures above 400 °C in combination with flue gas temperatures above 650 °C result in strong fouling of the superheater tubes and thus reduced travelling times due to the ash melting and sticky property of the ash.

Though higher temperatures result in an improved efficiency usually the above mentioned temperature limits are applied.

In order to be able to apply temperatures above the steam temperature of 420 °C without increasing the risk of corrosion a system was developed including a separately gas fired superheater being integrated to the steam generator. This separately fired superheater is integrated to the boiler without being in contact with the corrosion causing flue gas of the combustion system.

As the direct fired superheater is operated with LNG there must be a case to case investigation if the improvement of the efficiency is economic in consideration of the LNG prices. In any case such an implication is useful where because of other reasons very high steam temperatures are required for example if the steam is fed into an existing adjacent plant which is already operated with higher parameters.

This was exactly the case for the REC Harlingen plant. The generated steam from the boiler is fed into the neighboured plant. The existing turbine with operating parameters of 85 bar and 455-460 °C was originally operated with steam coming from a gas fired boiler. This gas fired boiler was taken out of operation after the completion of the waste boiler respectively was replaced by this. The old boiler will in the future only be operated in the stand-by mode, i.e. will only be in operation during shut-down periods of the new waste incineration unit. The shut-down of the purely gas fired boiler results in savings of approx. 75 Mio. m³ of LNG per annum.

It was the intention of the operator to run the waste boiler only up to a steam temperature of 420 °C and to apply a further super-heating up to 460 °C in the separately fired superheater. Because of the restrictions in the boiler house it was not possible to do the additional super-heating in a separate system. Thus the concept was developed to integrate the superheater into the waste boiler however, without bringing the superheater in contact with the flue gas from the incineration process.

The directly fired superheater is arranged in an adiabatic chamber upstream the economizer (Figure 7). The necessary heat is generated by two gas fired burners (2 • 8 MW) on the left and right hand side of this chamber. The flue gas from the gas-burning process is added to main flue gas stream coming from the incineration process before entering the economizer at a similar temperature level (approx. 450 °C).

The gas fired combustion chamber is executed on an adiabatic basis in order to avoid the application of additional steam being heated up to the final steam temperature.

The advantages as there are

- no separately arranged superheater inside the boiler house without additional space requirements,
- no piping necessary between the main boiler and the separate superheater as the superheater is integrated into the main boiler,
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- no additional flue gas duct work or no separate stack for the directly heated superheater,
- higher degree of efficiency,
- lower investment cost in comparison to a separately arranged superheater inside the boiler house

must be compared with the additional gas requirement (approx. 1.000-1.500m³/h).

The steam (87 bar, 465 °C, approx. 113 t/h) is transported by an approx. 800 m long piping system to the Frisia plant. There it is utilized, condensed and the condensate is pumped back to the waste incineration plant.

The flue gas cleaning plant is made up of an electrostatic precipitator subsequent to the boiler, a bag-house filter where a mixture of activated carbon and bicarbonate is added as well as a low temperature SCR catalytic system. The clean flue gas is finally led to the stack. The clean gas data as stipulated in the planning permission are far below the EU directive values.

With an efficiency of approx. 80 % the Harlingen plant has the highest efficiency of all EfW plants operated in the Netherlands. It was Omrin's intention to find the highest possible effect for the environment under the proviso of lowest tariffs for the waste disposal. Moderate investment cost as well as an efficiently educated operating crew finally contribute to the fact that the gate fees for the treatment of waste in the Harlingen plant are clearly below 100 EUR per ton.

With the regard to the execution of the project the very particular approach of the engineering and consultant office MAKE must be mentioned. In applying an Integrated Project Management approach it was possible to improve the cooperation and the direct exchange of information between the various lot suppliers. The project management was mainly taken over by two engineers who were able to concentrate on their specific task as being organisation and technology.
The positive attitude of the suppliers to create a joint project was extremely helpful during the entire execution period even under very difficult wintertime conditions.

4. Operation Experience

Since the commissioning of the plant in average approx. 48 trucks per day (Monday-Friday) deliver waste to the plant which is stored and mixed inside the 12,000 m³ waste bunker.

Since then the plant is in full load mode without interruptions and the guaranteed operational parameters were constantly and without delay proven.

Only a few weeks after the provisional takeover it must be stated that the overall plant concept based on vast experience has proven its reliability and that all parties are highly satisfied about the results of the project. The integrated gas fired superheater fulfils without any operational problems the highest expectations.

CO values below 3 mg/m³ₙ give proof of a premium incineration process as well as the NOx values behind the boiler in a range of 250-350 mg/m³ₙ. The clean gas values at the stack are far below the required emission limit values.

The following maximum daily average values were fixed in the permission respectively achieved during operation at the stack outlet.

**Table 1: Limit and operational value**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Limit Value</th>
<th>Operational Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust</td>
<td>mg/m³ₙ</td>
<td>5</td>
</tr>
<tr>
<td>HCl</td>
<td>mg/m³ₙ</td>
<td>8</td>
</tr>
<tr>
<td>NOx</td>
<td>mg/m³ₙ</td>
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</tr>
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<td>CO</td>
<td>mg/m³ₙ</td>
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<tr>
<td>SO₂</td>
<td>mg/m³ₙ</td>
<td>40</td>
</tr>
<tr>
<td>CH₄</td>
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<td>Hg</td>
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</tr>
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<td>HF</td>
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</tr>
<tr>
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<td>mg/m³ₙ</td>
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</tr>
<tr>
<td>Cd + Tl*</td>
<td>mg/m³ₙ</td>
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<td>Sum heavy metals</td>
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<tr>
<td>PCDD/F*</td>
<td>ng TEQ/m³ₙ</td>
<td>0.1</td>
</tr>
</tbody>
</table>

* Definition of values refer to [http://www.omrin.nl/over_omrin/REC_Harlingen.aspx](http://www.omrin.nl/over_omrin/REC_Harlingen.aspx)

The effective emission data are publicly available [4].

The balance for the main consumables and residues at a throughput of 228,000 t/y is as follows:

- Sodiumbicarbonate: 5,000 t/a
- Activated Carbon: 1,000 t/a
- Residues FGC: 6,000 t/a
- Fly Ash: 4,000 t/a
- Bottom Ash: 40,000 t/a
The plant is operated by 35 persons in a five-shift-system and convinces with highest performance by applying a perfect design of the individual components and systems (Figure 8).

5. Summary
For each individual new built project the aim is to achieve a maximum disposal security under consideration of lowest gate fees.

It becomes clear that there is no general solution for this problem, however, a project specific proceeding and optimum plant concept is to be defined.

This also includes the question in how far a general contractor system must be applied to realize a project. It became very clear during the execution of the Harlingen project that the lotwise tendering has finally resulted in an optimum plant concept and it must be emphasized that such proceeding was also accepted by the institutions being responsible for project finance. A turnkey approach must not necessarily result in the optimum solution in particular in consideration of the prevailing contractor structures as of today.

In case of a lotwise tendering it is of highest importance to have a competent partner for the planning that provides knowledge in the field of technology as well as in the field of project management, however, is still in a position to achieve an optimum result with a minimum personnel exposure in a joint cooperation with the suppliers.

In addition it must be emphasized that the tendering of a complex project such as an EfW plant is hardly possible within a one-fits-all-strategy approach. The individual bidders must be given the opportunity to work out their optimum plant and process concept.

The project REC Harlingen gives clear proof that a pragmatic approach for the tendering and construction of a complex project such as an EfW plant finally emanates in an approved result for all involved parties.

6. Credentials
We would like to take the opportunity to express our thanks for the engineering and consultant office MAKE as well as our principal Omrin for the efficient and perfect cooperation during this extensive and complex project.
7. References

[1] Regeling van de Minister van Economische Zaken, No. WJZ 3073206