IEA Bioenergy, Task 33
Thermal gasification of biomass

WORKSHOP

"Biomass gasification opportunities in the forest industry"

19 October 2011 Piteå, Sweden

REPORT

Summarized by Dr. Jitka Hrbek, VUT, Austria

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Abstract

This publication provides the summary and conclusions from the workshop **'Biomass gasification opportunities in the forest industry'**, held for the IEA Bioenergy Task 33, on the 19 October 2011 in Smurfit Kappa Kraftliner, 941 86 Piteå, Sweden.

All workshop presentations can be found at www.ieatask33.org

Table 1: Workshop presentations

Richard Bain, NREL, USA	"Climate change and the P&P industry, the IPCC SSREN Report"
Rikard Gebart, ETC, Sweden	"Swedish BLG R&D program"
Ragnar Stare, Chemrec AB	"Chemrec pilot DP1 and BioDME project" "Chemrec industrial developments"
Jens Otterstedt, Sveaskog, Sweden	"A forest owner´s perspective on bioenergy"
Rikard Gebart, ETC, Sweden	"Swedish research, the Gasification Centre"
Esa Kurkela, VTT, Finland	"Fluidised-bed gasification R&D at VTT to support industrial development of BTL, SNG or bio-H2"
Richard Bain NREL, USA	"Biomass gasification Activities in North America"
Reinhard Rauch, TUV, Austria	"Gasification based co-generation"
Timo Honkala, Metso Power, Finland	"Metso gasification"
Kari Salo, Andritz Carbona Oy	"Biomass gasification in P&P industry"
Veikko Jokela, NSE Oy	"NSE gasification"

This report presents an overview of the workshop and includes the activities in thermal biomass gasification in Sweden, Finland, Austria and North America.

Introduction

Historically wood was once the main fuel for humanity. They burned it to heat their homes and cook their food.

The current global energy system is dominated by fossil fuels and renewable energy holds a second-rate role, because renewable energy costs are still higher than existing energy prices based on fossil fuels.

But now, the point where the cost of producing energy from fossil fuels exceeds the cost of renewable fuels is approaching or may already have been reached in some areas. With a few exceptions in the near future, energy from fossil fuels will cost more money than the same amount of energy supplied through the biomass conversion.

World production of biomass is estimated at 146 billion metric tons a year, mostly wild plant growth. Some farm crops and trees can produce up to 20 metric tons per acre of biomass a year. Types of algae and grasses may produce 50 metric tons per year.

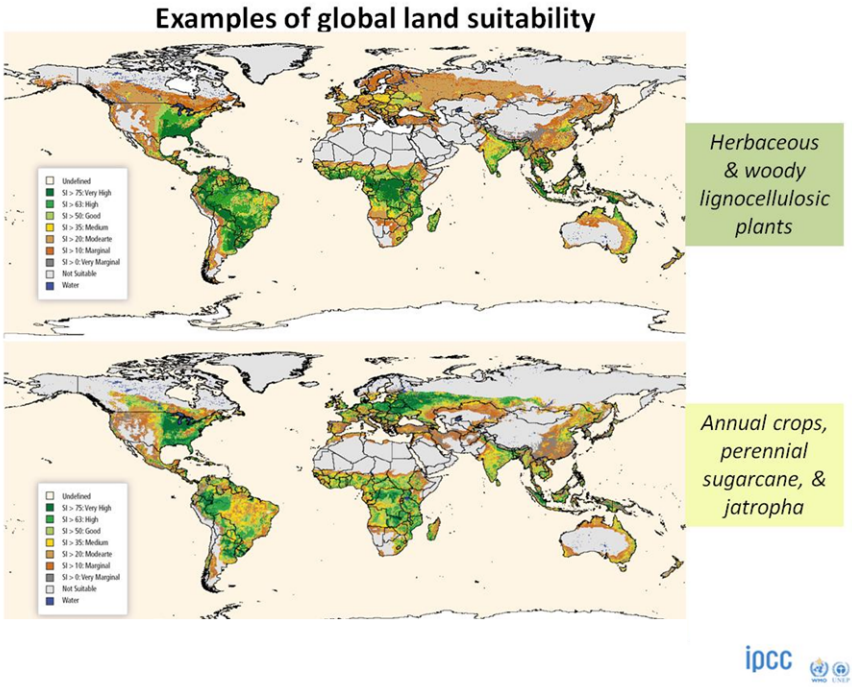
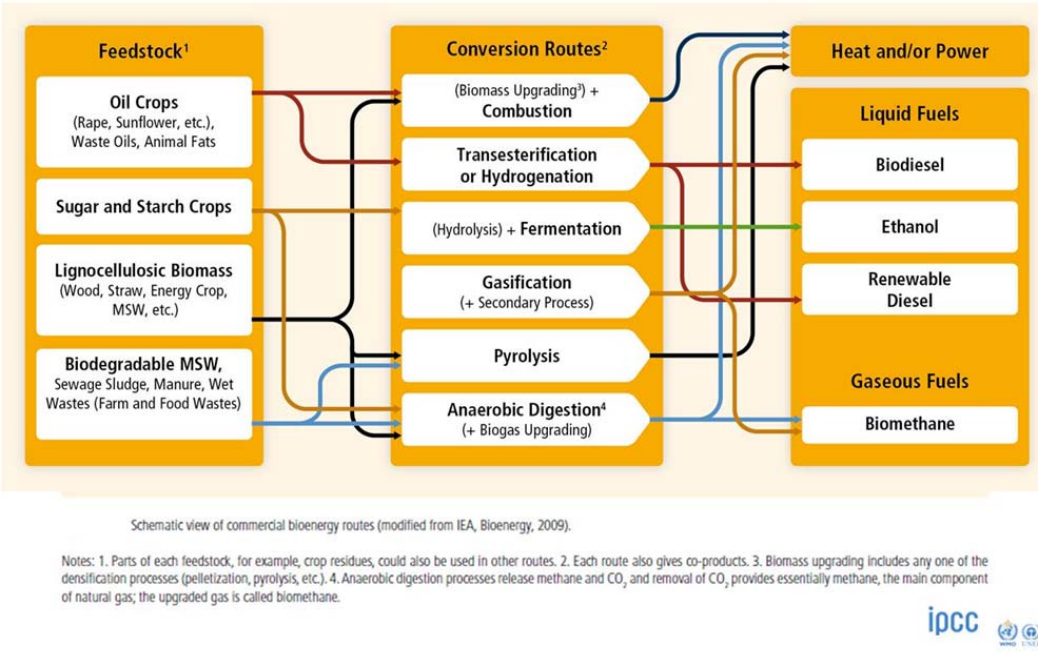


Figure: Global land biomass suitability

Biomass conversion may be conducted on two broad pathways: thermo-chemical decomposition (pyrolysis, gasification and combustion) and biological digestion.

Following figure shows the commercial bioenergy routes, from feedstock to a product. As a feedstock, oil crops, sugar and starch crops, lignocellulosic biomass and biodegradable municipal solid waste are mentioned.



Schematic view of commercial bioenergy routes (modified from IEA, Bioenergy, 2009).

Notes: 1. Parts of each feedstock, for example, crop residues, could also be used in other routes. 2. Each route also gives co-products. 3. Biomass upgrading includes any one of the densification processes (pelletization, pyrolysis, etc.). 4. Anaerobic digestion processes release methane and CO_2 and removal of CO_2 provides essentially methane, the main component of natural gas; the upgraded gas is called biomethane.

Figure: Bioenergy routes from feedstock to a product

Swedish Forest Owner´s Perspective on Bioenergy

Sveaskog is the leading forest owner in Europe with its base in the Swedish boreal forests. Sveaskog owns about 600 million hectares, what is about 18% of the world forest land and 20 % of the world industrial timber. It is a leading supplier of saw logs, pulpwood and bioenergy and has about 730 employees.

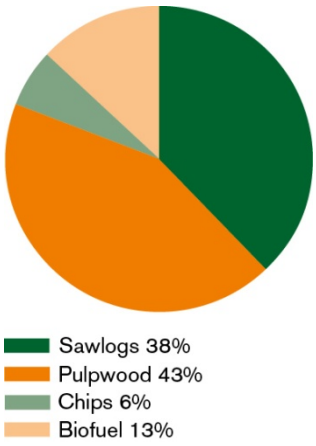


Figure: Sveaskog´s products

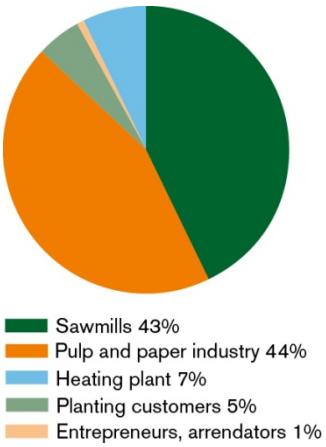


Figure: Sveaskog´s customers

The most important customers for Sveaskog are sawmills and the pulp and paper industry.

Based on the new energy-political framework in Europe and growing demand of bioenergy, there are new challenges and opportunities for the forest industry. Furthermore, the Sweden renewable target in 2020 is the highest within the EU.

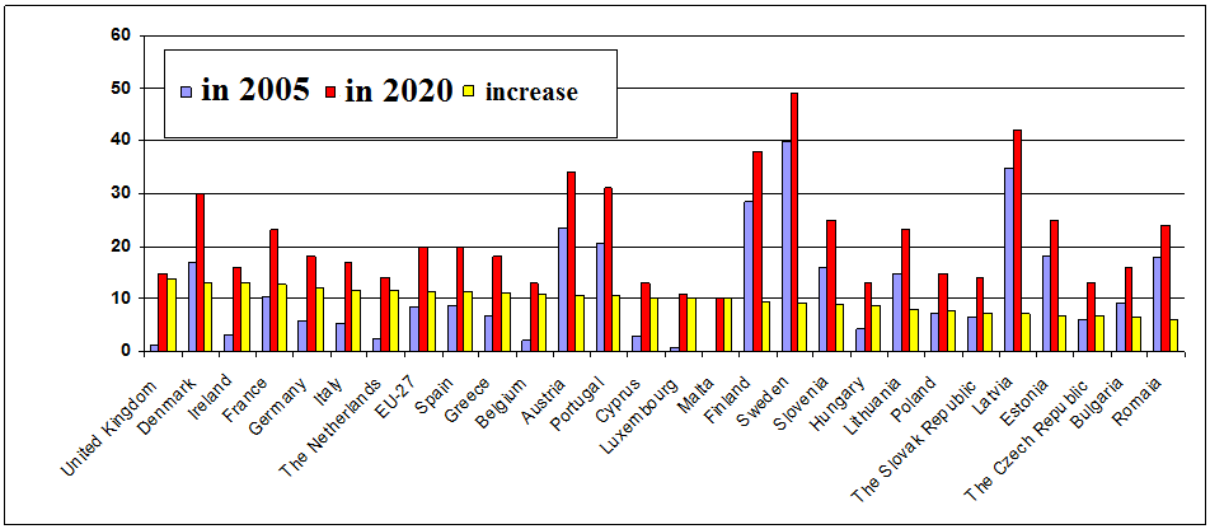


Figure: Share renewable energy 2005 and target 2020-target in Europe

Sveaskog´s key challenges:

- European biomass demand for energy will double until 2020.

- Huge challenges to mobilize the required biomass, forests are key.
- Biomass prices likely to increase.
- Biomass imports (outside of Europe) will increase.
- Sustainability will be an issue in some regions.
- Efficient use of biomass should be encouraged.
- New technologies are needed, especially to replace fossil in the transport sector - gasification technology is very important!!

Sweden has shown that a transition from fossil to renewable energy is possible. Today, bioenergy in Sweden is the largest energy source.

As a response to growing energy demand and new developments in bioenergy field, Sveaskog´s target is to increase forest growth by about 20% by 2030.

Thermal Biomass Gasification in Sweden

The Swedish Centre for Biomass Gasification

It is a competence centre funded by the Swedish Energy Agency, industry and academia. The centre is coordinated by University in Luleå (LTU). In total there are 25 companies, 9 universities and 2 institutes involved. Annual budget for the next 10 years is about € 5 millions.

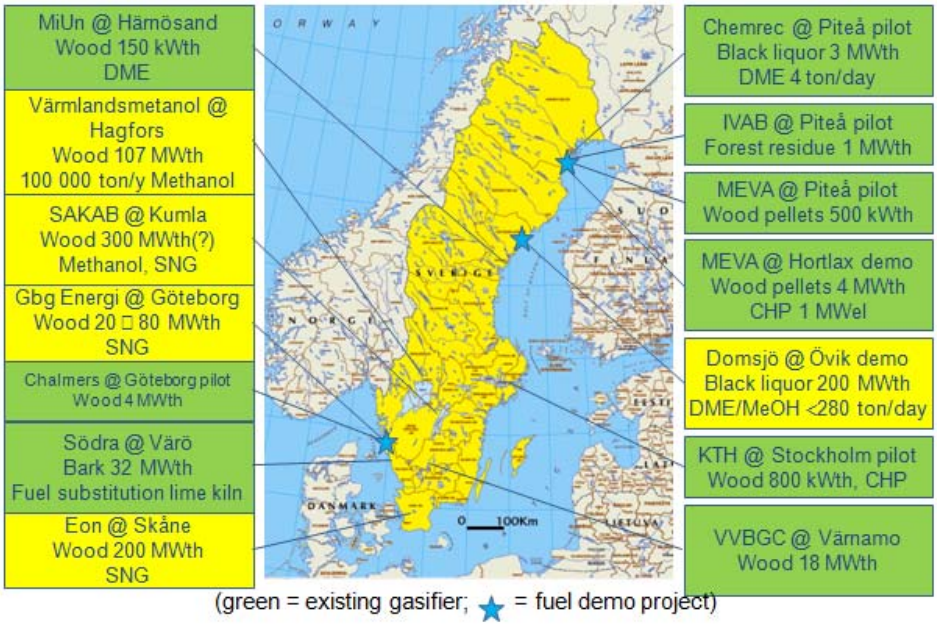


Figure: Swedish gasification projects in 2011

ETC (Energy Technology Centre)

ETC is a research and development centre for renewable energy with focus on combustion, gasification and biorefining processes. In collaboration with private companies and public and academic institutions, ETC carries out research and development projects, designs products, and analyses and solves problems associated with renewable energy sources. ETC has a highly competent staff and advanced experimental and computational facilities.

One of the projects is **"Transportation Fuels from Forest Residues via PEBG".** The project is scheduled from 2009-2012. Industry and society sectors are involved in the project

The project is based on pressurized entrained flow biomass gasification of low grade wood powder. The objectives of applied research and process development around a pilot plant are:

I. Proof-of-concept
II. Scientific basis for a continuous development

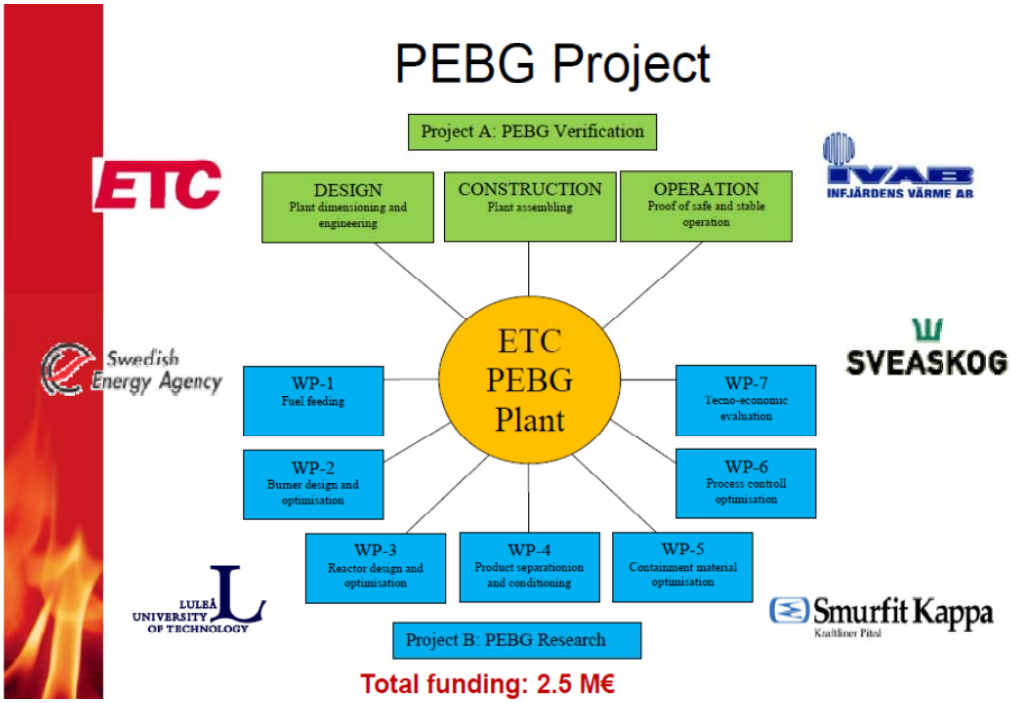


Figure: PEBG Project and project partners

IVAB Gasifier

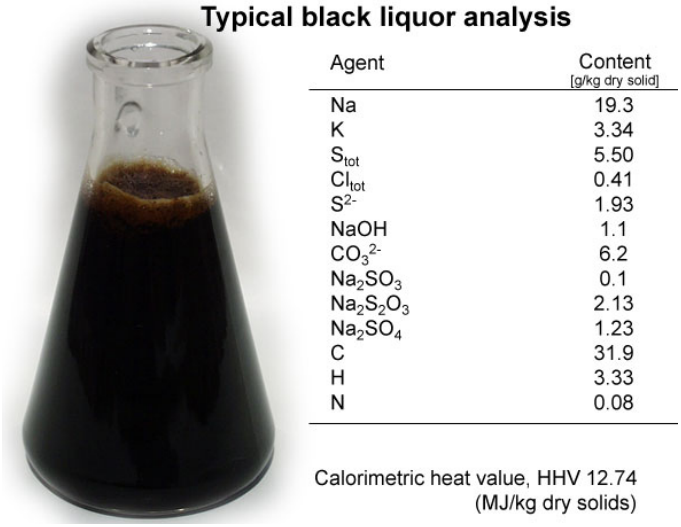
The IVAB gasifier is a pilot plant for direct gasification of biomass powder to syngas (CO + H_2). The pilot plant is situated in the ETC Gasification Centre, and R&D is performed by ETC and LTU. It is based on the PEBG concept. The objective is to verify the technology concept for future commercialization.

The Swedish Black Liquor Gasification R&D Program

Black liquor is the spent cooking liquor from the Kraft process when digesting pulpwood into paper pulp removing lignin, hemicelluloses and other extractives from the wood to free the cellulose fibers. Approximately 7 tonnes of black liquor are produced in the manufacture of one tonne of pulp.

Based on the black liquor properties it is suitable for pressurized entrained flow gasification.

The black liquor is an aqueous solution of lignin residues, hemicelluloses, and the inorganic chemicals used in the process. It comprises 15% solids by weight of which 10% are inorganic and 5% are organic. Normally the organics in black liquor are 40-45% soaps, 35-45% lignin and 10-15% other organics.



Typical black liquor analysis

Agent	Content [g/kg dry solid]
Na	19.3
K	3.34
S_{tot}	5.50
Cl_{tot}	0.41
S^{2-}	1.93
NaOH	1.1
CO_3^{2-}	6.2
Na_2SO_3	0.1
$Na_2S_2O_3$	2.13
Na_2SO_4	1.23
C	31.9
H	3.33
N	0.08

Calorimetric heat value, HHV 12.74 (MJ/kg dry solids)

Figure: Black liquor analysis

In Sweden, the black liquor production is concentrated at app. 20 pulp mills. Estimates have shown that about 25% of Sweden's use of gasoline and diesel can be replaced with synthetic fuels from black liquor.

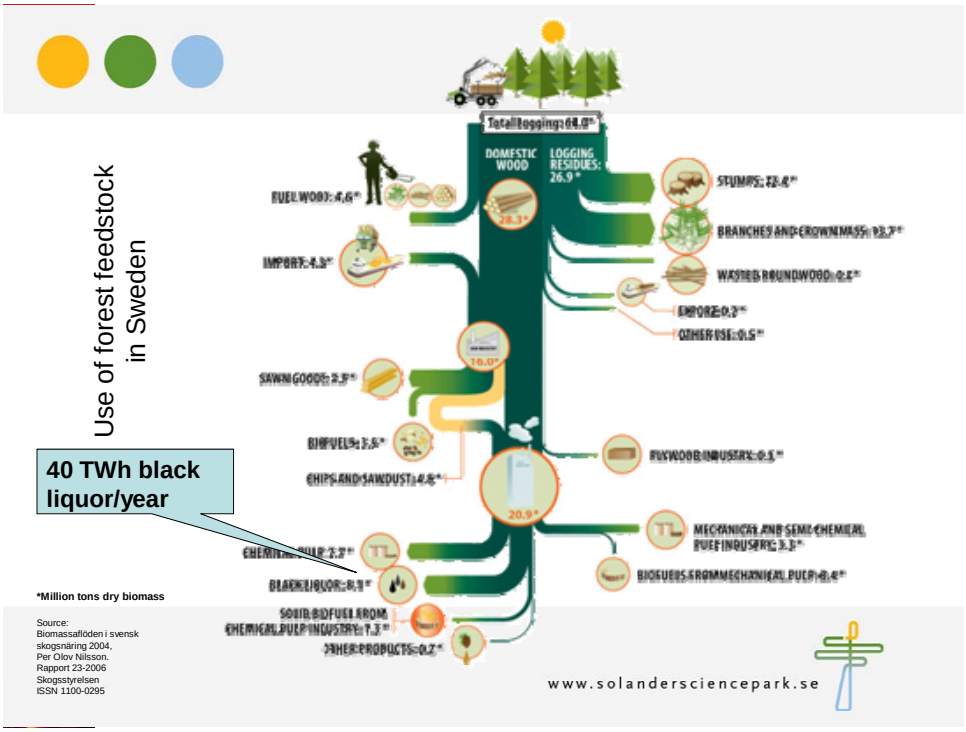


Figure: Use of forest feedstock in Sweden

Black liquor gasification has in Sweden relatively long history. In 1987 the first pilot plant for a "Chemrec" gasifier was built in Hofors. The first pressurized gasification pilot plant was in Skoghall in 1994. In 2005 the development plant (DP-1) was commissioned. Since 2007, the second phase of black liquor gasification is going on.

Chemrec

The DP-1 Gasifier

The Development Plant 1 is located at the Smurfit Kappa mill in Piteå in Sweden. It is used for development and technical demonstration.

The DP-1 gasifier – operation conditions:

- Thermal power: 300MW_{th} (20 ton BL/day)
- Oxygen blown
- Pressure: 30 bar
- Temperature: 1000°C
- Accumulated run time > 13 000 hours (August 2011)
- Provides BioDME plant with syngas

The black liquor enters the gasifier already highly preheated. During the tests on DP-1, the influence of BL (black liquor) preheating temperature on burner spray characteristics was investigated. There were experimental methods, "hot probe", EMF and camera probe provided during the tests. Also the gas sampling and characterization of hot gas cooler from

different levels in quench. Further, the characterization of tar components in liquid samples and selective absorption of H_2S in short time contactors was investigated.

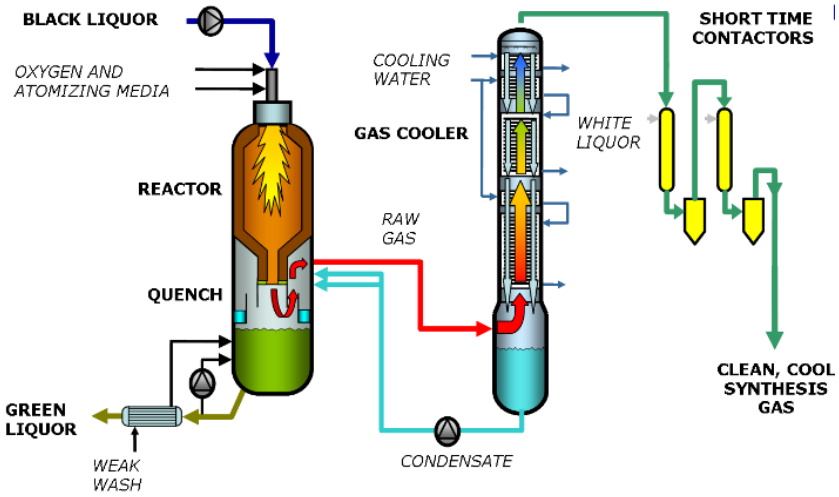


Figure: DP-1 and gas cooling system

Plant activity today

- Syngas provider for BioDME downstream train
- Development and optimization of process parameters
  - Atomization
  - Further optimization of quench operation
- Component development & testing
  - New designs tested for core components
  - Materials testing
- Gain experience of operating , to see what is needed to achieve a high availability
- Marketing, sales and educational purpose
- Test potential clients spent cooking liquors
  - *The knowledge base needed for scale-up to a larger plant!*

BioDME Project

BioDME consortium consists of 9 different companies and institutions involved in the project.

Chemrec builds and operates the BioDME plant, based on Haldor Topsøe technology; Volvo develops trucks; ETC, the Energy Technology Centre in Piteå, contributes its technical expertise. Preem is responsible for BioDME distribution and builds fuel stations in Sweden. Total is responsible for fuel and lubricant specifications. The project is financed by the participants, the EU and the Swedish Energy Agency.

The project was started at 1 September 2008; duration is 48 months. Total budget is 28,4 M€. EU funding is 8,2 M€ and the Swedish Energy Agency contributes 9,6 M€.

The process of BioDME production can be seen in the following diagram.

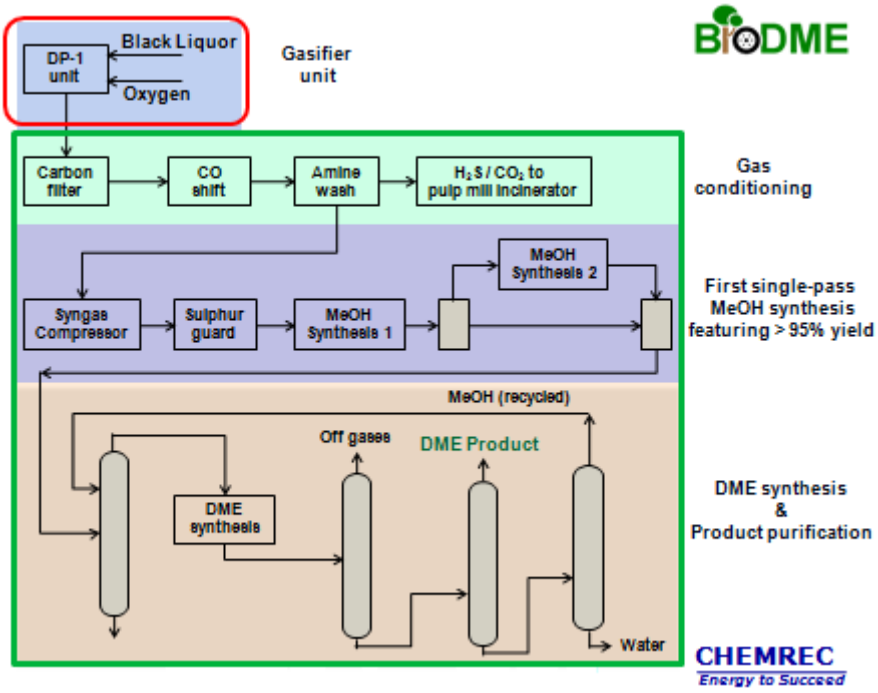


Figure: BioDME production process

The first bio-methanol (7 m^3) was produced on 18 July 2011. First BioDMe was produced on 27 July 2011. The pilot plant is expected to be in full operation in November 2011.

Fuel distribution

At the present there are 4 filling stations dedicated for the 10 DME trucks in Sweden. The technology and safety regulations are based on LPG and modified for DME. Investment is about 200 000 € per filling station.

Figure: 10 field test trucks

Chemrec – further industrial developments (Scale-up)

- The New Bern Booster gasifier, > 47 000 h of full-scale operation
- Commercial atmospheric, air-blown gasifier to boost recovery capacity

- Capacity 300 t BLS/d, about 15% of total mill recovery capacity (~47 MW $_{fuel}$)
- Installed in 1996, operated >47 000 h until October 2008
- Reached 95% annual availability and 2 years refractory life
- Of great importance for development of refractory system and other components

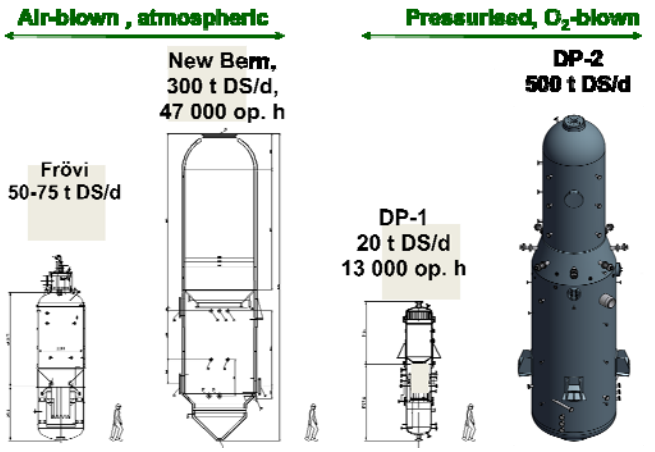


Figure: Scale-up: Operating experience

Chemrec – the Domsjö Project, Örnsköldsvik, Sweden

The scheduled start-up for the Domsjö project is in 2015. The planned products and capacity of the dual product plant is 100 000 t/y DME or 140 000 t MeOH/y. The project costs are approx. € 300 million.

The Domsjö is already a biorefinery today. The scheme of Domsjö with BioMethanol and BioDME production can be seen below.

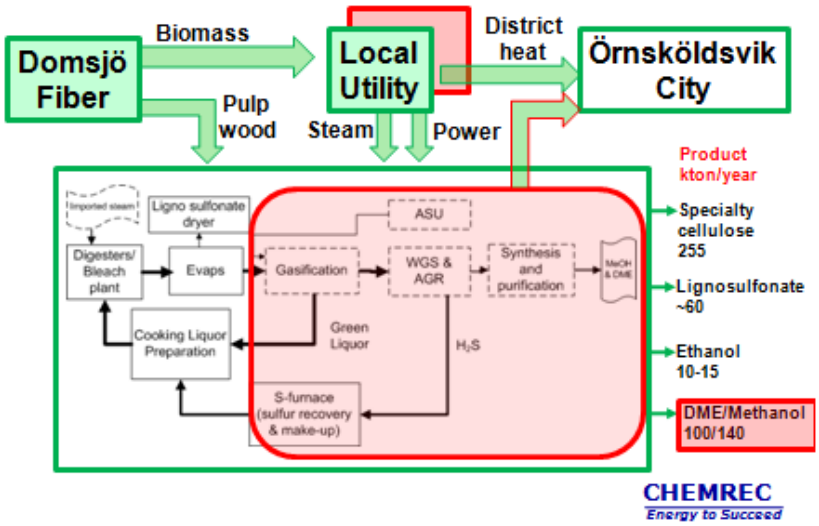


Figure: The Domsjö project

NSE Biofuels Oy

NSE Biofuels Oy is owned by Neste Oil Oy and Stora Enso Oy. The current business is to produce syngas from woody biomass to be used as fuel in Stora Enso Varkaus pulp mill's lime kiln.

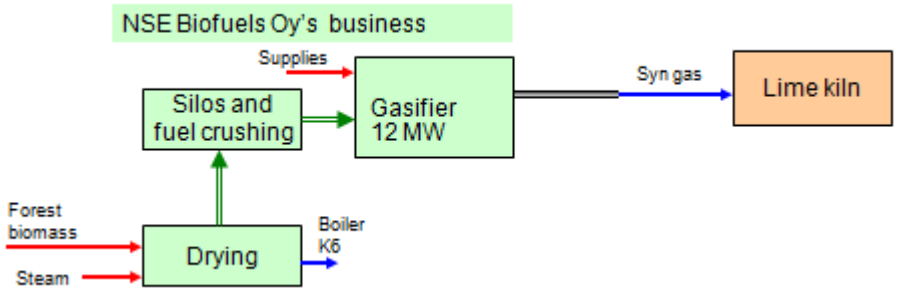


Figure: NSE Biofuels Oy's current business at Stora Enso Varkaus pulp mill

The future goal is an implementation of the first commercial BTL plant and further to develop profitable businesses based on experiences and on market demands (NOSE-Project).

NSE BTL concept:

- Combined competencies of two different industries:
  - Forest industry has strong raw material supply and logistics know how.
  - Oil refining industry has process, product and distribution know how.
- Forest based feed stock, the technical concept allows high tolerance for varying biomass properties.
- FT wax offers extension in renewable feed stock base for high quality traffic fuels outside food supply chain.
- Efficient energy integration with host plant.
- More than 85 % GHG savings compared to fossil transportation fuel.
- New, potential business area for forest industry.

NOSE project objectives:

- To develop and verify BTL technology based on biomass gasification route.
- To provide the overall commercial technology concept.
- To evaluate the techno-economic feasibility of the production concept.

Project partners are VTT, Foster Wheeler, NesteJacobs, Stora Enso and Neste Oil.

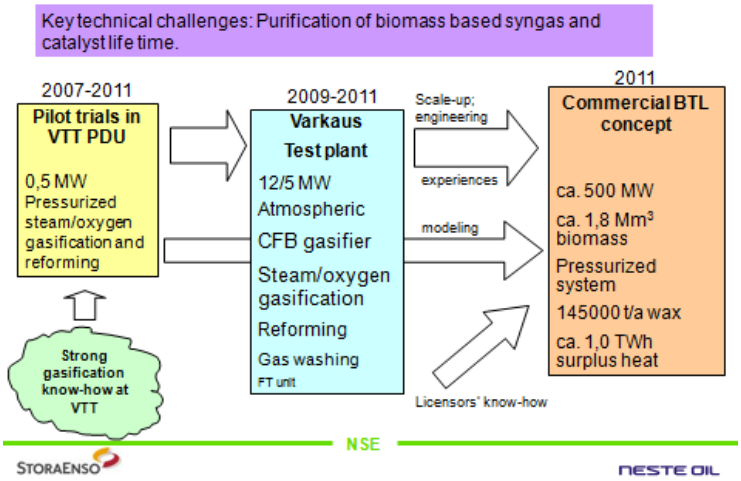


Figure: Stepwise BTL concept development

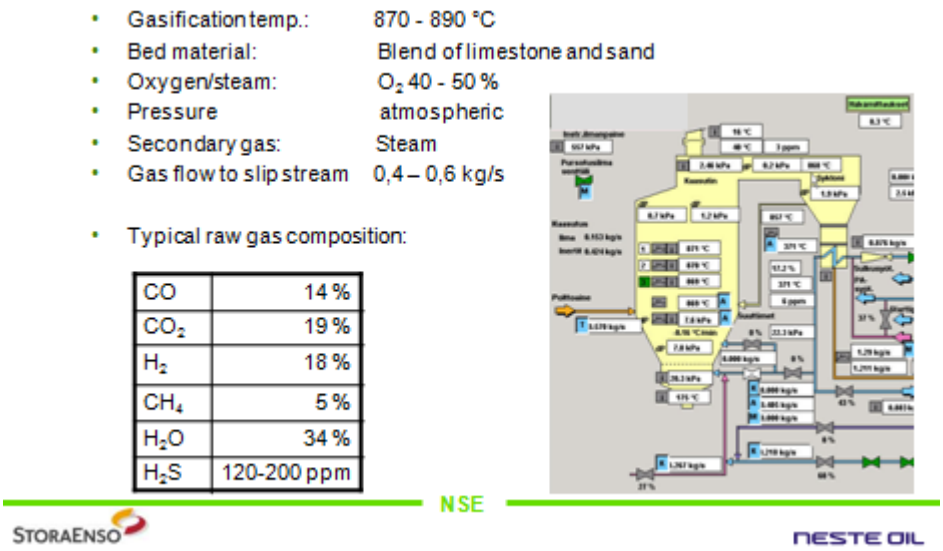


Figure: CFB steam/oxygen gasification at Varkaus test plant

The typical feed stock is a mixture of wood chips from logging residues, energy wood chips, bark and saw dust.

Current status:

- Trials completed in Varkaus test plant at the end of August 2011.
- Developed BTL- technology works and the life time of catalysts is long enough for industrial use.
- Decision to start Basic Engineering is waiting for the outcome of NER 300 funding application, expected in Q3-Q4/2012.
- To meet the profitability targets of commercial BTL plant is a challenge.
- Biomass dryer and air-blown CFB- gasifier continue production of raw syngas for mill's lime kiln.

SunPine Biorefinery – Second generation biofuels

This presentation can be found at www.ieatask33.org in section Site visits presentations.

SunPine AB was founded in 2006 and environmental permission obtained in March 2008. It is owned by KIRAM AB, Preem AB, Sveaskog and Södra Skogsägarna. It has about 20 employees.

The production of crude tall diesel started in April 2010, and investment costs were approx. € 32 mill.

Crude Tall Oil (CTO)

- CTO is a renewable, non food raw material.
- CTO is a residual product from the kraft sulphate process. After the digester (anthraquinone can be used for increased yield), soap is separated from the black liquor and acidulated with sulphuric acid into CTO.
- 2-3 procent of the wood becomes CTO.
- Swedish CTO volume is approx. 200 kton/year.
- CTO main components are fatty acids, resin acids and neutral elements.
- Sterols are part of the neutral elements, and are today recovered and used in functional foods.

Production facility for crude tall diesel

The feedstock for the crude tall diesel is the crude tall oil and methanol. Products are crude tall diesel (55%) and tall oil pitch (45%). The capacity is 100 000 m^3/year (about 2,5% of the Swedish diesel volume)

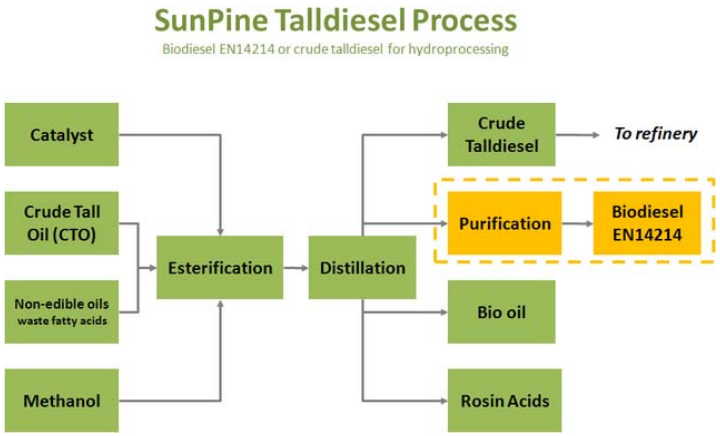


Figure: The SunPine process

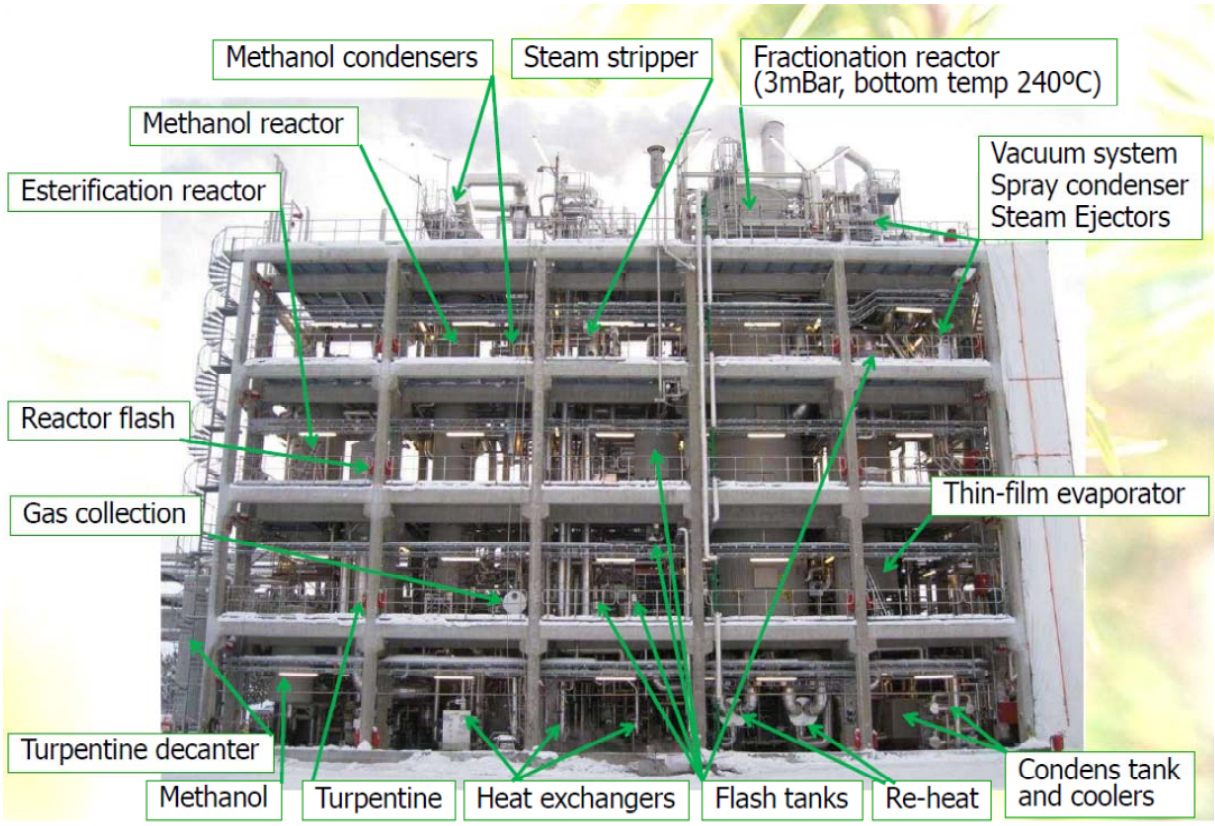


Figure: SunPine full scale production unit (25 m high, 35 meters bride)

SunPine – future plans:

- Increase feed
- Increase yield
- Process optimization
- Recovery of resin acids
- Recovery of anthraquinone
- Recovery of phytosterols

Thermal Biomass Gasification in Finland

VTT (Technical research centre of Finland)

VTT Technical Research Centre of Finland is a globally networked multi-technological contract research organization. VTT provides high-end technology solutions and innovation services. It enhances the customers' competitiveness, thereby creating prerequisites for society's sustainable development, employment, and wellbeing.

Biomass-to-Syngas projects at VTT in 2011

- NEXTUCG: 2007 – 2011
  - Industrial project funded by NSE Biofuels (Neste Oil ja Stora Enso), co-operation also with Foster Wheeler
  - Resulted in NER300 proposal – large FT-production unit
- NORDSYNGAS: 2010-14
  - Nordic co-operation: Luleå, Piteå, Sinteff, VTT
  - Fundamental aspects of pressurised gasification
  - System studies related to integrated plants to pulp and paper industries
- GASIFICATION REACTIVITY 2011 – 2014
  - Fundamental research with Åbo Akademi and Jyväskylä Univ.
  - Funded by Finnish Akademi
- US-CO-OPERATION PROJECT ON EVALUATION OF GASIFICATION-BASED SYSTEMS 2011-12
  - Ilkka Hannula as visiting scientist at Princeton University (USA)
  - Co-utilisation of biomass and coal for liquids and electricity and combinations of biotechnical and thermochemical routes
  - Evaluation of US development projects
  - Aspen modelling of selected concepts and technologies
- PRODUCTION OF SNG OR H_2 FROM BIOMASS 2011 - 2014
  - Evaluation of process alternatives – less capital intensive and suitable to smaller size than BtL plants
  - Pre-competitive R&D on gasification and gas cleaning

Advanced analysis technique for gasification gas

- The aim has been to develop better analysis methods for the impurities in biomass gasification gas
  - Shorten the analysis time, improve accuracy and reduce labor intensity
  - From off-line to on-line
- Research subjects:
  - Analysis of small concentrations of sulphur in the gasification gas
  - Improved analysis method for alkali metals
  - Establish on-line-tar analysis for light tars
  - Improved NH_3- and HCN-measurement methods
- Development work in a projects with Carbona, Neste, Stora Enso, Foster Wheeler , Metso, VAPO, UPM and Gasum

"Rapid" on-line tar analysis of reformed product gas

- Analysis time 5-20 min (several possible operation modes)
- Calibrated compounds:
  - Benzene
  - Toluene
  - Naphthalene
  - Phenanthrene
  - Anthracene
  - Fluoranthene
  - Pyrene
  - (if desired, 30 additional compounds)
- HP-1 (10 m x 0.53 mm x 0.26 µm) or HP Ultra 2 –column (25 m x 0.32 mm x 0.52 µm)
- Gas phase samples online
- Can be connected to the reactor automation system
- Has been in use at VTT for more than three Years

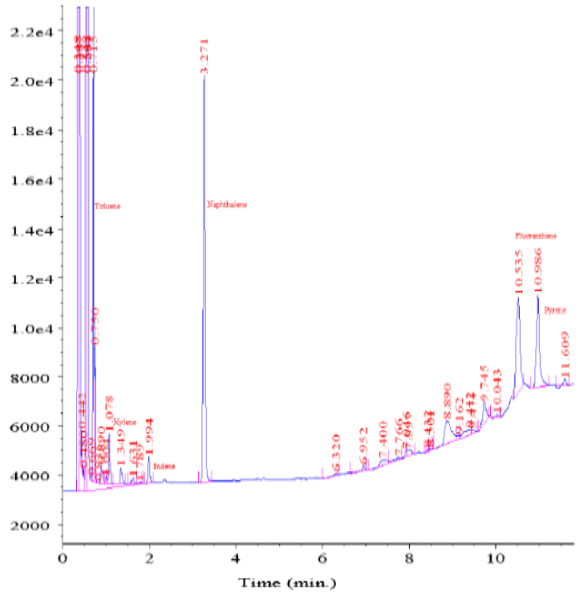


Figure: On-line tar analysis

More than 500 tar measurements were carried out and compared. Under carefully controlled conditions, both the Tar Protocol and the on-line method give consistent results.

Woody biomass based gasification process development for H_2 or SNG production (Vetaani project)

- Tekes/Biorefine project 1.6.2011 – 31.12.2013
- Total budget 1,5 M€, TEKES 60 %, VTT 30 %, companies 10 % (GASUM, HELEN, Metso, NesteOil, HVK, Outotec)
- Applications:
  - SNG, suitable for pipeline distribution
  - Bio-Hydrogen or hydrogen-methane gas mixture, e.g., for refineries
  - Clean fuel gas for SOFC power plants or NG based IGCC
  - Clean medium-Btu gas for industrial process kilns
- R&D methods
  - System studies using Aspen Plus modeling tools
  - Selective tar reformer and hot filtration R&D
  - Indirectly heated gasification and reforming
  - Overall process optimization: Higher efficiency and/or lower costs

Targets for catalytic reforming and shift conversion in SNG applications

- Complete conversion of C_2-hydrocarbon gases
- Low conversion of CH_4
- Tar conversion > 99 %
- As high benzene conversion as possible

- Shift conversion before gas cooling in order to minimize total steam consumption

Figure: Conversions achieved in VTT´s reformer

Metso Gasification

Metso is a global supplier of sustainable technology and services. Metso´s customers operate in mining, construction, energy, oil and gas, recycling and pulp and paper industries. Metso employs about 28 500 people in over 50 countries.

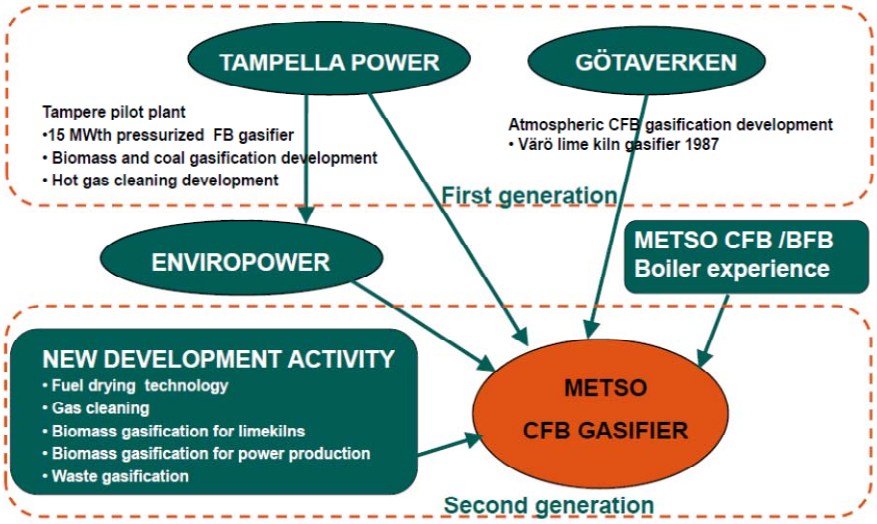


Figure: Metso´s evolution in gasification

Metso´s CFB gasifier

CFB Gasifier	
Size	20 – 140 (200) MWth
Fuel	Biomass, waste
Gasification media	Air (steam)
Operating temperature	750 – 900 C
Operating pressure	5-30 kPa(g) /0,05-0,3 atm(g)
Product gas heating value	3-7 MJ/kg (LHV)

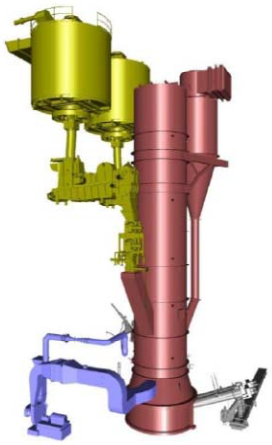


Figure: Metso´s CFB gasifier

From coal-firing to biomass gasification

Metso plans modification of an existing coal-fired plant (Vaskiluoto coal-fired plant in Vaasa) to biomass gasification facility. The benefits of the project are relatively low investment costs, short delivery time and minimized production interference, integrated drying process and availability of storage capacity.

Vaskiluoto coal-fired plant in Vaasa has been in operation since 1982. It produces 230 MW_{el} and 170 MW_{th}, which is about 90% of the district heat needs in the Vaasa region. The coal consumption is 400 000 – 500 000 t/year.

Now, it is planned to adjoin a 140 MW biomass gasifier and dryer and replace up to 40 % of coal by biomass. The contract was signed in June 2011 and plant operation is scheduled for December 2012. Total project cost is approximately € 40 millions.

Lahti Energia – solid waste gasification

The start up of the Lahti gasification plant is scheduled for April 2012. Total investment was € 157 millions. The capacity is 160 (2x80) $MW_{fuel,}$ 50 MW_{el} and 90 $MW_{th.}$

The temperature of the gasification process will be about 850-900°C. Then the product gas will be cooled to approx. 400°C and filtered. The clean gas will be burned in a gas fired boiler.

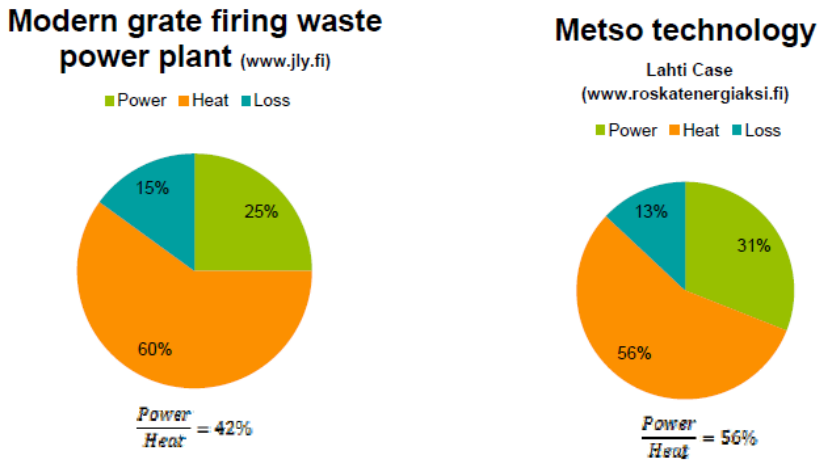


Figure: The comparison of modern grate firing power plant and Metso waste gasification

As can be seen in the figure above, the Metso technology offers higher power production efficiency in waste utilization.

Biomass Gasification in Pulp and Paper Industry (Andritz/Carbona)

Andritz/Carbona is active in different gasification areas:

- Equipment for biomass preparation and handling
- Belt and drum dryers
- CFB gasifiers (atmospheric, air blown, for boilers and kilns; 10-150 MW_{th})

- BFB gasifiers (low pressure, air blown; 10 – 50 MW_{th})

Circulating fluidized bed gasifiers (CFB)

Metsä-Botnia Joutseno, gasification plant (start up in summer 2012)
Target:

- To replace 100% NG at lime kiln with gasification gas
- To utilize biomass side products from mill
- To utilize waste heat available from mill for biomass drying
- To deliver whole line of Andritz products from fuel handling to lime kiln burner

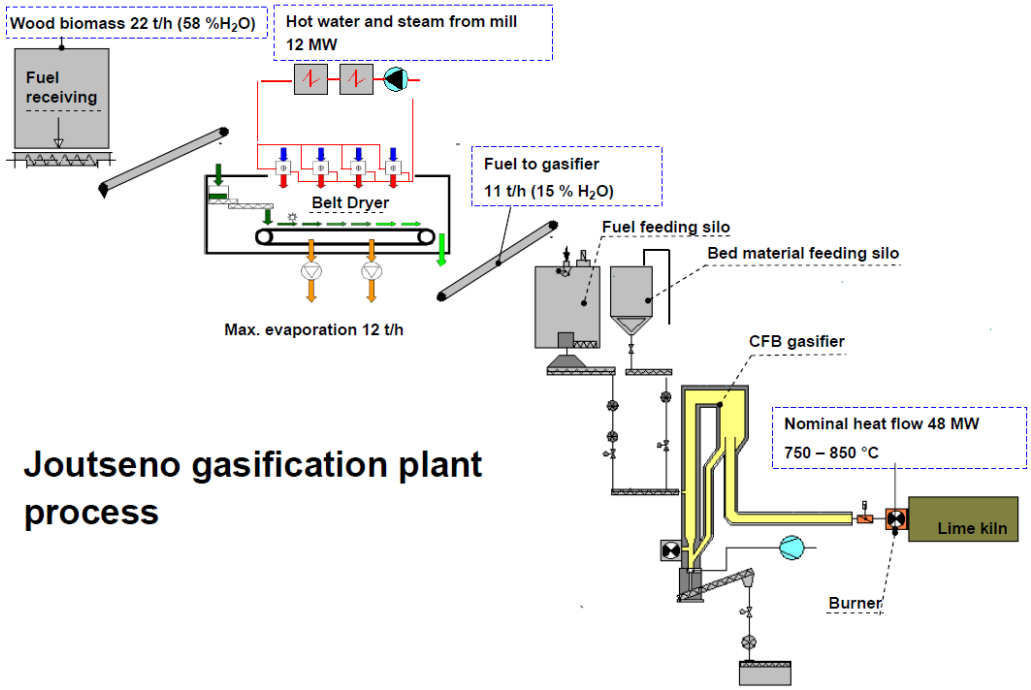


Figure: Metsä-Botnia Joutseno, gasification plant process

Lime kiln gasifier features:

- Can utilize cheapest fuel residues with high ash content
- Degree of fuel drying moderate, can be adjusted according to kiln properties
- Low temperature heat to be used in belt drying
- Harmful fuel ash/soil in gas can be minimized
- Lime quality not to be affected
- Total replacement of fossil fuels
- Lime kiln capacity stays as before
- Excellent gasifier operation history during decades
- CO_2 benefits and short pay-back time for the investment

Bubbling fluidized bed gasifiers (BFB)

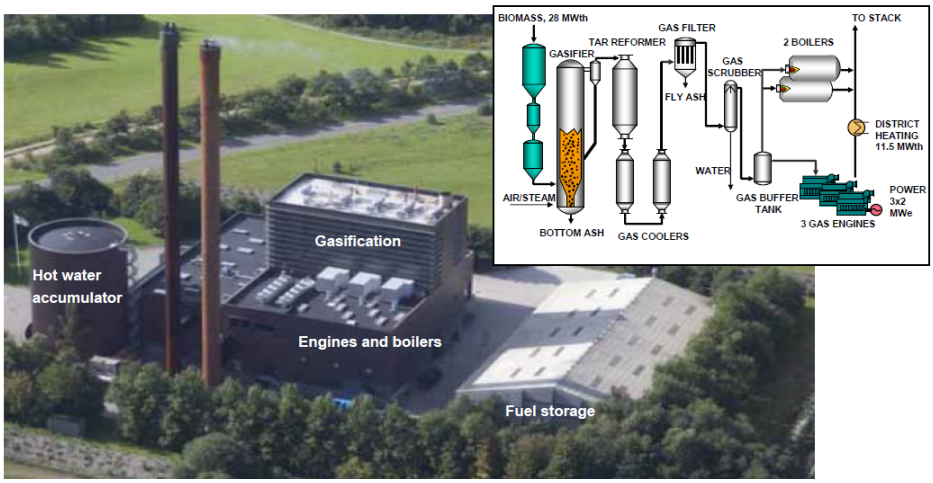


Figure: CHP plant in Skive, Denmark

The Skive plant consists of pressurized BFB gasifier, air blown, with capacity 19,5 MW_{fuel} (max. 28 MW_{fuel}), heat (11, 5 MW_{th}) and power (6,0 MW_{el}), 3 gas engines and 2 gas boilers. As a fuel are wood pellets and wood chips utilized.

Test facility at Gas Technology Institute in Illinois, USA

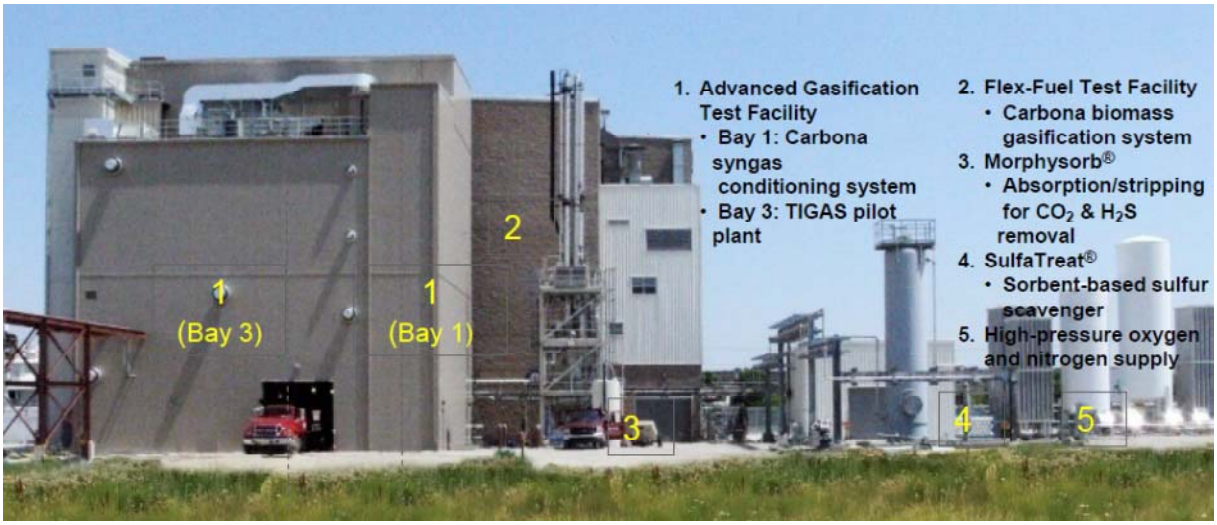


Figure: Gas Technology Institute facilities, Illinois, USA

High efficiency power generation (η_e = 40-50 %)

The concept is based on pressurized air-blown BFB gasifier (20 bar, demonstrated in Tampere, Finland). Hot product gas is cleaned by filtration and cooled by integrated steam cycle. The electricity is produced in gas turbine with air extraction. There is also a burner for high temperature LCV gas. IGCC technology will be commercialized in near future. The details can be seen in the following schematic figure.

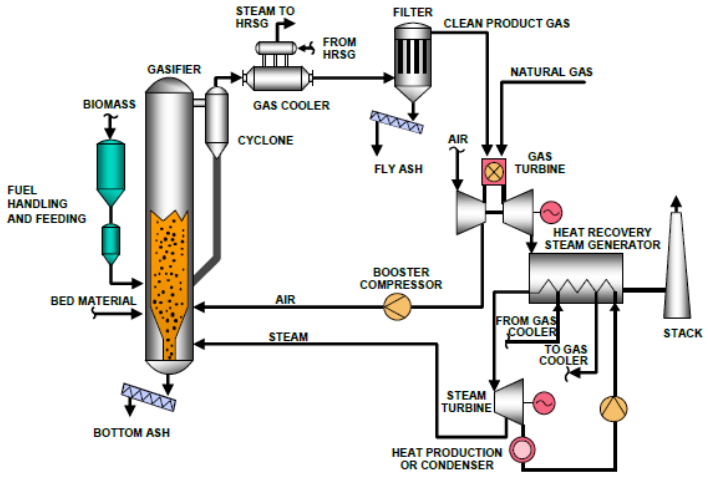


Figure: ICGG technology

Thermal Biomass Gasification in Austria

Economic frame conditions in Austria

The actual biomass costs in Austria are 0.018 – 0.019 €/kWh, which is about 80 – 90 €/t_{dry}. Feed in rate for electricity (not valid anymore) was 16 c€/kWh for electricity from forest wood chips, < 2 MW_{el}, independent of echnology. Price of heat is 0.02 – 0.04 €/kWh and depends on average biomass price and light heating oil price. There is no funding of investment costs, except of demonstrations plants in Austria.

R&D on large scale gasification

The funding for R&D in the area of gasification comes either from the EC or national funding (e.g. climate and energy fund).

Most R&D projects consist of a consortium, where scientific partners (Vienna University of Technology, Bioenergy 2020+, engineering partners (e.g. Repotec, TeconEngineering, Güssing Renewable Energy, etc.) and operators (e.g. Biomass CHP Güssing, Mondi, Begas Energie AG, OMV, etc.) work close together.

In the following discussion some examples of actual R&D in the area of gasification are given:

Distribution of elements in DFB gasifier

The distribution of nitrogen, chlorine and sulphur using DFB gasifier was studied at TUV. This is a quite important aspect, if waste fuels are used, as then the gas treatment has to be modified.

In the flue gas components such as NO, SO_2 and HCl were found. In the product gas NH_3, H_2S and HCl were detected. But the interesting result was that more than 99% of the impurities go to the product gas, so no special gas treatment for the flue gas is necessary if waste fuels are used in a dual fluidized bed gasifier.

G-volution system

At TUV an advanced system of dual fluidized bed biomass gasification was developed. The gasification part of a DFB reactor is divided in several zones, where the reactor diameter narrows. The product gas velocity in this narrow part is higher, than in the following wider section. In this wider section the product gas comes into more intensive contact with a bed material (e.g. dolomite, olivine) and tar content in the gas is reduced. At the present time cold flow models are being studied, and in the future a hot reactor of about 100kW fuel input will be built.

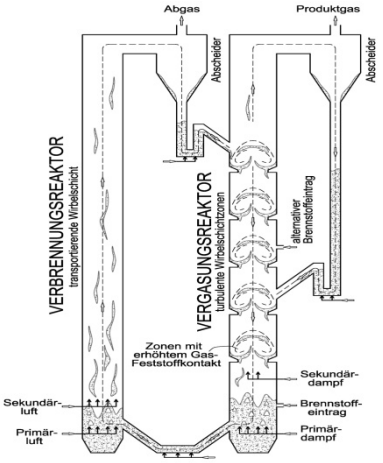


Figure: G-volution system

Gasification and synthetic biofuels – research along the process chain

At Bioenergy 2020+ R&D on the whole process chain of biomass gasification is done in cooperation with TUV. On the one side there is R&D on optimization existing biomass CHPs, like Güssing and Oberwart, on the other side also new concepts like polygeneration are introduced. One example is the separation of hydrogen from the biomass CHP Oberwart. Here the complete process chain to separate hydrogen and to use it in a PEM fuel cell is being investigated. Another example is the FT synthesis, where also the whole chain from wood chips, through the usage of the FT diesel in engines is being investigated.

Mixed alcohols

This project is funded by “Klima und Energiefonds” and Bioenergy 2020+. The aim of this project is to develop a fundamental know-how in the synthesis of mixed alcohols from biomass. Main advantage is very simple gas cleaning, due to sulphur resistant catalyst. During the process, the synthesis gas goes through the steam reformerand glycol scrubber; afterwards it is compressed and passes MAS reactor to condenser, where the mixed alcohols are produced.

The first experiments are already done and the first liters of mixed alcohols have been produced and analyzed.

Thermal biomass gasification in the USA

Current Biofuels Status and Biopower in the USA

Nowadays, corn ethanol is the most common biofuel in North America. There are 218 commercial plants with 14 554 billion gal/year nameplate capacity; the production of corn ethanol is about 12 000 billion gal/year and an additional 0,27 billion gal/year are planned or under construction. The price for corn ethanol is about 270 cents/gal (status March 2011).

The capacity of biodiesel is about 2,85 billion gal/year (status April 2011).
The biofuels facilities in North America are situated mostly in north-east part of the USA.

The capacity of Biopower is about 10,5 GW (status 2010). The costs range between 0,08 – 0,12 USD/kWh. The Biopower plants are situated in the eastern part and western coastal parts of the USA. There are a lot of biomass gasifier developers in the USA. The complete table can be found in the workshop-presentation, given by R. Bain.

Gasification technologies in the USA (selected)

Nexterra

A gasification system of Nexterra can be found at University of South Carolina. The start up was at the end of 2007. The power is 1,38 MW_{el} and capacity 60 000 lbs/hr of high pressure steam for district heating. The biomass (wood residues, moisture 25-55 %) is converted to combustible gas with 3 gasifiers. Syngas is burned in the oxidizer. The hot flue gas is directed through heat recovery steam generator to produce steam. Steam is sent to a back pressure turbine to produce electricity. Turbine exhaust steam is distributed to campus heating system.

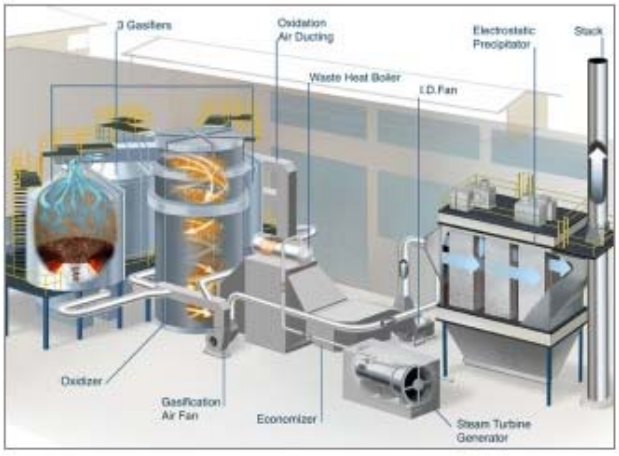


Figure: Illustration of Nexterra´s gasification system at USC

Enerkem

The process converts waste and residuals into advanced biofuels

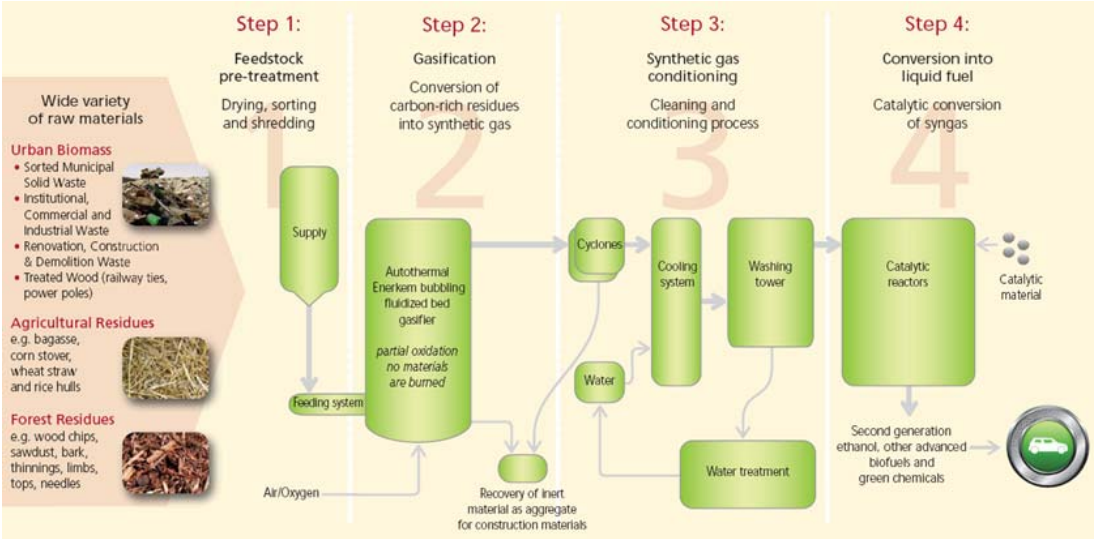


Figure: Enerkem – a unique gasification and syngas to biofuels technology

Enerkem promotes sustainable development and that is why it uses the non-recyclable portion of the waste and creates value from the forest and agricultural residues. From one ton of waste (dry basis) 360 liters of ethanol are produced. The process requires little use of water and allows for its reuse in a closed circuit.

GTI Biomass Gasification Activities

Within the "2nd generation biofuels project", there are provided laboratory and pilot-scale test for Andritz/Carbona and UPM F-T project. The maximum feed rate of biomass is 40 tons/day. The gasifier is pressurized (25 bar) oxygen blown.

Taylor Biomass Energy, LLC

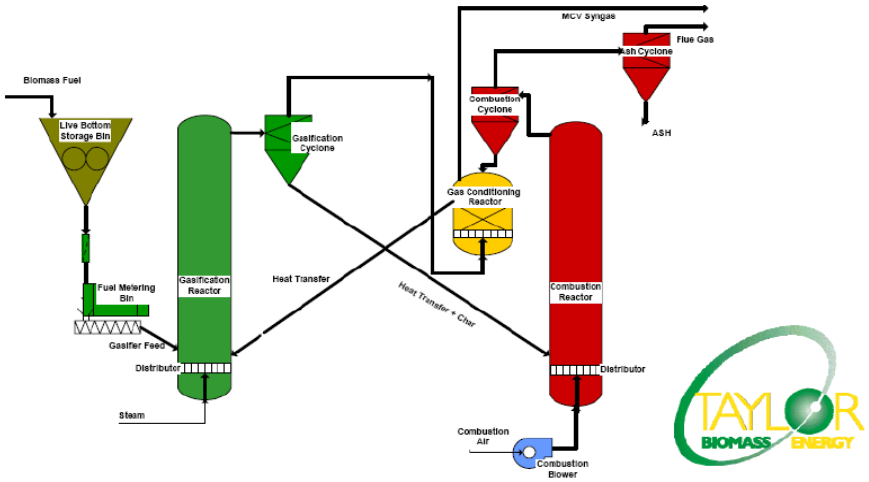


Figure: Taylor Biomass Energy system

The company has 3 gasifiers projects in North America, in Montgomery, NY; Alberta, Canada, and Maryland.

Montgomery, NY

- Feedstock: MSW
- bed material: calcite and dolomite
- modular gasification facility
- process system for liquid fuels and hydrogen production
- 24 MW combined cycle system
- Sells "green energy" to NY grid

Alberta, Canada

- 24 MW combined cycle system

Maryland

- Synthesis to FT liquids

TRI Technology and Projects

TRI´s core technology is deep fluidized bed, indirectly heated, steam reforming of biomass. TRI´s black liquor gasifier has been commercially operational for six years (Trenton, Ontario). Two separate DOE "Small-Scale Biorefinery Projects" are employing TRI technology:

- New Page, Wisconsin Rapids, WI; 500 dry tons per day biomass to FT fuels and tail gas. Class 10 study underway ($30 million award, 2008)
- Flambeau River Biofuels, Park Falls, WI; 1000 dry tons per day biomass to FT fuels. Class 30 completed ($30 million award, 2008)

ICM, Inc.

ICM Inc.'s gasification technology has been successfully tested and supported at rates up to 250 tons per day by the Department of Energy. ICM currently offers three commercial-scale unit designs with feedstock processing ranges of 150-200 TPD, 300-350 TPD and 450-500 TPD.

ICM owns and operates a 200 ton per day commercial demonstration auger gasification unit in Newton, KS that was installed to process municipal solid waste from the Harvey County, KS landfill. Since commencing operations at the facility, ICM has tested more than a dozen feedstocks and amassed more than 2,100 hours of operation on the unit.

Projects: ReVenture Project, Charlotte, NC: ReVenture Park is a proposed waste-to-energy facility for Charlotte, NC. Forsite Development, the lead developer for the project, selected the biomass gasifier technology by ICM, Inc.

Coskata – Project Lighthouse

The project is based on partnership between Coskata and Alter NRG. A semi-commercial demonstration, Westinghouse plasma gasifier is located in Madison, PA. The feedstocks are

pine chips and capacity is 50 000 gal /year of ethanol. The successful start up was announced in October 2009.

University of California & West Biofuels

Thermochemical conversion of biomass to mixed alcohols is provided using 5 ton/day dual fluidized bed gasifier based on “Pyrox Process”. The facility works under atmospheric pressure with air-blown combustor. It is now in start-up.

Figure: Mixed alcohols facility at University of California

Conclusions:

The workshop **‘Biomass gasification opportunities in the forest industry’** was held at the IEA Bioenergy Task 33 meeting, on the 19 October 2011 in Smurfit Kappa Kraftliner, 941 86 Piteå, Sweden. Highlights of the thermal biomass gasification in Sweden, Finland, Austria and USA were presented.

The forest industry was represented by Sveaskog, which is the leading forest owner in Europe with its base in the Swedish boreal forests. It owns about 600 million hectares, what is about 18% of the world forest land and 20 % of the world industrial timber. It is leading supplier of saw logs, pulpwood and bioenergy. The most important customers for Sveaskog were in the past sawmills and the pulp and paper industry. Based on new energy-political framework in Europe and growing demand of bioenergy, the new challenges and opportunities for forest industry occur and biomass gasification is being a very attractive process for the forest industry.

One of the most important Swedish projects is “Transportation Fuels from Forest Residues via PEBG”. The project is scheduled from 2009-2012. Into the project research, industry and society sectors are involved. The project is based on pressurized entrained flow biomass gasification of low grade wood powder. The total funding of the project is 2,5 M€.

In Sweden, the black liquor production is concentrated at app. 20 pulp mills. Estimates have shown that about 25% of Sweden's use of gasoline and diesel can be replaced with synthetic fuels from black liquor. The Chemrec is one of the Swedish companies' active in R&D in the utilization of black liquor. The details of the Chemrec DP-1 gasifier were presented.

Further, Chemrec builds and operates the BioDME plant, based on Haldor Topsøe technology; Volvo Trucks develops, builds and places DME trucks with Delphi providing fuel injection system technology. ETC, the Energy Technology Centre in Piteå, contributes its technical expertise. The project duration is 48 months (till September 2012) and total budget is 28,4 M€.

NSE Biofuels Oy (Sweden) is owned by Neste Oil Oy and Stora Enso Oy. The current business is to produce syngas from woody biomass to be used as fuel in Stora Enso's Varkaus pulp mill lime kiln.

In Finland the technical research is concentrated at VTT (Technical Research Centre of Finland). During the workshop the actual projects such as the biomass to syngas process and the production of hydrogen and SNG were presented.

Further, Metso, a global supplier of sustainable technology and services, presented their CFB gasifier and their plans of modification of existing coal-fired plant (Vaskiluoto coal-fired plant in Vaasa) to biomass gasification facility. The benefits of the project should be relatively low investment cots, short delivery time and minimized production interference, integrated drying process and availability of storage capacity.

Andritz/Carbona reported on Metsä-Botnia Joutseno, gasification plant. The start up of the plant is scheduled to summer 2012). The targets are to replace 100% NG at lime kiln with gasification gas and utilize biomass side products from mill, further utilize waste heat available from mill for biomass drying and deliver whole line of Andritz products from fuel handling to lime kiln burner.

In Austria most R&D projects consists of a consortium, where scientific partners (Vienna University of Technology, Bioenergy 2020+, engineering partners (e.g. Repotec, TeconEngineering, Güssing Renewable Energy, etc.) and operators (e.g. Biomass CHP Güssing, Mondi, Begas Energie AG, OMV, etc.) work close together.

During the workshop it was reported on projects at VUT such as distribution of elements in the DFB gasifier, G-volution system, gasification and synthetic biofuels and mixed alcohols. This project is funded by "Klima und Energiefonds" and Bioenergy 2020+. Aim of this project is to get a fundamental know-how in the synthesis of mixed alcohols from biomass. The first experiments are already done and the first liters of mixed alcohols were produced and analysed.

The state of the art on thermal gasification in the USA and selected gasification technologies (Nexterra, Enerkem, etc.) and projects were presented.

Nowadays, corn ethanol is the most common biofuel in North America. There are 218 commercial plants there, with 14 554 billion gal/year nameplate capacity, the production of corn ethanol is about 12 000 billion gal/year and additional 0,27 billion gal/year are planned or under construction. The price for corn ethanol is about 270 cents/gal (status March 2011). The capacity of biodiesel is about 2,85 billion gal/year (status April 2011).

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The workshop with a title “Biomass gasification opportunities in the forest industry” was a very informative appointment for all workshop participants. More than 30 experts from the biomass gasification area and forest industry had a possibility to exchange the important information in RD&D of thermal biomass gasification process and the new opportunities for forest industry.