LANDFILL GAS TO ENERGY-COMBINED ENGINE AND ORC-PROCESS

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THIRD INTERNATIONAL SYMPOSIUM ON ENERGY FROM BIOMASS AND WASTE

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Helsinki Regional Environmental Services Authority, HSY

- HSY is responsible for waste and water management of four Helsinki Metropolitan area cities
- Turnover over 300 million euros
- Number of employees: 750

**HSY Waste Management:**
- Provides waste management services for over 1 million inhabitants of Metropolitan area
- Owns and operates the largest landfill site in Nordic Countries
- Turnover: 100 million euros
- Number of employees: 140
- Amount of waste received annually: 700,000 tons
  - MSW app. 300,000 tons
Landfill gas

- 1 ton of waste can generate 100 – 200 m$^3$ gas
- The energy content ca 50 % of that of natural gas
- 2 m$^3$ landfill gas corresponds to 1 litre fuel oil
- Main components: CH$_4$ (55 %), CO$_2$ (45 %)
- Trace components: O$_2$, N$_2$, H$_2$S, VOC, halogens
Recovery benefits

- Reducing odour annoyance
- Reducing GHG-emissions
- Reducing fire- and explosion risk
- Utilization possibilities of recovered gas

Gas recovery is provided by decision of the Council of State in Finland
Utilization alternatives of landfill gas

- Heating
- Electricity
- Combined heat and power
- Industrial processes
- Vehicle fuel
Recovery and utilization of landfill gas in Finland

- 2009 in total 110.9 million m$^3$ gas recovered at 35 landfills
- 67.7 million m$^3$ was utilized producing:
  - 251 GWh district heating
  - 17 GWh mechanical energy
  - 18 GWh electricity
Recovered and utilized landfill gas in 2009

HSY Landfill
Landfill Gas formation

- Gas is produced in anaerobic decomposition of organic waste
- The degradation process proceeds from aerobic acid stage to anaerobic methane phase
- The main components are methane, carbon dioxide and water vapour
- The gas also contains oxygen, hydrogen, nitrogen and small concentrations of impurities such as hydrogen sulphide and halogens
The degradation process
Factors influencing the degradation rate

• Quality of waste
• Humidity
• Oxygen concentration
• Sulphate concentration
• Nutrients (optimal COD$_{cr}$:N:P = 100:0,44:0,08)
• Temperature
• pH (optimal 6 - 8)
Ämmässuo Landfill Site

• Largest landfill site in the Nordic countries
  – Old landfill area established in 1987 and closed in 2007, landscaping ongoing
  – New landfill area opened in 2007, currently in active use

• Approximately 12 milj. ton waste disposed (2010)

• Area 52 ha (old landfill) + 62 ha (new landfill)

• Filling area height max 100 m from sea level, height of waste fill 40 m

• Gas recovery since 1996

• Landfill gas recovery over 7000 m³/h (2010)
Gas recovery system

Old landfill

- 220 Gas wells
- 4 pumping stations
- 7 regulating stations
- 4 flares
- Drying and boosting station for the gas to be utilized

New Landfill

- 65 vertical gas wells with bottom collection
- 3 regulating stations with automatic suction pressure control
- 1 pumping station
New landfill 13-50 ha
65 gas wells
3 regulating stations
~ 4 000 m³/h (2015)

Old landfill 50 ha
Total volume ~15 Mm³
220 gas wells
4 pumping stations
7 regulating stations
~ 9 000 m³/h

Gas Power Plant
Gas well network
Gas well
Gas utilization steps 1996-2011

- **1996** collection of the gas for flaring begins
- **2001** first study of utilization possibilities
  - About 15 % utilized in heating of the site buildings
- **2004** Landfill gas drying and boosting station and transfer line buildup
  - Landfill gas utilization in district heating production starts
  - 50 % utilization rate was reached
- **2007** Pumping capacity enhancement
  - Utilization rate 65 % was reached
- **2007** The planning of the Gas fired power plant starts
- **2009** Construction work of the power plant
- **2010** Power plant commissioning and start up in may 2010
  - Electricity and heat production begins, utilization rate nearly 100 %
- **2010-2011** ORC-process construction and commissioning
Drying and boosting station (2004)

- Gas drying by cooling to +2 °C
- Gas analysis and determination of caloric value
- Boosting: 1 bar; 2 rotary compressors a’ 3500 Nm³/h
- Gas cooling and quantity measurement
- Basically unmanned plant, which is controlled by the gas demand at the district heating plant (until 5/2010)
Transfer and utilization (2004)

- Transfer pipe length 11 km,
- Utilization in Fortum’s 37 MW (maximum gas consumption) district heating boiler
- Energy production 140 GWH/a (32 million m³/a gas)
- Substitutes the use of fossil fuels and diminishes accordingly emissions from combustion of fossil fuels
  - 45 ton/a reduction of carbon dioxide
  - 70 ton/a reduction of sulfur dioxide
  - 80 ton/a reduction of nitrogen oxides
Pipeline installation (Fortum)
District heating production with landfill gas until 2010

• Peak power station
• Three boilers, total output 130 MW
• Two heavy oil fired, one multi fuel (gas and oil)
• Noviter 40 MW
• Burner by Saacke
Ämmässuo Landfill Gas Power Plant
Why electricity production?

- Landfill gas utilization studies 2001 - 2005
  - Maximum gas production in 2010
    - Either markets for gas or utilization system must be available
  - District heat production
    - Limited utilization (winter season)
    - Pricing of the gas
  - Upgrading and feed into the natural gas grid
    - Investment cost of the gas cleanup and pressurization system
    - Absence of the pipeline (for upgraded landfill gas = pressurized biomethane)
  - Use in vehicles
    - Lack of gas fired vehicles
      - Vehicle fleet needed: 1000 trucks or 7000 personal cars
      - Bus and waste transportation contracted within Metropolitan

- Conclusion: electricity production is the most economical and ecological utilization concept for HSY and Helsinki Metropolitan Area
Power Plant site in 12.6.2009
Power Plant site in 21.5.2010
Power Plant
Transfer station
flares
Transfer pipeline 11 km
Power plant project steps

• Acceptance of environmental permit 7.11.2007
• Acceptance of the project plan in the Board of HSY 2008
• Application of the investment support 10/2008
• Competitive tendering of the project 10/2008
• Decision on process contractor (Sarlin/MWM) 12/2008
• Design of the power plant building 2/2009
• Competitive tendering of the main contractor of the power plant building 4/2009
• Decision on main contractor (YIT) 5/2009
• Construction work of the power plant 5/2009 – 2/2010
• Electricity production starts 5/2010
Technical facts

• Based on gas engine technology
• Energy production: max. 17 MW electricity and ~13 MW heat
• Independent 110 kV electricity grid connection
• Fuel: CO2-neutral landfill gas and biowaste digestion gas (from 2013 on)
• Additional electricity production with ORC process from exhaust gases.
• Investment cost. 15 M€
• Energy investment support from State of Finland 22% = 3,4 M Euros
MWM TCG 2032

Engine type: V 16

length: mm 8,900

width: mm 2,750

high: mm 3,800

weight: kg 47,600
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<thead>
<tr>
<th></th>
<th>kW</th>
<th>%</th>
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<tbody>
<tr>
<td>Electricity production</td>
<td>3,917</td>
<td>42.0</td>
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<tr>
<td>efficiency (el)</td>
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<td>42.0</td>
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<tr>
<td>efficiency (th)</td>
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<td>44.1</td>
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<tr>
<td>Total efficiency</td>
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ORC, Organic Rankine Cycle-process

- Utilizes exhaust gas heat for additional electricity production
- Combines
  - Heat exchangers
  - Thermal oil circuit
  - Organic medium (toluene, pentane)
  - Turbine generator set
  - Condenser