IEA Bioenergy, Task 33 – Gasification of Biomass and Waste

Workshop

Small scale gasification for CHP

03. May 2017, Innsbruck, Austria

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and

Prof. Kevin Whitty, University of Utah

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Introduction

The security of supply and climate change issues and the recent growth of the local power generation by means of renewable energies technologies are providing real opportunities for the development of small scale biomass gasification systems, which provide a competitive way to convert diverse, highly distributed and low-value lignocellulosic biomass to syngas for combined heat and power generation.

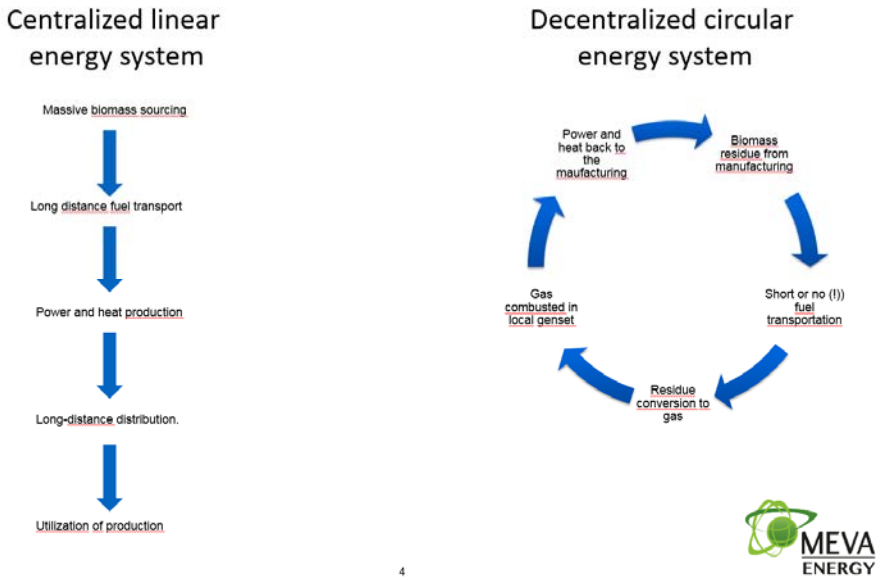

Figure 1: Comparison of centralized and decentralized energy systems (by Meva Energy)

Nowadays, there are many suppliers of small scale gasification facilities and hundreds of units sold to satisfied customers, which shows that this gasification technology is proved and provides a great potential for the future.

Small scale gasification for CHP

workshop presentations

Session I

Small scale gasification for CHP production – experience reports

Status quo from biomass gasification CHP-plant systems in Germany

Bernhard Böcker-Riese, FEE, BR Energy Group AG

At the beginning of the presentation the working group 'Biomass Gasification' from the renewable energy organization 'Fördergesellschaft Erneuerbare Energien e.V.' (FEE) was introduced, following by a manufacturer survey on small scale gasification and CHP. A list of manufacturers active as of 31.12.2016 is shown in the following table.

Table 1: Manufacturers of small scale gasification plants in Germany and abroad (FEE members shown in red)

A.H.T. Pyrogas Vertriebs GmbH	Mothermilk GmbH
Bauer Holzenergie GmbH & Co. KG	Nexterra
Bernd Joos	Pyrox Italia Srl
Blue Tower GmbH	Qalovis Farmer Automatic
BR Energy Group AG	Energy GmbH
Burkhardt GmbH	ReGaWatt GmbH
Christof Holding AG	REPOTEC GmbH
Entrade Energiesysteme AG	Revogas in Burgeis IT
EQTEC	Spanner Re2 GmbH
Ettenberger GmbH & Co. KG / Biotech GmbH	Stadtwerke Rosenheim GmbH & Co. KG
Fröling Heizkessel- und Behälterbau Ges.m.b.H.	SynCraft GmbH
GLOCK Ökoenergie GmbH	URBAS-Maschinenfabrik GmbH
Gräbner Hans – Behälter- und Apparatebau Holzgasanlagen	Volter Oy
Hargassner GmbH	GTS Syngas
Holzenergie Wegscheid GmbH	Xyloenergy GmbH
Kohlbach Holding GmbH	Xylogas / EAF Energieanlagenforschung GmbH
Kopf Syngas GmbH & Co. KG	
Ligento Green Power GmbH	
LiPRO Energy GmbH & Co. KG	
Maschinen- und Anlagenbau Werner GmbH, KWS Strohmenger	

As can be seen in the following figure the **Burkhardt GmbH** has the most total installed capacity. This company produces gasification facilities with el. output of 50, 165 or 180 kW and thermal output 100, 260 and 270 kW. Pellets are used as a feedstock and electrical efficiency is about 30%. The trend nowadays by Burkhardt is serial production, assembling of ascending moving bed co-current flow gas generators and wood gasification CHP plants. Recently the Burkhardt systems are available with 50 kWel output and dual fuel engines have been replaced by otto engines lately.

Status by end 2016: 171 plants in customer hands (information based on current state and contracts)

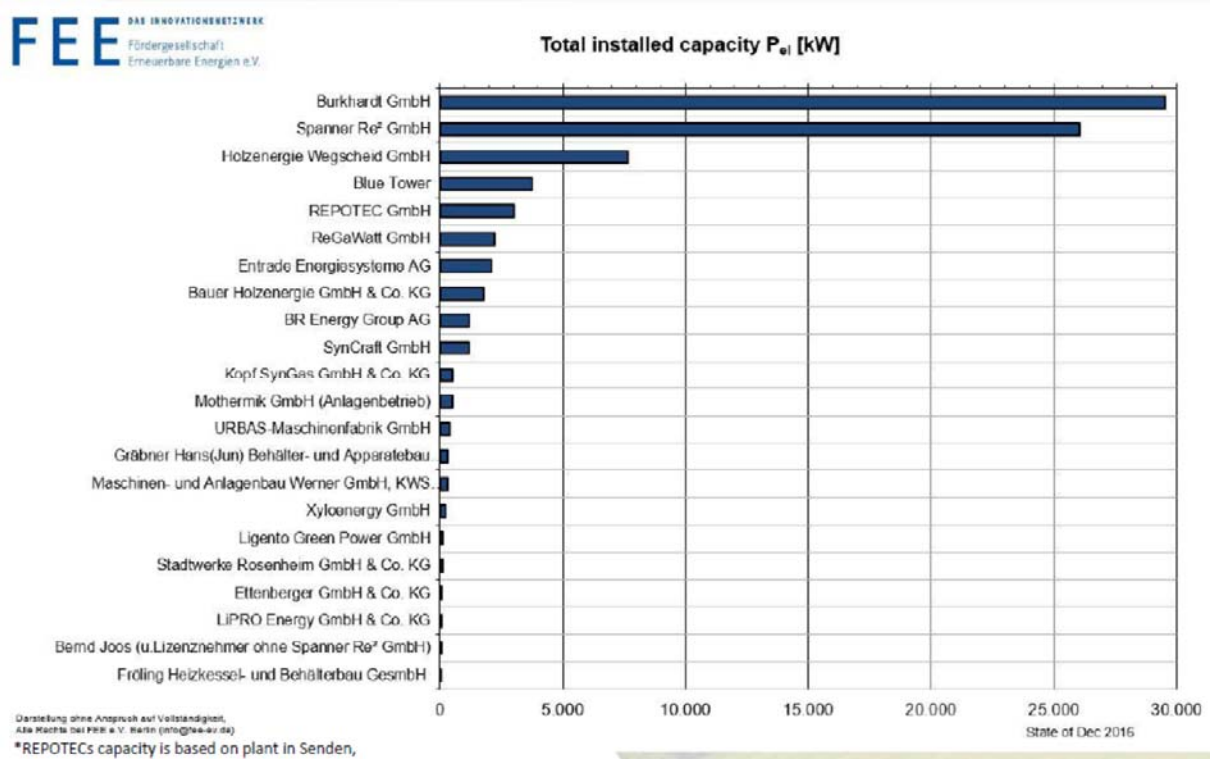

Figure 2: Total installed capacity by the manufacturers

The **Spanner** CHP plants with descending co-current flow in fixed bed and dry gas cleaning with el. output between 9-45 kW and thermal output 25-108 kW are fueled with wood chips. The electrical efficiency is 23-25%.

Status by end 2016: 623 plants in customer hands
Latest news: off-grid installation with battery has been successfully tested.

Holz Energie Wegscheid gasifiers are based on fixed bed co-current flow. They are produced with the output of 65, 125 and 140 kWel. and 110, 230 and 260 kWth. At the moment there are 107 plants in customer hands.

Regawatt gasifier is based on descending fixed bed in counter flow + combustion chamber+ optional electricity generation by hot gas turbines. Output: until 2450 kWel and 4300 kWth.
Now even available as a counter-current flow system, gas cleaning and gas engine
Status end 2016: Gas generators in 4 locations in customer hands, with 4 site-specific gas uses

Lipro Energy uses challenging fuels as a feedstock in the small-scale power range < 50kWel.

Operating experience small scale gasification - CHP

Peter Urbas, Urbas

A short overview on Urbas Maschinenfabrik GmbH was given. The company was founded in 1929 and it is active in areas of:

- energy technology
- steel construction
- hydroelectric

Biomass boilers produced by URBAS have output between 0,5 and 25 MWth.

Urbas gasification facilities are based on the concept of modular construction. The construction steps of modular URBAS gasification facilities can be seen in the following figure.

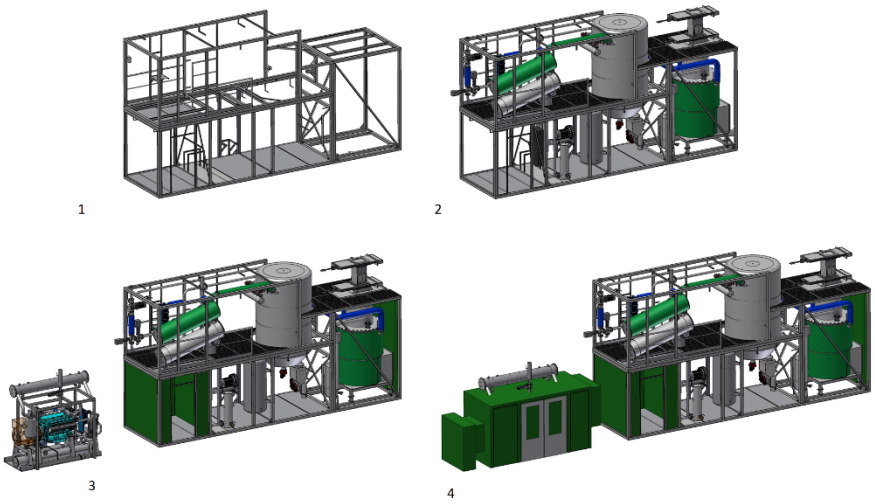

Figure 3: Urbas modular systems

The biomass fuel (wood chips) is essential for long term functionality and efficiency of the gasifier CHP.

Wood chips specifications:	Forest woodchip.:	100%
	Sapwood.:	< 30%
	Bark:	< 10%
	Moisture Content.:	5 < w < 18 %
	Heating Value.: 4,2–4,8kWh/kg	

Important points for long-term continuous operation are:

- Proven technology
- Site-specific installation
- Suitable biomass
- Good maintenance
- Good cooperation between customer and supplier

Small scale CHP with MEVA entrained flow gasification

Niclas Davidsson, MEVA

Meva´s gasification technology is based on entrained flow cyclone gasification. It was developed to utilize pulverized biomass fuels, such as wood dust, straw, rice husks, bark.

Standard plant output dimensions are 1.2 MWe and 2.4 MWth (CHP) or 3,5 Mwgas (gas application).

One commercial plant for local district heating/power production has been sold to the local Swedish utility Pitea Energi.

MEVA works closely on development and market cooperation with global engine and generator (genset) manufacturer Cummins Inc.

Two applications:

- Decentralized renewable CHP
- Decentralized renewable gas production

The driver is a shift from centralized to decentralized power and heat. The following table offers a comparison between these two types of plants.

Table 2: Comparison of centralized and decentralized power plants

Power plant type	Centralized	Decentralized
Plant size	> 10 MWe	< 10 MWe
Financing model	Government/ community	Privately
Engineering model	True project, individual design	Modular product, standard blue print
Efficiency	With highly efficient, expensive technology	With low distribution and transport losses
Operational model	24/7, should never stop	Could be operated 24/7, but also be used as fast response units
Supply chain	Linear	Circular
Parties involved	Feedstock seller, feedstock transporter, plant owner, power and heat distributor, end-consumer	Potentially the ***same company*** supplying feedstock, producing and consuming power and heat

The gasifier principle and advantages:

- Functional principle
  - feedstock is mixed with pre-heated air and blown into the hot reactor at high speed. Ash exits at bottom, biogas exits at top centre.
- Several key USP:s
  - The combined reactor and particle separator provides for multi-functional use of the reactor body
  - Simplicity in design: few moving parts. No exotic materials: only ceramics and steel.

- Most important… MEVA's is the only gasifier accepting low cost small fraction feedstock such as saw dust, husks and wood fibre.

MEVA´s gasification facility: VIPP 1.2 – operational specifications

Input:

- 1 ton fuel/hour
- Recommended moisture level of feedstock 10%
- Any pulverized biofuel (accepts saw dust, bark and wood flour, etc)
- Internal power demand 70 kW

Output:

- 1.2 MWe via Cummins gas engine QSV91
- 2.4 MWth
- Engineered for 8,000 hours of annual operation
- 320 days/year (24 hours/day)

Typical gas composition can be seen in the following table.

Table 3: Gas composition - MEVA gasifier

Component	Vol %
CO	20
H2	11
CH4	3
Ethene, ethyne	2
Bensen	0.2
N2	50
CO2	12

WoodRoll® – breakthrough technology for cleanest energy gas from biomass

Rolf Ljunggren, Cortus Energy

Cortus Energy was founded in 2006 to develop and commercialize the patented gasification process WoodRoll®. WoodRoll® is a gasification process for biomass, producing clean energy gas with a high energy value.

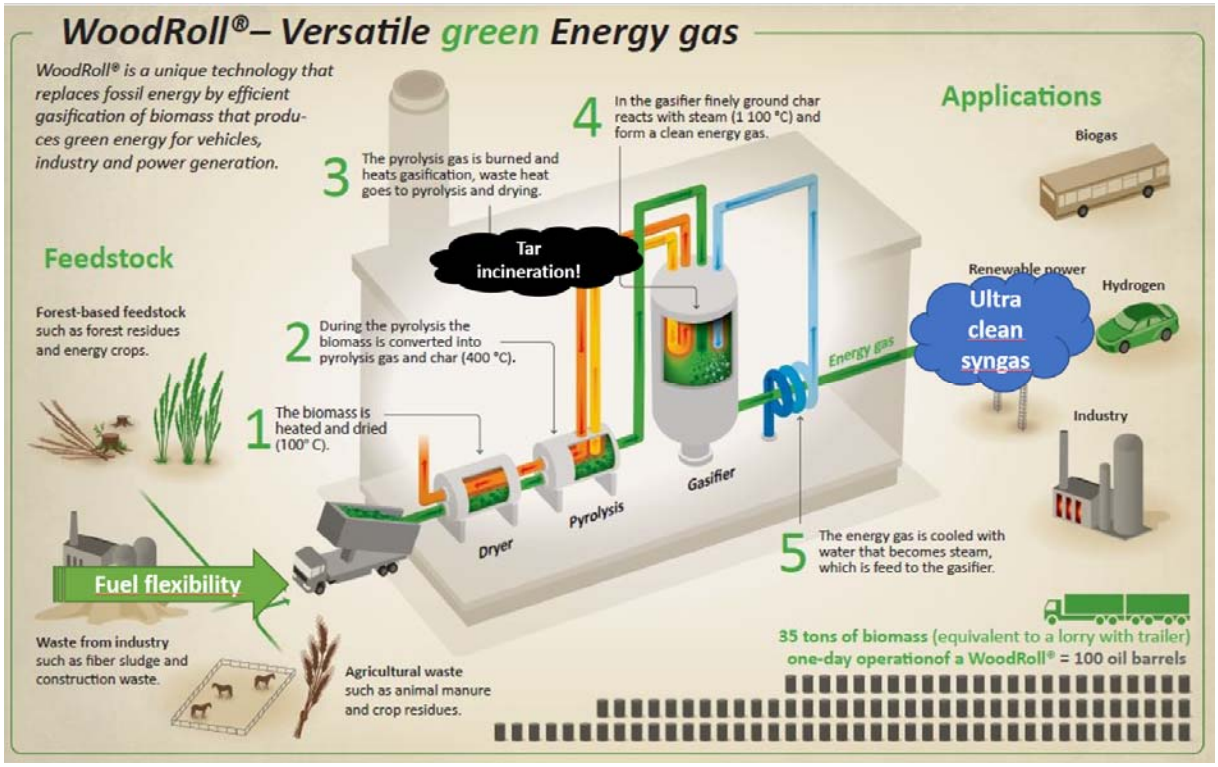

Figure 4: The WoodRoll® technology

Typical gas composition can be seen in the following figure.

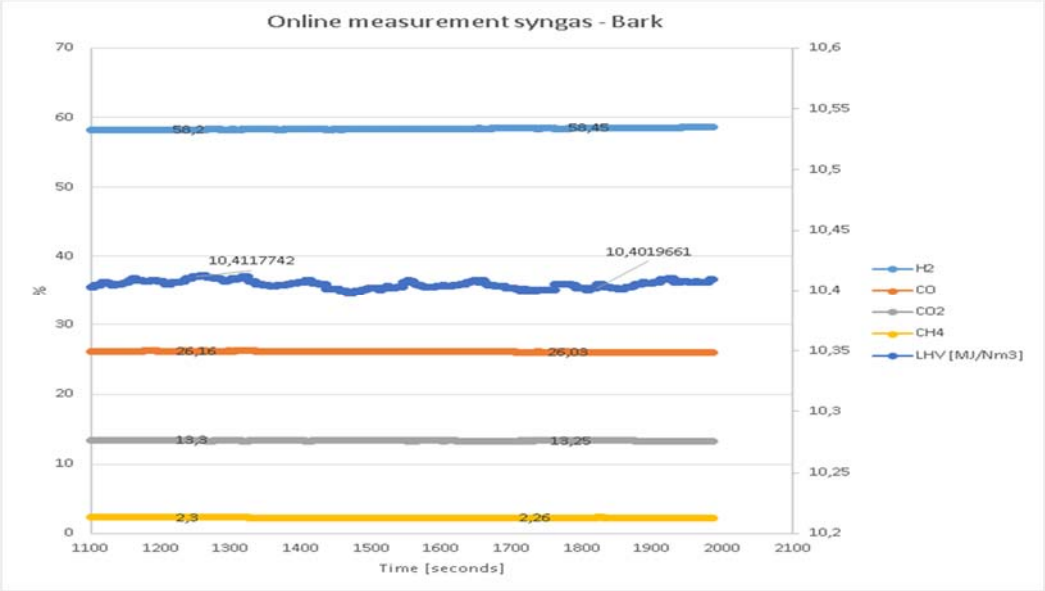

Figure 5: WoodRoll® – gas composition

Operations in Köping

2016:

- Syngas cleaning for catalytic process:
  - Green gas fuel station
  - Biogas Expose
- Fuel tests:
  - Cheap biofuels - Biogas Expose
- Catalytic cracking

2017

- Biocoke
- Methanation
  - Biogas Expose
- Hydrogen
  - Fuel cells for heat and power
- Fuel tests: biofuels from Japan, cheap biofuels - Biogas Expose

Höganäs AB and Cortus AB collaborate for renewable energy under a 20 years renewable energy supply contract.

- Höganäs wants to be the first steel manufacturer to replace fossil such as natural gas and coke with renewable energy to stay ahead of the competition
- Cortus has an excellent first commercial and industrial plant to operate in 2018

A cooperation has been running since 2012 within Jernkontoret (Swedish Iron and Steel Society).

WoodRoll® in Höganäs – background

- A pre-design (Basic engineering) has been completed for Höganäs in 2015/16 at a cost of 8.5 MSEK, where industry, institutes and academia together have developed a basis for the introduction of renewable energy in the production facilities at Högnäs.
- The pre-design includes:
  - *Manufacturing, installation, commissioning of a WoodRoll®®- plant (Cortus/Höganäs)*
  - *Environmental impact study as a life cycle analysis (Swerea)*
  - *Modeling, simulation and analysis of heating process impact in Höganäs (KTH)*
  - *Energy optimization of the system – gasification and furnace (KTH)*
- The parties are finalizing a 20 year supply contract

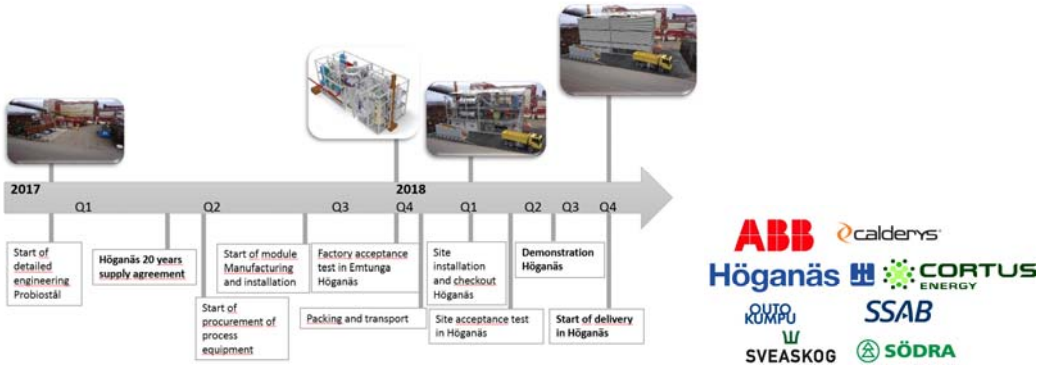

Figure 6: Time schedule and partners of the project

Modular 6 MW WoodRoll®

- The plant is sectioned into function blocks
- Cortus is responsible for process engineering
- Design support from ÅF, WSP (AutoCAD Inventor)
- The engineering is based on the pilot plant in Köping
- Process equipment is bought from established suppliers
- Modules
    - The plant consist of 14 modules
    - The basic module size is 4.45 m * 13.35 m * 4.00 m

Forest Energy

- A strategic joint agreemeent was made between Forest Energy and Cortus Energy in May 2016, including up to 25 plants whithin 5 years.
- Order for basic engineering for the first common project in June 2016. The work was finished in December 2016.
- The aim with the basic engineering is to have a technical basis and documentation for new heat and power projects in Japan.
- The application for support of the 20 year electricity supply (PPA) for the first project is submitted.
- Applications for further projects will be made during 2017.
- The projects are based on co-ownership and a structured finanzing avaible on the Japanese market.
- Order of the first plant is expected before mid 2017.

Mariposa, California

- An **EPIC grant of 5 MUSD** has been granted by California Energy Commission on the 24th of March 2017 for this project
- The project group has been working for nearly two years for a joint heat and power project in Mariposa (California) based on a modular 6 MW WoodRoll® with double gas engines and heat recovery
- In 2016 MBP received support from the state for a pre-design study of a biomass heat and power plant based on a modular 6 MW WoodRoll®

- Environmental permit application has been sent in (March 2017)
- For a realization phase of the project, possibilites for further collaborations with other parties in California are necessary and under investigation. This is a prerequisite for implementation of the project.
- Basic engineering will be started in the second half of 2017.
- A plant order is expected early 2018.

Utilization of special gases with gas engines – Requirements and experiences

Martin Schneider, GE Jenbacher

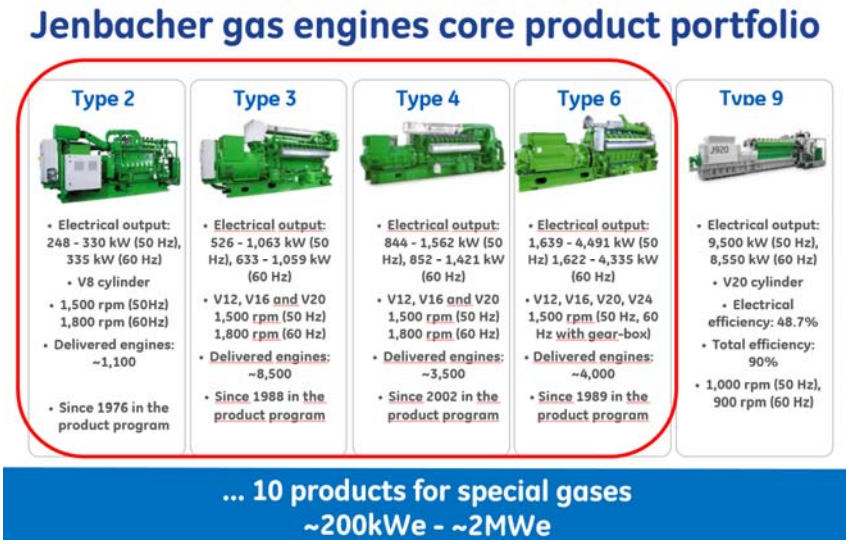

Figure 7: Jenbacher gas engines core portfolio

Important gas parameters:

- heating value
- methane number (parameter for knocking resistance of a gas)
- laminar flame speed (the speed at laminar front at which the oxidation takes place)

Waste gasification:

- approx. 32 MWel installed, majority in Japan
- more than 500 000 operating hours

Biomass gasification:

- almost 100 MWel installed, majority in Europe
    - Harboore
    - Güssing
    - Stans
    - Skive, etc.

Crucial points in the utilization of wood gas are the gas cleaning technology and fulfillment of emissions requirements, unburned CO- content of the gas requires exhaust gas after-treatment.

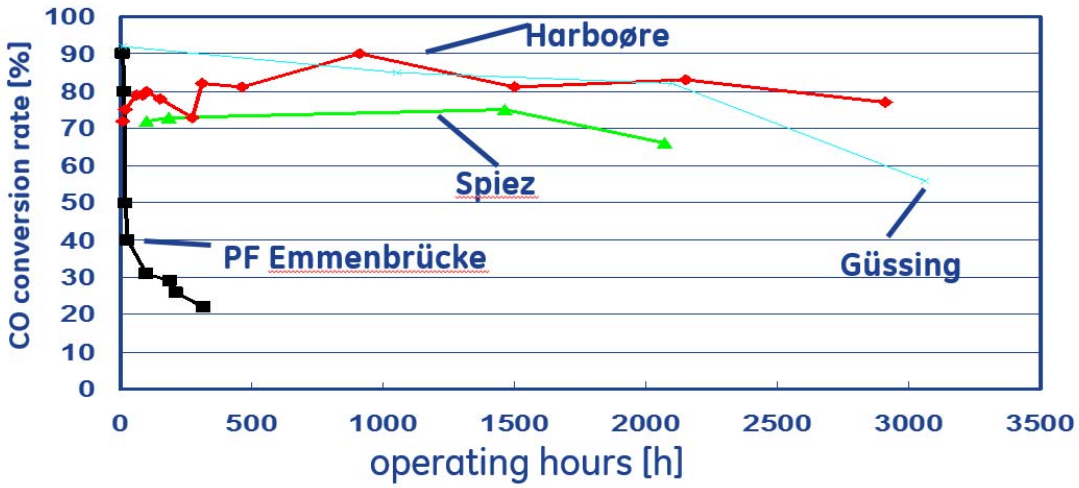

Figure 8: Conversion rates and operating hours

Summary:

- wide range of H_2–containing gases can be used in gas engines
- key factor is laminar flame speed
- main challenges:
- gas contamination (tar, humidity....)
- VOC/CO- emissions
- Health & Safety requirements

CMD ECO20: a small-scale combined heat and power system

Maurizio La Villetta, CMD Engine

CMD has operated on the market since 1971 providing a full range of engineering, production & commercial services “from concept to market”.

Table 4: ECO20 main parameters

Nominal Electric Power	20 kWe_p
Nominal Thermal Power	40 kWt
Output voltage	400 V
Frequency	Three Phase 50 Hz
Mass flow rate biomass (kg/h)	22
Specific consumption (kg/kWh)	1.1
Volumetric flow rate syngas (Nm^3/h)	54
Height	300 cm
Width	180 cm
Length	180 cm
Weight	1600 Kg
dB a 7m	67dB

CMD ECO20

- ECO 20 processes wood chips, but the aim of the company is the future use of biomasses to be chosen from a big family of products or by-products of the wood and agro-food industries.
    - Up to now more than 13 kind of biomasses were tested in several mixtures.
- The handling systems are designed for biomass size category G30 and moisture content up to 20%.

Syngas composition of 4 tested feedstocks is shown in the table below.

Table 5: Results of feedstock tests

Syngas composition for 4 collected samples

	Test 1	Test 2	Test 3	Test 4	Mean value
H_2 %	11.8	13.4	14.0	14.1	13.32
N_2 %	66.1	61.7	59.8	59.1	61.67
CO %	12.5	14.1	14.2	15.1	13.97
CH_4 %	1.0	1.2	1.5	1.5	1.3
CO_2 %	8.5	9.5	10.4	10.2	9.65
C_2H_6 %	0.1	0.1	0.1	0.1	0.1

Though the system is in a first phase of development research, it is ready to be marketed.

The system installation has several advantages, including:

- to be used in mountain and rural areas where electrical supply is difficult

- modular units (2 units can produce 40 kWe and 80 kWth)

Staged gasification by Ronda Engineering

Giovanni Ronda, Ronda Engineering

Ronda Engineering, is an Italian north east side company producing CHP gasification plants using biomass as a feedstock.

The Ronda technology is based on staged gasification, syngas is used in Otto cycle engines, el. output is 1,5 or 3 kW.

The activity carried out by Ronda Engineering started in 2007 building a pilot plant wherewith Ronda performed test on these materials:

- Urban solid waste
- Sludge
- Manure
- Wood

A 1.25 kW plant in Südtirol was realized with positive technical advisory of Protos S.p.a. (primary technical advisory company).

Product philosophy

1. Search the right solution to transform biomass into environmental zero impact byproducts
2. Use of any kind of biomass
3. Every necessary process step is integrated in the plant
4. Modules based system factory tested to have easy transportation and installation

Session II

Byproducts from thermal gasification

Valorization of By-Products from Small Scale Gasification (SSG)

Martin Rüegsegger, ETECA

One point how to run successfully a small scale gasification CHP unit is also valorization of the byproducts.

- By-Products are often waste, but waste can be valuable
- By-Products are better recycled than dumped
- Closed loop are advised
- Incentives such as feed in tariffs are under threat
- Extra income on small scale gasification units are highly desirable

Potential byproducts include:

- C-containing reactor ashes
- Condensates
- Filter fly dust, -cakes and -ashes
- Sludge
- Waste water
- CO2 containing exhaust gas

- http://www.biochar-international.org/
- http://www.european-biochar.org/en/
- http://biochar-science.net/
- http://www.oekozentrum.ch/322-0-Gruendung-des-Pflanzenkohle-Netzwerks-Charnetch.html
- http://Charnet.ch
- http://www.ithaka-institut.org/en/

Figure 9: Various organizations interested in bio-char

Introduction of char and coal on to the market

- Name the Product, declare the use
- Specifications of the product are necessary to be proved
- EU regulations need to be taken into consideration, but
- For authorizations and regulations, Germany ≠ Austria ≠ Switzerland ...
- Even in within a given country there may be different provincial procedures
- Guidelines and standard procedures needed!

Co-production of bio-energy and biochar

Guadalupe Aranda Almansa, ECN

What is biochar?

•A "charcoal"-like product with a large internal pore surface.
•Volatiles are degassed and form a burnable gas for energy generation.
•The carbon skeleton remains as a biochar product.
•Depending on the quality, temperature treatment and pore size distribution, biochar can be used for:
1) Soil improvement
2) Filter applications (like active carbon)
3) Energy product (low volatile cokes)
•Bio-CCS option (up to 1000 years carbon storage).

Biochar production methods:

- Pyrolysis + subsequent activation.
- Low temperature gasification (T < 700°C).

•Difference to deal with tar condensation:

- Pyrolysis + activation: removal of tars.
- Gasification: avoid condensation of tars.

•International standards for PAH content: IBI norm (international) and EBC (European).

- EBC: 2 quality grades: OK (PAH < 12 mg/kg) and premium (PAH < 4 mg/kg).

•ECN process (FB low-T gasification) developed to avoid condensation by leading the produced gases away from the char and avoid condensation by "harvesting" the biochar from the hot zone.

- Tar concentrations recently < 1 mg/kg standard.

The most important quality aspect is tar. Gasification results in extremely low tar levels if harvested from the hot zone. Pyrolysis biochars can be activated to remove tars.

ENERCHAR

- Currently the most important biochar project in the Netherlands
- Reduce energy prices for the greenhouse by using 10-15% agro-residues

+ co-production of biochar

- Biochar used as peat replacement
- Target is commercial application in the Netherlands
    - •Reduction of the cost price for bio-energy of 2 to 5 eurocent/kWh by means of cheaper fuel (10-15% agro-residues) and co-production of biochar (based on replacement of peat and light weight materials in potting soil, estimated at 300 euro/ton).
    - •Realistic greenhouse tests to lead to sufficient confidence in biochar-containing potting soil to enter the market after the project.
    - •First successful pot trials.

The carbon makes the difference

Marcel Huber, SynCraft

SynCraft is a supplier of turn-key wood power plants with output of 200, 300 or 400 kWel., it was founded in 2009.

The technology is based on a floating bed reactor. The technology scheme and output variations can be seen in the figure below.

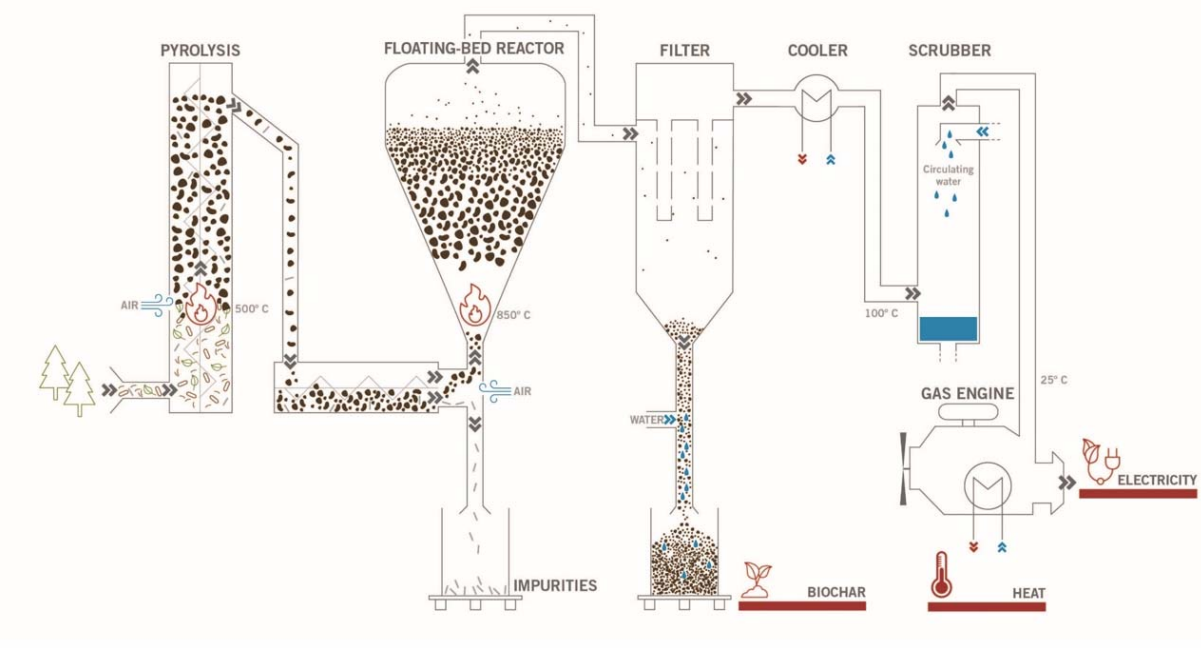

Figure 10: SynCraft technology

Table 6: SynCraft – output and input parameters

	CW 700-200	CW 1000-300	CW 1200-400
Electrical power	200 kW	300 kW	400 kW
Thermal power (basic variant)	326 kW	488 kW	615 kW
Thermal power up to	481 kW	719 kW	920 kW
Fuel heat capacity	721 kW	1.067 kW	1.368 kW
Fuel demand	140 kg/h	208 kg/h	267 kg/h
Specific fuel demand	0.70 kg/kWh_{el}	0.69 kg/kWh_{el}	0.67 kg/kWh_{el}
Charcoal by-product	1.95 m^3/d	2.9 m^3/d	3.7 m^3/d

One of the byproducts is biochar, its utilization paths could be:

- terra preta production
- manure treatment
- BBQ charcoal
- animal feeding

Summary

- Decentralised wood power plant
- Total efficiency of 92% due to LT recovery
  - 30% electric efficiency from dry wood due to gasifier/gas engine combination
- High potential for further economic performance boost due to high-quality charcoal as by-product

Modular gasification of torrefied biomass

Robin Post van der Burg, Erwin Eijmans, Torrgas

Features of Torrgas torrefaction technology:

- Flexibility to accommodate different feedstock
- Scalability in solid conveying and heat transfer mechanisms
- Heat integration between the torrefaction reactor and a waste heat source
- Inherent safety owing to the volatility of the raw biomass
- Variability in operational parameters for adapting to optimum torrefaction process conditions
- Reactor volume optimization achieved through the highest possible filling rates

Torrgas **syngas** can substitute natural gas or propane in existing gas burners.

- Drop-in properties: 12 MJ/kg, nitrogen and tar free syngas meets requirements for direct mixing without major burner modifications.
- Skid mounted bio-syngas generator: up to 15 MWth feed capacity can be installed on portable skid due to high volumetric reactor output.
- Limited logistic handling: torrefied biomass handling is far less complicated and space intensive than that of untreated biomass.

Torrgas **char** has a wide range of applications:

- Activated carbon market: water and flue-gas cleaning.
- Soil Enhancer (biochar): a high-carbon soil supplement that retains water, microbes and nutrients.
- Metallurgical char: high purity biochar can produce high purity steel with low carbon footprint.
- Petcoke replacement for producers (Titanium, Silicon Carbide) requiring low sulfur petcoke.
- BBQ-briquettes: the high carbon content / low volatile content makes it an ideal recreational fuel.

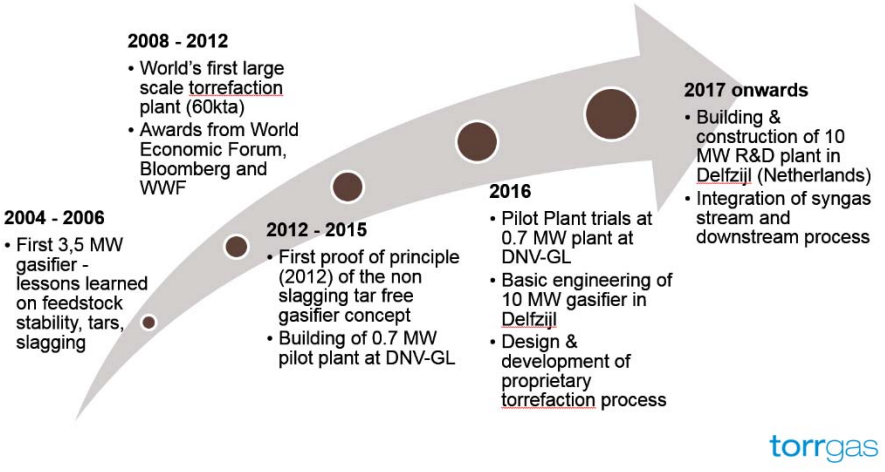

Figure 11: Torrgas history and future plans

Quality of ashes from thermal gasification of sewage sludge and biomass for use as CPK fertilizers

Tobias Pape Thomsen, DTU

Two types of gasification facilities were introduced:

TwoStage Down Draft gasification

- Small scale application (<2 MWTH). Stand alone unit.
- Eff.: Cold gas efficiency 93%
- Current R&D focus: Gas synthesis, fuel/electrolysis cell integration and ash
- Fuel: Wood chips, sewage sludge pellets and straw with additives

Camilla
Thermal capacity: 25-50 kW
Location: DTU Risø Campus
Owner: DTU

Viking
Thermal capacity: 75-100 kW
Location: DTU Risø Campus
Owner: DTU

Figure 12: Two-stage down draft gasification (DTU)

Low Temperature Circulating Fluidized Bed gasification (LT-CFB/Pyroneer)

- Fully scalable. Stand-alone (R&D) or w. boiler (commercial)
- Eff.: Hot gas efficiency up to 95%
- Current R&D focus: Gas cleaning, fuel & product flexibility and ash quality
- Fuel: Straw, sewage sludge, manure fibers, biogas fibers, various organic residues from food industry and fuel mixes

100 kW LT-CFB
Location: DTU Risø Campus
Owner: DTU

6 MW Pyroneer
Location: Asnæs power plant
Owner: DONG Energy

Figure 13: Low temperature circulating fluidized bed gasification (DTU)

General motivation of ash utilization:

1) Improve the life cycle impact of thermal gasification:

- Reduce pollution e.g. toxicity and eutrophication
- Recover and reuse critical elements
- Enhance soil quality and sequester carbon

2) Improve feasibility of thermal gasification in a circular economy:

- Develop new markets
- Valorise ash products

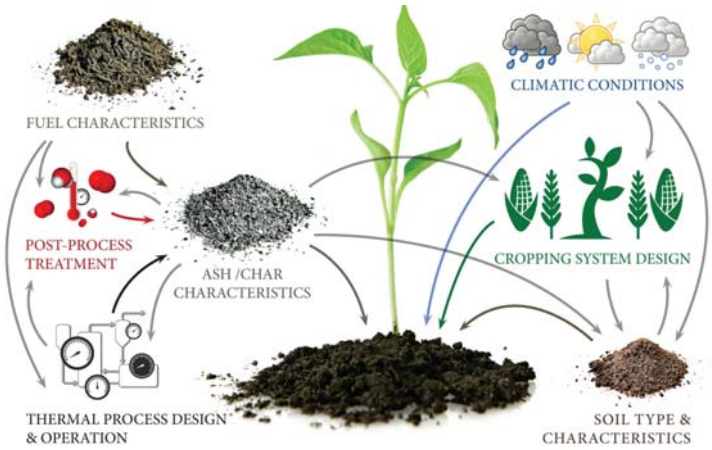

Figure 14: Ash investigations: Effects on plant yield

Ash investigations: BGG involvement

- Practical and legal aspects w. farmers & consultants
- Toxicological aspects w. KU, DTU ENV and RUC
- Fertilizer potential and –value w. KU, AU, farmers and consultants
- Soil enhancement properties and –value w. KU, RUC, farmers and consultants

- Influence of fuel characteristics w. DFBT, DONG, KU, AU
- Influence of thermal process design and operation w. DFBT, DONG, Dall Energy, KU
- Influence of post-process treatment w. DTU BYG, KU

Thomsen, T. P. (2016) Closing the Loop - Utilization of Secondary Resources by Low Temperature Thermal Gasification, PhD thesis, Technical University of Denmark

Figure 15: Result example: Tech. influence on ash quality

Results regarding particle size, tech. and fuel influence on:

- Cd load
- P fertilizer value were presented

Ash quality – general conclusions:

- Not simple!
- Substantial variation from
    - Fuel
    - Technology
    - Post-process treatment
    - End-use scenario
- General trends
    - Generally low ECO-tox of biomass ashes
    - Highly stabile C content (carbon sequestration)
    - Profound liming effect
    - High loss of N, minor loss of P and K
    - Increase water and nutrient retention
- Immense potential benefits
- Success only through cooperation

Summary

The focus of the workshop was thermal gasification of biomass at comparatively small scale with electricity production of at most a few hundred kilowatts, since there are hundreds of biomass gasifiers at that scale operating throughout the world and further are planned.

56 experts from 11 countries representing government, industry and academia participated in the workshop. Twelve presentations covering experience with small scale gasification, and byproducts from thermal gasification systems were given. Many of the speakers represented also companies either providing or operating small scale gasifiers and it was clear that these types of gasification systems have achieved commercial maturity and can reliably be continuously operated.

All presentations from the workshop are available at the web site of IEA Bioenergy Task 33 (task33.ieabioenergy.com).