Status report on thermal biomass gasification in countries participating in IEA Bioenergy Task 33

2016

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April 2016

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Executive summary

This report gives an overview on the thermal biomass gasification projects/facilities in countries participating in IEA Bioenergy Task 33 (Thermal gasification of biomass), their status, size and technology applied as well as detailed information concerning e.g. feedstock, output, etc.

The report is based on Country reports from member countries and interactive online database of thermal biomass gasification facilities, which is a part of the IEA Bioenergy Task website (www.ieabioenergytask33.org).

In Triennium 2013-2015 there were 10 countries participating in the Task 33:

- Austria
- Denmark
- Finland
- Germany
- Italy
- Sweden
- Switzerland
- The Netherlands
- Norway
- USA

The actual Country reports, which can be found at the Task 33 website (http://www.ieatask33.org/content/participants/country_reports), give an excellent overview about the status of thermal biomass gasification in each member country and inform about:

- Policy
- Programs
- R&D Institutes
- Industries
- Projects
- Implementations

This report gives a detailed overview about 86 commercial, demonstration and pilot facilities in IEA Bioenergy member countries. It was not possible to include all facilities because of a huge amount of small-scale facilities (e.g. there are over 140 Burkardt CHP gasifiers in operation at this time).

From the mentioned 86 thermal gasification facilities, there are 62 in operation, 5 under construction, 2 planned, 16 on hold and for 1 the status is not really clear.

Most of the facilities in this report (53) are combined heat and power (CHP). The second most common application of gasification is for synthesis purpose (18) and 15 facilities are mentioned as other gasification technology (e.g. flue gas (heat)).

The thermal gasification facilities for CHP production (53 facilities in this report) can be divided into 41 operational, 4 under construction, 7 idle and 1 no status.

The facilities for synthesis purpose (18 in this report) can be divided into 10 opearational, 2 planned and 6 idle.

The other facilities (15 in this report) can be divided into 11 operational, 1 under construction and 3 idle.

The Task 33 thermal gasification facilities database also includes some facilities which are not in member countries. These facilities are not included in the report.

It is necessary to point out that this report gives an overview on the status at the end of 2015 and that information may have changed since that time. For example, new facilities may have been built or facilities may have shut down with time.

1. Introduction

Thermal gasification of biomass can be seen as a partial solution to environmental problems, especially the accumulation of greenhouse gases in the atmosphere and saving fossil fuels, as well as waste disposal.

The future energy supply of mankind is characterised by increasing energy demand of the growing population, the limitation of fossil fuels and the impacts of energy utilisation on the environment. One possibility how to solve these problems is the use of renewable energy, such as wind and solar energy, utilisation of biomass etc.

At the website of IEA Bioenergy Task 33 an online biomass gasification facilities database can be found, which offers an overview about gasification facilities operating in Task 33 member countries. The database was created in close cooperation with IEA Bioenergy Task 39 (Commercializing Liquid Biofuels).

All the thermal biomass gasification facilities in the database can be divided by technology, type and status.

There are four technologies of gasification installations in the database; the biomass feedstock is used for these technologies respectively

- Fuel gas (heat)
- Power/CHP (combined heat and power)
- Fuel synthesis
- Other gasification technologies

Type/size of facilities in the database can be divided into

- TRL 9 Commercial
- TRL 6-7 Demonstration
- TRL 4-5 Pilot

Notice: **Technology Readiness Level** (TRL) is a method of estimating technology maturity of Critical Technology Elements (CTE) of a program during the acquisition process. They are determined during a Technology Readiness Assessment (TRA) that examines program concepts, technology requirements, and demonstrated technology capabilities. TRL are based on a scale from 1 to 9 with 9 being the most mature technology. The use of TRLs enables consistent, uniform, discussions of technical maturity across different types of technology

All gasification facilities can be divided also by status:

- Planned
- Under construction
- Stopped while under construction
- Commissioning
- Operational
- Non operational
- Idle
- No status

Table 1: Scope of projects under investigations

Project	Thermal biomass gasification with product gas as an output
Conversion technology	Thermochemical technology (gasification)
Raw material	Lignocellulosic biomass, waste
Product gas used for	Fuel gas (heat) Power/CHP Fuel Synthesis Other gasification technology
Type of facility	TRL 9 Commercial TRL 6-7 Demonstration TRL 4-5 Pilot
Status	Planned Under construction Stopped while under construction Commissioning Operational Non operational Idle No status
Minimum Data	Project owner Facility location Usage of product gas Raw material End product Output capacity Status
Optional Data	Additionally, project owners are asked to provide more detailed information, including brief technology description, flow sheet, photos, pictures, relevant publications etc.

2. Thermal gasification of biomass

2.1 Introduction

Mankind has used biomass energy or “bioenergy,” the energy from organic matter, for thousands of years, ever since people started burning wood to cook food and/or to keep warm.

Today, wood is still our largest biomass energy resource. But many other sources of biomass can now be used, including plants, residues from agriculture or forestry, and the organic component of municipal and industrial wastes.
Biomass refers to all forms of plant based material that can be converted into usable energy, such as wood, sugarcane, crop and forestry residues, etc.

Biomass offers considerable flexibility of fuel supply due to the range and the diversity of products that can be produced at small or large scales, in a centralised or dispersed manner. It can be burnt directly, converted to liquid fuels, anaerobically digested to produce biogas, or thermally converted, e.g. gasification.

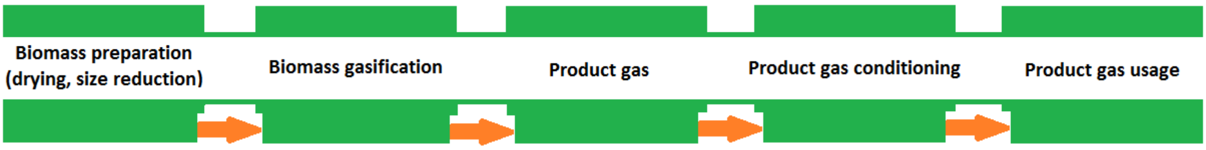

Figure 1: Process chain

2.2 Biomass preparation

Thermal biomass gasification takes place in a reactor called gasifier. Before entering the gasifier, the biomass has to be prepared for the gasification process, which involves being broken down to a suitable size and dried to suitably low moisture content. It should be also free from undesirable ingredients, such as stones or metals (e.g. waste wood), which could cause operational problems.

2.3 Process description

Thermal gasification is a complete thermal breakdown of the biomass particles into a combustible gas, volatiles and ash in an enclosed reactor (gasifier) in the presence of any externally supplied oxidizing agent (air, O_2, H_2O, CO_2, etc.) when equivalent ratio (ER) is < 1. ER = 1 if the stoichiometric amount of oxidising agent is present. Stoichiometric amount is the theoretical amount of air or any other oxidizing agent required to burn the fuel completely.

Gasification is an intermediate step between pyrolysis and combustion. It is a two-step, endothermic process. During the first step the volatile components of the fuel are vaporized at temperatures below 600°C by a set of complex reactions. No oxygen or other reactive agent is needed in this phase of the process.

Hydrocarbon gases, hydrogen, carbon monoxide, carbon dioxide, tar and water vapour are included in the volatile vapours. Char (fixed carbon) and ash are the by-products of the process which are not vaporized. In the second step, char is gasified through the reactions with oxygen, steam, carbon dioxide and/or hydrogen. In some gasification processes, some of the unburned char is combusted to release the heat needed for the endothermic gasification reactions.Main gasification products are gas, char, and tars. Gasification products, their composition and amount are strongly influenced by gasification agent, temperature, and pressure, heating rate and fuel characteristics (composition, water content, granulometry). Gaseous products formed during the gasification may be further used for heating or electricity production. The main gas components are CO, H_2, CO_2, H_2O, CH_4 and other hydrocarbons.

Following table shows the most important gasification reactions.

Table 2: Most important gasification reactions

Primary devolatilization				
Biomass	→	Primary tar (CH_xO_y) CO, H_2, CO_2, CH_4, C_2H_4, H_2O Carbon		[eq.1]
Tar cracking and reforming				
Primary tar	→	Secondary tar CO, CO_2, CH_4, C_2H_4, H_2		[eq. 2]
Homogenous gas-phase-reactions			**ΔH**	
Secondary tars	→	C, CO, H_2		[eq. 3]
H_2 + 0,5 O_2	→	H_2O	-242 kJ/mol	[eq. 4]
CO + 0,5 O_2	→	CO_2	-283 kJ/mol	[eq. 5]
CH_4 + 0,5 O_2	→	CO + 2 H_2	-110 kJ/mol	[eq. 6]
CH_4 + CO_2	→	2 CO + 2 H_2	+247 kJ/mol	[eq. 7]
CH_4 + H_2O	→	CO + 3 H_2	+206 kJ/mol	[eq. 8]
CO + H_2O	→	CO_2 + H_2	-40,9 kJ/mol	[eq. 9]
Heterogenous reactions				
C + O_2	→	CO_2	-393,5 kJ/mol	[eq. 10]
C + 0,5 O_2	→	CO	-123,1 kJ/mol	[eq. 11]
C + CO_2	→	2 CO	+159,9 kJ/mol	[eq. 12]
C + H_2O	→	CO +H_2	+118,5 kJ/mol	[eq. 13]
C + 2 H_2	→	CH_4	-87,5 kJ/mol	[eq. 14]

[eq. 4]	H2 – Combustion (oxidation)
[eq. 5]	CO - Combustion (oxidation)
[eq. 6]	CH4 - Combustion (oxidation)
[eq. 7]	Dry reforming reaction
[eq. 8]	Steam reforming methanisation
[eq. 9]	Water-gas-shift reaction
[eq. 10]	Oxidation of carbon
[eq. 11]	Partial oxidation
[eq. 12]	Boudoard equilibrium
[eq. 13]	Water gas reaction (steam reforming)
[eq. 14]	Methane production reaction

2.4 Types of gasifiers

In the past decades much R&D was done to develop special gasification systems to convert biomass to synthesis gas, or to adapt coal gasification technology for biomass. These systems can be divided into several groups according to:

- Design of reactor: fixed bed - fluidised bed - entrained flow
- Production and transport of the heat into the gasification reactor: allothermal – autothermal
- Type of gasification agent: air, oxygen, steam – mixtures of steam and oxygen

2.4.1 Fixed bed, fluidised bed, entrained flow gasifiers

According to the design of the fuel bed and the way how the fuel is brought into contact with the gasification agent, the gasifiers can be divided into:

- fixed bed
- fluidized bed
- entrained flow

The differences in the design of the gasification reactor are shown in the following figure.

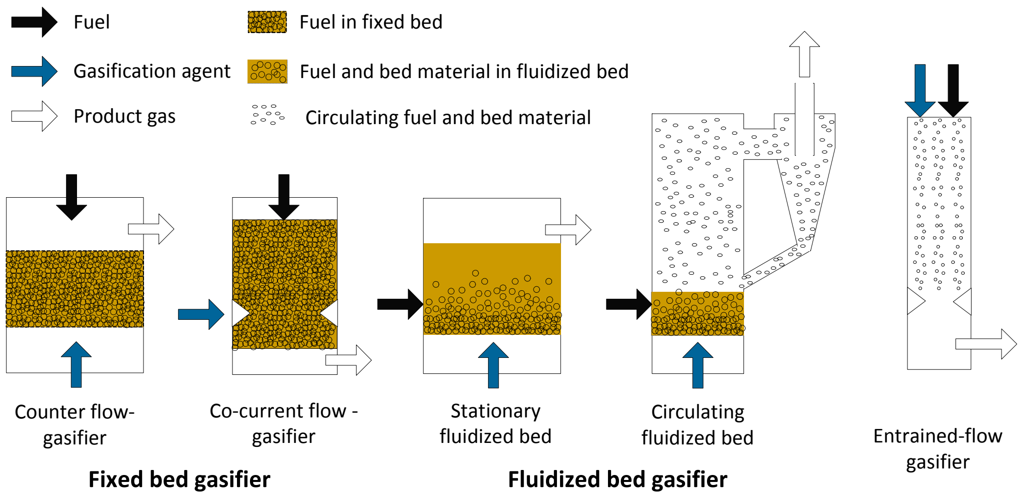

Figure 2: Different types of gasifiers

Fixed bed gasifiers can be divided into:

- updraft
- downdraft
- cross-draft

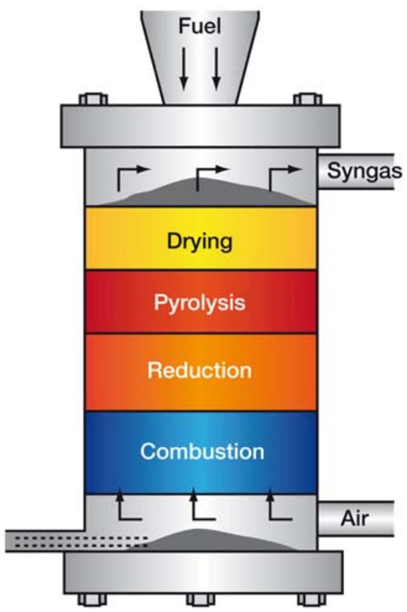

Figure 3: Fixed bed updraft gasifier [1]

An **updraft gasifier** has clearly defined zones for partial combustion, reduction, and pyrolysis. Air is introduced at the bottom and flows counter current to fuel flow. The product gas is drawn from the reactor at higher location. The updraft gasifier achieves the highest efficiency as the hot gas passes through fuel bed and leaves the gasifier at low temperature. The sensible heat given by gas is used to preheat and dry fuel.

These gasifiers are best suited for applications where moderate amounts of dust in the fuel gas are acceptable and a higher flame temperature is required.

In a **downdraft** gasifier, the feedstock enters from the top and gasification agent from the top or from the side. Product gas moves the same direction as gasification agent.

The produced gas leaves the gasifier at a high temperature, and most of this heat is often transferred to the gasification agent. Since all tars must pass through a hot bed of char in this configuration, tar levels are much lower than the updraft type.

The **cross-draft** gasifier is used mainly for the gasification of charcoal. Extremely high temperatures in the combustion zone (1,500°C or even higher) are associated with this gasifier, resulting in material selection challenges. However, this type of gasifier may be implemented at small scales (under $10kW_{el}$), hence it is suitable for de-central implementation.

Fluidised-bed gasifiers

In this gasifier type fluidizing agent is blown through a bed of solid particles at a sufficient velocity to keep these in a state of suspension. The bed is heated and the feedstock is introduced as soon as a sufficiently high temperature is reached. The fuel particles are introduced at the bottom of the reactor or they can be fed into the the bed or over the bed as well. The particles are very quickly mixed with the bed material and almost instantaneously heated up to the bed temperature. As a result of this treatment the fuel is pyrolysed very fast, resulting in a component mix with a relatively large amount of gaseous materials. Further gasification and tar-conversion reactions occur in the gas phase.

Fluidized bed gasifiers can better process materials with higher ash-content as typical for biomass and in general this type of gasifiers is better suitable for large-scale operations. The temperature within fluid-bed gasifiers is about 750°C-900°C. Due to this processing temperatures the tar-conversion rates are not very high. Other measures have to be taken in order to produce a tar-free gas.

Stationary (bubbling) fluidized bed gasifier (SFB or BFB)

In a stationary fluid-bed gasifier the bed material (e.g. silica sand, olivine, etc.) forms a suspended “bubbling” highly turbulent fluidized bed. The gasification agent enters the reactor at the bottom with speeds high enough to the set the bed material into fluidized conditions, but low enough not to carry away the bed material.
Due to these conditions the processed material (typically entering the reactor from the side) is optimally mixed with the hot bed material, leading to a fast pyrolysis as well as uniform conditions in the reactor. The pyrolysis gases together with the ash particles leave from the head space, or “freeboard” region, above the bed. Due to high temperatures, additional homogenous and heterogeneous reactions take place. The larger the head space available, the lower the amount of tar in the product gas. From the head space the gas typically enters an attached cyclone, where the ash and char particles are separated from the product.
The main advantages of this set-up are the intensive mixing in the bed, leading to uniform conditions in the reactor (is of significance in case of scale-ups), flexibility towards changes in moisture and ash in the processed material as well as the possibility to process materials with low ash melting point. A disadvantage is the high tar and dust content in the product gas requiring an appropriate gas cleaning, possibly incomplete char burn-out as well as high temperature of the product gas. For biomass feedstock with low ash melting point (below the

processing temperature) the use of fluidized bed gasifiers is not suitable due to a possible clustering of the bed material with ash, resulting in particle agglomeration and defluidisation of the bed.

Circulating fluidized bed (CFB) gasifier

The set-up of the circulating fluid-bed gasifier is similar to the stationary fluid-bed gasifier with the main difference that the gasification agent enters the reactor at velocities leading to carryover of the bed material. The bed material consists of particles with grain of 0,2-0,4mm. Comparing to the stationary fluidized bed (SFB) gasifiers, there is no bed surface observable. The bed material is distributed in the complete reactor with higher densities in bottom sections. The bed material as well as the ash are separated from the product gas in the cyclone stage and recycled back to the reactor.

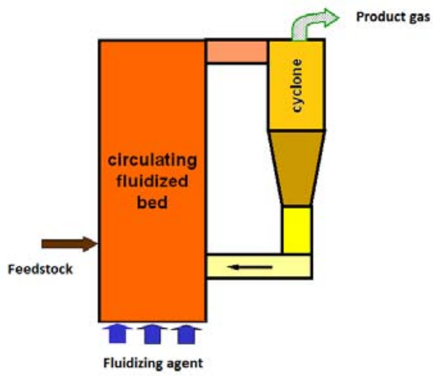

Figure 4: Circulating fluidized bed reactor

The main advantages and disadvantages of the CFB gasifier are similar to the SFB gasifiers. Beside this, the CFB has a higher cross-sectional capacity leading to even better up-scale capabilities of this technology.

Circulating fluidized two-bed gasifier

In the circulating fluidized two-bed gasifier, also called double bed gasifier, the circulating bed material is used as a heat carrier.

In this set-up the gasification is performed in one fluidized bed and the bed material is transferred into the second bed, where the necessary gasification heat is generated by combustion of a part of the processed material (e.g., unconverted char) or of external material. The heated-up bed material is transferred back to the gasification bed. The main advantages of this system are the possibility to optimize the combustion and gasification parts separately. Due to the separation of the two reaction spaces it is possible to run the combustion with air, while the gasification can be performed with an appropriate gasification agent, leading to better quality products than from air gasification. This set-up is the basis of several allothermal implementations of fluidized bed gasifiers.

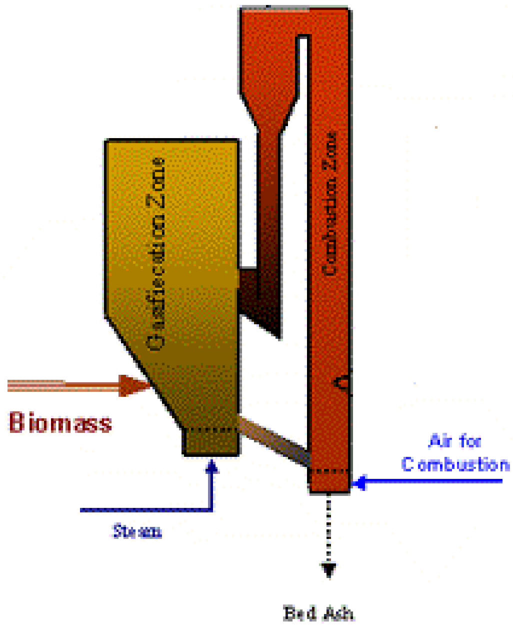

Figure 5: Circulating fluidized two-bed gasifier

As an example of the circulating fludized two-bed gasifier the gasification plant in Güssing, Austria can be mentioned.

Entrained Flow Gasifier

The principle of the entrained flow gasifier differs significantly from the gasifier types described previously. The processed material enters the gasifier at the top, together with the gasification agent. For some configurations, there may be an additional pilot flame providing the initial energy demand. Typically, the entrained flow gasifier is operated at high pressure (up to 100bar) and at high temperatures (up to 1 200°C or even higher). Due to these conditions, the gasification process takes place rapidly and the product gas is low in tar and methane content. The walls of the reactor may be refractory-lined, or they may be a steam- or water-cooled membrane wall reactor. For the membrane wall reactor, slag and ash proceeding from the top of the reactor build up a film, which protects the inner reactor surface from corrosion. Due to the high operation temperatures (above the ash melting point), the ash is removed in liquid form. However, typically the ash removal takes place after a cooling down of the product gas in water. Due to this feature, the entrained flow gasifier may be used for biomass feedstock with low ash melting point.

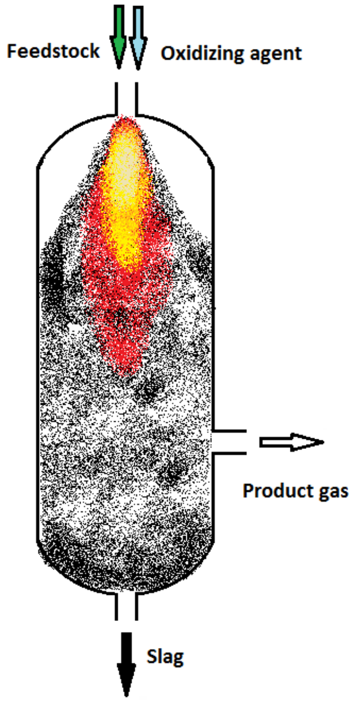

Figure 6: Entrained flow gasifier

Historically, the entrained flow gasifier has typically been used for the gasification of different feedstocks (crude oil, natural gas, and coal), but can be also used for bio syncrude oil from biomass pyrolysis or black liquor. However, in combination with an upstream low-temperature pyrolysis step this process may be applied to biomass material as well (a suitable external pilot flame may be required). In this setup, the pyrolysis gas from the low temperature step is used as auxiliary fuel and the pyrolysis char is the processed material.
The advantages of the entrained flow gasifier are the rapid flow rate within the reactor (typically retention times in seconds) and the high-quality product gas. The disadvantages are the severe conditions and associated challenges with materials of construction, the requirement for a pilot flame fuel of sufficient high quality, the requirement to pulverize the processed material (typically ~ 100µm, alternatively liquid or gaseous feed may be used) and to cool down the product gas for ash removal.[2]

2.4.2 Autothermal and allothermal gasifiers

Autothermal gasifiers *provide the necessary heat of reaction by means of partial oxidation within the gasification reactor. If air is used as oxidizing agent during the process, the product gas contains a high amount of nitrogen. So for synthesis gas production either pure oxygen (in entrained flow reactors) or mixtures of oxygen and steam (in fluidised bed reactors) are used as gasification agent.*

The great advantage of the autothermal gasification is the direct internal heating of the reactants and therefore more efficient energy utilisation. The process is simpler compared to allothermal gasification and thus also the process costs are lower.

On the other hand, the lower heating value (LHV) of the product gas is lower than with allothermal gasification. If the air is used as oxidizing agent, the LHV is about 4-6 MJ/Nm^3; if the mixture of oxygen and steam is used LHV about 10-12 MJ/Nm^3 can be reached.

Allothermal (or indirect) gasification is characterized by the separation of the processes of heat production and heat consumption. The allothermal gasification facility almost always consists of two reactors, connected by an energy flow. Biomass is gasified in the first reactor and the remaining solid residue (char) or product gas is combusted in the second reactor to produce the heat for the first process. The transport of the heat can be done either by circulating a bed material, or by heat exchangers.

Allothermal gasifiers generally produce two gas streams: a medium calorific product gas (gasification reactor) with little or no nitrogen and a flue gas (combustion reactor). The production of an N_2-free gas without the need of pure oxygen is one of the advantages over autothermal gasification processes. Another important advantage is the complete carbon conversion and that there is no problematic waste produced. All carbon containing streams from the product gas cleaning (e.g. dust, tars) can be recycled to the combustion zone and there converted to heat, which is used for the gasification reactions. The LHV of the product gas is about 12-14 MJ/Nm^3 if the steam is used as oxidizing agent.

2.4.3 Oxygen and steam blown gasifiers

The typical composition of a dry gas produced during the biomass gasification process is shown in the following table. As can be seen, the concentration of the gas compounds during oxygen and steam gasification is completely different. During oxygen gasification, the combustion products (CO_2, H_2O) are in the product gas and take part in the chemical reactions, mainly in water gas shift reaction.

On the other hand, a higher amount of hydrogen in the product gas can be found during steam gasification. The hydrogen found in the product gas does not originate only from the fuel as in the case of oxygen gasification, but also from the steam (H_2O).

Table 3: Typical ranges of product gas composition for selected gasifiers[3]

Compound		**Air gasification** **Fixed bed**	**Oxygen gasification** **Entrained flow**	**Steam gasification** **Fluidized bed**
CO	Vol. %	13-18	45-55	25-30
CO_2	Vol. %	12-16	10-15	20-25
H_2	Vol. %	11-16	23-28	35-40
CH_4	Vol. %	2-6	0-1	9-11
N_2	Vol. %	45-60	0-1	0-5
Calorific value	MJ/Nm^3	4-6	10-12	12-14

3. Product gas cleaning and upgrading

Product gas

The composition of the gas and the level of undesirable components (tars, dust, ash content) produced during thermal biomass gasification process are dependent on many factors such as feedstock composition, reactor type and operating parameters (temperature, pressure, oxygen fuel ratio, fluidizing agent, etc.).
The main components of the product gas are combustible and inert gases and undesirable impurities.

- Combustible gases - mainly:
  - hydrogen (H_2)
  - carbon monoxide (CO)
  - methane (CH_4)
  - short chain hydrocarbons

- Inert gases - mainly:
  - nitrogen (N_2)
  - carbon dioxide (CO_2)
  - steam (H_2O)

- Impurities – depending on the temperature:
  - Solid: ash, dust, bed material, alkali salts

- Gaseous: sulphur (e.g. CS, H_2S), nitrogen (e.g. NH_3, HCN…) and halogen compounds
- Liquid: at low temperature tar, at high temperature ash

Depending on the gas utilization concept, different contaminants have to be removed to reach the required quality of the gas. Additionally, the design of the gas cleaning system must be made in accordance to the overall conversion system. Typically, more than one cleaning step is necessary.

The composition of the product gas is a truly multi-dimensional problem: In the following paragraphs a selection of the main parameters and their influences on the product gas composition is given [2].

Gasification temperature

The increase of the gasification temperature leads to an increase of the reaction rates and associated faster time to reach chemical equilibrium. For low temperature systems (i.e. fixed and fluidized beds), increasing the temperature will in general lead to a shift in the gas composition towards higher H_2 concentration and lower CO and CH_4 content; the CO_2 concentration is typically not influenced by the temperature. For high temperature entrained-flow gasifiers, increasing temperature is achieved by increasing O_2/fuel ratio, so that both H_2 and CO decrease with temperature while CO_2 concentration increases. At high temperatures typically low tar concentrations are observed.

Gasification pressure

The influence of pressure on product gas composition is generally limited. For some fixed and fluidized bed systems, an increase of the pressure will lead to an increase of the concentration of the 3 and 4 atomic molecules (CO_2 and CH_4) and a decrease of the H_2 and CO concentrations.

Gasification agent

The use of air as gasification agent will lead to (usually unwanted) presence of nitrogen in the product gas, diluting the gas and reducing its heating value. The highest concentrations of H_2 may be achieved using steam as gasification agent. Hence by variation of the steam/O_2 ratio an influence on the H_2/CO ratio may be achieved.

Type of gasification reactor and the tar concentration

As the type of gasification reactor usually determines the reaction conditions, the above mentioned tendencies in terms of temperature and pressure may be observed. Beside this, the “alignment” of the reaction zones as well as the temperature in the reactor will determine the tar concentration. The highest tar concentrations are typically obtained in updraft gasifiers (see also corresponding section for explanation). Downdraft gasifiers (due to alignment of the reaction zones) as well as the entrained flow gasifiers (due to high reactor temperature) in general provide a product gas with low tar concentration. The tar concentration in the product gas of fluid-bed gasifiers will be intermediate.

Type of biomass used as fuel
Keeping all process parameters constant, the type of biomass used as fuel will have no or only a minor influence on the main product gas composition.
This is not true for the content of impurities: If the biomass feedstock contains for example nitrogen or sulphur, those elements will be found in the product gas in form of NOx, SOx, H_2S, NH_3, etc. In this case a suitable gas cleaning system has to be applied.

The ash softening point of the feedstock will influence the selection of the appropriate gasification technology. For example: using a fluid-bed gasifier with a temperature range above the ash softening point would lead to clumping and possible agglomeration of the bed material; hence a careful analysis of the feedstock prior to its gasification has to be performed.

After leaving the gasifier, the product gas has to be cleaned and perhaps upgraded in further processing steps. The following section focuses only on the typical requirements for the gas upgrading as required for bio-fuels production.

3.1 Gas cleaning

Reasons for gas cleaning are prevention of corrosion, erosion and deposits in the process lines as well as prevention of poisoning of catalysts. Following typical impurities can be found in the product gas. [2]

Dust and alkali metal compounds
Dust, ash, bed material and alkali metal compounds are removed from the product gas using cyclones and filter units.

Tar
Tars are high-boiling and highly viscous organic compounds, which condense at ~300 – 400°C. Tar removal is performed using physical methods, by cooling down the gas and performing a gas wash with special solvents (such as biodiesel) or through condensation in a wet electro filter. Currently under development are catalytic tar removal processes where the tar is converted to gaseous compounds such as H_2 and CO.

Sulphur compounds
The removal of sulphur compounds is crucial due to its catalyst poisoning effects. Typical sulphur tolerances of catalysts are well below 1 ppm. The sulphur removal can be performed by known methods such as Amine gas treating, Benfield process or similar.

Nitrogen and chloride (halides) compounds
Nitrogen and halide compounds may cause corrosion and / or act as catalyst poisons, hence an efficient removal using for example wet washing is required.
The amount of the mentioned impurities is strongly dependent on the applied gasification Technology. Obviously, the best strategy to minimize their amount is the application of favorable process conditions.

Gas cleaning for combined heat and power production (CHP)

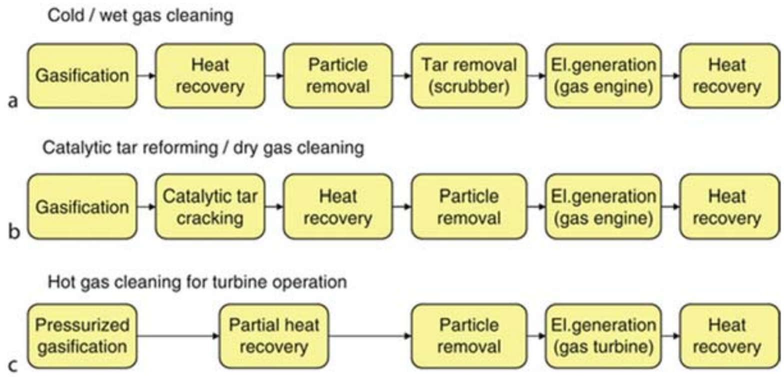

Figure 7: Typical process chain of gas cleaning for CHP applications

Cold gas cleaning is used frequently for small scale fixed bed gasification, hot gas cleaning is beneficial for pressurized gasification.

Gas cleaning for synthesis applications

Synthesis applications usually require catalytic conversion steps, more intensive cleaning etc. Especially H_2S and other organic sulphur compounds are catalyst poisons, so they must be removed to as low as < 1 ppm. Furthermore, CO_2 acts as an inert in many processes, making CO_2- removal desirable.
The additional gas cleaning steps have to be integrated into the above described cleaning concepts.

3.2 Gas upgrading

Several processes are subsumed under the term gas upgrading [2]:

<u>Water-gas-shift (WGS) reaction</u>
Using the (reversible) water-gas-shift reaction:

$CO + H_2O \leftrightarrow CO_2 + H_2$

the CO / H_2 ratio may be modified in order to obtain the typically required ratio of
H_2 / CO = 1.5 to 3.0. This can be achieved in catalytic reactors typically employing iron or copper-based catalytsts.

<u>Gas reforming</u>
Using gas reforming reactions, short-chain organic molecules may be converted to CO and H_2 through endothermic reactions such as the example for methane:

$CH_4 + H_2O \rightarrow CO + 3\ H_2$

<u>Removal of inert gas fractions – mainly CO_2</u>

CO_2 is on one hand inert in the subsequent synthesis reactions; however, it will increase required volume, load and energy demand for downstream systems (for example for compression steps), hence a removal is advantageous. CO_2 removal can be performed by

- physical methods: absorption to water or other solvents such as polyethylene-glycol (trade name "selexol") or cold methanol (trade name "Rectisol")
- chemical methods: chemical glycol or ethanolamine based absorbents
- other methods such as Pressure Swing Adsorption or Temperature Swing Adsorption

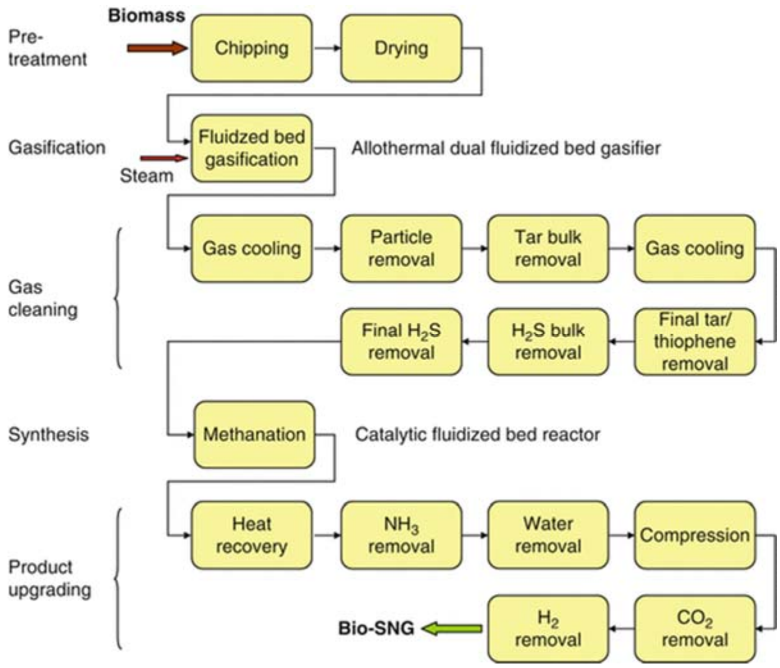

Figure 8: Example of process chain for Bio-SNG production

Methane and higher hydrocarbons normally act as inert during the synthesis reactions, so they have to be treated similar to inerts. These components are mainly present in fluidised bed reactors and not in high temperature gasification. As the heating value of the hydrocarbons is much higher than of H_2 and CO, already a small amount of hydrocarbons in the gas can contain much energy of the synthesis gas. So, the overall conversion from biomass to final product (e.g. FT liquids) is reduced by already small amounts of hydrocarbons produced in the gasifier. Therefore, in most cases the hydrocarbons are converted in a reformer to H_2 and CO, to maximise the conversion from biomass to the final desired product. The only exeption is the production of BioSNG. Here, a high content of methane and non-tar hydrocarbons in the synthesis gas are favoured, as then the highest conversion efficiency to BioSNG is achieved.

Catalyst poisons deactivate the synthesis catalyst and have to be removed to very low levels. The most well-known poison is sulphur, which can be in form of H_2S, COS, mercaptans or thiophens in the synthesis gas. The organic sulphur components are mainly present in fluidised bed gasifiers, and not in high temperature gasification. So, the removal technology has to be adapted to the type of the sulphur components, as e.g. thiophens cannot be removed by ZnO adsorbers.

Almost all synthesis reactions occur under elevated pressure and the synthesis gas has to be compressed during the gas treatment. By the choice of a pressurized gasifier, the electricity consumption of the compressor can be reduced or avoided. Until now only oxygen or oxygen/steam blown gasifiers have been operated under elevated pressure, and for these the investment and operation costs for an air separation unit have to be taken into account. For this reason, for small scale applications (< 100MW fuel input), mainly indirect atmospheric gasifiers are considered, to avoid the costs of the oxygen production.

The choice of the gasification reactor is not easy, as it influences the whole conversion chain. For example, the gas treatment has to be adjusted to the type of gasifier and the synthesis should also fit to the properties of the synthesis gas (e.g. H_2:CO ratio, amount of inerts). Up to date no single "winner" can be identified and R&D on the different types of conversion chains from biomass to transportation fuels and chemicals continues.

4. Product gas applications

The gas from thermal biomass gasification is very valuable product, which can be used in many ways. The most common ways are described below.

4.1 Co-firing

Cofiring is the combustion of two different types of materials at the same time. One of the advantages of cofiring is that an existing plant can be used to burn a new fuel, which may be cheaper or more environmentally friendly.

The co-firing systems, according to the current state of the art and the future perspectives, can be divided into direct and indirect cofiring technologies.

Direct cofiring refers to those systems where combustion of two or more fuels takes place in the same combustion device or boiler simultaneously. The secondary fuel (biomass, waste) may be either mixed with the primary fuel (e.g. coal) before the combustion starts or fed by a separate device, e.g. specific biomass burners. Direct biomass cofiring systems entail advantages of simplicity and economics. However direct cofiring systems are also more sensitive to variations in fuel quality and heterogeneity. Additionally, other problems limit the rate of secondary fuel replacing the original fuels. For example, ash deposition (fouling and slagging) and corrosion usually increase with the use of biomass and wastes replacing coal, what may shorten the lifespan of some components.

Indirect cofiring, on the contrary, separates the combustion/gasification of both solid fuels, though combustion/product gasses may be mixed afterwards.

Indirect cofiring systems usually involve more complex and expensive solutions, but they also usually reduce problems related with corrosion, fouling, slagging, etc. This, a priori, allows cofiring rates larger than direct systems, that is, larger percentages of coal substituted by biomass or waste. In addition, indirect cofiring systems are in general better for fuel mixtures where secondary fuel may include potential contaminants like heavy metals or other dangerous inorganic compounds.

4.2 Combined heat and power generation (CHP)

Cogeneration or combined heat and power (CHP) is the use of a heat engine or power station to simultaneously generate electricity and useful heat.

The product gas is filtered to remove particulates, cooled to drop out any moisture and then run to a reciprocating engine which drives a generating set to produce electric power.

Combined heat and power (CHP) technologies based on biomass combustion and gasification have been developed intensively over the past ten years. Typical fields of application for these CHP technologies are wood-processing industries, district heating systems and industries with a high process heat or cooling demand. These applications represent a great market potential in Europe as well as worldwide.

CHP technologies based on biomass combustion and gasification offer great potential to reduce CO_2 emissions since they are based on the utilisation of renewable energy sources. Now there are over 200 commercial gasification facilities, mainly small-scale gasifiers for CHP production.

4.3 Fuel synthesis

The actual R&D on applications for synthesis gas from biomass is mainly focused on transportation fuels and only very little on chemicals. Most of the R&D is done on Fischer Tropsch, hydrogen, methanol (including MtG, MtD, MtO, DME), ethanol, mixed alcohols and SNG. Therefore, in the following, a short description of the different synthesis technologies is given. [4]

Requirements on the gasification reactor for synthesis

To use the product gas from a biomass gasifier as synthesis gas, there are several properties, which have to be taken into account:

- H_2:CO ratio
- Amount of inerts, like nitrogen
- Amount of methane and higher hydrocarbons
- Catalyst poisons like sulphur-, nitrogen- and chlorine components
- Operation pressure

Synthesis gas consists mainly of hydrogen and carbon monoxide. In some cases also small amounts of carbon dioxide or methane are present. For most synthesis a H_2:CO ratio of 2 is required. This ratio is normally adjusted in a separate catalytic reactor before the synthesis reactor, where some CO is converted to hydrogen by the water gas shift reaction. If the gasifier produces already the correct H_2:CO ratio, the exothermal water gas shift reaction can be avoided, which reduces investment and operation costs and also increases the efficiency.

Impurities like nitrogen act as inert during the synthesis and their concentrations have to be as low as possible. The inerts reduce the partial pressures of the reactive species H_2 and CO and by this effect reduce the conversion. Especially for synthesis reactions, where the product is separated as a liquid and where a recycle of remaining unconverted gas is performed (e.g. methanol), the inerts have to be bled off as they would otherwise be accumulated. Also for production of BioSNG the inerts have to be below 1 vol%, as otherwise the heating value of the BioSNG will not fulfil the requirements of natural gas.

4.3.1 Fischer Tropsch synthesis

Fischer–Tropsch (FT) synthesis is based on the conversion of a mixture of carbon monoxide and hydrogen into liquid hydrocarbons.

The FT synthesis can be represented by following chemical reactions:

$$(2n+1)H_2 + nCO \rightarrow C_nH_{(2n+2)} + nH_2O$$

$$2nH_2 + nCO \rightarrow C_nH_{2n} + nH_2O$$

The process, a key component of gas to liquids technology, produces synthetic fuels and chemicals from biomass (but also coal or natural gas is used in large scale).

Depending on the temperature, the process can be divided into Low-Temperature (LTFT, 200-260°C) and High-Temperature (HTFT, 300-350°C) Fischer-Tropsch synthesis.

During the LTFT (up to 260°C) a higher fraction of higher-boiling hydrocarbons (above 360°C) is produced. Also the total distillate yield is higher than during HTFT. Higher temperature leads to faster reactions and higher conversion rates but also tends to favor methane, olefin and aromatics production. Typical pressures range is from one to several tens of atmospheres. Increasing the pressure leads to higher conversion rates and also favors formation of long-chained alkanes, both of which are desirable. Even higher pressures would be favorable, but the benefits may not justify the additional costs of high-pressure equipment and costs for pressurizing.

A variety of catalysts can be used for the Fischer–Tropsch process, but the most common are the transition metals such as cobalt, iron, and ruthenium. Nickel could also be used, but tends to favor methane formation. In LTFT cobalt or iron based catalyst are mostly used, whereas in HTFT only iron based catalysts are used.

The advantage of the cobalt based catalysts is a much longer lifetime. Less unsaturated hydrocarbons and alcohols are produced compared to the iron based catalysts. On the other hand, iron based catalysts are more tolerant to sulphur and can be also used to adjust the H_2:CO ratio, if it is lower than 2, by means of the water-gas shift reaction.

4.3.2 Hydrogen production

Hydrogen can be produced from the gasification product gas through the steam reforming and water-gas shift reactions. Using a dual fluidized bed gasification system with CO_2 adsorption along with suitable catalysts, it is possible to achieve a hydrogen yield up to 70 vol% directly in the gasifier.

Furthermore, the costs of hydrogen production by biomass gasification in very large scale are competitive with natural gas reforming.

Hydrogen is one of the most promising energy carriers for the future. Therefore, it is expected that biomass gasification processes will be available for large-scale hydrogen production.

Several investigations on hydrogen production methods have been conducted over the past several decades. Biomass is potentially a reliable energy source for hydrogen production. It is renewable, abundant, easy to use and CO_2 neutral.

4.3.3 Methanol production

Methanol, also known as methyl alcohol, wood alcohol, or wood spirits, is often abbreviated as MeOH. It can be produced from fossil or renewable resources and can be used either directly as a transportation fuel, or can be converted further to hydrocarbons.

Methanol is produced from synthesis gas by the hydrogenation of carbon oxides over a suitable catalyst (e.g., copper oxide, zinc oxide, or chromium oxide-based):

$$\mathbf{CO + 2H_2 \leftrightarrow CH_3OH}$$

$$\mathbf{CO_2 + 3H_2 \leftrightarrow CH_3OH + H_2O}$$

The first reaction is the primary methanol synthesis reaction. A small amount of CO_2 in the feed (2-10%) acts as a promoter of this primary reaction and helps maintain catalyst activity. The stoichiometry of both reactions is satisfied when R in the following relation is at least 2.03. In many cases H_2 builds up in the recycle loop, which leads to an actual R value of the combined synthesis feed (makeup plus recycle feed) of 3 to 4.

$$R = \frac{H_2 - CO_2}{CO + CO_2}$$

The methanol synthesis reactions are exothermic and give a net decrease in molar volume. Therefore, the equilibrium is favoured by high pressure and low temperature. During production, heat is released and has to be removed to maintain optimum catalyst life and reaction rate. Typically, about 0.3 % of the produced methanol reacts further to form side products as dimethyl ether, formaldehyde or higher alcohols.

The catalyst deactivates primarily because of loss of active copper due to physical blockage of the active sites by large by-product molecules, poisoning by halogens or sulphur in the synthesis gas, which irreversibly form inactive copper salts, and sintering of the copper crystallites into larger crystals, which then have a lower surface to volume ratio.

Conventionally, methanol is produced in two-phase systems: the reactants and products forming the gas phase and the catalyst being the solid phase. The production of methanol from synthesis gas was first developed at BASF in 1922 Germany. This process used a zinc oxide / chromium oxide catalyst with poor selectivity, and required extremely vigorous conditions—pressures ranging from 300–1000 bar, and temperatures of about 400 °C. In the 1960s and 70s the more active Cu/Zn/Al catalyst was developed allowing more energy-efficient and cost-effective plants, and larger scales. Processes under development at present focus on shifting the equilibrium to the product side to achieve higher conversion per pass. Examples are the gas/solid/solid trickle flow reactor, with a fine adsorbent powder flowing down a catalyst bed and picking up the produced methanol; and liquid phase methanol processes where reactants, product, and catalyst are suspended in a liquid. Fundamentally different could be the direct conversion of methane to methanol, but despite a century of research this method has not yet proven to be economically feasible.

Methanol to diesel

The MTD process first converts methanol into propylene, this is followed by olefin oligomerization (conversion to distillates), then product separation-plus-hydrogenation.

The process yields mostly kerosene and diesel, along with a small yield of gasoline and light ends. The near-zero sulphur / polyaromatics diesel fuel resulting from this process differs from more conventional Fischer-Tropsch diesel only in cetane numbe (>52 via "Methanol-to-Synfuel" versus >70 cetane for FT diesel). The incidental gasoline stream can not only be near-zero sulfur, but can also have commercial octane ratings (92 RON, 80 MON) and maximally 11 % aromatics.

Methanol to gasoline

In the 1970s, Mobil developed and commercialised a methanol to gasoline (MTG) process. A plant was built in Montunui / New Zealand in 1985 and sold to Methanex. It produced gasoline until 1997 when the plant was permanently idled. If the gasoline is to be sold without additional blending, then further treating is necessary to reduce the amount of benzenes.

Methanol to olefins

Methanol-to-olefin synthesis is a commercially attractive process, because of the high-demand of propylene and ethylene on the market. Nowadays, these compounds are produced mainly through the non-catalytic steam cracking of fossil fuels (naphtha). The methanol-to-olefin (MTO) process, however, uses zeolite-based catalysts that efficiently convert methanol into propylene and ethylene.

Dimethyl ether

Dimethyl ether (DME, CH_3OCH_3) is generally produced by dehydration of methanol. In actual R&D projects, the methanol production and dehydration processes are combined in one reactor, such that DME is produced directly from synthesis gas slightly more efficiently than methanol. In addition, the direct synthesis of DME allows H_2:CO ratios of about 1, which is an advantage for oxygen blown gasifiers.

Like methanol, DME has promising features as fuel candidate with both the Otto and the diesel engine. With adaptations to engine and fuel system, DME can be used in diesel engines, leading to higher fuel efficiency and lower emissions. In Otto engines, DME can be used with LPG. Since DME is as easily reformed as methanol, it has a big potential as fuel of fuel cell vehicles. DME has physical properties similar to LPG and can be handled as a liquid, using the same infrastructure as LPG.

4.3.4 Mixed alcohols

The catalytic conversion of synthesis gas to mixed alcohols is nowadays of great importance because mixed alcohols are valuable additives to gasoline to increase the octane number and reduce environmental pollution. Furthermore, a great benefit of the mixed alcohol synthesis is the high resistance of the catalysts against sulphur poisoning and the fact that the gas cleaning facilities can be simpler compared to other syntheses. Mixed alcohols can be also converted to high quality fuels through dehydration and oligomerization.

Normally, the alkali-doped oxides (zinc and chromium oxides) and alkali-doped sulfides (molybdenum sulfides) are used for mixed alcohols synthesis. Depending on process conditions and catalysts, the main primary products are generally methanol and water. Ethanol, propanol, butanol etc. are produced through methanol synthesis followed by its successive homologation. The reaction of the mixed alcohols synthesis is shown below.

$$nCO + 2nH_2 \rightarrow C_nH_{2n+1}OH + (n-1)H_2O$$

Due to reaction stoichiometry the proposed H_2-to-CO ratio is 2, but the ideal ratio is closer to 1 because of the water gas shift reaction.

4.3.5 Bio-SNG

Natural gas that is produced from coal or biomass is known as “synthetic natural gas” or “substitute natural gas” (SNG). The typical catalyst for methanation is nickel and the main reaction is

$CO + 3H_2 \rightarrow CH_4 + H_2O$

Ni-based catalysts are also active in water-gas shift and hydration of higher hydrocarbons, like olefins. Normally a H_2:CO ratio of 3 is necessary, which is achieved in a water gas shift reactor before the methantion. In some types of reactors, e.g. fluidized beds, the water gas shift can be done also in parallel with the methanation, so no external adjustment of the H_2:CO ratio is necessary. The methanation can be done at atmospheric pressure, although from the thermodynamics higher pressure is preferred.

As Ni-based catalysts are sensitive to sulphur poisoning, gas treatment before the methanation is quite important, and sulphur compounds have to be removed to below 0.1ppm.

There is one main difference in the synthesis gas treatment compared to other synthesis. Almost all gasifiers have some methane in the product gas, depending on the operation temperature. As methane does not have to be converted for methanation, high methane content in the synthesis gas is a big advantage for the production of BioSNG (the overall efficiency is higher, the higher the methane content in the product gas is). So, indirect gasifiers, which have a methane content of 10 vol% or more, are especially advantageous for methanation.

The most notable commerical plant for producion of SNG from biomass is the GoBiGas plant in Gothenburg, Sweden.

5. Highlights of thermal biomass gasification

In this chapter, the most important commercial facilities as references for the thermal biomass gasification are presented.

5.1 Thermal biomass gasification in large scale

FICFB gasification in Güssing [5]

In the year 2002 an 8 MW CHP plant based on a fast internal circulating fluidized bed (FICFB) steam blown gasifier producing heat and power (4.5 MWth, 2 MWel) with a gas engine went into operation in Guessing, Austria. At the middle of 2002 the gasifier and the gas cleaning system was coupled with the gas engine. Renet-Austria, a competence network on energy from biomass, consisting of experts from universities and industry, started to develop this process further to a commercial stage. During the last years a lot of improvements were incorporated into the system. These improvements were connected on the one hand with changes in construction (e.g. feeding system, online particle separation) and on the other hand with advances in the operation performance.

Due to the excellent performance that was reached during the last years, several additional research projects were initiated in Güssing. The synthesis gas from the circulating allothermal fluidized bed gasifier is nearly free of nitrogen and has an high hydrogen content. For this reason it is well suited for fuel cells as well as several synthesis products. Therefore, projects aiming at the development of processes for the production of hydrogen and Fischer Tropsch liquids are currently being carried out.

Gasification process

In Güssing an innovative process for combined heat and power production based on steam gasification has been successfully demonstrated. Biomass is gasified in a circulating dual fluidised bed reactor. The product gas is cooled, cleaned (2 stages) and used in a gas engine to produce electric power.

Wood chips from forestry are the main fuel for the demonstration plant. The wood trunks are dried naturally by storage of about 1-2 years in the forest. Then they are delivered to the CHP-plant and chipped there. When the biomass is used, it has a water content of about 25-40%.

The heat produced in the process is partly used internally, e.g. for air preheating, steam production, etc., and the rest is delivered to an existing district heating system. The net electricity produced is delivered to the electrical grid.

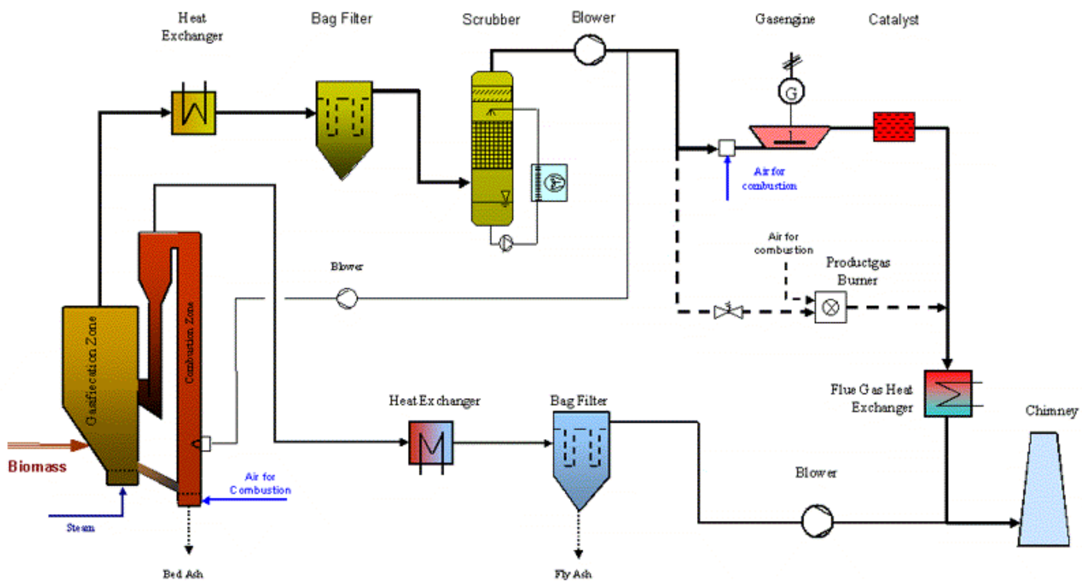

Figure 9: FICB Güssing – flow sheet

Biomass chips are transported from a day stoarge hopper to a metering bin and fed into the fluidised bed reactor via screw feeders. The fluidised bed gasifier consists of two zones, a gasification zone and a combustion zone. The gasification zone is fluidised with steam, which is generated by waste heat of the process, to produce a nitrogen free synthesis gas. The combustion zone is fluidized with air and delivers the heat for the gasification process via the circulating bed material.

Gas cooling and cleaning

A water cooled heat exchanger reduces the temperature from 850°C – 900°C to about 150°C – 180°C. The synthesis gas is cooled and cleaned by a two stage cleaning system. The first stage of the cleaning system is a fabric filter to separate the particles and some of the tar from the synthesis gas. These particles are recycled to the combustion zone of the gasifier. In a second stage the gas is liberated from tar by a scrubber.

Spent scrubber liquid saturated with tar and condensate is vaporized and fed for thermal disposal into the combustion zone of the gasifier. The scrubber is used to reduce the temperature of the clean synthesis gas to about 40 °C. The clean gas is finally fed into a gas engine to produce electricity and heat. If the gas engine is not in operation the whole amount of synthesis gas can be burned in a backup boiler to produce heat.

The flue gas of the gas engine is catalytically oxidized to reduce the CO emissions. The sensible heat of the engine's flue gas is used to produce district heat. The flue gas from the combustion zone is used for preheating air, superheating steam as well as to deliver heat to the district heating grid. A gas filter separates the particles before the flue gas of the combustion zone is released via a stack to the environment. The plant fulfils all emission requirements. The operation experience shows that there is only one solid residue which is the fly ash from the flue gas. This fly ash is fully burned out, with the carbon content as determined by loss of ignition lower than 0.5 w- %. The plant produces no condensate which has to be disposed externally.

Reduction of operation means

For the gasifier a circulating fluidized bed technology is applied. This means tha bed material which has limited attrition rate during operation is necessary. This attrition rate and therefore the loss of the bed material depends mainly on the kind of the material, the velocities of the riser, and the separation efficiency of the cyclone. On the base of the operation experience, some simulation work, and optimization of these parameters a reduction of the bed material loss by more than 70 % could be obtained.

Another material necessary for the operation is the so-called precoat material. This precoat material is necessary to avoid condensation of tar compounds directly on the filter bag, which could lead to plugging or even to damage of the filter cloth. At the beginning a swing operation with two filters (one in operation mode, on-line, another in pre-coating mode, off-line) was applied. Now this operation mode has been changed to an online operation, which works without any problems. This leads to a dramatic reduction in the need of the precoat material down to about 20 % of the original amount and also to a reduction in the nitrogen consumption.

The scrubber for the tar separation is operated with biodiesel. The spent biodiesel together with some condensate is fed into the combustion chamber of the gasifier. With this scrubber the overall tar in the synthesis gas can be reduced over 90 %. The operation experience leads to a slight reduction of the biodiesel required of about 25 %. The general aim of all these efforts is the reduction of the costs and therefore the improvement of the economy of the plant.

Research projects

The favourable characteristics of the product gas (low nitrogen content, high hydrogen content, H2:CO ratio of 1.6 – 1.8) allow also other applications of this synthesis gas. Research projects concerning the production of electricity in a SOFC (solid oxide fuel cell), the synthesis of SNG (synthetic natural gas), and Fischer-Tropsch liquids and have been started.

The following figure gives an overview about possible applications of the synthesis gas from a steam blown gasifier.

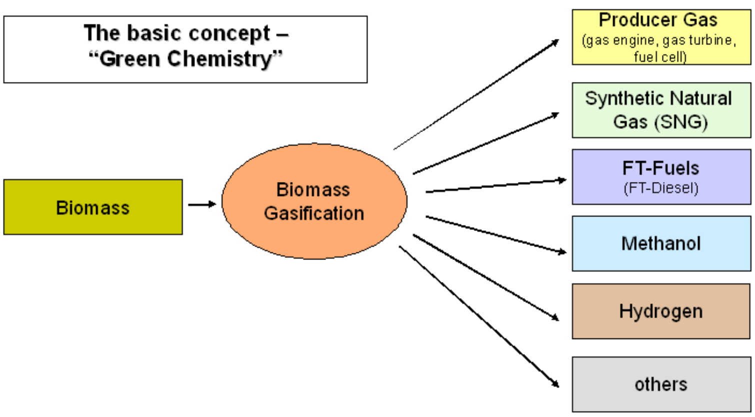

Figure 10: Possibilities of applications of the product gas from FICFB Güssing

Status since 2009

In 2009 Renet Austria and the Austrian Bioenergy Centre merged together and formed BIOENERGY2020+, a centre of excellence, funded by the COMET programme from Austria. With the support of BIOENERGY2020+ a new Technikum center was erected, where now R&D on FT, mixed alcohols or hydrogen is carried out.

Figure 11: Site in Güssing

Based on the technology of the FICFB plant in Güssing, further plants in Oberwart, Senden (Germany), Gothenburg (Sweden), Burgeis (Italy) and Gaya (France) have been built.

Gothenburg Biomass Gasification Project, GoBiGas [6]

In the 1980’s a national natural gas grid was built in southern and western parts of Sweden, with natural gas from Denmark. This network is an important part of the conversion to renewable energy. Gothenburg Energy has invested heavily in biogas and sees biogas as one of tomorrow's most important energy sources. A major benefit of biogas is that you can use the existing natural gas grid for distribution. Natural gas is becoming a bridge over to the renewable biogas.

Gothenburg Biomass Gasification Project, GoBiGas, is the name of Göteborg Energi's large investments in biogas production by gasification of biofuels and waste from forestry. GoBiGas was granted financial aid of 222 million for the first stage of 160 GWh output from the Swedish Energy Agency, as one of three selected biofuel projects, subject to acceptance from the European Commission in relation to state aid regulations. Stage 2 received a grant of 58,8 million Euro from the NER300 program in 2012, but it was not realized (see bellow).

Biogas replaces natural gas – biomass becomes biogas

The purpose of the GoBiGas biogas project is to produce biomethane (Bio-SNG) by thermal gasification of forest residues as branches, roots and tops. The biomass is converted to a flammable gas in the gasification plant. This so-called synthesis gas is purified and then upgraded in a methanation plant to biogas with a quality comparable to natural gas to enable the two types of gases to be mixed in the gas network, until the natural gas is phased out. Since biogas is produced from renewable sources it does not contribute to the climate change by increasing emissions of carbon dioxide as fossil fuels do.

GoBiGas is based on novel technology

In spring 2006, Göteborg Energi conducted a feasibility study with Swedish and Dutch expertise in order to compare the technology and economics of two gasification technologies, indirect gasification and pressurized oxygen blown gasification. In 2007 in-depth studies of various gasification technologies were carried out with multiple suppliers. The choice fell on indirect gasification with technology from the Austrian company Repotec, based on technical and economic performance and operational experience.

Furthermore, Göteborg Energi cooperates on R&D, in particular with Chalmers University of Technology, and has invested in a research facility for indirect gasification constructed as an add-on to an existing 11 MW CFB biofuel boiler located at Chalmers University of Technology.

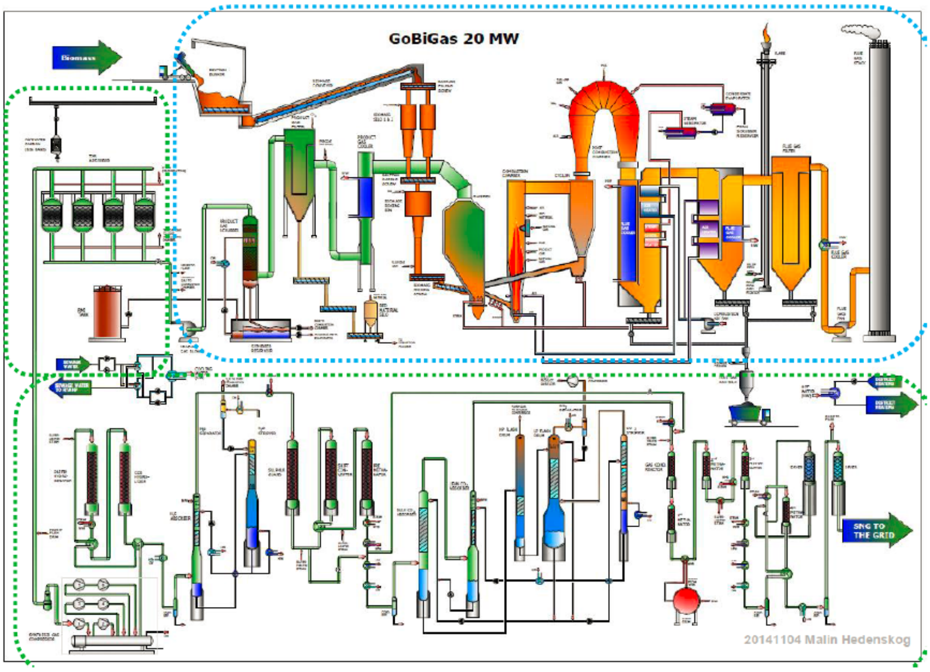

Figure 12: Biomass to SNG – GoBiGas project

The gasification plant was scheduled to be built in two stages, the first stage (about 20 MWgas) and a second stage (about 80-100 MWgas) to follow shortly after an evaluation period of the first plant.

In 2008/2009 a basic design of the proposed technique for stage 1 was developed. Repotec has built a small gas plant in Güssing, Austria, which has been in commercial operation since 2002, and on the same site, there is also a pilot methanation plant, based on technology from the Swiss company CTU. From October 2009 to January 2010 the GoBiGas project evaluated the technology by sending operational staff to this site.

At the end a competing technology from Haldor Topöe of Denmark was selected, while the supplier of the gasification plant was Valmet under a license from Repotec. The general engineering contractor was Jacobs Engineering of the Netherlands. The commissioning began in October 2013 and several difficulties had to be overcome until a more regular operation could be initiated in August 2015. In February 2016 it was announced that the plant was considered to be operational.

The second stage (about 80-100 MWgas) received a grant from the NER300 program, which originally was scheduled to be in service in 2016, was postponed indefinitely in December 2015 for economic reasons.

Localization in the Rya area on Hisingen

Stage 1 was built in the Rya harbour, on the same site as the existing Rya hot water plant and with other facilities of the company in the area, just off the Älvsborgs bridge. Stage 2 was planned to be built on the same site.

Figure 13: GoBiGas – foto

Status (beginning of October 2015)

- Gasifier operation approx. 9 000 hours
- MCR load proven on pellets
- Gas quality (relative to design values) good
- Pellets are very clean and generates certain specific issues
- Bed material activation has been a learning experience
- SNG product in a longer campaign in December 2014
- In 2015 periods of grid supply (days) on some occasions
- 60-70 % of design capacity
- 900 hours continuous run in August-September 2015 at 80 % load
- Biogas quality better than design specialization
- Overall efficiency during the long run close to target
- Installation of chip feeding equipment on-going

Skive plant [7]

At the Skive gasification demonstration project in Denmark, a bubbling fluidized bed (BFB) gasifier is used to produce gas from wood-based biomass. This gas is then used in of reciprocating engines in a combined heat and power (CHP) application.

Based on a low pressure BFB system and three gas engines, a single gasification plant supplies fuel to all the engines. The commissioning of the plant started in late 2007 and, using one gas engine, operations initially began in the early summer of 2008. The second and third gas engines were installed during summer 2008.

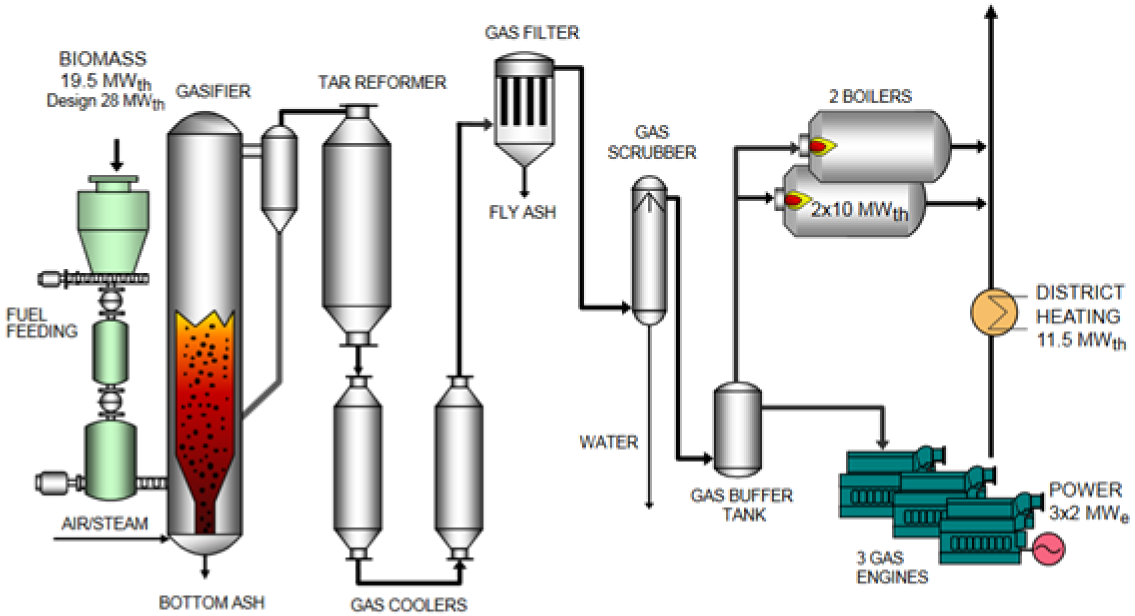

Figure 14: Skive plant – flow sheet

The project was financed on commercial basis, but as it is a first-of-a-kind demonstration facility, subsidies are provided by the EU, the US Department of Energy and the Danish Energy Agency (DEA).

The biomass gasification-gas engine concept was selected by Skive in 2004 because in small-scale decentralized CHP power generation, the electrical efficiency must be maximized to make the plant economically feasible. The gasification technology enables the plant to produce about 30% more electricity than a conventional steam process from the same amount of biomass.

The local district heating company, I/S Skive Fjernvarme, is the owner and also acted as the main contractor in the project, having responsibility for integrating the various component parts.

The gasification plant was supplied by Carbona, a subsidiary of pulp and paper technology firm Andritz Oy, which also possessed Circulating Fluidized Bed gasification technology (CFB). The scope of Carbona's supply contract included fuel feeding, gasification equipment, gas cleaning (tar reforming catalyst and filter), gas cooling and distribution systems. Meanwhile, GE Jenbacher AG/Austria supplied three of its JMS620GS-engines, specifically developed for low calorific gas combustion. The Technical Research Center of Finland (VTT) also acted as a subcontractor and licensed tar reformer technology to Carbona. VTT further participated in the design of the tar reformer and testing of the plant.

Operational characteristics

The gasification plant was designed to utilize wood pellets and/or chips. The moisture content of wood pellets is typically below 10%, while the moisture content of wood chips can be up to 30%. Fuel, initially pellets, is supplied from the existing indoor wood pellet storage site next to the gasification plant.

The fuel is fed through two lock hopper systems by feeding screws into the lower section of the gasifier's fluidized bed. The gasifier is operated at a maximum of 2 bar over pressure and 850°C temperature. Air is used as the gasification medium and dolomite is used as the fluidized bed material.

The product gas (dry gas after reformer) contains about 20% carbon monoxide (CO), 12% carbon dioxide (CO_2), 16% hydrogen (H_2) and 4% methane (CH_4) by volume. It has a heating value of about 5 MJ/kg.

In normal operations, the first step in the gas cleanup process is a novel catalytic cracker that reforms tar compounds generated during the gasification process to hydrogen and carbon monoxide. Next, the gas is cooled and passed through bag filters to remove dust. The filtered product is then scrubbed with water where it cools to 30 °C while the water content decreases. The heat from the gas removed in the scrubber is also used to generate district heat. The reheated gas of 80% relative humidity is then used in the internal combustion engines, each with a 2 MWe capacity.

Both the heat from gas engine cooling (lubrication oil and jacket cooling) and the exhaust gas is recovered for the production of district heat in separate heat exchangers. Product gas may also be utilized in two gas boilers of 10 MJ/s capacity to heat water for district heating or flared off in a possible emergency situation.

The plant is designed to operate at between 30% and 140% load, corresponding to 28 MW of fuel heat input. Operation with all three gas engines running at 13 bar is considered as 100% nominal load. Initially, the engines are expected to operate at 10 bar, corresponding to 80% load. The 130% load also corresponds to the full load operation of the boilers, which provide operational flexibility when the engines are not available due to regular maintenance.

The capacity of the CHP plant is controlled by the heat demand of the district heating network. The overall plant performance using wood pellets gives a maximum efficiency of 87%.

Commissioning, start up, and operations

Plant commissioning and cold testing started in September 2007 and the gasifier hot start-up and the first gasification were executed later that year. The start-up occurred stepwise with the gasifier–gas cooler–filter–and gas boiler process operated first, as an independent system, to verify the operation of the gas production system. Once this was supplying gas to the boilers and delivering district heating to the hot water network of the town, a new gas cleanup line was commissioned.

The performance of the gasification system was tested during spring 2008. Initially, plant sub-systems were optimized separately. Their integrated operation and the related optimization was conducted when the gasification plant, including the full gas cleanup train, first supplied gas to the boilers. During gas boiler tests, the product gas quality (all impurities and contaminants as specified by the gas engine vendor) was measured in detail. Based on the measured results it was decided to launch the gas engine operation with a single unit. The engine achieved full load, grid-connected operation after a few days. After start-up of the first engine, in May 2008, the most important operational considerations were evaluated.

The results achieved so far showed that the gasifier system design is highly suitable for this type of application. The gasifier is working as predicted and the raw gas quality including the gas heating value corresponds well with the original design requirements. The gas cleaning system has also been thoroughly tested, showing that the required gas quality has been achieved.

Demonstration plant challenges

The experience with the Skive plant demonstrates that the path from a pilot plant to a demonstration plant is a difficult one – long, arduous, and full of challenges. The technical challenges have included: scale-up from pilot to commercial, a lack of long-term data, integrated plant control, missing detail from design information, and a long and costly commissioning period requiring extensive measurement and testing.

The economic challenges are those related to the high investment and operating costs due to its first-of-a-kind nature. The lending banks commit a thorough due diligence, and liquidated damages requirements are normally strict, therefore government grants and subsidies are currently required. The type of plant supply contract is not that clear in a demonstration project – it can be a turnkey contract or the owner can act as the general contractor or some model in between, depending on decisions on risk sharing.

The institutional challenges are fuel availability and supply, renewable energy prices and government carbon emission reduction targets, and availability of subsidies such as investment and tax credit supports. In addition, the goals of stakeholders may be conflicting. The owner of the project wants to produce cheap electricity and heat and the equipment vendor to demonstrate new technology. The most critical aspect, however, for a successful demonstration project is to have the right project owner and the right location.

Figure 15: Skive plant

The Skive project has managed to overcome these challenges and now is operating and demonstrating the feasibility of this new technology.

Lahti Energy´s Kymijärvi II [8]

Lahti Energy's Kymijärvi II is a demonstration plant using a waste material as a feedstock.

- 160 MW/250 000 ton/a SRF
- Electricity production 50 MW
- District heating 90 MW
- Electricity efficiency (net) 31%
- Total investment 160 M€

After Kymijärvi II, new plants of similar type can be built by copying the solutions of Kymijärvi II. Along with Kymijärvi II, the technical solutions have reached a commercial stage.

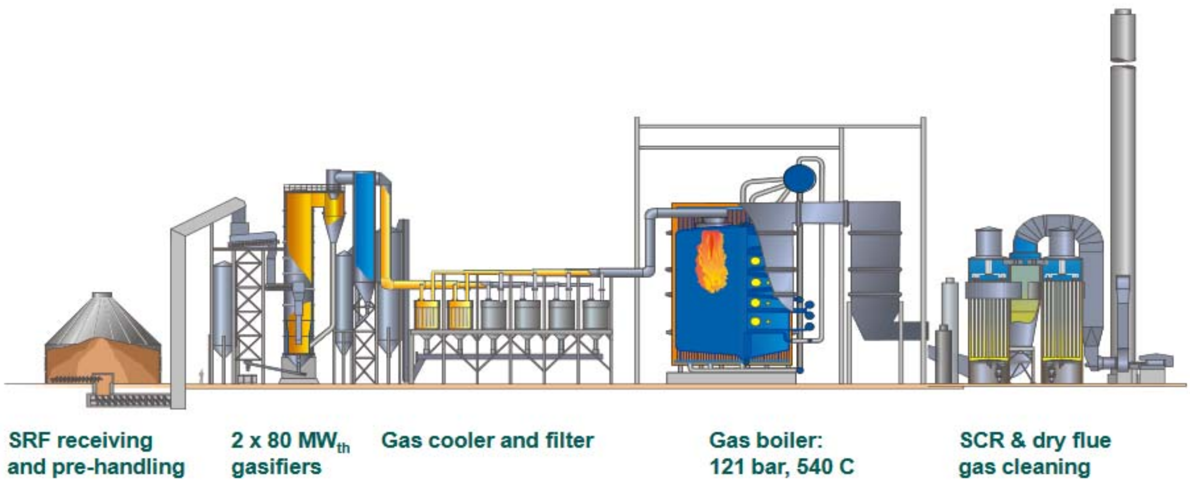

Figure 16: Lahti waste gasification plant

Fuel transfer from silo to gasifier

The fuel is discharged from the large fuel silos with the screw feeders at the bottom of the silos. The fuel moves through the screw feeder into the feeder below and then to the apron conveyor. The apron conveyor is similar to the baggage carousels at airports. The 240-metre-long conveyor takes the standard-height fuel bed from the feeder and moves the pile towards the gasifier. At the other end of the conveyor there is a smaller silo. By adjusting the speed of the conveyor, the surfaces of all silos are kept at the required height. If the levels of the silo fall, the discharge speed of the screws in the storage silos and the conveyor speed increase.

Both gasifiers have their own 200 m^3 silo. The long conveyor belt also has a final magnet that removes any remaining magnetic metal from the fuel.

Fuel gasification

Kymijärvi II has two atmospheric pressure circulating fluidised bed (CFB) gasifiers. The height of each gasifier is 25 m, with an outer diameter of 5 m. The gasifiers are started up with natural gas. Each gasifier has a bed of sand and lime particles which heats the fuel arriving in the reactor and acts as a heat compensator and stabiliser. The bed starts to fluidize when air is blown under it.

Feedstock is SRF (solid recovered fuel), sorted household waste, industrial waste and demolition wood. Fuel moisture is 15-25 %, LHV 13-20 MJ/kg. Fuel is fed from the silo to the gasification reactor where it is gasified at 850-900°C. In the gasification reaction, the fuel reacts with oxygen, resulting in a multiphase chemical reaction. Oxygen comes into the reactor along with the gasifying air. The amount of oxygen is kept low so that the fuel will not burn, but is gasified.

The main components of the product gas produced in gasification are carbon monoxide, methane, hydrogen, carbon dioxide, steam, and nitrogen originating from the gasifying air. The consistency of product gas varies according to the fuel properties and gasification temperature. The bed materials absorb some of the impurities of the product gas. The gas is separated from the solid bed material. The sand, lime and ash are recovered, and the hot gas continues its journey towards the gas cooler.

Gas cooling

In the gasification of solid recovered fuel, impurities that cause boiler corrosion, are transferred to the product gas. Therefore, the product gas is cooled from 900 degrees to about 400 degrees so that materials causing corrosion, such as alkali chlorides, turn from gas into solid particles, which can be filtered out. However, the product gas must not be cooled too much so that the tars in the gas will not start to condense. Water, which is obtained from a separate feedwater container and which circulates in the water circuit, is used in cooling. In gas cooling, the heat energy transferred to water is utilised in the production process. It is used to preheat the feedwater conducted to the boiler. Therefore, the cooling of the product gas does not increase the heat load to Lake Vesijärvi.

Gas cleaning

The cooled product gas is cleaned of particulate material with mechanical hot filtering. One filtering line has six filter units. One filter unit has about 300 filter elements, 'candles'. The diameter of one element is about 20 cm and its height is 2.5 metres. The filter element is a fibre tube that is enclosed at its lower end. One element weighs about 10 kg.

Gas containing solids flows through the filter elements and the particles remain on the surface of the elements. When the thickness of the solids on the surface of the elements exceeds a certain limit, the bed of solids is detached with nitrogen pulses. The nitrogen pulse momentarily turns the gas flow outwards from inside the tube, so that the solids fall into the bottom cone of the filter, from where they are removed into the ash system. Nitrogen is used in cleaning because hot product gas would ignite when coming into contact with the oxygen in the air. The filters are replaced every 2-3 years.

Ashes

The gasification process produces three kinds of ashes: bottom ash, filter ash and fly ash. Bottom ash is formed in the gasifier and it consists of fuel and bed materials (sand, lime). Filter ash is formed in the filter units and its particle sizes are smaller. It contains carbon and impurities condensed from the gas. Fly ash is captured by filters in connection with the cleaning of the boiler flue gases. The ash content of the fuel in Kymijärvi II is about 10%.

The bottom ash of the Kymijärvi II gasifier is taken to the Miekka landfill in Lahti. The filter ash and the fly ash are treated by an outside operator. Filter ash contains carbon and its utilisation possibilities are currently being investigated.

Boiler

The boiler is a natural-circulation steam boiler with a water tube structure, producing superheated steam. The boiler is designed for the combustion of both gasification product gas and natural gas. The ceiling of the boiler furnace has four burners, two for each gasifier line. The burners are ignited with natural gas. Once the flame has ignited, the natural gas is switched to gasifier product gas, which is used as the primary fuel of the boiler. A total of 24 cubic metres of gas per second is fed into the boiler, and a total of 86,000 cubic metres of gas is burned in an hour. Burning of clean gas produces a temperature of 850 degrees, which vaporises the water circulating in the boiler. The steam temperature is 540 °C and pressure 121 bar.

Flare burner

The flare burner is a safety device in case the boiler encounters a problem and it is not possible to feed all of the gas coming from the gasifier line into the boiler. If gas has to be directed into the flare, it will ignite and burn the gas. In such a case, a flame is visible at the top of the flare.

The cleaning of flue gases

When gas is burned in the boiler, flue gases containing nitrogen oxides, acid gases, heavy metals, dioxins and furans are formed. For this reason, flue gases are cleaned before they enter the chimney stack. Flue gas cleaning is implemented so that the NO_x catalyst reduces the nitrogen oxides into nitrogen, the bag filter filters the ash and the reaction products of the additives, sodium carbonate ($NaHCO_3$) neutralises the acid gases and the activated carbon binds heavy metals, dioxins and furans.

Turbine and generator

The steam superheated in the boiler is directed into the turbine. The high pressure of the steam pushes the turbine blade wheel into motion and makes the turbine rotor spin. The rotating movement is converted into electricity with a generator connected to the shaft. The residual steam leaving the turbine still contains a lot of energy, which is conducted to the district heating network through district heat exchangers. The turbine of Kymijärvi II is a Siemens SST 800 Tandem, weighing 173 tonnes with a rotation speed of 3,000 revolutions per minute. The generator is a Siemens Gen5-100A-2P (60MVA) and it weighs 83 tonnes. Both of them were manufactured in Germany.

Producing district heat and electricity

Kymijärvi II produces 50 MW of electricity and 90 MW of district heat. The district heat covers the heating need of 30,000 detached one-family houses for an entire year, and the amount of electricity covers the annual electricity need of 75,000 apartments. All district heat produced at Kymijärvi II is conducted along the trunk network to customers in the Lahti and Hollola region. The electricity goes into the national grid.

Connection to the district heating network

Kymijärvi II is connected to the district heating network in the pumping station of Kymijärvi I. District heat can be produced at the new power plant as a completely separate production plant of its own or alternatively together with Kymijärvi I. The main line leaving the pumping station is massive, DN800. Hot district heating water leaves the power plant area in two main directions. The transmission line DN700 leads into the Lahti city centre and the trunk line DN500 runs in the direction of Mukkula. Both lines branch off fairly soon into several branches. The district heat from the Kymijärvi power plants heats up 8,000 properties in the Lahti and Hollola region. There are tens of thousands of dwellings heated with district heat. Over 90% of properties in the area of the city of Lahti are connected to district heating.

Connection to the electricity network

Kymijärvi II is connected to the electricity network with a 110-kV connection at the Kymijärvi substation, which is owned by LE-Sähköverkko Ltd a subsidiary of Lahti Energy. A 110-kV switchgear (E09) serving the power plant is under the management of the power plant. From the Kymijärvi substation, there are connections further into the national grid via three different transmission connections. The latest of the transmission connections is the 110-kV underground cable connection of Mustankallio – Kymijärvi, which was built in 2012 to safeguard electricity distribution produced by the Kymijärvi production units.

Figure 17: Lahti waste gasification plant - foto

Wood chips gasification CHP plant in Harboøre [9]

Development of biomass up-draft gasification technology to full scale has been performed by Babcock & Wilcox Vølund A/S through an on-going development programme that started in the eighties. In 1989 a 1 MW pilot scale plant was erected at Kyndby værket – a Danish utility power plant. This plant was later dismantled, but the know-how was incorporated into a full scale plant – The Harboøre plant (The Harboore plant) - together with experience from a 50 kW pilot plant and the results of numerous university studies.

Figure 18: Harboore plant

The Harboore plant was erected in 1996. The first step was to demonstrate that a full scale updraft gasifier could be operated in a manner that would provide a reliable supply of heat to the nearby village by utilising the raw, untreated product gas in a boiler. The experience gathered in the first years resulted in modification and optimization of the fuel feeding system, the gasification agent, the temperature control etc. The second step was to upgrade the plant to produce power by adding gas engines in April 2000. This step involved the development of a gas cleaning system for removing the extensive amount of tar and water in the raw, untreated product gas. It was chosen to implement a wet gas cleaning system with gas coolers and a wet electrostatic precipitator. Consequently, the need for a waste water treatment system arose. Several options were evaluated and tested, including centrifuges and osmotic filtering. Finally, a waste water cleaning system based on gravimetric separation of organic and aqueous phases followed by a thermal treatment of the aqueous phase was developed and patented. The implementation and commissioning of the waste water treatment system was carried out in the period 2002 to 2003. Since then, the plant has been in ordinary operation producing power for the grid and heat for district heating. Lately, the focus of the development has been directed towards optimization, minor improvement, retrieving experience, further up-scaling, and development of new applications derived from the experience from the Harboore plant.

Plant description

The Harboore plant can be divided into the following main components:

- 3.7 MWth up-draft gasifier with fuel feed, ash extraction system, and air humidifier
- Gas cooling and cleaning system
- Two gas engines with generators and exhaust boilers

- Waste water cleaning system named the Tarwatc system
- Heavy tar fired boiler with storage tank for heavy tar
- Product gas fired boiler

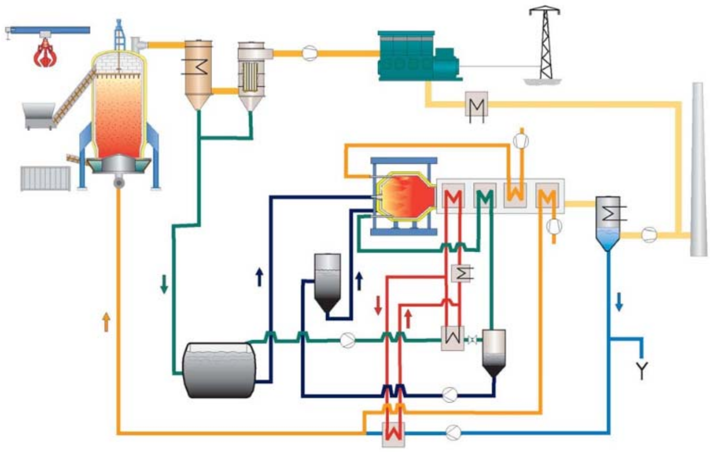

Figure 19: Harboore plant – flow sheet

The gasifier is fuelled solely with non-pre-treated wood chips. In the gasifier the wood chips are converted with hot humid air into a product gas that leaves the gasifier at the top. The ash is continuously removed from the grate at the bottom of the gasifier. Aerosols and tar droplets leave the gasifier together with the product gas. These impurities are removed in the gas cooler and in the cleaning system. The result is a product gas free of tar and aerosols, a heavy tar fraction, and an aqueous phase with a high content of soluble organics.

Product gas composition:

- LHV 6,5-7 MJ/Nm^3
- 18-19 % H_2
- 27-30 % CO
- 7 – 10 % CO_2
- 3 -5 % CH_4

The heavy tar is stored and is used as an auxiliary fuel instead of oil in a separate heavy tar fired boiler for peak loads and during maintenance of the rest of the system. The aqueous phase is handled by the Tarwatc system (TAR-WATer Cleaning system), which is, in principle, a thermal treatment utilising the organic pollutants of the aqueous phase as its energy source. The effluents from the Tarwatc system are a flue gas and a condensate consisting of water with only traces of contaminants. The product gas is used to power two Jenbacher gas engines with a maximum rating of 648 and 768 kWe power. The engines supply heat to the district heating grid, air preheating for the supply of hot humid air to the gasifier, and energy for the Tarwatc system. The latter is subsequently recovered in the flue gas cooler/condenser of the Tarwatc system. As the plant was originally intended solely for the supply of heat, it is also equipped with a boiler that can be fired with the product gas. This boiler was the primary heat source before the plant was fitted with gas engines.

The Harboore plant remains an important reference for biomass gasification and is in continuous full scale operation.

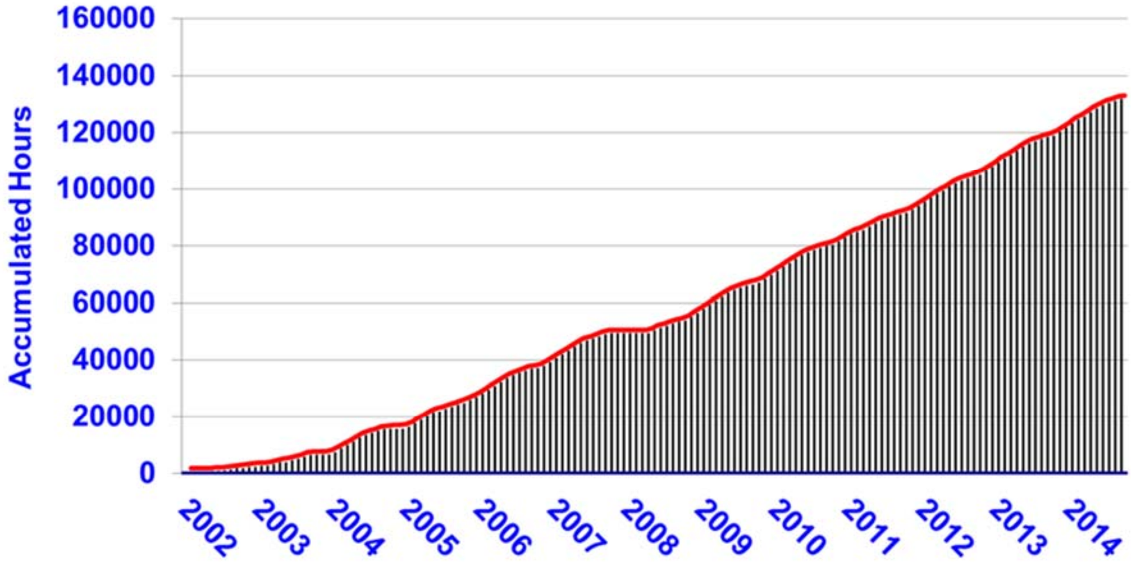

Figure 20: The engine operation hours accumulated until 2014

Bioliq [10]

The bioliq® process, developed at the Karlsruhe Institut für Technologie (KIT) aims at the production of synthetic fuels and chemicals from biomass. The bioliq® technology is based on a two-step process with decentral pyrolysis for the production of transportable slurry from biomass (e.g. straw) and central slurry gasification and BtL production. At KIT Karlsruhe a pilot plant with 2 MW fast pyrolysis and biosyn-crude production and a 5 MWth high pressure entrained flow gasifier operated up to 8 MPa (both in cooperation with Lurgi GmbH, Frankfurt), as well as the hot gas cleaning (MUT Advanced Heating GmbH, Jena), dimethylether and final gasoline synthesis (Chemieanlagenbau Chemnitz GmbH) are in operation.

A flow sheet of the process can be seen in the following figure.

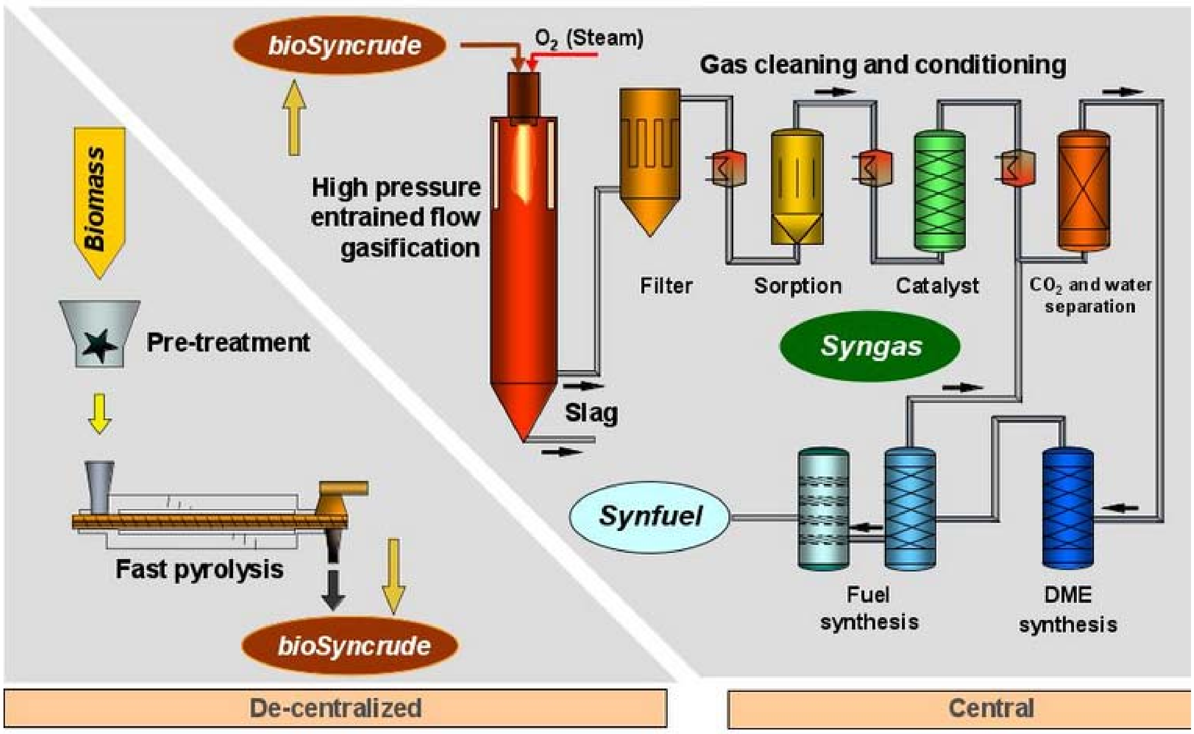

Figure 21: The bioliq process

The Bioliq development project has been divided into 4 stages.

Stage 1

The project Bioliq I (Flash pyrolysis) was funded by the Federal Ministry of Food and Agriculture (BMEL). For construction, joint operation and further process development Lurgi AG (now: Air Liquide Construction and Engineering Germany GmbH) was contracted. Start-up was on November 3, 2005.

Stage 2

After receiving grants from the Federal Ministry of Food, Agriculture, and Consumer Protection (BMELV), construction was started on-site the Bioliq® facility mid of the year 2010 after the engineering phase had been finished.

Stage 3 + 4

First activities for the erection of the Bioliq gas cleaning and fuel synthesis plants were begun late 2010 and complted late 2011. Functional testing of the plant components and subsystems was performed by using an artificial syngas mixture produced of bottled gas. After the gasification process was tested, in July 2013 the dimethyl ether synthesis plant was also succesful tested by using the artificial syngas mixture of the company LINDE.

5.2 Thermal biomass gasification in small scale

Burkhardt gasification facilities [11]

Burkhardt started out as a classical company for heating and plumbing, later ventured into the area of renewable energies with CHPs fueled by vegetable oil in 2004. At the same time, methods to convert wood into electricity were researched. In 2010 the Burkhardt wood gasifier was developed, which is by now being produced modularly and in series thanks to the continuous optimization of the processes. Since 2011, wood gas cogeneration plants have been sold to customers all over Germany, in parts of Europe and even in Japan with environmentally friendly heat and power. In 2014, the company received the Bavarian Energy Award for this development.

Fuel

In order to be able to ensure a uniform and stable gasification process, the fuel used at Burkhardt is just as homogeneous: wood pellets. Burkhardt's wood gasification process is perfectly designed for the ideal properties of the standardized pressed pellets (EN Plus A1) with their flow and transport characteristics, thus achieving above-average efficiency. The fuel does not need to be dried before use or stored in any special way, but can be used directly and efficiently in the plants. The fuel is fed into the reactor from below. Together with the high-quality fuel and air, this results in a constant, rising parallel flow with a stationary fluidized bed. This way, the steady gasification processes is achieve that results in steady follow-up processes.

Features

- 260-270 kWth | 165-180 kWel
- Pellets as feedstock
- Fluidized bed process in cocurrent flow
- Max. 8 000 h/a operating time
- 110 kg/h fuel requirement (at 10 % moist. cont.)
- Gas utilization via motor
- 90°C | 70°C flow/return temperature
- Required installation space at least 8 x 5 x 5 m
- 120 grid feeding plants

Burkhardt Wood Gasifier V 3.90

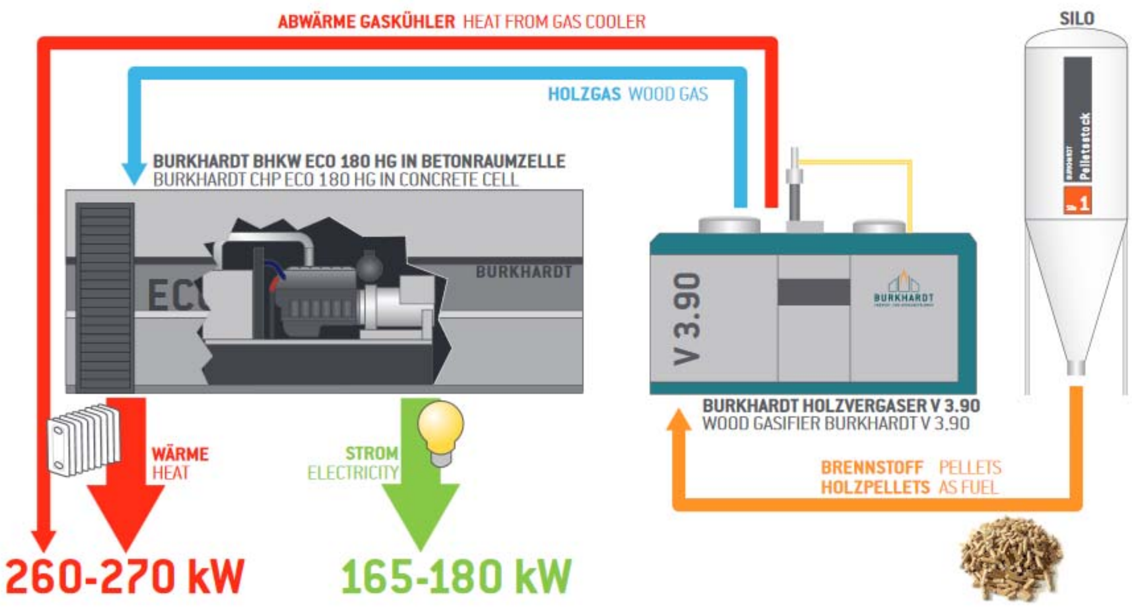

Figure 22: Burkhardt gasifier

The map shown in the following references overview provides a picture about the successful operation of Burkhardt gasification facilities.

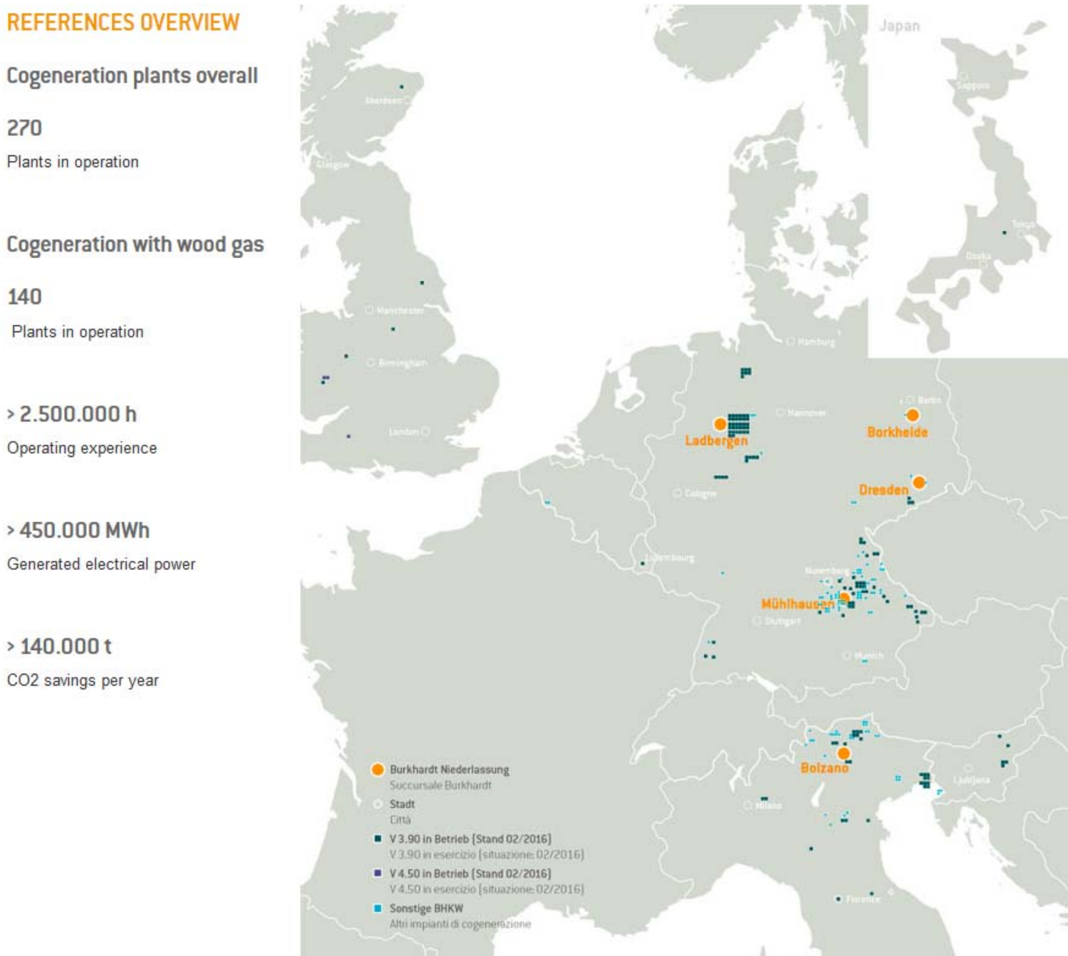

Figure 23: Burkhardt references

Spanner gasification facilities [12]

According to principles of cogeneration, the Spanner Wood Cogeneration System converts wood chips into biomass electricity and heat with high efficiency. The systems are run using natural wood chips and provide attractive cost advantages and/or increased power yields according to location and legal conditions. Hundreds of these systems are used in Europe, Asia and North America in agriculture and forestry, hotels, restaurants and heat grids, powered with biomass electricity and heat from the wood gasifier.

The Spanner gasifier has provided great results for hundreds of operators over a total of several million operating hours: a compact reformer, condensate-free wood gas purification and intelligent, fully-automated process regulation. The performance sizes of 30 kWel or 45 kWel have proved themselves, as these dimensions have proven as particularly good in covering base loads for heating grids. If necessary, several systems can be combined seamlessly.

The heart of the wood cogeneration plant is an efficient, robust combined heat and power system (CHP). The plant consists of an innovative reformer and a CHP, powered by the system of wood gasification.

Depending on the system of wood gasification, the plant generates biomass electricity between 30 and 45 kWel and a total heat power of 80 to 120 kWth. Wood chip consumption is between 30 and 45kg/h equalling consumption of approx. 1kg/h wood chips per kWel electric output, powered by wood gasifier.

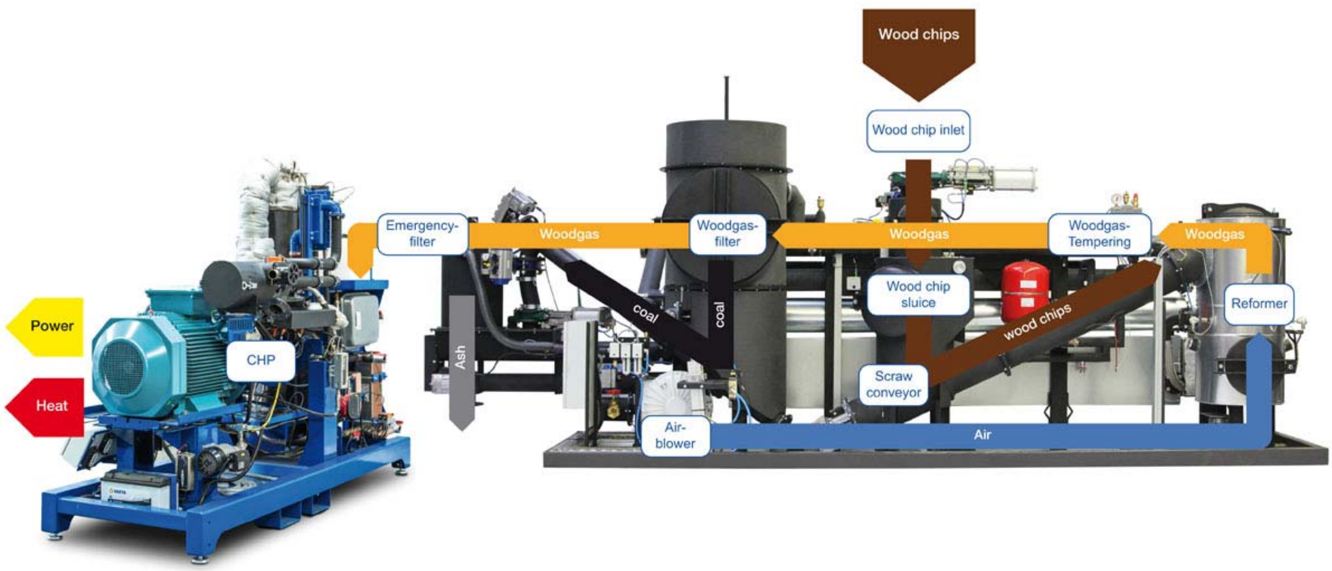

Figure 24: Spanner gasification and cogeneration units

Features

- 73 kWth | 30 kWel
- 2. type of plant: 108 kWth | 45 kWel
- Unadulterated wood, forest chips (at 30 kWel), wood chips
- Quality of charge material: 13 % moist. cont., 30 % fine content
- Fixed-bed process in cocurrent flow
- max. 8200 h/a operating time
- Gas utilization via motor
- 85°C | 65°C flow/return temperature
- 440 grid feeding plants
- Since 2008
- Distributing countries: D, A, CH, I, CZ, SLO, LV, CDN, GB, FIN, HR, J, PL

Urbas gasification facilities [13]

URBAS has been designing, building and pioneering energy systems for the intelligent use of biomass fuels for over 20 years, thriving to achieve maximum sustainability through both economic and environmental objectives.

Plants are designed to generate heat and electricity through the best use of biomass fuels. The combined generation of heat and electricity ensures maximum efficiency in the utilization of biomass fuels. URBAS have realized such CHP plants based on the steam cycle which are available as turnkey, URBAS biomass cogeneration plants.

A combustible gas, wood gas, is drawn from wood through a means of thermochemical processes which take place in a specially designed reactor. The raw gas is then separated of dust and tars through a filtering system. This cleaned gas is then used to produce combined heat and power through a gas engine + generator. Unlike other CHP technologies which are based on the combustion of biomass, and require a working medium, (water in a steam turbine, heat oil in the ORC-process) wood gas cogeneration requires no intermediate medium, thus resulting in a higher electrical efficiency throughout the entire system.

Features

• 150 - 620 kWth | 70 - 300 kWel

• Unadulterated wood, wood chips

• Quality of charge material: 15 % moist. cont., P100c EN 14961,max. 150 mm chip

• Fixed-bed process in concurrent flow

• max. 8 580 h/a operating time

• Since 2008

• 14 grid feeding plants

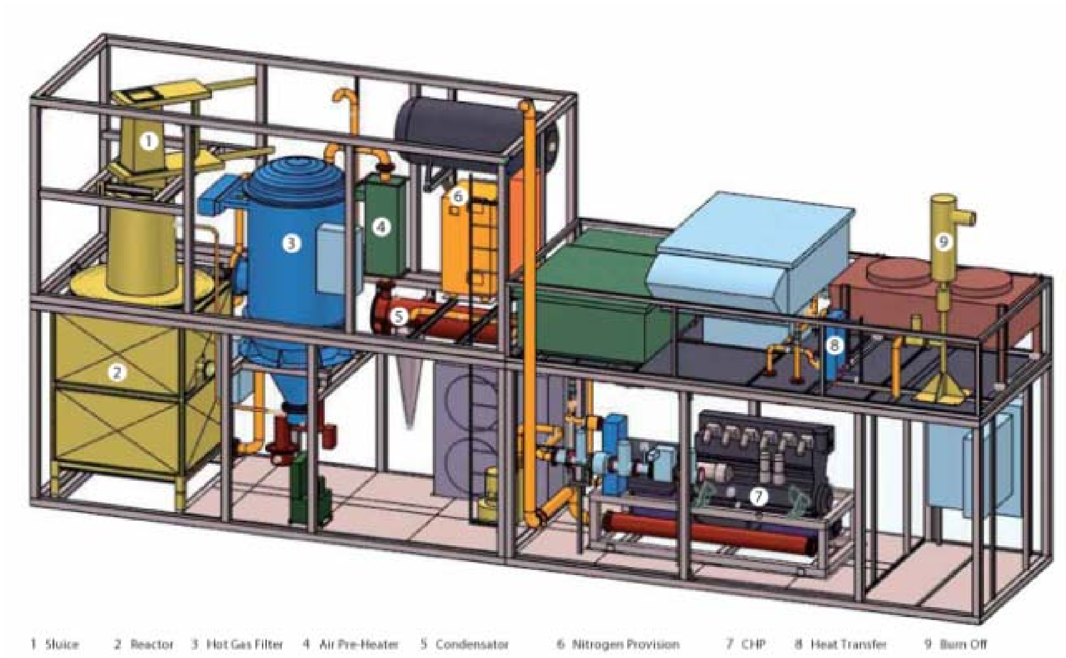

Figure 25: Urbas gasification of biomass – container form

References

	Project	Start up	Contact	Output	Application	Feedstock	
						Wood chips	Off - cuts
1	**Demonstrationsanlagen URBAS** A - 9113 Ruden	Development since 2001	Ing. Peter Urbas DI Wolfgang Felsberger	150 kWel +300 kWth + Kessel	CHP - Process heating for own supply	x	x
2	**Fernwärme Neumarkt Ges.m.b.H. & Co KG** A - 8820 Neumarkt	August 08	BM Herbert Ofner fernwaerme8820@gmail.com + 43 664 4501564	2 x 120 kWel + 580 kWth	CHP - District heating	x	
3	**Friedrich Wahl GmbH & Co. KG** D - 74429 Sulzbach Laufen	October 09	GF Sabine Mertzlufft s.mertzlufft@wahl-holzwerk.de +49 7976 9858 40	1 x 130 kWel + 280 kWth	CHP - Process heating for own supply		x
4	**Holzstrom GmbH** A - 5145 Neukirchen an der Enknach	July 11	GF Johann Wurhofer johann.wurhofer@aon.at + 43 664 2425408	2 x 175 kWel + 600 KWth	CHP - District heating	x	
5	**Stadtwerke Konstanz GmbH** D - 78467 Konstanz	December 11	DI Olaf Westerhoff +49 7531 803 266	1 x 140 kWel + 300 kWth	CHP - District heating	x	
6	**Biowärme Mallnitz Gmbh** A - 9822 Mallnitz	November 13	Hr. Anton Glantschnig glantschnig.anton@peak.at + 43 664 156 78 58	1 x 250 kWel + 540 kWth	CHP - District heating	x	
7	**Rau GmbH** D - 72336 Balingen	December 13	GF Joahim Rau linda.rau@rau-gmbh.de + 49 7433 9882 14	1 x 150 kWel + 280 kWth	CHP - Process heating	x	x
8	**Energieversorgung Vals GmbH** I - 39037 Mühlbach	December 14	Kurt Bacher + 39 0472 979042	1 x 296 kWel + 550 kWth	CHP - District heating	x	
9	**Biowärme Eberndorf** A - 9141 Eberndorf	March 15	Ing. Peter Urbas p.urbas@urbas.at + 43 664 1235923	1 x 130 kWel + 250 kWth; 1 x 300 kWel + 600 kWth	CHP - District heating	x	
10	**green Power GmbH** A - 8230 Hartberg	July 15	Andreas Windhaber andreas.windhaber@gat-solar.at +43 3176 8127 0	1 x 200 kWel + 320 kWth	CHP - District heating	x	
11	**Energia Uno** I - 05100 Terni	August 15	Marco Cinaglia +39 3408191329	1 x 199 kWel + 340 kWth	CHP - Process heating	x	
12	**Lamprecht GmbH** I - 3902 Kastelbell	November 15	Hr. Oskar Pfeifer info@lamprecht-holz.com + 39 0473 624131	1 x 199 kWel + 320 kWth	CHP - Process heating	x	
13	**Azienda. Agri. S.A.B.I** I - 47010 Galeata	December 15	Luca Zannotti luca1407@gmail.com + 39 0543 981793	1 x 199 kWel + 320 kWth	CHP - District heating	x	
14	**Prijedor** BIH - 79101 Prijedor	December 15	Zoran Knezevic knezevic.zoran@toplanapd.com +38 765 845 232	1 x 250 kWel + 530 kWth	CHP - District heating	x	
15	**FW Mals** I - 39024 Mals	December 15	Dr.Mag. Ulrich Veith ulrich.veith@gemeinde.mals.bz.it + 39 349 5707 171	2 x 149 kWel + 280 kWth	CHP - District heating	x	
16	**Azienda Agricola Isca di Calvello**	January 15	Gianfranco Misuriello +39 3334711383	1 x 199 kWel + 340 kWth	CHP - Process heating	x	
17	**Chetra SK s.r.o.** SK - 06801 Medzilaborce	January 16	Olga Hethy +49 1637227525	3 x 150 kWel + 840 kWth	CHP - Process heating	x	

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[9] http://www.volund.dk/~/media/Downloads/Conference_papers_-_BIO/Gelsenkirchen_2010_-_Updraft_gasification_-_status_on_the_Harboore_technology.pdf

[10] http://www.bioliq.de/english/55.php

[11] http://burkhardt-energy.com/download/C59ee2843X14cfa2bd10cXY3fea/Burkhardt_Energietechnik_01_2015_GER_ENG_web.pdf

[12] http://www.holz-kraft.de/en/products/wood-cogeneration-plant

[13] www.urbas.at

6. Thermal biomass gasification facilities in Task 33 member countries

The facilities mentioned in this chapter are divided by technology, the usage of the syngas respectively.

- Combined heat and power facilites
- Fuel synthesis facilities
- Other gasification (innovative) technologies

The status of thermal gasification facilites – explanation

Operational	Under construction	Planned	Non operational	No status

6.1 Combined heat and power facilites (CHP)

Nr.	Owner	Name	Status	Page
1	Aerni Pratteln	CHP Pratteln	Non operational	61
2	AEW Energie AG	Pelletvergasser AEW Rheinfelden	Under construction	62
3	Agnion Technologies GmbH	CHP Agnion Biomasse Heizkraftwerk Pfaffenhofen	Operational	63
4	Andritz-Carbona	Skive CHP plant	Operational	64
5	Autogasnord	-	Operational	65
6	Azienda Agricola Camardo	-	Operational	66
7	Azienda Agricola Isca di Calvello	Urbas Calvello	Operational	67
8	Azienda Agricola San Vittore	-	Operational	68
9	Azienda Tessile Parmense	GAS 1000	No status	69
10	Babcock&Wilcox Volund	CHP Haarbøre	Operational	70
11	Biomasse Energie GmbH	FICFB Villach	Non operational	71
12	Biowaerme Eberndorf	CHP Urbas Eberndorf	Operational	72
13	Biowaerme Mallnitz	CHP Urbas Mallnitz	Operational	73
14	Ciamber	-	Operational	74
15	Comune Quingentole	-	Operational	75
16	Duchi Fratelli Societa Agricola / Agroenergia	-	Operational	76
17	EMPA Duebendorf	CHP Duebendorf	Non operational	77

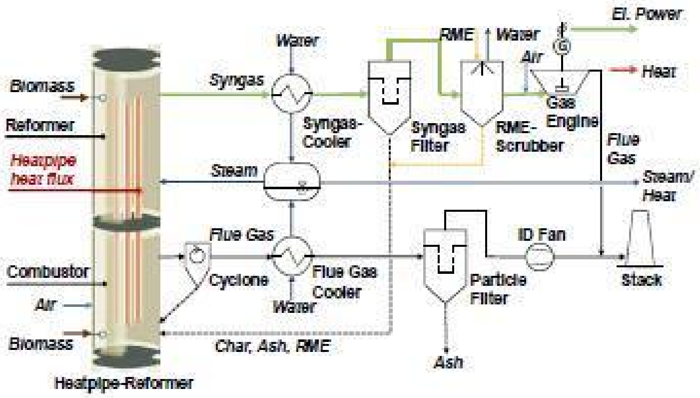
18	Energia Uno	Urbas Terni		78
19	Energie Oberwart	FICFB Oberwart		79
20	Fernwaerme Neumarkt GmbH&Co. KG	CHP Urbas Neumarkt		80
21	Friedrich Wahl GmbH & co. KG	CHP Urbas Sulzbasch-Laufen		81
22	Graested Fjernvarme	CHP BioSynergi pilot plant		82
23	Guascor Italia	Rossano Calabro		83
24	Guessing Renewable Energy	FICFB Guessing		84
25	HEH Holzenergie	CHP Pfalzfeld		85
26	H.H. Käser GmbH	Holzgasanlage 1 Käser Gasel		86
27	H.H. Käser GmbH	Holzgasanlage 2 Käser Gasel		87
28	Hilleroed Bioforgasning P/S	BioSynergi CHP demonstration plant		88
29	Holzstrom aus Nidwalden	CHP Pyroforce Nidwalden		89
30	Holzstrom GmbH	CHP Urbas Neukirchen		90
31	HoSt	CFB Tzum		91
32	HS Energieanlagen GmbH	CHP Heatpipe Reformer Neufahrn		92
33	Josef Bucher AG Escholzmatt	Holzverstromungsanlage Bucher Escholzmatt		93
34	Lahti Energia Oy	Kymijärvi II		94
35	Lamprecht	Lamprecht GmbH		95
36	l´Azienda Tenca dei Fratelli Zanotti / AB energy	Orzinuovi		96
37	Mekrjärvi research Station	District heating plant		97
38	MEVA Innovation	VIPP Demonstration		98
39	Nurmes	Micro-scale biomass gasification CHP Volter		99
40	PoliTo	Wood gasifier		100
41	Pyroneer – DONG Energy Power A/S	Pyroneer Demonstration Plant		101
42	Rau GmbH	Urbas Balingen		102
43	Stadtwerke Duesseldorf	CHP Arnsberg-Wildhausen		103
44	Stadtwerke Konstanz GmbH	CHP Urbas Konstanz		104
45	Stadtwerke Rosenheim GmbH	CHP Stadtwerke Rosenheim		105
46	Stadtwerke Ulm/Neu-Ulm	CHP Stadtwerke Ulm		106
47	Steiner A. & Cie AG	-		107
48	Stirling DK	CHP Flensburg		108

49	Urbas Energietechnik	CHP Demonstrationsanlagen URBAS		109
50	Volter	Kempele Ecovillage		110
51	VVBGC AB	Vaxjö Värnamo Biomass Gasification Center AB		111
52	Waermeversorgung Grossenhain	CHP Grossenhain		112
53	Weiss	Hillerød two stage gasifier		113
54	Woodpower in Wila	CHP Wila		114

Project name	CHP Pratteln
Project owner	Aerni Pratteln
Status	Non operational
Start up	2009
Country	Switzerland
City	Pratteln
Type	TRL 6-7 Demonstration
Technology	CHP
Raw Material	Wood chips dried
Input 1 Name	Wood chips dries
Output 1 Name	Power (electricity‘)
Output 1 Capacity	0,13
Output 1Unit	MWel
Output 2 Name	Heat
Output 2 Capacity	0,26
Output 2 Unit	MWth
Technology Brief	downdraft Kuntschar/Wegscheid/Aerni modificated
Additional Information	Closed down due of technical reasons. Operational 2009-2014.
Contact	non

Project name	Pelletvergasser AEW Rheinfelden
Project owner	AEW Energie AG
Status	Under construction
Start up	End 2016
Country	Switzerland
City	CH–4310 Rheinfelden
Type	TRL 9 commercial
Technology	Power/CHP
Raw Material	lignocellulosic crops
Input 1 Name	Wood pellet
Input 1 Capacity	110
Input 1Unit	kg/h
Input additional Information	2.64 t/d
Output 1 Name	electricity
Output 1 Capacity	0.165
Output 1Unit	MWel
Output 2 Name	heat
Output 2 Capacity	0.260
Output 2 Unit	MWtherm
Output additional Information	CHP Unit 0,165 Mwel + 0,26 MWth for district heating
Total Investment	X Mio CHF
Total Investment Currency	CHF
Total Investment Explanation	Investment Includes: building, heat and power gasifier unit, feedstock bunker, connection to heating device and power.
Technology Brief	Burkhardt pellet Gasifier CHP (fluidized bed in co current flow)
Additional Information	www.aew.ch/home.html http://burkhardt-energy.com/hp538/Technik.htm http://www.rheinfelden.ch/de/
Contact	marcel.kraenzlin@aew.ch louis.luz@aew.ch

Project name	CHP Agnion Biomasse Heizkraftwerk Pfaffenhofen
Project owner	Agnion Technologies GmbH
Status	Operational
Start up	2001
Country	Germany
City	Pfaffenhofen
Type	TRL 4-5
Technology	CHP / Synthesis
Raw Material	Lignocellulosic crops
Input 1 Name	Waste wood
Input 1 Capacity	80 000
Input 1Unit	t/y
Output 1 Name	SNG
Output 1 Capacity	32,5
Output 1Unit	MW
Output 2 Name	Power (electricity)
Output 2 Capacity	6,1
Output 2 Unit	Mwel
Technology Brief	pilot plant for syngas generation; CHP and SNG applications
Additional Information	www.agnion.de
Contact	Not known



Project name	Skive CHP plant
Project owner	Andritz-Carbona
Status	Operational
Start up	2008
Country	Denmark
City	Skive
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood pellets
Input 1 Capacity	100
Input 1Unit	t/d
Output 1 Name	Power (electricity)
Output 1 Capacity	6
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	20
Output 2 Unit	MWth
Total Investment	33,3 Mio
Total Investment Currency	Euro
Partners	Carbona Cooperation, Aaen Consulting Engineers
Technology Brief	Europe’s largest for CFBG CHP Pressurized CFBG, Carbona
Additional Information	www.aaen-consulting.com
Contact	Sven Aaen, Aaen Consulting Engineers

Project name	
Project owner	Autogasnord
Status	Operational
Start up	
Country	Italy
City	Caluso
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,400
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,600
Output 2 Unit	MWth
Partners	Agroenergia/CIP Group/Energy calor/Sitech Italia
Technology Brief	Pyrogasification
Additional Information	www.autogasnord.it
Contact	Not known

Project name	
Project owner	Azienda agricola Camardo
Status	Operational
Start up	2012
Country	Italy
City	Pomarico
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,300
Technology Brief	Pyrogasifier
Additional Information	www.bioewatt.com
Contact	Not known

Project name	Urbas Calvello
Project owner	Azienda Agricola Isca di Calvello
Status	Operational
Start up	2015
Country	Italy
City	Calvello
Type	CHP
Technology	TRL 9 Commercial
Raw Material	Wood chips
Output 1 Name	Power
Output 1 Capacity	0,199
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,34
Output 2 Unit	MWth
Partners	Urbas
Technology Brief	A combustible gas, wood gas, is drawn from wood through a means of thermochemical processes, which take place in a specially designed reactor. The raw gas is then separated of dust and tars through a filtering system. This cleaned gas is then used to produce combined heat and power through a gas engine + generator. Unlike other CHP technologies which are based on the combustion of biomass, and require a working medium, (water in a steam turbine, heat oil in the ORC-process) wood gas cogeneration requires no intermediate medium thus resulting in a higher electrical efficiency throughout the entire system.
Additional Information	
Contact	Gianfranco Misuriello +39 3334711383

Project name	
Project owner	Azienda Agricola San Vittore
Status	Operational
Start up	
Country	Italy
City	Vigevano
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,500
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,400
Output 2 Unit	MWth
Technology Brief	Downdraft gasifier
Additional Information	
Contact	Not known

Project name	GAS 1000
Project owner	Azienda Tessile Parmense
Status	Not known
Start up	
Country	Italy
City	Parma
Type	TRL 9 Commercial
Technology	CHP
Output 1 Name	Power (electricity)
Output 1 Capacity	1
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	2
Output 2 Unit	MWth
Partners	
Technology Brief	fixed bed – downdraft with ICE
Additional Information	www.bioenergy-world.com/europe/2008/IMG/pdf/28_Bettella_CAEMA.pdf
Contact	Not known

Project name	CHP B&W Harboøre
Project owner	Babcock&Wilcox Volund
Status	Operational
Start up	1996
Country	Denmark
City	Harboore
Type	TRL9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	1
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	3
Output 2 Unit	MWth
Total Investment	100,6 Mio.
Total Investment Currency	DKK
Total Investment Explanation	100,6 mio DKK for electromechanical parts
Partners	
Technology Brief	Originally designed for district heating only, later in 2000 CHP capability added; updraft gasifier (Dr. Gratzke); air blown
Contact	Robert Heeb roh@volund.dk

Project name	FICFB Villach
Project owner	Biomasse Energie GmbH
Status	Idle
Start up	
Country	Austria
City	Villach
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	3,7
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	6,7
Output 2 Unit	MWth
Technology Brief	FICFB gasifier
Contact	Not known

Project name	CHP Urbas Eberndorf
Project owner	Biowärme Eberndorf
Status	Operational
Start up	2015
Country	Austria
City	Eberndorf
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,300 + 0,130
Output 1Unit	MWel
Output 2 Name	Heat
Output 2 Capacity	0,600 + 0,250
Output 2 Unit	MWth
Partners	Urbas Stahl&Anlagenbau, Voelkermarkt
Technology Brief	A combustible gas, wood gas, is drawn from wood through a means of thermochemical processes which take place in a specially designed reactor. The raw gas is then separated of dust and tars through a filtering system. This cleaned gas is then used to produce combined heat and power through a gas engine + generator. Unlike other CHP technologies which are based on the combustion of biomass, and require a working medium, (water in a steam turbine, heat oil in the ORC-process) wood gas cogeneration requires no intermediate medium thus resulting in a higher electrical efficiency throughout the entire system.
Additional Information	
Contact	Ing. Peter Urbas p.urbas@urbas.at

Project name	Urbas Mallnitz
Project owner	Biowaerme Mallnitz GmbH
Status	Operational
Start up	2013
Country	Austria
City	Mallnitz
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,250
Output 1Unit	MWel
Output 2 Name	Heat
Output 2 Capacity	0,540
Output 2 Unit	MWth
Technology Brief	A combustible gas, wood gas, is drawn from wood through a means of thermochemical processes which take place in a specially designed reactor. The raw gas is then separated of dust and tars through a filtering system. This cleaned gas is then used to produce combined heat and power through a gas engine + generator. Unlike other CHP technologies which are based on the combustion of biomass, and require a working medium, (water in a steam turbine, heat oil in the ORC-process) wood gas cogeneration requires no intermediate medium thus resulting in a higher electrical efficiency throughout the entire system.
Contact	Anton Glantschnig Tel. +43 664 156 78 58

Project name	
Project owner	Ciamber
Status	Operational
Start up	
Country	Italy
City	Forno di Zoldo
Type	TRL 9 Commercial
Technology	CHP
Output 1 Name	Power (electricity)
Output 1 Capacity	1
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,8
Output 2 Unit	MWth
Partners	Edilgoima srl
Technology Brief	Downdraft with 4 engines Cummins power generation 1710-G
Contact	Not known

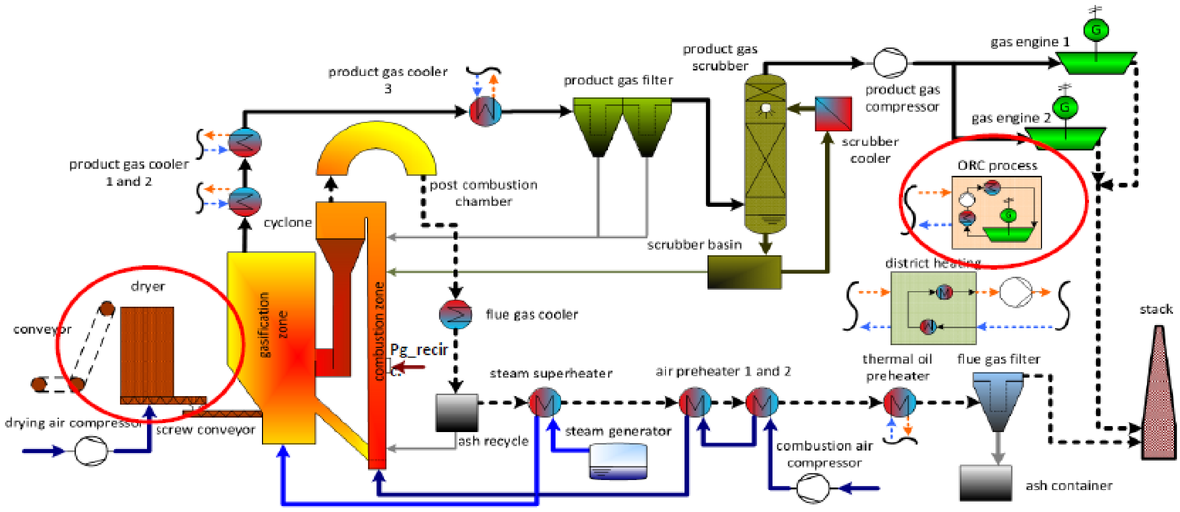
Project name	
Project owner	Comune Quingentole
Status	Operational
Start up	2006
Country	Italy
City	Quingentole
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power
Output 1 Capacity	0,070
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,140
Output 2 Unit	MWth
Technology Brief	Downdraft gasifier
Additional Information	www.bioenergy-world.com/europe/2008/IMG/pdf/28_Bettella_CAEMA.pdf www.caemaenergia.com
Contact	www.comune.quingentole.mn.it

Project name	
Project owner	Duchi Fratelli Societa Agricola/Agroenergia
Status	Operational
Start up	2010
Country	Italy
City	Gadesco Pieve Delmona
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,960
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	3,2
Output 2 Unit	MWth
Partners	Agroenergia
Technology Brief	3 gasifier downdraft open core
Contact	Not known

Project name	CHP Dübendorf
Project owner	EMPA Duebendorf
Status	Stopped while under construction
Start up	
Country	Switzerland
City	Duebendorf
Type	TRL 9 Commercial
Technology	Power/CHP
Raw Material	Lignocellulosic crops
Input 1 Name	dried chips from waste wood
Output 1 Name	Power (electircity)
Output 1 Capacity	0,7
Output 1Unit	Mwel
Partners	EKZ / Woodpower
Technology Brief	Downdraft Woodpower gasifier.
Additional Information	After 2 Mio CHF investment project cancelled and abounded project stopped
Contact	non

Project name	Urbas Terni
Project owner	Energia Uno
Status	Operational
Start up	2015
Country	Italy
City	Terni
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Lignocellulosic biomass
Input 1 Name	Wood chips
Output 1 Name	Power
Output 1 Capacity	0,199
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,340
Output 2 Unit	MWth
Technology Brief	A combustible gas, wood gas, is drawn from wood through a means of thermochemical processes which take place in a specially designed reactor. The raw gas is then separated of dust and tars through a filtering system. This cleaned gas is then used to produce combined heat and power through a gas engine + generator. Unlike other CHP technologies which are based on the combustion of biomass, and require a working medium, (water in a steam turbine, heat oil in the ORC-process) wood gas cogeneration requires no intermediate medium thus resulting in a higher electrical efficiency throughout the entire system.
Additional Information	
Contact	Marco Cinaglia Phone: +39 3408191329

Project name	FICFB Oberwart
Project owner	Energie Oberwart
Status	Operational
Start up	2008
Country	Austria
City	Oberwart
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	2,8
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	4,1
Output 2 Unit	MWth
Total Investment	16 Mio
Total Investment Currency	Euro
Partners	Ortner Anlagenbau
Technology Brief	FICFB, steam as oxidizing agent in gasification zone, air in combustion zone; the same technology as in Guessing, ORC added
Additional Information	
Contact	Ing. DI (FH) Dr. Klaus Bosch Tel.: +43 (0) 26829015-752



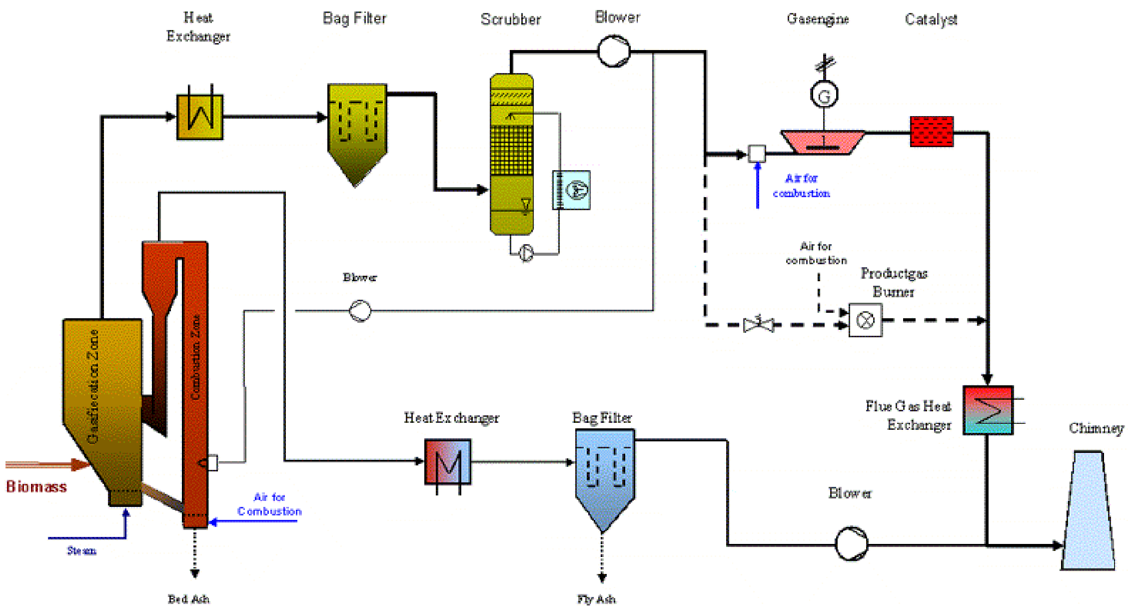
Project name	CHP Urbas Neumarkt
Project owner	Fernwäme Neumarkt Ges.m.b.H. & Co.KG
Status	Operational
Start up	2008
Country	Austria
City	Neumarkt
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,240
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,580
Output 2 Unit	MWth
Partners	Urbas Stahl&Anlagenbau, Voellkermarkt
Technology Brief	A combustible gas, wood gas, is drawn from wood through a means of thermochemical processes which take place in a specially designed reactor. The raw gas is then separated of dust and tars through a filtering system. This cleaned gas is then used to produce combined heat and power through a gas engine + generator. Unlike other CHP technologies which are based on the combustion of biomass, and require a working medium, (water in a steam turbine, heat oil in the ORC-process) wood gas cogeneration requires no intermediate medium thus resulting in a higher electrical efficiency throughout the entire system.
Contact	Herbert Ofner Tel.:+43 664 4501564

Project name	CHP Urbas Sulzbach-Laufen
Project owner	Friedrich Wahl GmbH & Co. KG
Status	Operational
Start up	2009
Country	Germany
City	Sulzbach-Laufen
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,13
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,28
Output 2 Unit	MWth
Partners	Urbas
Technology Brief	The gasificator works in the scheme of a downdraft gasifer, which is an improvement 81ft he gasificator of Imbert. A combustible gas, wood gas, is drawn from wood through a means of thermochemical processes which take place in a specially designed reactor. The raw gas is then separated of dust and tars through a filtering system. This cleaned gas is then used to produce combined heat and power through a gas engine + generator. Unlike other CHP technologies which are based on the combustion of biomass, and require a working medium, (water in a steam turbine, heat oil in the ORC-process) wood gas cogeneration requires no intermediate medium thus resulting in a higher electrical efficiency throughout the entire system.
Contact	Sabine Mertzlufft Tel. +49 7976 9858 40

Project name	CHP BioSynergi pilot plant
Project owner	Graested Fjernvarme
Status	Operational
Start up	2003 (commissioning)
Country	Denmark
City	Graested
Type	TRL 4-5 Pilot
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,090
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,200
Output 2 Unit	MWth
Technology Brief	The aim 82ft h demonstrate and optimize a staged Open Core gasifier fuelled with forest wood chips (45-50 % moisture on wet basis), as a part of a CHP plant. The plant includes all components from wood chip storage and drying to output of energy in the manner of electricity for the electric distribution network and heat for delivery 82ft he private district heating plant in the town of Graested.
Contact	Henrik Houmann Jakobsen hhj@BioSynergi.dk

Project name	Rossano Calabro (CS)
Project owner	Guascor Italia
Status	Operational
Start up	2003
Country	Italy
City	Rossano Calabro
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Olive husks, industry wood, agro-forest waste
Output 1 Name	Power (electricit)
Output 1 Capacity	4,2
Output 1Unit	Mwel
Technology Brief	There are three independent systems connected to complete the plant: biomass feeding and gasification, biogas cleaning system, and biogas condition and electric generation system. The gasifier is feed by wooden residues by wood industry and agro-forest and olive husk, the annual biomass consumption is 35868 t/a (Source: CTI).
Contact	Guascor Italia Via Orvieto, 12 – Pomezia (RM) Tel. 06/9162780 Fax. 06/91251042 commerciale@guascor.it

Project name	FICFB Guessing
Project owner	Guessing Renewable Energy
Status	Operational
Start up	2002
Country	Austria
City	Guessing
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Input 1 Capacity	3
Input 1Unit	t/h
Output 1 Name	Power (electricity)
Output 1 Capacity	2
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	4,5
Output 2 Unit	MWth
Partners	Austrian Energy
Technology Brief	The basic idea of the FICFB concept is to divide the fluidised bed into two zones, a gasification zone and a combustion zone. Due 84ft he favourable characteristics 84ft he product gas (low nitrogen, high hydrogen content) there are several research projects, which use slip streams of the product gas.
Contact	Ing. Reinhard Koch r.koch@eee-info.net



Project name	CHP Pfalzfeld
Project owner	HEH Holzenergie
Status	Under construction
Start up	
Country	Germany
City	Pfalzfeld
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Lignocellulosic crops
Output 1 Name	Power (electricity)
Output 1 Capacity	4 x 0,25
Output 1Unit	Mwel
Output 2 Name	Heat
Partners	Mothermik CHP Technology GmbH
Technology Brief	Fixed bed downdraft gasifier, air blown
Contact	Not known

Project name	Holzgasanlage 1 Käser Gasel
Project owner	H.H. Käser GmbH Bodenackerweg 31 3144 Gasel
Status	operational
Start up	15.12.2015
Country	Switzerland
City	CH-3144 Gasel
Type	TRL 9 commercial
Technology	CHP downdraft fixbed gasifier
Raw Material	lignocellulosic crops
Input 1 Name	Wood chip
Input 1 Capacity	133
Input 1Unit	kg/h
Input additional Information	3.2 t/d
Output 1 Name	electricity
Output 1 Capacity	0.140
Output 1Unit	MWel
Output 2 Name	heat
Output 2 Capacity	0.240
Output 2 Unit	MWtherm
Output additional Information	CHP Unit 0,14 Mwel + 0,24 MWth for commercial chip wood drying unit
Total Investment	0.750 Mio CHF
Total Investment Currency	CHF
Total Investment Explanation	Investment Includes: CHP gasifier unit, connection to heating device and power.
Technology Brief	Downdraft Ligento Gasifier
Additional Information	http://www.hhkaeser.ch/hh-kaser http://www.gunep.ch/aktuell/index.html#a1100 http://www.ligento.de/produktdaten.html
Contact	info@hhkaeser.ch

Project name	Holzgasanlage 2 Käser Gasel
Project owner	H.H. Käser GmbH Bodenackerweg 31 3144 Gasel
Status	commissioning
Start up	March 2016
Country	Switzerland
City	CH-3144 Gasel
Type	TRL 9 commercial
Technology	CHP downdraft fixbed gasifier
Raw Material	lignocellulosic crops
Input 1 Name	Wood chip
Input 1 Capacity	133
Input 1Unit	kg/h
Input additional Information	3.2 t/d
Output 1 Name	electricity
Output 1 Capacity	0.140
Output 1Unit	MWel
Output 2 Name	heat
Output 2 Capacity	0.240
Output 2 Unit	MWtherm
Output additional Information	CHP Unit 0,14 Mwel + 0,24 MWth for commercial chip wood drying unit
Total Investment	0.750 Mio CHF
Total Investment Currency	CHF
Total Investment Explanation	Investment Includes: CHP gasifier unit, connection to heating device and power.
Technology Brief	Downdraft Ligento Gasifier
Additional Information	http://www.hhkaeser.ch/hh-kaser http://www.gunep.ch/aktuell/index.html#a1100 http://www.ligento.de/produktdaten.html
Contact	info@hhkaeser.ch

Project name	BioSynergi CHP demonstration plant
Project owner	Hilleroed Bioforgasning P/S
Status	Operational
Start up	2015
Country	Denmark
City	Hillerod
Type	TRL 6-7 Demonstration
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,300
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,750
Partners	Hillerod Forsyning/Hillerod Varme A/S, BioSynergi Proces ApS
Technology Brief	Staged Open Core downdraft gasifier fuelled with forest wood chips (45-50 % moisture on wet basis), as a part of a IC engine based CHP plant. The annual generation at the plant is expected 88ft h 2,000 MWh electricity and 5,000 MWh heat.
Contact	Erik Christiansen mail@bioforgasning.dk

Project name	CHP Pyroforce Nidwalden
Project owner	Holzstrom aus Nidwalden
Status	operational
Start up	2007
Country	Switzerland
City	Stans
Type	TRL 9 Commercial
Technology	Power/CHP
Raw Material	Lignocellulosic crops
Input 1 Name	dried chips from demolition wood
Output 1 Name	Power (electircity)
Output 1 Capacity	1,38
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	1,2
Output 2 Unit	MWth
Technology Brief	2-zone downdraft Pyroforce gasifier
Additional Information	
Contact	Bernhard Boecker-Riese boecker-riese@br-engineering.ch Hans Bieri holzverstromung@korporation-stans.ch

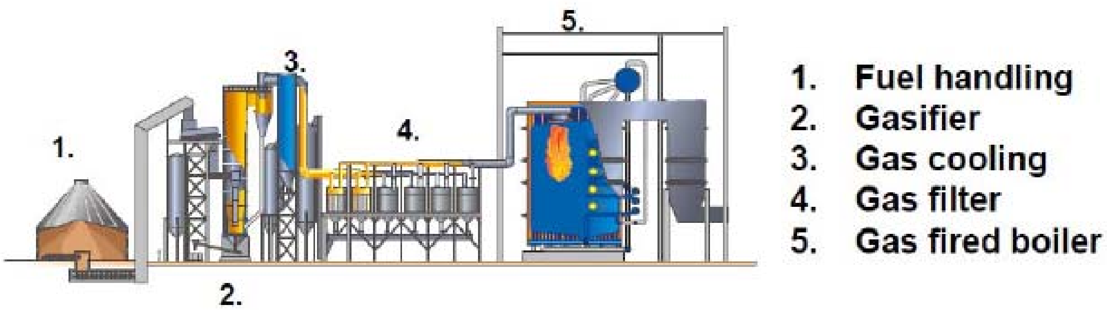
Project name	CHP Urbas Neukirchen
Project owner	Holzstrom GmbH
Status	Operational
Start up	2011
Country	Austria
City	Neukirchen an der Enknach
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	2x0,175
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,600
Output 2 Unit	MWth
Partners	Urbas StahlAnlagenbau, Voelkermarkt
Technology Brief	A combustible gas, wood gas, is drawn from wood through a means of thermochemical processes which take place in a specially designed reactor. The raw gas is then separated of dust and tars through a filtering system. This cleaned gas is then used to produce combined heat and power through a gas engine + generator. Unlike other CHP technologies which are based on the combustion of biomass, and require a working medium, (water in a steam turbine, heat oil in the ORC-process) wood gas cogeneration requires no intermediate medium thus resulting in a higher electrical efficiency throughout the entire system.
Additional Information	www.urbas.at
Contact	Johann Wurhofer Tel.: +43 664 2425408

Project name	CFB Tzum
Project owner	HoSt
Status	idle
Start up	2006
Country	The Netherlands
City	Tzum
Type	TRL 6-7 Demonstration
Technology	CHP
Raw Material	Chicken manure
Output 1 Name	Power (electricity)
Output 1 Capacity	
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	3
Output 2Unit	MWth
Technology Brief	HoSt constructed a 3 MWth chicken manure gasifier in Tzum in the Netherlands. The gasifier is a circulating fluidized bed (CFB). The gas is used in a low-Nox gas boiler to produce heat and electricity. The chicken farm uses the heat. Power is delivered 91ft he grid. The plant has been successfully started spring 2006. During 2006 and 2007 several improvements have been made (new ash removal system, new fuel dryer, …). It has been operated 3500 h in 2007. Main problem remains the supply of sufficiently dry fuel (chicken manure). HoSt constructed a second chicken manure gasifier in Portugal 91ft he91 of a 1 Mwe CHP plant in 2010.
Additional Information	http://www.host.nl
Contact	Not known

Project name	CHP Heatpipe Reformer Neufahrn bei Freising
Project owner	HS Energieanlagen GmbH
Status	Operational
Start up	
Country	Germany
City	Neufahrn bei Freising
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Lignocellulosic crops
Input 1 Name	Waste and clean wood
Output 1 Name	Power (electricity)
Output 1 Capacity	0,11
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,25
Output 2 Unit	MWth
Partners	Hartl KG
Technology Brief	Heat pipe reformer, FB; allotherm, steam blown CHP; heat supply for a nearby electrical distributor and the HS Energieanlagen GmbH office
Additional Information	
Contact	Not known

Project name	Holzverstromungsanlage Bucher Escholzmatt
Project owner	Josef Bucher AG Escholzmatt
Status	operational
Start up	1.4.2015
Country	Switzerland
City	CH-6182 Escholzmatt
Type	TRL 9 commercial
Technology	CHP downdraft fixbed gasifier
Raw Material	lignocellulosic crops
Input 1 Name	Wood chip
Input 1 Capacity	4700
Input 1Unit	m3/y
Input additional Information	15 m3/d
Output 1 Name	electricity
Output 1 Capacity	0.130
Output 1Unit	MWel
Output 2 Name	heat
Output 2 Capacity	0.260
Output 2 Unit	MWtherm
Output additional Information	CHP Unit 0,13 Mwel + 0,26 MWth for district heating
Total Investment	1.5 Mio CHF
Total Investment Currency	CHF
Total Investment Explanation	Investment Includes: building, heat and power gasifier unit, connection to district heating and power as well Feedstock bunker and handling devices.
Technology Brief	Downstream Wegscheidt Gasifier
Additional Information	http://www.bucherholz.ch http://www.bucherholz.ch/press/Gewerbepost%20PDF%20Beilage%202015.pdf http://www.holzenergie-wegscheid.de/
Contact	jbagholz@bluewin.ch

Project name	Kymijärvi II
Project owner	Lahti Energia Oy
Status	Operational
Start up	2012
Country	Finland
City	Lahti
Type	TRL 9 Commercial
Technology	CHP
Raw Material	SRF
Output 1 Name	Power (electricity)
Output 1 Capacity	50
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	90
Output 2 Unit	MWth
Partners	Valmet
Technology Brief	The power plant in the Kymijärvi power plant area is based on the CFB gasification technology equipped with innovative gas cooling and cleaning system before combusting the product gas in a specially designed gas fired boiler. Valmet delivered the CFB gasification process, plus gas cooling and cleaning, steam boiler and flue gas cleaning system. The SRF is gasified at 850-900 °C in two CFB-gasifier units (2x80 MW) and converted into product gas, the gas is then purified and the resulting clean ecogas is combusted in an ordinary natural gas boiler. The raw material 94ft he SRF is energy-containing waste.In the gasification of SRF, impurities, that cause boiler corrosion, are transferred 94ft he product gas. The product gas is cooled from 900 degrees to about 400 degrees so that materials causing corrosion turn from gas into solid particles. Then, the solid particles can be filtered out so that the resulting gas is clean. The total fuel input 94ft he plant is 160 MW; the power plant produces 50 MW of electricity and 90 MW of district heat for the city of Lahti.
Additional Information	Juhani Isakkson, Valmet; Hemmo Takala, Lahti Energia Oy
Contact	juhani.isaksson@valmet.com, tel. +358 40 8304402



Project name	Lamprecht
Project owner	Lamprecht GmH
Status	Operational
Start up	2015
Country	Italy
City	Kastelbell
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,199
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	320
Output 2 Unit	MWth
Partners	Urbas
Technology Brief	Urbas gasifier container type
Additional Information	
Contact	Oskar Pfeifer info@lamprecht-holz.com

Project name	Orzinuovi
Project owner	l'Azienda Tenca dei Fratelli Zanotti/AB energy
Status	Operational
Start up	2009
Country	Italy
City	Orzinuovi
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Forestry waste
Output 1 Name	Power (electricity)
Output 1 Capacity	0,300
Output 1Unit	Mwel
Partners	Bio-e-watt
Technology Brief	Downdraft – open core gasifier
Additional Information	http://www.crpa.it/media/documents/crpa_www/Progetti/Seq-Cure/Documentazione/Deliverable_2008/Deliverable_02.pdf
Contact	dott. Fabio Santelli T +39 031.758247 F +39 031.7600548 E-mail: info@bio-e-watt.com

Project name	Mekrijärvi Research Station
Project owner	
Status	Operational
Start up	2005
Country	Finland
City	Ilomantsi
Type	TRL 4-5 Pilot
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,030
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,080
Output 2Unit	MWth
Partners	Volter
Technology Brief	The wood chips are gasified and converted to wood gas which is buned. The plant generates 80 kW heat and 30 kW electricity. The small-CHP is also used for research purpose.
Additional Information	http://volter.fi/portfolio/chp-plant-mekrijarvi/
Contact	Mekrijärvi Research Station Tel. +358 2944 53684

Project name	MEVA VIPP Pilot, PEGB Pilot
Project owner	SP ETC
Status	Operational
Start up	2006, 2011
Country	Sweden
City	Piteå
Type	TRL 4-5 Pilot
Technology	Other gasification Technology R&D activity with no dedicated product
Raw Material	Lignocellulosic crops
Input 1 Name	Woody biomass
Input 2 Name	Pyrolysis oil
Output 1 Name	Heat
Output 1 Capacity	0,5
Output 1Unit	MWth
Output 2 Name	Heat
Output 2 Capacity	1
Output 2 Unit	MWth
Partners	MEVA Innovation and IVAB, respectively.
Technology Brief	Cyclone gasifier with gas cleaning,dismantled 2015, pressurized entrained flow gasifier
Additional Information	www.sö.se/etc
Contact	Magnus Marklund ph: +46 911 23 2385 email: magnus.marklund@sp.se

Project name	Micro-scale biomass gasification CHP Volter
Project owner	Nurmes
Status	Operational
Start up	2012
Country	Finland
City	Nurmes
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Wood chips (dry, good quality)
Output 1 Name	Power (electricity)
Output 1 Capacity	0,040
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,100
Output 2 Unit	MWth
Partners	Volter
Technology Brief	Wood chips are gasified in a downdraft gasifier at 900-1200 C. The product gas is cooled, filtered and wood gas is then burned to provide electricity. The thermal energy produced by the generator is used in a farm to heat water and for drying wood chips.
Additional Information	www.volter.fi
Contact	matti.arffman@e-farm.fi +358 44 783 1700

Project name	Wood Gasifier
Project owner	PoliTO
Status	Operational
Start up	
Country	Italy
City	Alessandria
Type	TRL 6-7 Demonstration
Technology	CHP
Raw Material	Forestry waste
Input 1 Name	Wood
Input 1 Capacity	4100
Input 1Unit	t/y
Output 1 Name	Power (electricity)
Output 1 Capacity	0,640
Output 1Unit	Mwel
Partners	IPLA
Technology Brief	The process has been developed by poliTO and the system is experimental. The plant is fed with 4100 t/a biomass from forest.
Contact	Not known

Project name	Pyroneer Demonstration Plant
Project owner	Pyroneer – DONG Energy Power A/S
Status	Idle
Start up	
Country	Denmark
City	Kalundborg
Type	TRL 6-7 Demonstration
Technology	CHP
Raw Material	Wheat straw
Output 1 Name	Heat
Output 1 Capacity	6
Output 1Unit	MWth
Partners	
Technology Brief	The Pyroneer gasifier typically consists of three main components; a pyrolysis chamber, a char reactor and a recirculating cyclone. Cleaning the gas may simply be done with a second cyclone. Gas co-fired into coal boiler. Stable and safe operation demonstrated. Ash used for fertiliser field tests.
Additional Information	Status End 2015: Technology not sold, project mothballed, staff moved/fired
Contact	Anders Boisen, andbo@dongenergy.dk

Project name	Urbas Balingen
Project owner	Rau GmbH
Status	Operational
Start up	2013
Country	Germany
City	Balingen
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Lignocellulosic crops
Input 1 Name	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,250
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,550
Output 2 Unit	MWth
Partners	Urbas
Technology Brief	A combustible gas, wood gas, is drawn from wood through a means of thermochemical processes which take place in a specially designed reactor. The raw gas is then separated of dust and tars through a filtering system. This cleaned gas is then used to produce combined heat and power through a gas engine + generator. Unlike other CHP technologies which are based on the combustion of biomass, and require a working medium, (water in a steam turbine, heat oil in the ORC-process) wood gas cogeneration requires no intermediate medium thus resulting in a higher electrical efficiency throughout the entire system.
Additional Information	www.urba.at
Contact	Joahim Rau Tel. +49 7433988214

Project name	CHP Arnsberg-Wildhausen
Project owner	Stadtwerke Duesseldorf
Status	Operational
Start up	2016
Country	Germany
City	Arnsberg-Wildhausen
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Lignocellulosic crops
Output 1 Name	Power (heat)
Output 1 Capacity	0,27
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,41
Output 2Unit	MWth
Technology Brief	fixed bed downdraft gasifier, air blown
Partners	Biomass Engeneering Ltd., UK; Biomass Energiesyteme, Dortmund;
Contact	Thomas Nemitz tnemitz@swd-ag.de

Project name	CHP Urbas Konstanz
Project owner	STADTWERKE KONSTANZ GmbH
Status	Operational
Start up	2011
Country	Germany
City	Konstanz
Type	TRL9 Commercial
Technology	CHP
Raw Material	Wood chips
Output 1 Capacity	Power (electricity)
Output 1Unit	0,140
Output 2 Name	Mwel
Output 2 Capacity	Heat
Output 2 Unit	0,300
Output 3 Name	MWth
Partners	Urbas
Technology Brief	A combustible gas, wood gas, is drawn from wood through a means of thermochemical processes which take place in a specially designed reactor. The raw gas is then separated of dust and tars through a filtering system. This cleaned gas is then used to produce combined heat and power through a gas engine + generator. Unlike other CHP technologies which are based on the combustion of biomass, and require a working medium, (water in a steam turbine, heat oil in the ORC-process) wood gas cogeneration requires no intermediate medium thus resulting in a higher electrical efficiency throughout the entire system.
Additional Information	www.urbas.at
Contact	DI Olaf Westerhoff Tel.: +49 7531 803 226

Project name	CHP Stadtwerke Rosenheim
Project owner	Stadtwerke Rosenheim GmbH
Status	Operational
Start up	2015
Country	Germany
City	Rosenheim
Type	TRL 9 Commerical
Technology	CHP
Raw Material	Wood chips
Output 1 Capacity	42
Output 1Unit	kg/h
Output 1 Name	Power (electricity)
Output 1 Capacity	0,050
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,095
Output 2 Unit	MWth
Technology Brief	Development since 2007. Fluidized bed reactor, combination of concurent and eddy flow, gas utilization via motor.
Contact	Rolf Waller rolf.waller@swro.de

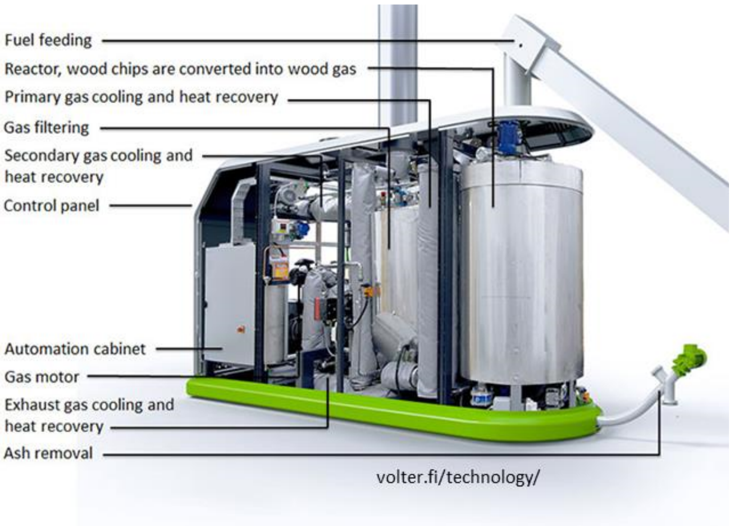
Project name	CHP Stadtwerke Ulm/Neu-Ulm
Project owner	Stadtwerke Ulm/Neu-Ulm
Status	Operational
Start up	2011
Country	Germany
City	Neu-Ulm
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Lignocellulosic crops
Input 1 Name	Wood chips
Input 1 Capacity	14,3
Input 1Unit	Mwfuel
Output 1 Name	Power (electricity)
Output 1 Capacity	4,6
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	15
Output 2 Unit	MWth
Total Investment	33 Mio
Total Investment Currency	Euro
Partners	Repotec
Technology Brief	FICFB; allotherm; steam blown; gas engine 4 Mwel and ORC 0,6 Mwel
Additional Information	
Contact	Not known

Project name	
Project owner	Steiner A. & Cie AG
Status	operational
Start up	2013
Country	Switzerland
City	Ettiswill
Type	TRL 9 Commercial
Technology	Power/CHP
Raw Material	Lignocellulosic crops
Input 1 Name	Wood chips
Output 1 Name	Power (electircity)
Output 1 Capacity	0,045
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,105
Output 2 Unit	MWth
Technology Brief	Downdraft Spanner gasifier
Additional Information	
Contact	Urs Steiner steiner-saegerei@bluewin.ch

Project name	CHP Flensburg
Project owner	Stirling DK
Status	Operational
Start up	2009
Country	Germany
City	Langballig
Type	TRL 9 Commercial
Technology	CHP
Raw Material	Lignocellulosic crops
Input 1 Name	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,070
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,280
Output 2 Unit	MWth
Partners	Stirling
Technology Brief	Updraft gasifier and two stirling engines
Contact	Annabell Möller, am@stirling.dk, +45 88 18 48 07

Project name	CHP Demonstrationsanlagen URBAS
Project owner	Urbas Energietechnik
Status	Operational
Start up	2001
Country	Austria
City	Ruden
Type	TRL 6-7 Demonstration
Technology	CHP
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,150
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,300
Output 2 Unit	MWth
Partners	Urbas Stahl&Anlagenbau, Voelkermarkt
Technology Brief	A combustible gas, wood gas, is drawn from wood through a means of thermochemical processes which take place in a specially designed reactor. The raw gas is then separated of dust and tars through a filtering system. This cleaned gas is then used to produce combined heat and power through a gas engine + generator. Unlike other CHP technologies which are based on the combustion of biomass, and require a working medium, (water in a steam turbine, heat oil in the ORC-process) wood gas cogeneration requires no intermediate medium thus resulting in a higher electrical efficiency throughout the entire system.
Additional Information	
Contact	Ing. Peter Urbas DI Wolfgang Felsberger Tel.+43 4232 25210

Project name	Kempele Ecovillage
Project owner	Volter
Status	Operational
Start up	2009
Country	Finland
City	Kempele
Type	TRL 4-5 Pilot
Technology	CHP
Raw Material	Wood chips (dry, good quality)
Output 1 Name	Power (electricity)
Output 1 Capacity	0,300
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	0,800
Output 2 Unit	MWth
Partners	Volter
Technology Brief	The power plant first converts the wood chips to wood gas, which is then burned to provide electricity. The thermal energy produced by the generator is used to heat water, which warms the houses as it passes through pipes in the floors. The energy created suffices to provide the ten houses with heat and electricity all year round. A windmill stands ready to supply extra power in case the power plant falls short. The ecovillage concept represents a remarkable achievement in an area where winter temperatures can reach minus 40 degrees.
Additional Information	www.volter.fi
Contact	Jarno Haapakoski, Volter +358 40 739 0461



Project name	Växjö Värnamo Biomass Gasification Center AB
Project owner	VVBGC AB
Status	Idle
Start up	1995
Country	Sweden
City	Värnamo
Type	TRL 6-7 Demonstration
Technology	Other gasification Technology CHP/Synthesis
Raw Material	Lignocellulosic crops
Input 1 Name	Woody biomass, agrowaste
Output 1 Name	Power (electricity)
Output 1 Capacity	6
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	8
Output 2 Unit	MWth
Output 3 Name	Clean syngas
Output 3 Capacity	1000
Output 3 Unit	m3/h
Partners	Foster Wheeler, E.ON for CHP
Technology Brief	The plant was originally built for CHP production based on an IGCC concept. Fuel was fed by means of a lock hopper system. The gasifier was an airblown CFB operating at approx 20 atm. Downstream 111ft he gasifier and its associated cyclone, the gas was cooled to 400 C and then passed a hot gas filter in which particulateds were removed. The gas was then directly routed to either the flare or an SGT100 gas trubine. Bleed air from the gas turbione compressor was used in the gasifier after pressure boosting. The exhaust gas from the turbine passed a HRSG generating steam at 45 bar 450 C and also some district heating before being released 111ft he stack. The steam was used in a steam turbine, after which there was a district heating condenser. The plant was operated in this way until 2000 when it was mothballed. There has been several attempts to revive the plant for use as a steam-oxygen blown unit for synthesis gas production. The last attempt failed in 2011 for lack of industrial financing.
Additional Information	www.vvbgc.se
Contact	Gunnar Crona email: info@vvbgc.se +46 370 69 41 00

Project name	CHP Grossenhain
Project owner	Waermeversorgung Grossenhain /POW AG

Status	Operational
Start up	
Country	Germany
City	Grossenhain
Type	TRL9 Commercial
Technology	CHP
Raw Material	Lignocellulosic crops
Output 1 Name	Power (electricity)
Output 1 Capacity	6
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	21
Output 2 Unit	MWth
Total Investment	12 Mio
Total Investment Currency	Euro
Technology Brief	Fluidized bed CHP
Additional Information	
Contact	Not known

Project name	Hillerod two stage gasifier
Project owner	Weiss
Status	Commissioning
Start up	
Country	Denmark
City	Hillerod
Type	TRL 6-7 Demonstration
Technology	CHP
Raw Material	Wet wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,500
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	1
Output 2 Unit	MWth
Partners	DTU, Weiss, COWI
Technology Brief	Staged down draft Gasifier Developed and patented by DTU, Scale-up by Weiss and DTU, Licensed by COWI
Additional Information	
Contact	Bjarne Skyrum, bjs@weiss-as.dk

Project name	CHP Wila
Project owner	Holzstrom aus Nidwalden
Status	operational
Start up	2007
Country	Switzerland
City	Stans
Type	TRL 9 Commercial
Technology	Power/CHP
Raw Material	Lignocellulosic crops
Input 1 Name	dried chips from demolition wood
Output 1 Name	Power (electircity)
Output 1 Capacity	1,38
Output 1Unit	Mwel
Output 2 Name	Heat
Output 2 Capacity	1,2
Output 2 Unit	MWth
Technology Brief	2-zone downdraft Pyroforce gasifier
Additional Information	
Contact	Bernhard Boecker-Riese boecker-riese@br-engineering.ch Hans Bieri holzverstromung@korporation-stans.ch

6.1.1 Industry Guide Thermochemical Biomass Gasification 2015

At this place The Industry Guide Thermochemical Biomass Gasification, which presents the technology and protagonists in this business sector, should be mentioned.

With 35 producers, suppliers, service providers the Industry guide gives a compact register of the most important European players, their competences and products.

In the process of biomass gasification woodchips, pellets or comparable biomass is transformed highly efficiently and climate neutrally into heat and electricity.

The Guide was published by FEE (Foerdergeselschaft Erneuerbare Energien) and it is online at http://www.fee-ev.de/branchenguide.html

The gasification plants are listed below, the features of the plants are:

PARAMETER – FEATURES OF BIOMASS GASIFICATION PLANTS

Range of capacity	Produced thermal and electric energy (in kW)
Type of rawmaterial	Unadulterated wood or other biomasses (e. g. according to BiomasseV 2014)
Shape and quality of rawmaterial	Details about shape (wood chips, pellets) and quality (moisture content, lumpiness, fine content and longest wood chip)
Gasification process and reaction	Information about the specific process of thermochemical energy conversion (reaction bed and direction of flow)
Number of grid feeding plants	Number of the installed plants that feed into the grid, closing date: December 31, 2014
Max. operating time	per year
Fuel requirement	Fuel requirement at nominal load
Flow / Return temperature	Preferred temperature for heat extraction
Required installation room	Minimum space (W x H x D) for the gasification plant excluding the recommended supply unit, with current output, without heat transferal station and storage
Startup and shutdown times	Time from '0' to full load and from full load to fail-safe status 'off'
Number of staff	in the field of biomass gasification
Market entry	Year of the first product / plant sold in the field of biomass gasification
Distributing countries	international abbreviations

ABBREVIATIONS

CHP	Combined Heat and Power
ORC	Organic Rankine Cycle
moist. cont.	moisture content
USP	Unique Selling Point

BR Engineering GmbH

FEATURES

- From 200 kW_{th} | from 200 kW_{el}
- Unadulterated wood, wood chips, other biomasses (among others hogged fuel)
- Quality of charge material: 15% moist. cont., G30-G100, 5% fine content with less than 10 mm, max. 250 mm chip
- Fixed-bed process (optional: moving-bed) in combination of cocurrent and countercurrent flow
- Max. 8 000 h/a operating time
- 720 g/h fuel requirement (at 12% moist. cont.) for 1 kWh_{el}
- Gas utilization via motor
- 90°C | 70°C flow/return temperature
- USP: proven for demolition wood / ash free of char
- List of reference plants at FEE
- 2 grid feeding plants
- Since 1997

For 20 years the team of BR Engineering (part of the BR Energy Group AG) has been working successfully in the field of highly efficient usage of biogenic residues. Demonstrating their reliability for more than eight years, our current reactors of the type 'Sirion' particularly distinguish themselves through low-maintenance operation and durable components.
The 'Synthurion' model is a completely new development: it works highly efficient with a cold gas efficiency of 90%, qualifies for the production of biochar and processes a wide range of input materials independent of the fine content.
Experience with us the exciting world of sustainable biomass-based power generation.

CONTACT

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FEE

BURKHARDT
ENERGIE- UND GEBÄUDETECHNIK

Burkhardt GmbH

FEATURES

- 260-270 kW_{th} | 165-180 kW_{el}
- Pellets
- Fluidized bed process in cocurrent flow
- Max. 8 000 h/a operating time
- 110 kg/h fuel requirement (at 10% moist. cont.)
- Gas utilization via motor
- 90°C | 70°C flow/return temperature
- Required installation space at least 8 x 5x 5 m
- List of reference plants available at producer
- 120 grid feeding plants
- Since 2008

With a great deal of research and development work, we were able to eliminate the early defects of the original wood gasification. Since 2011 we offer wood gas cogeneration plants that now supply customers all over Germany, in parts of Europe and even in Japan with environmentally friendly heat and power. Our V 3.90 wood gasifier with downstream CHP has an electric efficiency of more than 30%. 2015: In ECO 165 HG CHP runs a pilot injection gas motor that has been especially adapted to run with wood gas only.
Several factors have contributed to this success:
a) homogeneous output due to the use of standardized pellets
b) patented procedure with 'hovering reaction layer'
c) ECO 165 HG without pilot oil

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FEE

Holzenergie Wegscheid GmbH

FEATURES

- 110-260 kW_{th} | 65-140 kW_{el}
- Unadulterated wood, briquettes and maxi-sized pellets, wood chips
- Quality of charge material:
  10 % residual moisture,
  lumpiness 50-70mm,
  2 % fine content, max. 70 mm chip
- Fixed-bed process in cocurrent flow
- Max. 8 490 h/a operating time
- Gas utilization via motor
- Required installation space:
  10 x 8 x 5 m
- Performance guarantee insurance and long filter life
- List of reference plants at producer
- 25 employees
- 34 grid feeding plants
- Distributing countries:
  D, A, CH, I, SLO, J, CDN, F, PL

Only quality endures. A credo we have lived by for years. Innovation and absolute customer focus are the central pillars of our philosophy. Our systems' reliability and high efficiency are based on in-depth knowledge and continuous development.
Insured revenues from the CHP-power and an annual availability of 95 % speak for themselves.
The different units with a capacity of 65 kW_{el}/ 110 kW_{th}, 125 kW_{el}/230 kW_{th} and 140 kW_{el}/ 260 kW_{th} can be flexibly extended up to several megawatt.
From planning to maintenance and remote maintenance – we are there for you with advice and support.

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www.holzenergie-wegscheid.de

FEE

REGAWATT

ReGaWatt GmbH

FEATURES

- $600\text{-}4300\ kW_{th}$ | $300\text{-}2000\ kW_{el}$
- Wood chips from various sources up to 30 % bark and landscape management chips
- Quality of charge material: M30 - M50, G100, max. 20 % fine content at 11,2 mm, max. 250 mm chip
- Fixed-bed in countercurrent flow
- Gas utilization via motor, gas turbine, combustion chamber
- USP: indifferent to various fuel qualities by using updraft gasification
- List of reference plants at producer
- 4 grid feeding plants
- Since 2010
- Distributing countries: EU

ReGaWatt is your specialist for turnkey energy systems. With our KombiPowerSystem® we have developed the future of decentralized energy supply:

- Due to the updraft principle a complete burnout of the ash is achieved
- Combination with gas engines or gas turbines is possible, depending on the heat demand of the customer
- Very low emissions through afterburning of the engine exhaust
- No fuel drying required
- Partial load capability down to 20 %
- Tailor-made plant concepts with heat extraction as process hot water, steam or thermal oil are possible
- Power production by ORC is possible and also in use

The best technologies, we perfectly put together to your KombiPowerSystem®!

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info@regawatt.de | www.regawatt.de FEE

Spanner Re²

Spanner Re² GmbH

FEATURES

- 73 kW_{th} | 30 kW_{el}
- 2. type of plant: 108 kW_{th} | 45 kW_{el}
- Unadulterated wood, forest chips (at 30 kW_{el}), wood chips
- Quality of charge material: 13 % moist. cont., 30 % fine content
- Fixed-bed process in cocurrent flow
- max. 8200 h/a operating time
- Gas utilization via motor
- 85°C | 65°C flow/return temperature
- 440 grid feeding plants
- List of reference plants at producer and FEE
- Since 2008
- Distributing countries: D, A, CH, I, CZ, SLO, LV, CDN, GB, FIN, HR, J, PL

Spanner Re² wood cogeneration plants are small combined heat and power (CHP) plants that generate onsite heat and power from locally sourced wood chip. This combined approach is the most efficient and sustainable way of energy production because it ensures that energy is consumed close to the point of generation. With Spanner Re² wood cogeneration plants energy is generated where and when it's needed. If required, heat can also be stored in hot water accumulator tanks. Spanner Re² wood cogeneration plants are quality made and engineered in Germany. They have a proven track record in Germany and abroad.

For further information please see contact details below.

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www.holz-kraft.de

FEE

stadtwerke rosenheim

Stadtwerke Rosenheim GmbH & Co. KG

FEATURES

- 95 kW_{th} | 50 kW_{el}
- Unadulterated wood, wood chips
- Quality of charge material: 12% moist. cont., lumpiness 30 x 30 x 30 mm, 5% fine content at max. 2 mm, max. 60 mm chip
- Fluidized bed and tiered process, combination of concurrent and eddy flow
- 42 kg/h fuel requirement 12% moist. cont.
- Gas utilization via motor
- USP: very high gas quality, energy-efficient (>75% fuel utilization rate)
- Staff: 12
- Since 2015
- Distributing countries: DE, AT, I

The Stadtwerke Rosenheim (Rosenheim Municipal Utilities) introduces its own wood gasifier:
A reliable, effective and safe technology that converts wood-derived energy efficiently. Therefore operators achieve exceedingly higher power and heat outputs.
During the development of the wood gasifier starting in 2007, we were able to profit from our long lasting experience in the operation of power plants.
This makes our process, the so-called 'Rosenheimer Verfahren', unique. Starting in 2015, our first gasifiers will be delivered to reference customers. We, as a municipal utility, can provide an all-in-one solution: From the energy concept and the engineering to the operation of the plant.

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FEE

SYNCRAFT

SynCraft

FEATURES

- 350-625 kW_{th} | 180-324 kW_{el}
- Modular construction enables more than 1 MW
- Unadulterated wood, tree and shrub cuttings, waste wood class A, wood chips
- Quality of charge material: 15% moist. cont., P16-P45, max. 200 mm chip
- Tiered process in cocurrent flow (floating fixed-bed)
- Max. 7500 h/a operating time
- Gas utilization via motor
- Installation room: 6 x 10,5 x 8 m
- Fuel flexibility
- No additives needed
- By-product bio char
- Electric efficiency 30%
- 3 grid feeding plants

The fuel makes the difference.
Our biomass power plants are so flexible with regard to the raw material used that we can employ all forest residues, such as offcuts and sawmill by-products, for fuel without compromising fine or bark content.
Thanks to our patented impurities-discharge, we are also tolerant against stones and nails. All this is made possible by the innovative floating fixed-bed technology, which allows both, maximum efficiency and maximum fuel flexibility and therefore offers clear economic advantages for our customers.
Experience it yourself and visit one of our reference plants.

CONTACT

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craftwerk@syncraft.at
www.syncraft.at

FEE

XYLOENERGY

Xyloenergy GmbH

FEATURES

- 380 kW_{th} | 360 kW_{el}
- Unadulterated wood, wood chips
- Quality of charge material:
  18% moist. cont.,
  lumpiness: 50x 50x 5 to
  100x 100x 20 mm,
  3% fine content at 10 mm,
  max. 180 mm chip
- Fixed-bed process in cocurrent flow
- max. 7500 h/a operating time
- 240 kg/h fuel requirement
  (at 15% moist. cont.)
- Installation room: 20x 10x 10 m
- 120 min. | 5 min. startup/shutdown time
- USP: plant can produce electric capacity via 100% diesel/bio-diesel as well;
  utilization of waste wood
- 1 grid feeding plant
- Distributing countries: EU

XYLOENERGY is an interdisciplinary team of specialists with extensive experience in the fields of thermochemical conversion of biomass.
We design and implement biomass power plants with the innovative XYLOENERGY wood gasification technology, which is characterized by particularly high levels of efficiency and profitability.
The sophisticated XYLOENERGY process operates as a closed system, so neither tars nor other condensates have to be disposed.
The performance of the process has already been proven in the scope of international projects.
We realize our projects together with a strong and global player as partner within the EU and in the future also worldwide.

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FEE

Ettenberger GmbH & Co. KG

We are working with a new process of biomass gasification for the generation of heat and power from woody substrates. The complete energy conversion of the input substrates is achieved via a thermochemical process without energy afflicted remains.

FEATURES

- 52 kW_{th} | 25 kW_{el}
- Unadulterated wood, wood chips, short rotation plants
- Quality of charge material: 15-22% moist. cont., lumpiness 10-50 mm, 15% fine content, max. 80 mm chip
- Tiered gasification process in combination
- 25 kg/h fuel requirement (at 15% moist. cont.)
- 2 min | 1 min startup/shutdown times
- USP: least remaining quantity
- 3 grid feeding plants

CONTACT

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https://www.facebook.com/woodgas

KOPF SynGas GmbH & Co. KG

The Kopf SynGas process closes the gap to an energy self-suffient sewage treatment plant and produces heat and power from sewage sludge. 15 years of operational experience as well as consistent research and development form the foundations of our sophisticated technology. We take over planning activities, the projecting phase and – if desired – also operation and maintenance of the plants.

FEATURES

- 600 kW_{th} | 560 kW_{el}
- Sewage sludge (10% moist. cont.)
- Fluidized bed process
- Unique selling point (USP): Sewage sludge mono utilization
- 2 grid feeding plants
- Since 2000

CONTACT

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KWS STROHMENGER GMBH

Wood Gasifier System Werner

The wood gasification plant 'System Werner' offers one of the most innovative solutions to obtain power from wood. With its sophisticated gas flow system it produces a nearly tar free fuel gas at a low level of wood supply. The subsequent gas treatment including dehumidification secures an optimal motor operation.

FEATURES

- 550 kW_{th} | 300 kW_{el}
- Unadulterated wood, wood chips
- Quality of charge material: 10 % moist. cont., G100, 5 % fine content, max. 250 mm chip
- Fixed-bed process in cocurrent flow
- 210 kg/h fuel requirement (at 10 % moist. cont.)
- Gas utilization via motor
- 1 grid feeding plant

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Ligento® green power

Ligento green power GmbH

Ligento manufactures ready-to-use container plants with facilities to dry and store wood chips for the production of power and heat from solid biomass wood. A low fuel requirement, fully automatic process management and a certified co-channel safety control are excellent features of the plant.

FEATURES

- 240 kW_{th} | 140 kW_{el}
- Unadulterated wood, residual wood from forestry, short rotation plants, wood chips
- Quality of charge material: 45 % moist. cont., G30/G50/G100, partial sifting, max. 200 mm chip
- Fixed-bed process in cocurrent flow
- 130 kg/h fuel requirement (at 10 % moist. cont.)
- Installation ca. 13,5 x 18,5 x 6 m in container modules
- 2 grid feeding plants

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Meva Energy AB

Meva Energy provides entrained flow gasification systems in the range of 1-5 MW_{el}. In particular, our systems provide a very even and stable gas production.
Meva Energy's system accepts wood chips and pellets but also second generation biomass such as saw dust, straw, olive husks, rice husks etc.

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FEE

FEATURES

- 2400 kW_{th} | 1200 kW_{el}
- Unadulterated wood, wood chips, pellets, saw dust, husks, straw
- Quality of charge material: 12 % moist. cont., lumpiness 1 mm (otherwise grinding)
- Entrained flow in cocurrent flow
- max. 8000 h/a operating time
- 960 kg/h fuel requirement (at 10 % moist. cont.)
- 1 grid feeding plant

Qalovis GmbH

Qalovis is an innovative manufacturer of customized machines and systems for refining biogenic waste materials. With our Q-PowerGen-System we offer you a Biomass-Stirling-CHP plant without cost-intensive gas cleaning by making use of a separate burning chamber for emission-reduced gas conversion.

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www.qalovis.com

FEE

FEATURES

- 120 kW_{th} | 36 kW_{el}
- Unadulterated wood, residual wood from forestry and landscape conservation, wood chips, pellets
- Quality of charge material: 20 % moist. cont., 20 % fine content, max. 80 mm chip
- Fixed-bed process in cocurrent flow
- Gas utilization via combustion chamber / Stirling motor
- USP: no scrubbing of gas needed
- 1 grid feeding plant

URBAS
energietechnik

URBAS Maschinenfabrik GmbH

Power and heat from biomass on small scale capacity level. Plants with market maturity, over 50 000 hours of operation and a benchmark with 8 588 full load hours per year. Urbas provides complete solutions on greenfield sites or as an addition to e.g. existing heating plants.

FEATURES

- 150 - 620 kW_{th} | 70 - 300 kW_{el}
- Unadulterated wood, wood chips
- Quality of charge material: 15 % moist. cont., P100c EN 14961, max. 150 mm chip
- Fixed-bed process in concurrent flow
- max. 8 580 h/a operating time
- Since 2008
- 14 grid feeding plants

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6.2 Fuel synthesis facilities

The status of thermal gasification facilites – explanation

Operational	Under construction	Planned	Non operational	No status

Nr.	Owner	Name	Status	Page
1	Bio SNG Guessing	Synthesis Demo Guessing		130
2	CHOREN Fuel Freiberg GmbH & Co. KG	Synthesis CHOREN beta plant Freiberg		131
3	CHOREN Industries GmbH	Synthesis CHOREN sigma plant Schwed		132
4	CHOREN Industries GmbH	Synthesis CHOREN alpha plant Freiberg		133
5	Cutec	Synthesis Cutec Clausthal-Zellerfeld		134
6	E.ON gasification Development AB	Bio2G		135
7	Fulcrum Bioenergy Sierra Biofuels Plant	Synthesis Fulcrum BioEnergy City of McCarran		136
8	Goeteborg Energi	GoBiGas		137
9	GTI Gas Technology Institute	GTI gasifier Des Plaines		138
10	INEOS New Planet BioEnergy	Synthesis INEOS Plant Vero Beach		139
11	Karlsruhe Institute of Technology (KIT)	Synthesis bioliq – process Karlsruhe		140
12	LTU green Fuels	DP1 + DP2 pilot		141
15	Stora Enso	Gasifier at Varkaus paper mill (former Corenso)		142
16	VaermlandsMetanol AB	VaermlandsMetanol Hag fors		143
17	Vienna University of Technology / bioenergy 2020+	FT pilot plant Guessing		144
18	VTT Technical Research Centre of Finland Ltd.	Pressurized FB for synthesis gas production		145

19	VTT Technical Research Centre of Finland Ltd.	Dual fluidized bed steam gasification pilot plant		146
20	West Biofuels	LLC Thermal reformer Synthesis West Biofuels Woodland, CA		147

Project name	Synthesis Demo Guessing
Project owner	Bio SNG Guessing
Status	On Hold
Start up	2008
Country	Austria
City	Güssing
Type	TRL 6-7 Demonstration
Technology	Fuel synthesis
Raw Material	Lignocellulosic crops
Input 1 Name	Syngas from gasifier (FICFB Guessing)
Input 1 Capacity	350
Input 1Unit	m3/h
Output 1 Name	SNG
Output 1 Capacity	100
Output 1Unit	m^3/h
Technology Brief	Here a small demonstration plant in a size of 1 MW SNG output was in operation. The methanation was done in a fluidized bed reactor at about 350°C and at a pressure of 1-5 bars. As catalyst a nickel based catalyst is used. The demonstration plant includes the additional gas cleaning to remove sulphur and chlorine components, the methanation itself and the raw SNG upgrading to a natural gas quality. The SNG had the same quality as natural gas in Austria and was used in a CNG tank filling station. The experimental campaigns are finished and energetic efficiencies from wood to SNG of more than 60% were achieved.
Additional Information	www.ficfb.at
Contact	reinhard.rauch@bioenergy2020.eu

Project name	Synthesis CHOREN alpha plant Freiberg
Project owner	CHOREN Industries GmbH
Status	Idle
Start up	1998
Country	Germany
City	Freiberg
Type	TRL 4-5 Pilot
Technology	Synthesis
Raw Material	Lignocellulosic biomass
Output 1 Name	FT liquids
Output 1 Capacity	53
Output 1Unit	t/y
Partners	
Technology Brief	The so-called Alpha plant, a pilot plant for fuel gas and syngas from renewable hydrocarbon sources, was put into operation in 1998. The first liquid products were synthesized from wood on a laboratory scale as early as 2001, and then for the first time in continuous operation in 2003. The successor to this pilot system is the Beta plant, the world's first commercial-scale plant for the synthesis of BtL (biomass-to-liquid) fuel.
Additional Information	
Contact	Not known

Project name	Synthesis CHOREN beta plant Freiberg
Project owner	CHOREN Fuel Freiberg GmbH & Co. KG
Status	Stopped while under construction
Start up	
Country	Germany
City	Freiberg
Type	TRL 6-7 Demonstration
Technology	Fuel synthesis
Raw Material	Lignocellulosic crops
Input 1 Name	Dry wood chips from recycled wood and residual forestry wood; additionally in the future fast growing wood from short-rotation crops
Output 1 Name	FT liquids
Output 1 Capacity	13 500
Output 1Unit	t/y
Total investment	100 000 000
Total Investment Currency	Euro
Technology Brief	BtL production; 3-staged gasification at 6 bar with Fischer Tropsch Synthesis; demonstration plant
Additional Information	www.choren.com
Contact	Not known

Project name	Synthesis CHOREN sigma plant Schwedt
Project owner	CHOREN Industries GmbH
Status	Stopped while under construction
Start up	
Country	Germany
City	Schwedt
Type	TRL 8 First-of-a-kind commerial demo
Technology	Fuel synthesis
Raw Material	Lignocellulosic crops
Input 1 Name	Dry wood chips from recycled wood; fast growing wood from short-rotation crops
Output 1 Name	FT liquids
Output 1 Capacity	200 000
Output 1Unit	t/y
Contact	info@choren.com +49 3731 2662 0

Project name	Synthesis Cutec Clausthal-Zellerfeld
Project owner	Cutec
Status	Operational
Start up	1990
Country	Germany
City	Clausthal-Zellerfeld
Type	TRL 1-5
Technology	Fuel synthesis
Raw Material	Lignocellulosic crops
Input 1 Name	Straw, wood, dried silage, organic residues
Output 1 Name	FT liquids
Output 1 Capacity	0,02
Output 1Unit	t/y
Technology Brief	BtL production; atmospheric gasifier; artfuel project
Contact	Stefan Vodegel stefan.vodegel@cutec.de

Project name	Bio2G
Project owner	E.ON Gasification Development AB
Status	idle
Start up	
Country	Sweden
City	Scania province
Type	TRL 9 Commercial
Technology	Fuel Synthesis
Raw Material	Other
Input 1 Name	Woody Biomass
Input 1 Capacity	300
Input 1Unit	MW
Output 1 Name	SNG / bio-methane
Output 1 Capacity	200
Output 1Unit	MW
Output 2 Name	Heat
Output 2 Capacity	50
Output 2 Unit	MWth
Technology Brief	The technology selected for the gasification system is based on pressurised oxygen blown gasification in a fludized bed followed by hot gas cleaning (tar reforming, HAT filter), cold gas cleaning (water scrubber, acid gas removal), compression, WGS and synthesis of methane.
Additional Information	
Contact	Björn Fredriksson-Möller +46 40 255 716 email: bjorn.moller@eon.se

Project name	Synthesis Fulcrum BioEnergy City of McCarran
Project owner	Fulcrum BioEnergyâ€™s Sierra Biofuels Plant
Status	Planned
Start up	2017
Country	USA, Nevada
City	City of McCarran
Type	TRL 7 - Prototype
Technology	Fuel synthesis
Raw Material	Biomass / Biomass coal blends
Input 1 Name	Organic residues and waste streams
Input 1 Capacity	90000
Input 1Unit	t/y
Output 1 Name	Ethanol
Output 1 Capacity	4.731
Output 1Unit	m3/h
Output 2 Name	Power (electricity)
Technology Brief	In Plasma Enhanced Melter Â® (PEM) system provides a means of producing renewable energy from waste. The PEM process utilizes heat from plasma (electrically charged vapor) to convert waste feedstocks to valuable products including power generation.
Additional Information	The plant will convert 90,000 tons of MSW into 10.5 million gallons of ethanol per year. Fulcrum has obtained the necessary local and state regulatory permits.
Contact	info@fulcrum-bioenergy.com

Project name	GoBiGas
Project owner	Goeteborg Energi
Status	operational
Start up	2013
Country	Sweden
City	Ryahamnen, Göteborg
Type	TRL 6-7 Demonstration
Technology	Fuel Synthesis
Raw Material	Lignocellulosic crops
Input 1 Name	Wood pellets
Input 1 Capacity	30; 6,5
Input 1Unit	MW; t/h
Input 2 Name	Forest residues
Input 2 Capacity	30; 6,5
Input 2Unit	MW; t/h
Output 1 Name	SNG
Output 1 Capacity	20
Output 1Unit	MW
Output 2 Name	Heat
Output 2 Capacity	5
Output 2 Unit	MWth
Partners	Repotec, Metso Power, Jacobs Process, Haldor Topsoe
Technology Brief	The gasification technology is based on the Repotec indirect gasification, which is supllemented by gas upgrading and SNG synthesis. The GoBiGas 1 project was planned as a demonstrator to be followed by a fully industrial plant of 80-100 MW bio-methane output on the same site. Göteborg Energi made a successful NER 300 application for support for this expansion. However, in late 2015 the City Council,being the owner of Göteborg Energi, took a decision to cancel the project GoBiGas 2.
Additional Information	http://gobigas.goteborgenergi.se/
Contact	Freddy Tengberg email: Freddy.tengberg@goteborgenergi.se +46 706 29 22 44

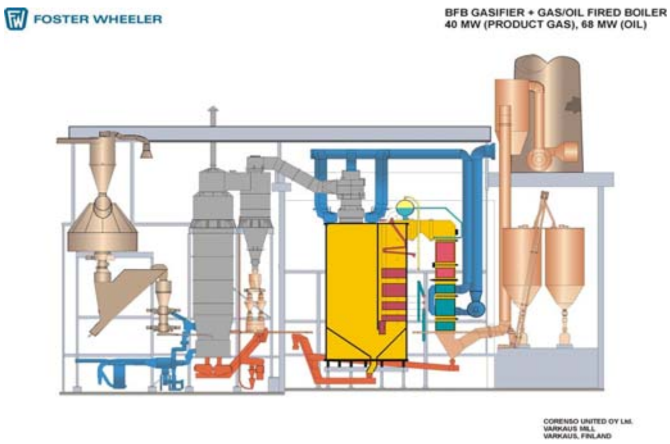
Project name	GTI gasifier Des Plaines
Project owner	GTI Gas Technology Institute
Status	Operational
Start up	
Country	USA, Illinois
City	Des Plaines
Type	TRL 4-5 Pilot
Technology	Fuel synthesis
Raw Material	Lignocellulosic crops
Input 1 Name	Pellets, wood chips
Input 1 Capacity	24
Input 1Unit	t/d
Output 1 Name	Heat
Output 1 Capacity	5
Output 1Unit	MWth
Output 2 Name	Gasoline – type fuels
Output 2 Capacity	37,8500
Output 2 Unit	m3/y
Funding	2 000 000
Funding Currency	US Dollar
Partners	Carbona (Finland and USA) biomass gasification process (based on cooperation with VTT of Finland), Velocys (USA) Fischer Tropsch Technology, UPM (funding); Andritz Carbona;
Technology Brief	Carbona (Finland and USA) biomass gasification process is originally based on licenses from the Gas Technology Institute and has subsequently been developed further by Carbona.
Additional Information	Gasification, sulfur removal, and tar reforming will be conducted at 1000 kg/h. The WGS, compression, CO2 removal, and heat exchange will be conducted at about 1400 scd/h (1/50th of the gasifier stream). The FT reactor will produce about 25 gal/d
Contact	Not known

Project name	Synthesis INEOS Plant Vero Beach
Project owner	INEOS New Planet BioEnergy
Status	Idle
Start up	2012
Country	USA, Florida
City	Vero Beach
Type	TRL 4-5 Pilot
Technology	Fuel Synthesis
Raw Material	Waste material
Input 1 Name	Vegetative waste, MSW
Input 1 Capacity	300
Input 1Unit	t/d
Output 1 Name	Ethanol
Output 1 Capacity	3,47
Output 1Unit	m3/h
Output 2 Name	Power (electricity)
Output 2 Capacity	6
Output 2 Unit	MWel
Partners	INEOS Bio, New Planet Energy, EPC firm AMEC
Contact	Synthesis Plant Vero Beach Dan Cummings biopress@ineos.com

Project name	Synthesis bioliq - process Karlsruhe
Project owner	Karlsruhe Institute of Technology (KIT)
Status	operational
Start up	2012
Country	Germany
City	Karlsruhe
Type	TRL 4-5 Pilot
Technology	Fuel synthesis
Raw Material	Lignocellulosic crops
Input 1 Name	Straw
Input 1 Capacity	1
Input 1Unit	t/h
Output 1 Name	Gasoline type fuels
Output 1 Capacity	608
Output 1Unit	t/y
Partners	KIT, Lurgi, MUT, MLR
Total Investment	64 mio.
Total Investment Currency	Euro
Technology Brief	The bioliq process, developed at the Karlsruhe Institut für Technologie (KIT) aims at the production of synthetic fuels and chemicals from biomass. The bioliq technology is based on a two step process with decentral pyrolysis for the production of transportable slurry from biomass (e.g. straw) and central slurry gasification and BtL production. At KIT Karlsruhe a pilot plant with 2 MW fast pyrolysis and biosyn-crude production and 5 MWth high pressure entrained flow gasifier operated up to 8 MPa (both in cooperation with Lurgi GmbH, Frankfurt), as well as the hot gas clean-ing (MUT Advanced Heating GmbH, Jena), dimethylether and final gasoline synthesis (Chemieanlagenbau Chemnitz GmbH) are in operation.
Additional Information	
Contact	Mark Eberhard mark.eberhard@kit.edu

Project name	DP1+DME pilot
Project owner	LTU Green Fuels
Status	operational
Start up	2011
Country	Sweden
City	Pitea
Type	TRL 4-5 Pilot
Technology	Fuel Synthesis
Raw Material	Other
Input 1 Name	Black Liquor
Output 1 Name	Clean Syngas
Output 1 Capacity	2
Output 1Unit	MW
Output 2 Name	DME
Output 2 Capacity	4
Output 2 Unit	t/d
Partners	Biosyngas program: Chemrec AB, Haldor Topsöe, Volvo Truck, Preem, Smurfit Kappa, Sveaskog, Perstorp, Södra, Holmen, Flogas and ETC.
Technology Brief	The Chemrec process uses a refractory-lined entrained bed reactor in which concentrated black liquor is gasified under reducing conditions at around 1000°C. The liquor is decomposed in the reaction zone into melt droplets consisting of sodium compounds, and a combustible gas containing H2 and CO. The smelt droplets and the combustible gas are separated in a quench dissolver where they are simultaneously brought into direct contact with a cooling liquid. The melt droplets dissolve in the liquid to form a green liquor solution. The gas leaving the quench dissolver is cooled producing steam. The cooling is done in counter current mode which means that the gas is efficiently washed of particulate matter. The gas is then free of melt droplets and can be scrubbed for H2S removal and then used as a clean fuel or syngas. The DME pilot was installed in 2011. Since the end of the Chemrec BLG program and the Bio-DME project in 2012, aan industrially co-funded 160 MSEK R&D porgam was initiated in 2014 with the obejct ive of widening the fuel basis, develop new synthesis gas cleaning and synthesis reactror and catalyst technologie
Contact	Rikard Gebart, ph: +46 920492196 email: rikard.gebart@ltu.se

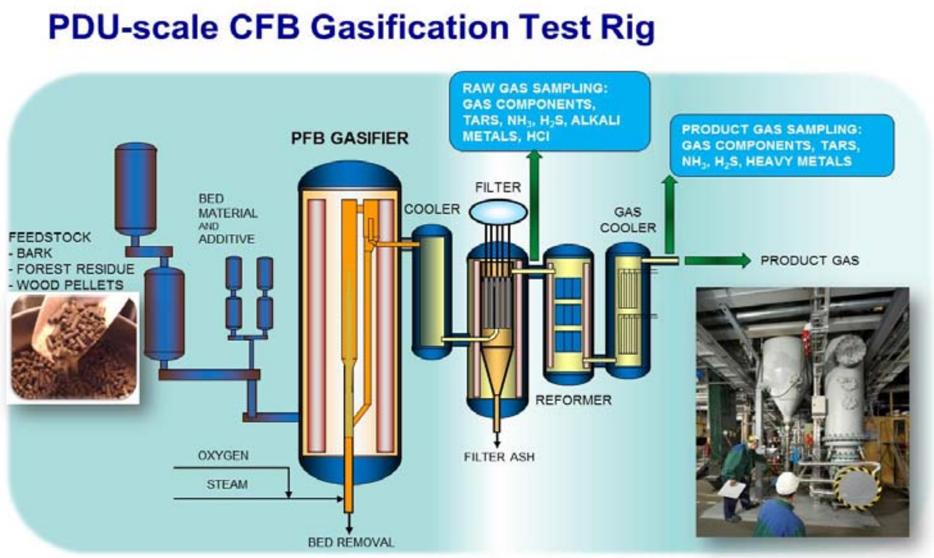
Project name	Gasifier at Varkaus paper mill (former Corenso)
Project owner	Stora Enso
Status	Operational
Start up	2001
Country	Finland
City	Varkaus
Type	TRL 9 Commercial
Technology	Other innovative technology
Raw Material	Waste fuels, plastic waste
Output 1 Name	Synthesis gas
Output 1 Capacity	50
Output 1Unit	MW
Partners	Stora Enso (former Corenso United Ltd, years 2001-2010)
Technology Brief	Stand-alone gasification plant at Varkaus paper mill in Varkaus, Finland. The commercial application of the atmospheric BFB gasification was first realized in Varkaus by Corenso United Ltd and the 50 MW gasifier was taken into operation in 2001, developed by VTT & Foster Wheeler Energia Oy. Clean aluminium-containing plastic waste (rejected from Juice Container Recycling Process) was gasified in a BFB gasifier. Wood fiber from used liquid packages was used into coreboard production. The plastics-derived, cyclone-cleaned gas was combusted in a boiler where it replaced heavy fuel oil. This ECOGAS-plant plant was in commercial operation 2001-2010. Since ECOGAS closed the gasifier was modifed to CFB and BFB mode by Foster Wheeler. In addition, oxygen-enriched air as fluidising agent was provided to the gasifier. The modifed gasifier is suitable for industrial tests with other waste fuels.
Contact	Teppo Pakarinen Tel. +358 40 585 3294



Project name	Värmlandsmetanol Hag fors
Project owner	VärmlandsMetanol AB
Status	Planned
Start up	
Country	Sweden
City	Hagfors
Type	TRL 9 Commercial
Technology	Fuel Synthesis
Raw Material	Lignocellulosic crops
Input 1 Name	Woody Biomass
Output 1 Name	Methanol
Output 1 Capacity	130 000
Output 1Unit	m3/y
Partners	VärmlandsMetanol AB, UHDE, LRF, Hagfors commune
Technology Brief	HTW gasification unit followed by gas clean-up and methanol synthesis
Additional Information	www.varmlandsmetanol.se
Contact	Björn Gillberg +46 563 165 60 bjorn.gillberg@varmalndsmetanol.se

Project name	FT pilot Guessing
Project owner	Vienna University of Technology / BIOENERGY 2020+
Status	Operational
Start up	2005
Country	Austria
City	Güssing
Type	TRL 4-5 Pilot
Technology	Fuel synthesis
Raw Material	Syngas from FICFB Gasifier
Input 1 Capacity	5
Input 1Unit	*Nm³/h
Output 1 Name	Raw FT product
Output 1 Capacity	5
Output 1Unit	*kg/day
Technology Brief	Aim of the work is to convert the product gas (PG) of the Biomass gasification plant with a Fischer-Tropsch (FT) process to liquid fuels, especially to diesel. A FT-pilot plant is operated, which converts about 5 Nm3/h PG at 20bar in a Slurry reactor to FT-products. The gas cleaning of the raw PG consists of several steps and consists of wet scrubbers and dry adsorbers. As catalyst in the slurry reactor, iron and cobalt based catalyst are used. The results from a Cobalt catalysts give mainly an n-alkane distribution from C1 to compounds higher than C60 n-alkanes. The iron based catalysts give more alkenes and oxygenated compounds. The analyses of the diesel fraction from the distillation of the FT-raw product show that the obtained diesel from the Cobalt catalyst has cetan-numbers of about 80 and is free of sulphur and aromatics.
Additional Information	www.ficfb.at
Contact	reinhard.rauch@tuwien.ac.at

Project name	Pressurized fluidised-bed gasification Process Development Unit (UCG-PDU) for synthesis gas production
Project owner	VTT Technical Research Centre of Finland Ltd
Status	Operational
Start up	2007
Country	Finland
City	Espoo
Type	TRL 4-5 Pilot
Technology	Synthesis
Raw Material	Biomass; bark, forest residue, wood pellets, peat, wastes
Output 1 Capacity	0,5
Output 1Unit	MW
Partners	Several industrial partners
Technology Brief	Pressurised CFB gasifier by steam-oxygen has been developed at VTT for syngas applications and to support industrial demo-projects. The wood feedstocks are firstly converted into raw gasification gas, which is then filtered at ca. 600 ˚C before catalytic reforming of tars and hydrocarbon gases. The fuel capacity is 500 kW and fuel feeding 120 kg/h.
Additional Information	http://www.vttresearch.com/services/bioeconomy/liquid-biofuels1/methanol-and-methane-based-fuels1/gasification-of-biomass-and-waste
Contact	Esa Kurkela,VTT & Ilkka Hiltunen, VTT esa.kurkela@vtt.fi, +358405026231



Project name	Dual Fluidized-Bed steam gasification pilot plant
Project owner	VTT Technical Research Centre of Finland Ltd
Status	Operational
Start up	2013
Country	Finland
City	Espoo
Type	TRL 4-5 Pilot
Technology	Synthesis
Raw Material	Biomass; bark, forest residue, wood pellets, other
Output 1 Name	Synthesis gas
Output 1 Capacity	0,35
Output 1Unit	MW
Technology Brief	Dual Fluidized-Bed (DFB) gasifier is used for process development work. Gasifier is atmosheric pressure, with feed capacity up to 80 kg/h. Hot filtration and gas reforming
Additional Information	http://www.vttresearch.com/services/bioeconomy/liquid-biofuels1/methanol-and-methane-based-fuels1/gasification-of-biomass-and-waste
Contact	Esa Kurkela,VTT & Ilkka Hiltunen, VTT esa.kurkela@vtt.fi, +358 40502 6231 ilkka.hiltunen@vtt.fi, +358 400 226730

Project name	LLC Thermal Reformer Synthesis West BiofuelsWoodland , CA
Project owner	West Biofuels
Status	Operational
Start up	2007
Country	USA, CA
City	Woodland
Type	TRL 4-5 Pilot
Technology	Fuel synthesis
Raw Material	Forest residues
Input 1 Name	clean wood, waste wood
Input 1 Capacity	5
Input 1Unit	t/d
Output 1 Name	FT liquids
Partners	University of California
Technology Brief	West Biofuels uses dual fluidized bed thermal reforming system that breaks down biomass into its molecular components through chemical reactions brought on by high heat, oxygen and steam at low pressure.
Additional Information	
Contact	Matt Summers matt.summers@westbiofuels.com

6.3 Other gasification (innovative) technologies

In this chapter all gasification facilities, which purpose is not CHP generation or fuel synthesis, are listed.

The status of thermal gasification facilites – explanation

Operational	Under construction	Planned	Non operational	No status

Nr.	Owner	Name	Status	Page
1	BioMCN	BioMCN Farmsum		149
2	Chalmers Technical University	Centre for Indirect Gasification of Biomass		150
3	Co-Ver Energy Holding	Lake Maggiore Tecnoparco		151
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9	Ilomantsin Lämpö Oy	District heating plant		157
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Project name	BioMCN Farmsum
Project owner	BioMCN
Status	Idlel
Start up	2009
Country	The Netherlands
City	Farmsum
Type	TRL 9 Commercial
Technology	Other innovative technology
Raw Material	Biodiesel and oleochemicals
Output 1 Name	Methanol
Output 1 Capacity	200 000
Output 1Unit	t/y
Partners	Waterland, Teijin, NOM
Technology Brief	Converting glycerine (a by-product from biodiesel production) into bio-methanol. Raw gycerin is purified and injected into the natural gas reformers of the existing methanol plant. Glycerin share in glycerin/natural gas is approximately 40%. 150-200 kton/y of bio-methanol is produced. BioMCN stopped making biomethanol based on glycerine medio 2013.
Additional Information	www.biomcn.eu
Contact	info@biomcn.eu

Project name	Centre for Indirect Gasification of Biomass
Project owner	Chalmers Technical University
Status	Operational
Start up	2008
Country	Sweden
City	Göteborg
Type	TRL 4-5 Pilot
Technology	Other gasification Technology R&D activity with no dedicated product
Raw Material	Lignocellulosic crops
Input 1 Name	Woody biomass
Output 1 Name	Heat
Output 1 Capacity	4
Output 1Unit	MWth
Partners	Göteborg Energi, Metso Power, Akademiska hus
Technology Brief	The idea is to combine an existing CFB co-generation boilers with an indirect gasification system, drawing hot sand from the combustor of the CFB boiler to the piggy-back gasifier and recirculating char and cold sand back from this unit
Additional Information	www.chalmers.se
Contact	Henrik Thunman ph:+46 31 772 11451 email henrik.thunman@chalmers.se

Project name	Lake Maggiore Tecnoparco
Project owner	co-Ver Energy Holding
Status	Operational
Start up	2008
Country	Italy
City	Verbania
Type	TRL 9 Commercial
Technology	Other gasification technology
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,250
Output 1Unit	MWel
Technology Brief	Pyrogasifier Ultra high gasification temperature
Additional Information	http://www.co-ver-energy.it/comunicazione/discoverymagazine/Magazine_CO-VER_Energy_Holding_10.08.pdf
Contact	CO-VER Energy Holding Headquarters Via 42 Martiri, 165 28924 Verbania (VB) Italy Phone +39 0323 585511 Fax +39 0323 585535 coverenergyholding@co-ver-energy.it

Project name	MILENA Gasifier
Project owner	ECN
Status	Operational
Start up	2009
Country	The Netherlands
City	Petten
Type	TRL-4-5 Pilot
Technology	Other gasification technology
Raw Material	Wood, waste
Output 1 Name	Tar free producer gas
Output 1 Capacity	200
Output 1Unit	m^3/h
Partners	ECN
Technology Brief	Indirect gasification (MILENA-technology), gas cooler, cyclone, OLGA tar removal, water scrubber, gas boiler
Additional Information	Related publications http://www.ecn.nl/docs/library/report/2011/m11078.pdf http://www.ecn.nl/docs/library/report/2010/b10016.pdf http://www.ecn.nl/docs/library/report/2009/m09120.pdf http://pubs.acs.org/doi/abs/10.1021/ef9007032?prevSearch=%255Bauthor%253A%2Brabou%255D&searchHistoryKey=
Contact	Christian van de Meijden vandermeijden@ecn.nl

Project name	Waste Paper Rejects Gasification
Project owner	Eska Graphic Board
Status	Under construction
Start up	2016
Country	The Netherlands
City	Hoogezand
Type	TRL 9 Commercial
Technology	Other gasification technolgy
Raw Material	Paper reject
Input 1 Capacity	25 000
Input 1Unit	t/h
Technology Brief	Gasification based on air blown Circulating Fluidised Bed (CFB) technology operating at atmospheric pressure. Produced syngas is combusted in waste heat recovery boiler to produce saturated steam.
Additional Information	
Contact	Bodewes, Bert <B.Bodewes@eskagraphicboard.com>

Project name	Wood gasifier
Project owner	RWE Essent
Status	Waiting for decision on Life Time Extension (subsidy dependent)
Start up	2005
Country	The Netherlands
City	Geertruidenberg
Type	TRL 9 Commercial
Technology	Other gasification technology (cofiring)
Raw Material	Waste wood, RDF
Input 1 Capacity	150 000
Input 1Unit	t/y
Output 1 Name	Power (electricity)
Output 1 Capacity	34
Output 1Unit	MWel
Partners	Essent
Technology Brief	At the Amer Power Station in Geertruidenberg, a CFB gasifier plant has been constructed to produce gas as fuel for the Amer-9 600 MWe pulverized coal power plant, which is operated as large CHP plant. The project originally was to be started in 2000. The 83 MWth gasifier is to convert about 150,000 t/y demolition wood, replacing 70,000 t/y of coal. The gasifier is a low-pressure Lurgi CFB operating at 750 - 850°C. Originally, the raw gas was to be cleaned from particles, ammonia, and tars before entering the coal boiler. This has been modified to the much simpler system where the raw gas is partially cooled to approximately 450°C and particulate reduction by cyclones. During commissioning, practical problems mostly related to the fuel supply system. After modifications and successful trials in 2005, the gasifier had to be stopped. In the Dutch interpretation of the European WID (Waste Incineration Directive), the complete coal-fired plant was identified in December 2005 as waste incinerator because of the demolition wood fired gasifier. This situation has been solved November 2006 by allowing wood gas on the national "white list" of clean biomass fuels under certain conditions related to the concentration of 9 heavy metals. The gasifier typically operates 5000 h per year.
Contact	W. Willeboer, RWE Essent wim.willeboer@essent.nl

Project name	Blue Tower Technology Herten
Project owner	H2Herten GmbH
Status	Operational
Start up	2009
Country	Germany
City	Herten
Type	TRL 6-7 Demonstration
Technology	Other innovative technology
Raw Material	Lignocellulosic crops
Input 1 Name	Syngas
Input 1 Capacity	13
Input 1Unit	MW
Output 1 Name	Hydrogen
Output 1 Capacity	150
Output 1Unit	m3/h
Output 2 Name	Heat
Output 2 Capacity	37,500
Output 2 Unit	MWh p.a
Total Investment	24,6 mio
Total Investment Currency	EURO
Technology Brief	Green hydrogen is expected to be produced in the blue tower using a multi-stage reforming process. The technique: green waste (roadside greenery) is decomposed at temperatures around 600°C of which 80 % is converted into gas. The remaining solids are converted into coke which can be used again to generate the process heat that is required. The gas produced is purified into a very hydrogen rich 'blue gas' (approx. 50% hydrogen) at approximately 950°C using water vapour. This hydrogen rich gas is concentrated into pure hydrogen or is used in gas motors to generate electricity. With a thermal input of 13 megawatts the process yields 150 cubic metres of hydrogen an hour and 37,500 MWh p.a. of electricity. This is equivalent to the energy consumption of 12,000 homes. The project is setting new technical as well as economical standards.
Additional Information	www.htvg.de
Contact	info@htvg.de

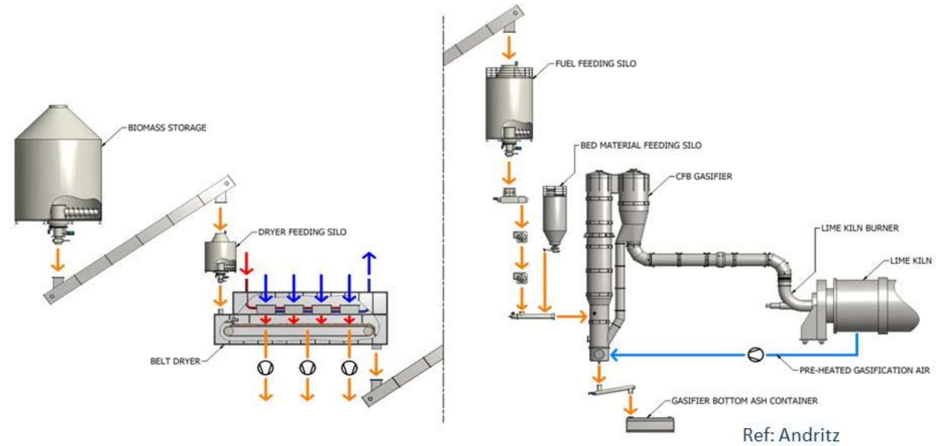
Project name	
Project owner	ICQ/SIAG/ERBA
Status	Operational
Start up	2009
Country	Italy
City	Torre S.Susanna
Type	TRL 6-7 Demonstration
Technology	Other gasification technology (Pyrogasifier)
Raw Material	Wood chips
Output 1 Name	Power (electricity)
Output 1 Capacity	0,500
Output 1Unit	MWel
Output 2 Name	Heat
Output 2 Capacity	2
Output 2 Unit	MWth
Technology Brief	It is a biomass plants with syngas production from molecular dissociation and pyrogasification of woodchips for a total power of gas generated amounting to 2,000 kWth.The Torre Santa Susanna plant was carried out inside a project financed by PON (National Operative Plan). The aim of the project was the development and the optimisation of a biomass gasification process carried out in three phase: drying, pyrolysis and gasification, and an high quality syngas production to use in internal combustion engine.
Additional Information	http://77.43.21.234/files/files_news2/00034.pdf
Contact	Tel.: 39 (0) 6 8404301 Fax: 39 (0) 6 840430231 info@gruppoicq.com

Project name	Ilomantsi district heating
Project owner	Ilomantsin Lämpö Oy
Status	Operational
Start up	1996
Country	Finland
City	Ilomantsi
Type	TRL 9 Commercial
Technology	Fuel gas (heat)
Raw Material	peat, wood chips
Output 1 Name	Heat
Output 1 Capacity	6
Output 1Unit	MWth
Technology Brief	The biomass (peat,wood chips) is gasified in two updraft fixed bed gasifiers. The product gas is combusted in a boiler.
Additional Information	
Contact	Ilomantsin Lämpö Oy Tel .+358 13882373

Project name	District heating plant
Project owner	Kauhajoen Lämpöhuolto Oy
Status	Operational
Start up	1985
Country	Finland
City	Kauhajoki
Type	TRL 9 Commercial
Technology	Fuel gas (heat)
Raw Material	Peat, wood chips
Output 1 Name	Heat
Output 1 Capacity	8+5
Output 1Unit	MWth
Technology Brief	The biomass (peat,wood chips) is gasified in two updraft fixed bed gasifiers. The product gas is combusted in a boiler.
Additional Information	http://www.lampohuolto.fi/
Contact	Kauhajoen Lämpöhuolto Oy Tel. +358 207 459 776

Project name	District heating plant
Project owner	Kiteen Lämpö Oy
Status	Operational
Start up	1986
Country	Finland
City	Kitee
Type	TRL 9 Commercial
Technology	Fuel gas (heat)
Raw Material	Wood chips, sod peat
Output 1 Name	Heat
Output 1 Capacity	6
Output 1Unit	MWth
Technology Brief	The biomass (wood chips, peat) is gasified in a updraft fixed bed gasifier. The product gas is combusted in a boiler. The heating plant generates 6 MW heat.
Additional Information	http://www.kiteenlampo.fi
Contact	Kiteen Lämpö Oy, Ilkka Hämäläinen Tel. +358 50 5988492

Project name	Lime kiln gasifier
Project owner	Metsä Fibre Oy, Joutseno Mill
Status	Operational
Start up	2012
Country	Finland
City	Joutseno
Type	TRL 9 Commercial
Technology	Other gasification technology (lime kiln cofiring)
Raw Material	Bark
Output 1 Name	Heat
Output 1 Capacity	48
Output 1Unit	MWth
Partners	Andritz (supplier)
Technology Brief	The bark is first dried in a belt dryer from Andritz , with an evaporation/drying rate of 12 t/h. The fuel handling system includes an innovative dryer which utilizes the mill's excess heat for bark drying. Moisture is reduced from the 50% level to about 15% in the dryer. The fuel is fed to the CFB-gasifier and gasified at about 750-800° C. Product gas after recycle cyclone is directly combusted in a lime kiln of the Joutseno pulp mill. The gas produced is finally burned in the lime kiln with a burner developed by ANDRITZ. Wood gas replaces natural gas.
Additional Information	
Contact	Veli-Matti Pietarinen, Andritz veli-matti.pietarinen@andritz.com



Project name	Wood co-gasification in IGCC
Project owner	NUON/Vattenfall
Status	Non operational (shut down)
Start up	
Country	The Netherlands
City	Buggenum
Type	TRL 9 Commercial
Technology	Other gasification technology (cofiring)
Raw Material	Biomass coal blends
Output 1 Name	Power (electricity)
Output 1 Capacity	30 in 250 plant
Output 1Unit	MWel
Partners	NUON/Vattenfall
Technology Brief	NUON operates a 253 MWe coal gasification plant in Buggenum (the former Demcolec Power station). It is an Integrated Gasification Combined Cycle plant (IGCC) with Shell entrained flow gasification technology and Siemens gas turbine. After several successful biomass co-gasification trials with biomass input up to 30 wt%, the plant has been modified to co-gasify 30 wt% wood on a continuous basis. New biomass storage and feedings systems were put into operation in spring 2006. Since 2007, the plant has been operated with approximately 10% (energy) biomass. In 2011, activities were started to increase the co-firing share to 50% or more. In 2013 it was decided to close down the installation, due to low energy prices and relatively high cost of operation of the plant.
Additional Information	www.nuon.com http://www.nuon.com/company/core-business/energy-generation/power-stations/buggenum/
Contact	Not known

Project name	Lime kiln gasifier Varkaus
Project owner	Stora Enso
Status	Operational
Start up	2008
Country	Finland
City	Varkaus
Type	TRL 9 Commercial
Technology	Other innovative technology
Raw Material	Wood biomass
Output 1 Name	Fuel gas to lime kiln
Output 1 Capacity	12
Output 1Unit	MW
Partners	Amec Foster Wheeler
Technology Brief	The 12 MWth gasifier is providing currently fuel gas to Stora Enso's limekiln at Varkaus. The gasifier is a 12 MWth CFB-unit, which has been running since the end of 2008. It started first as air-blown gasifier in order to produce only the raw gas for the lime kiln. In 2009-2011 the gasifier was mainly operated in the oxygen-steam mode to produce low nitrogen content gas for the BTL demonstration purpose. NSE biofuels Oy, a joint venture between Neste Oil and Stora Enso, opened a demonstration plant at Stora Enso's Varkaus Mill in Finland in 2009. The main goal was to demonstrate Biomass-to-Liquids (BTL) technology which is based on steam-oxygen blown CFB gasification followed by hot filtration and catalytic tar reforming. After completing the successful demonstration programme for Neste Oil and Stora Enso (supplier Foster Wheeler) in 2011, the plant was modified to air-blown operation.
Additional Information	http://www.storaenso.com/
Contact	Juha Palonen, Amec Foster Wheeler Juha.Palonen@fwfin.fwc.com

Project name	Wood gasification facility to generate steam for industrial laundry in Turku
Project owner	Turku energia and Gasek Oy
Status	Operational
Start up	2013
Country	Finland
City	Turku
Type	TRL 9 Commercial
Technology	Other gasification technology
Raw Material	Wood chips
Output 1 Name	Steam
Output 1 Capacity	1,2
Output 1Unit	MWth
Partners	Turku Energia and energy technology company GASEK Oy
Technology Brief	The gasifier will turn wood chips into gaseous fuel, which are burned in the boiler earlier operated on heavy fuel oil. GASEK's wood gasifier is a co-current gasifier and it's based on the pyrolysis technique. The wood chips are moving in the reactor in the same direction as the gasification air, which is fed in quantities that are considerably lower than is required for combustion. The gasification temperature is 800-1200°C, which prevents formation of damaging tar compounds. This results in tar compounds cracking into lighter fractions.
Additional Information	http://www.gasek.fi/en/
Contact	Turku Energia, jari.kuivanen@turkuenergia.fi, Tel. +358 50 5573 261