IEA Bioenergy

Webinar Task 33

The past, present and future of gasification

Speakers: Berend Vreugdenhil and Jitka Hrbek

Moderator: Luc Pelkmans

Outline

- Past – Presenter Vreugdenhil –
- Present – Presenter Hrbek –
- Future – Presenter Vreugdenhil –
- Concluding remarks
- Questions –Pelkmans moderator –

Goal of the webinar

1. To show the long history of gasification and the versatility of its applications
2. To show the current applications and developments using gasification
3. To show a possible future for gasification and to set some boundary conditions for this to happen

Gasification

Partial combustion of a feedstock, with the goal to generate heat that converts the remaining feedstock into gas.

Divisions can be made on:

Low – Medium – High temperature → strong effect on composition of the gas

Fixed bed – Fluid Bed –Entrained flow → determines the technology

Direct vs. Indirect → strong effect on the quality of the gas

Gasification past

Application	Pre-industrial	1900-2000	2001 - today
Coal to gas	-	Yes	Yes
Coal to liquid	-	Yes	Yes
Crude oil to liquid	-	Few	Yes
CHP IGCC with NG / Coal	-	Yes	Yes
Small scale biomass CHP		No	Yes
Large scale biomass CHP	-	No	Yes
Co firing biomass	-	Yes	Yes
MSW		No	Yes
Biomass to syngas	Yes, for food preservation	Yes, short time mobile application	Yes
Biomass to liquid	Yes, for tars and chemicals	No	No
Biomass CHP with IGCC	-	Demonstrated	No
Biomass to SNG	-	No	Demonstrated

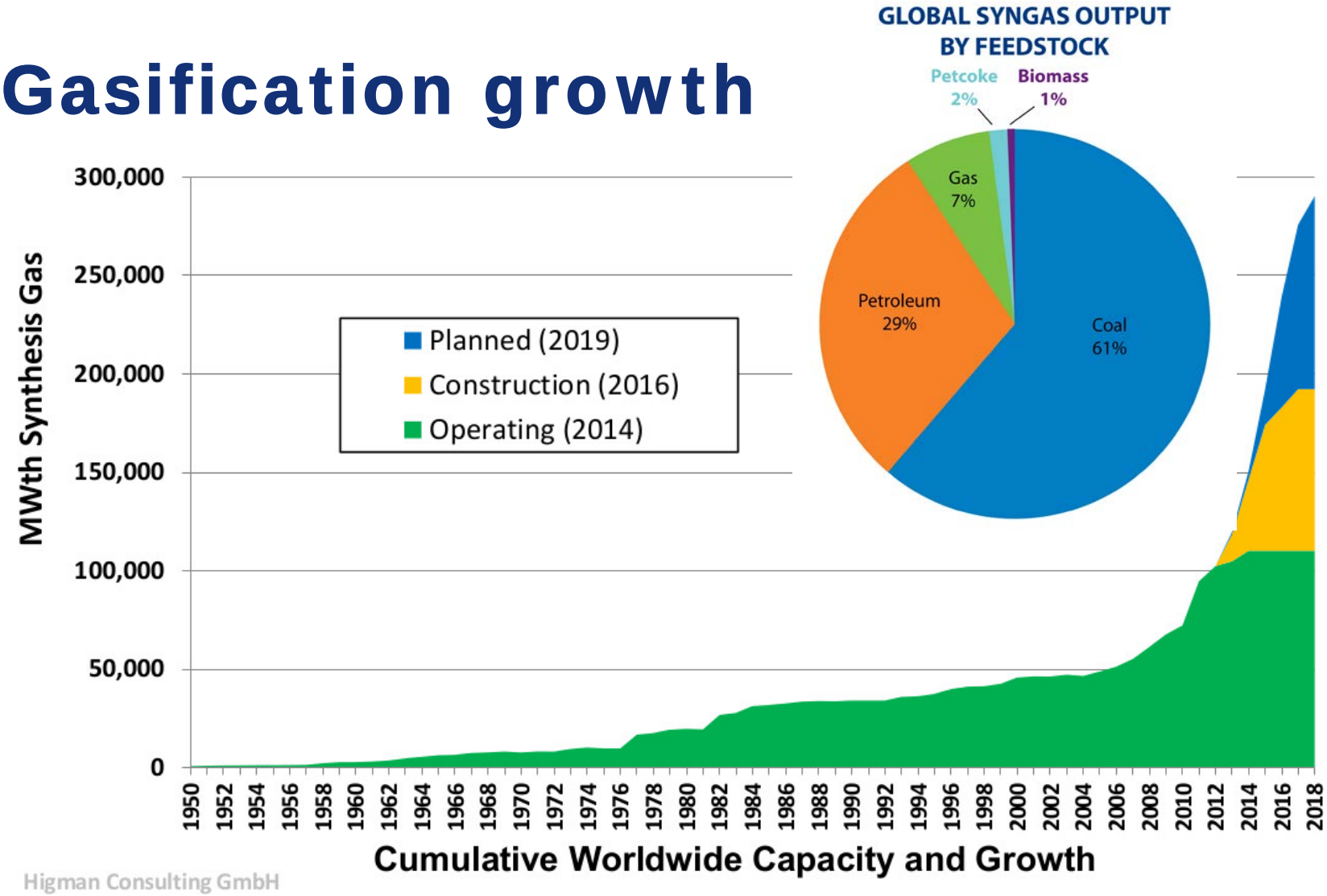
Some of its more unusual applications

Charcoal bus, Japan (Author KY Metro)

Town gas (Westergasfabriek Amsterdam)

Kitchen application, Indonesia (Author Djoewito Atmowidjojo)

Gasification growth



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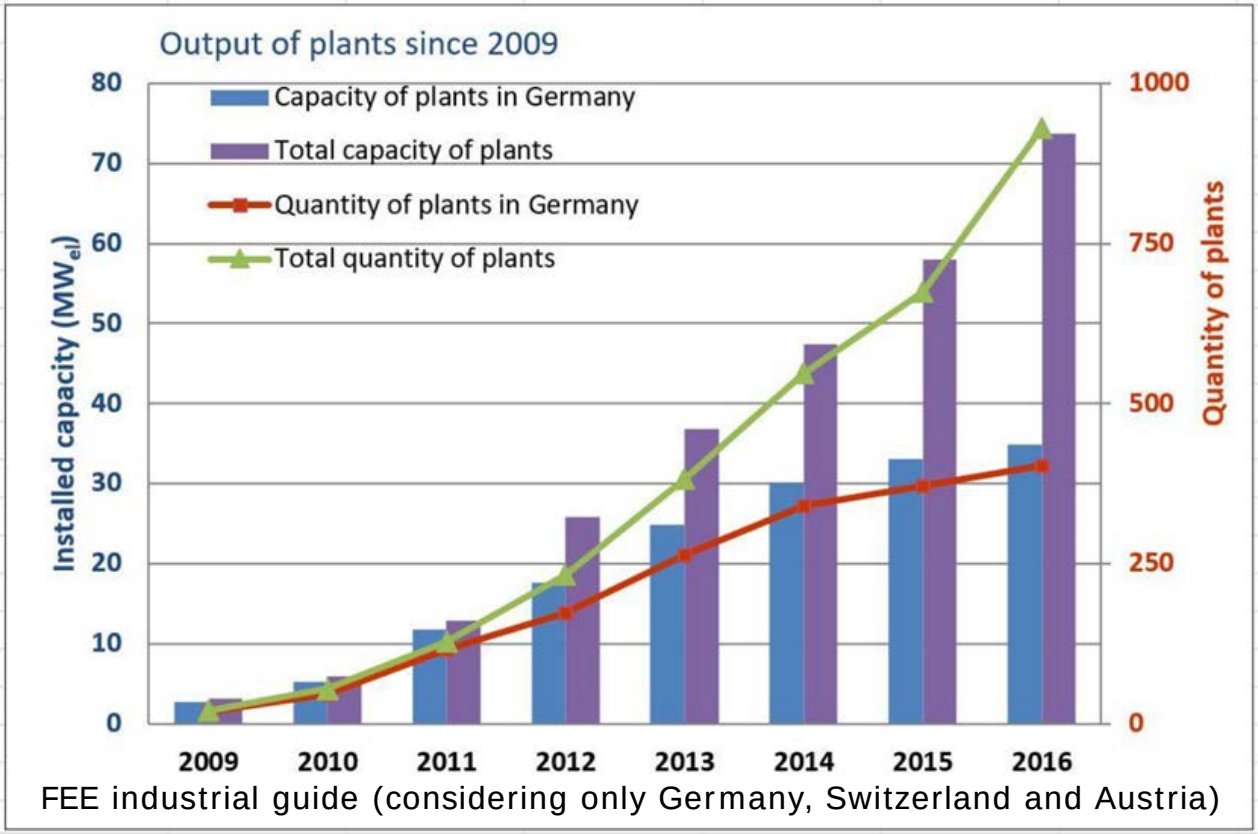
Gasification – large scale applications

Top 20 Operating Commercial Gasification Projects by Size

Gasification Plant Name	Location	Gasification Technology	No. Gasifiers	MWth SG Output	Start-up Year	Feed/ Product
Pearl GTL	Qatar	Shell	18+0	10936	2011	Natural Gas/FT Liquids
Sasol Synfuels II (West)	South Africa	Lurgi FBDB	40+0	7048	1977	Subbit. coal/FT liquids
Sasol Synfuels III (East)	South Africa	Lurgi FBDB	40+0	7048	1982	Subbit. coal/FT liquids
Inner Mongolia Chemical Plant	China	Shell	3+0	3373	2011	Lignite/Methanol
Shenhua Ningxia Coal to Polypropylene I	China	Siemens	4+1	1912	2011	Coal/Methanol
Great Plains Synfuels Plant	United States	Lurgi FBDB	12+2	1900.3	1984	Lignite/SNG
Shenhua Baotou Coal-to-Olefins Plant	China	GE	5+2	1750	2011	Coal/Methanol
Hexigten SNG Plant	China	SEDIN	12+2	1670	2012	Coal/SNG
SARLUX IGCC Project	Italy	GE	3+0	1300	2000	Visbreaker residue/Electricity
ISAB Energy IGCC Project	Italy	GE	2+0	1203	1999	ROSE asphalt/Electricity
Sanwei Neimenggu Methanol Plant	China	GE	4+2	1167	2011	Coal/Methanol
Edwardsport IGCC	United States	GE	2+0	1150	2013	Coal/Electricity
Tianjin Chemical Plant	China	Shell	2+0	1124	2010	Coal/
Henan Jinkai	China	HT-L	4+0	1120	2012	Coal/Ammonia
Yunnan Methanol & DME Plant	China	BGL	4+1	1120	2011	Coal/Methanol
Bintulu GTL Plant	Malaysia	Shell	6+0	1032.4	1993	Natural gas/FT liquids
Long Lake Integrated Upgrading Project	Canada	Shell	4+0	1025	2008	Asphalt/Hydrogen
Leuna Methanol Plant	Germany	Shell	6+0	984.3	1985	Visbreaker residue/H2
Amuay Flexicoker	Venezuela	Flexicoking	1+0	966	1980	Petcoke/Flexigas
Shenhua Erdos	China	Shell	2+0	861	2008	Coal/H2

Gasification is dominated by fossil based technologies.
Gasification is developed towards a variety of products

Gasification – small scale applications



FEE industrial guide (considering only Germany, Switzerland and Austria)

Small scale gasification excels in biomass gasifiers. Typical products are heat and/or power

Large scale deployment
Great plains synfuel plant

1972 – Decision taken to build a coal gasification flagship

Inflation

Suffer from legislation

Politics

Changing governments

Not meeting emission limits

Off-take contracts

Falling energy prices

1980 – Construction finally started

1984 – Getting online

1985 – Nearly abandoned → DoE took ownership

1988 – Basin Electric obtained ownership and formed the Dakota Gasification Company

https://www.dakotagas.com/about-us/history

Dakota Gasification Company

Started as a coal to synthetic natural gas project

1984 – Anhydrous ammonia

1984 – Sulphur

1985 – Light oils as wood preservatives

1990 – Phenol

1990 – Krypton / Xenon

1993 – Cresylic acid

1994 – Fertilizer

1997 – CO_2 for EOR

2014 – Urea / Ammonium sulfate

2014 – Tar oil

2014 – Liquified CO_2

2017 – Diesel exhaust fluid

And the list is incomplete

Learnings so far

- Gasification has been around for centuries
- Gasification has been successfully applied for a long list of products (some temporary)
- The early applications were actually high value products (chemicals)
- Percentage installed capacity for biomass gasification is small
- Number biomass gasifiers is actually quite large
- Gasification has the opportunity to develop from single product to refinery unit
- Gasification is flexible towards the desired output

Present status of gasification - Jitka Hrbek

Content

- **Status of thermal gasification** of biomass and waste **in** IEA Bioenergy Task 33 **member countries** (Triennium 2016-18)

Austria	Norway
Denmark	Sweden
Germany	Switzerland
Italy	USA
The Netherlands	

- Overview and description of reference facilities

- Conclusions of actual status

Austria

In comparison with the past time, the boom of small scale gasification facilities can be observed

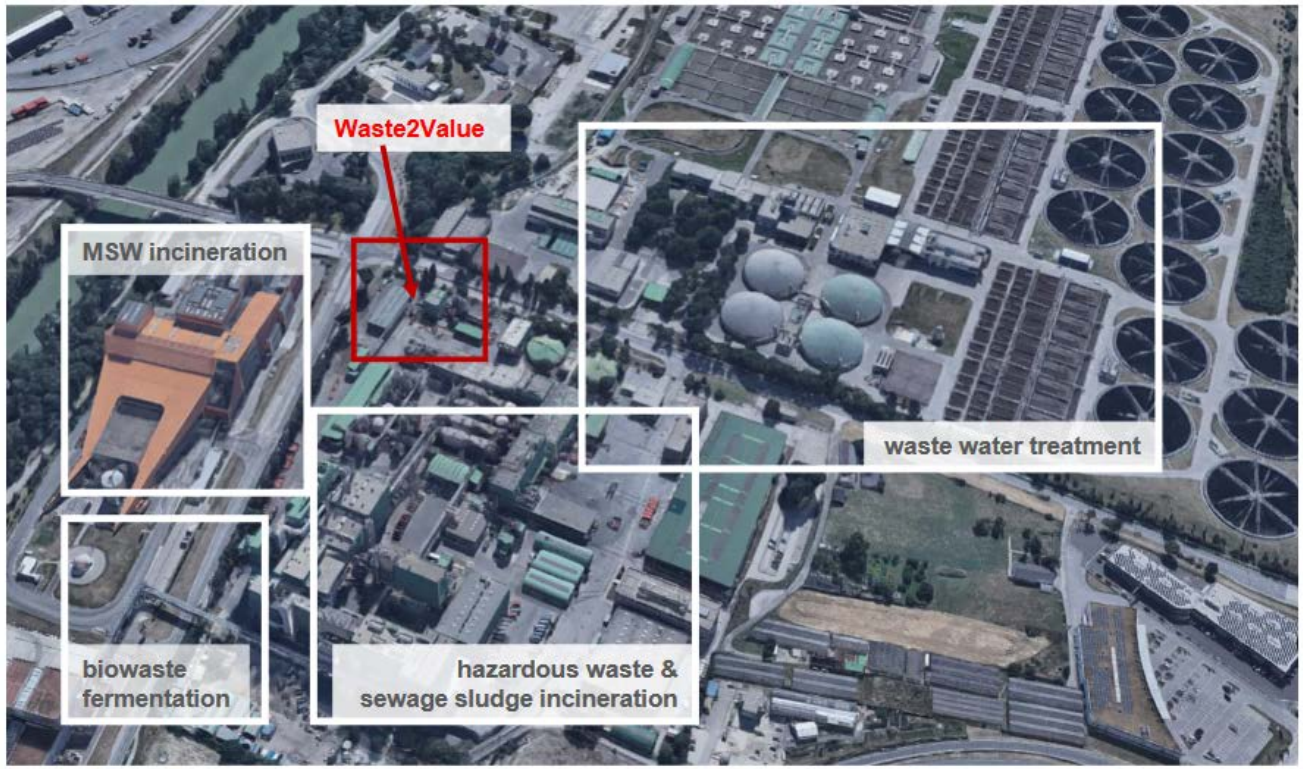
- Urbas (https://www.urbas.at/)
- Syncraft (http://www.syncraft.at/index.php/)
- Glock-ökoenergie (https://www.glock-oeko.com/)
- Hargassner (https://www.glock-oeko.com/)
- Fröling (https://www.froeling.com/at.html)

Contrary to this, all large scale facilities e.g. Güssing, Oberwart are on hold

R&D focuses on waste material feedstock characterisation and usage as well as product gas applications

Waste gasification facility will be build near Vienna (project Waste 2 value)

Austria
Waste 2 value project



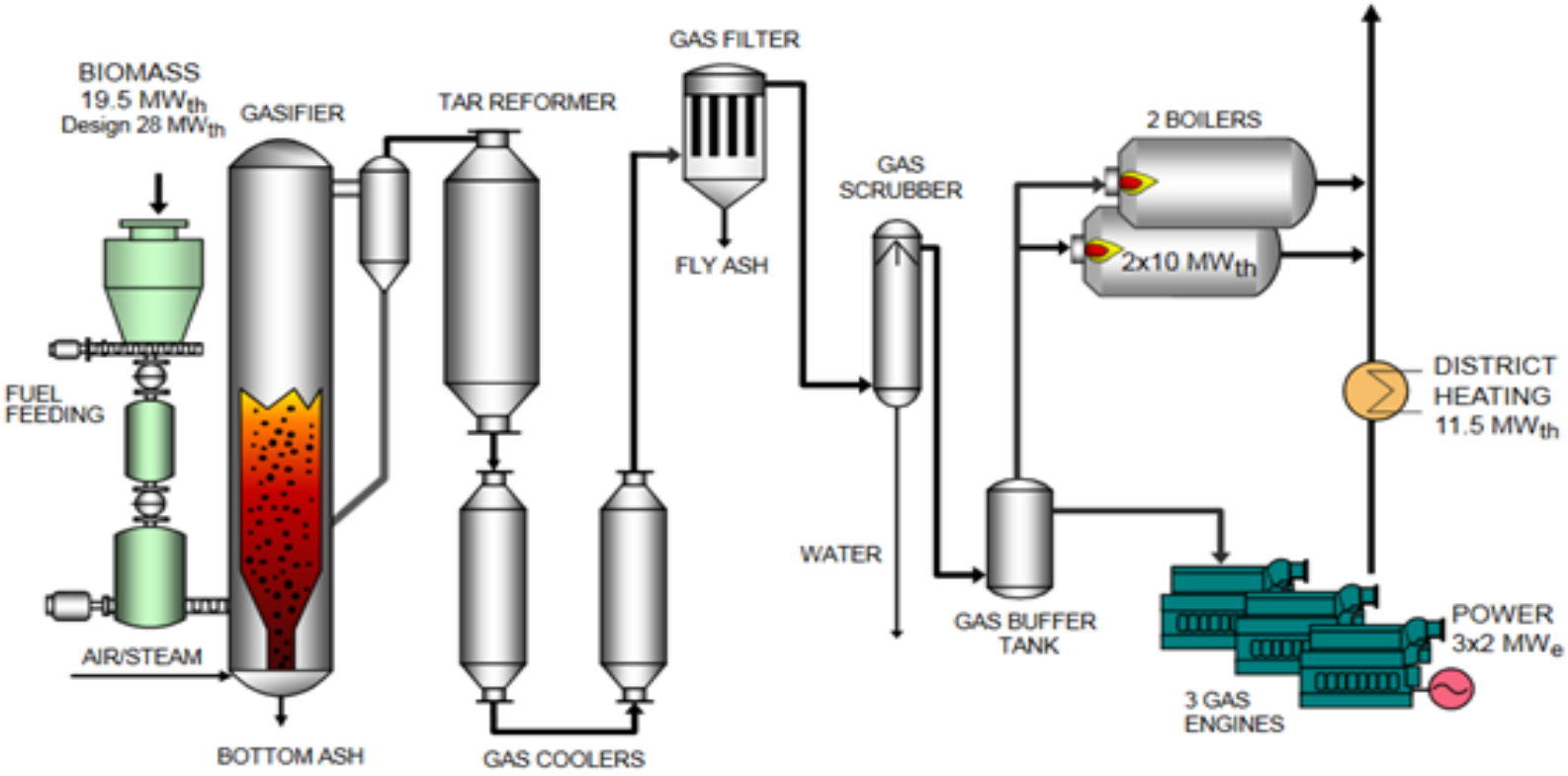
Construction begins this year, 2020
Commissioning with beginning 2021

Denmark
operational plants

Project name/ location	Technology	Input/ Feedstock	Output/ El./Th.	Usage/ Product	Start up/ Status
Harboøre CHP plant /Harboøre, DEN	Fixed bed - updraft	3,5 MW /forest wood chips	1 MW electric 1,9 MJ/s heat	CHP generation	1993 (CHP in 2000) /operational
Sindal CHP plant /Sindal, DEN	Staged updraft	5.5 MW /wood residues	0.8 MW electric 5 MJ/s heat	CHP generation	2018 /operational
Skive CHP plant /Skive, DEN	Bubbling fluidised bed	20 MW /wood pellets	6 MW electric 11,5 MJ/s heat	CHP generation	2008 /operational

Denmark
Skive plant

- BFB gasifier for CHP, woody biomass (input 20 MW) as feedstock, three engines (6 Mwel), heat (11,5 MWth) consumed in local district heating network and electricity sold to the grid.
- In operation since 2008, owned by Skive Fjernvarme



Denmark
other plants

- **Pyroneer plant, Kalundborg co-firing**

  CFB, 6 MWth, commissioning in 2011

  Feedstock: straw, manure fibres

  Cofiring in coal fired unit

  Planned upscaling up to 60 MWth, but technology not sold

  2015 mothballed, now at DTU, research ongoing

- **Viking gasifier, Hillerød CHP, Weiss**

  Staged gasifier, 500 kWel, heat for district heating

  Feedstock: wood chips

  Plant never came into commercial operation, dismantled in 2016

  Research still ongoing at DTU

- **Hillerød CHP, Biosynergi**

  Staged down draft gasifier developed and patented by DTU, Scale-up by Weiss and DTU, licensed by COWI

  In operation in 2017

  Minor technical challenges in combination with lack of further funding forced the company to cease activities in the last part of 2017, the plant has been dismantled in 2018

Germany
large scale gasifiers

Bioliq pilot plant (extra slide following)

Developed at KIT, aims the production of synthetic biofuels and chemicals, TRL 6

Technology is based on two staged process (decentr. pyrolysis, centralized gasification)

Feedstock: straw and other materials (0,5 t/h)

2 MW fast pyrolysis for biosyncrude, 5 MWth gasification (EF up to 8 Mpa)

Product: DME (608 t/y), final gasoline synthesis (360 t/y)

In operation since 2010,

DME and gasoline synthesis since 2014

Blue Energy Wood-CHP Senden

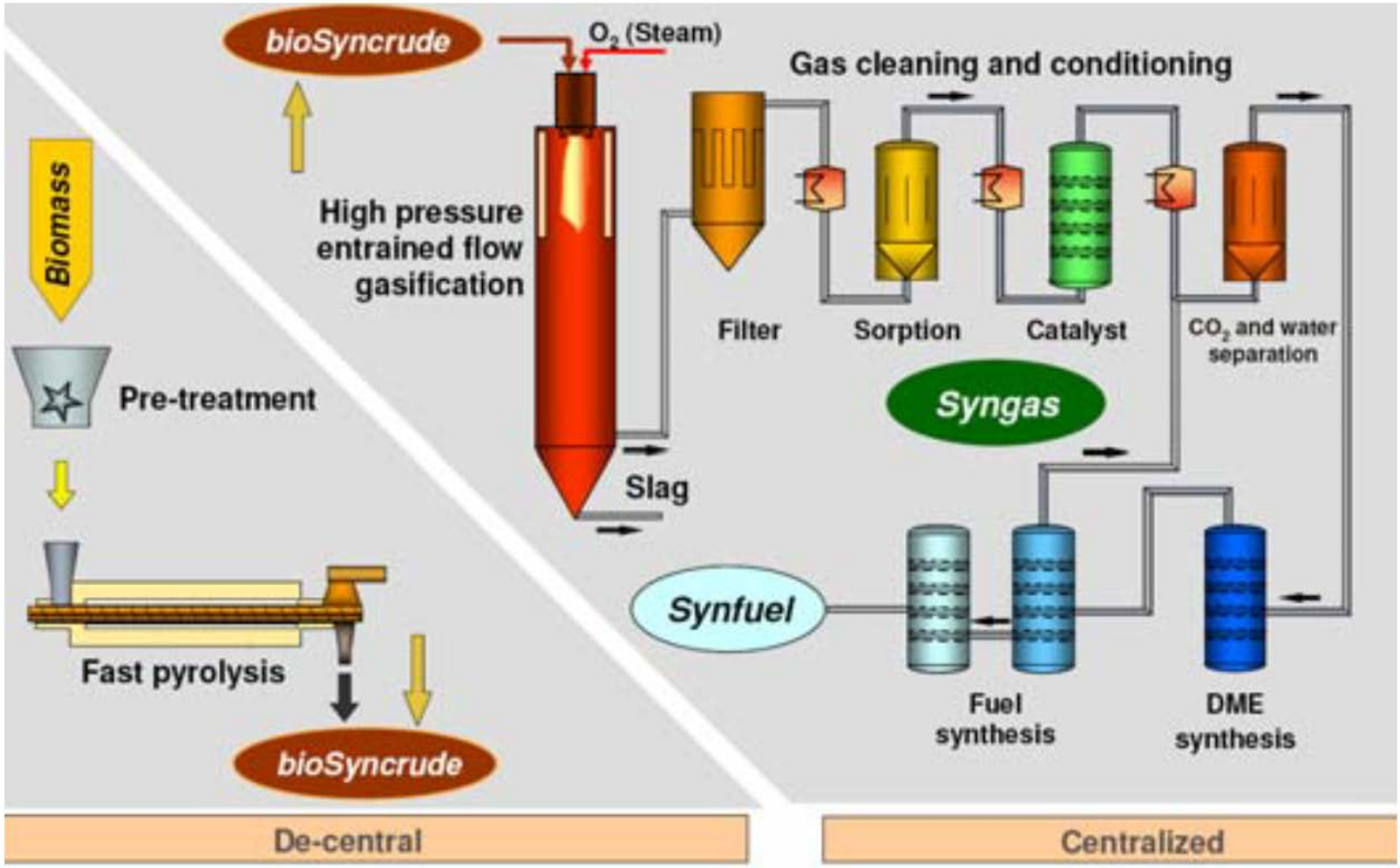
Technology based on FICB (as was in Güssing)

Feedstock: wood chiops

Output: 4,55 MWel, 15,1 MWth

Start up 2011, in operation till 2018, now on hold

Germany
bioliq plant



Germany
other gasifiers

Entrained flow gasifiers

- AirLiquide EC (https://www.engineering-airliquide.com/de/synthesegas)
- ThyssenKrupp Industrial Solution (TKIS) (https://www.thyssenkrupp-industrial-solutions.com/en/products-and-services/chemical-plants-and-processes/gasification/)

Fluidized bed gasifiers

- Sülze Kopf SynGas (www.kopf-syngas.de) – gasification for sewage sludge application (drying)
- Burkhardt GmbH (output: 50, 165, 180 kWel/wood pellets) – more than 240 plants
- Stadtwerke Rosenheim, staged gasification (http://www.swro.de/kraftwerke/holzvergaser.html)

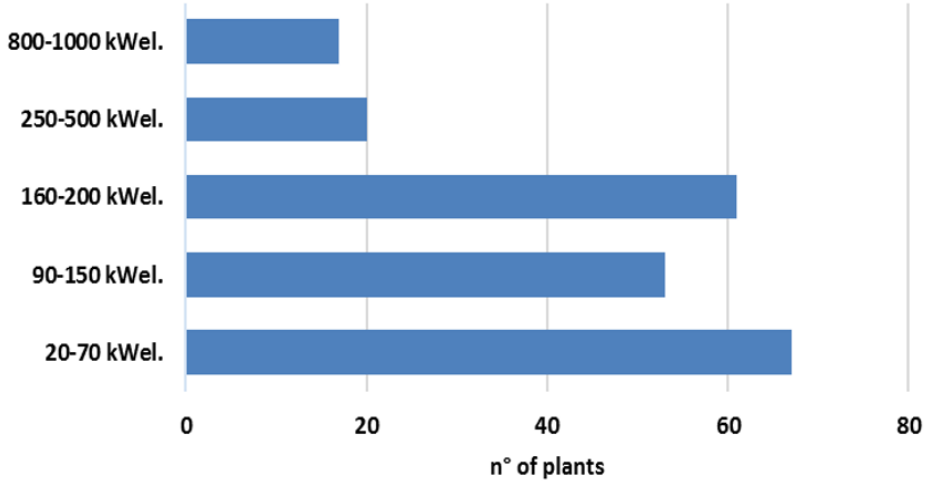
Fixed bed gasifiers

- LiPRO energy GmbH&CO.KG - output 30-50 kWel, 60-100 kWth (Web: www.lipro-energy.de)
- Spanner RE2 GmbH, output 2-9 kWel, 3-22 kWth (http://www.holz-kraft.com) – over 700 plants
- REGAWATT GmbH, output 300-2000 kWel, 600-4300 kWth – 6 plants in operation
- Biotech Energietechnik GmbH – multi-staged gasification, output 25 kWel./75 kWth (https://www.biotech-heizung.com)

Italy

Geographical area	N° Plants	%	kWel.	%
Northern Italy	140	64.2	32,141	73.8
Central Italy	51	23.4	7,141	16.4
Southern Italy and islands	27	12.4	4244	9.8
Total	**218**	**100.0**	**43,526**	**100.0**

Distribution by electrical output



Italy
fixed bed gasification

CMD S.p.A (http://eco20cmd.com/cmd-eco20/?lang=en)

- downdraft gasifier, output up to 20 kWel./40 kWth
- feedstock: forest residues, urban waste wood, mushroom manure, olive waste, sawdust, rice husk, shells, etc.

ESPE SRL (http://www.espegroup.com/en/biomass/cogenerator/)

- output 49 kWel/110 kWth

RESET s.r.l. (www.reset-energy.com)

- fully automatic plants, output 50-200 kWel
- high grade biochar

The Netherlands 1 / 3

Bio Energy Netherlands (BEN) (https://bioenergynetherlands.nl/)

- modular plants for CHP production, but in the future will use this platform to produce biogas, hydrogen and CO2

- in Nov. 2017 construction started, plant designed for 15 MWh of CHP and hydrogen

Essent / RWE (www.rwe.com)

- waste wood gasifier (Geertruidenberg) connected to a 600 MWe coal-fired power station

- CFB (Lurgi technology), capacity 85 MWth

ESKA (www.eska.com)

- CFB 12 MWth, paper reject, product gas as a feed to a boiler (steam production)

- technology supplied by Leroux & Lotz, implemented in 2016

ECN part of TNO

- ECN part of TNO has developed a technical route to convert biomass into substitute natural gas. This technology is based on the MILENA indirect gasifier combined with the first gas cleaning OLGA. This technology is commercialized through a joint venture between ECN part of TNO and Dahlman Renewable Technology (part of Synova)

The Netherlands 2/3

Mavitech Green Energy (http://www.mavitecgreenenergy.com/gasifications/

- turn-key technology, down-draft fixed bed
- feedstock: different manures and sludges
- product gas combusted directly after gasifier and usage of the heat
- Ecochar production to be sold

Synova (www.synovapower.com)

- waste-to-energy company
- developed stndardized modular unit based on MILENA ans OLGA of approx. 6 MW input, this so-called SMM can be used to couple to a power block to make circa 1.5 MWe electricity
- The first SMM to power will be in Thailand, North-East from Bangkok. Synova will own and operate the plant.

Synvalor (www.synvalor.com)

- new multi-staged vortex reactor for difficult fuels producing low-tar gas for e.g. gas engines
- test facility 50 kWel was built
- currently commissioning of gasifier in Gerbera grower, results expected

The Netherlands 3/3

Torrgas (http://torrgas.nl)

- aim is to be a leading provider of value chain solutions for plant scale (10-100 MW) syngas from torrefied biomass

- Torrgas has successfully commissioned their first demonstration plant at DNV-GL at 0.7 MWth and finished the Basic Engineering of 25 MWth (2*12,5 MW) gasification plant in Delfzijl. The syngas produced in the Delfzijl project will be converted into SNG. This project is together with Gasunie, Pörner, and DBI. The Delfzijl project is intended to start construction in 2019.

SCW (www.scwsystems.com)

- young company focusing on supercritical waster gasification (T>375°C, p>221 bar)

- A first demonstration plant is constructed in Alkmaar and the commissioning started in the second half of 2018. This installation has been connected to the high pressure transport grid round December 2018.

- Gasunie New Energy is directly involved in this development. Expected Green Gas production in 2019

Host (www.host.nl)

- one of the largest suppliers of bioenergy systems in Europe, focuses on the technological development of the processing of biomass and waste streams and the supply of systems for renewable energy from biomass and waste.

- Their CFB technology has been proven on various feedstock and their offers are in the range of a standard installation of 1-5 t/h or specialty plants of >5 t/h.

Norway

Small scale gasification

- Volter, started operation in 2016

In Norway, the prices of energy are relatively low, thus CHP production based on gasification is too expensive in comparison with other energy sources.

Other projects

Quantafuel - The plant in Skive will source plastic from local suppliers and produce local, environmentally friendly, high-quality fuel, an initial capacity of 60 metric tonnes of plastic waste per day, and will convert approximately 18 000 tons of plastic waste per year. Output more than 15 mill. L of hight quality recycled fuel.

- Preliminary capacity targets for full scale facilities are around 7 million litres of jet-fuel/year.

BioFuel - focuses on sustainable economic production of aviation biofuel from household waste

Sweden 1 / 4

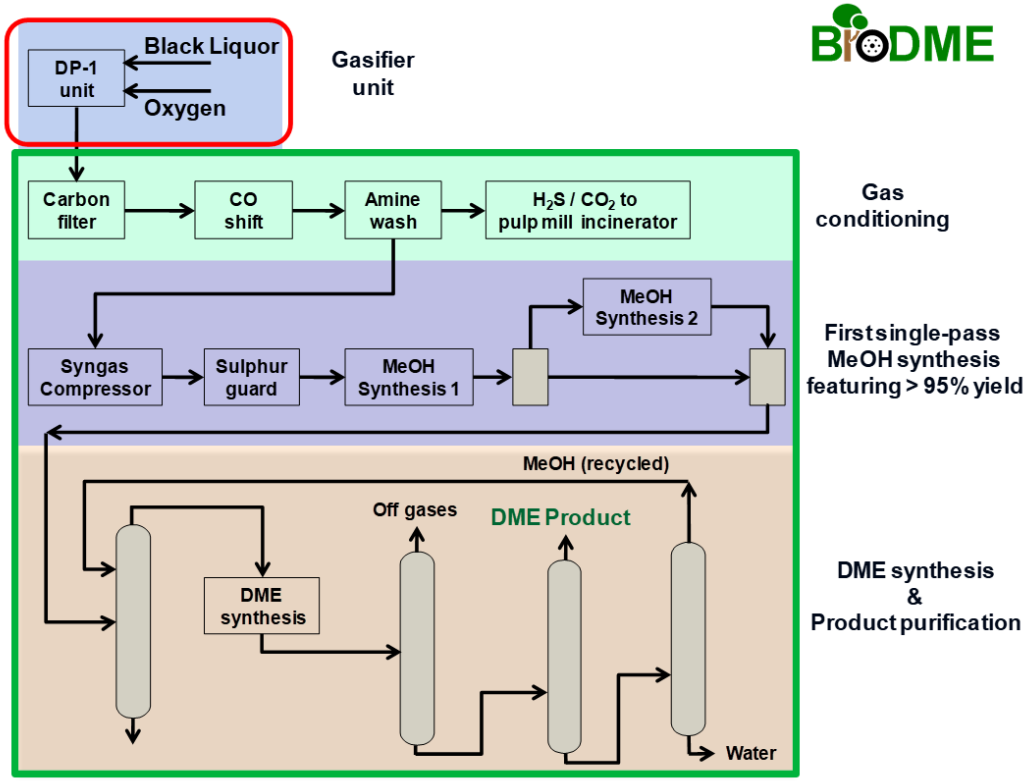
Small scale gasification

- Emåmejeriet, Hultsfred (www.bkvab.se, energikontorsydost.se)
- output 40 kWel/100 kWth

Large scale

- **GoBiGas** (extra slide)
- **LTU Green Fuels AB**
  - project ended in 2013

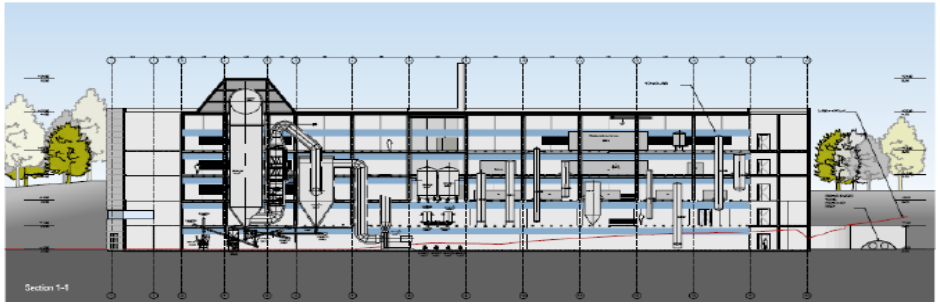
400 t of DME for Volvo trucks was produced, trucks operated for over 80 000 km



Sweden 2 / 4

GoBiGas – phase 1

Production:		Consumption:	
Bio-SNG	20 MW	Fuel (pellets)	32 MW
District heating	4 MW	Electricity	2,5 MW
Heat to heat pumps	8 MW	RME (bio-oil)	0,5 MW



Göteborg Energi

Official start-up of phase 1 in October 28, 2013

After 1 800 oper. hours, the plant was shut down and mothballed in May 2018

The reasons for shut down:

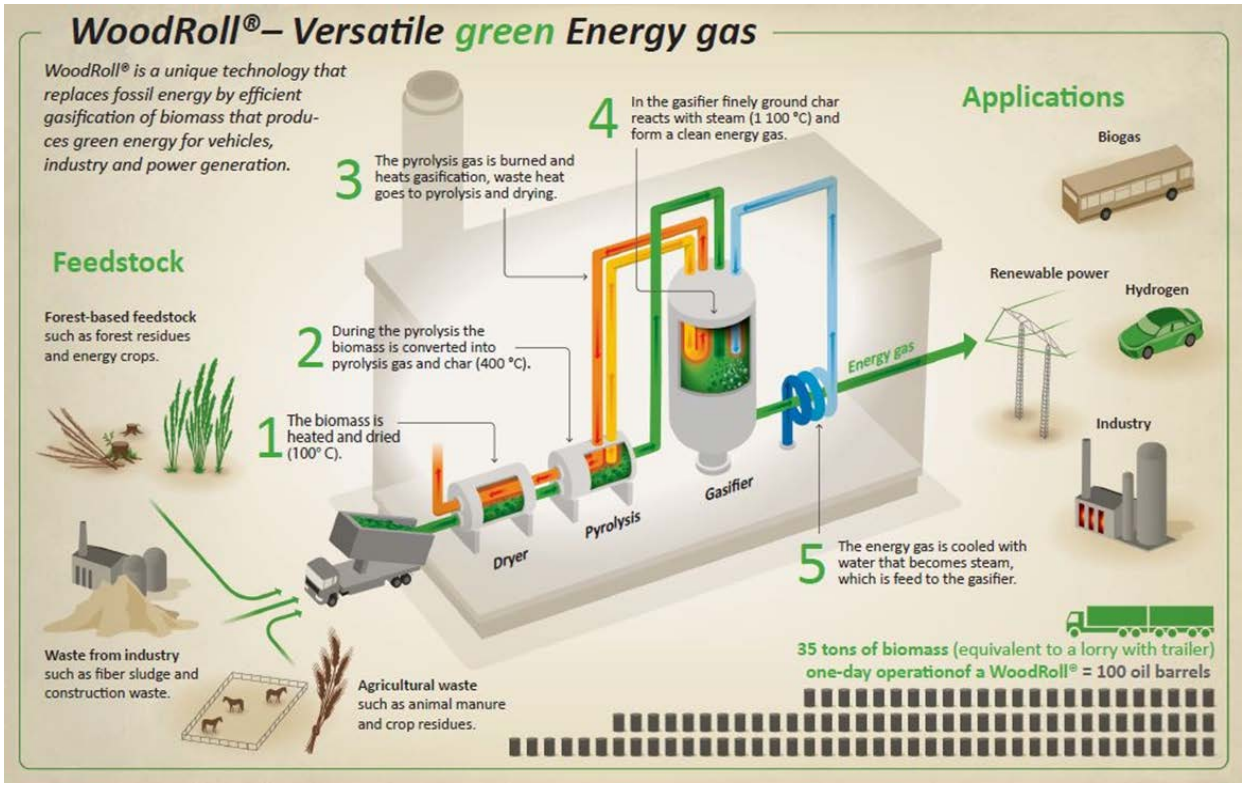
- the sales value of the bio-methane had not followed the projections

The second phase with output of 80-100 MW of biomethane was planed but this decission was canceled in November 2015

Sweden 3 / 4

Cortus Energy AB (www.cortus.com) – developed the WoodRoll Technology

After testing with the three stages operating off-line, a fully integrated unit has been constructed and was mechanically complete in early 2015. It has been reported that the gasifier has been operated over 5 000 hours in September 2018, and the dryer and pyrolyzer over 2 000 hours each.



Output:6 MWth

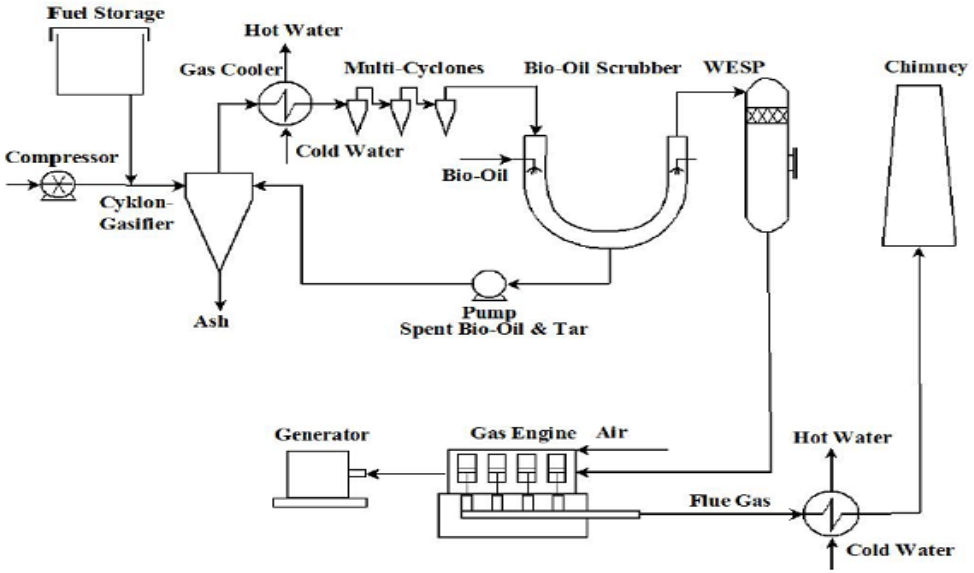
In late 2018, Cortus was also awarded a grant from the Swedish Sustainable Aviation fuel program to study the integration of the WoodRoll system with a FT system producing aviation fuel

Cortus cooperates with Japanese Forest Energy, California Energy Commissioning,Engie, Infinite Fuels GmbH

Sweden 4 / 4

MEVA Energy (www.mevaenergy.com)

- Cyclone gasification technology- VIPP (Vortex Intensive power process)
- Pilot plant at ETC (input 500 kWth crushed pellets, gas cleaning, engine with 100 kWel output; op.h 800,dismantled 2017)
- Scale up (5 MWth input, 1,2 MWel/2,4 MWth), commissioning 2014-15, rebuilt in 2016, since 2017 as R&D, over 2000 operating hours



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Switzerland

	Andreas Mehli Illanz	RE Puidoux	AEW Rheinfelden	Käser Gasel I+II	J. Bucher AG Escholz. I+II	A. Steiner + Cie. AG	Holzstrom in Stans I+II
Gasifier	Volter Fi	Regawatt	Burkhard	Ligento	Wegscheid	Spanner	2 units each 4 gassifier Pyroforce/BR
Type	downdraft	updraft	downdraft	downdraft	downdraft	downdraft	2-zone downdraft
Gas engine	40 kW el	Jennbacher+ ORC; Total = 890 kWel	165 kW	2 x 140 kW el	2 x 133 kW el	45 kW el	2 x 690 kW el Jennbacher
Waste heat therm	district heating	district heating	district heating	for BM drying	district heating drying wood chips	district heating	1,2 MW for district heating
extra BM-Boiler	-	yes	yes	no	Yes	yes	1,6 MW BM 1,7 MW oil
Fuel	Dry clean wood chips	clean wood chips	Pellets	Dry clean wood chips	Dry waste wood chips G 30-100	Dry waste wood chips	demolition wood/scrap wood chips
In operation since	2018	2018	2018	I = 2015 II = 2016	I = 2015 II = 2018	2013	2007

(Status Nov.2018)

USA

Red Rock Biofuels (www.redrockbio.com)

- Construction of Biofuels production plant in Lakeview, Orgegon
- Conversion of 136 000 t of woody biomass into 15 mill gall/year of biofuels (jet fuel, diesel)
- Under construction, start up 2020?

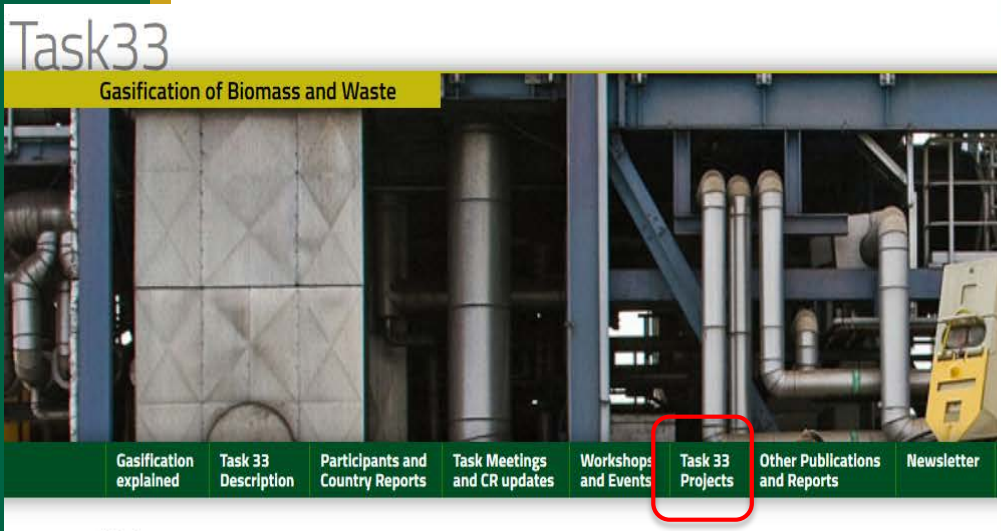
Aematis/Lanzatech (www.inentec.com, www.lanzatech.com)

- agricultural waste, syngas fermentation to ethanol – InEnTec plasma-assisted gasifier
- construction scheduled to start in 2020

Fulcrum Bioenergy

- conversion of 200 000 t/y of MSW into 10 mill.gall of syncrude oil
- fluidized bed steam reformer (www.tri-inc.net/steam-reforming-gasification)
- now under construction, operational with the end of 2020

www.task33.ieabioenergy.com



Welcome

Task 33 is a working group of international experts with the aim to promote the commercialization of efficient, economical and environmentally preferable thermal biomass gasification processes.

Latest Updates

2019-12-02 | Events

IEA Bioenergy Task 44 Workshop on Flexible Bioenergy

24. January 2020, Graz, Austria

Read more

2019-10-07 | Events

10. Internationale Anwenderkonferenz Biomassevergasung

10.12. 2019, MCI Innsbruck, Austria

The conference will be held in German language.

Read more

IEA BIOENERGY TASK 33 REPORTS

Date	Publication	Annex
10/2019	Status report on thermal gasification of biomass and waste 2019	Annex 1 - CHP operational facilites Annex 2 - CHP non operational facilities Annex 3- Fuel synthesis operational Annex 4 - Fuel synthesis non operational Annex 5 - Other gasif. technology operational Annex 6 - Other gasif. technology non operational
08/2019	Lessons learned about thermal biomass gasification	Historical documents
02/2019	InterTask project Biomass pre-treatment for bioenergy, Case study 3: Pretreatment of MSW for gasification	
12/2018	Gasification of waste for energy carriers	
12/2018	Hydrogen from biomass gasification	
11/2018	Valorisation of by-products from small scale thermal gasification	Annex 1- Market for carbon and charcoal Annex 2- Analytics Annex 3- Charcoal Annex 4- Dust, ash
10/2018	Thermal gasification based hybrid systems	
09/2018	Gas analysis guideline report - part I and part II	
07/2018	Implementation of bio-CCS in biofuels production	

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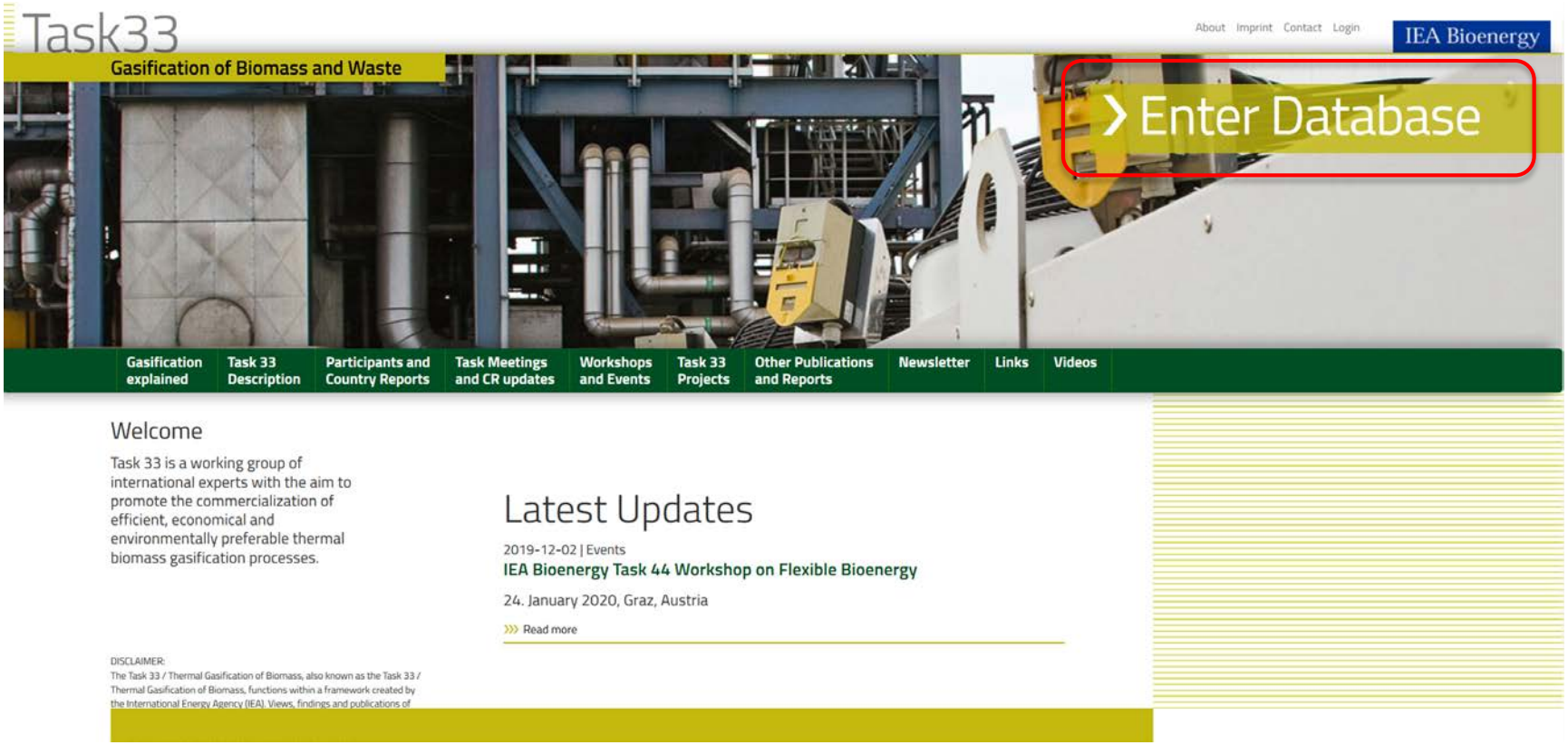

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Summary of the current status

- **Boom of small scale gasification for CHP** applications can be observed in Europe during the past 5 years (over 1500 facilities in operation)
- **Large scale gasification** facilities are mostly **closed for economic reasons** (e.g. Güssing, GoBiGas, Senden,…)
- **Feedstock** for gasification moves from clean wood to **waste and other difficult materials** (e.g. chicken manure, sewage sludge, RDF, etc.)
- Synthesis gas from gasification can be used in different ways, e.g. **biofuels production** (FT kerosene) seems to be a promissing way for the future
- **Combination** of thermal gasification with other renewables e.g. wind power or PV **offers new possibilities** for electrical grid balancing and/or energy storage
- **Bioenergy is one of the essential sources for energy supply in the world without fossils**

Future of gasification – Berend Vreugdenhil

Gasification future

SRIA's of ETIP Bioenergy and EERA Bioenergy

- Major role for gasification-based value chains in accordance with the SET plan and the Action 8 Implementation Plan
- Main R&D needs identified

www.etipbioenergy.eu

www.eera-bioenergy.eu

Upcoming developments

Gasification can be used for:

- Waste management
- Biofuel production with CCS
- Hydrogen production
- Refinery integration
- Steel industry
- …

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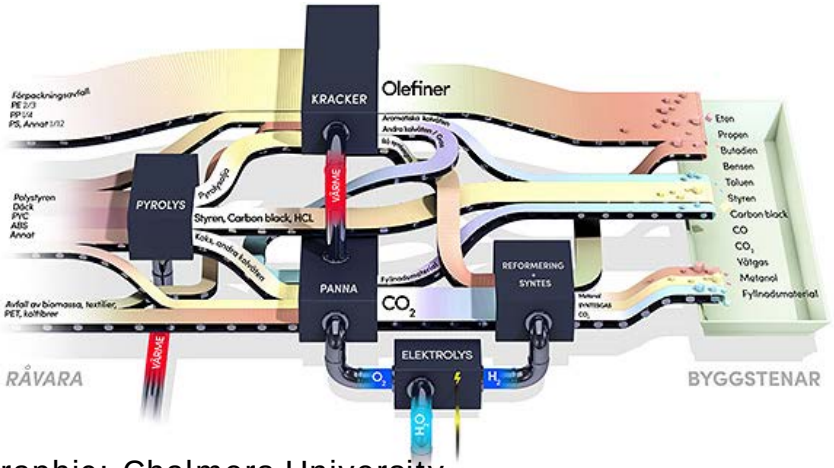
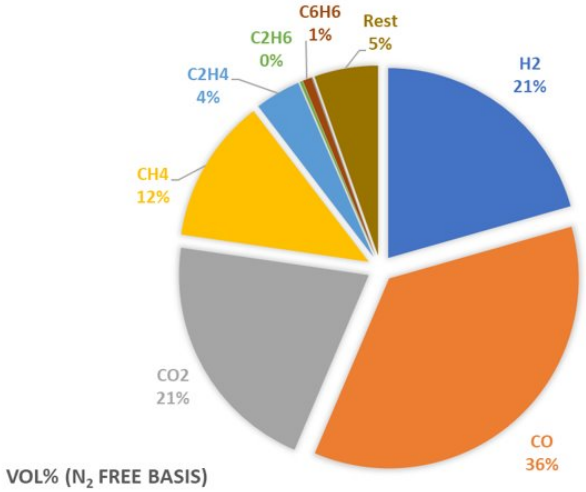
Refinery application



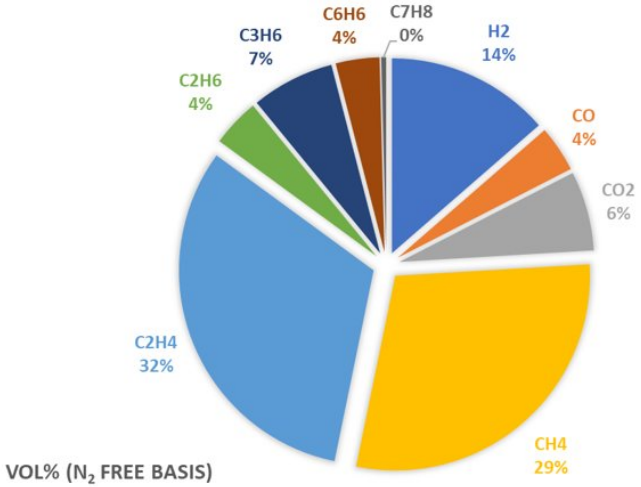
Graphic: Chalmers University

Gasification of beech wood



Source: TNO

Gasification of DKR310



Source: TNO

Gasification as a supplement to pyrolysis processes. Providing input to refinery processes

IEA Bioenergy

www.ieabioenergy.com

Höganäs AB – Steel industry

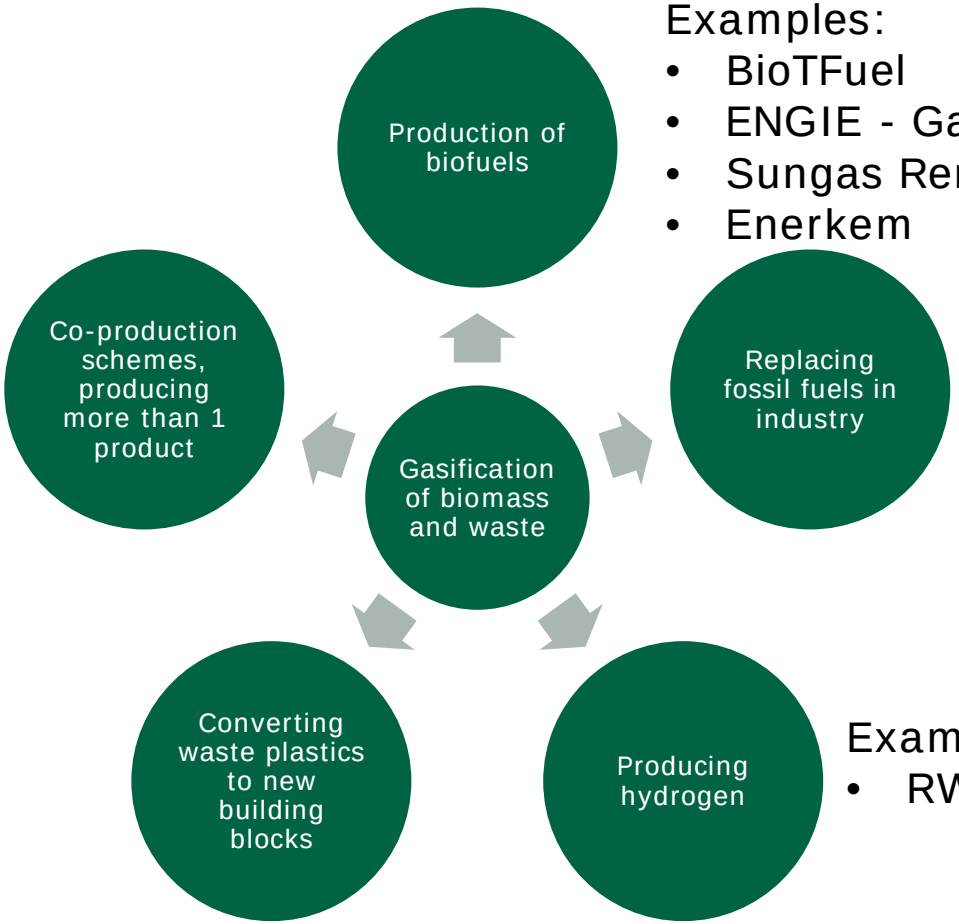
- At Höganäs AB a 14 (m) high gasifier is used to produce a gas from forrest residues to replace natural gas.

- Technology used is from Cortus Energy. The 6 MW Woodroll

Photo: Cortus Energy

How will this develop

Examples:
- Mavitec
- Torrgas
- Syncraft
- Synova
- Many others

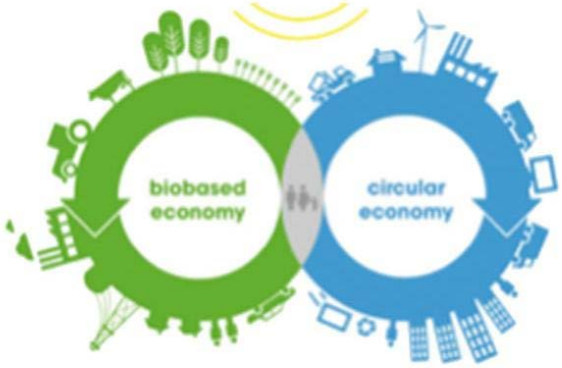


Examples:
- BioTFuel
- ENGIE - Gaya
- Sungas Renewables
- Enerkem

Example:
- RWE Furec

Conclusions

- Currently biofuels offer the possibility for gasification to grow; not in numbers, but in scale!
- Co-production is important in developing sound business cases (Dakota Gasification company)
- Gasification holds the key in unlocking the combination of a biobased economy and a circular economy



Warning!

- Gasification has so much potential to be applied in different fields of industry. On the one hand this will raise the expectations, whereas on the other hand people forget that the development pathways to these applications is not easy.
- This mismatch has led to good projects being stopped, not for technical reasons but mostly financial reasons.
- Gasification has the flexibility to change over time from one application to another. This strength can also be perceived as weakness, because it affects credibility.

Questions

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