This presentation is based primarily on material from the following R&D projects carried out at VTT

- **UCG** – project 1.1.2004 – 31.5.2007: Synthesis gas and ultra clean fuel gas from biomass
- **EU/LahtiSTREAMS**: Advanced Integrated Waste Management and WIE demonstration
- Previous Tekes and EU projects at VTT on biomass and waste gasification
Drivers for Biomass and Waste Gasification

- High-efficiency power from biomass at small-to-medium scale
- Efficient utilisation of wastes
- Liquid biofuels, renewable methane or H2 for transport
Atmospheric-pressure gasification for kilns and boilers

- Commercial lime-kiln gasifiers were constructed in 1980's by Ahlström Oy
- New development by Foster Wheeler in 1990's for boiler applications
- Gasifiers are now offered by
  - Foster Wheeler
  - Carbons/Andritz
  - Metso Power
- Feasible in size range 15-150 MW
- Fuel drying is often needed to achieve required flame properties

Efficient utilisation of wastes and biomass residues in existing power plants

- in operation since 1998
- no commissioning problems
- high fuel flexibility
- gasifier availability > 95 %
- boiler emissions decreased
- payback time ca. 8 years

Main boiler 360 MWₑ
Gasifier feed preparation
CFB gasifier of 60MW
Corenso gasifier in Varkaus, Finland
- gasification of aluminium containing plastic reject material
- complete recycling of liquid cartons (milk & juice packaging)
- 50 MW gas to boiler, 2100 t/year aluminium for re-use
- developed by VTT & Foster Wheeler Energia Oy in 1998 - 2000

in operation since autumn 2001

Waste utilisation by gasification
Lahti II – Alternative for conventional incineration:
- Gasification + Gas cleaning + Gas fired boiler + Flue gas cleaning
  - Fluidised bed gasification of SRF/RDF
  - Product gas cleaning
  - Removal of (corrosive) Cl and ash components (metals)
  - Clean gas fired in a gas fired boiler
  - No fouling or corrosive impurities
    - => High steam temperature & pressure
    - High power production efficiency
**Removal of chlorine & heavy metals by barrier filtration**

- **Filtration temperature range** 150 – 800 °C
- Depends on impurity to be removed, tar content, filter media, etc.

**Filter media**
- Rigid ceramic or metal candle filters (< 500-900 °C)
- Rigid ceramic fibre filters (< 900 °C)
- Ceramic bag filters (< 400 °C)
- Teflon bag filters (< 250 °C)

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**Fuel: SRF (RDF); Ceramic fabric filter (3M FB-900); Cyclone temperature 700-750°C; filter temperature 395°C**

![Graph showing the percentage of output for various elements in different samples: Bottom ash, Cyclone dust, Filter dust, Gas.](image-url)
EU-BigPower
Biomass Gasification for High Efficiency Power
Duration: 36 months (October 2005 – September 2008)
Overall Budget for the project: 2 943 k€
Financed in part by EU FP6

R&D organisations supporting industrial development
- VTT - Technical Research Centre of Finland
- TUV - Technical University of Vienna, Austria
- CERTH - Centre of Research & Technology Hellas, Greece
- TKK - Helsinki University of Technology, Finland

Gasification systems
- Condens Oy, Finland
- Carbona Oy, Finland
- Repotec GmbH, Austria
- Biomasse Kraftwerk Güssing, Austria
- (Kokemäki & Skive sites)

Power production equipment
- GE Jenbacher, Austria
- MTU CFC Solutions GmbH, Germany

Catalytic Gas Cleaning and filtration
- MEL Chemicals, United Kingdom
- NortaUAB, Lithuania
- Madison Filter Ltd, United Kingdom

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Impurity | Control method | Content and removal efficiency
---|---|---
Particulates | Bag filter | < 10 mg/m³
Tars | Catalytic reformer | < 100 mg/m³
(NH3 + HCN) | Catalytic reformer | < 5 mg/m³
Sulfur | Low sulfur feedstock and gas scrubbing | < 50 mg/m³
Chlorine | Low chlorine feedstock, gas filtering and scrubbing | < 50 mg/m³

Novel power plant: 1.8 MWe + 3.3 MW heat
- supplier: Condens Oy
- Kokemäki, Finland
- Commissioning phase
- total investment 5 M€
- electric efficiency 30 %
**SKIVE PROJECT, DENMARK**

- **Biomass** → **Gasifier** → **Gas Cooler** (Heat Recovery) → **Product Gas Filter** → **Fly Ash**
- **Air** → **Steam** → **Ash**
- **Tar Cracker** → **Boiler** → **District Heating 11.5 MWth** → **Flue Gas Heat Recovery** → **Power 5.4 MWe** → **Gas Engines**
- **Water Treatment** → **Product Gas Scrubbing** (Heat Recovery) → **Product Gas Buffer Tank** → **Stack**

**VTT TECHNICAL RESEARCH CENTRE OF FINLAND**

**Dual Fluidised-Bed Steam Gasification**
(Repotec, TUV & Biomasse Kraftwerk Güssing)

- **Biomass** → **Steam** → **Catalyst** → **Flue Gas Cooler** → **Flue Gas Heat Recovery** → **District Heating Boiler** → **Oil Burner** → **Chimney**

**Biomass-CHP-Plant-Güssing, 2 MWe + 4.5 MW heat**
Reforming catalysts

**Nickel**
+ Decomposes tar and ammonia simultaneously
+ Commercially available
- Requires high temperature ≥ 900 °C
- Deactivates easily by coke & sulphur

**ZrO₂**
+ Lower operation temperature ~700 °C
+ Tolerates catalyst poisons
- Tar conversion not complete
- Under development and testing

**Precious metals**
+ High activity
- Very expensive
- Long-term stability?

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**EU BigPower: WP1: Advanced Gas Cleaning**

(VTT, TKK, TUV, Madison Filter, MEL, Norta)

**New catalyst powders, MEL**
- new materials and optimised production
- supply of tailored raw materials to VTT, TKK & Norta

**New monoliths, VTT & TKK**
- new catalyst material and production method

**Metal substrate catalysts, Norta**
- input from VTT, TKK and MEL
- improved plasma coating method

**Catalytic filters, Madison Filter**
- improved catalysts and production methods

**Testing of new catalysts**
- laboratory-scale screening tests
- extended-time slip-stream tests at Kokemäki and Güssing
- full-scale testing of selected catalysts at Kokemäki
Recycling of scrubber effluents
- characterisation of waste waters from Kokemäki demo plant
- recycling of effluents to the gasifier

Replacement of nickel monoliths by more robust & cheaper catalysts
- slip-stream testing – started in May 2006
- testing in full gas stream – since fall 2007
- new materials from WP1 also in 2007

In-situ catalytic tar reforming
- construction of testing equipment
- single element testing at Kokemäki

Advanced Gas Engines and MCFC
Tasks and Results of GE Jenbacher and MTU Fuel Cell Solutions

Increased Engine performance and lower investment and operation costs
- higher efficiency and throughput
- evaluation of the effects of different design parameters on engine performance with BiGPower product gases
- materials optimisation and methods for minimising tar-related problems
- CO and NOx emission control
- testing at GEJ and Güssing

MTU's Fuel Cell HotModule
- process calculation tool for gasification gases
- MCFC process design for BiGPower gases
- performance and costs of BiG-MCFC systems
- design basis for demonstration project
Biomass – IGCC power plant
BiGPower Tasks and Results from WP4

Concept studies
- Gas turbine survey by Carbona
- Process modelling by CERTH
- Optimised concept
- Integration to existing power plants

Advanced gas cleaning
- Increased filtration temperature
- New ceramic filter media
- Testing of catalytic filters
- Selective oxidation of ammonia
  - Lab-scale testing by TKK
  - Tests at VTT’s new 500 kW pressurised gasifier

Synthesis Gas from Biomass

- VTT’s UltraClean Gas project (1.1.2004-31.5.2007)
  - VTT, TKK, Foster Wheeler, Neste Oil, Andritz, Vapo, PVO, UPM, StoraEnso, M-real, Botnia, Rintechno
  - pressurised gasification followed by catalytic reforming
  - 500 kW Process development Unit
  - studies for 150 – 400 MW plants integrated to pulp and paper industry

- Industrial follow-up projects
  - preliminary planning and design was made in VTT’s UCG project in 2006-2007
  - 15-50 MW demonstration in 2008-10 (lime kilns or power plant)
  - first commercial-scale FT-plant in 2012-14

Kemira’s peat ammonia plant in 1990
VTT’s 500 kW PDU for syngas and ultraclean fuel gas
Integration of FT-synthesis plant to pulp and paper mill

Paper & pulp

Wood, straw, energy crops, peat, RDF

Process steam & power

Gasification and gas treatment

Fuel gas + steam

FT-synthesis & upgrading

Biomass handling and drying

Energy to drying

Steam & oxygen

Paper & pulp mill

WoodDiesel

Integration of FT-synthesis plant to pulp and paper mill

Estimated Costs of Co-Produced FT Primary Liquids

260 MW feed, Interest on capital: 10 %, 20 a

Cost of final upgrading to automotive fuels: about 4 EUR/MWh

All cost data at early 2006 level
Notes: (1) Feedstock drying: from 50 % moisture to 30 % with secondary heat; from 30 % to 15 % with by-product steam. (2) FT: Fischer-Tropsch primary liquids; reforming loop included.

When utilised as automotive fuel, end-use costs increase significantly in this direction:

Estimated Production Costs for Alternative Syngas Products
260 MW_feed; Feedstock at 10 EUR/MWh; Interest on capital 10 %, 20 a

Estimated Forest-to-Wheel Costs
260 MW_feed; Feedstock at 10 EUR/MWh; Interest on capital 10 %, 20 a

Forest-to-Wheel Costs: Biomass-FT < Biomass-SNG < Biomass-H₂-FC

All cost data at early 2006 level
SYNTHESIS GAS FROM BIOMASS
FROM R&D TO INDUSTRIAL SUCCESS
(road map made in VTT’s UCG project in 2006)

First synfuel production plant
- 200-250 MW feed capacity
- 105 000 tons/a diesel fuel
- 3 % Finnish transport fuel
- start-up in 2012-14

Industrial demonstration: 15 MW
- replacement of oil/gas
- start-up in 2009

Biomass/waste gasification for power
(Lahem, Corense, Värnamo, Kokemäki)

Further R&D
- process optimisation
- waste gasification
- hydrogen technologies

New applications
- fuel cells, 2nd gen. IGCC
- hydrogen or methane
- renewable chemicals

VTT-UCG
Optimised syngas R&D & PDU-scale development

Peat ammonia plant
Oulu/Finland

R & D on hot filtration
and catalytic gas cleaning

Biomass gasification for synthesis applications
- fundamental studies supporting industrial development projects

- VTT, TKK and Åbo Akademi, total budget 1.5 M€
- Financing by Tekes Biorefin, VTT and 7 private companies
  (Carbona, Foster Wheeler, Metso Power, Neste Oil, Stora Enso, UPM & Vapo)
- Biomass characterisation for pressurised steam/oxygen-blown gasification
- Filter blinding and catalyst deactivation studies
- Tar reactions in non-catalytic and catalytic processes (reforming-cracking-oxidation)
- New system studies on FT-applications
- Development of measuring methods for tars and other gas contaminants
- Follow-up of foreign R&D projects
- IEA groups: “Biomass thermal gasification” and “Biomass Hydrogen”