IEA Bioenergy, Task 33 – Thermal Gasification of Biomass

Workshop

Liquid biofuels

04. – 05. November 2014, Karlsruhe, Germany

Summary by Dr. Jitka Hrbek, Vienna University of Technology
Checked by Prof. Kevin Whitty, University of Utah

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Introduction

Fuels from biomass have a great potential: In the short term, they will be able to replace part of our fossil energy sources and will contribute to an efficient mix of renewable energies. Covering a wide range of different fuels such as kerosene, diesel, and gasoline, BTL (biomass-to-liquid) fuels of the second/third generation offer various advantages over bioethanol or biodiesel. Almost any kind of biomass, whose origin and needs need not collide with those of plants grown for the food industry, can be used for biofuel production. Dry, cellulose-rich residual biomass from agriculture, forestry production, and landscaping is particularly suited for use in fuels.

Biofuels, biofuel feedstock and the technologies involved in producing them can be considered in terms of current bioenergy and advanced bioenergy.

Advantages of BTL Fuels over Conventional Fuels

- Reduction of carbon dioxide emissions
- Lessening fossil fuel use
- Greater independence from energy imports
- Strengthening of regional agriculture
- Wide range of raw materials, i. e. high mass potential
- No competition for land with food production
- Infrastructures: Current filling stations and routes of distribution can continue to be used
- Fuels ("Designer fuels") can be tailored to the needs of different types of engines
- Cover a large variety of fuel types

Biomass to Liquid – The Karlsruhe bioliq® Process

An innovative approach for BTL is the bioliq® concept developed at Karlsruhe Institute of Technology (KIT) in Germany. On the occasion of their last transnational managing group meeting, hosted by KIT-ITAS, the project members of BioenNW had a visit to the Bioliq® pilot plant. Its aim is to cover the whole process chain required for producing customized fuels from residual biomass. Being mainly synthesized from dry straw or wood, the BTL fuels offer environmental and climatic benefits through cleaner combustion. The integrative process chain, moreover, enables production of synthesis gas and chemicals.

bioliq® mainly intends to convert large, local quantities of residual biomass by densifying energy. To save carbon dioxide and reduce transport distances to refineries, the Karlsruhe BTL concept combines decentralized production of energy-rich bioliqSynCrude® by means of rapid pyrolysis and central processing with final industrial-scale refinement. Since the energy density of bioliqSynCrude® is by more than one order of magnitude higher compared to dry straw, it is evident that the method's efficiency is enhanced by decentralized energy densification.

Table 1: Presentations overview

Author	Title
MANFRED WÖRGETTER bioenergy 2020+, Austria	**Introduction IEA Task 39: Commercializing Liquid Biofuels**
THOMAS WURZEL Air Liquide Global E&C, Germany	**2nd generation biofuels – the bioliq technology and economic perspectives**
RIKARD GEBART Luleå University of Technology, Sweden	**Conversion of forest industry by-products to methanol and DME**
HOLGER KITTELMANN Linde Engineering Dresden GmbH, Germany	**Carbo-V – biomass gasification technology**
MALIN HEDENSKOG Göteborg Energi, Sweden	**GoBiGas project – experiences and operational progress**
RALF ABRAHAM, NORBERT ULLRICH UHDE GmbH, Germany	**An update on the BioTfueL project and other activities of TKIS-PT in the area of biomass gasification**
JOHN BØGILD HANSEN Haldor Topsøe, Denmark	**Haldor Topsøes biobased sustainable fuel production technologies**
JÖRG SAUER KIT - Institut fuer Katalyseforschung und -technologie (IKFT), Germany	**Modified MtG-processes for BtL and Power-to-Fuels**
THOMAS BÜLTER EVONIK Industries AG, Germany	**Speciality chemicals from syngas fermentation**
PETER PFEIFFER KIT – Institut für Mikroverfahrenstechnik (IMVT),Germany	**Technology for Fischer-Tropsch synthesis of liquid fuel in small scale**

MANFRED WÖRGETTER, bioenergy 2020+, Austria

Introduction IEA Task 39: Commercializing Liquid Biofuels

Task 39 is a group of international experts working on commercializing sustainable biofuels used for transportation. It is a part of the International Energy Agency's (IEA) implementation agreement for bioenergy, IEA Bioenergy.

Purpose of Task 39

The goal of Task 39 is to provide participants with comprehensive information to assist with the development and deployment of transportation biofuels. The Task coordinates both technical and infrastructure issues related to biofuels. To meet this goal, the Task objectives are to:

1. Provide information and analyses on policy, markets and implementation issues that help encourage the adoption of sustainable conventional biofuels and help commercialize advanced liquid biofuels as a replacement for fossil-based fuels
2. Catalyse cooperative research and development projects that will help participants develop improved, cost-effective processes for the production of advanced liquid biofuels
3. Provide information dissemination, outreach to stakeholders, and coordination with other related groups

Guiding Principles – IEA Bioenergy

Vision: To accelerate the production and use of environmentally sound, socially accepted and cost-competitive bioenergy on a sustainable basis. To achieve a substantial bioenergy contribution to future global energy demands by thus providing increased security of supply while reducing greenhouse gas emissions from energy use.

Mission: To facilitate the commercialization and market deployment of environmentally sound, socially acceptable, and cost competitive bioenergy systems and technologies, and to advise policy and industrial decision makers accordingly.

Strategy: To provide platforms for international collaboration and information exchange in bioenergy research, development, demonstration, and policy analysis. This includes:

• Development of networks
• Dissemination of information
• Provision of science-based technology analysis
• Involvement of industry in support and advice to policy makers

For more information: http://task39.org/

THOMAS WURZEL, Air Liquide Global E&C, Germany

2nd generation biofuels – the bioliq technology and economic perspectives

bioliq® is one answer to searching for high quality fuels or fuel components produced from sustainable biomass. The problem to be solved is the widely distributed availability of biomass connected to the need for centralized, large scale fuel production plants required by economies of scale. The solution is the de-centralized pre-treatment of biomass to obtain an intermediate energy carrier of high energy density (bioliqSyncrude), which can be transported economically over long distances to supply an industrial plant of reasonable size for synthetic fuel production. Fuels will be produced by chemical synthesis, which can be used as drop-in fuels or as stand-alone products, completely compatible with existing diesel or gasoline type fuels. Nearly any type of dry biomass can be utilized for this process; a focus is set on by-products and residues of agriculture, forestry or landscaping.

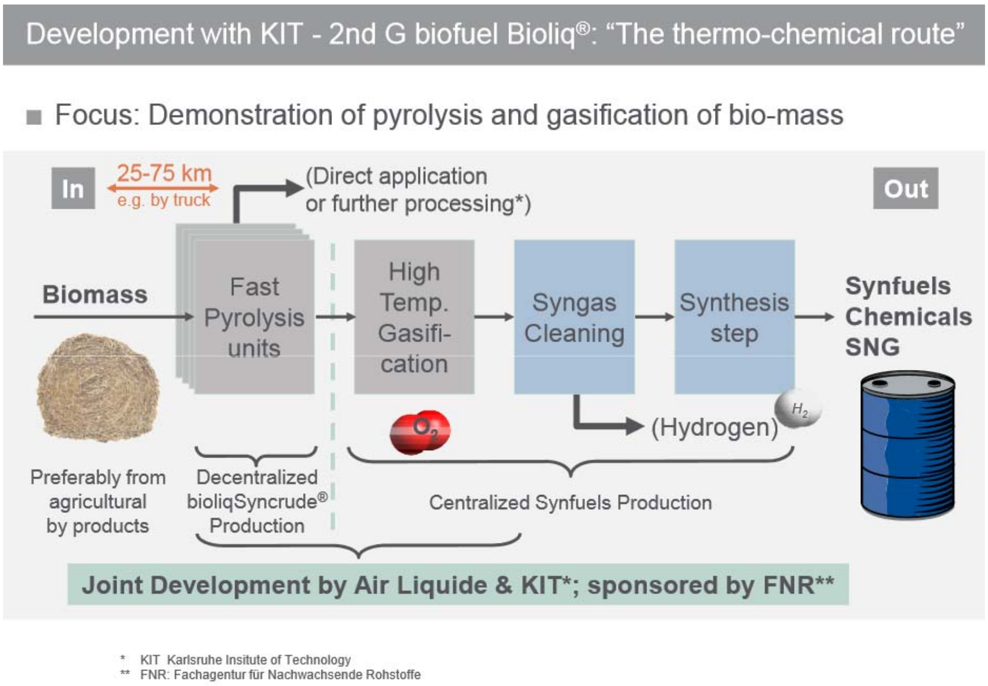

Figure 1: Development of bioliq plant

Bioliq I – Plant information

- **Plant data**
  - Pyrolysis of 500 kg/h of biomass (air dry) at approx. 500 °C via hot sand employed as heat carrier medium
  - Hot sand is heated and circulated via natural/(product gas combustion)
  - Staged condensation of liquid pyrolysis products: Biotar & Aqueous Condensate
  - Feed for bioliq II: bioliqSyncrude® (1 t/h)
  - Suspension of liquid pyrolysis products (Biotar + Aqueous Condensate) + Char
- **Achievements**
  - Routine campaigns to prolong operation and prepare for commercialisation
  - 1600 h of heat carrier loop operation (incl. test operations for heat carrier system only)
  - 290 h of biomass feed → 53 tons of pyrolysis products:
  - 18 tons of Biotar , 20 tons of Aqueous Condensate and 15 tons of Char
- **AIR LIQUIDE R&D Topics**
  - Pyrolysis Product Condensation System - Simulation in Aspen Plus
  - Test trials with different feedstock types, product yield & characteristics
  - Optimization (e. g. heat carrier/biomass ratio, operation parameters) for stable operation together with KIT, Air Liquide R&D and Air Liquide Global E&C Solution
  - Preparation for upscaling

Bioliq II – EF gasification

bioliq®

Plant data:

- Pressurized EF slagging gasifier with full quench
- Temperatures up to 1200 °C
- 5 MW/~ 1,000 kg/h nominal feed 900 kg/h O_2
- Up to 80 bar gasif. pressure
- Production of green syngas for synthesis of biofuels or green chemicals

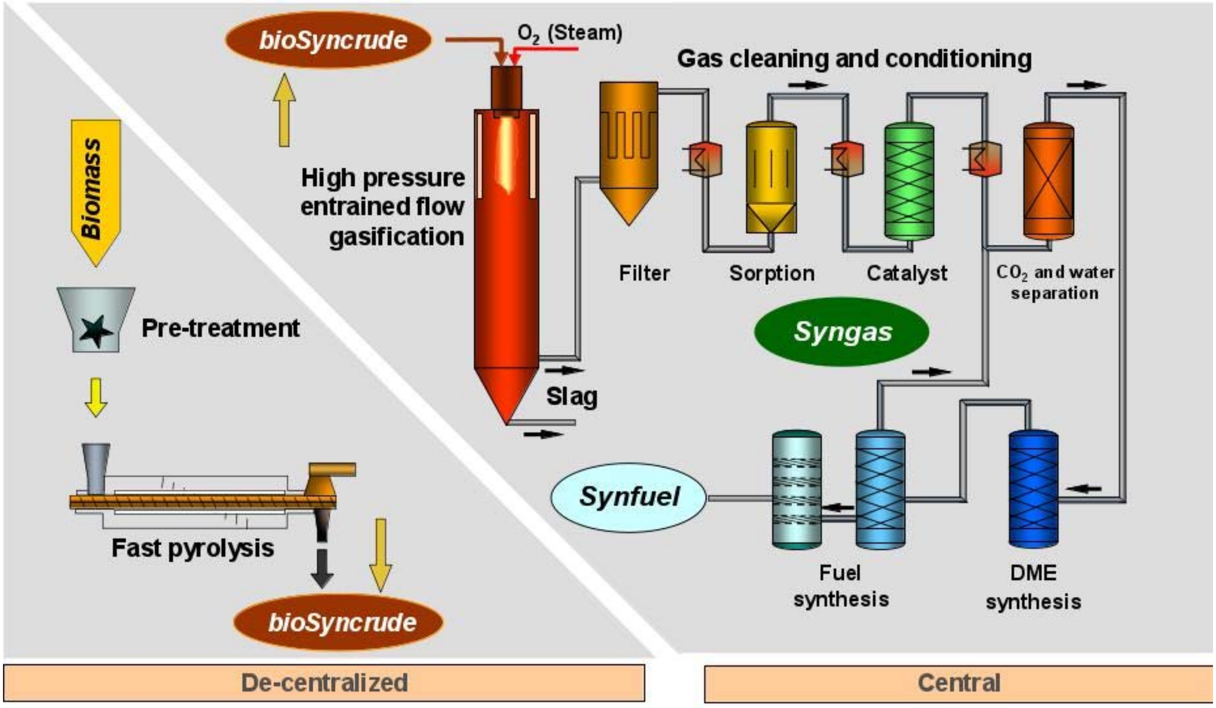

Figure 2: bioliq process

Project data:

- First successfuel gasification wirh liquid feedstock 40 bar October 2012
- Operation with synthetic slurry in 2013 at 80 bar
- Operation with bio-based feedstock in 2014
- Integration with bioliq 3&4 delivering first fuel

Technical challenges:

- Variety of green feed-stock material

Commercial challenges:

- Only a few customers cover the whole scope from feed-stock to product, which also makes it difficult to define the best down-stream product

RIKARD GEBART, Luleå University of Technology, Sweden

Conversion of forest industry by-products to methanol and DME

It has been estimated that residues and by-products from the Swedish forest industry can be converted to approximately 50 TWh/y of synthetic motor fuels. This corresponds to about 50% of the current need for the transport sector in Sweden. As a consequence of this great potential, the government and industry has been supporting research on technologies that can realize this potential for more than a decade. One of the more promising routes is production of methanol or DME via black liquor gasification. Black liquor is a by-product from pulp production and is available in large quantities at pulp mills.

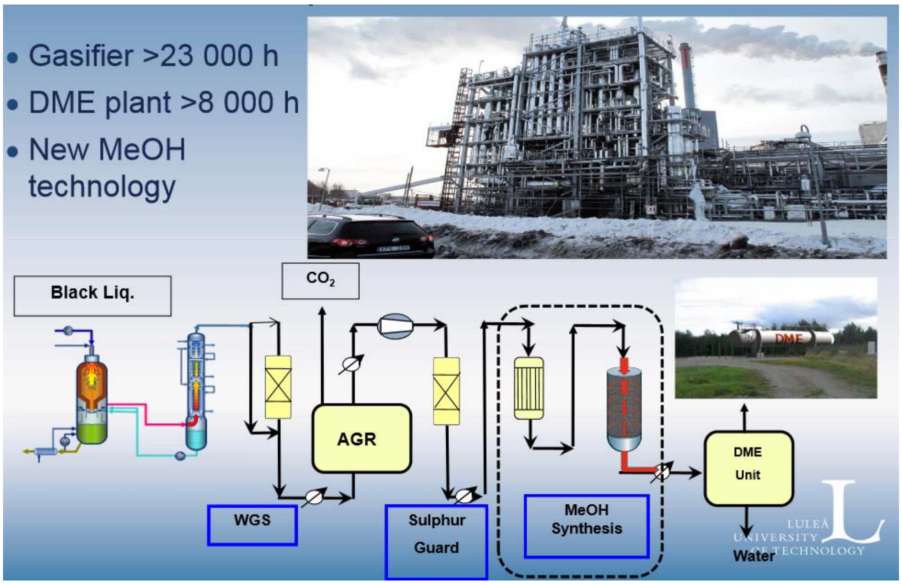

Figure 3: Black liquor to green DME demo

An important part of the research effort has been the construction of a pilot plant for black liquor gasification and synthesis of methanol and DME. The pilot plant comprises of state of the art technology for gasification and methanol synthesis. The methanol synthesis is based on a new invention by Haldor Topsoe; the condensing radial (CONRAD) catalytic reactor achieves almost complete syngas conversion to methanol without recirculation of syngas.

The pilot plant gasifier has been in operation for more than 23,000 hours, out of which more than 8,000 hours was with syngas conversion to methanol; this was converted to DME in a separate step. The DME from the pilot plant has been used for field tests in heavy duty trucks in commercial traffic. The accumulated driving distance of the trucks is more than 1 500 000 km.

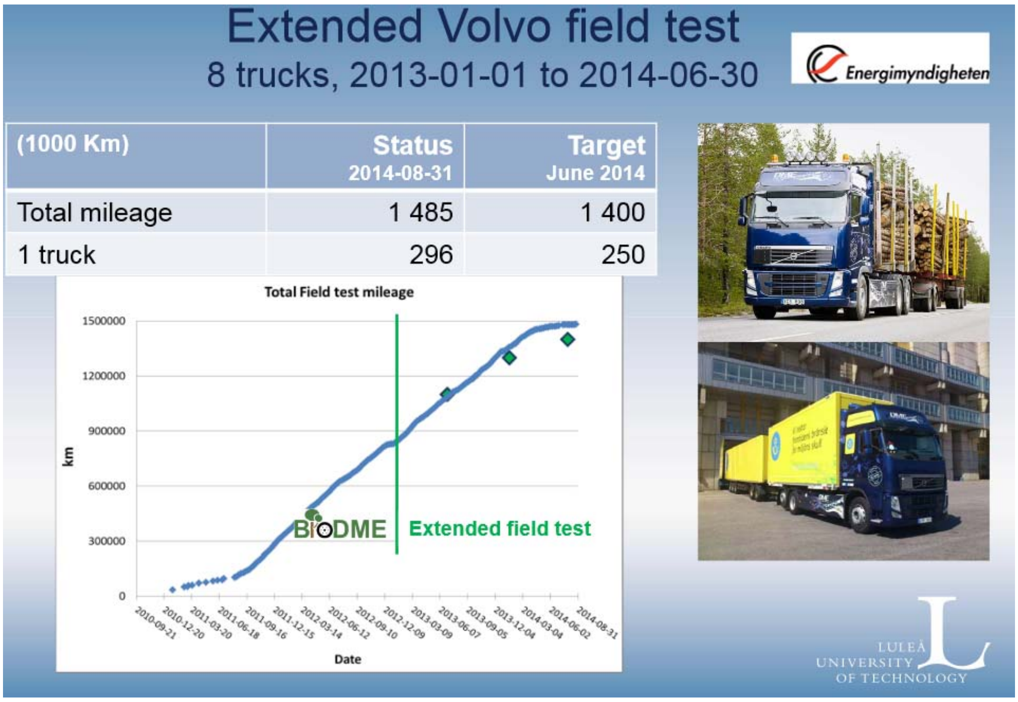

Figure 4: Truck field tests

The pilot plant is also used in an on-going research program with seven sub projects aimed at improving the process and at doing further field tests with methanol and DME in vehicles and industrial processes.

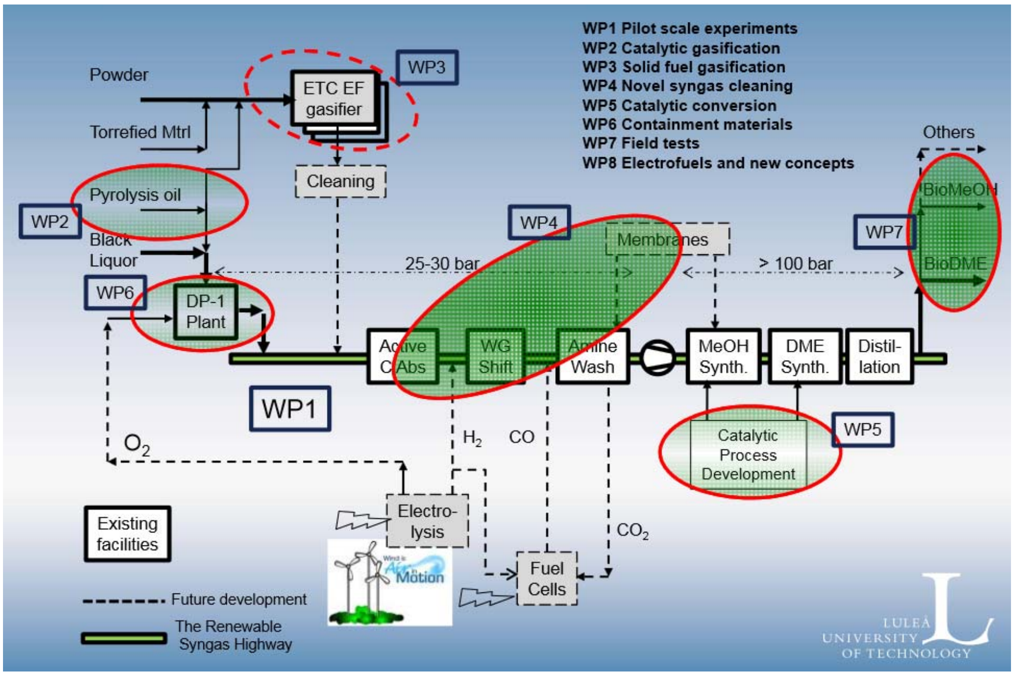

Figure 5: LTU Biosyngas program – phase 2

Conclusions:

- Black liquor gasification + MeOH/DME can be considered a proven technology
- Co-gasification looks promising but needs verification in pilot scale tests before it can be commercialized
- Containment solutions are available but cost reductions are possible
- Gas cleaning and solid biomass gasification are under development
- New methanol synthesis looks very promising

HOLGER KITTELMANN, Linde Engineering Dresden GmbH, Germany

Carbo-V – Biomass gasification technology; Status after application of sound engineering practices

Project background

The Carbo-V technology was operated for a short term but could not be put into stable operation. However, the operation of ~ 1200-2000 hrs. has shown the process principle; mechanical design problems led to repeated shut downs. Furthermore, Choren went into insolvency in July 2011 (Carbo-V® development since the early '90s) and Linde (LEDD) bought Carbo-V® Technology in Q1 2012 because synergies and add on´s for other Linde technologies identified (ASU, Rectisol, CO2, H2, etc.) including all related know how, operation records, trademarks and patents.
Linde (LEDD) established a consolidation project (successfully completed) and as a final step, Linde demonstrated stable operation of Carbo-V technology and its successful integration in biofuel / biochemical production.

Project status

- Carbo-V ® technology is a driver regarding cold gas efficiency, syngas quality and carbon conversion rate compared to other technologies available for woody biomass gasification
- The consolidation confirmed that problems at the demo plant envisaged are not related to the technology and its principles
- The consolidation confirmed that problems at the demo plant are shortcomings in the selection of the right equipment type and consequently, engineering professionalism
- Systematic investigations and tests at universities and with vendors provided appropriate explanations for the problems and found sound solutions for the future design
- Kinetic and fluid dynamic modeling and simulations calibrated with operational results from the previous operating period provide a sound basis for the design modifications undertaken

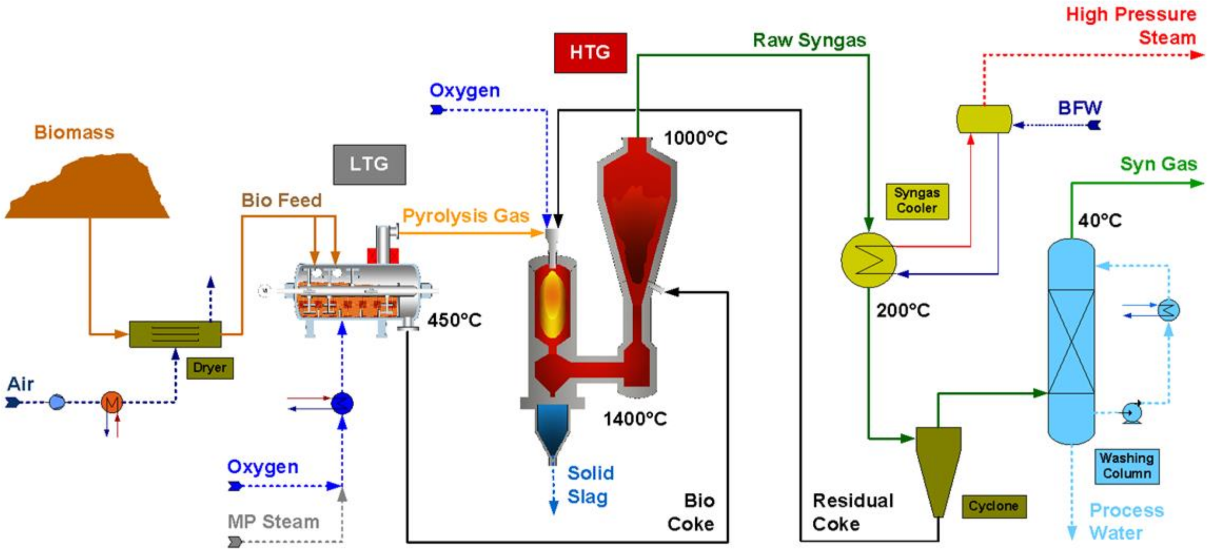

Figure 6: Actual status of Carbo-V process

Technology features – highlights:

- Cold gas efficiency more than 73%
- Tar-free and methane-lean raw syngas → unique feature of Carbo-V technology
- Highest possible carbon conversion rate (> 99.5 % by mass)
- No biomass pretreatment necessary (except drying and chipping)
- Plants with high installed capacity possible (scale up)

Table 2: Syngas quality

Syngas	Vol. %
CO	38…41
CO_2	24…27
H_2	31…33
CH_4	0.1…0.2
N_2	1…2
H_2S/COS	0.01

Technology improvement by Linde (compared to both technology status):

- Simplification and optimization of process
- Reduction in number of equipment items by 1/3
- Fewer mechanical feeding devices
- New main burner
- Self-flowing slag additive and new slag discharge system
- Improved robustness and availability
- Usage of standard equipment as much as possible
- Shifting of critical equipment from main process stream to side streams
- Considerable reduction of mechanical feeding and sluicing devises
- Reasonable buffer volumes
- Reasonable redundancies / easy replacement concepts at critical parts
- Optimization of layout, reductions of plant heights by 30m
- Safety compliant instrumentation concept

MALIN HEDENSKOG , Göteborg Energi, Sweden

GoBiGas project – experiences and operational progress

Facts in short

GoBiGas is the first plant in the world to produce bio-methane from biomass continuously through gasification.

- Uses forest residues as feed stock
- Polygeneration – producing fuel and heat, in future electricity
- The first Swedish plant to inject bio-methane into the national grid for:
  - Vehicle fuel
  - Feedstock to process industry
  - Fuel to CHP or heat production

Commercial scale in two phases:

- 20 MW Demonstration plant, partly financed by the Swedish Energy Agency
- 80 – 100 MW commercial plant, when first phase has been proven successful and acceptable revenues can be met.
- Phase 2, Selected project by the EU-Commission in NER300

GoBiGas project – Milestones

- Pre-studies gasification and methanation for bio-methane production in 2005
- Ambition to build a large 100 MW plant⇔ 100,000 vehicles
- Decision to split the project into two phases, a demonstration plant to be followed by a commercial plant
- Awarded funding from the Swedish Energy Agency Sep 25, 2009
- Board decision to implement Dec 16, 2010
- Contract award gasification (Valmet/ Repotec)
- Contract award methanation technology (Haldor Topsoe)
- Contract award methanation and utility (Jacobs as EPCM)
- Mechanically complete Dec 2013
- First gasification Nov 13, 2013

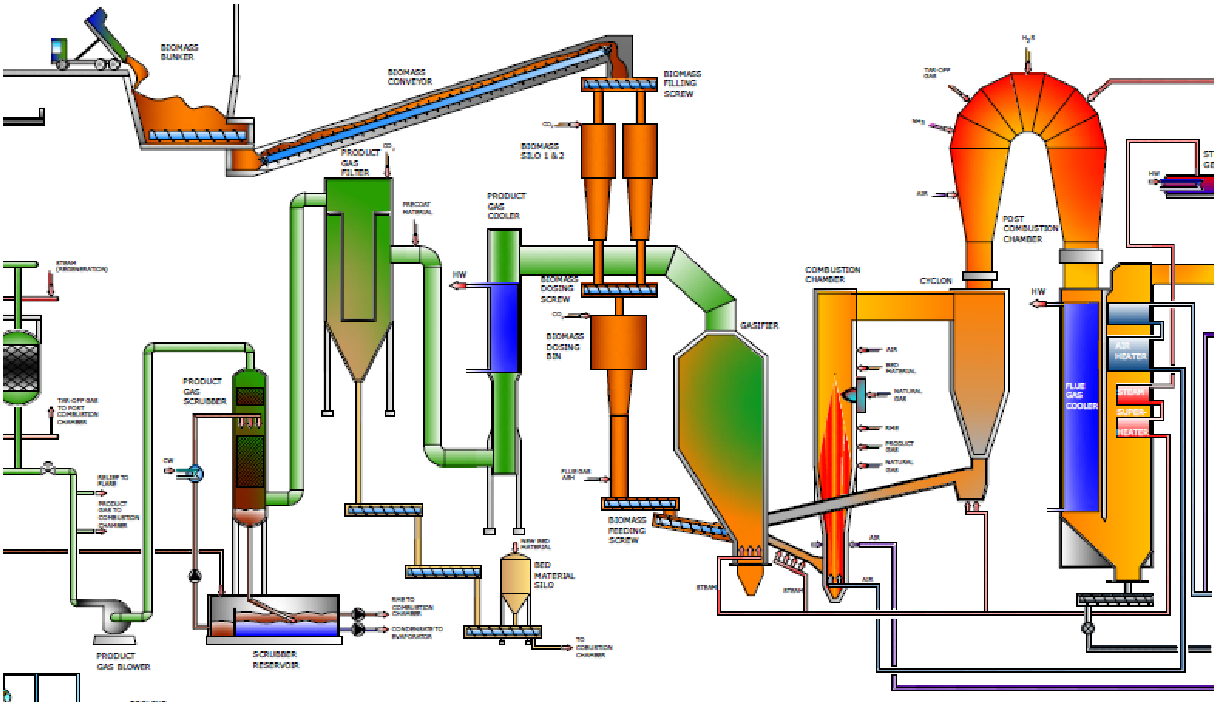

Figure 7: GoBiGas project – gasification part

Gasification experiences:

Part I

- First gasification Nov 13 2013
- Operating hours total: April 2014 ~200 hr
- Cleaning of product gas cooler
- Refractory repair
- Malfunction of RME-scrubber
- Pressure fluctuations
- Reprogramming of sequences (fuel, ash etc)

Part II

- Operating hours total: October 2014 ~1200 hr
- Gasification and gas composition (i.e. less tars) improved by adding alkali due to lack of ash components in pellets
- Fuel feeding – measurements ongoing and will be evaluated during autumn
- Increased design pressure in product gas system

- Activated carbon beds and gas compressor have been taken into operation

Project status in May 2014:

- Organization for operation and maintenance have been in place for one year
- Commissioning of gasification and methanation on-going
- Totally 1200 hours of gasification
- ***Schedule***
  - Gas to grid during Q4 2014

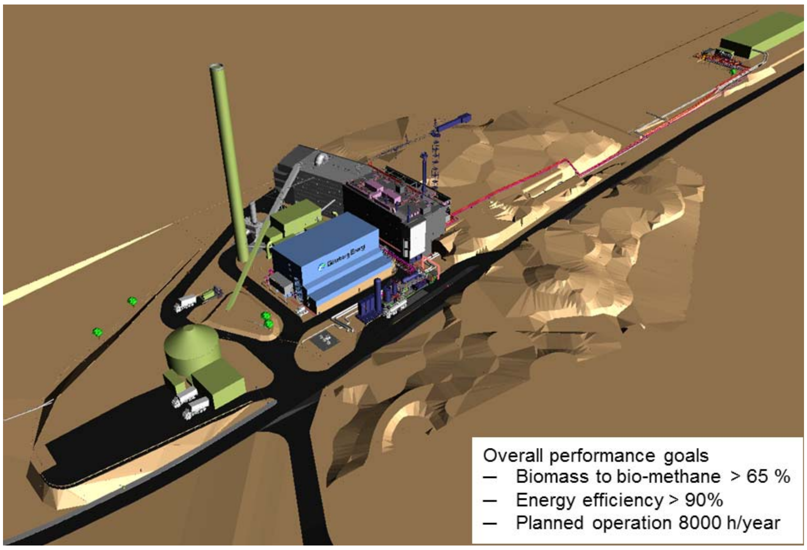

Figure 8: GoBiGas project

Basic data

Production:

- Bio-methane 20 MW
- 160 GWh/ yr ⇔ 16 MNm3/ yr
- District Heating 50 GWh/yr

Consumption:

- Fuel 32 MW
- Electricity 3 MW
- RME (bio-oil) 0,5 MW

RALF ABRAHAM, NORBERT ULLRICH, UHDE GmbH, Germany

An update on the BioTfueL project and other activities of TKIS*-PT in the area of biomass gasification

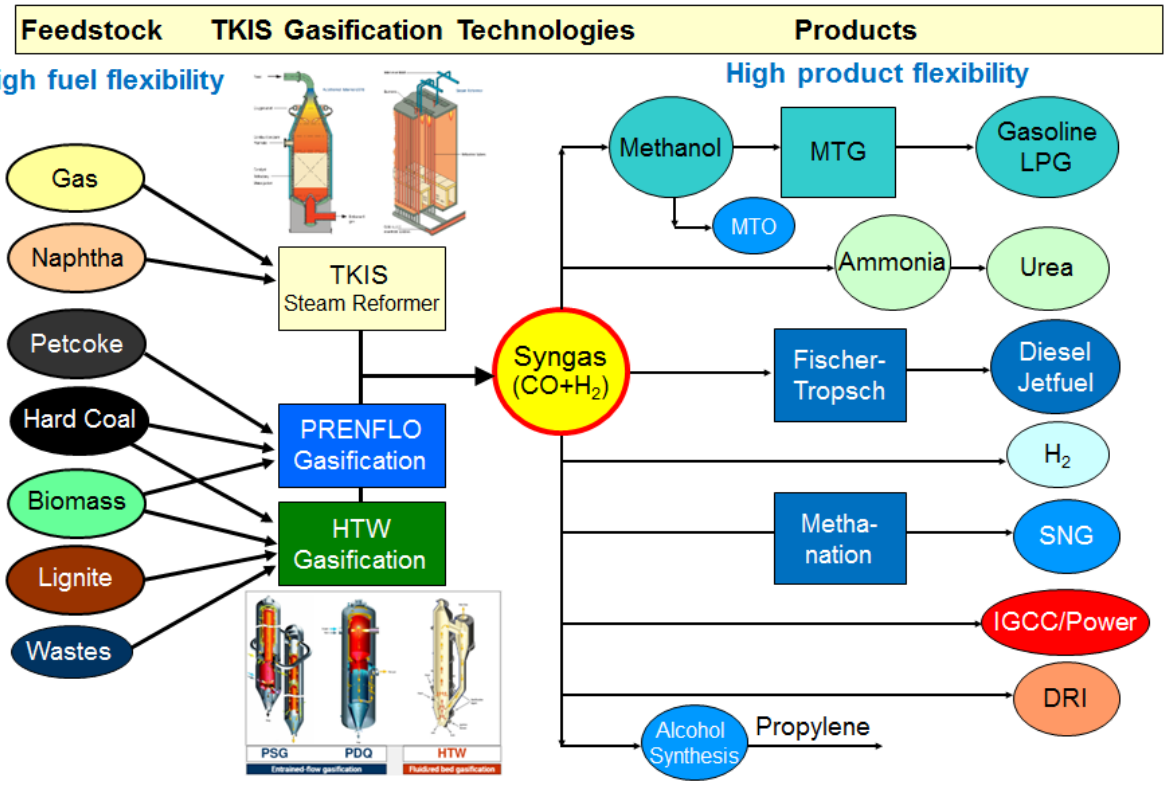

Figure 9: TKIS fuel and product flexibility for syngas product routes

*TKIS = ThyssenKrupp Industrial Solutions

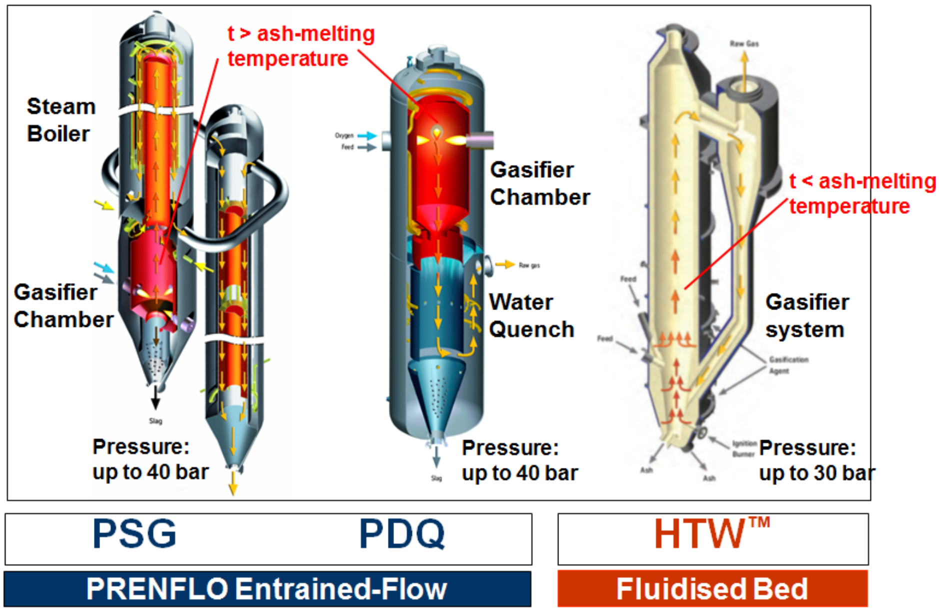

Figure 10: TKIS Proprietary gasification technologies

The PRENFLO Direct Quench (PDQ) process is an optimized design of Uhde's PRENFLO PSG gasification process (steam generation) for chemical applications (e.g. ammonia, methanol, hydrogen, synthetic fuel) and IGCC plants with Carbon Capture and Storage (CCS), where hydrogen-rich syngases are required. It combines the technologically advanced dry feed system, multiple burners and membrane wall of the PRENFLO PSG process with a proprietary water quench system which saturates the raw syngas with water for subsequent gas treatment.

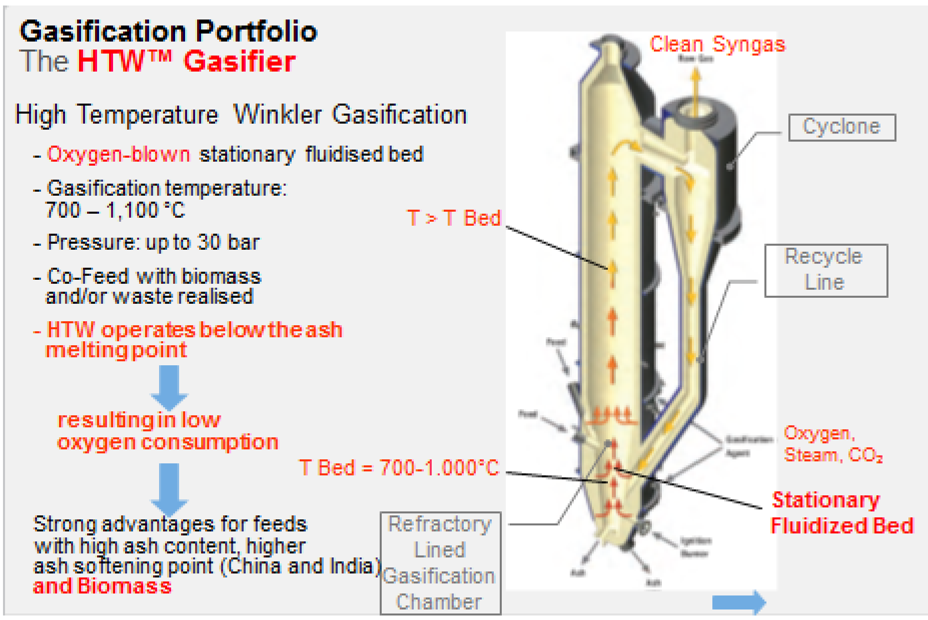

Figure 11: HTW Gasifier

The fluidized-bed gasification process was developed in the 1920's in Germany by Fritz Winkler. Commercial-scale Winkler gasifiers were operated in over 40 applications around the world. In the

1970's, ThyssenKrupp Uhde together with Rheinische Braunkohlen - werke AG commenced with the development of a pressurised version of the Winkler gasifier – the High-Temperature Winkler (HTW) gasification process. The HTW process enables shorter residence time, higher reaction velocity, and higher reactor throughput for larger plant capacity, higher carbon conversion rate, higher plant efficiency and improved syngas quality.

In 1978, the HTW pilot plant started-up in Frechen, Germany, with a pressure of 10 bar. The operating experience gained therein laid the foundation for the design and construction of the HTW commercial-scale plant at Berrenrath, which started-up in 1986 to convert Rhenish brown coal into methanol.

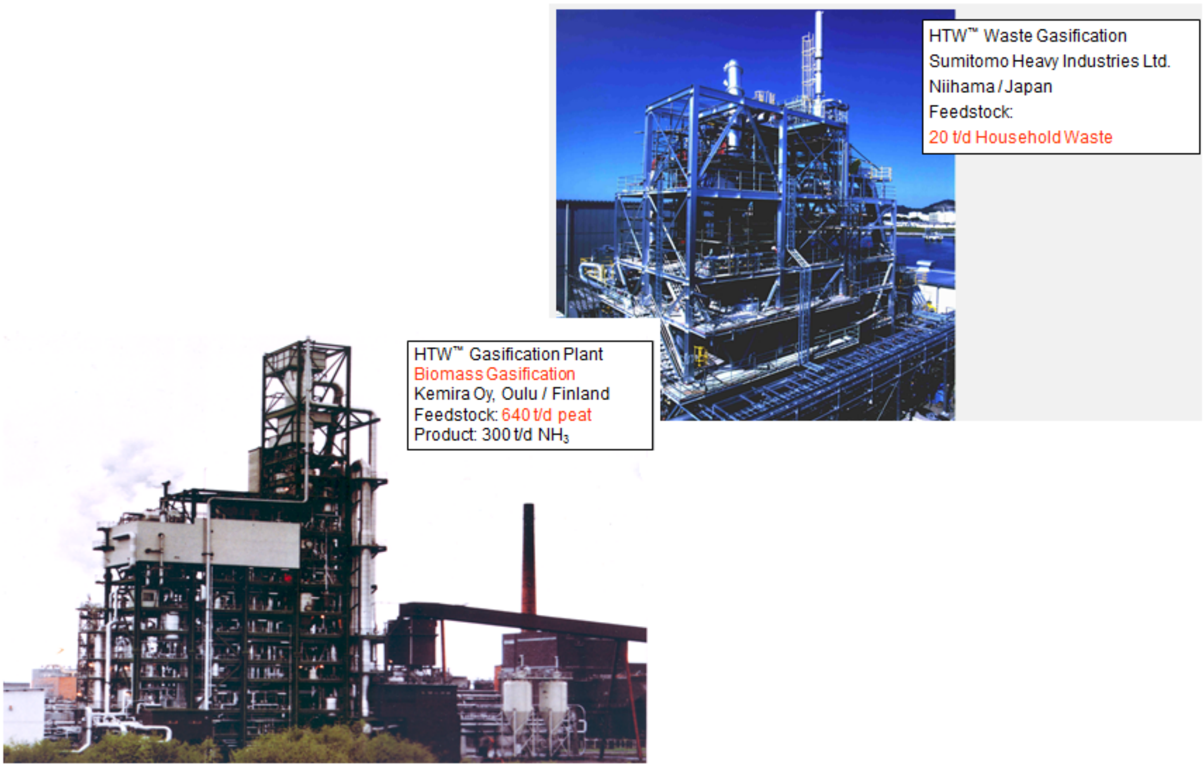

Figure 12: HTW Gasification plants in Japan and Finland

HTW Demoplant in Darmstadt

The test plant already exists (former Test-Gasifier from Foster Wheeler, Sweden) and it is installed in Darmstadt (for Carbonate and Chemical Looping). Existing fluidized bed gasifier will be converted to HTW gasifier (stationary fluidized bed) with capacity of 100-200 kg/h (500 kW to 1 MW_{th}) by atm. Pressure. Scheduled Start up is Q1 2015.

The plant will be used by TKIS for gasification tests of different feed materials and different customers:

- Different types of biomass
- High ash brown coal
- Reactive hard coals with high ash melting point

The B-XTL BioTfuel – Project

BioTfueL is integrating the various technology stages of the biomass-to-liquid process with the intention of commercialization. The completely integrated industrial process chain will enable various biomasses and fossil resources, in both liquid and solid form, to be applied to produce high-quality biofuels.

This flexibility of the resulting process chain is intended to allow a high level of efficiency in optimizing a continuous fuel supply to industrial plants, particularly with regard to economic and logistical parameters. The process will include the drying and crushing of the biomass, torrefaction, gasification, purification of the synthesis gas and its ultimate conversion to second generation biofuels using Fischer-Tropsch synthesis.

The BioTfuel project partners—Total, IFP, the French Atomic Energy Board, and Sofiproteol—selected the PRENFLO process on the basis of its flexibility in processing a wide variety of biomasses and other resources. It allows high energy efficiency and enables very pure synthesis gas to be produced. A torrefaction pre-treatment plant, which facilitates the application of biomass in the PRENFLO-PDQ entrained-flow gasifier, and ensures lowest possible energy consumption, is installed to allow the use of a wide range of biomasses.

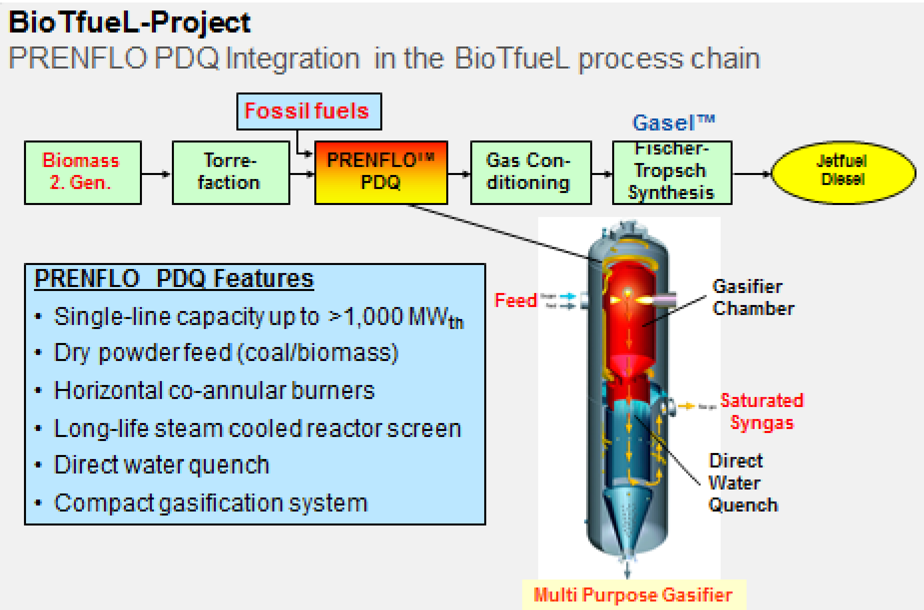

Figure 13: Prenflo PDQ integration in the BioTfuel process chain

The PRENFLO Direct Quench (PDQ) process is an optimized design of Uhde's PRENFLO PSG gasification process (steam generation) for chemical applications (e.g. ammonia, methanol, hydrogen, synthetic fuel) and IGCC plants with Carbon Capture and Storage (CCS), where hydrogen-rich syngases are required. It combines the technologically advanced dry feed system, multiple burners and membrane wall of the PRENFLO PSG process with a proprietary water quench system which saturates the raw syngas with water for subsequent gas treatment.

The PRENFLO process is currently being used successfully in Puertollano, Spain where the world's largest combined cycle power station with integrated coal gasification is in operation using petrol coke, coal and biomass as charge materials. Uhde's PRENFLO process is based on the Koppers-Totzek coal gasification process which was developed around 70 years ago.

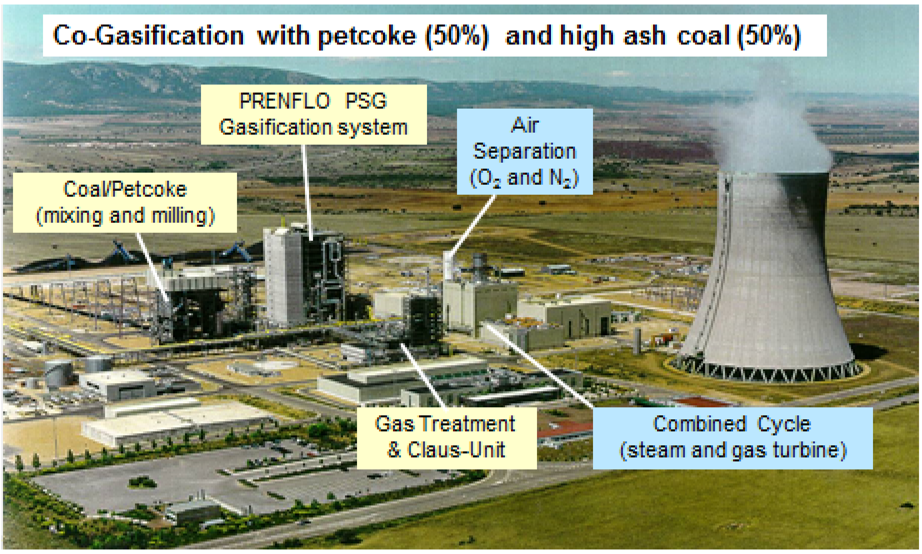

Figure 14: World largest single-train IGCC (300 MWel), Elcogas IGCC Power plant, Puertollano

Summary - ThyssenKrupp Industrial Solutions

- has more than 70 years of experience in gasification
- can offer different gasification technologies for Liquid Biofuels Solutions
- is a technology provider and EPC contractor
- One Megatrend is feedstock flexibility specially with green fuels
- Co-generation of different feedstock will be one key for the future
- The BioTfueL demonstration project objectives are to develop, demonstrate and commercialize a full B-XTL chain for the production of biodiesel and bio kerosene

JOHN BØGILD HANSEN, Haldor Topsøe, Denmark

Haldor Topsøes biobased sustainable fuel production technologies

Haldor Topsøe – basic data

- Founded in 1940 by Dr. Haldor Topsøe
- Revenue: 600 million Euros
- 2900 employees
- Headquarters in Denmark
- Catalyst manufacture in Denmark and the USA

Tar reforming – enabling technology for biomass gasification
Gasification of biomass results in a syngas that contains tars and contaminants

- 1000 -2500 ppm tar
- 50 – 100 ppm S, particulates
- 850-930°C, 1-30 bar g
- Ammonia decomposition

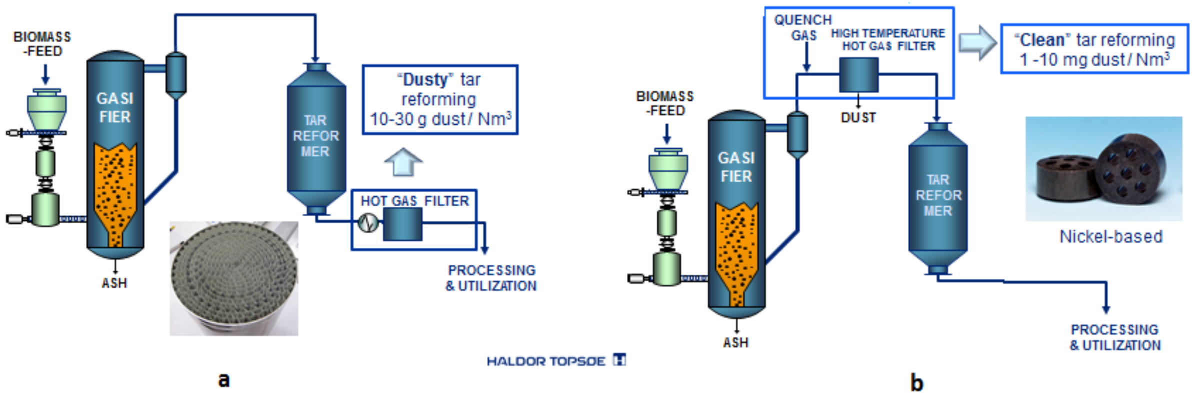

Figure 15: Dusty (a) and clean (b) tar reforming

Dusty tar reforming is now commercially proven; clean tar reforming has been demonstrated in connection with successful meOH/DME and gasoline synthesis at 25 bbl/day.

TIGAS - Topsøe Integrated Gasoline Synthesis

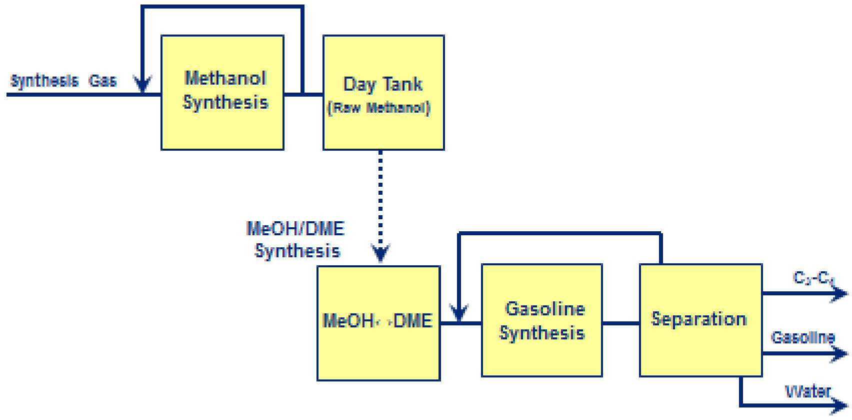

Figure 16: Topsøe Integrated Gasoline Synthesis

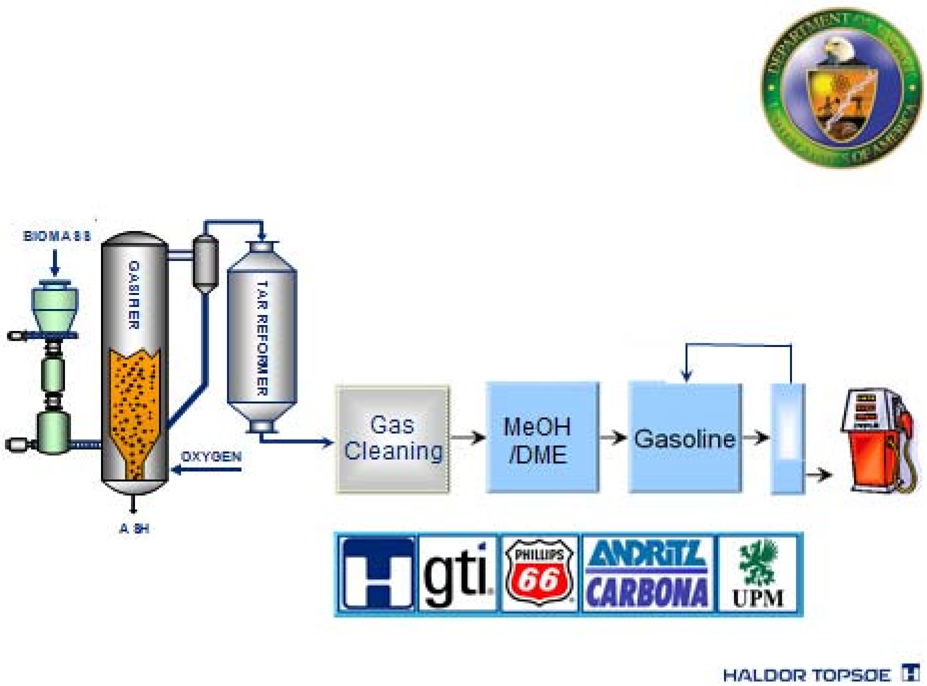

Figure 17: 25 bbl/d Demonstration plant

In a recently completed project, Gas Technology Institute (GTI) worked with Haldor Topsøe, Inc. on an integrated biorefinery to make renewable "drop-in" gasoline. The use of renewable gasoline could reduce lifecycle greenhouse gas emissions by approximately 92% when compared to conventional gasoline.

The basic principle in the TIGAS process is the integration of methanol/dimethylether synthesis and the subsequent conversion into gasoline in a single synthesis loop. As the methanol/DME synthesis is very flexible, a variety of synthesis gas compositions may be applied.

The TIGAS process offers a number of benefits, including the elimination of the intermediate production and storage of methanol; the integration of the methanol reaction to form DME immediately; improved conversion efficiency, which reduces steam consumption; and the potential for CO_2 removal.

Topsøe's TIGAS process is based on in-house research and development of process and catalysts.

Fuel cell and electrolyser

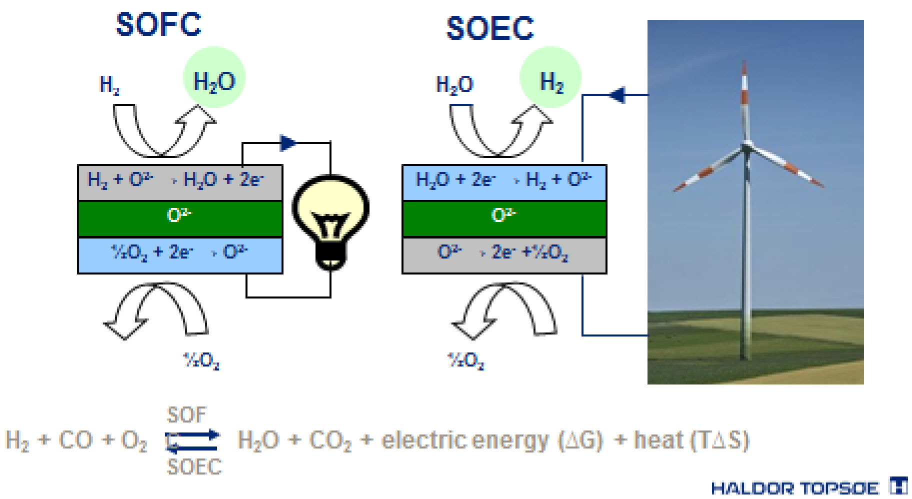

Figure 18: Fuel cell and electrolyser

Coupling SOEC with biomass gasification can double the biomass potential by converting excess carbon.

New EUDP project – 40 kW SOEC and 10 Nm^3/h methane
Participants:

- Haldor Topsøe A/S
- Aarhus University
- HMN Naturgas
- Naturgas Fyn
- EnergiMidt
- Xergi
- DGC
- PlanEnergi
- Ea Energianalyse
- Cemtec

JÖRG SAUER, KIT - Institut fuer Katalyseforschung und -technologie (IKFT), Germany

Modified MtG-processes for BtL and Power-to-Fuels

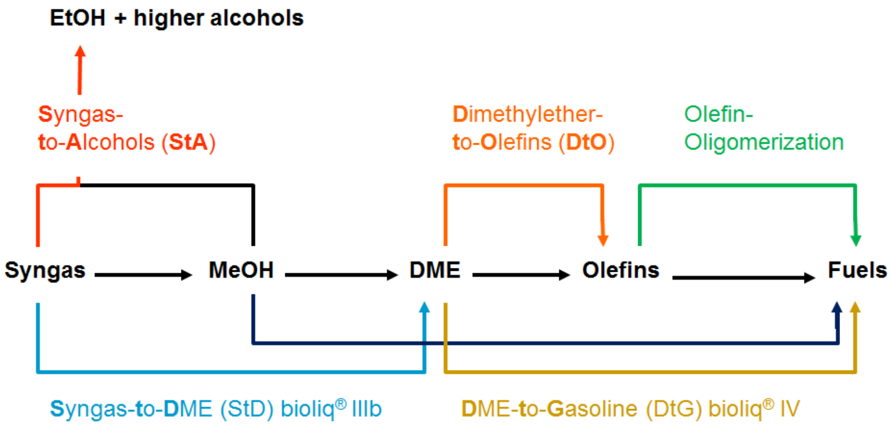

Figure 19: Many options of MtG (methanol-to-gasoline process)

Catalysts:

- $CO/CO_2/H_2$ to Methanol:
  - Copper-Catalysts:
    - $Cu/ZnO/Al_2O_3$
- Methanol to DME:
  - Acidic Oxides:
    - Al_2O_3
    - Zeolithes
- DME to Olefins, DME to Gasoline, Olefin Oligomerization:
  - Zeolites (ZSM5)

Reasons for Modifications to MtG:

- Different feedstocks for syngas
- Different syngas qualities
- Demands for new or different products
- Scale of implementation

Examples:

- Direct DME-Synthesis
- Modified ZSM-5 Catalysts for Gasoline Stage
- New Fuels from Methanol / DME
- Homogeneous Catalysis to Methanol / DME

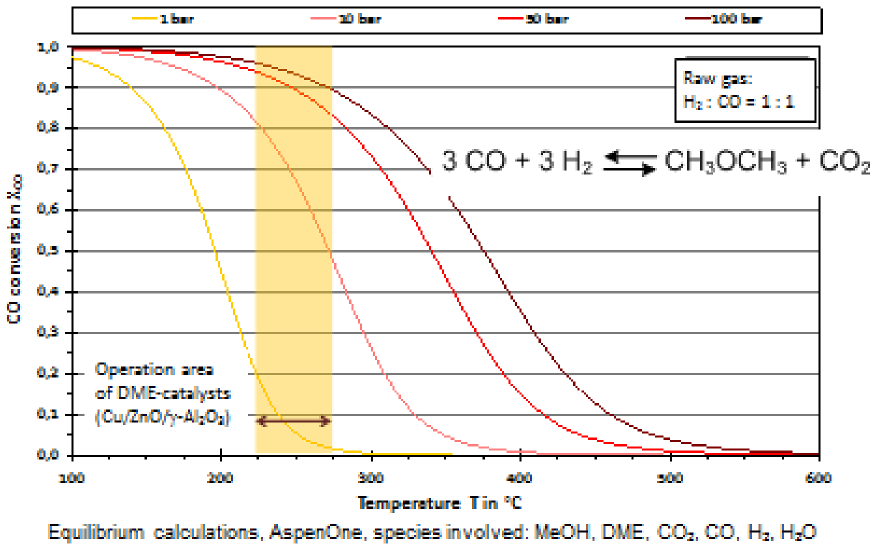

Figure 20: One step DME synthesis with bi-functional catalyst

Gasoline from DME

Compared to the MtG process, the DtG process (dimethyl ether to gasoline) offers advantages in terms of heat of reaction, reactor design and process conditions. The reaction typically occurs on zeolites of the H-ZSM-5 type, producing hydrocarbons up to C_{10} units.

Hierarchic structures (micro- and meso-porores) change diffusion properties in zeolites and consequently product selectivity in catalysis.

KIT provides systematic investigations of zeolite materials and their modification as well as studies on lab-scale fuel synthesis and dependency of catalyst suitability by structural parameters and long-term experiments, coking and regeneration studies.

KIT – conclusions:

- The availability of cheap natural gas and an overcapacity for methanol in China drives investments and R&D for new MtG-technologies
- The German “Energiewende” may pave the way for DME, Gasoline or other liquids from “synthetic syngas” (H_2+CO_2)
- New catalysts for the “gasoline stage” give the opportunity to increased selectivity and increased time-on-stream and subsequently increased availability
- Homogeneous Catalysis offers a potential for to overcome the present limitation by the thermodynamic equilibrium
- OMEs may be a new option for clean and efficient diesel fuels from methanol

THOMAS BÜLTER , EVONIK Industries AG, Germany

Speciality chemicals from syngas fermentation

Evonik is one of the world's leading specialty chemicals companies and a leading manufacturer of biobased polyaminde PA 12.

This new process is using palm kernel oil as raw material; compared to other chemical route fewer production steps are needed. The key step utilizes an E.coli strain in a fermenter (two phase fermentation). The pilot plant started up in 2013.

Syngas fermentation is 3rd generation technology

Generation	Raw material	Biotechnology
1st gen	Plant oils Wheat Corn Sugar	Direct fermentation
2nd gen	Biomass residues from agriculture and forestry	Lignocellulose hydrolysis Integrated fermentation
3rd gen	Municipal waste Plant residues Industrial waste gases	Syngas fermentation

Figure 21: Syngas fermentation

Syngas (CO, CO_2, H_2) is broadly and easily accessible. The pathways of utilisation of $H_2/CO_2/CO$ are shown in the following figure.

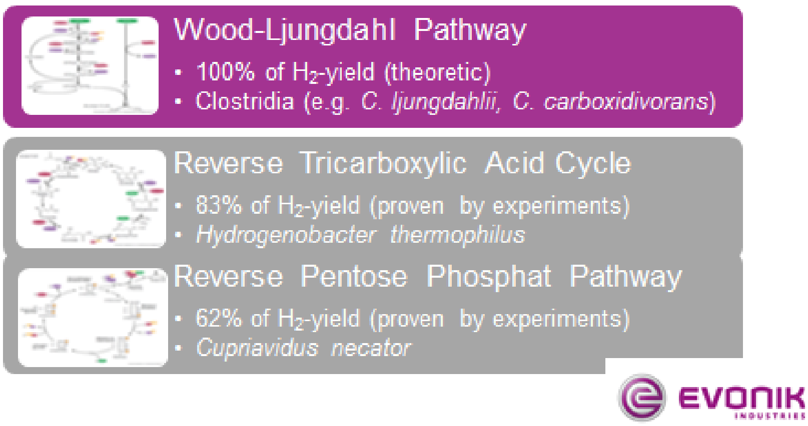

Figure 22: Pathways of utilisation of $H_2/CO_2/CO$

Syngas digesting microorganism synthesing chemicals of interest:

Homoacetogenic Bacteria (*Clostridium ljungdahlii, C. carboxidivorans*)

Advantage:

- Acetate/EtOH-Processes already established (Lanzatech et al.)
- Wood-Ljungdahl Pathway, 100% of H_2-yield (theoretic)

Disadvantage:

- Difficult to delete by-product producing pathways
- Thermodynamic limitations in the cell (acetate as by-product?)
- So far only low value products shown

Hydrogen-Oxidizing Bacteria (e.g. *Cupriavidus necator*)

Advantage:

- GMOs are state of the art
- High C-yield
- High value products shown

Disadvantage:

- Low hydrogen yield

Summary – EVONIK

- Biochemicals from syngas use alternative raw materials significantly increasing feedstock flexibility
- Syngas fermentation opens a new access to speciality chemicals but has some thermodynamic and genetic limitations
- Syngas fermentation provides an attractive approach to invest close to the customers with a very competitive cost position

PETER PFEIFFER , KIT – Institut für Mikroverfahrenstechnik (IMVT),Germany

Technology for Fischer-Tropsch synthesis of liquid fuel in small scale

Since crude oil is getting more expensive, biomass and biogas are getting more attention for fuel and chemicals production. Since the total gas output from biomass gasification and biogas plants is usually low due to high biomass transportation costs, a scale down of conventional technology may not be favourable in terms of efficiency, modularity and size requirements.

Microchannel reactors have been proven to enable near-isothermal operation of the highly exothermic Fischer-Tropsch reaction without catalyst dilution in a packed bed type arrangement.

The contribution addressed the degree of process intensification on the reactor level as well as the potential for process integration and simplification in Fischer-Tropsch synthesis by the use of microchannel systems. On the reactor level, it has been identified that the heat transfer potential of the catalyst bed in microchannel size is still dependent on the catalyst bed height, and the formation of gaseous by-products is increased by higher active site temperature.

Despite the fact that smaller microchannels somehow outperform larger microchannels, the overall reactor productivity can always be enhanced by a factor of 2. This is already valid when comparing microchannel reactors with the production capacity of some barrels per day (2-6 bpd) versus large plants like Oryx GtL (24.000 bpd). Main reason for this advantage is less mass transfer limitation and / or less catalyst dilution.

Based on these improvements, KIT is aiming at further improving the cost competitiveness of small scale installations for decentralized applications (biogas, biomass as well as electricity storage options by power-to-fuel options) by reduction of plant complexity via process integration, e.g. combinations of synthesis and hydrocracking in one reactor. Container plants are a further basis for commercializing the technology via a spin-off company.

Summary

The synthetic bio fuels produced from biomass are fully compatible to the already existing, conventional fuels and can be used as a drop-in, but also as stand-alone products. The quality of the high performance fuels or fuel components should improve the combustion properties and emissions significantly.

The workshop offered a very good overview and important information on liquid biofuels from biomass; a large attendance of the workshop has shown that this topic is very present and has a great chance for the future.

All the presentations can be found at the Task 33 website. (www.ieatask 33.org)