Alternative Thermal Treatment for Municipal Solid Waste-to-Energy plants!

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TURNKEY PROJECT
designer and supplier
for Environment and Energy…

WtE Sheffield, UK
recovers Energy from Municipal Solid Waste of 82 million people around the world!
operates facilities using 2,2 million tons of solid fuel per year

Baku, Azerbaïdjan: 500,000 tons MSW /year
CNIM Group

424 Flue Gas Treatment lines in 26 countries since 1952!

WtE Amagerforbraending, Copenhagen, Denmark
“...provide impartial information about the range of technologies referred to as Advanced Thermal Treatment (ATT) – the principle ones being gasification and pyrolysis. These technologies are designed to recover energy (in the form of heat, electricity or fuel) and can contribute to the diversion of biodegradable municipal waste (BMW) from landfill. ...“
What is the purpose of ATT for MSW?

- In Japan, direct melting of residues because of IBA disposal problems and dioxins limitation
- In Europe or USA, hope of higher efficient combustion cycles for power production ... and subsidies in UK
- Better/different image of gasification vs incineration as Gas in general is perceived as a non polluting energy source
- Confusion between Syngas and Natural Gas or Biogas
- After CTL (Coal to Liquids), WTL (Waste) hope / dream?
Syngas ≠ Biogas

SYNGAS (Thermal Waste gasification)
main combustible CO+H₂ mixed with N₂ + CO₂ + H₂O
≠

BIOGAS (Landfill or Anaerobic digestion)
main combustible CH₄ mixed with CO₂

From GE 2012
Waste Thermal gasification Syngas characteristics

- Fluctuating composition with heterogeneous feedstock requiring in general preparation, drying…
- Very low NCV around 0.5-1 kWh/Nm³ with air (cf ROC « Standard 2MJ/Nm³/ Advanced 4MJ/Nm³») with wet, high ash content and low NCV feedstock
- <<1/5 of Biogas NCV! Suitable for boiler use! Limit for engine!
- Syngas highly toxic (lethal if 1.3% CO) & explosive! Polluted by tars, dust, H₂S…difficult to clean!
- Problems of burn-out in char/residues?
- Small scale of waste projects!

“Universal" gasifier, able to handle all or most fuels or fuel types, does not exist! (FAO wood gasifier study)
Carbon Gasification reactions

**Combustion**

1. \( C + \frac{1}{2} O_2 \rightarrow CO \) (-111 MJ/kmol)
2. \( CO + \frac{1}{2} O_2 \rightarrow CO_2 \) (-283 MJ/kmol)
3. \( H_2 + \frac{1}{2} O_2 \rightarrow H_2O \) (-242 MJ/kmol)

**Other gasification reactions**

4. \( C + H_2O \leftrightarrow CO + H_2 \) "the Water-Gas Reaction“ (+131 MJ/kmol)
5. \( C + CO_2 \leftrightarrow 2CO \) "the Boudouard Reaction“ (+172 MJ/kmol)
6. \( C + 2H_2 \leftrightarrow CH_4 \) "the Methanation Reaction (-75 MJ/kmol)

With total carbon conversion, in homogeneous gas phase

7. \( CO + H_2O \leftrightarrow CO_2 + H_2 \) "Water-Gas-Shift Reaction" (-41 MJ/kmol)
8. \( CH_4 + H_2O \leftrightarrow CO_2 + 3 H_2 \) "Steam-Methane-Reforming Reaction" (+206 MJ/kmol)
9. \( CO + 2H_2 \leftrightarrow CH_3OH \) « Hydrogenation Reaction », then Fischer Tropsch
Typical Syngas composition

- **$N_2$ excluded**
- **Arena 2012**
Fossil fuel Gasification (coal, oil...) is not new!

- Gasification combined with steam and limited oxygen in a heated & pressurized vessel
- \( \text{H}_2/\text{CO} \) ratio important for chemicals (\( \text{H}_2, \text{CH}_3\text{OH}, \text{NH}_3... \)), for liquid fuels production (Fischer Tropsch) with low inerts content (\( \text{N}_2, \text{H}_2\text{O}, \text{CO}_2... \)) with catalysts
- Tars, dust or pollutants contents importance for power application

World Gasification Capacity and Planned Growth –by Product
Source: NETL 2010 Worldwide Gasification Database

1 million vehicles during World War II
World Gasification capacity by fuel

World Gasification Capacity and Planned Growth – by Fuel
Source: NETL 2010 Worldwide Gasification Database
Biomass gasification Syngas characteristics

Oxygen –steam gasification
Syngas NCV = 10-20 MJ/m³

But typical biomass gasification is atmospheric with air

<table>
<thead>
<tr>
<th>Component</th>
<th>Wood Gas (vol. %)</th>
<th>Charcoal Gas (vol. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N₂</td>
<td>50 - 54</td>
<td>55 - 65</td>
</tr>
<tr>
<td>CO</td>
<td>17 - 22</td>
<td>28 - 32</td>
</tr>
<tr>
<td>CO₂</td>
<td>9 - 15</td>
<td>1 - 3</td>
</tr>
<tr>
<td>H₂</td>
<td>12 - 20</td>
<td>4 - 10</td>
</tr>
<tr>
<td>CH₄</td>
<td>2 - 3</td>
<td>0 - 2</td>
</tr>
<tr>
<td>CV MJ/m³</td>
<td>5 – 5,9</td>
<td>4,5 – 5,6</td>
</tr>
</tbody>
</table>

Arena 2012
Thermal waste conversion (ISWA 2013)

Pyrolysis
- Heating without oxygen
  - Char
  - Combustible gas, high tar levels

Gasification
- Heating with steam / limited air
  - Combustible gas, medium tar levels
  - Ash

Combustion
- Air
  - Flue gas (CO₂ and steam)

Pyrolysis gas
- Char and ash
- Landfill

End conversion of gas
- Gas boiler
- Flue gas, CO₂
- Gas engine
- Fuel cell
- Gas turbine
- Synthesis to liquid fuel

Flue gas
- Heat
- Flue gas
- Ash
- Landfill and recycling
Waste gasification types (Themellis 2013)

Two types of gasification

1. GASIFICATION FOLLOWED BY FULL COMBUSTION – Goal of Improved Emissions and Higher Energy Efficiency
   - MSW → Low Temperature Gasification → Low Quality Syngas → Combustion of syngas → Conventional Boiler, APC, Power Gen
   - Air
   - Reduced NOx, Less gas flow

« Staged » gasification /combustion!

2. GASIFICATION TO SYNGAS – Goal of Combined-Cycle Power or High-Value End-Products
   - MSW → High Temperature Gasification → High Quality Syngas → Syngas Cleaning
   - O2/Air
   - Combined Cycle Power
   - Liquid Fuels Production
   - Hydrogen Production

« True » gasification?

Fr : Gazéification ≠ Méthanisation (« Anaerobic digestion »)

completed by information and photos collected and compiled from different web sites such as mentioned companies sites
Pyrolysis type (Siemens, Mitsui, Takuma...)

Siemens Fürth (D) stopped in 1998

Mitsui Toyohashi (J) 2002
Thermoselect Pyrolysis/ Gasification

Karlsruhe (D) Started in 1999
Stopped in 2004

Rome Malagrotta 1 (It) Started in 2008
Stopped in 2012

Chiba (J)
Thermoselect : the only « True » MSW Gasification with experience?!

This technology seems to be the only one known with commercial references in operation on MSW with Syngas not burn in a gas boiler downstream!

Utilisation of Pyrolysis gas Thermoselect Mutsu/JP

Experience in Japan of Syngas use after cleaning:
- Export for mixing with steel shaft furnace gases
- or partially in gas engine

Condensate, deposits (water, tar, naphtalenes.....)

But risks of deposits, problems of CO emission at the engine outlet and gas engine size limits (<2MWe).

Pyrolysis gas:
- $H_2$: 20 - 40%
- CO: 35 - 40%
- $CO_2$: 25 - 35%
- $N_2$: 2 - 5%
- LHV = 1.5 - 2 kWh/Nm³

Commissioning: 2/2003
> 19,000 oh (10/2005)

From GE 2012

Fuel gas
TI 1000 – 030G

Thermoselect Mutsu/JP
2 x JGS 616 GS SN.L

ISWA CONGRESS 2016 - 19-21/09/2016 NOVI SAD
CCORD’HOMME@CNIM.COM
Type Shaft Furnace (JFE, Nippon Steel, Alter NRG…)

- NCV indicated: 5,9MJ/Nm³ (NS)
Type Fluidized Bed (Ebara, Kobelco, MHIEC, HZI, Valmet...)

- Ebara: Kwaseong (K) 2010
- Kobelco: Sagamihara (J) 2010
- MHIEC: Kushiro (J) 2006
Plasma Gasification type (Westinghouse / AlterNGR)

Hitachi Metals: Utashinai (J) 2003 stopped in 2013

Municipal Solid Waste:
- 1000 tpd
- Moisture Content: 29%
- Inorganic Material: 23%
- Other Inputs: Flux Material: 141 tpd
- Coke: 40 tpd
- Total: 1181 tpd

No metal content in this waste source:
- Slag: 250 tpd

Coarse Particulate Matter: 20 tpd

Fine Particulate Matter & Heavy Metals Removed: 20 tpd

Sulphur Removed: 0.1-1 tpd

Electricity via Combined Cycle: 40 MW Gross

For Sale to Market
- i.e. Aggregate
- Landfill for disposal or recycle back into gasifier
- Sludge to Landfill
- For Sale to Market

For Sale to Market
- Gas Turbine
- HRSG
- Steam Turbine
- Electricity

Clims String
Plasma Gasification (AIR PRODUCTS / Westinghouse)
Tees Valley UK

2 phases
• TV 1: 300kt/year - 50MWe with syngas cleaning, compression and Gas Turbine!
  Start-up planned in 2014 -15- 16 - 17...
• TV 2 replica of TV1: NTP 2014
  « World’s Largest Plasma Gasifier! » (Scale-up 900%!)
Plasma Gasification type (Europlasma CHO Power)

Europlasma : Morcenx (F) 2012

In heavy maintenance in 2013 for gasifier replacement
Start up in 2014 with major problems

RESIDUAL WASTE

1. WASTE TO FUEL

2. FUEL TO GAS
Type Moving Grate (Energos)

- Low NOx without de-NOx (about 50 mg/Nm3)
- Gasification – ROC in UK

1. Fuel bunker
2. Fuel crane
3. Hopper
4. Primary chamber (Gasification)
5. Secondary chamber (High temperature oxidation)
6. Heat Recovery Steam generator (HRSG)
7. Lime and carbon silo
8. Bag house filter
9. Filter residue silo
10. Flue gas fan
11. Chimney
12. Bottom ash extraction
13. Steam turbine
14. Air cooled condenser

Energos Sarpsborg II (NW) 2010
Plants IN OPERATION using ATT by Country

- **Asia**: 113 Plants, 84%
  - Japan: 95 Plants, 71%
  - Korea: 15 Plants
  - Malaysia: 1 Plant
  - Taiwan: 1 Plant
  - Singapore: 1 Plant

- **Europe**: 21 Plants, 16%
  - Germany: 5 Plants
  - Italy: 2 Plants
  - Norway: 6 Plants
  - Poland: 1 Plant
  - Scotland: 1 Plant
  - Slovenia: 1 Plant
  - Sweden: 1 Plant
  - UK: 1 Plant

102 plants with lines < 5 t/h
Only 6 plants with lines > 10 t/h
What are the technologies used for MSW thermal treatment?

Number of plants in commercial operation (> 5t/h) - Source: Ecoprog

**Grate**
- North America
- Japan
- Europe
- China
- Others

**CFB**
- North America
- Japan
- Europe
- China
- Others

**Gasification**
- North America
- Japan
- Europe
- China
- Others

**Pyrolysis**
- North America
- Japan
- Europe
- China
- Others

**Plasma**
- North America
- Japan
- Europe
- China
- Others

**Others**
- North America
- Japan
- Europe
- China
- Others

**Number of plants in commercial operation (> 5t/h)**

- **Grate**
  - *Others*
  - *North America*
  - *Japan*
  - *Europe*
  - *China*

- **CFB**
  - *North America*
  - *Japan*
  - *Europe*
  - *China*
  - *Others*

- **Gasification**
  - *North America*
  - *Japan*
  - *Europe*
  - *China*
  - *Others*

- **Pyrolysis**
  - *North America*
  - *Japan*
  - *Europe*
  - *China*
  - *Others*

- **Plasma**
  - *North America*
  - *Japan*
  - *Europe*
  - *China*
  - *Others*
CNIM-MARTIN Vario Gas System
Main technical points

- No waste preparation required
- Gasification easily obtained with limited preheated under-grate air
- Main product: well mixed Syngas with the required calorific values for UK ACT subsidies
- Staged immediate post combustion of the SynGas, avoiding any Syngas pollutants complex treatment
## What’s remaining for UK MSW/RDF WtE market in ATT?

<table>
<thead>
<tr>
<th>Type</th>
<th>Process</th>
<th>Main technical difficulties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluidized bed</td>
<td>Dense or Bubbling FB</td>
<td>Waste Preparation &amp; low inert content required. Max size and low temperature in bed</td>
</tr>
<tr>
<td></td>
<td>Circulating FB</td>
<td>Idem + Syngas cleaning (TARS)</td>
</tr>
<tr>
<td></td>
<td>BFB with plasma</td>
<td>Idem + plasma</td>
</tr>
<tr>
<td>Grate</td>
<td>transport</td>
<td>Waste preparation, performances</td>
</tr>
<tr>
<td></td>
<td>grate</td>
<td>Syngas LCV for low NCV waste</td>
</tr>
<tr>
<td>Shaft furnace</td>
<td>Shaft furnace</td>
<td>Coke + O2</td>
</tr>
<tr>
<td></td>
<td>with plasma assistance</td>
<td>Slag outlet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Idem + Syngas cleaning and use</td>
</tr>
<tr>
<td>Pyrolysis or Thermolysis</td>
<td></td>
<td>Energy input for pyrolysis, Char pollution for external use</td>
</tr>
</tbody>
</table>
Reliable and proven technologies! Technologies which fit to purpose!

- Buy a device but also a performance!
  “x passengers to carry in comfort and safety for y km/year with z l fuel /100km during n days/year for Y years …”

- Importance of availability and performances to reach cost optimum!
Reliable and proven technologies! Development of alternative technologies?

Also subject to performances and availability concern to obtain the cost goal!

Some are proven, but often not reliable or cheap enough!

WWII gasifier bus with fuel trailer & refill

Some could be Science Fiction!!!

Back to the future!

...with Fusion engine!
Advanced Thermal Treatment of MSW in UK

“...many examples of ATT processes that are established, viable and bankable on various waste streams (e.g. biomass, industrial wastes, tyres etc.) but a lesser number proven on municipal wastes “

“...most commercial gasification facilities processing MSW derived feedstock utilize a secondary combustion chamber to burn the syngas and recover energy via a steam circuit, and whilst this is not incineration, the differences between the processes in practical and efficiency terms are much more modest “
Conclusion

Alternative thermal waste treatment processes...

... can make sense in case of
- special framework conditions or regulations (like in Japan),
- special waste fractions (calorific value, pollutant content, ash content etc.),
- (upstream) in connection with other thermal plants (cement & power plants)

... normally require high effort
- waste pretreatment
- product treatment
- additives (e.g. coke, lime, oxygen)
- of money

Waste incineration...

... is state of the art for the treatment of mixed municipal solid waste
New “ATT” plants in Japan after the 11/03/2011 disaster!!

- 16Mt of Earthquake debris + 10Mt Tsunami deposits generated
- 34 Temporary incinerators in Iwate, Miyagi, and Fukushima prefectures used for the treatment of combustible debris!

Source: TAKUMA

Source: Japanese Ministry of Environment
A closing thought
Waste-to-Energy is paving the way for Energy Transition and Circular Economy!