Possibilities for Application of the Entrained Flow Gasifier for the Processing of Municipal Solid Waste in the Republic of Serbia

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Gasifier Configurations

Moving Bed

Entrained Flow

Fluidized Bed

Transport

Siemens Gasifier

• The gasifier is a dry feed, oxygen-blown, top fired reactor with a water wall screen in the gasifier.

• It is able to convert a large range of fuels and is ideally suited for lower-rank fuels like lignite with high ash and moisture and other corresponding fuel types like biomass or liquid refinery residues.

• Particle size distribution and moisture level depend on the type of feedstock used; typical ranges are below 0.5 mm and 2-12 % moisture.

• Conversion takes place at temperatures of around 1,300°C to 1,800°C.

• These high temperatures, in combination with the dry feed system, allow for the almost complete conversion of the feedstock.

• The produced raw gas mainly consists of CO, H2 and small amounts of CO2 and is free of any higher hydrocarbons.
Siemens Gasifier

Fuel

Oxygen, Steam

Buner

Pressur. water outlet

Cooling screen

Pressur. water inlet

Quench water

Cooling jacket

Gas outlet

Water overflow

Granulated slag
Siemens Gasification Combined Cycle

Gas Island

- **Coal Preparation**
  - Coal
- **Air Separation Unit**
  - Oxygen
- **Gasifier**
  - Raw syngas
- **Gasifier Island**
  - Slag and Filter cake
  - Sulfur
- **CO₂ removal or Enhanced Oil Recovery (EOR)**

Power Island

- **Air**
  - N₂
- **CCPP** (Combined Cycle Power Plant)
  - H₂ rich syngas
- **Electricity**

Co-Production of Chemicals

- **Synthesis**
  - Transportation fuels
  - Methanol
  - Ammonia
  - Hydrogen

Siemens PG scope of delivery
Specific Problems of MSW Processing

- An estimated composition. MSW is a complex mix of materials derived from a number of sources within urban areas, in turn destined for various handling, processing and disposal routes - MSW as a fuel can vary in type, format and relative quantity of components.

- MSW might include a number of composite materials and is likely to contain traces of hazardous elements (for example, lead, mercury, paints, pesticide, etc.) that could create operational and environmental risks.

- The percentage of biodegradable components (including organic ones), moisture and ash content directly influence both the energy value and the behaviour of MSW as fuel.

⇒ The composition of MSW for processing has to be constantly followed throughout the lifetime of the plant and the adjustments performed if required

⇒ Some experience from the biomass gasification as the fairly mature technology could be utilised in designing MSW gasification
## Incineration vs Gasification

<table>
<thead>
<tr>
<th>Potential advantage/benefit of gasification vs. incineration</th>
<th>Related drawbacks/issues that hinder the benefit of gasification</th>
</tr>
</thead>
</table>
| (a) the combustible gas generated by gasification (gas) is easier to handle, meter and control than MSW  
(b) the homogenous, gas-phase combustion of syngas can be carried out under conditions more favourable than those achievable with MSW | (a) since gas is highly toxic and explosive, its presence raises major security concerns and requires sophisticated control equipment  
(b) since feedstock is oxidized/converted in two steps (gasification + gas combustion/conversion) plants tend to be more complex and costly, more difficult to operate and maintain, less reliable |
| The reducing conditions in the gasifier:  
(i) improve the quality of solid residues, particularly metals  
(ii) reduce the generation of some pollutants (dioxins, furans and NO\textsubscript{X}) | The actual production of pollutants depends on how gas is processed downstream of the gasifier; if gas is eventually oxidized, dioxins, furans and N\textsubscript{ox} may still be an issue |
| Gas can be used, after proper treatment, in highly efficient internally-fired cycles (gas turbines and combined cycles, Otto engines) | (a) Required gas treatment is costly and causes significant energy consumption/losses  
(b) Due to the consumption/losses of gasification and syngas clean-up, overall energy conversion efficiency is typically lower than that of combustion plants  
(c) At the small scale typical of waste treatment plants, efficiency of internally-fired systems is low (especially if gas turbine based) |
| Gas can be used, after proper treatment, to generate high-quality fuels (diesel fuel, gasoline or hydrogen) or chemicals | (a) Required gas treatment very demanding and costly  
(b) At the small scale typical of waste treatment plants, synthesizing quality fuels or chemicals can entail prohibitive costs |
| Gasification at high pressure enhances the opportunities to increase energy conversion efficiency and reduce costs | Pressurized waste gasification poses formidable challenges and has not been attempted by any technology developer |
Application of Entrained Flow Gasifier for MSW Processing

• It is necessary to study the optimal parameters, such as type of gasification agents and its flow rate, and temperature, for the thermal treatment of MSW and its composites, such as wood, plastics, as a feedstock to derive the maximum possible energy.

• The design of the plant should provide reliable and commercially viable operation.

Initial step for the selection of the technology is the calculation of gross revenue in order to estimate the viability of such projects

As the practical example was used the region of Niš, Serbia, with the following parameters:

➢ Waste composition as published in 2015
➢ Nominal MSW quantity for calculations 100000 t/year
➢ Plant operation based on assumed 330 working days per year on 24 working hours basis
### Average solid waste composition for the region of Niš, Serbia

<table>
<thead>
<tr>
<th>MSW composition:</th>
<th>%</th>
<th>t/year</th>
<th>%</th>
<th>t/year</th>
<th>t/day</th>
<th>t/h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>dry matter</td>
<td></td>
<td>dry matter</td>
<td>dry matter</td>
<td>dry matter</td>
</tr>
<tr>
<td>Organics</td>
<td>31.2</td>
<td>31200</td>
<td>35</td>
<td>10920</td>
<td>33.1</td>
<td>1.38</td>
</tr>
<tr>
<td>Paper, Cardboard</td>
<td>13.39</td>
<td>13390</td>
<td>50</td>
<td>6695</td>
<td>20.3</td>
<td>0.85</td>
</tr>
<tr>
<td>Wood</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastics</td>
<td>31.86</td>
<td>31860</td>
<td>95</td>
<td>30267</td>
<td>91.7</td>
<td>3.82</td>
</tr>
<tr>
<td>Rubber, leather, textiles, diapers</td>
<td>7.33</td>
<td>7330</td>
<td>80</td>
<td>5864</td>
<td>17.8</td>
<td>0.74</td>
</tr>
<tr>
<td>Metals</td>
<td>1.62</td>
<td>1620</td>
<td>100</td>
<td>1620</td>
<td>4.9</td>
<td>0.2</td>
</tr>
<tr>
<td>Glass</td>
<td>5.6</td>
<td>5600</td>
<td>100</td>
<td>5600</td>
<td>17</td>
<td>0.71</td>
</tr>
<tr>
<td>Stones, sand, ceramics</td>
<td>9</td>
<td>9000</td>
<td>80</td>
<td>7200</td>
<td>21.8</td>
<td>0.91</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100</td>
<td>100000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**MSW input for gasification**

<table>
<thead>
<tr>
<th>Category</th>
<th>t/year</th>
<th>t/day</th>
<th>t/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic fraction</td>
<td>10920</td>
<td>33.1</td>
<td>1.38</td>
</tr>
<tr>
<td>Paper/cardboard</td>
<td>6695</td>
<td>20.3</td>
<td>0.85</td>
</tr>
<tr>
<td>Plastics</td>
<td>30267</td>
<td>91.7</td>
<td>3.82</td>
</tr>
<tr>
<td>Rubber, rags, leather, diapers</td>
<td>5864</td>
<td>17.8</td>
<td>0.74</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>53746</td>
<td>163</td>
<td>6.79</td>
</tr>
</tbody>
</table>
### Energy content of MSW components

<table>
<thead>
<tr>
<th>Selected MSW component</th>
<th>Specific energy content kWh/t dry</th>
<th>Available energy content kWh/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic fraction</td>
<td>33.1</td>
<td>3500</td>
</tr>
<tr>
<td>Paper/cardboard</td>
<td>20.3</td>
<td>3800</td>
</tr>
<tr>
<td>Plastics</td>
<td>91.7</td>
<td>9100</td>
</tr>
<tr>
<td>Rubber, rags, leather, diapers, etc.</td>
<td>17.8</td>
<td>4100</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>143.3</strong></td>
<td>-</td>
</tr>
</tbody>
</table>

**Available energy content kWh/day:**

115,850

77,140

834,470

72,980

1,100,440
Gross electrical and thermal energy production

<table>
<thead>
<tr>
<th></th>
<th>Units</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical energy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy content of syngas</td>
<td>kWh/day</td>
<td>1,100,440</td>
</tr>
<tr>
<td>Overall process conversion efficiency</td>
<td>%</td>
<td>80</td>
</tr>
<tr>
<td>Total energy generated</td>
<td>kWh/day</td>
<td>880,352</td>
</tr>
<tr>
<td>Conversion into electricity</td>
<td>%</td>
<td>42</td>
</tr>
<tr>
<td>Produced electric energy</td>
<td>kWh/day</td>
<td>369,748</td>
</tr>
<tr>
<td><strong>Thermal energy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remaining thermal energy</td>
<td>kWh/day</td>
<td>730,692</td>
</tr>
</tbody>
</table>
Conclusions

• Entrained flow gasification should be taken into consideration for the conversion of non-recyclable MSW components into energy, in particular within combined heat and power (CHP) plant.
• Siemens’ proprietary solution was presented as a specific example for several reasons, including their long experience and practical applications, high carbon conversion coefficient, syngas purification, their own solution for Integrated Gasification Combined Cycle (IGCC), etc. Hence, such well tested and documented system provides a sound basis to adapt to MSW as feedstock.
• The specific requirements for MSW gasification point out that perhaps the most critical segment in the process is the fuel feeding system. The starting working platform might be the industrial gasification of biomass in use in entrained flow gasifiers, further adjusted to MSW composition on a case-by-case basis.
• The provided yield and gross revenue analysis, based on the average MSW composition for the region of Niš in the Republic of Serbia, shows the potential of entrained flow gasification. With the assumed round figure of 100000 t/year of MSW for processing, the example can be easily adjusted to another location, i.e. quantity and/or composition.