Country Report: Japan

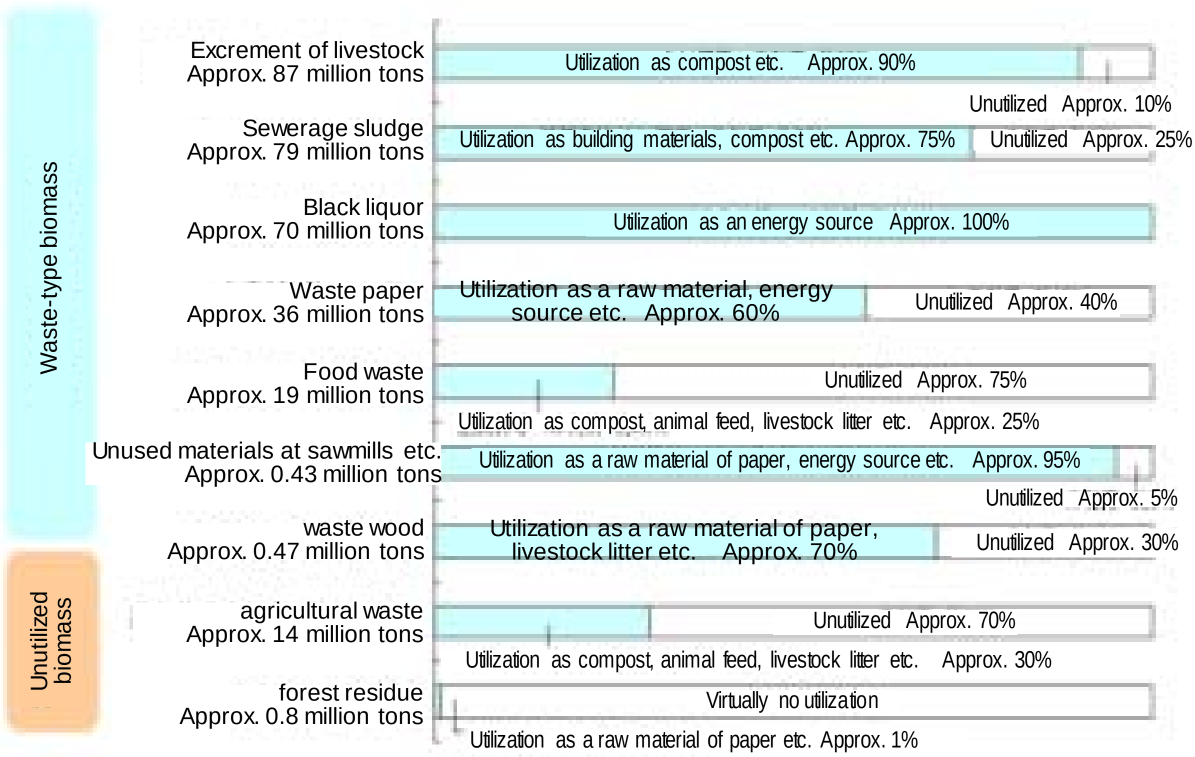
Background

The graph below illustrates the current status of resources in Japan.

In Japan, agricultural waste and forest residue are considered to have great potential as resources for synthetic fuel materials. However, as forests have steep slopes and wide distribution, there is still an issue relating to the collection of such resources.

In addition, food waste and waste paper also have high potential as resources because of the amount of reserves, however, food waste, in particular, has high a percentage of water content and loses a great deal of energy during its energy conversion. Therefore, high-efficiency drying technologies will be necessary.

Residue at lumbermills and surplus wood at construction sites are already used for the purpose of power generation and heat utilization. However, in order to develop energy recovery from simple incineration (gasification), and utilize such resources, there may be an opportunity for introducing refinery processes (synthetic fuel production process) as a new business, while ensuring necessary energy for production processes. In particular, there is a common point of view that heat, which is often not fully utilized, should be utilized as a fuel source. However, because many lumbermills in Japan are small in size, synthetic fuel production technologies, which are economically efficient in large-scale systems, cannot be adopted by such small lumbermills. Consequently, synthetic fuel producing processes will be introduced as a combined residue utilization system in industrial complexes with multiple companies.



This is a similar idea to black liquor which is derived from the paper industry. In Japan, streamlining of production in the paper industry has been achieved and integrated production systems have become mainstream. Through this integration, black liquor is now utilized efficiently as energy and any shortages are supplemented by coal utilization. Therefore, there will be potential for the paper industry to develop synthetic fuel production as a new business utilizing the surplus energy produced as a result of further streamlining of processes in the future.

Policies

The following outlines biofuel policies that have been established in Japan.

The "New National Energy Strategy" announced in May 2006, set a goal of reducing dependence on fossil fuels in the transportation sector by 80% by 2030, while improving energy efficiency by 30%.

"Next Generation of Vehicles and Fuel Initiative" released in May 2007, summarized the results of various discussions held between the automobile and oil industries about how to combine and develop the five eco-friendly automobile technologies, which include battery, clean diesel, hydrogen and fuel cell battery and biofuel technologies.
Based on this initiative, the introduction of biofuel was regarded as an important measure in order to diversify fuel. In particular, in-depth examination has been carried out relating to bioethanol.
As a policy for introducing bioethanol, developing ethanol production technologies using cellulosic materials is necessary, with consideration to issues such as CO_2 emission reduction effectiveness, competition between food supply and fuel supply needs and industrial competitiveness. At the same time, it is essential to improve economic efficiency for ethanol production in order to make prices competitive with gasoline prices in the medium to long term.
Therefore, a "Bio-fuel Technology Innovation Plan", which includes specific goals, technology development and a roadmap, needed to be formulated among public and private cooperation in order to achieve technological innovation that enables bioethanol to be produced effectively and economically from cellulosic biomass.

The "Bio-fuel Technology Innovation Plan" announced in March 2008, illustrated specific model cases for bioethanol production, such as the Biomass Nippon Strategy and Technology Innovation case, and summarized a roadmap for policies and benchmarks of technology development for achieving bioethanol production. Issues from a life cycle assessment perspective, such as competition with food needs, effect on ecosystems, etc., are now being addressed.

The "Cool-Earth 50 – Innovative Technologies Development Project" also formulated in March 2008, established a biofuel roadmap up to 2050. Roadmaps were also established for alternative diesel and gasoline fuels, respectively. Biomass to Liquid (BTL) was set forth as a key technology to achieve the utilization of diesel alternative fuel by the year 2030.

Under the “Basic Energy Plan” approved by the Cabinet in July 2010, the expanded introduction of renewable energy is an important measure to combat global warming, improve energy self-sufficiency ratios, diversify energy resources and promote training in the environmental industry, and the Plan aimed to have renewable energy account for 10% of the primary energy supply by the year 2020.
The plan also aimed to have biofuel account for more than 3% of gasoline use in Japan by the year 2030, under the condition that biofuels will effectively reduce greenhouse gases, has a stable supply and is economically efficient. Additionally, the plan aimed at expanding the introduction of next-generation biofuels that use cellulose and algae by the year 2030.

The “Act of Sophisticated Methods of Energy Supply Structures” implemented in August 2009, was established to promote the use of non-fossil energy resources and the efficient use of fossil energy resources by energy suppliers for the purpose of ensuring a stable and reliable energy supply.
In September 2010, under the same Act, basic policies and criteria were established to promote the use of non-fossil energy resources and the effective use of fossil energy resources by energy suppliers. For bioethanol, oil companies are mandated to supply a mixture of bioethanol and gasoline as automotive fuels. The LCA CO_2 reduction effects for bioethanol are evaluated based on the amount of gasoline supplied by each company in Japan.

Those policies, especially “Cool-Earth 50 – Innovative Technologies Development Project” and “Basic Energy Plan” promote BTL technology development, although the goals set in the plan are scheduled to be revised due to the Great East Japan Earthquake in March 2011.

Projects

NEDO is now carrying out the following three technology development projects using biomass.

・Development of an Innovative and Comprehensive Production System for Cellulosic Bioethanol
・Development of Technologies for High-efficiency Conversion of Biomass and other Energy
・Strategic Development of Next Generation Bioenergy Utilization Technologies

The “Development of an Innovative and Comprehensive Production System for Cellulosic Bioethanol” project outlines a production system, which integrates the cultivation of crops for stable a supply of large-scale cellulosic biomass and the production of ethanol, in order to produce bioethanol from biomass materials, such as plants and trees that are not in competition with the food supply. The project also evaluates environment burdens and economic efficiency by carrying out R&D for the achieving the goals set forth in the “Bio-fuel Technology Innovation Plan.”

The “Development of Technologies for High-efficiency Conversion of Biomass and other Energy” project carries out R&D for energy conversion and comprehensive utilization technologies. The project, implemented From FY2009, aims at the development of element technologies for collecting and transporting biomass, and creating energy producing plants that do not compete with food needs, and uses breeding technologies such as genetic modification, which is expected to be commercialized between 2015 - 2030.

The “Strategic Development of Next Generation Bioenergy Utilization Technologies” project carries out R&D in two phases; one phase involves the development of application technology that supports technological developments for practical applications within five years after the project in order to promote biomass use. The other phase of next-generation technology development aims at developing practical applications by the year 2030 for bio fuel production technologies derived from BTL and micro alga. This project started in FY2010 and will be carried out for seven years. Public solicitations regarding BTL developments were held in FY2010 and 2011 and two projects were implemented in FY2010 and three in FY2011. The total budgets for both phases are 500 million yen in FY2010 (five million euro), 1.5 billion yen in FY2011 (15 million euro).

R&D Institutes and Universities

In Japan, large number of research institutes and universities are involved in field of biomass research, however, limited numbers of research institutes and universities study biomass-to-energy conversion technologies, especially biomass thermal gasification.

Here shows national institutes and universities, which have studied biomass thermal gasification.

National Institute of Advanced Industrial Science and Technology (AIST)

*Energy Research Institute (Tsukuba)

*Biomass Technology Research Center (Hiroshima)

*Research Core for Asian Biomass Energy (Tsukuba)

*Research Center for New Fuels and Vehicle Technology (Tsukuba)

The AIST is a national institute under the jurisdiction of METI. The AIST is consisted of institutes and centers. In the AIST, there are some research institutes and research centers, which study “energy” (not only biomass but also solar, wind, electricity, coal, geothermal, so on) in general.

Forestry and Forest Products Research Institute (FFPRI)

Japan International Research Center for Agriculture Science (JIRCAS)

National Agriculture and Food Research Organization (NARO)

The FFPRI, the JIRCAS and the NARO are national institutes under the jurisdiction of MAFF.

Universities:

The University of Tokyo
Kyoto University
Hiroshima University
Kyushu University
Hokkaido University
University of Tsukuba
Gunma University
Tokyo Institute of Technology

Many universities and college study biomass-related research fields such as forestation, utilization of biomass, valuable products from biomass, catalyst and gene analysis. However, very limited numbers of universities study “thermochemical conversion technologies” for ”biomass”.

The universities listed above have performed “thermochemical biomass conversion” researches. Most of their researches are in laboratory stage. Some of these universities also study “coal”.

Industries:

In Japan, scales of gasification-power and heat generation (CHP) applications are relatively small, from very small of 30kW scale to relatively large of 2MW scale. Many companies developed their own gasifiers, most of which are fixed bed type gasifiers and some of which are rotary kiln and entrained flow type gasifiers. Kawasaki Heavy Industries Ltd., JFE Engineering Corporation, Tsukishima Kikai, Satake, Torisumi Co. Ltd., and so on have/had developed fixed-bed type gasifiers, mostly in National projects or with subsidies. Chugai Ro Co., Ltd., has developed a rotary-kiln type gasifier. Biomass Energy Corporation developed a small-scale entrained-flow type gasifier. Shimizu Corporation has modified it for treating urban wastes.

A fluidized bed type gasifier and an entrained-flow type gasifier are reported suitable gasifiers for bio-fuel synthesis (catalytic synthesis in latter part). As for a fluidized bed type gasifier for methanol synthesis, TAKUMA has developed and constructed a test plant (0.5 t/d scale) in Kyoto.

As for an entrained-flow type gasifier for liquid fuel synthesis, Mitsubish Heavy Industries Ltd. has developed and constructed 2 gasifiers; one is 240kg/d scale and the other is 2t/d scale.

(Implementations are listed later)

Implementation

Some small-sized gasification plants have been developed in Japan, however, only a few biomass gasification systems for liquid fuel production have been developed, due raw materials procurement restrictions.

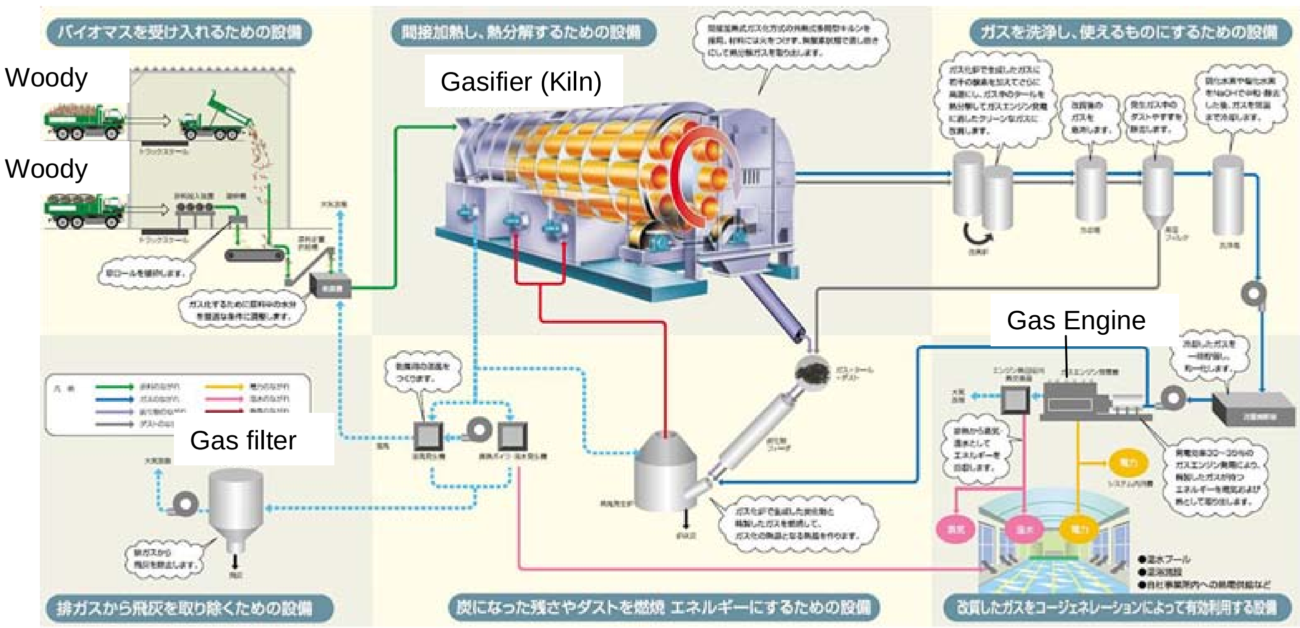
Small-sized gasification power plants with high efficiency gas engines are considered to be suitable for biomass in Japan, which has limited energy resources. In the future, small plants that enable local production for local consumption are expected to expand. In order to realize this, it will be necessary to lower costs for constructing and maintaining facilities.

Cogeneration:

- Chugai Ro Co., Ltd.

Chugai Ro Co., Ltd. is developing biomass gasification generation systems by utilizing an indirect gasification system called external heating type Multi-Retort Rotary Kiln. These systems, installed in Yamaguchi and Kumamoto Prefectures, are used in NEDO’s Verification Tests and Results Survey for Biomass and Other Untapped Energy, and Demonstration Test for Forest Biomass Gasification and Gas Engine Co-Generation System. The biomass gasification method generates gas by heating materials externally and modifies the gas by using oxygen. The gas is then refined and utilized as gas engine fuel. Carbide generated by the gasification and part of the modified gas are supplied to hot-blast ovens and used to heat the gasification furnace. The figure below shows syngas generated by gasification and syngas modified by oxygen.

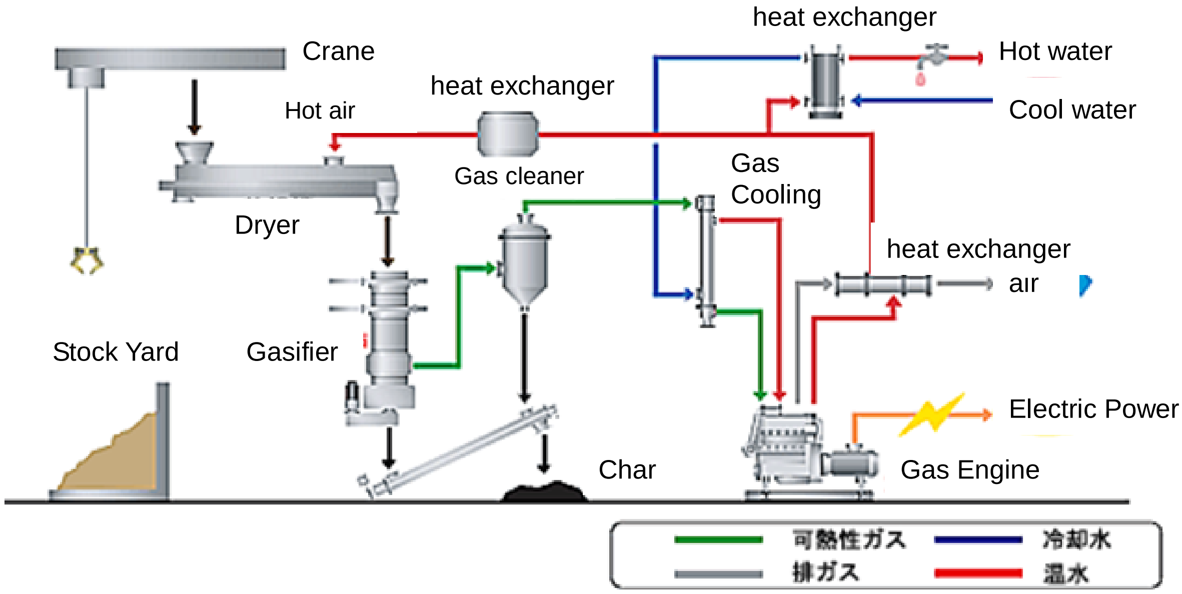
The Chugai Ro, system, compared with fixed-bed gasification systems, features greater versatility such as handling various forms of materials. The system is different from normal oxidation (partial oxidation), and offers a high amount of heat generation from syngas gained from gasification furnace, however, energy is required to produce necessary oxygen for gas modification, which reduces the amount of energy that can be supplied externally.



- Tsukishima Kikai Co., Ltd.

Tsukishima Kikai Co., Ltd. has developed a biomass gasification cogeneration system using a down-draft fixed-bed gasifier. This system has been installed in Kuzumaki, Iwate Prefecture under the NEDO project, Verification Tests and Results Survey for Biomass and Other Untapped Energy, and in Chichibu, Saitama Prefecture using a grant from the Forestry Agency, an affiliated agency of Japan's Ministry of Agriculture, Forestry and Fisheries.

With the concept of "local production for local consumption" in mind, this system with simple configuration has employed daily start-stop (DSS) operations, which shortens the start-stop time. Exhaust heat generated from a gas engine is recovered and used to dry feedstock. However, as a down-draft gasifier is used, powdery biomass, such as sawdust, needs to be solidified before being fed.



➢ Kawasaki Heavy Industries, Ltd.

The NEDO project, Tests for Locally Systemized Biomass Energy, was carried out in Niyodogawa, Kochi Prefecture using a biomass low-temperature pressurized fluidized-bed system, which was developed by Kawasaki Heavy Industries, Ltd. under NEDO's entrustment.

In conventional gasification systems, which are normally equipped with a tar removal system, the removed tar cannot be utilized as energy. In this system, woody biomass is gasified by a fluidized-bed gasifier at relatively low temperature around 650℃. As the fluidized-bed gasifier holds the same pressure as a gas turbine, the produced gas that contains combustible gas and tar is directly supplied to the gas turbine as a fuel to generate electricity. The produced gas can therefore be utilized without the need to remove substances or modify temperature and pressure, thereby achieving more efficient energy recovery.

Moreover, part of the compressed air used in the gas turbine, after going through a heat exchanger, is recycled as a gasifying agent in the gasifier. Despite its small size, this system can generate high-efficiency electricity at high efficiency. According to Kawasaki Heavy Industries, Ltd., a bench scale system (24 kilowatt) as well as the larger capacity system used in NEDO project (150 kilowatt) demonstrated the power generation efficiency of 12-15%, and commercial-size systems (650 kilowatt) can achieve 20%. One of the great features of this system is that it can employ DSS operation.

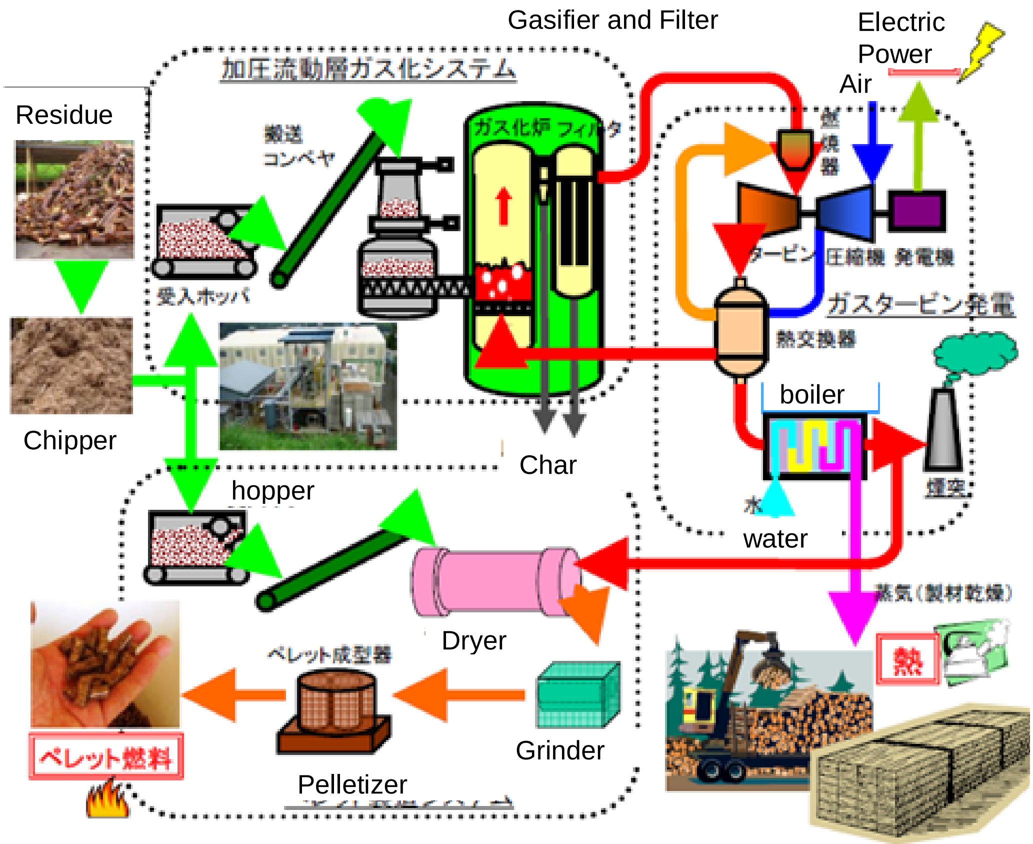


Table　Implementation of Biomass Gasification-Electricity Power

Company/ Organization	Type of　Gasifier	Capacity	Feedstock	Introduction* (plant)
Chugai Ro Co., Ltd.	Rotary kiln	100- a few 100kW-scale	Woody/ Herbaceous	3
Tsukishima Kikai Co., Ltd.	Down draft	100-200kW	Woody	3
JFE Engineering Corporation	Up draft	MW-scale (2MW)	Woody	2
CRIEPI** & Okadora Co.,	Carbonization-gasification	―	Woody/ Wastes	1

Company/ Organization	Type of Gasifier	Capacity	Feedstock	Introduction* (plant)
Ltd				
Kawasaki Heavy Industries, Ltd.	Down draft	100-200kW	Woody	3
	Fluidized bed	150kW (commercial MW-scale)	Woody	1
SATAKE Corporation	Down draft	several 10kW ～100kW	Woody/Herba-ceous/ Agricul-tural residue	37
TORISUMI Co., Ltd	Down draft	300kW	Woody	1
Shinko Plantech Co., Ltd, & OTOMO Co., & Toyo System Co., Ltd	Up draft	55kW	Manure	1
Yagi Kensetsu Co., & Ube Techno Eng. Co., Ltd	Two steps- steam reforming	30kW	Wasted wood chip	1
Tokyo Gas Co., Ltd & TAKUMA Co., Ltd	Circulated fluidized bed	157kW	Sludge	1
Meidensha Corporation	Up draft	36kW	Woody	1
Shimizu Corporation	Suspension/External Heat Type Gasification	30kW	Woody Waste paper	1

*Including only test/demonstration stage plant

**Central Research Institute of Electric Power Industry

Pyrolysis and gasification for liquid fuels:

- Mitsubishi Heavy Industries, Ltd.

The following is an outline of an entrained-flow gasification system including methanol synthesis, which is being studied by a group led by Mitsubishi Heavy Industries, Ltd.

Mitsubishi Heavy Industries Ltd. (MHI) and National Institute of Advanced Industrial Science and Technology (AIST) in Tsukuba have been cooperating for more than 10 years to develop a biomass gasification and liquid fuel synthesis system with a partial combustion entrained-flow gasifier. The gasifier has single reactor, to which biomass, steam and oxygen are fed. Part of the feedstock biomass is combusted to produce heat and to keep temperature necessary for progressing gasification reactions. The MHI first developed a 240 kg/day-scale pilot plant in their Nagasaki Research Laboratory. Based on its results, the MHI developed a 2 t/day-scale test plant as a part of the High-Efficiency Bioenergy Conversion Project sponsored by the New Energy Development Organization (NEDO). It was the first successful and complete system of biomass pretreatment, feeding, gasification, purification and methanol synthesis with a stand-alone entrained-flow gasifier. Its cold gas efficiency was higher than 60% and weight conversion rate from biomass to methanol was higher than 20 wt-% (energy conversion rate was higher than 30%). The MHI also developed a simulator to estimate performances of biomass gasification and methanol/DME synthesis plants. Cold gas efficiency and methanol synthesis yield of a commercial plant of 50-200t/day-scale were respectively estimated to be higher than 75% and 40 wt-% (energy conversion rate was higher than 60%).

The MHI developed char and tar recycle systems and examined their performances with the pilot plant, by using both of which carbon conversion rate was improved about 4%. They also developed gaseous compositions control systems by using a methane reform/synthesis catalyst ($CH_4+H_2O \leftrightarrow CO+3H_2$) and a water shift reaction catalyst ($CO+H_2O \rightarrow CO_2+H_2$). The MHI studied a sulfur purification system of low cost.

As well known, entrained-flow and fluidized bed gasifiers are merely applicable to BTL plants because gaseous compositions should be adjustable and no nitrogen should be included. However, both of them have subjects. Typical scale of the precedentially developed entrained-flow gasifier is 3 000 t/day or larger and it is very difficult to collect such amounts of biomass. Scale of a fluidized bed gasifier is smaller, but it generates relatively large amounts of tar. A tar reformer or a tar remover is necessary to be operated together in order to prevent tar from deactivating the BTL catalyst. Operation of the total system becomes complicated and both initial and running costs become expensive. The MHI designed a promising BTL commercial plant with an entrained-flow gasifier of practical scale of 50-200 t/day with very small tar yield. Its carbon conversion rate was estimated to be 99% or higher, and gaseous compositions of the synthesized gas were highly controllable. This gasification technology to combine FT Synthesis to produce bio diesel had been examined. However, fiscal support to develop such promising plants was terminated in 2010. Now, AIST has studied this type gasification using a laboratory scale entrained-flow gasifier to produce LPG.