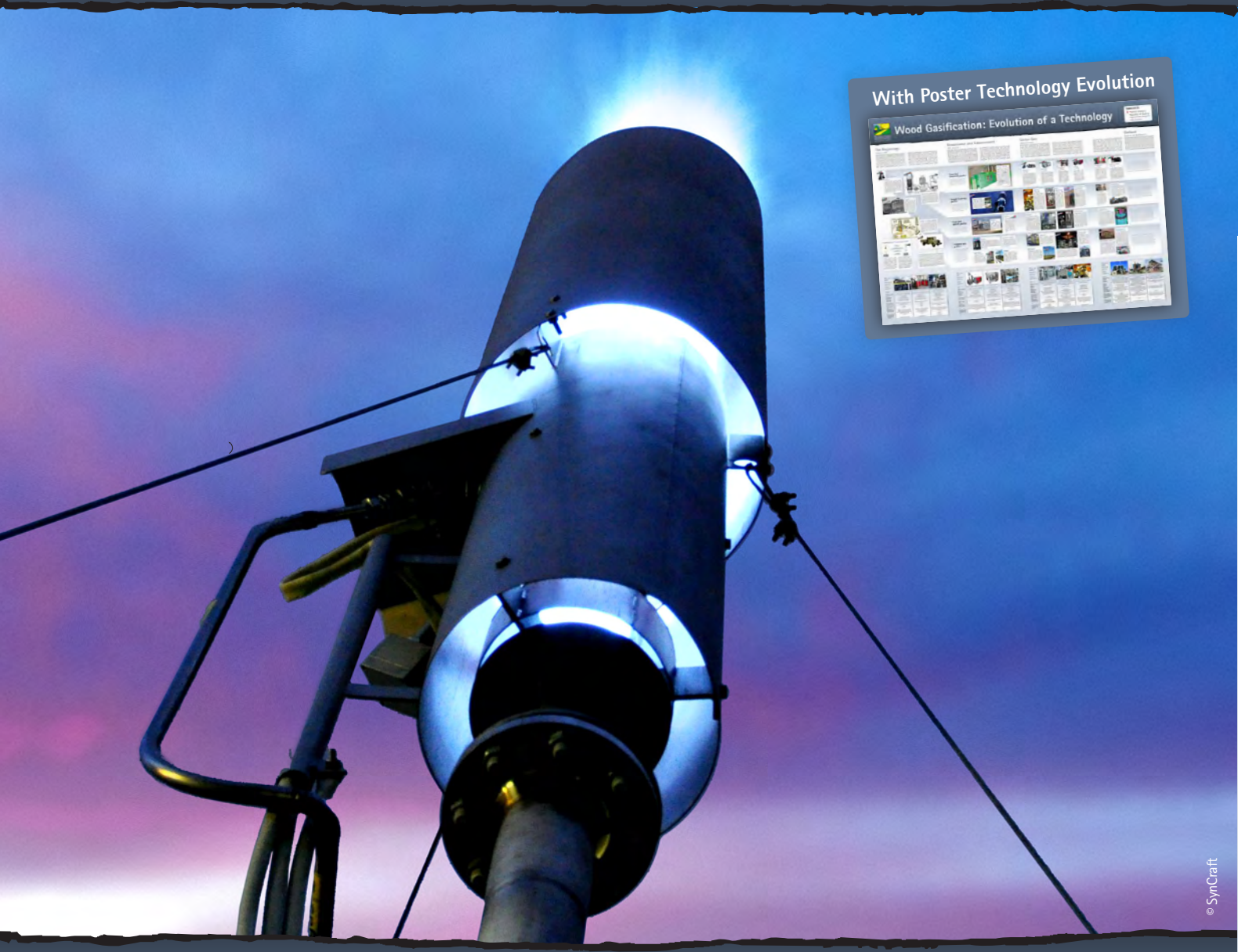
Wood Gas

klimaaktiv Partner

Power – Fuels – Natural Gas Substitute



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Österreichischer Biomasse-Verband
Austrian Biomass Association

Supported by
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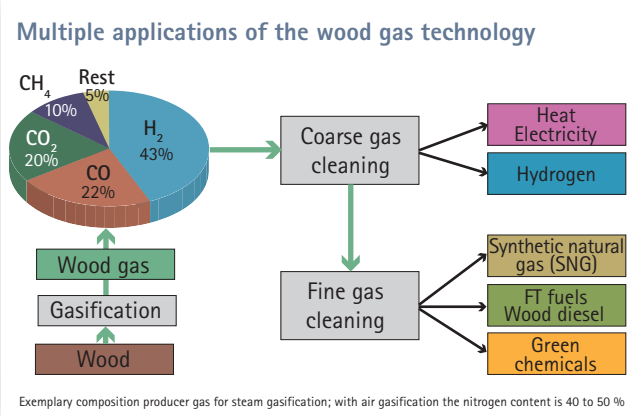
Agriculture, Regions and Tourism

Wood gasification – the new option

The method of wood gasification was invented more than 200 years ago. Innovative Austrian and German companies have substantially promoted this technology since the beginning of this century. While the focus of wood gasification was initially on the generation of power and heat, the production of hydrogen, synthetic natural gas, diesel and kerosene is now also one of its numerous applications. Thus, wood gasification represents a significant development of bioenergy use and the realization of bioeconomy.



© TU Wien, diagram ABA

Fig. 1: Wood is separated into a producer gas, from which, after cleaning via synthesis steps, e.g. SNG or wood diesel can be produced.

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Federal minister Köstinger and the president of the ABA Titschenbacher (r.) visited Prof. Hofbauer's wood gas research center at TU Wien.

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Forest conversion – e.g. oak planting as part of the climate-fit mountain forest Tyrol - leads to higher proportions of hardwood and energy wood.

Wood gas technology

In the wood gasification process, operations similar to wood combustion take place, however, with a significantly reduced oxygen supply. A producer gas (wood gas) is being created, which can be used to produce electricity, fuels (wood diesel, hydrogen, kerosene, etc.) or as a raw material for chemical products after the process of gas cleaning (Fig. 1). The composition of the producer gas varies depending on the gasification technology used. If the gas is further processed, it can be fed into the natural gas pipeline network and transported to consumers over long distances or temporarily stocked in natural gas storage facilities.

Ideal complement to wood boilers

Wood gasification is an ideal complement to modern wood heating (pellets, wood chips, logwood) – convincing with their high level of efficiency at the lowest possible cost – as well as to biogas plants that generate gas from non-ligneous biomass. Small wood gasification plants need a high fuel quality for the combined production of electricity and heat, whereas larger plants can be operated with materials ranging from wood over agricultural residues up to sewage sludge. A combustion nearly free of fine dust, high energy efficiency and smaller plant sizes (in comparison to fossil refineries) are further advantages.

Decreasing use despite expansion

Currently, more than half of Austria's bioenergy is being used for space heating. Despite an increasing use of wood central heating systems and local and remote district heating from biomass - a result of the replacement of natural gas and oil heating - the amount of the utilized fuel in space heating is decreasing in the long term, leading to resources for other applications. Although roughly 6,000 MW capacity of biomass boilers have been installed in Austria since 2010, the level of total bioenergy use has shrunk slightly in this time period. A more efficient boiler technology, an improved building insulation and warmer winters are the main causes for this development. In the field of wood heating, pellet heating systems are becoming more and more popular, replacing logwood heating systems, resulting in additional raw material potential.

Long-term increase of wood supply

Presently, there is an enormous oversupply of low-quality wood. This situation will last for a long time due to the superposition of several effects: The increasing use of renewable raw materials in goods production and the construction industry leads to additional quantities of by-products, residues and waste (forest wood chips, firewood, sawdust, black liquor, bark, waste wood). Furthermore, global warming and the necessary conversion of forests into mixed stands lead to a sharply growing accumulation of low-quality wood (forest maintenance, higher proportions of deciduous wood, storm damage, snow breakage, infestation by bark beetles, fungi or bacteria). If the attempt of using this timber volume fails, the carbon stored in the wood will rot as CO_2 into the atmosphere and will exacerbate the climate crisis.

New sales markets for energy wood

Potentials far from being exploited

Even if assuming an increase of biomass boiler sales from around 12,000 to 40,000 units annually, the addition of 1 TWh of electricity from solid biomass per year, the yearly feed-in of 5 TWh of renewable gas, the construction of 500 additional biomass local district heating systems and 200 MW local green gas plants in industry as well as the construction of 250 MW large-scale plants for the production of wood diesel and wood gas until 2030, still, roughly 190 PJ of sustainably available bioenergy potential would remain unused (Fig. 2). This potential would enable a complete switching of agriculture and forestry to wood diesel (biomass demand 20 PJ) along with the operation of all gas power plants and gas CHP plants (biomass demand 50 PJ). Waste heat from wood gasification and CHP systems can make a considerable contribution to the phasing out of natural gas heating systems and fossil district heating (Fig. 3). The remaining potential could be used for the decarbonization in industry, commerce and mobility.

Achieving real climate protection

In sum, wood gasification provides the chance of 100 % renewable district heating and 100 % real (not only on the balance sheet) renewable electricity regeneration. With the production of wood diesel and wood gas, the technology can realize the change to renewable mobility in areas usually unsuitable for electrification. Wood gasification could be implemented as a troubleshooter and thus, save enormous costs in various sectors because existing infrastructure – ranging from the gas network to the vehicle fleet – could then be used continuously. The use of elaborately produced and processed wood gas for purposes of room heating is not recommendable (exceptions exist for densely built-up areas) due to cost-effective and efficient renewable alternatives.

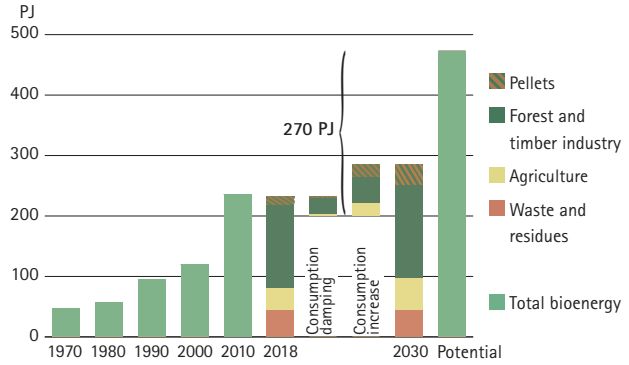
Profitability of wood gas plants

Electricity, gas and diesel from wood can all be produced at a cost level corresponding to the end customer prices of conventional energy sources, including taxes, charges and network costs. However, prices for fossil fuels in international trade are so low that wood gas applications can only prevail themselves without subsidies, if fossil fuels are no longer available or if their prices are accordingly raised. The funding intensity of large wood gas and wood diesel plants (100 MW rated thermal input) as well as Local-Green-Gas-applications are located in the lower part of the range of renewable energies. Appropriate fundings are recommended for the market launch of the first plants. Operational subsidies (feed-in tariff or market premium) are particularly needed for electricity from wood gas due to low electricity prices.

Funding-free in the long term

In the evaluation of wood gas technologies, additional effects, next to the production costs, must be taken into account: regional jobs, reduction of greenhouse gas emissions and investments in electricity storage, use of existing infrastructure, reduction of energy imports and purchasing power outflow, increase in self-sufficiency and crisis resilience and, last but not least, the development of a new industry branch. Austria is already the world market leader in the biomass boiler industry. If the government program is effectuated successfully and Austria becomes climate neutral until 2040, the use of fossil fuels will be excluded and wood gas will be competitive without any subsidies.

Gross inland consumption of bioenergy, 1970 to 2018, estimated consumption for 2030 and overall potential



	Energy use	Change in consumption 2018 to 2030				Energy use
PJ	2018		–	+	Result	2030
Pellets	14	Raise in boiler sales to 40,000 units/a	2	22	20	34
Forest and timber industry	137	Green electricity from solid biomass	7	10	3	147
		Wood furnaces <1 MW	18	11	–7	
		Wood boilers industry, district heating >1 MW	3	10	7	
		Wood gas/wood diesel		7	7	
Agricultural feedstock (including biogas)	37	Constant electricity generation, +5 TWh green gas feed-in, biofuels 1st generation steady	3	20	17	54
Waste and residues	44	Steady				44
Total	232		33	80	47	279

Source: Statistics Austria, energy balances 1970–2018; Potential assessment, ABA

Fig. 2: The comparison of increasing and dampening effects results in a rise in consumption of 47 PJ bioenergy by 2030.

Biomass potential by application and sector in PJ

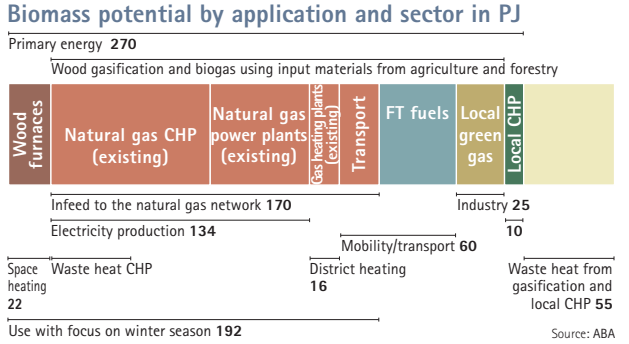


Fig. 3: The majority of the additional bioenergy potential could be used to generate heat and electricity during the winter season.

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Along with the construction of new plants such as biomass district heating plants, rising amounts of damaged wood could be utilized.

CHP – heat and power

Electricity around the clock

Wood power plants manage to deliver steady or controllable energy demand-actuated at any time and any weather. In a system in need of reliable electricity supply, they offer an inexpensive alternative to fluctuating electricity generators that have to be supplemented by storages. Proportionally, wood CHP plants generate much more district heating (two thirds) than electricity. Thus, they provide around 17 % of Austria's total district heating production. Especially in winter, when the increased demand for electricity from heat pumps, electric heaters or electric cars is largely covered by fossil power plants and nuclear electricity imports, wood power plants offer relieving help.

Focus on a small performance range

The wish of producing electricity as well as heat was mainly expressed by heating plant operators. The provision of base heat load in the district heating plant by the wood gas system spares the partial load operation of the boiler in summer. From an economic point of view, investing in a system only makes sense, if there is a continuous need for heat in summer, e.g. in larger farms or sawmills. Since 2010, wood gas CHP systems were installed at around 50 locations in Austria. Several systems were often connected in cascade in order to achieve higher levels of performance. Austria has hundreds of heating plants, where a switching to combined electricity and heat production would make perfect technical sense.

Tab. 1: Example of economic requirements for wood gas CHP

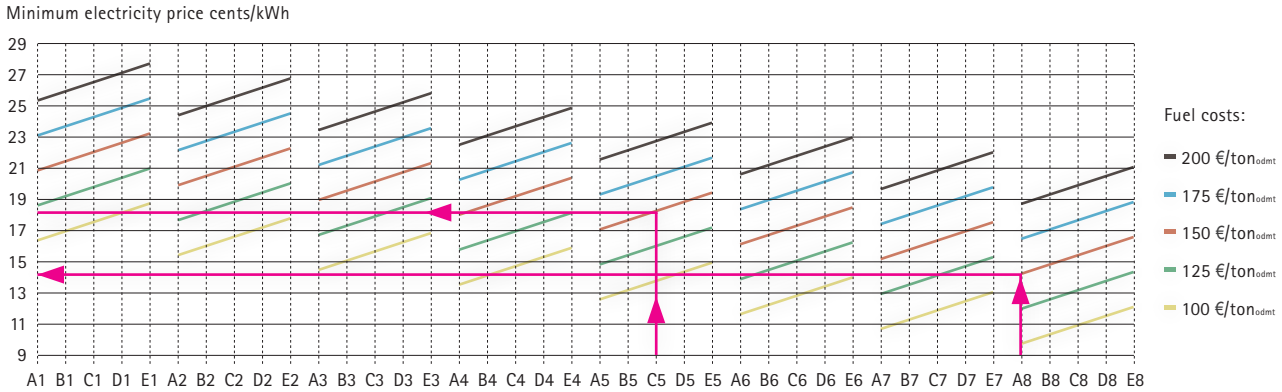
	Costs
Depreciation, interest	6.8 cents/kWh$_{el}$
Biomass (wood chips, pellets)	12.5 cents/kWh$_{el}$
Personnel, charging	4.4 cents/kWh$_{el}$
Maintenance, service	2.7 cents/kWh$_{el}$
Other costs	0.6 cents/kWh$_{el}$
Heat sales	–6.2 cents/kWh$_{el}$
Sum	**20.8 cents/kWh$_{el}$**

Location at heating plant in Upper Austria, plant size 110 kW$_{el}$/230 kW$_{th}$; source: Biomasseverband OÖ

EAG builds a new framework

The construction of a minimum of 17 MW$_{el}$ biomass CHP plants per year was determined in the Austrian Renewable Energy Act (EAG) in July 2021. By 2030, additional 1 TWh of electricity should be generated from biomass, half of it in the range of <500 kW$_{el}$. All existing systems shall be transferred into the EAG and their funding options shall be raised to 30 years. The rigid tariff system will be converted to a sliding market premium system. The market premium is a variable surcharge on the market price. Thus, the operator can achieve higher revenues, but he has to market the electricity by himself. The so-called „value to be applied" (market price plus market premium), defined by the regulation, will be decisive for the future success of the EAG. Practical experience shows that an effective remuneration level of 21 to 22 cents/kWh is necessary for economic operation (Tab. 1).

Economic feasibility assessment with an amortization of twelve years



Assumptions: Data from an investigation of various wood gas plants, being calculated using a specific example in accordance with the averaged manufacturer and operator information. Return on capital 3 %, 7,500 full-load hours, amortization time 12 years, annual fuel cost increase 3 %, system size 20 to 150 kW$_{el}$, drying technology and fuel drying considered, calculation Biomasseverband OÖ, graphic display ABA.

Investment costs/ Heat price	5,500 €/ kWel	6,000 €/ kWel	6,500 €/ kWel	7,000 €/ kWel	7,500 €/ kWel
25 €/MWh	A1	B1	C1	D1	E1
30 €/MWh	A2	B2	C2	D2	E2
35 €/MWh	A3	B3	C3	D3	E3
40 €/MWh	A4	B4	C4	D4	E4
45 €/MWh	A5	B5	C5	D5	E5
50 €/MWh	A6	B6	C6	D6	E6
55 €/MWh	A7	B7	C7	D7	E7
60 €/MWh	A8	B8	C8	D8	E8

Estimation of economic efficiency:
1.) Look for the category (letter/number combination) in the table that corresponds to the investment and heat generation costs (after the boiler, but before the heat distribution)!
2.) On the X-axis of the chart, you will find the category from the table. At the intersection with the line of the realizable raw material price, you can now read on the Y-axis which electricity revenue is at least necessary so that the plant pays for itself within 12 years. If the realizable electricity price is above this value, the plant can pay for itself earlier; if it lies below, later.

Example: A district heating plant budgeting with an investment of 6,500 € per kW of electrical output to be installed and having heat generation costs of around 45 €/MWh (wood chip costs: 150 €/ton$_{odmt}$) after the boiler (C5) then requires a feed-in tariff of at least 18.3 Cent/kWh to pay for itself after 12 years.

Example business: A hospital that was previously heated using fossil fuels with heat generation costs of 60 €/MWh and which can obtain wood chips for 150 €/ton$_{odmt}$, would amortize after about 12 years, assuming an investment of 5,500 € per kW of electrical power to be installed (A8) with an electricity price of 14.2 cents/kWh.

This is a rough assessment, based on average values and, thus, only intended as a first assistance in elaborating whether a further discussion of the topic wood gas CHP plants is of interest to you. If you want to be on the safe side, please look for further advice!

Wood diesel (Fischer-Tropsch fuel)

Characteristics of wood diesel

In the production of wood diesel, a fuel is obtained from the producer gas, which was generated in the process of wood gasification, making use of Fischer-Tropsch synthesis. Wood diesel is a drop-in fuel meeting all common fuel standards, which can be used in conventional vehicles without conversion. Moreover, Fischer-Tropsch fuels have better characteristics than their fossil counterparts: they burn significantly less pollutants and emit less fine dust and other harmful substances. Wood diesel can save 90 % of greenhouse gas emissions compared to fossil fuels, and 75 % in comparison to battery electric cars (BEV), based on the Austrian electricity mix.

Useful, where alternatives are needed

In Austria, the biomass potential for wood diesel is sufficient in order to be able to supply domains such as agriculture, military, aircraft, construction machinery, emergency and municipal vehicles and also a part of transport of heavy goods with renewable fuels. However, the potential remains insufficient for a switching of freight or car traffic. In this case, alternatives such as e-mobility, increased freight transport by rail and the expansion of public transport represent better solutions. Wood diesel is particularly useful in areas with no viable alternatives and where special purpose vehicles are in use for long periods of time.

Tab. 2: Key figures for a wood diesel plant

Rated thermal input	100 MW
Investment costs	202 million €
Fuel requirement	400,000 m^3/a
Fuel production[1]	40 million liters/a
Production costs[2]	1.15 to 1.4 €/liter
Waste heat production	20 MW
Total efficiency	70 %
Full load hours	7,500 h

[1]: at 8,000 hours including by-products; [2]: depending on the wood price class. Source: TU Wien

Tab. 3: Economic evaluation of wood diesel production

Wood price class (€/t_{odmt})[1]	HK 100	HK 75	HK 50
Investment support	66 %	45 %	24 %
Eco-diesel market premium[2]	0.36 €/l	0.24 €/l	0.13 €/l
CO_2 tax	169 €/t	114 €|t	60 €/t

[1]: HK 100=100 €/t_{odmt} etc.; [2]: Market premium at the market price of fossil diesel 1.03 €/l excluding VAT; Profitability given for each of the three measures (without combination). Source: TU Wien

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By producing wood diesel, the entire agricultural and forestry vehicle fleet could be operated petroleum-free.

Example agriculture and forestry

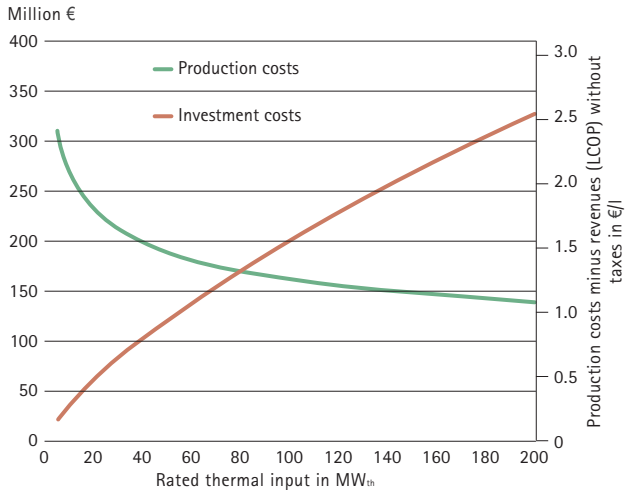
© Steyr Traktoren

The TU Wien (Technical University Vienna) has shown in a study, how Austrian agriculture and forestry could be converted to wood diesel by 2035. Nine plants with a rated thermal input of 100 MW, distributed all over the federal territory of Austria, would be necessary for this shift (Tab. 2, Fig. 4). As an advantage, the existing vehicle fleet could be used continuously. According to Statistics Austria, 420,000 tractors are approved for their use in agriculture and forestry in Austria and around 4,000 are added annually. If these vehicles had to be exchanged for new propulsion technologies before their typical useful life, the costs – assuming that these technologies are available at the same costs – would be over 20 billion €. In contrast, the investments in wood diesel plants would be comparatively low with 2 billion €. In addition, by switching agriculture and forestry to wood diesel, Austria could meet most of its EU targets for advanced biofuels.

Wood diesel as a complement

Wood diesel can be another option for a quicker change to renewable energies along with the established biofuels of the first (crop-based) and second (waste-based) generation (biodiesel, bioethanol, vegetable oil). The use of biogas tractors, e-tractors or hydrogen should likewise be further developed and supported with funding programs. Wood diesel can be mixed with fossil diesel and other biofuels or simply be used in its pure form in diesel engines. Adding between 7 % and 15 % of wood diesel to fossil diesel generates one of the premium fuels, already being sold at petrol stations with various brand names. Thus, it is important to further enhance the engine technology aiming at higher admixtures. Many engines and machines are already approved for the pure use of biofuels. However, there is still a need to catch up in order to make full use of the possibilities of the fuel standards. The exit from mineral oil can only be effectively executed if constant progress is made in the development of all existing alternative drive systems.

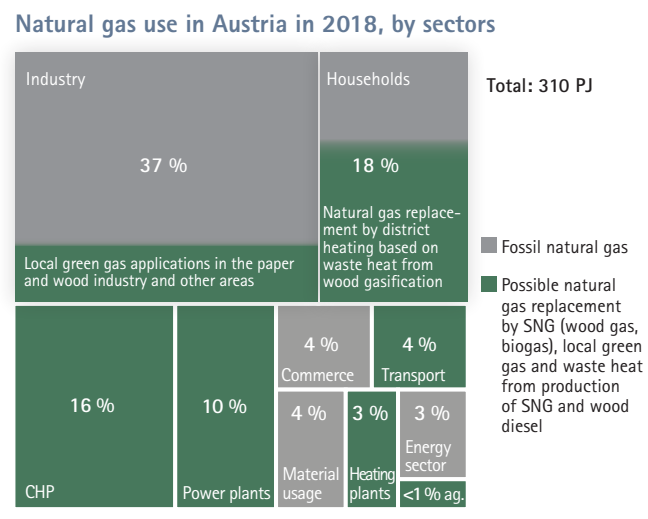
Investment and production costs of wood diesel plants according to plant size



Source: TU Wien

Fig. 4: If rated thermal input increases, production costs for wood diesel decrease; at 100 MW they are around 1.2 €/liter.

Synthetic natural gas (SNG) from wood



Source: Statistics Austria, energy balance 2018; potential assessment of ABA

Fig. 5: Natural gas use in Austria in 2018 by sectors and possible contribution of biomethane to the defossilization of the gas network by 2040

Natural gas: usage in Austria

In terms of quantity, natural gas is the second most important energy source in Austria. Austria has an extensive natural gas network of 44,000 km in length and gas storage facilities that can temporarily store the annual demand for natural gas. 37 % of natural gas is being used in industry, 26 % for electricity generation and 18 % for space heating (Fig. 5). The rest is roughly equally divided among commerce, transport, material use, heating plants and the energy sector. The natural gas sector is closely linked to the provision of electricity and district heating by electricity generation and the arising waste heat. Natural gas power plants form a backup for power production and, furthermore, they provide flexible power. This makes them essential for a secure power supply. The federal government plans to feed in 5 TWh of renewable gas into the natural gas network by 2030.

Green gas for 50 % of the demand

An estimation of potential by the research institute BEST has shown that around half of the natural gas consumption can be covered by renewable gas (biogas and wood gas) without compromising the sustainability limits or withdrawing raw material from other applications. The total gas consumption – even when additionally using synthesis gases produced from electricity – must be greatly reduced in order to successfully implement the energy transition. Therefore, renewable gas should be used as a priority, where there are no viable alternatives. In terms of space heating, gas should only be used in exceptional cases if no other solutions (remote district heating, local district heating, pellet heating, wood heating, solar thermal, heat pumps) are available. The study „Heat future 2050" by the TU Wien has proven that a competitive, renewable alternative exists for almost all gas heating systems.

Tab. 4: Economic evaluation of SNG production

Wood price class (€/t_{odmt})[1]	HK 100	HK 75	HK 50
Investment support	72 %	44 %	16 %
Wood gas market premium[2]	50 €/MWh	42 €/MWh	34 €/MWh
CO_2 tax[3]	117 €/t	70 €/t	24 €/t

[1]: HK 100=100 €/t_{odmt} etc.; [2]: Market premium for tax and duty exemption and natural gas price 30 €/MWh.; [3]: at a natural gas price of 60 €/MWh exluding VAT (privately purchased natural gas); Profitability given for each of the three measures (without combination). Source: TU Wien

Biogas closes winter electricity gap

Particularly in the winter half of the year, Austria is dependent on fossil-fuel power generation and electricity imports in order to be able to cover domestic electricity consumption. In 2019, the difference between renewable electricity production and electricity demand in Austria in the winter half-year (winter electricity gap) was 15 TWh. This gap was closed by imports and fossil electricity production, of which almost 8 TWh came from fossil natural gas. Biomethane can make a significant contribution to the closure of the winter electricity gap. Fed-in wood gas (SNG) should, therefore, primarily be used in the existing power plant park for combined electricity and heat production or in peak load power plants. Thus, both carbon footprints would be improved – the one of district heating (waste heat from gas CHP would be partly renewable) and the one of electromobility and heat pumps.

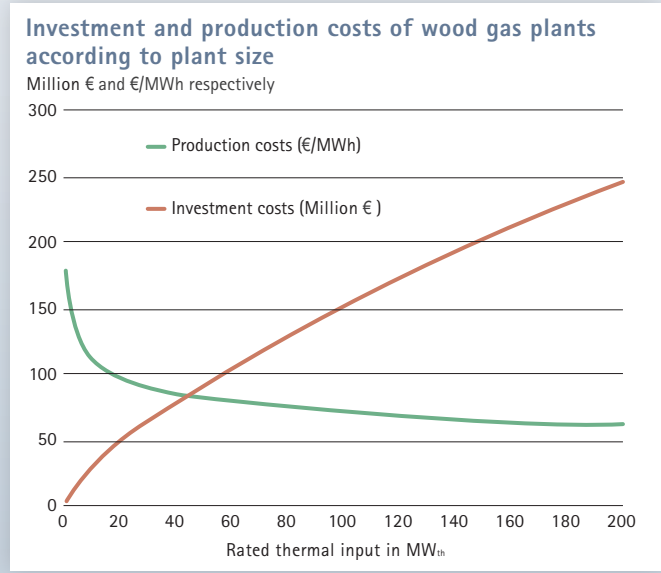
Gas waste heat replaces gas boilers

The prioritized use of wood gas (SNG), fed into the natural gas network, in power generation, mobility and industry can complete the energy transition in many areas. The waste heat from wood gas and wood diesel production would be sufficient to replace around half of the current use of natural gas in space heating. However, this requires the consistent conversion of objects heated with natural gas to district heating. Similar to wood diesel, wood gas (SNG) can also make a significant contribution in some areas of mobility. Gas-powered cars, trucks and buses are available on the market.

Tab. 5: Key figures for a wood gas (SNG) plant

Rated thermal input	100 MW
Investment costs	150 million €
Fuel requirement	400,000 fm/a
SNG production	51 million Nm^3/a / 500,000 MWh/a
Production costs[1]	65 to 80 €/MWh
Waste heat production	20 MW
Total efficiency	80 %
Full load hours	7,500 h

[1]: depending on the wood price class. Source: TU Wien



Source: TU Wien

Fig. 6: With increasing rated thermal input, the production costs of SNG decrease; at 100 MW they are around 75 €/MWh.

Local green gas

Green gas for natural gas boilers

Local green gas applications are another valuable option for the reduction of the use of fossil natural gas. The producer gas, which is generated in wood gasification, does not need any extensive cleaning, but can be used directly (without the feed-in into the natural gas network) in an adapted gas burner. Thus, this technology is especially suitable for high temperature applications in industry. The production of local green gas is much cheaper than the feed-in into the natural gas network, since no processing of natural gas is needed. However, extensive fuel logistics are required. Resulting from this, the technology seems especially interesting for wood industry companies with a corresponding logistics concept.

Natural gas consumption in industry

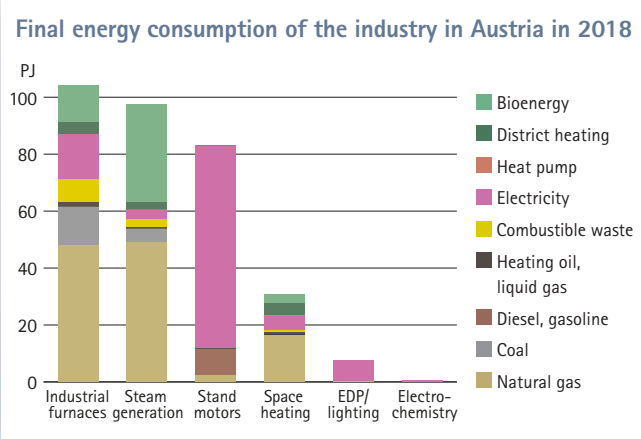
The energy and industry sector is responsible for around 45 % of greenhouse gas emissions in Austria. With 324 PJ, the industry consumed around 30 % of final energy in Austria in 2018. 62 % of this percentage were used for process heat (industrial furnaces and steam generation), natural gas was the energy source for half of it (Fig. 7). In the industrial sector, the paper industry is the largest consumer of natural gas, followed by (petro-) chemicals and the iron and steel production. If the industry's use of natural gas (around 100 PJ) for process heat were to be replaced with woody biomass, emissions could be reduced by 6.75 million tons of CO_2eq and, thus, the calculated goal from the climate and energy strategy could be fulfilled in the industry sector.

Suitable for temperatures > 1,000 °C

With a share of 24 %, bioenergy is already the second most important energy source for the provision of process heat, following natural gas (Fig. 7). Main areas of application can be found in the wood (mainly industrial furnaces) and paper (steam generation) industry. A direct combustion of solid biomass is only suitable for the generation of process heat in the low and medium temperature range <500 °C. If wood is being converted into a producer gas, the gas flame can reach temperatures > 1,000 °C during the combustion process. A producer gas from wood gas systems can be used as a substitute for natural gas without extensive cleaning. Therefore, natural gas burners merely have to be replaced with burners for low calorific gas.

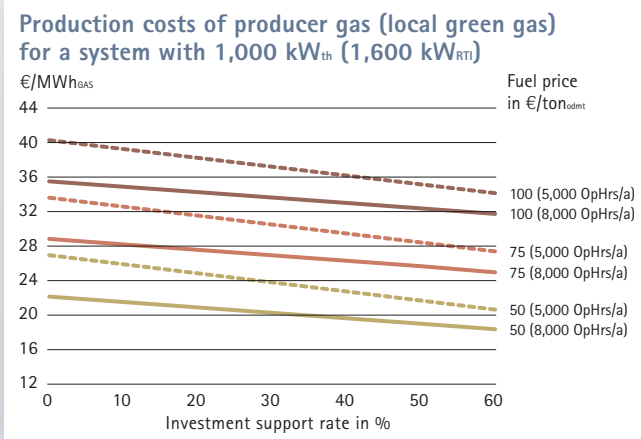
Investment support or market premium

The production costs of local green gas depend on the size of the plant and its operating hours. Assuming a natural gas price of 30 €/MWh and raw material costs of 100 €/ton_{odmt} or 20 €/MWh, plants with 60 % funding and 8,000 operating hours could produce producer gas at the same cost (Fig. 8). If raw material costs decrease to 75 €/ton_{odmt}, systems with 5,000 operating hours and 35 % funding could be built as well. Overall, the funding of investments plays a relatively minor role in the gas generation costs. It could be a major incentive, if local green gas plants were incorporated in a quota for renewable gas, as the additional costs per MWh compared to the market price for natural gas are much lower than in the case of synthetic natural gas (SNG).



© Source: Statistics Austria, useful energy analysis Austria 2018

Fig. 7: 62 % of the final energy consumption in industry is process heat, whereby natural gas is used as an energy source for half of it.



Source: proPellets Austria, PMS GmbH

Fig. 8: With raw material costs of 75 €/ton_{odmt}, an investment support of around 35 % ensures competitiveness with natural gas.

© UPM

In Austria, the paper and printing industry is the industrial sector with the highest consumption of natural gas.

© ABA

Local green gas offers the opportunity of replacing the high level of natural gas used in industry for steam generation with bioenergy.

Additional information

Overview wood gas systems

Plant manufacturer	Rated thermal input gasifier kW from-to	Wood gas CHP plants: Electrical power kW from-to[2]	Wood gas CHP plants: Thermal power kW from-to[2]	Feed-in of wood gas into gas network	Local green gas	Wood diesel	Hydrogen	Biochar
Burkhardt GmbH		50–180	110–270					
Entrenco GmbH		25–50	60–120					
Fröling Heizkessel- und Behälterbau GmbH		46–56	95–115					
GLOCK ecotech GmbH		18–50	44–110					
Hargassner GmbH		20	60					
Holzenergie Wegscheid GmbH		65–133	130–270					
LiPRO Energy GmbH & CO. KG		30–50	60–90					
Polytechnik Luft- und Feuerungstechnik GmbH	400–1,500							
ReGaWatt GmbH	1,600–8,000	420–2,300	870–5,600			O	O	
Spanner Re² GmbH		35–600	79.5s–1,200					
Stadtwerke Rosenheim GmbH & Co. KG		50–180	110–380					
Syncraft® GmbH	700–3,000	200–1,000	155–1,540		x		O	x
URBAS Stahl- und Anlagenbau GmbH	500–2,000	120–600	250–1,000					
Windhager Zentralheizung GmbH	7–100							
Xylowatt S.A.	2,800–7,300	750–2,000	1,500–4,000				O	x
System designer								
BEST – Bioenergy and Sustainable Technologies GmbH[1]	100–35,000	x			x	O	O	
GET – Güssing Energy Technologies GmbH		x		x	x	O	O	x
Güssing Renewable Energy GmbH	4,500–45,000	1,200–2,400	1,400–24,000			O	O	
Pörner Ingenieurgesellschaft mbH	500–45,000	O		O	O	x	O	O
Repotec/Aichernig Engineering GmbH		x		x	x	O	O	x
ERNEUERBARE ENERGIE – Ing. Leo Riebenbauer GmbH		18–540	44–810		x	O	O	x
SMS group Process Technologies GmbH	1,000–20,000	O		O	O	O	O	

x = implemented commercial plants; O = no commercial systems available yet; [1] research facility; [2] given information applies to one module.
Company information, table makes no claim to completeness.

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Österreichischer Biomasse-Verband
Austrian Biomass Association

Wood Gasification: Evolution of a Technology

Supported by
Federal Ministry Republic of Austria Agriculture, Regions and Tourism

The Beginnings

1786 to 1950

From a purely scientific point of view, the beginnings of wood gasification are mainly about understanding the underlying mechanisms of this technology; the fact that wood itself does not burn per se, but only the emitting gases was one of the main findings of that time. This process step is nowadays known as pyrolysis. In addition to a flammable gas, pyrolysis primarily produces valuable charcoal. The conversion of this coal into a combustible gas – i.e. the process step of gasification – initiated the name of the entire process: wood gasification. From a technical point of view, until 1950, almost only fixed-bed downdraft gasifiers were built and operated. In the following years, further bold developments and process combinations resulted in the variants of the wood and biomass gasification known today. In the year 1922, Fritz Winkler succeeded in developing a gas generator capable of converting brown coal into a synthesis gas for the first time, by making use of fluidized bed technology: the Winkler-gasifier was born. In the Second World War, vehicles based on wood gas increasingly gained importance. During the war years, around 6 million vehicles were powered by generator gas and truck mileages of over 300,000 km were realized.

Renaissance and Advancement

1951 to 2005

Before 2000, hardly any noteworthy new developments in wood gasification can be mentioned due to factors such as industrialization, the oversupply of fossil fuels and the population's only moderately developed environmental awareness. With the adoption of the Kyoto-Protocol in 1977 and an increasing awareness of climate change, wood gasification and its advancements, then, experienced a renaissance. Early on in the beginning of fixed-bed downdraft gasification, people recognized that co-current flow of gas and fuel could quickly lead to an undesirable compression. Therefore, wood chips of an appropriately large size (10 x 10 cm edge length) had to be chosen. The development of the updraft gasifier made it possible to avoid this fact, however, it resulted in extremely high tar loads at the outlet of the gasifier. At the same time, the TU Wien (Technical University Vienna) developed the fluidized bed gasification, ideally suitable for large-scale plants. With the development of a gas scrubber, the TU Wien achieved a breakthrough in gas cleaning. Inspired by the relatively low tar values in small fixed-bed downdraft gasifiers, the Technical University of Denmark (DTU) developed the staged fixed-bed gasifier, characterized by its very low tar values (around 100 times lower than in fluidized bed systems).

Status Quo

2005 until today

Shortly after the turn of the millennium, wood gasification technology was not only characterized by many interesting development approaches and a lot of euphoria, but also by many setbacks. In the field of fixed-bed gasification technology, in particular, some major projects even had to be canceled due to insurmountable scale-up barriers. In the meantime, fixed-bed gasifiers with a system availability of over 8,000 full load hours have become state of the art and are commercially considered as fully developed. Numerous Austrian and German manufacturers offer plants between 10 and 500 kW (sometimes up to 600 kW) of electrical power on the market. The combination of several modules in cascade enables the production of larger systems. Classic fixed-bed gasifiers generate clean wood gas from dry, high-quality wood chips of defined particle size or from pellets, thus, the process of gas cleaning can be carried out in a very simple manner. The staged floating fixed-bed gasification is more flexible in terms of particle size and fuel quality. Concerning updraft gasification, new developments focusing on extremely low-emission heat production by means of a clean post-combustion of the gases are of particular interest. Wood gas from fluidized bed gasification shows a higher particle and tar load, therefore, in contrast to the other above-mentioned processes, gas cleaning technologies such as fabric filters or biodiesel scrubbers are used. In fluidized bed gasifiers, even low-grade fuels can be applied, in contrast to the floating fixed-bed gasification. In a dual fluidized bed gasification system (DFB = Dual Fluidized Bed), steam or CO_2 can also be fed as gasification agent instead of air, leading to the emergence of a high-quality, nitrogen-free synthesis gas. This kind of synthesis gas can be employed to produce premium fuels, aviation fuels, synthetic natural gas, hydrogen, methanol, ethanol or chemicals.

Outlook

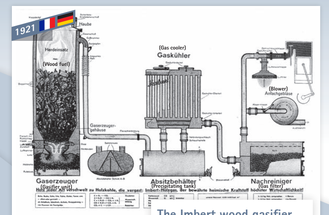
Research and development

Commercial applications prove that wood gas production is already state of the art. In the area of fixed-bed gasification, research focuses on the reduction of the share of fuel costs in overall operating costs from over 50 % down to a third. Fluidized bed gasification can be integrated into industries, infrastructure or biorefineries in sizes up to a few 100 MW and offers the possibility to use external hydrogen for grid stabilization via the combination with a Power-to-X route or the provision of high-temperature heat. Currently, numerous basic research projects investigate this matter. Combinations such as SNG and wood diesel production can already be implemented at short notice.

1799

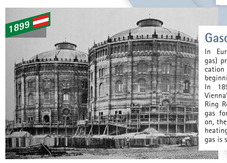
Invention

The French engineer and later professor Philippe Lebon is the first to discover the properties and effects of wood distillation and presents his findings to the public in 1786. In 1799, he is granted a patent for a gas-powered, so-called „thermal lamp", which is presumably used for lighting as well as room heating. Lebon develops a heating system for a hotel in Paris. Wood gas is being fed into the room and, there, burned in a controlled manner. Lebon is murdered in 1804 at the age of 37 on the day of Napoleon's self-coronation.



The Imbert wood gasifier

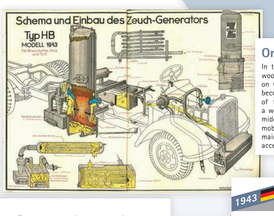
In 1921, the Franco-German chemical engineer Georges Imbert designs the Imbert gasifier, a gasifier being operated entirely with charcoal in its first form. Only in 1926, Imbert finally manages to develop his wood gasifier and his first version for motor vehicles in 1927. The Imbert gasifier still represents the technical basis for most wood gasification systems in use today.



1899

Gasometer

In Europe, town gas (coal gas) produced by coal gasification is widely used at the beginning of the 20th century. In 1899, the lanterns on Vienna's Ringstraße (Vienna Ring Road) are lit with town gas for the first time. Later on, the gas is also utilized for heating and cooking. Town gas is stored in gasometers.

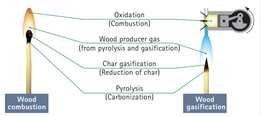


On the road with wood gas

In the course of the Second World War, the wood gas drive becomes socially acceptable on vehicles, especially in Germany, and soon becomes a familiar sight on the streets. One of the best-known vehicles equipped with a wood gasifier is the Opel Blitz, a light and middle-weight truck. In order to maintain mobility in times of fuel shortages, high maintenance costs and low efficiency are accepted.

1943

Functioning of a wood gas plant



If wood is heated, its main components, (hemi-) cellulose and lignin, split up into smaller components. These smaller hydrocarbons are now gaseous and flammable. For example, if you let a match burn down, you will see that the flame is burning above the match.

A wood gas system works in a similar way: Firstly, the wood is converted into coal by what is known as pyrolysis, secondly, coal is converted into gas, in the process of (charcoal) gasification. Both processes – combustion and gasification – produce flammable gases.

Combined heat and power with wood gas

In a wood gas CHP plant, the gas is burned in a piston engine after cleaning and cooling. The engine drives a generator that produces electricity. Employing wood gasification, electrical efficiencies of over 30 % can be reached. If the waste heat is additionally used, up to 80 % of solar energy, which is stored in the wood, can be converted into useful energy. No other technology specified in converting wood into electricity manages to achieve higher electricity yields, especially, in the low output range.

Fixed-bed downdraft gasifier

In fixed-bed downdraft gasifiers, the air and fuel flow move in the same direction. A low tar content in fuel, but higher demands on the raw material quality are the results of this method.

2004

Urbas >120 kW_{el}

In 2004, the Carinthian company Urbas launches the first commercial fixed-bed gasifier in a small series with around 110 kW electrical output. In the year 2013, 8,600 operating hours are demonstrated in a customer plant within one year (world record). The current systems deliver up to 600 kW_{el} in one unit. With over 50 customer systems, the second system will also be built in Japan in 2022. The Urbas plant exemplifies the market launch of wood gasification – a milestone in the history of biomass power generation.

Staged fixed-bed gasifier

In the staged (floating-) fixed-bed gasification, the pyrolysis (reduction to charcoal) and the charcoal gasification occur in separate places. However, little tar and low demands on the fuel do require a complex technology.

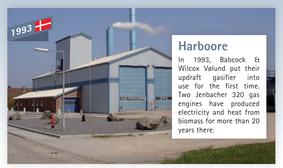
2002

Staged „Viking"

In 2002, the DTU puts its staged fixed-bed gasifier „Viking" into operation for the first time. Since then, the blue wood gas flame has become a symbol of tar-free or utmost tar-free gasification: an important advancement in the history of wood gasification.

Fixed-bed updraft gasifier

In the case of fixed-bed updraft gasifiers, the air and fuel flow are conducted in opposite directions. Higher tar contents in the gas, but lower demands on the fuel quality are the results.



1993

Harboore

In 1993, Babcock & Wilcox Volund put their updraft gasifier into use for the first time. Two Jenbacher 320 gas engines have produced electricity and heat from biomass for more than 20 years there.

Tar as a challenge

2003

The Danish company Valund has to keep enhancing the process for another ten years, until they are able to come up with the development of a suitable tar separator in the year 2003. Thus, the product updraft gasifier combined with a gas engine is commercially available for the first time.

Fluidized bed gasifier

In fluidized bed gasifiers, the fuel is kept in suspension by high air velocities. The gasification of the previous grounded material only takes a few seconds. The fluidized bed guarantees a better heat transport than fixed-bed gasifiers. The method is preferably implemented in large-scale plants.

2000

Güssing

In 2000, the most famous and scientifically most important biomass gasification plant, so far, was put into operation in Güssing for the first time. The dual fluidized bed gas generation was developed at the TU Wien, directed by Hermann Hofbauer. The plant produces 2 MW_{el} at around 8,000 full load hours per year. It runs until 2016 and reaches around 100,000 operating hours.

Biodiesel scrubber

The TU Wien has managed to solve the problem of tar separation in Güssing permanently, by developing a biodiesel scrubber, generated with rapeseed methyl ester. Consequently, the tar problem can be eliminated in other gasification processes as well.

Natural gas instead of CHP

2008

Following several years of development, the world's first methanation plant for wood gas is put into use in Güssing in the year 2008. By utilizing this system, it is first possible to produce biomethane from wood.

2014

GoBiGas

In 2014, a 20 MW_{th} plant for biomethane production, the so-called GoBiGas (Göthenburg Biomass Gasification Project) is started in Gothenburg, Sweden. Activated charcoal is used to reduce the tar amount. The successful demo operation of this largest wood gasification plant (32 MW_{th}), so far, ends in 2017 after 15,000 operating hours.

2007

Spanner Re^2 >68 kW_{el}

In 2007, the company Spanner Re^2 starts the serial development of wood power plants. Performing more than 40 million operating hours, the Spanner Re^2 systems, installed around the world, have positively stood the test in practice – not only in the low output range. Spanner Re^2 has also established itself on the international market as manufacturer of complete CHP solutions in the megawatt range (cascades up to 4 MW_{el}).

2008

Burkhardt >180 kW_{el}

In 2008, the German company Burkhardt develops an updraft co-current flow gasifier, operated with standardized wood pellets. The wood gasification systems, which are now in series production, are currently in operation more than 250 times worldwide and impress with their long operating times and high electrical and thermal efficiency levels.

2009

Wegscheid >133 kW_{el}

With more than 90,000 operating hours since 2009, Holzenergie Wegscheid's system prototype is rather exemplary. Since company foundation, more than 150 systems, including multi-module systems, have been installed worldwide. As of 2017, the systems are additionally available as plug & play or in container construction.

2013

Fröling >50 kW_{el}

The renowned Upper Austrian boiler manufacturer Fröling has implemented numerous wood gas CHP projects across Europe since the year 2013. Their range of delivery involves individual solutions and turnkey systems, including fuel processing (e.g. drying and sieving).

2015

Hargassner >20 kW_{el}

Since 2015, the Hargassner company offers a small power plant that generates decentralized heat and electricity. The KWK 60/20 outlines an interesting solution for the medium output range, in particular, for commercial enterprises, public buildings and operators of local district heating networks.

2015

GLOCK ecotech >18 kW_{el}

In 2015, following five years of development, the first prototype of the wood gas power plant is installed at the Mayer company in Zeltweg. This pilot project marks the start of the product launch. In accordance with its customer, GLOCK ecotech further develops the plant to its readiness for series production, thus, subsequent CHP units can be delivered already 2016. The first plant has a running time of 42,450 operating hours in September 2021.

The plants have become marketable. Manufacturers focus on achieving long plant runtimes and increased efficiencies. Research is conducted in terms of higher fuel tolerance and the use of alternative gasification agents (e.g. water vapor). System flexibility is achieved by the interconnection of several modules. The combination of heat and electricity production remains the main area of application in the small and medium power range.

2004

Xylowatt >750 kW_{el}

Since 2001, Xylowatt has been designing, supplying and operating wood gasification systems with an output of 750 kW$_{el}$ or more. The NOTAR® gasifier developed by Xylowatt produces clean synthesis gas without any tar residues. All systems are operated as „zero waste" systems; meaning no waste needs to be disposed, except of not further reducible solid matter. Xylowatt is a pioneer in the variable use of biochar and the production of hydrogen from synthesis gas.

2007

World upside down

In the year 2006, scientists at MCI Innsbruck design the staged floating fixed-bed gasifier, which is operated against gravity. By using this method, conventional wood chips can be effectively processed without any restrictions in terms of fines (dust) or bark content for the first time. In addition, no auxiliary materials are required.

2013

Climate-positive power plants

After almost seven years of development, the first commercial floating fixed-bed gasifier with 250 kW$_{el}$ is put into operation in South Tyrol. By 2020 SynCraft, a high-tech company based in Tyrol, will build and implement power plants, generating electricity, heat and renewable carbon from forest residues, worldwide. If the pure carbon is correctly utilized, e.g. as soil improvement, the power plants can function in a climate-positive way as „reverse power plants".

2015

Rosenheim

The so-called Rosenheim method for wood gasification is a staged pyrolysis-fluidized bed process, operated in co-current flow. The market launch by Stadtwerke Rosenheim takes place in 2015. A research project on the use of waste wood has been conducted since 2020.

LiPRO Energy

Starting in 2012, a team of engineers from Oldenburg, Germany, has been developing a fully automated, staged wood gasification process. After several field systems, LiPRO Energy launches its systems on the market in the year 2017. The plant is very efficient and is also able to produce a high-quality synthesis gas from inferior, natural wood chips due to its staged process method.

2017

The two-stage process leads to a high gas quality and allows a high level of raw material flexibility. Currently, extensive work is carried out in the staged fixed-bed gasification on the development of a gasifier that also utilizes agricultural residues. Series of tests with fermentation residues from biogas plants have already been successfully completed. Multi-stage gasifiers are suitable for the production of local green gas instead of natural gas in industry as well.

ReGaWatt combi power system

The gasifier of the 1.6 to 8 MW power class, developed by ReGaWatt, is insensitive to fuel quality due to its counterflow principle, hence, moist wood can easily be exploited. For electricity production, the gasifier can be expanded with a gas engine or ORC system functioning as a combination power system. The post-combustion of the engine exhaust gases ensures low emissions, thus, neither filters nor boiler cleaning are necessary. Tar is produced as a liquid pyrolysis oil and serves as a valuable by-product.

2012

2016

Zero-emission technology <100 kW

The wood chip updraft gasifier, developed by Windhager in cooperation with the research institute BIOS Bioenergiesysteme in 2016, makes use of the filtering effect of the fuel. The carbonized layer of wood chips acts like an active carbon filter, which the wood gas needs to pass by on its way to the top. The gases are burned in such a clean manner through secondary and tertiary air above the carbon filter, hence, dust emissions can hardly be measured.

POLY H.E.L.D. – extreme air staging

In 2019, Polytechnik launches an updraft gasifier in the 400 to 1,500 kW range with integrated grate, aiming at the minimization of particulate matter emissions. The usage of the extremely staged combustion reduces dust emissions to <20 mg/Nm^3 with efficiencies >92 %. Elaborate gas cleaning is no longer needed as the rising gases are burned immediately and exclusively for heat production. Low fuel requirements and the absence of filters characterize the POLY H.E.L.D system as an economical solution.

2019

In the field of counterflow gasification, one focus lies on the development of low-dust wood firing systems designed for pure heat generation without electrostatic filters or cyclones. The robustness of the updraft gasifier also predestines the system for alternative fuels such as waste wood, sieve overflow from composting plants or agricultural residues; additionally, the range of fuels is constantly being expanded. Further potential lies in the areas of local green gas, hydrogen production and motor fuel production from the by-product pyrolysis oil.

2014

Hydrogen

The dual fluidized bed gasification plant in Oberwart successfully demonstrates the production of hydrogen on a smaller scale, managing more than several thousand operating hours. On this basis, a scale-up to the size of an industrial demo system can be started at any time.

Wind diesel

Wind diesel is the enhancement of a combined DFB Fischer-Tropsch wood gas system to a power-to-liquid process. This means, that high-quality second-generation biodiesel can be produced from surplus wind power. The hydrogen, generated by electrolysis from wind power, is fed into the synthesis process. Between 2014 and 2017, the concept is tested on a laboratory scale.

2017

2018

Demonstration facility Nongbua

Following eight years of development, the demonstration plant in Nongbua/Thailand is going into operation with 1 MW_{el} in 2018. The plant generates electricity and heat and, consequently, storage cooling. Furthermore, it functions as a research facility for hydrogen and aviation fuels. Agricultural and forestry residues are processed as fuel, including cassava or empty palm oil fruitbunch.

Daigo wood power plant

In Daigo/Japan, a 4.2 MW dual fluidized bed wood gasifier is about to go into operation in autumn 2020. Achieving an output of 1.2 MW_{el}, the plant should primarily produce electricity; the thermal output amounts to 1.5 MW.

2020

2021

Waste2Value, Vienna

In order to demonstrate the use of residual materials on an industrial scale, a 1 MW pilot plant is implemented in Vienna-Simmering, as a part of the „Waste2Value" project. The plant represents the key technology for subsequent utilization of the synthesis gas produced by the plant, such as Fischer-Tropsch diesel, kerosene, mixed alcohols, SNG and green hydrogen. CO_2 is produced as a by-product and, for example, used in greenhouses. The commissioning is planned for summer 2021.

Real laboratory – a learning system

The Austrian federal government has announced that it will provide the funds for a 5 MW real laboratory for the production of hydrogen, diesel and SNG from wood. The laboratory should show all elements of an industrial system and is a necessary step in the development of the technology to industrial scales. From 2024 on, after the commissioning, first long-term test in the real laboratory could be investigated. Based on these results, first industrial plants with a size of 100 MW could be built.

2022

The advancements of the fluidized bed gasifier leave the area of classic combined heat and power plants. In addition to the production of synthetic natural gas (SNG), wood diesel or hydrogen, dual fluidized bed gasifiers also have the potential to process a wide range of raw materials. In Austria, several large projects of wood diesel and SNG could be implemented in the next few years. From an economic point of view, an optimal system size is around 100 MW rated thermal input.

Wood gas CHP reference projects manufacturers

Project	Hotel Haffhus in Ueckermünde/DE	Nahwärme Dellach im Gailtal/AT	Ökoenergie-Biowärme Obervellach GmbH & Co KG/AT
Producer, Location	GLOCK ecotech GmbH, Griffen/AT	HARGASSNER GmbH, Weng/Innkreis/AT	URBAS GmbH, Völkermarkt/AT
Size of Plant/Module	18 kW electrical, 44 kW thermal	20 kW electrical, 61 kW thermal	250 kW electrical, 420 kW thermal
Efficiency	27,07 % el / 62,26 % th	23,5 % el / 72 % th	31,25 % el / 52,5 % th
Technology	Fixed-bed downdraft gasifier	Fixed-bed downdraft gasifier	Modified fixed-bed downdraft gasifier
Fuel according to EN ISO 17225	Wood chips size P16S to P31S, class A1; wood pellets ENplus A1	Wood chips size P16 to P31S, class A1	Wood chips size >P63
Water Content	<23 %	<15 %	<15 % (when placed in bunker <50 %)
Fuel Consumption	18 kg/h	20 kg/h	200 kg/h
Special Features	Complete self-supply of hotel with electricity, Separation from public grid (CHP/PV/power storage)	Compact, fully integrated design; Highest fuel efficiency; 100 % upstream heat use	Drying and fine part screening integrated in the feed; Variable flow temperature for dairy
Number of Units operating in AT	45 plants	10 plants	11 plants, 8 locations
Contact	www.glock-ecotech.com	www.hargassner.at	www.urbas.at

Source: Paid advertisement based on manufacturer information

Wood gas CHP reference projects manufacturers

Project	District heating supply Scheibbs/AT	CraftWERK Innsbruck/AT	Energy self-sufficient future, comm. Kirchschlag/AT
Producer, Location	Fröling GesmbH, Grieskirchen/AT	SynCraft GmbH, Schwaz/AT	Spanner Re^2 GmbH, Neufahrn i.NB/DE
Size of Plant/Module	4 x 56 kW electrical, 4 x 115 kW thermal	261 kW electrical, 395 kW thermal	340 kW electrical, 615 kW thermal
Efficiency	28 % el / 58 % th	29 % el / 63 % th	28 % el / 53 % th
Technology	Optimized fixed-bed downdraft gasifier	Patented, staged floating fixed-bed gasifier	Patented fixed-bed downdraft gasifier
Fuel according to EN ISO 17225	Wood chips size P31S to P45S, class A1; pellets	Wood chips size P31S / P45S, including fine material and bark	Wood chips size P31S, fine material portion: F10, ash content: A1.0, max. fine material portion (<4 mm grain size) 30 %
Water Content	<10 %	<50 % (integrated pre-drying)	<13 %
Fuel Consumption	40 kg/h	215 kg/h	0,85 kg/kW_{el}
Special Features	High efficiency because of modern MAN natural gas engine; Support by factory customer service; First customer systems in operation since 2013, numerous references	50 % forest residues, High tolerance for contaminants	5 wood power plants (HKA 70) in cascade; 2.700 MWh/a electricity for 675 households; District heating network >3.400 m supplies almost whole community (250 households)
Number of Units operating in AT	>30 plants	5 plants	>20 plants
Contact	www.froeling.com	www.syncraft.at	www.holz-kraft.com

Source: Paid advertisement based on manufacturer information

Wood gas (CHP) reference projects manufacturers

Project	Nahwärme Murau Stolzalpe, Murau, Murauer Stadtwerke Ges.m.b.H./AT	Zero-Dust-Technology, Fernwärme Sulzberg/AT	Hospital Mont-Godinne/BE
Producer, Location	Burkhardt GmbH, Mühlhausen/DE	Polytechnik GmbH, Weissenbach/AT	Xylowatt S.A., Louvain La Neuve/BE
Project Products	Electricity and heat	Heat; Emission reduction of dust <20 mg/Nm^3, 25 % less NOx	Electricity and heat
Size of Plant/Module	3 x 165 kW electrical, 3 x 260 kW thermal	450 kW + 600 kW	750 kW electrical, 1,500 kW thermal
Efficiency	30 % el / 47 % th	up to 93 %	30 % el / 60 % th
Technology	Updraught co-current flow gasifier with stationary fluidized bed	Staged updraft gasifier up to 3,000 kW	Staged fixed-bed gasifier
Fuel according to EN ISO 17225	Wood pellets EN Plus A1	Wood chips size P45 to P63, pellets, agripellets	Wood chips size P31S
Water Content	<10 %	<45 %	<10 %
Fuel Consumption	110 kg/h per plant	POLY H.E.L.D. 450: 145 kg/h, H.E.L.D. 600: 195 kg/h	640 kg/h
Special Features	Standardized fuel, Compact system technology, Especially developed plant portal	Staged combustion reduces dust emissions up to 100 times with maximum efficiency; Reduced electricity and fuel consumption; No filter system	Notar gasifier produces a gas that is 99.96 % tar-free; Zero waste system, no waste is produced; Extraction of hydrogen and biochar possible
Number of Units operating in AT	13 plants, 7 locations	5 plants (by the end of 2020)	n. s.
Contact	www.burkhardt-gruppe.de	www.polytechnik.at	www.xylowatt.com

Source: Paid advertisement based on manufacturer information

Wood gas (CHP) reference projects system designers

Project	KWS Ökokraft GmbH, Ternitz/AT	Nongbua Green Power/TH	Waste 2 Value, Vienna/AT
System Designer, Location	ERNEUERBARE ENERGIE – Ing. Leo Riebenbauer GbmH, Pinggau/AT	Güssing Renewable Energy Intl. Gmbh, Bangkok/TH	BEST – Bioenergy and Sustainable Technology GmbH, Graz/AT
Services performed	General planning, entire project management, detailed planning, construction and funding processing, commissioning, handover	Planning, procurement, commissioning, test operation (BOOT), know-how transfer (BOOT), carbon recycling	Basic engineering; Design and integration of the plant in the industrial context
Project Products	Heat, electricity, by-product biochar	Electricity and heat, FT products, hydrogen (laboratory scale)	Synthesis gas ($CO/H_2/CH_4$) and subsequently FT diesel, hydrogen, methane
Size of Plant/Module	400 kW electrical, 615 kW thermal	1 MW electrical, up to 2,4 MW thermal (depending on the use for wood drying)	n.s.
Efficiency	Highly efficient system (SynCraft)	30 % el / 50 % th	n. s.
Technology	Staged fixed-bed gasifier	Dual fluidized bed gasification (DFB)	Dual fluidized bed gasification (DFB)
Fuel according to EN ISO 17225	Forest wood chips without processing, including drying	Inferior quality wood chips up to size P45, waste, residual wood, bagasse, cassava, empty palm oil fruitbunch	Wood chips, sewage sludge, residues
Water Content	<15 %	<50 %	<40 %
Fuel Consumption	267 kg/h	1,000 kg_{wood}/h	n.s.
Special Features / References	GU-planning for clients with products from the following manufacturers: Fröling, SynCraft, URBAS, Burkhardt, GLOCK Ökoenergie.	No liquid residues, ash as the only residue; Wide range of fuels; Polygeneration	Industry-oriented research facility for the material use of wood-based fuel and residues including sewage sludge
Number of Units operating in AT	6 (highly efficient systems, implemented as general contractor (GC) planner)	1 plant	n.s.
Contact	www.riebenbauer.at	www.gussingrenewable.com	www.best-research.eu

Source: Paid advertisement based on company information