Waste to Energy – Gasification of SRF

Matti Nieminen
VTT Technical Research Centre of Finland

IEA Bioenergy Workshop on Production and utilisation options for Solid Recovered Fuels
Dublin, 20th October 2011
Terminology (1)

- **waste and waste derived fuels**
  - municipal solid waste (MSW)
  - mixed waste
  - household waste
    - RDF/SRF
  - source separated waste
    - biowaste
    - specific fractions: metal waste, glass, paper/board, etc
  - **SRF (Solid Recovered Fuel)**

- **commercial and industrial waste (CIW)**
  - SRF
  - specific waste fractions: electronic scrap, auto shredder residue (ASR), plastic waste, sewage sludge, etc.
Terminology (2)

- **incineration**
  - primary target: reduction of volume of waste instead of landfilling
  - product: primarily heat (district heat, process heat)
  - limited power production

- **co-firing of waste derived fuels**
  - primary target: utilise energy content of waste
  - by-processing of waste derived fuels/SRF
  - waste derived fuels as secondary fuel
  - conventional boiler technology
  - special requirements for flue gas cleaning set by WID Waste Incineration Directive)
Terminology (3)

- **Waste to Energy technologies (WtE)**
  - specially designed for utilisation of waste/waste derived fuels only
  - primary targets: efficient utilisation of energy content of waste and reduction of waste volume
  - high efficiency
    - for power and heat
  - can be based on
    - conventional grate firing
    - fluidised bed combustion
    - gasification
    - other technologies
Driving forces for development of high efficiency WtE technology

- Serious need to improve overall energy production efficiency of waste incinerators

- Driving forces/regulations
  - Common policy directs to more efficient use of all kind of waste
  - Climate change/CO\(_2\) reduction

- Significant needs to reduce landfilling (especially in Europe)
- Sustainability
  - Targets to recycle, reuse and utilise waste
- Price of energy
- Etc.
Direct co-firing of waste derived fuels

- share of co-fired waste restricted by corrosion and deposits
  - aluminium content
  - chlorine content
  - alkali metal content
  - etc.

- regulations related to flue gas cleaning
  - Waste Incineration Directive (WID)/national law is applied

- primary driving force: savings in fuel cost
Indirect co-firing of waste derived fuels based on gasification

- waste derived fuels gasified in a separate (fluidised bed) gasifier

- product gas co-fired with coal (or other fuels) in a large scale boiler

- co-firing in a large scale boiler enables benefits of large scale steam cycle, i.e. high power production efficiency

REMARK! Focus of this presentation on gasification technologies with some gas cleaning or with possibility for gas cleaning. Technologies based on two-stage combustion are excluded (Thermoselect, Ebara, Energos, Kobelco, etc.)
Clean biomass (or in some cases clean waste)
Proven reference: Lahti (Kymijärvi power plant), Finland

- in operation since 1998
- no commissioning problems
- gasifier availability > 95%
- boiler emissions decreased
Biomass rich in harmful impurities/waste derived fuels (SRF, high quality RDF)

- Wheat straw: rich in potassium & chlorine
- Demolition wood waste: heavy metals
- SRF/RDF : heavy metals, chlorine
- Plastic waste with some PVC: chlorine
- Sewage sludge: heavy metals

- Emissions
- Boiler corrosion
- Fouling

Gasification + Gas Cleaning + Co-firing
GASIFICATION

SYNGAS (CO + H₂)

FT-diesel fuel
Methanol, DME
Gasoline, jet-fuel
Hydrogen
Synthetic methane
Chemicals

Industrial kilns
Co-firing in boilers
Gas turbines
Engines
Fuel cells

FUEL GAS

Wide Feedstock basis

High-Quality Final Products
Biomass rich in harmful impurities/waste derived fuels

DRY CLEANING AND CHLORINE REMOVAL

- Coal/oil-fired boiler
- Condensing power plant / CHP plant
- Ovens/kilns
- HRSG of gas-fired combined cycle plant
Gasification & gas cleaning R&D at VTT

- Air blown CFB gasification (+BFB + Fixed Bed)
- Gas cooling to 350-500°C
- HCl removal: Ca(OH)$_2$ + inherent Ca, Na, K
- Gas filtration (removal of ash, alkali metals, heavy metals)
- Fuels: Wheat straw, demolition wood, several qualities of SRF/RDF, industrial wastes, sewage sludge, plastic waste, Auto Shredder Residue, electronic scrap, etc.

RDF pellets
Removal of chlorine & heavy metals

- Chlorine removal
  - especially when SRF/RDF is gasified
  - target: residual HCl concentration 100..200 ppm (v)
  - inherent alkali metals
  - sorbent injection (Ca(OH)$_2$) if needed
  - filtration at 350…500°C

- efficient enough
- low cost
Removal of chlorine & heavy metals

- Removal of heavy metals
  - gas cooling (350…500°C)
  - condensation of vapour phase metals
  - filtration
  - target set by WID

- most of metals can be captured easily
  - below 450…500°C
    - Cd, Pb, Zn
  - exception: Hg
Chlorine removal

- 60…95 % efficiency typical
- high Na & K content => no need for additional sorbent
  - wheat straw
  - some waste materials

BFB gasification
SRF pellet
Ceramic fabric filter (FB-900)
Filtration at 410-420°C
Fuel: SRF; Ceramic fabric filter (3M FB-900); Cyclone temperature 700-750°C; filter temperature 395°C

% of output

Bottom ash  Cyclone dust  Filter dust  Gas

Na  K  Cl  Al  Ca  Hg  Sn  Sb  As  Cd  Pb  V  Mn  Co  Ni  Cu  Zn  Mo  Cr  Si  Mg
Fuel: SRF pellets; Rigid ceramic fibre filter (Tenmat); filter temperature 500°C

% of output

As Cd Co Cr Cu Mn Ni Pb Sb Sn V Zn

Bottom ash Filter dust Gas

- Bottom ash
- Filter dust
- Gas
### Examples of gasification and gas cleaning test trials at VTT

<table>
<thead>
<tr>
<th>Test trial Year/Week</th>
<th>Gasifier</th>
<th>Gasifier fuel</th>
<th>Filter/operation temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999/21</td>
<td>CFB</td>
<td>Wood chips</td>
<td>Bag filter (FB 900)/345-360°C</td>
</tr>
<tr>
<td>1999/24</td>
<td>CFB</td>
<td>SRF</td>
<td>Bag filter (FB 900)/360-370°C</td>
</tr>
<tr>
<td>1999/35</td>
<td>CFB</td>
<td>SRF</td>
<td>Bag filter (FB 900)/360°C</td>
</tr>
<tr>
<td>1999/38</td>
<td>CFB</td>
<td>SRF</td>
<td>Bag filter (FB 900)/450-460°C</td>
</tr>
<tr>
<td>2000/44</td>
<td>CFB</td>
<td>Coal+PVC</td>
<td>Bag filter (FB 900)/395°C</td>
</tr>
<tr>
<td>2000/20</td>
<td>CFB</td>
<td>SRF</td>
<td>Bag filter (FB 900)/410°C</td>
</tr>
<tr>
<td>2000/23</td>
<td>CFB</td>
<td>SRF</td>
<td>Bag filter (FB 900)/445°C</td>
</tr>
<tr>
<td>2000/36</td>
<td>CFB</td>
<td>Recycled PE+PP</td>
<td>Bag filter (FB 900)/395°C</td>
</tr>
<tr>
<td>2000/38</td>
<td>CFB</td>
<td>SRF+wood pellets</td>
<td>Bag filter (FB 900)/393°C</td>
</tr>
<tr>
<td>2001/11</td>
<td>CFB</td>
<td>Recycled PE+PP</td>
<td>Bag filter (FB 900)/400°C</td>
</tr>
<tr>
<td>2001/20</td>
<td>CFB</td>
<td>Coal+recycled PE+PP</td>
<td>Bag filter (FB 900)/395°C</td>
</tr>
<tr>
<td>2001/48</td>
<td>BFB</td>
<td>SRF</td>
<td>Bag filter (FB 900)/380-400°C</td>
</tr>
<tr>
<td>2001/50</td>
<td>BFB</td>
<td>SRF</td>
<td>Bag filter (FB 900)/390-410°C</td>
</tr>
<tr>
<td>2002/07</td>
<td>BFB</td>
<td>SRF</td>
<td>Bag filter (FB 900)/400-420°C</td>
</tr>
<tr>
<td>2002/10</td>
<td>BFB</td>
<td>SRF</td>
<td>Bag filter (FB 900)/400-420°C</td>
</tr>
<tr>
<td>2002/23</td>
<td>CFB</td>
<td>Dried sewage sludge</td>
<td>Bag filter (FB 900)/400°C</td>
</tr>
<tr>
<td>2002/42</td>
<td>CFB</td>
<td>Sewage sludge+wood chips</td>
<td>Bag filter (FB 900)/350°C</td>
</tr>
<tr>
<td>2002/50</td>
<td>BFB</td>
<td>Wood waste</td>
<td>Bag filter (FB 900)/370°C</td>
</tr>
<tr>
<td>2003/10</td>
<td>BFB</td>
<td>SRF</td>
<td>Bag filter (FB 900)/360-390°C</td>
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<tr>
<td>2003/23</td>
<td>CFB</td>
<td>Demolition wood</td>
<td>Rigid ceramic fibre filter/500°C</td>
</tr>
<tr>
<td>2003/23</td>
<td>CFB</td>
<td>SRF</td>
<td>Rigid ceramic fibre filter/500°C</td>
</tr>
</tbody>
</table>

**Gas cleaning by filter:**
- particles
- chlorine
- heavy metals
Gasification & gas cleaning example:

<table>
<thead>
<tr>
<th>Fuel Contaminants CFB gasification (70 % RDF/30% wood)</th>
<th>ppm-wt (d.b.)</th>
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<tbody>
<tr>
<td>Ca</td>
<td>12290</td>
</tr>
<tr>
<td>Hg</td>
<td>0.10</td>
</tr>
<tr>
<td>Sn</td>
<td>11</td>
</tr>
<tr>
<td>Sb</td>
<td>14</td>
</tr>
<tr>
<td>As</td>
<td>3.0</td>
</tr>
<tr>
<td>Cd</td>
<td>2.1</td>
</tr>
<tr>
<td>Pb</td>
<td>47</td>
</tr>
<tr>
<td>V</td>
<td>4.7</td>
</tr>
<tr>
<td>Mn</td>
<td>110</td>
</tr>
<tr>
<td>Co</td>
<td>5.3</td>
</tr>
<tr>
<td>Ni</td>
<td>8</td>
</tr>
<tr>
<td>Cu</td>
<td>340</td>
</tr>
<tr>
<td>Zn</td>
<td>224</td>
</tr>
<tr>
<td>Mo</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Cr</td>
<td>50</td>
</tr>
<tr>
<td>Si</td>
<td>12300</td>
</tr>
<tr>
<td>Mg</td>
<td>1250</td>
</tr>
<tr>
<td>Cl</td>
<td>4700</td>
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</tbody>
</table>

SRF+wood waste

Cleaned gas

<table>
<thead>
<tr>
<th>Cleaned gas</th>
<th>ppm(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>0,0</td>
</tr>
<tr>
<td>K</td>
<td>0,0</td>
</tr>
<tr>
<td>Cl</td>
<td>109,0</td>
</tr>
<tr>
<td>Al</td>
<td>0,0</td>
</tr>
<tr>
<td>Ca</td>
<td>0,0</td>
</tr>
<tr>
<td>Hg</td>
<td>0,025</td>
</tr>
<tr>
<td>Sn</td>
<td>0,0</td>
</tr>
<tr>
<td>Sb</td>
<td>0,0</td>
</tr>
<tr>
<td>As</td>
<td>0,0</td>
</tr>
<tr>
<td>Cd</td>
<td>0,0</td>
</tr>
<tr>
<td>Pb</td>
<td>0,024</td>
</tr>
<tr>
<td>V</td>
<td>0,0</td>
</tr>
<tr>
<td>Mn</td>
<td>0,0</td>
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<tr>
<td>Co</td>
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<tr>
<td>Ni</td>
<td>0,0</td>
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<td>Cu</td>
<td>0,11</td>
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<tr>
<td>Zn</td>
<td>0,51</td>
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<td>Mo</td>
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<td>Cr</td>
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</tr>
<tr>
<td>Si</td>
<td>0,0</td>
</tr>
<tr>
<td>Mg</td>
<td>0,0</td>
</tr>
</tbody>
</table>
Power production efficiency

CHP plant:
SRF to power 30...35 %

Condensing power plant:
SRF to power 35...40 %

Gasifier

(planned projects, not implemented)
Gasification based WtE technology

- Fluidised bed gasification of SRF/RDF
- Product gas cleaning (dry scrubbing)
- Removal of (corrosive) Cl and ash components (metals)
- Clean gas fired in a gas fired boiler
- No fouling or corrosive impurities

=> High steam parameters

- High power production efficiency
- Feasibility well competitive compared to conventional incineration (mass burning)
- Fulfils gas cleaning requirements set by WID
Gasification + Gas cleaning + Gas fired boiler + Flue gas cleaning

Gasifier → Gas cooling → Gas cleaning → Natural gas/ oil → Gas boiler → Electricit, process steam

Flue gas cleaning

Bag house, Ca(OH)$_2$ + activated carbon

Steam turbine

High pressure steam

Electricity, process steam
Metso’s Gasification Projects
Lahti Energia – Gasification Power Plant

2 x 80 MW$_{th}$ gasifiers
Waste-derived fuel
50 MW$_e$ & 90 MW$_{heat}$

1. Fuel handling
2. Gasifier
3. Gas cooling
4. Gas filter
5. Gas boiler and flue gas cleaning

Start-up April 2012
Total investment 157 M€

Overall efficiency 87%
120 bar/540°C
An artist’s view on the new Lahti Energia WtE plant
Lahti Kymijärvi power plant construction site (20.10.2011)
(http://www.roskatenergiaksi.fi/kamerat/kamera-1)
Foster Wheeler design for gasification based WtE plant
**Special application: Corenso gasifier in Varkaus, Finland**
- at a recycling plant for multi-material packaging
- 50 MW gas to boiler, 2100 t/year aluminium for re-use
- in operation since autumn 2001, now 12 500 hours
- developed by VTT & Foster Wheeler Energia Oy, constructed by Foster Wheeler
Summary

- Fluidised bed gasification followed by efficient gas cleaning enables very efficient utilisation of the energy content of SRF and other waste derived fuels.

- Efficient gas cleaning usually necessary in order to remove harmful impurities (chlorine, alkali metals, heavy metals, ash).

- Produced gas can be utilised very efficiently in different applications:
  - co-firing with other fuels (gas, oil, coal, peat)
  - replacing of fossil fuels in industrial kilns
  - as a single fuel in gas fired boiler
Learn more about gasification based high efficiency WtE technologies

- visit LahtiStreams project web site

www.lahtistreams.com

(Advanced WtE technologies - seminar in Lahti, Finland, in May 2012)
VTT creates business from technology