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Innovative Concepts of High-Efficiency EfW Plants

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Municipal waste has characteristics that make it particularly suitable for the generation of heat and power. Waste is generally available close to the location of heat and power consumption in towns and densely populated areas. The technology used in modern Energy-from-Waste (EfW) plants is such that the waste is transformed into a reusable ash and that the flue gases are no longer a significant source of emissions. These points have been assured by the European Waste Incineration directive since 2005.

The standard Energy-from-Waste technology in Europe consists of grate-based combustion systems. Typically, these sometimes quite old plants produce 546 kWh of electricity per ton of waste, which corresponds to a gross energy efficiency of 18% referred to the gross heat input from waste and additional fuels (Basis: heating value of 10.44 MJ/kg and electricity production only). Due to in-plant consumption of an average of 150 kWh per ton of waste, this results in an average exported electricity of 396 kWh (net efficiency of 13 %). Most recent Energy-from-Waste plants use steam parameters of 40 bar / 400°C. Typically, these plants produce 650 kWh of electricity per ton of waste, which corresponds to a gross energy efficiency of 22% (heating value of 10.44 MJ/kg). With an in-plant consumption of 150 kWh, this typically results in exported electricity of 500 kWh (net efficiency of 17%). These data refer to the Best Available Technology document on waste incineration by the EU IPPC directive (BREF).

In some of the more advanced European countries, landfilling of municipal waste is restricted and efforts are being concentrated on further improving the energy efficiency of Energy-from-Waste plants beyond the values mentioned above. The driving force behind the implementation of high-energy systems is usually a premium for renewable electricity from waste, for example:

Netherlands	14.5 €/MWh for 10 years if efficiency > 26% (2003)
Italy	170 €/MWh with the CHP6 program (no longer valid)
Italy	80 €/MWh (variable) on the "green market" for 8 years
Spain	23.4 €/MWh in (Directive 1998); Bilbao: 30% premium on the electricity price

There is a large potential for improving the use of the energy contained in municipal waste. On the one hand, waste can be diverted from landfilling and, on the other, the energy efficiency of Energy-from-Waste plants can be improved. In this respect the main topics apply to power generation: Steam parameters (pressure and temperature of superheated steam), flue gas heat losses (temperature at boiler outlet, excess air rate), steam condensation conditions (air or water condensers), thermal cycles (intermediate superheating, external superheating, 2 or 3 pressure systems), in-plant consumption (SNCR/SCR, excess air rate).

Examples of recent innovative Energy-from-Waste plants with highly efficient power generation can be found in Brescia, Amsterdam and Bilbao (**Table 1**). The Brescia plant has an increased gross efficiency of produced electricity of 27% through increased steam parameters, reduced flue gas losses and minimized in-plant consumption. The new plant in Amsterdam achieves 30% with additional intermediate superheating and water condensers. A further increase in energy efficiency is then only possible by external superheating with natural gas in combined cycle plants, as in Bilbao. However, innovations also took place in the field of heat recovery. The Malmö plant is an example, where efficiency has been increased by using heat generated from flue gas condensation for district heating. Twence is another example, where a high degree of energy recovery is achieved by combining heat and power production.

Table 1: New Energy-from-Waste systems in Europe
(estimated produced electricity percentages are referred to the gross heat of the waste input)

<table>
<tr><th>Plant</th><th>Brescia # 1+2
(Italy)</th><th>Brescia # 3
(Italy)</th><th>Amsterdam # 5+6
(Netherlands)</th><th>Mainz
(Germany)</th><th>Bilbao
(Spain)</th></tr>
<tr><td>Start-up</td><td>1998</td><td>2004</td><td>2006</td><td>2003</td><td>2004</td></tr>
<tr><td>Combustion system</td><td>MARTIN reverse-acting grate</td><td>MARTIN reverse-acting grate</td><td>MARTIN horizontal grate</td><td>MARTIN reverse-acting grate</td><td>MARTIN reverse-acting grate</td></tr>
<tr><td>NOx reduction</td><td>SNCR</td><td>SNCR</td><td>SNCR</td><td>SNCR</td><td>SNCR</td></tr>
<tr><td>Special feature</td><td>Optimized for high efficiency</td><td>Optimized for high efficiency</td><td>Intermediate steam superheating and water condenser</td><td>Coupled with combined cycle process (natural gas turbine)</td><td>Integration with combined cycle process (natural gas turbine)</td></tr>
<tr><td>Fuel</td><td>MSW, sewage sludge, biomass</td><td>Biomass, sewage sludge</td><td>MSW</td><td>MSW, natural gas</td><td>MSW, natural gas</td></tr>
<tr><td>Steam pressure [bar]</td><td>61</td><td>73</td><td>130</td><td>40</td><td>100</td></tr>
<tr><td>Superheated steam temperature [°C]</td><td>450</td><td>480</td><td>440</td><td>400 / 555</td><td>540</td></tr>
<tr><td>Gas temperature at boiler outlet [°C]</td><td>135</td><td>135</td><td>180
(135 °C with additional heat recovery after ESP and fabric filter)</td><td>200</td><td>200</td></tr>
<tr><td rowspan="3">Electricity produced [%; gross]</td><td rowspan="3">27</td><td rowspan="3">28</td><td rowspan="3">> 30</td><td>> 40</td><td>46</td></tr>
<tr><td colspan="2">(referred to total gross heat of waste + natural gas)</td></tr>
<tr><td colspan="2">25,8
(referred to gross heat of waste)</td></tr>
</table>

In the case of power generation, the main limitation on increasing energy efficiency is posed by the increased cost and corrosion risk. For the use of heat, climatic limitations and the cost of district heating grids are important considerations. Generally speaking, the increase in efficiency leads to an increase of the overall complexity of the process. Additional skills and competence are needed for plant design, process control and operation. Nevertheless, cost-benefit and eco-efficiency analyses clearly show that these additional efforts should be made. In Europe, potential exists to increase the proportion of Energy-from-Waste to over 10% of

MARTIN®, MARTIN reverse-acting grate®, SYNCOM® are registered trademarks in some countries the overall renewable energy produced as half of the energy contained in municipal waste is of biogenic origin.

The presentation describes the potential and the limitations of the most common measures for increasing energy efficiency as well as examples of recent innovative Energy-from-Waste plants with highly efficient power generation using MARTIN technology.