

IEA Bioenergy Agreement: Task 33: Thermal Gasification of Biomass (2001-2003)
TECHNOLOGY BRIEF

Fluidized Bed Gasification, Gas Cleaning, and Fuel Gas Utilization Systems

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1 Introduction and background

Fluidized-bed biomass gasifiers directly connected to lime kilns or boilers have been in successful commercial operation since early 1980's. The technical feasibility of biomass-IGCC (Integrated Gasification Combined Cycle) process based on fluidized-bed gasification was also demonstrated already in 1990's. In 1980's the main driving force was the replacement of expensive oil or natural gas by cheaper biomass-derived fuel gases, while presently the international targets for reducing the CO₂ emissions are governing the energy policies in most countries. Fluidized-bed gasifiers are best suitable to relatively large-scale (> 10 MW) and have many interesting applications in connection to existing power plants, new advanced power cycles as well as the production of liquid biofuels. Fluidized-bed gasifiers are considered to be rather fuel flexible and are most suitable to feedstocks with high volatile matter content and high char reactivity.

The replacement of coal in existing pulverized coal-fired boilers can significantly lower the CO₂ emissions of power production in many countries already at short term. The present gasification and gas cleaning R&D work and the successful commercial experiences obtained in boiler applications will also help the development and market penetration of biomass gasification-based advanced power systems such as IGCC, engine cycles and fuel cell systems.

2 State-of-the Art

The fluidized-bed gasification technologies presently used or developed for biomass and waste materials can be divided into different categories on the basis of gasification and gas cleaning method. The following table summarises the most essential gasification technologies developed for utilisation of biomass. In addition to technologies listed in the table below some oxygen blown gasification pilot and demonstration plants, which have been originally developed for coal gasification, have been tested with biomass. Interest focused on oxygen (and steam) blown biomass gasification has increased recently significantly. Reason for this increased interest is to produce hydrogen and carbon monoxide rich syngas for production of liquid biofuels but also for fuel cells etc.

Gasification technology	Pilot tests	Demonstrated	Commercial	Examples of plants	Suppliers
Air-blown low-pressure gasifiers, no gas cleaning	x	x	x	Lahti/cocomb. in boiler	Foster Wheeler
				Ruien/cocomb/boiler	Foster Wheeler
				Corenso/plastics/boiler	Foster Wheeler
				Gertruidenberg/cocomb.boiler	Lurgi
				Zeltweg/cocomb/boiler*	Austrian Energy
				Creve in Chianti/boiler	TPS
Air-blown low-pressure, gas filtration	x			FW/Karhula, Lahti Slip-Stream TPS/Studsvik	Foster Wheeler, TPS
Air-blown pressurized gasifiers with dry gas cleaning	x	x		Värnamo, IGCC*	Foster Wheeler
	x			Tampere-pilot plant	Carbona
Oxygen-blown gasification, pressurized	x	x	(x)	HTW in Oulu - syn gas* Hawai/Renugas*	UHDE/Rheinbraun GTI
Steam gasifiers with indirect heating	x	x		Vermont - boiler	Battelle
				Gussing - gas engine	Repotec
Other types	x			Carbo-V pilot/Freiberg	Choren

* not existing or not in operation any more

3 Technical and Non-technical Barriers

Gasification technology	technical challenges	non-technical barriers
Air-blown low-pressure gasification for boilers and kilns (with dry gas cleaning)	<ul style="list-style-type: none"> gasification of high-alkali biomasses and RDF tar control to avoid problems in gas cooling and filtration durability of filters and design of gas coolers and filtering units removal of mercury in waste gasification filter ash quality and end use 	<ul style="list-style-type: none"> Competition with direct co-firing, higher investments European Waste Incineration Directive (limits to emissions from the main fuel) subsidies for biomass-alone plants but not for co-firing fuel availability, price level and contracting
Gasification with low-temperature gas cleaning (for engines, turbines etc.)	<ul style="list-style-type: none"> tar removal without producing toxic waste waters waste water treatment efficient use of waste heat 	<ul style="list-style-type: none"> economic competitiveness with steam cycles, co-firing etc. small difference in efficiency compared to steam cycles

Air-blown pressurized gasifiers for gas turbine applications	<ul style="list-style-type: none"> • gasification of high-alkali biomasses • multi-fuel operation required • further simplification of the process (no gas coolers) • advanced fuel feeding • filter ash quality and end use • NOx control technology 	<ul style="list-style-type: none"> • suitable only to large scale, feedstock availability limits the potential • difficulties in financing the first demonstration plants
Oxygen-blown gasification, pressurized (syngas for liquid biofuels or renewable chemicals)	<ul style="list-style-type: none"> • fuel flexibility and advanced feeding • improved syngas quality e.g. by catalytic reforming • optimised gas treatment 	<ul style="list-style-type: none"> • suitable only to large scale • feedstock availability limits the potential • difficulties in financing the first demonstration plants
Steam gasifiers with indirect heating (MCV gas for power or syngas)	<ul style="list-style-type: none"> • improved reliability and performance of dual-bed gasifiers • efficient tar control to avoid production of toxic waste waters • fuel flexibility (especially high-alkali biofuels), ash behavior in combustor 	<ul style="list-style-type: none"> • complicated and costly system for power production • Medium Calorific Value gas is not required in boilers, turbines or engines • difficulties in financing the first demonstration plants for synthesis gas production

4 Recent/New Developments

The Foster Wheeler Fluid-Bed gasifier at the Corenso recycling plant in Varkaus Finland has reached reliable commercial operation at the end of 2001. Aluminum-containing plastic reject material is gasified in this 50 MW plant. Aluminum is recovered for recycling and the product gas is burned in a boiler replacing heavy fuel oil in the power plant of StoraEnso. The plant has the following operation data:

- Operating hours 12500 h (until spring 2004), monthly availability in 2002 > 95 %
- Energy produced 165 GWh/a substituting 16 500 ton HFO/a

5 Subtask Coordinator Concluding Comments

The co-utilization of biomass/waste-derived LCV gas in coal-fired boilers seems to be an attractive short-term market for fluidized-bed gasifiers especially in Europe. The extremely good experiences obtained at Lahti and some other first demonstration plants are pioneering the success of fluidized-bed gasifiers. However, the markets for simple gasifiers without gas cleaning are rather limited and thus the development and demonstration of gas cleaning seems to play a key role in further commercialization of biomass gasification technologies.

In all biomass gasification processes, the product gas contains several types of gas contaminants, which have to be efficiently removed before utilizing the gas in advanced power systems. The high concentrations of tars and nitrogenous species (ammonia and HCN) are typical challenges of biomass gasification, where good solutions cannot be found from well-established coal gasification or conventional flue gas cleaning technologies. The tar problem has been the key technical hurdle, which has prevented the commercialization

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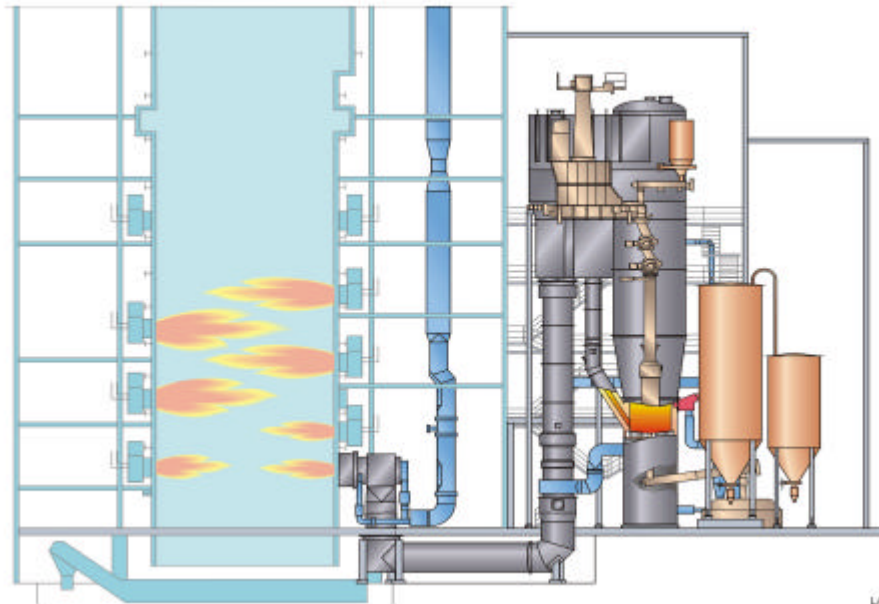
of environmentally sound small-scale CHP plants based on gasifiers and IC engines. The gas cooling and cleaning has also been the key technical problem in many of the existing and past gasification demonstration plants. Considering future applications, such as fuel cells or synthesis gas, even higher demand for gas quality in terms of the contents of tar and other contaminants will be faced. This cleaning needs to be performed with the smallest possible extra investment so as to make the use of such systems economically viable, especially for smaller scale units.

Appendices: Description of interesting demonstration/commercial projects and technologies

- Lahti
- Corenso

BIOMASS FUELLED CFB GASIFICATION & GAS CO-FIRING IN PC BOILER

Lahti Energia, Kymijärvi power plant, Lahti, FINLAND



LAHDEN LÄMPÖVOIMA
KYMIJÄRVI POWER PLANT
KYMIJÄRVI, FINLAND

Plant	Kymijärvi CHP plant, Lahti, Finland
Gasifier manufacturer	Foster Wheeler Energia Oy, Finland
Type of technology	atmospheric pressure CFB gasifier, no gas cleaning, gas co-fired in PC boiler
Capacity of the gasifier	60 MW _{th} (40-90 MW _{th} depending on fuel)
Annual availability of the gasifier	96.1...99.3 % (1998-2001)
Feedstocks	Wood chips, wood waste, saw dust, shavings, demolition wood, SRF (Solid Recovered Fuel), plastic waste
Commissioning	in the end of 1997
Investment	11.4 M€ (EU Thermie 3 M€)

Plant information

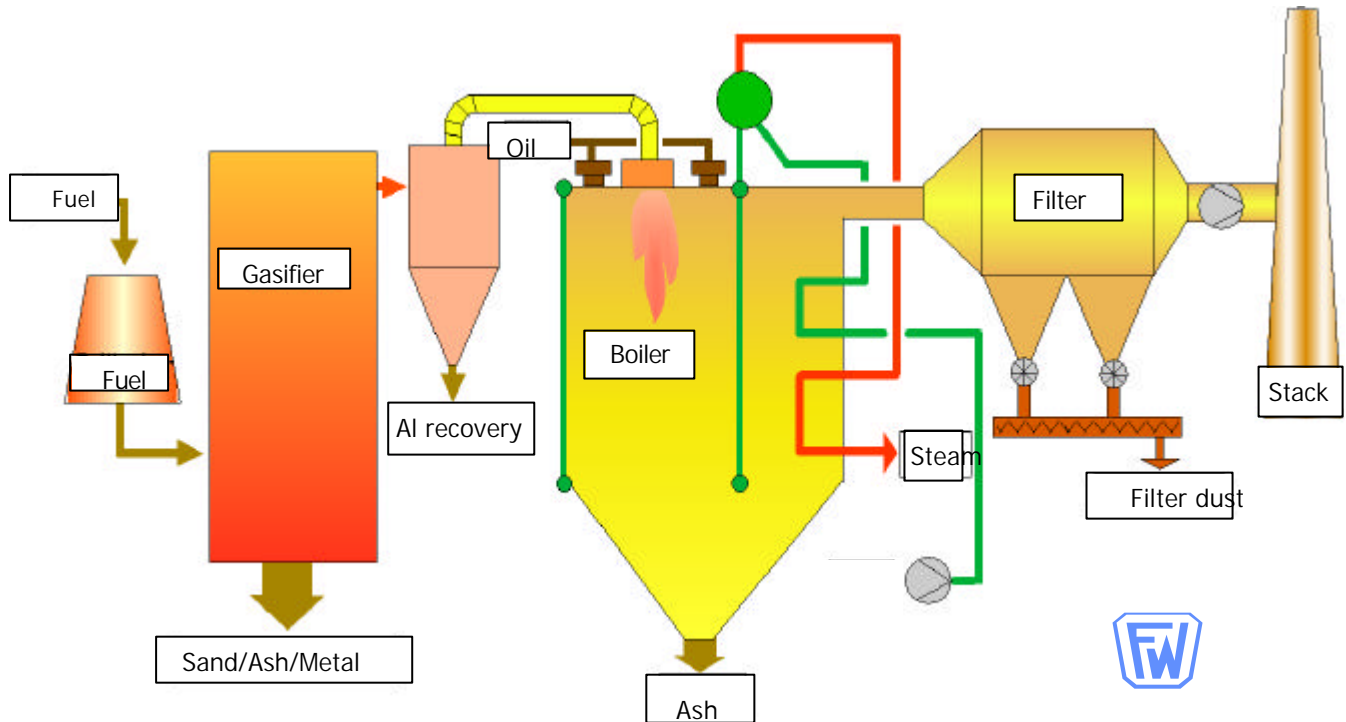
The Kymijärvi CHP plant produces electric power and district heat to the Lahti city. The maximum power capacity is 167 MW_e and the maximum district heat production is 240 MW. The annual operating time of the boiler is about 7000 h/a. The biomass/SRF gasifier was connected to the boiler at the end of 1997. The product gas for combustion is led directly from the gasifier through the air preheater to two burners, which are located below the coal burners in the boiler. The gas is combusted in the main boiler and it replaces part of the coal.

Concerning the gasification process itself, the results have met the expectations. The operating conditions as regards temperatures, pressures and flow rates have been as designed and the process measurements as regards the product gas, bottom ash and fly ash composition have been very close to the calculated values. Due to the high moisture content (up to 58%) of the gasifier fuels, the heating value of the product gas has been low, typically only 1.6–3.2 MJ/m³n. The operating experience of the gasifier during the years 1998–2003 has been excellent. The stability of the main boiler steam cycle has also been excellent.

The main boiler emissions were perhaps under the greatest interest as regards the measurement program of the monitoring phase. In summary, it can be stated that the changes in the emissions were very small.

Al containing PLASTIC WASTE fuelled FB gasification and gas firing in gas fired boiler

ECOGAS Energy plant, Corenso United Ltd, Varkaus, FINLAND



Plant	Varkaus Coreboard Mill, Varkaus, Finland
Gasifier manufacturer	Foster Wheeler Energia Oy, Finland
Type of technology	Atmospheric pressure BFB gasifier, Al separation, gas fired in a specially designed gas fired boiler
Capacity of the gasifier	50 MW _{th}
Production of aluminium	about 2500 t/a
Feedstock	Aluminium containing plastic reject material from liquid packaging recycling process (27 000 t/a)
Commissioning	2001
Investment	17 M€ (public financing 3 M€)

Plant information

The gasifier is fuelled by reject plastic material containing 10-15 % Al foil. Waste is reject from pulping process recycling fibres of used liquid packaging. Plastic waste is gasified in a bubbling fluidised bed gasifier and metallic aluminium is recovered from product gas. Gas is fired in a specially designed gas fired boiler producing process heat and steam for energy production. Total energy production is about 165 GWh/a and production of aluminium about 2500 t/a.