The effect of waste management systems on district heating

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Improvements of Waste Management Technology

a) Converting non-recyclable, non-hazardous waste into renewable energy using the same gasification technology

b) Generating energy from the anaerobic digestion of organic waste

c) Producing sustainable energy by exploiting the methane given off by the degradation process of landfill waste
Gasification

• Process of converting organic compounds into a mixture of gaseous species that is dominated by: carbon dioxide (CO$_2$), carbon monoxide (CO), hydrogen (H$_2$), and methane (CH$_4$).

• The gasification process converts biomass at high temperatures and in the presence of limited oxygen into an energy carrier as the presence of the hydrogen and methane demonstrates.

• Outcome: a multi-use product, which operates at lower temperatures.
# Gasification

Main characteristics of the chemical processes for thermal treatment of solid waste. Adapted from Arena and Mastellone (2009).

<table>
<thead>
<tr>
<th></th>
<th>Combustion</th>
<th>Gasification</th>
<th>Pyrolysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aim of the process</strong></td>
<td>To maximize waste conversion to high temperature flue gases, mainly CO₂ and H₂O</td>
<td>To maximize waste conversion to high heating value fuel gases, mainly CO, H₂ and CH₄</td>
<td>To maximize thermal decomposition of solid waste to gases and condensed phases</td>
</tr>
<tr>
<td><strong>Operating conditions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Reaction environment</strong></td>
<td>Oxidizing (oxidant amount larger than that required by stoichiometric combustion)</td>
<td>Reducing (oxidant amount lower than that required by stoichiometric combustion)</td>
<td>Total absence of any oxidant</td>
</tr>
<tr>
<td><strong>Reactant gas</strong></td>
<td>Air</td>
<td>Air, pure oxygen, oxygen-enriched air, steam</td>
<td>None</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>Between 850°C and 1200°C</td>
<td>Between 550-900°C (in air gasification) and 1000-1600°C</td>
<td>Between 500°C and 800°C</td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>Generally atmospheric</td>
<td>Generally atmospheric</td>
<td>Slight over-pressure</td>
</tr>
<tr>
<td><strong>Process output</strong></td>
<td>CO₂, H₂O</td>
<td>CO₂, H₅, CO₂, H₂O, CH₄</td>
<td>CO₂, H₂, CH₄ and other hydrocarbons</td>
</tr>
<tr>
<td><strong>Pollutants</strong></td>
<td>SO₂, NOₓ, HCl, PCDD/F, particulate</td>
<td>H₂S, HCl, COS, NH₃, HCN, tar, alkali, particulate</td>
<td>H₂S, HCl, NH₃, HCN, tar, particulate</td>
</tr>
<tr>
<td><strong>Ash</strong></td>
<td>Bottom ash can be treated to recover ferrous (iron, steel) and non-ferrous metals (such as aluminum, copper and zinc) and inert materials (to be utilized as a sustainable building material). Air Pollution Control residues are generally treated and disposed as industrial waste</td>
<td>As for combustion process, bottom ash are often produced as vitreous slag that can be utilized as backfilling material for road construction</td>
<td>Often having a not negligible carbon content. Treated and disposed as industrial special waste</td>
</tr>
<tr>
<td><strong>Gas cleaning</strong></td>
<td>Treated in air pollution control units to meet the emission limits and then sent to the stack</td>
<td>It is possible to clean the syngas to meet the standards of chemicals production processes or those of high efficiency energy conversion devices</td>
<td>It is possible to clean the syngas to meet the standards of chemicals production processes or those of high efficiency energy conversion devices</td>
</tr>
</tbody>
</table>

*Source: Arena (2012)*
The gasification of a solid waste includes a sequence of successive, endothermic and exothermic, steps:

1. Heating and drying (160°C)
2. Devolatilization (700°C)
3. A number of chemical reactions: the water–gas reaction, the Bouduard reaction and the hydrogasification.
District Heating

District heating systems:
- are a network of pipelines for distributing heat generated in either a centralized location or a number of distributed heat producing unit
- used for residential and commercial heating requirements such as space heating and water heating (Ancona et al., 2013).
Case Studies - Denmark

- Established a program to shift its power production from inefficient fossil fuel companies to municipal companies.

- Advantages of transfer to Combined Heat and Power (CHP):
  
  - Reliability, Scalability and Flexibility
  - Community Autonomy
  - Adoption of Renewable Energy
  - Cost Efficiency
Case Studies - Finland

Lahti Gasification Project – CHP built by SAACKE Group

Produces 50 MW of electricity and 90 MW of district heat

Supplies power and district heat to local communities
Case Studies - Sweden

• Pioneer in district heating systems
• Stockholm’s first district heating system was developed in the late 1950’s and the current system serves 80% of Stockholm’s heating needs.
• The heating sources are based on renewables, on waste energy and on residual heat from factories.
• Most of the city’s household waste is burned by the Högdalen cogeneration plant that also uses wastewater heat to fuel the district heating system and to produce electricity.
Conclusion

• Biomass gasification is economically viable and creates high value products (including electricity) in the district heating system.
• Regardless, the type of investment may differ greatly based on the regulatory environment (renewables in particular).
• Under the EU renewables and energy efficiency initiatives waste gasification should gain popularity in the district heating systems, given the continued technology development and the long-term policy instruments, to reach the 20/20/20 targets (Difs et al., 2010).
References

• Ancona, M.A., Bianchi, M., Branchini, L. and Melino, F. (2013), District heating network design and analysis; 68th Conference of the Italian Thermal Machines Engineering Association, ATI2013; Energy Procedia, 45, p.1225-1234

• Arafat, H.A. and Jijakli (2013): Modeling and comparative assessment of municipal solid waste
gasification for energy production; Waste Management, 33, p.1704-1713


