Trends and Drivers in Alternative Thermal Conversion of Waste

Task 36 - Material and Energy Valorisation of Waste in a Circular Economy

Dieter Stapf, Karlsruhe Institute of Technology (KIT)

Webinar, September 16, 2020
Typical Composition* of Residual Household Waste in Developed Countries

WEEE: Waste Electrical and Electronic Equipment

State-of-the-art Waste Incineration Technology:
Wast-to-Energy plant converting collected untreated waste to heat and power

IEA Bioenergy T36 webinar on „Valorization of fly ash from Waste-to-Energy plants“, October 7, 12:00 CEST
The EU Waste Hierarchy

• In the context of climate protection, environmental protection and the concept of a Circular Economy
European Waste Treatment Status in 2014

Policy Related to Landfilling* in Selected EU Countries

- Landfilling of untreated (combustible) waste to be terminated
  - Long lasting expiry periods
- Insufficient (or even no) incineration capacities in some countries
  - Growing waste produced, incineration capacities fully utilized
- Low acceptance of incineration in some countries

Underlying Legal Boundary Conditions

• Target „Recycling quotas“ 2030 (wt-%):

Plastic waste: 55 %
60 % Self-commitment Plastics Europe

MSW: 60 % Council, May 22, 2018

Plastics in packaging waste: 63 % (2022) Packaging law, Germany, Jan. 2019

Additional plastic waste recycling capacities required in EU until 2030: 11 Mt/a
# Plastics Production and Plastic Waste Generation

<table>
<thead>
<tr>
<th></th>
<th>EU 28+2*</th>
<th>Germany**</th>
<th>Italy***</th>
<th>Sweden****</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastics production</td>
<td>61.8</td>
<td>19.9</td>
<td>9.0(^{a})</td>
<td>1.3</td>
</tr>
<tr>
<td>Plastics consumption</td>
<td>51.2</td>
<td>12.6</td>
<td>7.1</td>
<td>n/a</td>
</tr>
<tr>
<td>Plastic waste</td>
<td>29.1</td>
<td>6.2</td>
<td>4.5</td>
<td>1.7</td>
</tr>
<tr>
<td>- Landfill</td>
<td>7.2</td>
<td>&lt; 0.1</td>
<td>1.6</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>- Energy recovery</td>
<td>12.4</td>
<td>3.2</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>- Recycling</td>
<td>9.4 (export 1.8)</td>
<td>2.9 (export: 0.6)</td>
<td>1.4</td>
<td>0.1</td>
</tr>
</tbody>
</table>

\(^{a}\) Estimated

Collection and Sorting of Lightweight Packaging Waste

Recycling Processes for Mixed Waste and their Key Products

**Physical processes**
- Recovered component

**Chemical processes**
- New material

**Mechanical sorting**

**Solvent extraction**

**Solvolysis**
- Building blocks

**Thermochemical conversion**
- Gasification
  - Syngas
- Pyrolysis
  - Pygas / -oil

- Mixed wastes
- Pure plastics,
- Poly-condensates
- Mixed wastes, composite materials
Thermochemical Recycling of Plastic Wastes

Commercial industrial scale Waste-to-Chemicals operations:
- Showa Denko, Kawasaki, Japan (Ammonia from separately collected packaging waste)
- Enerkem, Edmonton, Canada (Methanol / Ethanol from RDF)
  + W2C project, Rotterdam
- Nippon Steel, Hirohata (secondary raw materials by waste tire pyrolysis)

Historical (Shut down):
- SVZ, Schwarze Pumpe, Germany (RDF, sewage sludge, packaging waste to Methanol)
- Krupp Ude, Berrenrath, Germany (RDF to Methanol)
Industrial Capital Investment Projects: Chemical recycling of plastic wastes

- Plastic Energy, London, UK
  - Almeria, Sevilla, ES

- Recycling Technologies, Swindon, UK
  - RT7000 project, Perthshire, Scotland

- Sabic
  - Cooperation with Plastic Energy, Geleen, NL

- LyondelBasell
  - MoReTec-plant, Ferrara, IT

- BASF
  - Cooperation with Quantafuel, Oslo, NOR
CEMEX Cement Plant at Rüdersdorf, Germany: Waste gasification (CFB) to generate calciner heat

RHW Pyrolysis Plant at Burgau, Germany

CHP Production from Waste

- Started up in 1983
- Final capacity of 26 kt/a
- Shut down in Dec 2015
Process Chain of the Thermochemical Recycling of Waste to Secondary (Chemical) Feedstock
Waste-to-Chemicals Process Chain
Case: Gasification of RHW to Syngas for Methanol Production

pretreatment

conversion

upgrading

Household collection waste (RHW)

Gasifier feedstock (RDF, SRF)

Raw syngas

On-spec feed to methanol synthesis

- CO$_2$, CO, H$_2$, CH$_4$,
- tar components,
- H$_2$S, HCl, Hg, ...

H$_2$:CO = 2:1,
- tar free,
- contaminants concentrations below 0.1ppm, ...
Mechanical Pretreatment of Residual Household Waste RHW

<table>
<thead>
<tr>
<th>Parameter</th>
<th>RHW</th>
<th>RDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content wt-%</td>
<td>23.8</td>
<td>21.8</td>
</tr>
<tr>
<td>Combustibles wt-%</td>
<td>47.6</td>
<td>64.4</td>
</tr>
<tr>
<td>Ash content wt-%</td>
<td>28.6</td>
<td>13.8</td>
</tr>
<tr>
<td>Lower heating value MJ/kg</td>
<td>10.9</td>
<td>15.0</td>
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Syngas Upgrading Process Chain

- Process water
- Fluidized Bed Gasifier
- Gas cooling
- Tar Removal
- Filtration
- Water-Gas Shift
- Heat-Exchanger
- Gas Scrubbing
- Secondary Filter (Activated carbon)
- Compression

Particles:
- Sulphurous components
- Nitrogenous components
- Halogenes
- CH₄
- Waste Water
- CO₂

Methanol synthesis
Example of Material Flows in CFB-Gasification of Residual Household Waste to Methanol Syngas

Basic Flow Scheme of Pyrolysis Applied to Waste

Air

Feedstock → Pyrolysis → Aqueous Liquids → Combustion → Exhaust Gas

Pyrolysis → Gases → Condensation

Condensation → Organic Liquids

Solids
Example of Material Flows in Rotary Kiln Pyrolysis of Residual Household Waste

Economics of Selected Waste-to-Chemicals Value Chains**

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<tr>
<th>Process</th>
<th>Pretreatment [€/t_{RHW}]</th>
<th>Conversion [€/t_{RHW}]</th>
<th>Upgrading [€/t_{RHW}]</th>
<th>Total processing cost [€/t_{RHW}]</th>
<th>Revenues* [€/t_{RHW}]</th>
</tr>
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<tr>
<td>Gasification</td>
<td>21</td>
<td>86</td>
<td>105</td>
<td>212</td>
<td>- 68</td>
</tr>
<tr>
<td>Pyrolysis</td>
<td>21</td>
<td>162</td>
<td>0</td>
<td>183</td>
<td>- 86</td>
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*) Syngas @ 200 €/t  
Naphtha @ 500 €/t

**) Conversion unit size: ca. 100 MW; ca. 25 t/h of pretreated household waste (RDF)

Capital investment cost estimate accuracy: ± 30%
## Process Overview: Economies and Risk

### Technology Readiness Level TRL

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<th>Upgrading Rawgas / crude</th>
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<td>9</td>
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<td>5 - 6</td>
<td>3</td>
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- TRL 5: large scale prototype
- TRL 6: prototype system
- TRL 7: demonstration system
- TRL 8: first of a kind commercial system
- TRL 9: full commercial application

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Trends and Drivers in Alternative Thermal Conversion of Waste - Conclusions

• Pyrolysis and gasification thermally separate mixed wastes to generate secondary feedstocks for industrial processing
• Mostly not competitive to waste incineration when focused on power and heat production from waste
• Chemical recycling:
  • Competitiveness results from associated product revenues
  • Complements mechanical sorting
  • Maximizes recycling rates and minimizes greenhouse gas emissions
• Targeted R&D is needed in parallel with the development of policy incentives to allow these technologies to emerge
Report announcement

T36
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