Sino-Danish CDM Capacity Building

focusing on Biomass Projects in Local Provinces

Assessment Report on Biomass Technology Application

Energy Research Institute

Danish Technological Institute

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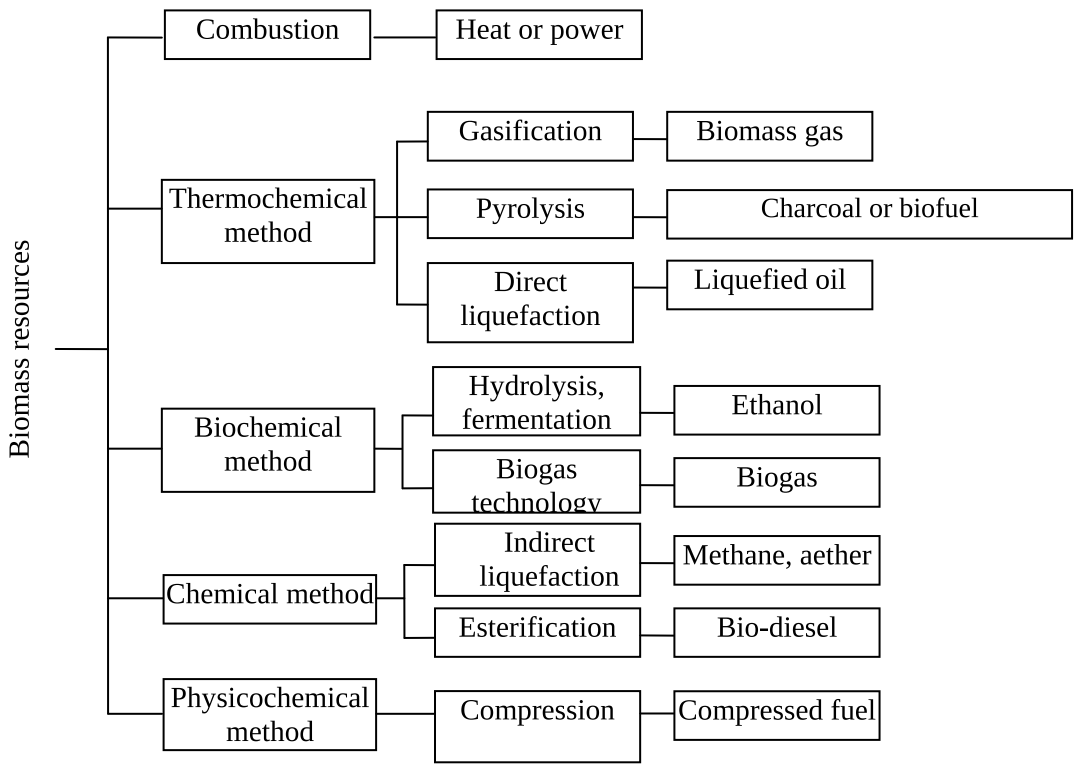
Background

With support of Danish Government, the *Sino-Danish CDM Capacity Building focusing on Biomass Projects in Local Provinces* has been implemented by the National Development and Reform Committee (NDRC) aiming to promote the exploitation and utilization of biomass resources through the Clean Development Mechanism (CDM). The purpose is to enhance the Chinese capacity of exploiting CDM biomass projects through status surveys on biomass resources and technology applications as basis for training activities focused on CDM methodologies. The project was formally started in March, 2007. The aim of the project contains three aspects. In the first place, to develop training on biomass CDM project screening and to improve the capacity of the implicated parties on CDM project development. Secondly, to improve the capacity of the national level units, including units directly involved in CDM project development and technological supporting units, in applying CDM baseline methodology developing biomass CDM projects. Finally, to develop corresponding training for_officers and research institutes of selected provinces improving their capacity of biomass CDM project identification and development.

In order to achieve the above mentioned targets, the staus for biomass technology development has been reviewed and summarized including technologies for: Biomass power and heat generation, Biomass bio-chemical conversion, Biomass liquid fuel production, and Biomass compression technology. The review also includes the supply chain of biomass resources and gas cleaning equipment (dust collector, filter bag, electrostatic filtration), as well as dust treatment.

The biomass energy utilization technologies are classified as follows. Each of them will be introduced in the following chapters.



Part one: Status of Biomass technology in China

1. Biomass power generation and thermal utilization technology

Biomass power generation is a technology that uses the energy of biomass burning or combustible gas burning after biomass conversion to generate electricity. Presently, the main technical routes of agriculture and forest biomass power generation include: biomass direct burning (direct burning), mixed burning with coal, oil or natural gas (mixed burning), and combustible gas burning after biomass conversion and purification (gas burning).

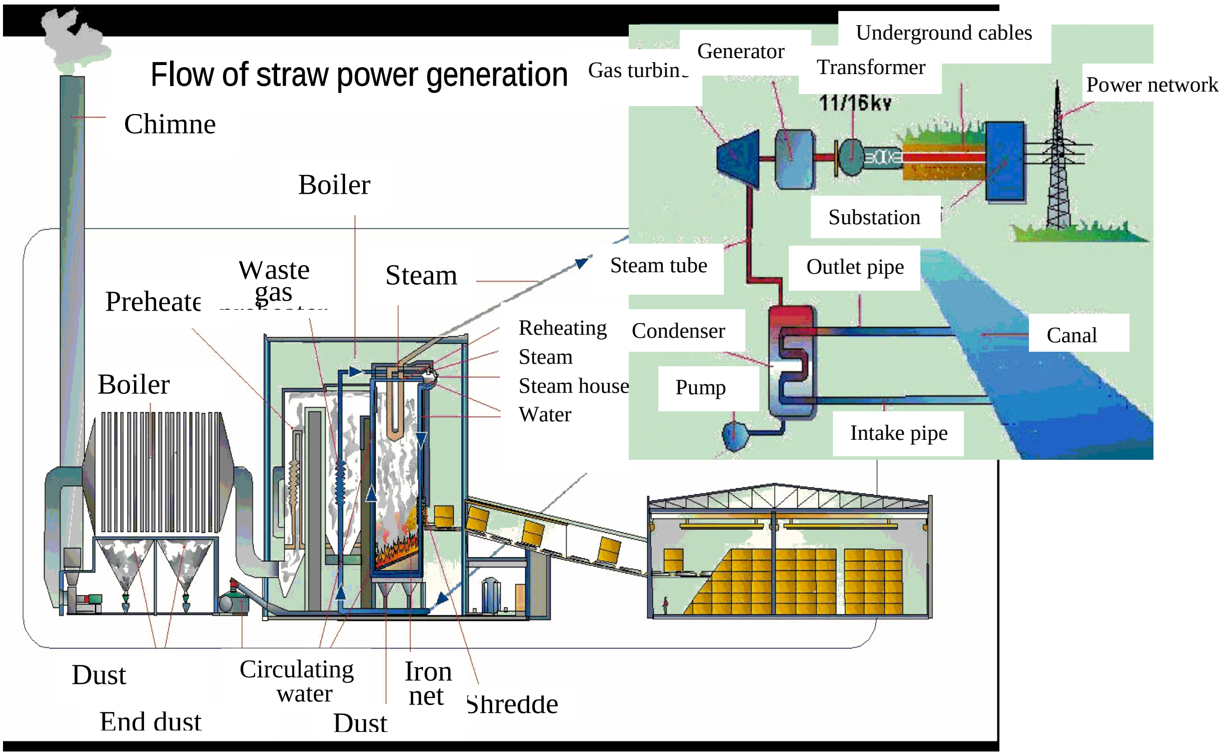
1.1 Biomass direct burning

1.1.1 Direct burning technology

Direct burning means biomass is the only fuel in biomass specialized steam boiler. Steam was produced during burning that drived steam turbine and generator to generate electricity. Main differences between straw direct burning and fossil fuel burning for power generation lie in the raw material pretreatment and the biomass specialized boiler, which are the key technology points ensuring boiler efficiency, life–span and smooth operation.

Biomass pretreatment → Boiler → Steam turbine → Generator → Power output

Technical route of biomass direct burning for power generation



There are all kinds of straw with different forms and components. Component analysis shows that biomass contains more water, more volatile, and less ash than coal. But the heat value of biomass is lower than coal’s because of the different combustion characteristics. It should be mentioned that the content of alkali metal in straw is higher than in coal, which causes lower ash melting point, so that ashes and residues tend to accumulate in boiler. Moreover, the heating surface is easy to be eroded by alkali metals in ash and chlorine in smoke. These harmful elements have a great relationship with biomass varieties, soil, fertilizers and cultivation custom, which result in different contents in different places. Among all kinds of straw, higher alkali metal content has been discovered in yellow straw including rice and wheat and corn straw as well as in rice husk. As a result, greater risk of ashes and residues deposit exists when burning these biomass materials. On the other hand, the alkali metal content in cotton straw and woody chips is much lower than in yellow straw. The risk of ashes and residues deposit is also smaller.

At present, design and manufacture of straw specialized boiler have just initiated in China. Among these, Wuxi Huaguang Boiler Co. Ltd has developed its own straw boiler with completely independent intellectual property rights, and put into production in Hebei Jinzhou straw power plant. Several national enterprises, Jinan Boiler plant for example, was entrusted by foreign companies to produce boiler body and grate of biomass specialized boiler according to the designs. Then the on-site assembly will be finished by these foreign companies. Some research institutes and equipment producing enterprises in China are also actively focusing on straw specialized boiler and pretreatment equipments. Some of them have already developed small scale tests and demonstration projects.

1.1.2 Utilization status of biomass direct burning for power generation

(1) The built national-level demonstration projects

Shandong Shan County National-level Demonstration Project: approved in September, 2004; built on November 8, 2006; put into production on December 1, 2006. It is the first commissioning project for straw direct burning. The boiler came from Jinan Boiler Plant, with 1×130t/h water cooling vibrating grate designed for high temperature and pressure was entrusted by Denmark. A 1×25MW extraction condensing unit was installed. Cotton straw was used as the main fuel, supplemented by wooden chips, peanut shells and so on. The total project investment is 0.337 billion RMB. According to 6000 h of operation annually, the annual output designed would be 156000kWh. The annual consumption of straw would be 150-200 thousand tons, which can increase farmer's income by 3000-4000RMB.

Hebei Jinzhou National-level Demonstration Project: approved in September, 2004; built in March, 2006; put in to production in 2007 for #1 unit. The boiler came from Wuxi Huaguang Co. Ltd whose 2×75t/h cooling vibrating grate was designed for medium temperature and pressure. And a 2×12MW extraction condensing unit was installed. Corn straw and wheat straw were used as the main fuels, supplemented by wooden chips.

(2) Other agriculture and forest biomass power generation projects

China Energy Conservation Investment Corporation (CECIC) Suqian Project: CECIC Suqian project is the first straw direct burning project for power generation with our domestic made equipments. This project was built by Biomass Branch of CECIC in December, 2005 and the total investment was about 28 million RMB. Construction scale was designed as 2×75t/h medium temperature and pressure circulating fluidized bed boiler with 2×12MW generators. It is a completely national technology innovation project. #1 boiler has been put into production since December 20, 2006. Rice straw and wheat straw were used as the main fuels, and the annual output of straw for burning would be 170-200 thousand tons, equal to 98 thousand tons of standard coal. The output would be 132000kWh.

Guoneng Biomass Power Generation Project: a series of biomass power generation plants were established and investigated successively in Jiangsu, Anhui, Henan, Jilin and Heilongjiang provinces. Up to now, 22 projects have been approved, 14 projects are under construction, 5 projects has been put into production. It has been predicted that10 of them will be commissioned for power generation by the end of the year 2007.

(3) Something about biomass cogeneration project

Biomass cogeneration project, which has been widely used abroad, should be encouraged in our future development for energy utilization efficiency of biomass cogeneration project is higher than pure condensing steam unit. For example, there are more than 6 straw dispersed thermal power plants in Denmark. However, power plant should first meet the operating security requirements in power system because steady and continuous output parameters are necessary for industries and civil heatings. Once heating was somehow cut off by power plant, it would cause big negative social effects. The present biomass direct burning projects in China are still in the demonstration stage, and problems of safe biomass supply for fuel has not been solved already. So risk exists in developing cogeneration projects. Moreover, the heat price of civil heating from cogeneration project has an opposite match with the cost， and the investment is also increased by spare units that are needed for cogeneration project so as to affect the economy of the project. As a result, there is no genuine biomass direct burning cogeneration project in China. Further demonstration and practice are needed to decide whether biomass direct burning cogeneration project should be developed or not.

1.1.3 Technology and economy brief assessment of biomass direct burning

(1) Technology assessment of biomass direct burning

Difficulties in biomass direct burning technology:

- Straw matching pretreatment equipment

On the physical properties, straw is quite different from coal in terms of larger packing volume and lower density. The pretreatments of straw, such as collecting, storing, transporting, cutting and crushing, make it much more difficult to use than coal.

- Problems of straw boiler fouling, slagging and corrosion

Straw specialized boiler is the main difference between straw direct burning and conventional coal burning. The key technology has been proved to be material applicability and steady operation of the boiler.

The industrial analysis shows that biomass contains more water, more volatile, and less ash than coal. But the heat value of biomass is lower than coal because of their differences in combustion characteristics.

The content of alkali metal (Potassium and Sodium) in straw is higher than in coal, which causes lower ash melting point so that ashes and residues tend to accumulate in boiler. Moreover, the heating surface is easily to be eroded by alkali metals in ash and chlorine in smoke, so as to affect the safe and highly efficient operation of the boiler.

Along with the construction and operation of demonstration project, it has been proved that straw boiler designed with foreign technology starts to adapt most of the biomass materials in China. The projects on straw boiler with independent intellectual property rights and its matching pretreatment equipment have also been put in to practice, which shows the possibility of expanding straw direct burning for heat supply and power generation in China. However, it should be recognized that there are still some technical problems in operation, such as corrosion and coking, which might be difficult to be observed in such a short time. After a long time operation of the demonstration projects, these problems would be discovered and tested.

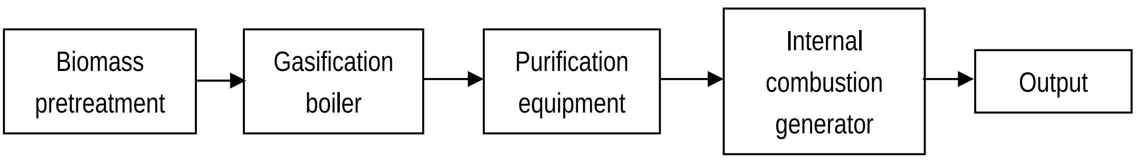
(2) Economy assessment of biomass direct burning for power generation

The cost of power generation from biomass direct burning is higher than that from conventional fossil fuel like coal because of the imports or independent developed technologies and equipments. And the price of biomass fuel is also higher than fossil fuel. Furthermore, the biomass direct burning projects are still in the demonstration stage in China. The investment and operation may be increased by some mistakes in plant designing, constructing and managing during gradually exploring. Therefore, power generation projects from biomass direct burning are not ready for commercial operation and need policy subsidy. The Chinese government has issued the trial rule of price and charged allocation management for power generation from renewable energy resources (Trail Rule). According to the Trail Rule, biomass power generation projects could get 0.25 RMB /kWh allowance for netting electrovalence.

1.2 Biomass Gasification Power Generation Technologies

1.2.1 Techniques of biomass gasification for power generation

Gasification power generation means gasifying the biomass material into combustible gas, burning after purification, driving internal combustion engine or gas turbine of generator to generate power. Biomass, as the material for biomass gasification, is transformed into combustion gas by thermal reaction at a high temperature in the media of air and steam. The main combustible component is comprised of CO and H_2, which are called biomass gas. The key point of gasification power generation is to develop gas purification technology and its matching equipments at a low cost, because there are some impurities in the biomass gas, such as tar, ash and trace alkali metal. Tar has been proved to be the main influence factor during the downstream operation.



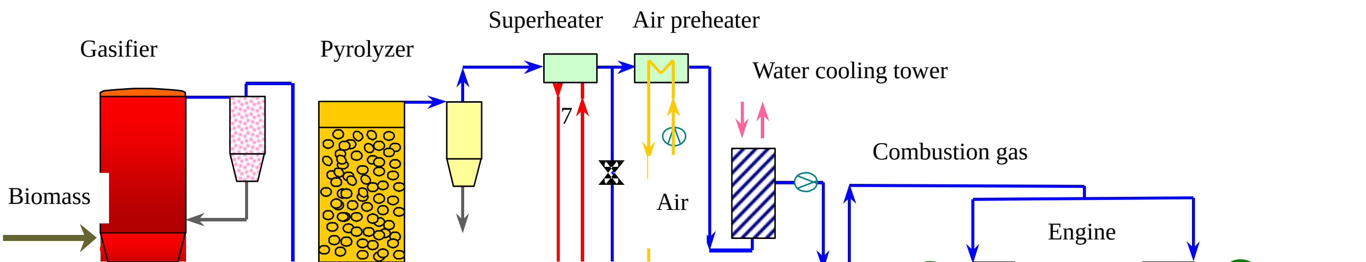
Technical route of biomass gasification power generation

1.2.2 Utilization status of biomass gasification for power generation

Research on gasification technology by Guangzhou Energy Research Institute (Guangzhou ERI), Chinese Academy of Science (CAS). The present gasification power generation technology applied to this project is mainly designed by Guangzhou ERI, CAS, which is called biomass circulating fluidized bed gasification technology. In this technology, the combustion gas, gasified from biomass, is purified through water and used for power generation. The purification processes in a water spray system to remove tar and ash from gas, but secondary pollution problem caused by tar has not been settled already. One technology is to crack the tar in the wastewater into sludge with some special bacteria so that the purified water can be recycled. However, this technology still needs project inspection and further promotion. Other technologies, such as catalytic cracking reaction of tar in high-temperature, are also being studied at the same time.

Recently, 20 biomass gasification power generation systems were built by Heilongjiang Land Reclamation Bureau using agro-solid waste, such as chaff and straw, as materials. The total investment was more than 40 million RMB and the annual output could be 75 GWh. In fact, there were already some projects formerly. During the Ninth Five Years' Plan, the first 1 MW chaff gasification power generation system was built in Putian, Fujian Province; the first sawdust gasification power generation plant was built by Hainan Sanya Wood Factory in Hainan Province; the first straw gasification power generation demonstration project was built in Handan, Hebei Province.

A 4MW chaff power generation plant built in Xinghua, Jiangsu Province. It is a demonstration project with the support of '863' fund from the Ministry of Science and Technology. This system contains a circulating fluidized bed gasification boiler and two internal combustion engines (1×400 kW and 1×600kW respectively), supplemented by a heat recovery boiler and a steam turbine for power generation. This project has been put into practice in October, 2005. Up to now the operating time has added up to 1500 h, which contains 1 month for the longest continuous operation. Chaff and cotton straw are used as the main fuel. The silicon in chaff residues is worth to be recovered because of the high concentration. The gas is purified in a water spray system to remove the tar and the ash. Wastewater can be recycled after bio-chemical treatment. 32, 000 tons dry biomass are used in this power plant and the output could be 28 GWh.



Jiangsu Xinghua Biomass gasification power generation plant

1.2.3 Technology and economy brief assessment of biomass gasification power generation

(1) Technology assessment of biomass gasification for power generation

Internal combustion generator is used in the gasification power generation system. The maximum economy scale is 10 MW which is restricted by the cost and the equipment scale. The agriculture production in China is based on the family unit, so the annual biomass supply from each family is limited. Gasification power generation technology is appropriate because the cost of big scale collection is too high. The investment of gasification power generation project is also smaller than that of direct burning project. The advantages of the gasification project are: small investment, easy operation and adaptable materials, which make it suitable to Chinese Situation

Second pollution problem still exists in the present technology of gasification power generation, however, this is only a matter of the circulating fluidized bed. The combustion gas gasified in circulating fluidized bed gasification boiler contains too much oxygen, so it is impossible to use the electrostatic tar precipitator in the purification system. As a result, the tar in gas far exceeds the standard. Water spray system could help remove tar from gas but cause big problems of tar wastewater treatment. These problems would disappear if fixed bed gasification equipment could be used. A biomass gasification power generation project in fixed beds has started in Gaoyou, Jiangsu Province, and will be built up by the end of 2007.

(2) Economy assessment of biomass gasification for power generation

Biomass gasification power generation project has a strong competitive ability for its much smaller investment compared with the direct burning project. However, the material cost is still much higher than the fossil fuel like coal. Therefore, it is necessary to take the tax preference policy to promote the development of biomass gasification power generation industry.

1.3 Coal-biomass mixed burning

1.3.1 Technics of coal-biomass mixed burning

The mixed burning of coal and biomass generally proceeds in the coal-fired boiler. Biomass is crushed first and transported to the feed opening of boiler, and fed into the boiler with a special burner. Then the mixed burning starts. According to the foreign tests, high chlorine and high alkaline biomass would not harm the boiler by corrosion and dust deposition when the weight percentage of biomass was below 20%.

1.3.2 Utilization status of coal-biomass mixed burning technology

Mixed burning is still at the demonstration stage for there is no preferential policy for biomass mixed burning in China. Zaozhuang Shiliquan Power Plant in Shandong province tested mixed burning in its #5 boiler (a 400 t steam boiler with a 140 MW generator). Biomass mixed percentage was determined by 20% and the annual mixed capacity could be 250, 000 tons of biomass. In 2006, the actual mixed amount of biomass was 55, 000 tons.

There are 21 small-scale thermal power plants built by Hongkong Xiexin Group Corporation in Jiangsu, Shandong, Anhui provinces, 7 of which are mixed with biomass. The materials include straw, chaff, wood chips, bulrush, sewage sludge and so on.

Top: Straw bin
Right upper: Straw transport system
Right lower: Feed tubes (straw in the middle, others are coal）。

Shandong Shiliquan coal-straw mixed burning power generation plant

1.3.3 Technology and economy brief assessment of coal-biomass mixed burning

Coal-biomass mixed burning for power generation is the most economical technology for biomass because of its simple operation, small investment and strong anti-risk ability. It has been used as the main biomass utilization technology in developed countries. However, the enterprises in China are still standing by and waiting for the preferential policy.

1.4 Municipal solid waste incineration for power generation

1.4.1 Technics of municipal solid waste incineration for power generation

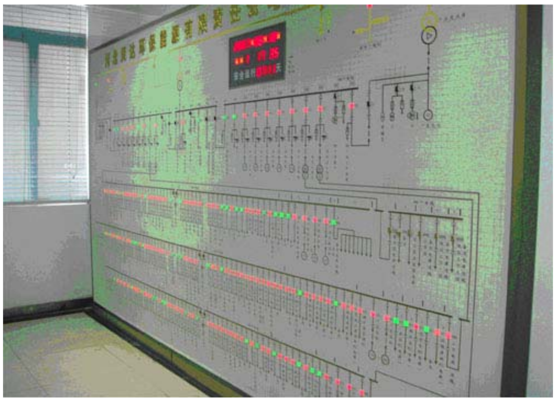
Municipal solid waste incineration for power generation is a technology of high-temperature thermochemical treatment. Municipal waste used as solid fuel is transported to furnace for burning. The combustible components in the waste react intensely when meeting the oxygen from the air at the temperature of 800-1000 ºC, and turn into high-temperature combustion gas as well as a few solid residues. Heat is released at the same time. When heat value reaches a certain temperature, the solid waste could self-ignition without any auxiliary fuel supply. The high-temperature combustion gas produces high temperature and pressure steam by heat exchanger in the boiler. The steam further drives the turbine and the generator to generate power. The residues could be land filled directly. After the incineration, bacteria and virus could be killed; odors could be pyrolyzed; smoke could meet the emission standards after treatment. In a word, incineration is an efficient technology to achieve the 3R standard (reduce, reuse and recycle).

1.4.2 Utilization status of municipal solid waste incineration for power generation

For quite a long time, the municipal solid waste has been treated in landfill or sanitary landfill in China. In recent years, the land for waste became limited for the population because the city scale was growing rapidly. A lot of municipal departments turned their eyes to incineration before landfill which was far more efficient on waste reduction. Shenzhen first introduced in 2 Martin incinerators with treatment capacity of 150t/d for single machine from Mitsubishi Heavy industries of Japan in 1988. A lot of small scale incineration boilers have been built successively all over the country since then. We have stepped the first step towards incineration treatment.

There were 66 waste incineration power generation plants in China by the end of 2005. There is no data for the recent two years, but according to the allocation work team of ERI, NDRC, 20 grid-connected power systems have been added in 2006. It develops very fast.

In the past, the advanced incineration power generation technologies all came from developed countries. For example, the technology of a 1200 t/d waste incineration power generation plant in Shanghai was introduced from France. However, Chinese technology is getting gradually mature on the circulating fluidized bed boiler. The circulating fluidized bed boilers in Wuxi Huaguang boiler Co. Ltd has already started to export



Top: Waste bin and grab
Right upper: Main workshop
Right lower: Display panel in the main control room

Hebei Shijiazhuang Waste Incineration Power Plant

1.4.3 Technology and economy brief assessment of municipal solid waste incineration for power generation

There are two main types of waste power generation boilers including Martin boiler and circulating fluidized bed boiler. Martin boiler doesn’t need fossil fuel except for ignition, so it is very convenient but expensive. The investment may be 0.25-0.3 million RMB/ (t·d). As a result, the depreciation and finance expenses are high, and the operation investment may be 150-200 RMB/t. This technology is feasible in developed areas and big cities.

The investment of circulating fluidized bed boiler is smaller than Martin boiler. The average operation cost may be 0.15-0.20 million RMB/ (t · d). However, no steady bed layer could be formed in circulating fluidized bed, so coal is necessary to help burning. The adding percentage is between 15% and 30% according to waste heat values. The maximum annual treatment capacity of circulating fluidized bed boiler is 500 t/d at present. This technology is feasible for waste treatment in medium and small cities.

2. Biomass bio-chemical conversion technology

2.1 Large and medium scale biogas projects in livestock and poultry farms

2.1.1 Technics of large and medium scale biogas projects in livestock and poultry farms

The large and medium scale biogas projects refer to the systematic projects with material pretreatment system and comprehensive utilization system. The volume of a biogas pool should be above 50 m^3 or the total volume should be above 100m^3; no matter which kind, the biogas yield should be higher than 50 m^3. There are two types of large and medium scale biogas producing technologies: energy ecotype and energy environmental protection type (EP type).

Large-scale biogas project in Zhejiang Lujiayuan Piggery

(1) The process of energy ecotype

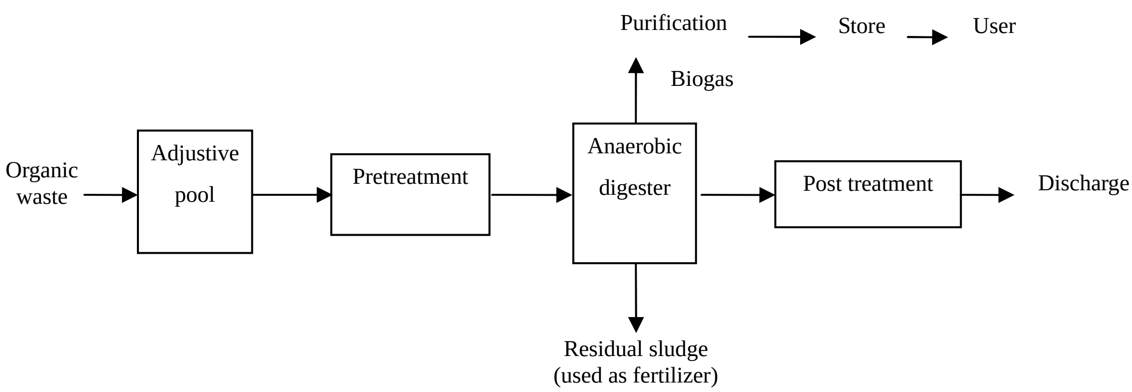
The energy ecotype means using farmland, fishpond or plant pond nearby the biogas project to decrease the residues and liquid after biogas fermentation. The biogas project becomes a link of a eco-agricultural district in this technology. This project is reasonable for the allocation of livestock and poultry industries and plant industries. There is no need to spend a lot of money on the liquid treatment, and the eco-agriculture can be improved at the same time.

(2) The process of energy EP type

If there is not enough land around biogas project, the residues must be produced into commercial fertilizer and the liquid must be discharged up to standard after a trail of treatments, such as aerobic fermentation. This kind of technology is regarded as energy EP type.

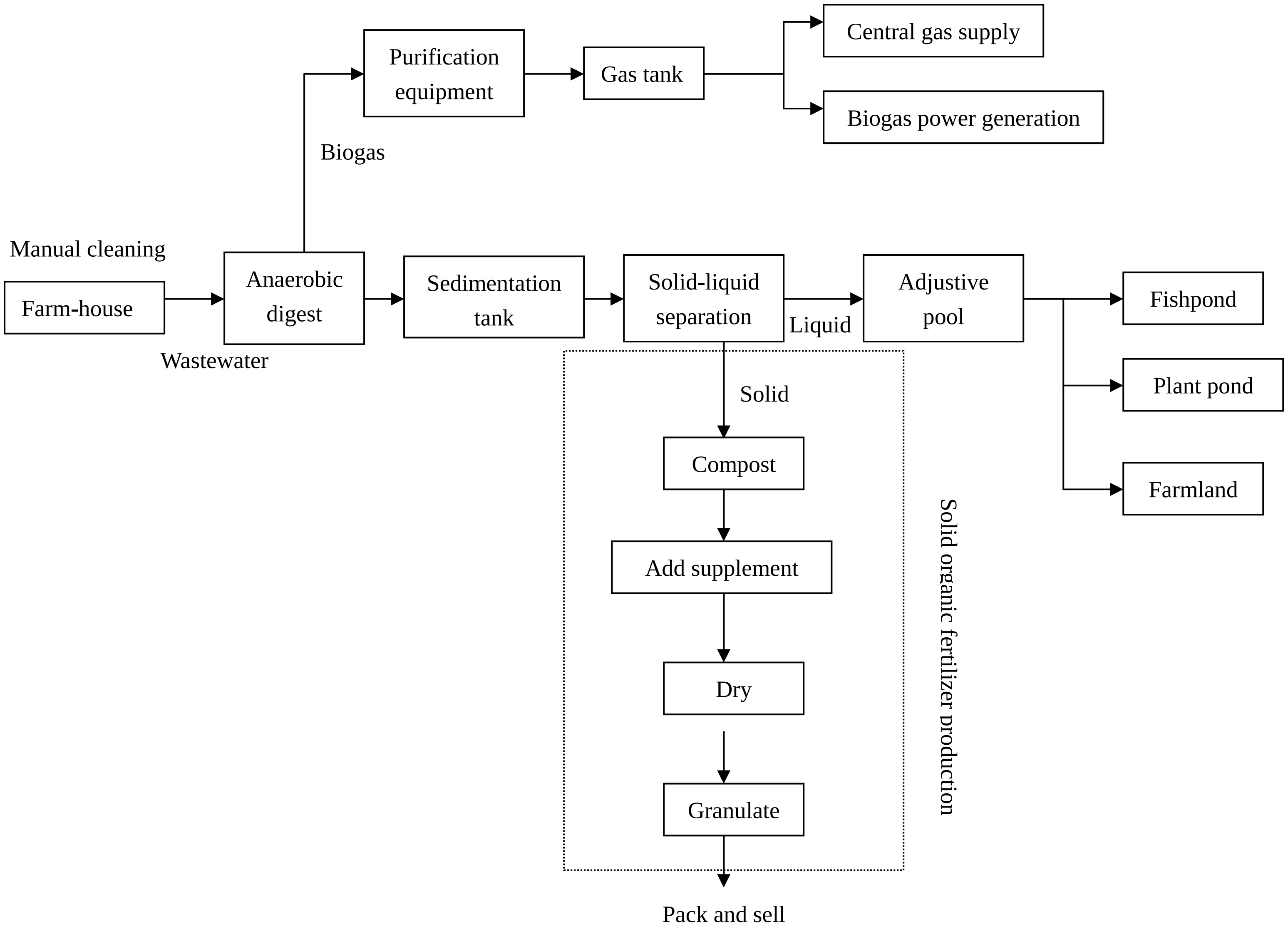
The energy EP type is devoted to reduce wastewater and dry matter in wastewater, for the main aim of energy EP type is to achieve the discharge standard. In some livestock industries such as cattle farm or piggery, people who use energy EP type clean manure with little water. They collect solid manure and use water to sweep the residues. The manure water is discharged into the adjustive pool for solid and liquid separation. The sediment from this pool will be digested aerobically together with solid manure to produce organic fertilizer, while the supernatant is transferred into biogas pool for biogas fermentation. This technology may help decrease the treatment cost of wastewater, but the biogas amount reduces, too.

A complete biogas project, whether big or not, is made up of a long operation chain, which contains material collection, pretreatment, anaerobic digestion, post treatment and biogas purification, store, transport, utilization. The manure residues and wastewater from farm-house flow across the grille, through water collection tank and arrive at the sedimentation tank with the help of a submersible sewage pump. The fresh manure are transported in to sedimentation tank, too. The mixture is pumped into digester after pretreatment, measurement and temperature elevation. The digested liquid flows through gas tank into the water collection tank as the greenhouse fertilizer. The biogas produced from digester goes through water seal tank to gas tank. One portion of the biogas is mixed burning with coal to produce steam for temperature elevation; the other portion can be transport through pipes for kitchen work or power generation. If the biogas project is in North China, the outdoor equipments and pipes should be carefully protected from cold.

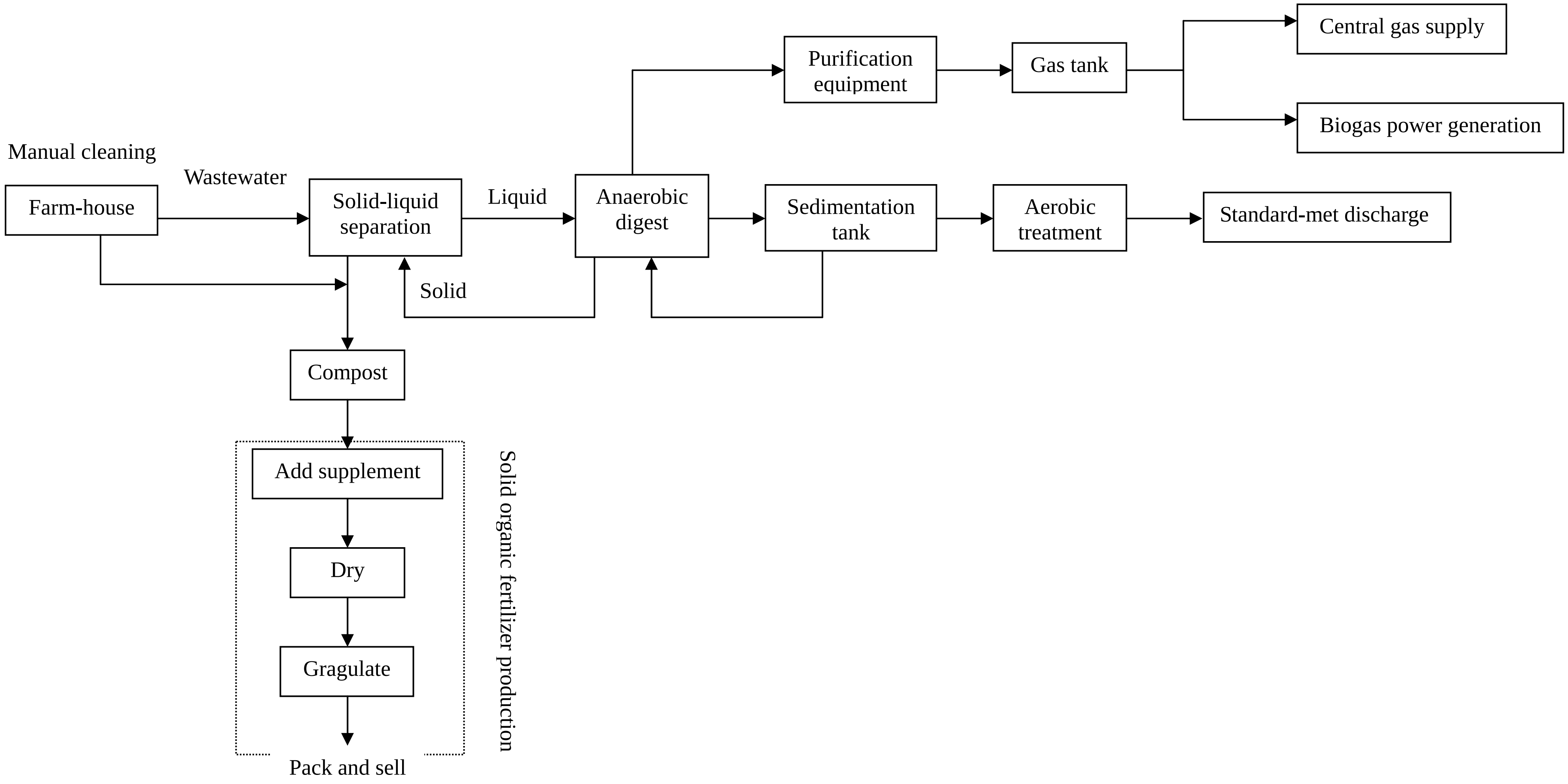


Basic process of biogas fermentation

The process of energy ecotype



The process of energy EP type



2.1.2 Utilization status of large and medium scale biogas projects in livestock and poultry farms

According to the statistics of Agriculture Ministry, there were 3,764 large and medium scale biogas projects in China by the end of 2005. The total tank volume was 1,724,100 m^3; total waste treated was 123 million tons; the annual biogas yield was 341 million m^3 and the total output added up to about 40 million kWh for more than 1.38 million users. 3,556 biogas projects of them were based on agricultural waste with a total tank volume of 1 million m^3. The total waste treated by these projects was 87.1 million tons; the annual biogas yield was 230 million m^3 for 1.32 million users.

2.1.3 Technology and economy brief assessment of large and medium scale biogas projects in livestock and poultry farms

At present, the technology of large and medium scale biogas projects in livestock and poultry farms is getting mature gradually. Many sorts of technology in possession of independent intellectual property rights are formed, and the matching equipments have reached or approached the international advanced level. However, there are still some problems compared with the foreign large and medium scale biogas projects, for example, biogas producing efficiency during fermentation is low universally and energy utilizes inefficiently; the operations lack whole integrative processing management so the problems could not be detected in time; the system intensive degree is inadequate with gas tank and fermentor separated so too much ground is occupied; the system lacks transportability and it is not able to remove holistically; the system lacks efficient management and maintenance so the service life is short relatively; and if the hydrogenation and heat preservation cannot be settled availably; the biogas projects in North China can not operate normally in winter. However, these problems do not affect further generalization of large and medium scale biogas projects in China.

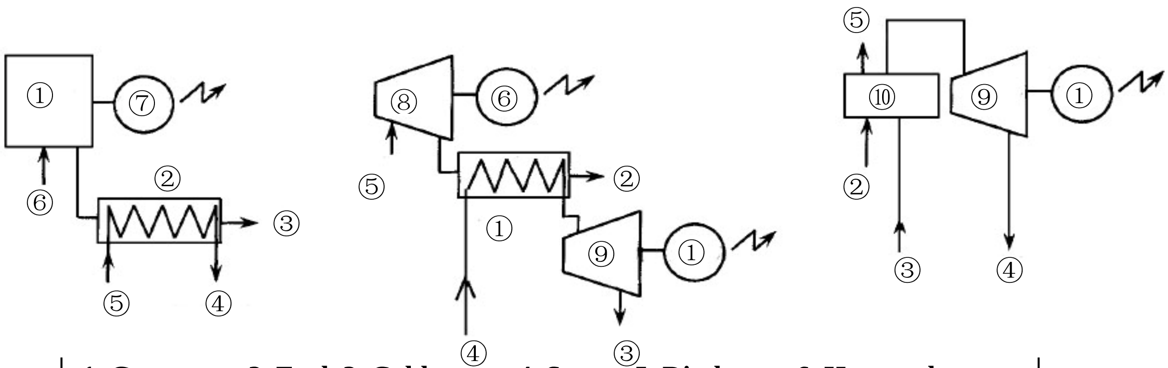
Large and medium biogas projects contain wastewater treatment facilities for high concentrated organic manure water, so plenty of biogas could be produced in low energy consumption without second pollution. Practice shows that biogas project which can produce energy and organic fertilizer simultaneously at a low operation cost is an important means to control livestock and poultry manure pollution. Large and medium biogas projects not only offer efficient measures to promote the local economy, improve our ecological environment and control pollution, but also bring economy benefits by all kinds of productions such as biogas, solid or liquid organic fertilizer.

2.2 Large-scale livestock and poultry manure for biogas power generation

Biogas is a high heat value combustion gas (CH_4 accounting 50-60% in biogas), has a heat value of is 21.52MJ/m^3. It can be used as fuel for engines to get a high quality power.

2.2.1 Technics of large-scale livestock and poultry manure for biogas power generation

All kinds of engines, such as internal combustion engine, gas turbine and steam turbine boiler, can be used as generator engine Biogas power generation. The structures of biogas power generation are shown as follows.



1. Generator. 2. Fuel. 3. Cold water. 4. Steam. 5. Discharge. 6. Heat exchanger. 7. Engine. 8. Gas turbine. 9. Steam turbine. 10. Boiler

Structures of different type power generator equipments

2.2.2 Utilization status of large-scale livestock and poultry manure for biogas power generation

The research on biomass power generation started in 1980s. Some institutes did some experiments on modification of biogas engine and the promotion of thermal efficiency successively. On one hand, some successful technologies have been introduced in China successfully. For example, Lanzhou Huazhuang Cow Reproduction Center introduced the Tdom biogas cogeneration equipments from Czechoslovakia and achieved Grid-connected power. On the other hand, the technologies of the domestic biogas generators are getting mature after tackling key technology problems. The performance index of some gas generators produced by Weichai and Shengdong companies have reached the international advanced level.

In 2005, the installed capacity of biogas projects from livestock and poultry was about 6,699 kW and the output was almost 8.73 GW.

2.2.3 Technology and economy brief assessment of large-scale livestock and poultry manure for biogas power generation

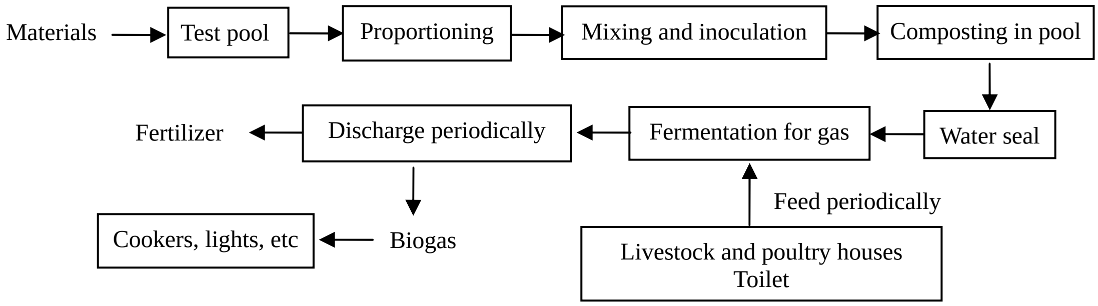
Generally speaking, large-scale livestock and poultry plants and municipal refuse landfill are the pillar industry and necessary public welfare, however the heavy pollution industry. Anaerobic digestion technology has been universally agreed to be the most effective for high concentrated organic wastewater control. Nevertheless, these projects usually locate far away from residents, biogas cannot serve them as fuel by central gas supply (the cost of pipes laying and pressure equipments is too high). The economy benefit of biogas is low if biogas is used as the boiler fuel instead of coal (the heat value of 1 m^3 biogas equals to 1 kg coal). Moreover, wastewater treatment plants and large-scale livestock and poultry plants are also dissipative power industries. The power supply to the enterprises in China, especially in the economy developed areas, is often restricted by the national power department in recent years because of the shortage of power supply (the power supply may be cut off for 1-2 days every week during the peak period). They have to purchase in high price for the power out of plan. Accordingly, many enterprises are aware that biogas power generation not only improves the value of biogas but also alleviate the pressure of power supply. Simultaneously, the residual heat could be reused for temperature compensate in biogas fermentation (especially in biogas projects of livestock and poultry) to promote the biogas producing efficiency and ensure safe and stable operation of the biogas projects.

2.3 Household biogas

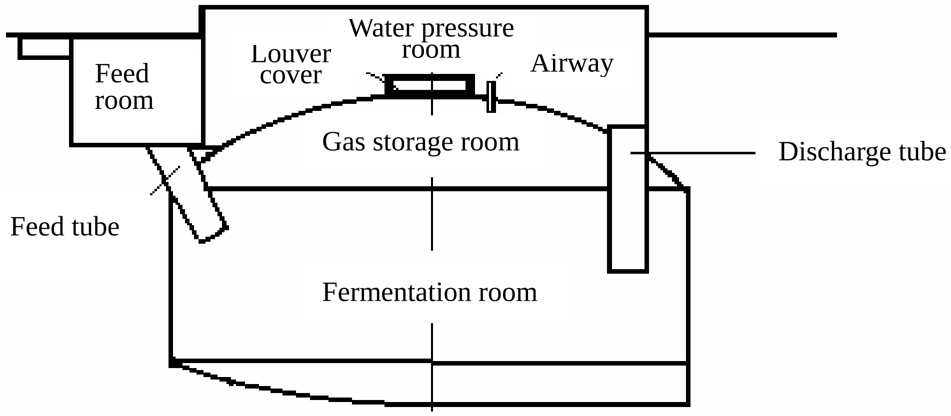
Household biogas system is used for rural energy utilization. Human and animal manures and the agricultural waste are put into the gas generating installation. Biogas will be generated under anaerobic conditions and then transported to each house as living fuel. The liquid and residues in gas generating installation can be used as organic fertilizer partly instead of chemical fertilizer

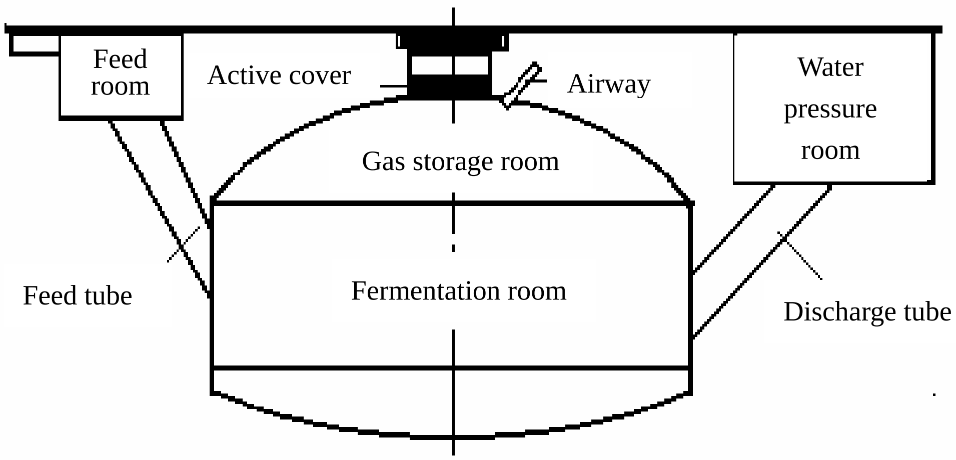
2.3.1 Technics of household biogas

Semicontinuous fermentation technology is usually adopted in rural household biogas systems in China, whose process is shown below. Water pressure biogas pool is the earliest equipment introduced to rural household for manual biogas generating. It is the most popular mode that has been generalized, and 85% of the biogas pools in China are designed in this mode. It is improved based on the “3 binding principles” of round-small-shallow, active cover, straight tube feed, which originates from people’s experience. According to the different location of water pressure equipment, water pressure biogas pool can be classified into side water pressure mode and top water pressure mode; according to the different locations of discharge, water pressure biogas pool can also be classified into middle discharge mode and bottom discharge mode (bottom discharge mode is usually used in North China); and classified according to the shape, there are cylindrical and ellipsoidal pools.



The process of rural household biogas pool





Side and top water pressure biogas pools

2.3.2 Utilization status of household biogas

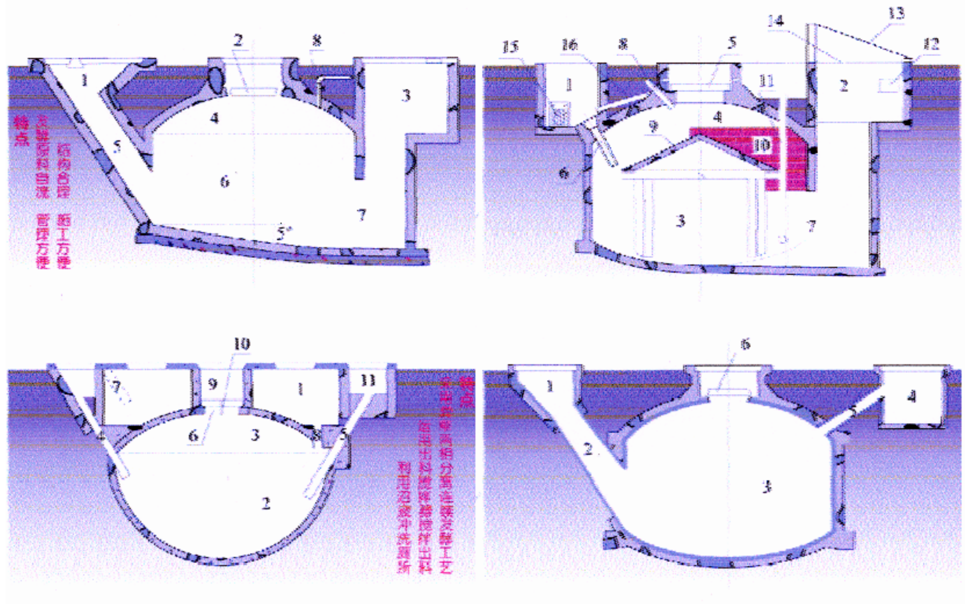
3.4 billion RMB was invested as special fund sustaining biogas construction during the Tenth

Five Years. 3.74 million rural households have been benefiting directly from it. By the end of 2005, there had been 18.07 million household biogas pools. Total annual output of biogas had been nearly 7 billion m^3, which equals to 5 million tce or 15.4 million ton coal.

2.3.3 Technology and economy brief assessment of household biogas

Biogas is a clean gas whose main components are methane and carbon dioxide. The low calorific value of 1 m^3 biogas equals to 0.714 kg tce. The output of the biogas pool has a great relationship with fermentation temperature. Generally, the annual output can be 500 m^3 in South China, while only 300 m^3 in North China. The average annual output of the whole country is 385 m^3, which equals to 275 kg tce. With biogas fertilizer substitute for chemical fertilizer, the net economy benefit could reach 152.54 Yuan.

Typical household biogas pools



Standard household biogas pools recommended by Ministry of Agriculture

2.4 Landfill gas

Landfill gas utilization is a technology using landfill gas (the main component is methane) produced from organic degradation as fuel. It is a clean, recycling technology for waste treatment.

2.4.1 Technics of landfill gas utilization

The landfill gas power generation system is generally made up of gas collection system, gas purification system, gas pressurized conveying system and gas utilization system (internal combustion engine for power generation or gas boiler for heat).

To gather the gas efficiently, the collection mode must be improved from passive emission system to active collection system. Thereby, rational layout is needed on the waste heap, such as vertical drilling well or horizontal laying collection net-pipes. The gas is transported through the net-pipes to the disposal and applied equipment for use. Meanwhile, the landfill sites should take measures to prevent leakage, cover (or close over) and drain for gathering farthest. Accordingly it can take promotion effects in normative management to a certain extent.

2.4.2 Utilization status of landfill gas

These years, the landfill sites in China attach importance to the collection and management gradually. Some adopt active landfill gas concentrated recovery and combustion system and some construct landfill gas power generation plants to recover and utilize it synthetically as clean energy. For example, Hangzhou Tianziling landfill, Wuxi Taohuashan landfill, Nanjing Shuige landfill and Guangzhou Datianshan landfill collect the landfill gas for power generation and enter the power grid for sale. Anshan Yangeryu landfill uses the landfill gas as traffic fuel after purification.

2.4.3 Technology and economy brief assessment- of landfill gas

(1) Technology assessment

Landfill gas power generation is a simple and easy technology, which can not only serve the landfill to reduce operation cost but also connect the grid for power supply. Both safe operation and economic benefits can be achieved. It needs less foundation investment and fewer equipments, furthermore, is easy to manage. However, the landfill takes up too much ground, and it is difficult and expensive to deal with the leachate. The problems are: the addresses are difficult to choose and farther and farther away from the city, these problems effect the rapid generalization of landfill gas for power generation.

Some technical problems need to be solved in the utilization of landfill gas:

- The process of landfill gas generation is complicated, and a lot of difficulties still exist in the reckoning of gas produce, gas cycle and gas rate, and the gas management.

- It is short of the experiences in manufacture, installation and transportation of landfill gas collection and utilization equipments.

(2) Economic assessment

According to financial analysis and national economy assessment, landfill gas power generation projects have strong externalities. The indirect benefit accounts for much of the total benefit. It is uneconomical from the financial analysis results. However, it will be well economical if the direct and indirect benefits from the national economy assessment are taken into account.

3. Biomass liquid fuel technology

Biomass liquid fuel is generally refers to fuel ethanol and bio-diesel which can be used for car driving. At present, the main raw material of fuel ethanol are amylum and saccharide, In the near future the whole world are quicken the speed to develop the technology of making ethanol from cellulose; the main material of bio-diesel is grease from various kinds of animal and plant.

3.1 Making fuel-ethanol from amylum material

3.1.1 The amylum material

The amylum material mainly consists of grist crop (such as corn and wheat etc) and earthnut-tuber amylum material (such as cassava and sweet potato).

The amylum content of corn and wheat is about 60%-70% and it is the main amylum material for producing fuel ethanol in the world (especially in America, China and Europe Union area), approximately 3.2 tons of corn for 1 ton of fuel ethanol. At present, there are four fixed enterprises in China using stale corn to produce fuel ethanol, the overall output is 1.02 million tons per year, For the sake of food security, the related government branches have already decided not to enlarge the scale.

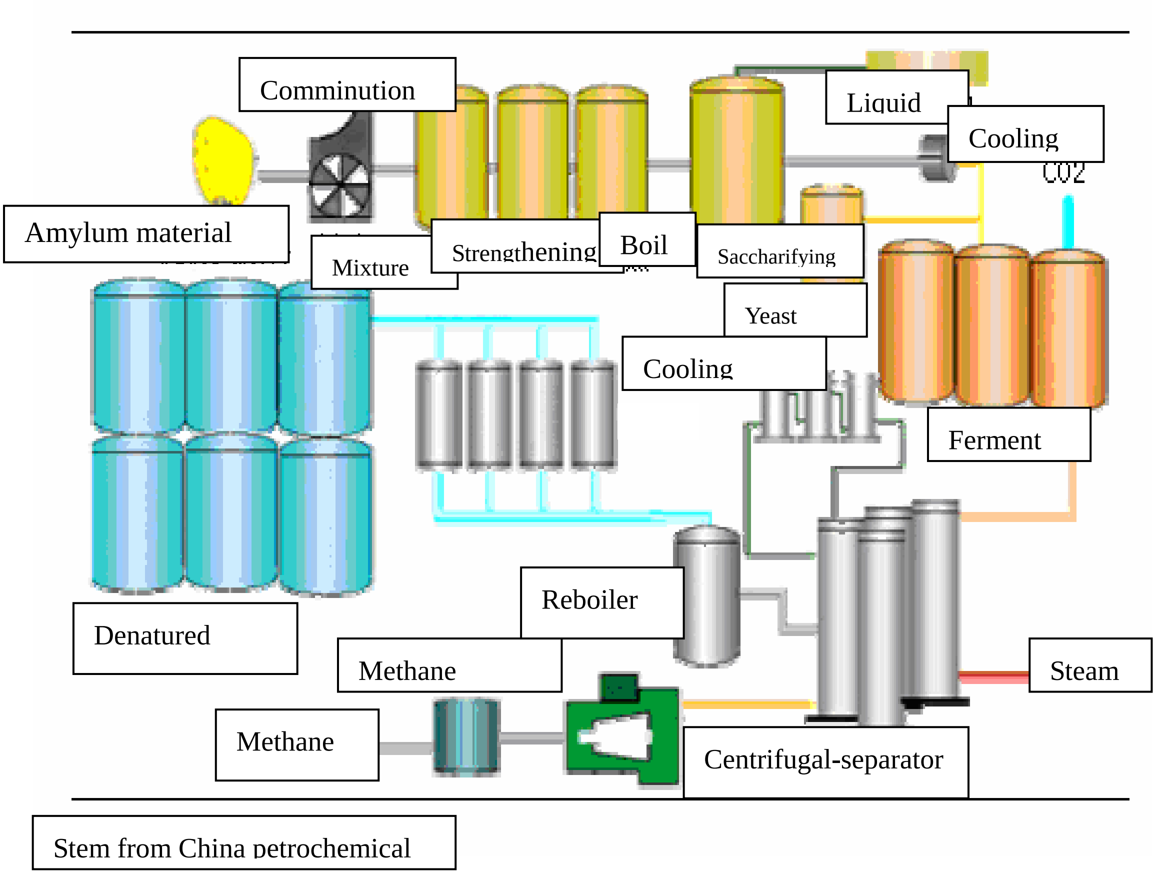
The amylum content of cassava can reach 25%-30% (dry cassava can reach 80%), cassava has a strong adaptability to soil and drought as well as barren conditions etc. The main producing areas in China are located in the north tropic, such as: Guangxi, Guangdong, Yunnan, Hainan and Taiwan etc. The planting area is approximately 420 thousand ha with an output of 4 million tons of earthnut per year. Cassava is mainly used for animal feed and ethanol producing. At present, one ha of cassava can produce 3 tons of ethanol averagely.

The amylum content of sweet potato is about 18%-20%, sweet potato is widely planted in the majority regions of China, and the planting area in 2005 is about 5 million hectares. The total output is approximately 1.07 million tons and the main planting areas are Sichuan, Henan, Shandong and Anhui provinces etc. At present, sweet potato is mainly used as fodder and material for producing amylum, but the general utilization level is relatively low, excess waste phenomena exist in some big producing provinces such as Sichuan etc. At present, 1 hectare of sweet potato can produce 2.5 tons of ethanol averagely.

In addition, some research institutions and enterprises are still grope for using basho, Jerusalem artichoke etc to produce fuel ethanol.

3.1.2 Technics of making fuel ethanol from amylum material

Making ethanol from amylum material is a traditional technics and it's very mature in technics. In the field of industry, the technics process of it generally comprises the following processes: material pretreatment, saccharifying, ferment, distillation and purification (refers to the chart below). In the pretreatment period, the material was crushed, braised, so as to intenerate and gelatinize amylum as well as to provide necessary catalyse conditions (such as sufficient contact surface area and moisture) for saccharifying enzyme; In the process of saccharifying, saccharifying enzyme hydrolyzes big molecule of amylum to hydatidiform mole monosaccharides; In the ferment process, glucose is transformed to ethanol by yeast; In the distillation and purification process, ethanol is extracted from fermentation broth and refine fuel ethanol by using distillation and other extracted methods.



The production process of amylum material fuel ethanol

3.1.3 Utilization status of technology of making fuel ethanol from amylum material

The technology of making ethanol from amylum material has a perennial and wide application in the industry of edible and industrial ethanol all over the world.

Before 2001, ethanol industry (the edible and industrial ethanol industries) in China was scattered and the scale was small, there were more than 200 professional ethanol producing enterprises, about 700 liquor-making enterprises had set up ethanol producing workshop, Among them, there was only one enterprise with the output over 200 thousand tons, 9 enterprises with output of 50-100 thousand tons, about more than 100 enterprises with output of myriad tons, others were small enterprises with output of kiloton. The main material contains various kinds of amylum material.

Since 2001, China has started to execute the experimental unit item of using ethanol gasoline for car-driving, four fuel ethanol enterprises have been set up in China focused on digesting stale grain, they were Jilin Fuel Alcohol limited company. Henan Tianguan Group Co, Ltd. BBCA Group, and Hei Longjiang Huarun alcohol Ltd. Except Henan Tianguan Group Co. Ltd use wheat as material, the other three enterprises all use corn as main production raw material, with the total output of 1.02 million tons, these four fuel ethanol experimental unit enterprises invested heavily in producing equipment and they all reached the international level. Besides, there are many other regions and enterprises are planning to use corn, cassava and sweet potato etc as raw material for ethanol producing.

But, in general, most domestic ethanol-producing technics and technology are all relatively laggard, especially in the aspects of technics equipment, automation, comprehensive utilization, waste residue water treatment and enterprise management etc that are far lagged behind from developed countries, these result in many problems such as general excess production cost of fuel ethanol, excessive investment in energy, low utilization rate of material and poor economic benefit etc.

3.1.4 Technology and economy brief assessment of making ethanol from amylum material

Using amylum material to produce ethanol which used as edible and industrial material has already realized its commercialization, but the fuel ethanol which uses corn as material is still lacks economic competitiveness compared with gasoline and other oil products, the main reason is the high cost of raw material. The material cost of making fuel ethanol from amylum material accounts for 60%-80% of the total, therefore, through developing high quality and high yield cassava and sweet potato etc, the production cost can be reduced and the economic competition can be enforced.

In order to push the utilization of ethanol fuel made from amylum, in the near future, our nation will need to provide the producing enterprises with preferential and supportive policies. At preset, the four domestic fixed fuel ethanol enterprises that are depend on government’s allowance keep making profits, the total allowance per year exceeds 20 million. In order to stimulate ethanol-producing enterprises to reduce cost as well as to alleviate national financial burden, the allowance given by state to ethanol producing enterprises was descending year by year during 2005 to 2008. At the same time, we actively develop high-yield and low cost production raw material such as cassava and sorgo, we also develop and utilize the advanced production technics to reduce energy consuming and to improve the utilization ratio and utilization efficiency of material.

3.2 Making fuel ethanol from glucide material

3.2.1 Glucide material

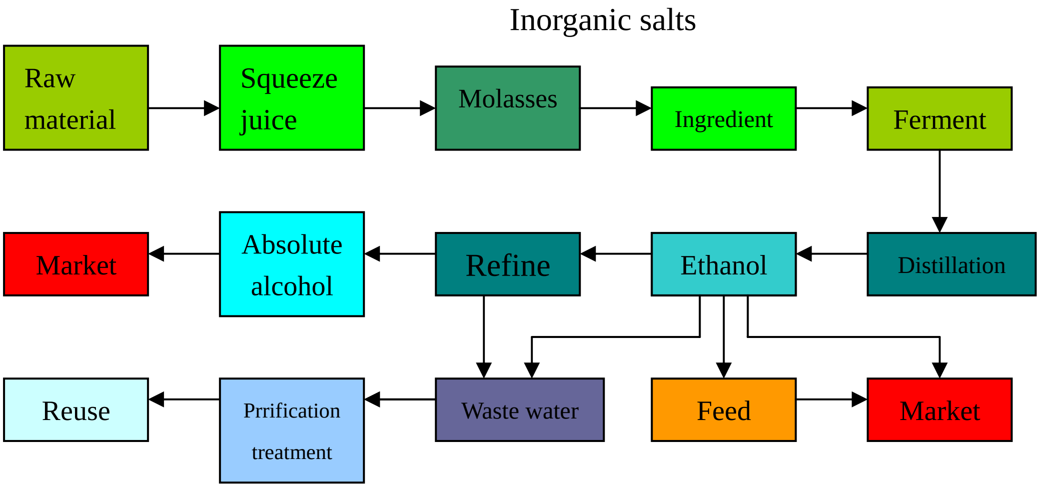
Glucide material that can be used to produce fuel ethanol is mainly consist of sugar cane and sweet grain sorghum

Sugar cane is the glucide crop that is suitable to be planted in tropic and semitropical areas and it's mainly used for producing glucide, In the recent decades, sugar cane was began to be used in Brazil etc for large-scale fuel ethanol production. Sometimes molasses (produced from saccharose-producing course) was used for fuel ethanol producing. In the recent years, the planting area of sugar cane (stem of sugar cane) in China is approximately 1.20 million hectares with an annual output reaches nearly 90 million tons. These sugar canes were basically used for producing saccharose. At present, the output of sugar cane stem is about 75 tons per hectare glebe that can produce 8 tons of fuel ethanol. China has already cultivated 3 kinds of energy source sugar cane breed and the output of sugar cane stem reached 121-130 tons per hectare, that's to say in the future each hectare of sugar cane can produce 11-14 tons of fuel ethanol.

Sorgo is one of the varieties of common grain sorghum, and its stem contains a great deal of sugar juice that can be used for fuel ethanol producing. Sorgo is able to bear drought, waterlogging and salt, it has a strong adaptability to soil. At present, sorgo is planted in Beijing, Tianjin, northeast part of China and Inner Mongolia etc, it's mainly used as dairy cow's feed and the material for sugar and wine producing. In the recent years, domestic institutions and enterprises begin to research on making ethanol from sorgo's stem and have made remarkable progresses in fine breeds cultivating and process technology. The series of "pure sweet sorgo" cultivated in China can get the same good harvest when planted in the soil which contains 3-5‰ salt compared with good soil, and each hectare of sorgos can produce 4-6 tons of fuel ethanol or so.

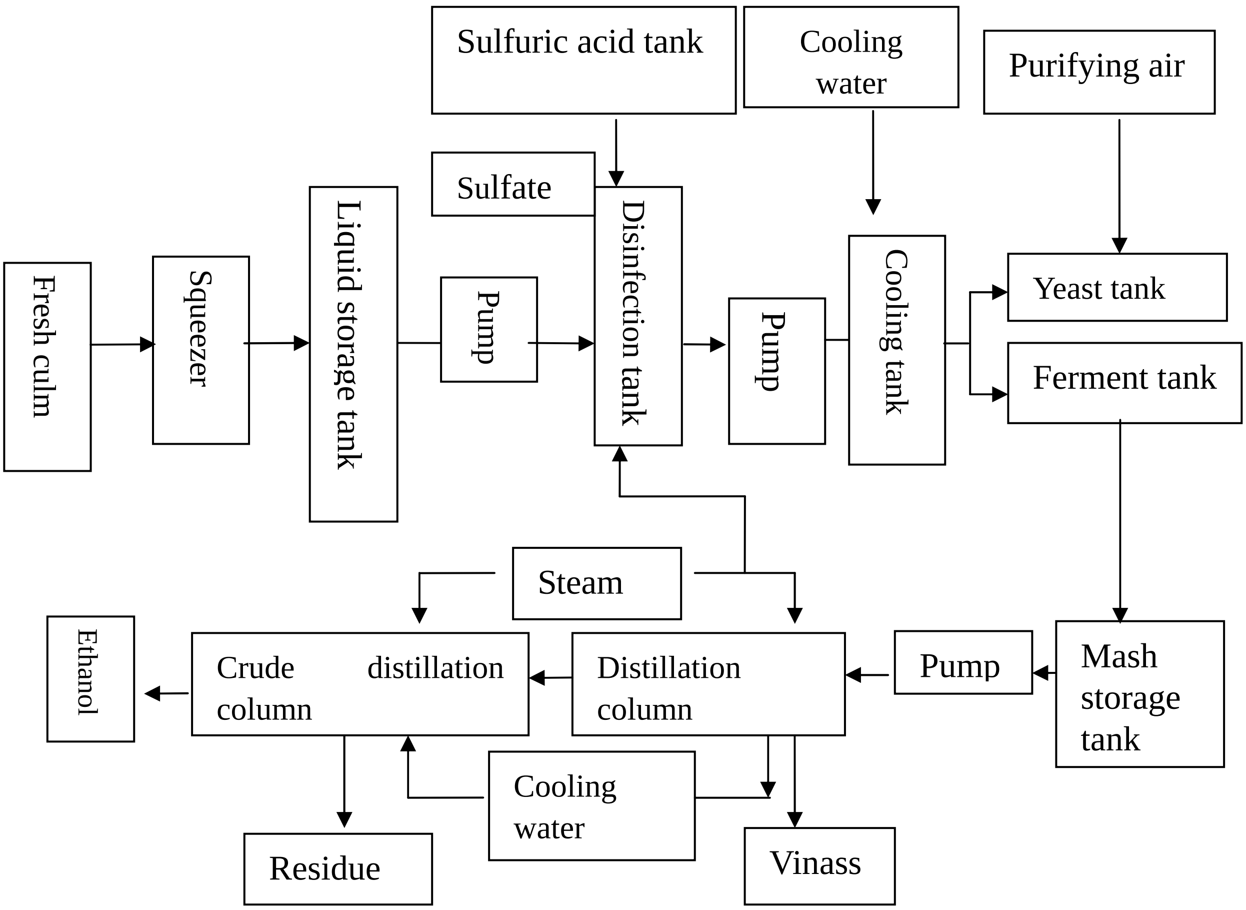
3.2.2 Technics of making fuel ethanol from glucide material

The powered sugar that glucide material contains is mainly saccharose, it can be hydrolyzed to grape sugar and fruit sugar by microzyme, saccharose can produce ethanol by fermenting grape sugar and fruit sugar in the oxygen-free conditions. Therefore, the technics courses of making ethanol from glucide material and amylum material are basically the same except the pretreatment methods before ferment are different and the subsequent processes are basically the same.



General process flow of making fuel ethanol from glucide material

At present, the whole world has developed the technological procedures of making ethanol from sorgos' stem, the main processes consist of Mechanical press, Acidification antisepsis, Cooling, Ferment and Distillation etc, refers to the chart below.



The flow chart of making ethanol from sorgo

Compared with amylum material, the ferment of glucide material lacks of saccharifying procedures and the subsequent processes are basically the same, so the key technology lies in solving problem of high energy consumption of distillation and rectification. But, there are some differences in the aspect of specific process details. In fact, the ferment efficiency of amylum material is 5-7% higher than glucide material, In normal conditions, the ferment efficiency of amylum material can reach 90% while the ferment efficiency of glucide material can only reach 85% or so.

3.2.3 Utilization status of technology of making fuel ethanol from glucide material

At present, the technology of making fuel ethanol from sugar cane and molasses is very mature and it has got a long commercialized application in Brazil etc. In China, except the technology of making fuel ethanol from sugar cane, we mainly focus on the technological procedures of making fuel ethanol from sorgo's stem. In the early stage of 1980th, people began to use sorgo's stalk to produce liquor in Henan, Liaoning and Inner Mongolia etc. In the middle stage of 1980th, Shenyang Agricultural University worked on how to use the juice of sorgo's stalk to produce ethanol and did some experiments using ethanol as fuel of gas engine and got valuable experience. In 1996, The Ministry of Science and Technology of the People's Republic of China supported to establish " The commercialized demonstration engineering of development and comprehensive utilization of high energy crop sorgos " in Hohhot, Inner Mongolia and has set up a production line based on making ethanol from sorgos' stalk, this has passed the check in December 1996 and created favorable conditions for popularizing the technology of making fuel ethanol from sorgos and its comprehensive utilization. Till 2001, the sorgo breeding has entered the substantive popularization stage while production technology of fuel ethanol entered the demonstration engineering construction stage with an output of 5000 tons per year.

"precocious number 1" sorgo production base

Brut distillation workshop of making fuel ethanol

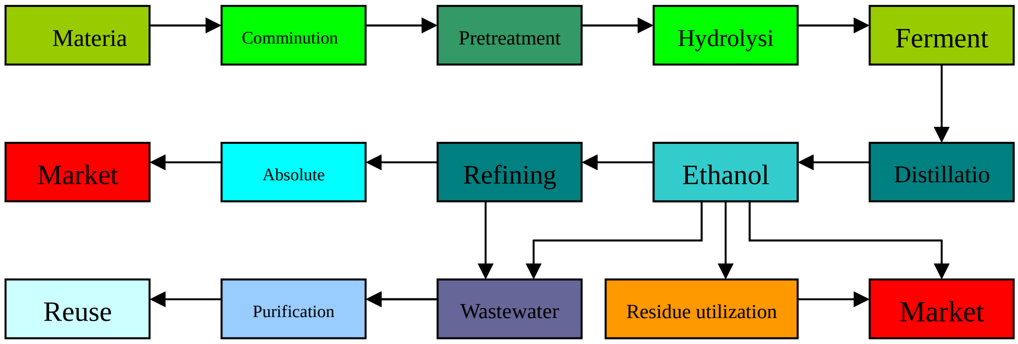
3.2.4 Technology and economy brief assessment of making fuel ethanol from glucide material

In those countries, Brazil for example, which possess superior natural condition and high productivity of sugar cane, sugar cane fuel ethanol has already completely realized its commercial production application and has possessed the ability to compete with gasoline material. Nowadays, although there is no ethanol production enterprise in China puts sugar cane material ethanol in to production, related reckoning shows that its production cost is lower than corn fuel ethanol. But due to the deficiency of saccharose supply and long term import needs, the key development direction of glucide fuel ethanol need to turn to sorgo fuel ethanol. According to reckoning, the production cost of sorgo fuel ethanol is about 4000 RMB per ton. Under the support of certain fiscal levy preferential policies, it is possible to realize its commercial application in the near future.

3.3 Making liquid fuel from cellulose material

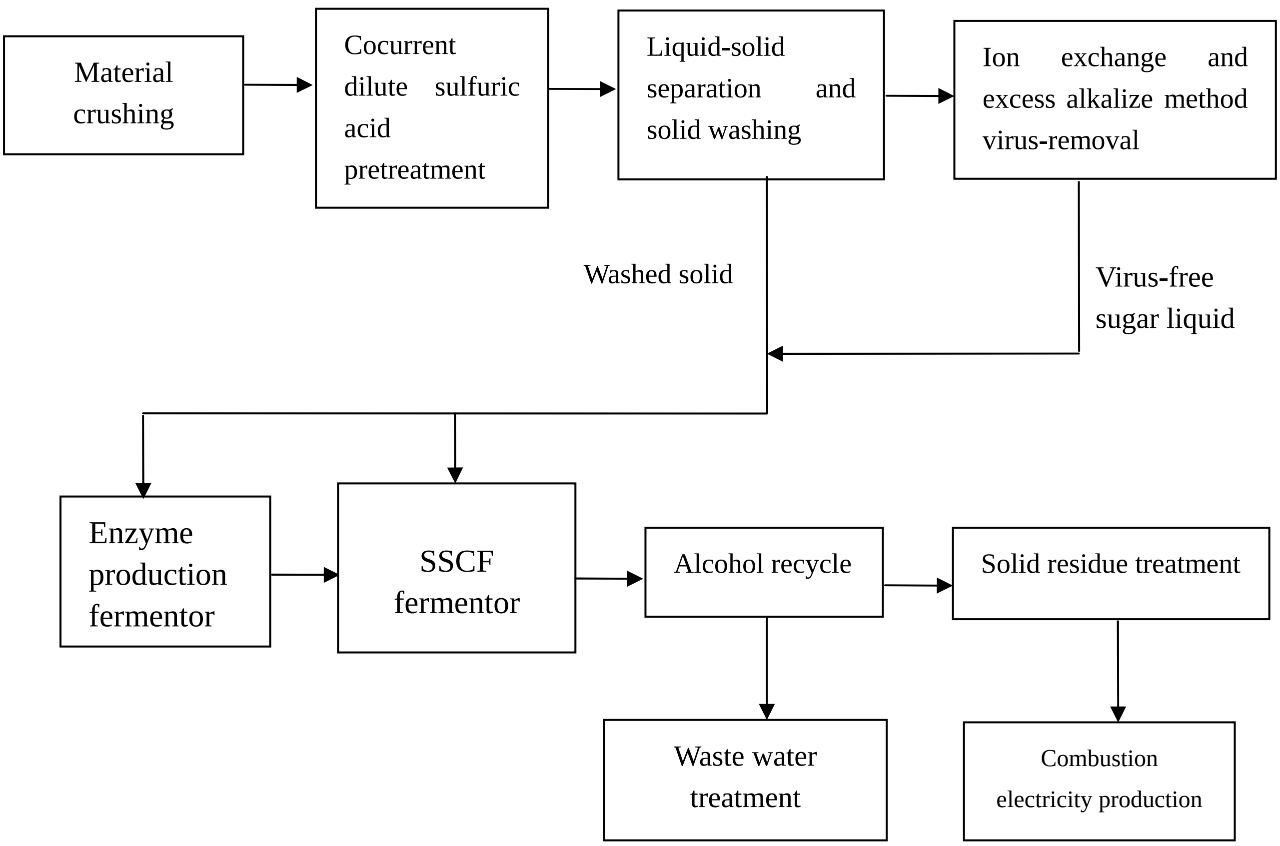
3.3.1 Technics of making liquid fuel from cellulose

The general process flow of making fuel ethanol from cellulose material refers to the chart below, it mainly consist of Pretreatment, Hydrolyze and Ferment etc. The difference of the processes of making ethanol from various kinds of cellulose material just lies in the processes of pretreatment and hydrolyze before ferment, the working procedures are basically the same after ferment. Pretreatment comprises physical comminuted method, chemical method and biological method etc. so as to minish the granularity of biomass material and increase the contact surface to enzyme, demolish the crystal structure of cellulose, this is good for high efficient hydrolysis. Hydrolysis process uses acid hydrolysis method or enzyme hydrolysis method to hydrolyze cellulose material (from pretreatment) to monosaccharides material such as yeast or bacteria that can be used for ethanol producing. All in all, the technics of diluent acid hydrolysis is very easy, the material treatment time is short, but the yield of sugar is very low and it can generate byproduct that is bad to ferment. Enzyme hydrolysis is a bio-chemical reaction that microorganism cellulose enzyme degrades cellulose, its merits are: the reaction is carried out under normal temperature, low energy consumption during the course, the output of sugar is very high (more than 95%), low pollution, but the needed time is long (generally several days), the production cost of enzyme is high, while the pretreatment cost of material for hydrolysis is very high.



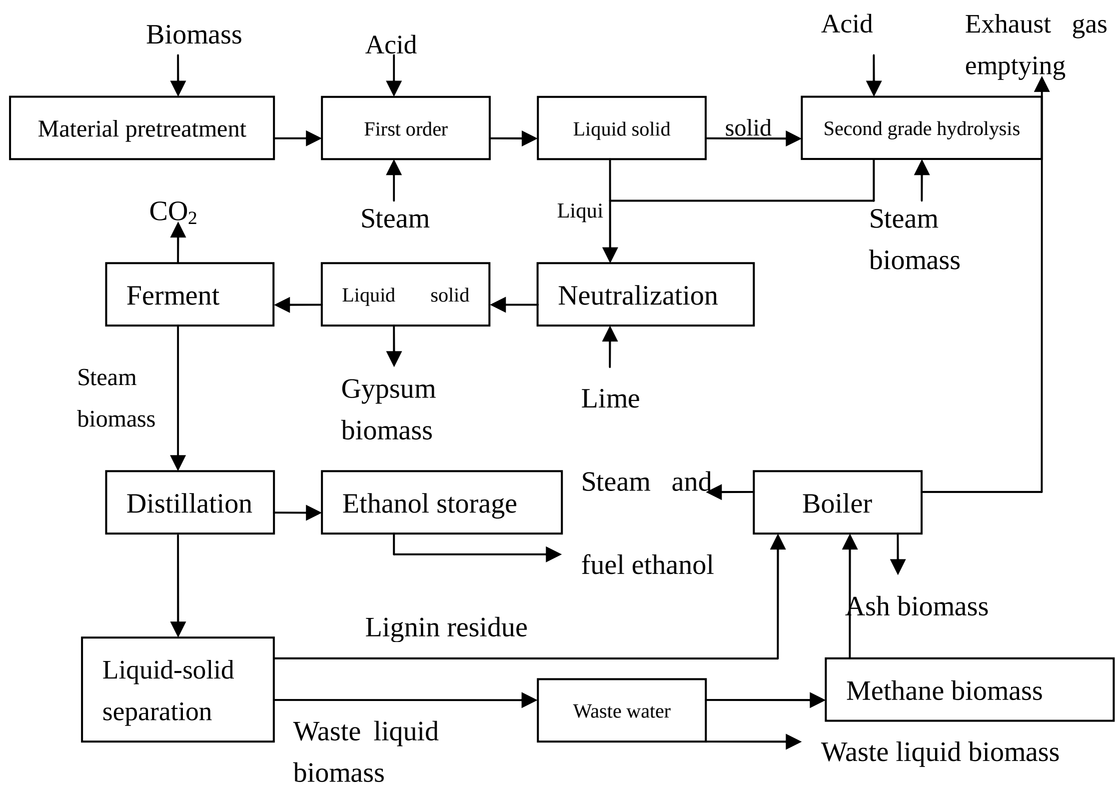
The general technological process of making fuel ethanol from cellulose material

In order to reduce the production cost of ethanol, the technics of saccharifying and ferment (SSCF) has been developed at the same time in 1970th, this has predigested the production equipment, also reduced the dosage of enzyme, it has became a promising technique that use biomass to make ethanol, the main problem is the matching between hydrolyze condition and ferment condition.



The flow chart of SSCF enzyme hydrolyzing ethanol

Another two promising technological processes of diluent acid hydrolysis refers to the chart be



The technological process flow chart of second grade dilute acid hydrolysis

3.3.2 Research and development status and prospect of the technology of using the cellulose material to make liquid fuel

At present, cellulose-ethanol production technology is in the Research and Development demonstration stage internationally and has not realized its commercial application. China began its research from 1950th through introducing technologies and autonomous exploitation, and it has expanded its research focused on making ethanol from woody scrap and cottonseed shell in Heilongjiang Nancha Timber factory. Suzhou grease chemistry factory and Beijing Guanghua Timber factory and has acquired several achievements. Since 1990th, with the implementation of national high tech "863" plan and the start-up of engineering of national ethanol gasoline substitute fuel, it has greatly stimulated the Research and Development of plant fiber of cellulose fuel ethanol. Up to now, the national 863 key task "Technology of making ethanol from cellulose waste" assumed by East China University of Science and Technology, Making fuel ethanol through an organic combining of bio-chemical method as well as heat transformation method and the test scale has already reached 600 tons; China National Petroleum Corporation has carried out an industrialized demonstration project research demonstration focusing on using corn stalk as raw material to make fuel ethanol in Jilin Fuel Corporation with an annual output of 3000 tons ethanol; Henan Tianguan Group Co. Ltd cooperates with Shandong University and Henan Agriculture

University and acquires a small breakthrough in the aspect of cellulose material pretreatment and the technology development of ethanol transformation, the work ready to be done is the industrial transformation of cellulose enzyme; BBCA Group works together with domestic related junior college academies and acquires a preliminary achievements in raw material pretreatment and the cultivation of cellulose enzyme; Besides that, there are many institutions and units (such as Nanjing University of Technology and Tsinghua University etc) are actively carried out this research and acquired several achievements. But, On the whole, this technology is not mature, there are still many key technical problems ready to be solved; Compared with foreign countries, the gap is small and prospect is very good.

3.4 Making biodiesel from oil plants

3.4.1 The introduction of oil plants

- **Cole**

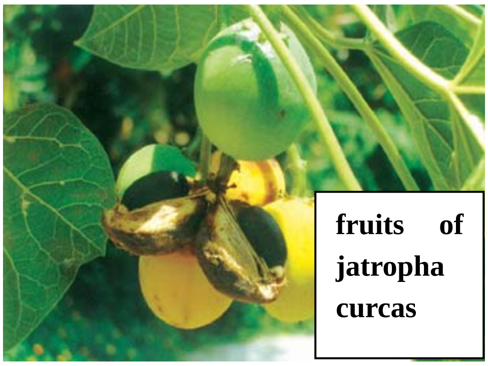
The main producing areas of cole in China are centrally located in the regions along Yangtze River valley such as Sichuan, Hubei, Hunan, Jiangxi, Anhui, Jiangsu, Zhejiang as well as Yunnan and Guizhou which are located in the southwest of China, Among them the planting area and output of cole in Hubei province are all ranking in the first place of China. At present, the planting area of cole in China is about 1.2 million mous, the output of rapeseed keeps approximately 12 million tons annually, more than 90% of them are used for making edible oil, with an annual output of rapeseed about 4.5 million tons, ranking in the first place of the world. There are some experts propose to use the glebe of central china and south china as well as southwest china to develop cole planting for energy use in winter seasons. At present, the average output of rapeseed in China is 100 kilograms per mou, with an oil extracting rate of 35%; with the improvement of breeding level and planting technology, it is hopeful to get an output of 150 kilograms per mou with an oil extracting rate of 40%.

- **Ricinus**

The main producing areas of ricinus in China are mainly located in the regions of the east of Inner Mongolia, the north of north china and northeast, among them, the region of Tongliao in Inner Mongolia, Baicheng in Jilin province and Shandong, Shanxi etc are the main producing areas of ricinus. The average output of ricinus is about 150 kilograms with oil-bearing rate of about 50% in seed, 65% in seed kernel. Castor oil has a wide application in the field of modern industry and a big potential of market development with many good characteristics such as big viscosity, high specific gravity, do not metamorphosing and burning in high temperature as well as solidifying in low temperature etc.

- **Jatropha curcas (little kiriko)**

Jatropha curcas is suitable to grow in the dry-hot valley regions, Asia is the Proterozoic and the world distributing center of jatropha curcas, In China, jatropha curcas is mainly distributed in Sichuan and Yunnan provinces. Jatropha curcas grows fast with strong vitality and high yield, the average fruit yield of a 5-year old forest stand jatropha curcas can reach 300-500 kilograms per mou, the average oil-bearing rate of fruit is above40%, the oil-bearing rate of seed can get more than 60% and it is the main acknowledged energy sources developing tree species internationally.



fruits of jatropha curcas

jatropha curcas

- **Pistacia chinensis**

Pistacia chinensis is distributed in north china, central china, south china and southwest china. It has a long life-span and full fruit period, for an adult tree, the fruit yield can reach 50-150 kilograms per plant, peak at 250 kilograms. The oil-bearing rate of pistacia chinensis seed is 43%; pistacia chinensis is Chinese important woody oil tree species.

- **Tungoiltree**

Tungoiltree is mainly distributed in Sichuan, Guizhou, Hunan, Yunnan, Guangxi provinces etc. Sichuan and Guizhou provinces are ranking in the front among these provinces with the biggest planting areas, approximately account for 50% of the total area nationally. The full fruit period of tungoiltree is 6-30 years after the seeds are seminated, the yield of a 10-year old tungoiltree can reach 45 kilograms. In the recent years, the yield of tungoiltree in China keeps 80-120 thousand tons and China is the main production country and main export country of tungoiltree in the world. The oil-bearing rate of tungoiltree seed is 33%-71%, tung oil is not easy to rot and there are no restrictions on the transport and storage conditions of tung oil

- **Wilson dogwood**

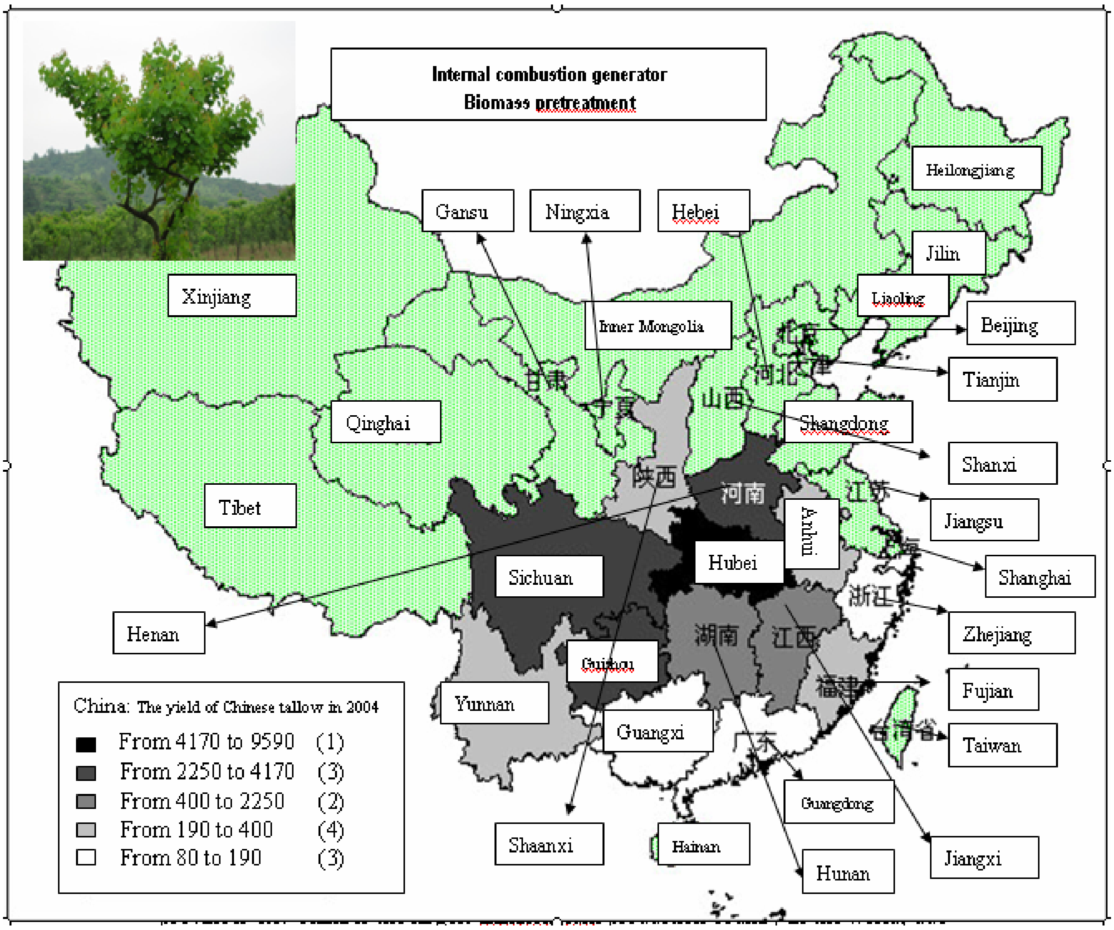
Wilson dogwood is originally planted in China and it is mainly distributed in the south part of Yangtze River valley and the southwest provinces of China, most distributed in Hunan, Jiangxi, Hubei etc. Wilson dogwood is suitable to grow in the limestone mountains, it is resist to Alkali, drought and barren, seedlings forestation began to fruit after 5-7 years, grafted seedlings forestation began to fruit after 2-3 years, the oil-bearing rate of fruit is 33%-36%, the yield of fruit can reach more than 45 kilograms per plant in full fruit period.

- **Xanthoceras sorbifolia**

Xanthoceras sorbifolia is a special tree species in China, it is mainly distributed in the northwest region of China, it has a strong adaptability to drought, barren, alkali. Xanthoceras sorbifolia bears fruit early, and the fruit-bearing rate of a five-year old orchard can reach 95%. Domestic data shows, “the seed yield of a 10-year old individual plant is about 5 kilograms; for a 30-year old individual plant, the seed yield is 20-35 kilograms, ripening period can last for more than 100 years”. The oil-bearing rate of Xanthoceras sorbifolia is 30.4%, for seed kernel, the oil-bearing rate can reach 66.4%, Xanthoceras sorbifolia is an important oil woody tree species in the north part of China. At present, the artificial cultivated area of Xanthoceras sorbifolia is less than 10 thousand mou, and the development potential is huge.

- **Chinese tallow (wax subtree, woody oil tree)**

Chinese tallow is originally planted in China and is widely distributed, from the north part like Shandong to the south part like Taiwan, Guangdong and Yunnan provinces etc, among them, the yield of Chinese tallow in Zhejiang province accounts for 1/3 of the total yield of China and its fruit quality is the best. Chinese tallow begins to bear fruits 3 years after field planting. 6 years later, it enters into its rich-in period, with an output of 350 kilograms per hectare. The seed of Chinese tallow also named white wax fruit, the oil-extracting rate of seed is can reach more than 40%.



● Zanthoxylum

Zanthoxylum is a special season spice of China, the main producing areas are located in Sichuan, Shanxi, Hebei, Shanxi, Henan, Hubei, Guizhou and Gansu provinces etc. China is the largest Zanthoxylum production country in the world, due to the increasing export quantity of Zanthoxylum in recent years. The planting area of Zanthoxylum rises sharply. As it is investigated that in the main producing areas the average output of dry Zanthoxylum can reach 100 kilograms or so, with 55 kilograms of by product prickly ash seed. The oil –bearing rate of Zanthoxylum can reach 25%-33%, the output of by product Zanthoxylum in China is more than 300 thousand tons annually, and the potential use for biomass energy development is huge.

● Oil-tea camellia

Oil-tea camellia is a Chinese specialty of woody edible oil tree and it is widely distributed in the regions along the south part of Yangtze River, among them, Hunan, Jiangxi, Guangxi, Zhejiang and Fujian provinces etc are the main producing areas. The seed kernel of oil-tea camellia is about 45%, and the average tea oil output of oil-tea camellia forest is about 150 kilograms. At present, the oil tea seed is mainly used to extract edible oil.

3.4.2 Technics of making bio diesel oil from woody oil plants

Bio-diesel is refers to fatty acid alkyl lipid (mainly refers to fatty methyl ester), which came from transesterification reaction that use fatty acid and alcohols (mainly alcohols) of animal and plants oil. The key production technology of bio-diesel is to reduce the investment and production cost of bio-diesel's production equipment and the environment pollution of sewage, enlarge the adaptation of process to material, it can be resolved mainly from the following aspects:

(1) Solvent's strengthening transesterification technology is adopted. This technology can dispose a wide source of raw oil including plant and animal oil with high acid value through introducing reactionless cosolvent in the transesterification reaction which greatly accelerated the reaction speed.

(2) The supercritical reaction's strengthening transesterification technology is adopted. Adding pressure and improving the reaction temperature are both important means to strengthen the reaction. With the temperature goes further high, when the temperature of reaction system is close to methanol's critical point, the mass transfer and reaction properties between reactants get obvious aggrandizement, Even if there were no catalyzer exist, transesterification can also goes smoothly. This technics can used to process raw material with high acid value, moreover, due to no use of catalyzer, the posttreatment is easy and there is no three wastes emission.

(3) Solid base catalyze technology. Solid base catalyst stands for the important direction of recent research and development, it can solve the problem of the separation between outcomes and catalyze, due to the adoption of solid base catalyst, the three wastes emission is greatly reduced. But the solid base catalyst is sensitive to both free fatty acid of oil and water, the life span of catalyst is generally short, it's hard to meet industrialization's demand.

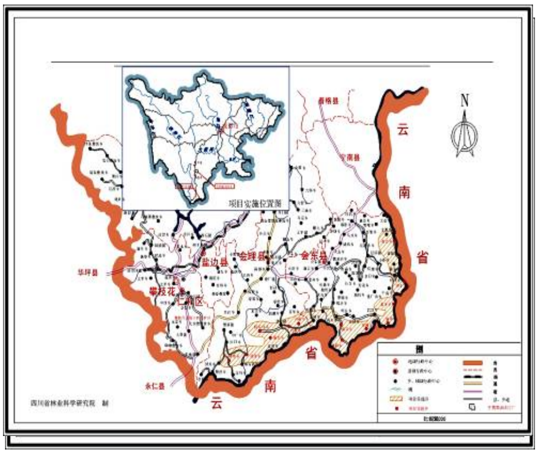
(4) Enzymatic catalysis transesterification technology. Enzyme catalyst is another kind of important transesterification catalyst, there are many researches focused on it, its merits are: transesterifications of triglyceride and free fatty acid proceed at the same time, this can process high acid value material; the concentration of by product glycerol is high and the catalysis can be used repeatedly, its shortcomings are: the cost of enzyme catalyst is high, enzyme catalyst is easy to lose its activity, its has a short life-span. The reaction temperature of enzyme catalyst is mild

and it is the direction of the development for the future. The direction of research for enzyme catalyst must be reducing the cost of enzyme, improving the conversion rate of transesterification.

3.4.3 Utilization status of technology of making bio-diesel from woody oil plants

At present, the development and research of making bio-diesel from woody oil plant has already acquired a preliminary phased achievement. The research contents involve: the filtration of oil plant, good varietal selection and cultivation as well as its process technics and equipment, the technology of transforming the seeds of little kiriko and pistacia chinensis as well as Wilson dogwood in to bio-diesel is especially mature, some enterprises have already entered in to the field of utilization of bio-diesel. Hunan Academy of Forestry and Hunan Tianyuan Bio clean Energy Co. Ltd have established a production line with capacity of 20 thousand tons of bio-diesel annually using Wilson dogwood oil and vegetable oil leftover as raw material; Chinese Academy of Forestry has established an integrated line with capacity of 500 tons of bio-diesel and chemical products; Hainan Zhenghe bio-energy corporation and Sichuan Gubin grease chemical corporation as well as Fujian Excellence Biomass Energy Co, Ltd have already developed technology owned freedom property. The production line of bio-diesel with capacity of more than myriad 10 thousand tons will be built successively. Sichuan University and Sichuan Yangtse River afforestation Bureau as well as Sichuan Academy of Forestry etc work together and focus on how to transform jatropha curcas to bio-diesel and its comprehensive utilization, they have developed the technology of using two-step transesterification method and tiny to emulsify the method to produce bio-diesel and established Medium Stage Test Workshops in Synthetic of little Kiriko bio-diesel mixed fuel with capacity of 200 tons per year, the B-15 mixed diesel oil they produced has passed 15 thousand kilometers driving test of diesel engine, the B-20 little kiriko bio-diesel complexed by microemulsion composite additive has been used in the diesel oil public automobiles of Chengdu Public Transportation Corporation, The diesel engines work smoothly, run reliably with main accessories wear normal, it has reached the standard of zero-sized diesel oil. The bio-diesel extracted from little kiriko by Guizhou University has passed the test of German relative corporation’s test and it shows that 5-10% little kiriko bio-diesel oil can be added to normal diesel oil for mixed use. Guizhou Zhongshui energy development limited corporation bought solid phase catalytic technology which has its own intelligent property right possessed by Guizhou University, the medium test production line built presently can operate smoothly with capacity of 300 tons of little kiriko bio-diesel per year and its production of bio-diesel has passed the test of Europe Union bio-diesel’s standard requirements and its property is super to the zero-sized diesel oil significantly.

The medium test device of physic nut bio diesel with capacity of 200 tons per year



The position schematic diagram of physic nut resource high efficient cultivation and its bio diesel industrialization demonstration project in Sichuan province

3.4.4 Technology of making bio-diesel from oil plants and its economical brief comment

At present, we still lack data for economical analysis and cost estimation of making bio-diesel from woody oil plants. We can only have a rough estimation according to the Tanezane yield, price, oil-bearing rate etc of several kinds of tree species that are suitable to making bio-diesel. The following are the 3 kinds of cost estimation of making bio-diesel from oil tree that has been successfully used for making bio-diesel.

Little kiriko: the oil-bearing rate of little kiriko seeds is 30-60% and the output of seed is 300-500 kilograms per mou. Calculate according to seed output of 300 kilograms per mou with 40% oil-bearing rate, the raw oil processing rate is 95% with seed’s price of 1.2-1.5RMB per kilogram and the income of seed per mou is 360-450 RMB.

We can get 100-110 kilograms raw oil through processing 300 kilograms kiriko. Calculate according to 3 tons of little kiriko for 1 ton of raw oil, the production cost of raw oil is about 4100-5000 RMB per ton (material cost 3600 subtract 4500 add processing cost 500 RMB). The processing cost through raw oil to diesel oil is 1000-1200 RMB per ton. The production cost of little kiriko bio-diesel oil is 5100-6200 RMB per ton.

Pistacia chinensis: the oil-bearing rate of pistacia chinensis seed is 35-50% and the seed output is 200-600 kilograms per mou. Calculate according to 300 kilograms seed per mou with 40% oil-bearing rate, the raw oil processing rate is 95%, seed’s price is 1.5-1.6 RMB per kilogram with seed income of 450-480 RMB per mou.

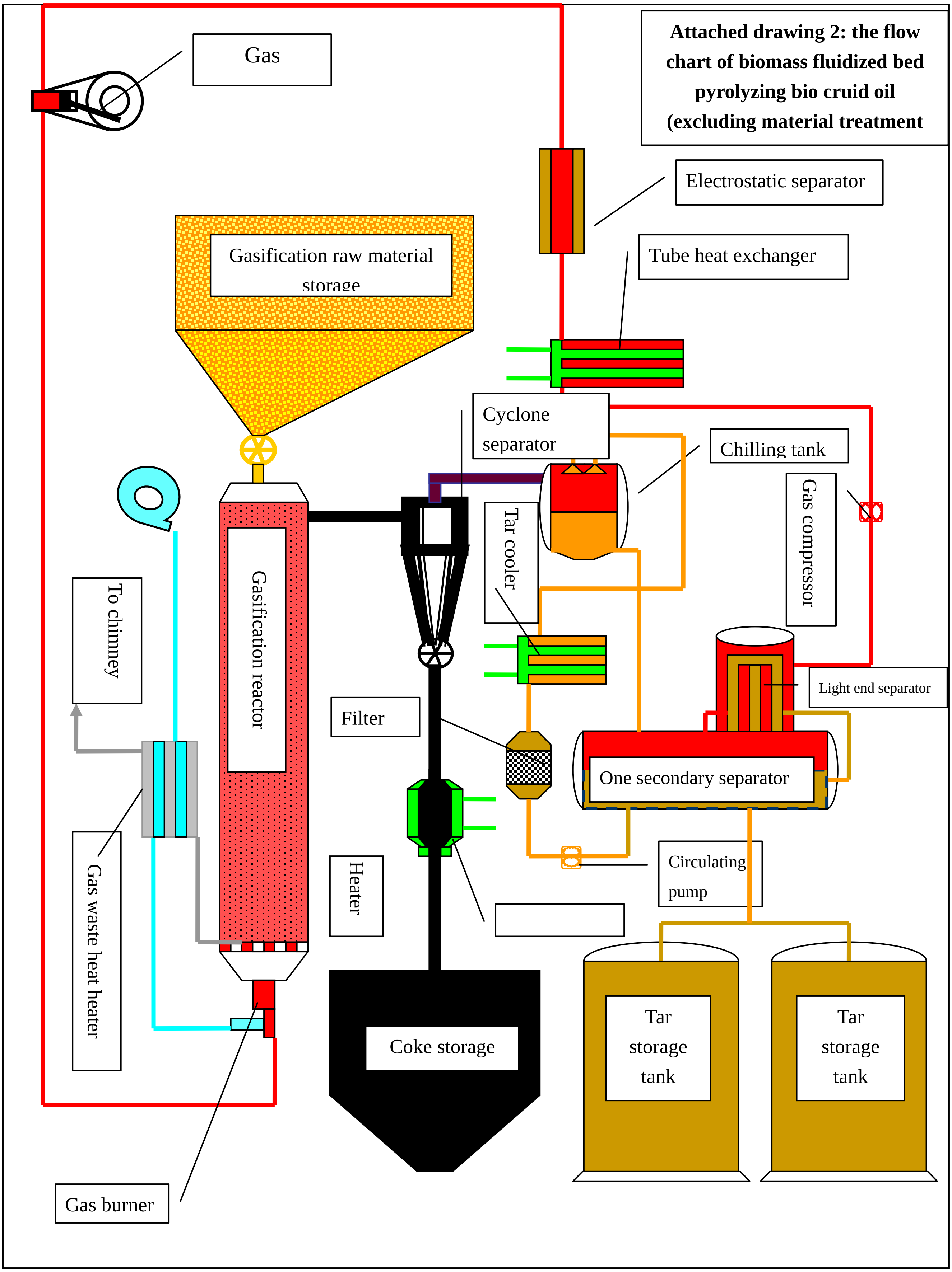
We can get 100-110 kilograms raw oil through processing 300 kilograms pistacia chinensis seed, Calculate according to 3 tons of pistacia chinensis seed for 1 ton of raw oil, the production cost of raw oil is 5000-5300 RMB per ton (raw material cost 4500-4800 add processing cost 500 RMB) with the processing cost from raw oil to diesel oil of 1000-1200 RMB per ton. The production cost of pistacia chinensis is 6000-6500 RMB per ton.

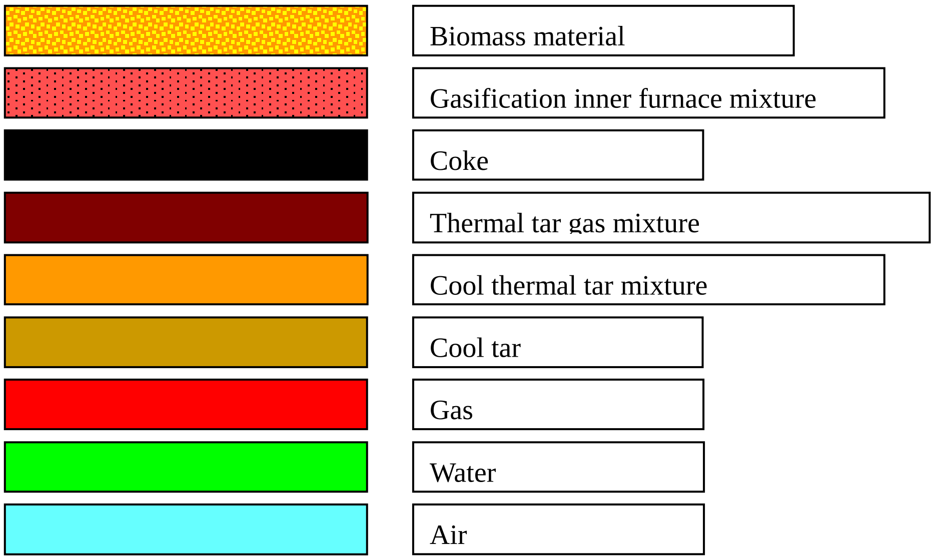
Wilson dogwood: the oil-bearing rate of Wilson dogwood fruit is 30-40% with an output of 200-700 kilograms per mou. Calculated according to 300 kilograms seed per mou with 35% oil-bearing rate, the raw oil processing rate is 95% and the price of seed is 1.2 RMB per kilogram with the income of seed 360 RMB per mou.

3.5 Making bio-oil from agroforestry residues pyrolytic

3.5.1 Technics of making bio-oil from agroforestry residues pyrolytic

Crop straw and forestry waste as well as waste from wood processing factories etc biomass material were pyrolyzed rapidly in fluidized bed gasifier after comminution, the mixture of wood coke and bio-oil and as well as biomass flammable gas which came from cracking will be separated, wood coke and bio-oil will be sold out as product after recovery while biomass flammable gas will provide heat source to fluidized bed gasifier. The whole process is divided to material treatment, gasification, separation of gas and liquid, reuse of gas, water circulation and automatic control etc subsystems, the process flow refers to chart below.


Attached drawing 2: the flow chart of biomass fluidized bed pyrolyzing bio cruid oil (excluding material treatment
Gas
Electrostatic separator
Gasification raw material storage
Tube heat exchanger
Cyclone separator
Chilling tank
Gas compressor
Tar cooler
To chimney
Gasification reactor
Light end separator
Filter
One secondary separator
Gas waste heat heater
Heater
Circulating pump
Coke storage
Tar storage tank
Tar storage tank
Gas burner



3.5.2 Utilization status of making bio-oil from agroforestry residues pyrolytic

In the recent years, our government pays much attention to the development of bio-diesel, In 2004, new and high technology and industry division of Ministry of Science and Technology started up “the fifteenth” national science and technology tackling key problems plan, item of “technical development of bio-diesel”; In 2005, national special agroforestry biomass engineer and replacement fuel development strategy research were began to carried out, in May, 2005, national 863 plan the field of biology and modern agriculture technology decided to start up the item of “technology development of biomass energy and its industrialization” in advance.

In China, although the research on wood pyrolytic technology begins early, it proceeds slowly, it only restricts within the stage of test and research. At present, domestic technology of making bio-oil from agroforestry residues pyrolytic is only applied in the University of Science and Technology of China with testers of treating capacity of 120 kilograms an hour.

3.5.3 Technology and economy brief assessment of making bio-oil from agroforestry residues pyrolytic

At present, the commercial device that successfully developed and built by Canadian Damao Corporation has been put in to production, with a treatment capacity of 100 tons of bio-material daily, the commercial device with a treatment capacity of 200 tons of bio material is in construction, It is predicted that it can put in to production in Aug.2007.The fuel heat value of biomass that mainly produced by this technology is 4500—6000kcal/kg, water-bearing rate is high, it can only be used as fuel oil. But there is so much humic acid exists in bio-fuel oil, PH value of fuel oil can reach 2-3, and it will have a corrosive effect to equipment for direct use. It is acknowledged by test research, when bio fuel oil is mixed with heavy oil with mixing proportion less than 15%, the effects to equipment can be neglected. But it still lacks the support of long-term test data.

According to the economical analysis results of the technology developed by Canadian Damao Corporation, the production cost of fuel oil and the price of heavy oil are almost the same (calculated according to the same heat value), but with the rising of biomass material price, the project economy has a great risk. If it can get the support of finance and taxation policy, this technology has intensive market competitiveness. At present, the domestic fuel consumption per year is more than 40 million tons, even if calculated by the consumption with 10% mixed rate, the market capacity can reach more than 4 million tons, and the needed bio-material is about 8 million tons.

4. Biomass compression forming technology

4.1 Technology types of compression building machine

4.1.1 Spiral extruding

The technology of screw thermal extrusion moulding is the compressed technology which has the longest research time and most equipment manufactures domestically, but it also has a high energy consumption (the compressed energy consumption is 150 kilowatt hour per ton) and a short screw life-span (free-repair, continuous use not exceeds 100 hours), these become the technology bottleneck.

The screw extruding compressed machine produced by Beijng Maowei Science and Technology development Ltd has solved the two major problems mentioned above and the production entered the commercial application stage. This technology uses electric heating, screw extruding compressed, with the biggest production capacity of 200-250 kilograms per hour for single machine and its production is empty rod hive with diameter of 55 milimeters, the energy consumption of compressed is 75 kilowatt hour per ton, the total energy consumption is 90 kilowatt hour per ton, the continuous using time of free-repair screw exceeds 1000 hours.

The merits of this technology are simple equipment and small investment while the shortcoming is little yield for single machine.

4.1.2 Ring mold rolling

Beijing Oumai Century S&T Co,Ltd. develops this technology and it enters into the commercial application stage. This technology uses steam heating compressed, with the biggest production capacity of 4 tons per hour for single machine and its productions are particles of 8-15 minimeters. The compressed energy consumption is 45 kilowatt hour per ton, the total energy consumption is 80-89 kilowatt hour per ton.

The merits of this technology are big production capacity for single machine, applicable and large-scale utilization, and the shortcoming is the big investment.

4.1.3 Stamping method

Developed by Hefei Tianyan Green Energy Development Ltd and has entered its commercial application stage. This technology uses electric heating and stamping forming with the biggest production capacity of 1 ton for single machine, the productions are solid rod hives with diameter of 70 minimeters, the compressed energy consumption is 60 kilowatt hour per ton and the total energy consumption is 70 kilowatt hour per ton. This company has already developed cooking stove that uses formed fuel rod, heating stove as well as boiler of 1 ton per hour.

The merits of this technology are: good production continuity and low energy consumption while the shortcoming is the big product size.

4.1.4 Cold compressed technology

Developed by Beijing Huizhongshi Science and Technology Ltd, this technology has entered its commercial application stage and it doesn’t need heating, with maximum production capacity of 0.5 ton per hour for single machine and its production are particles with diameter of 8 centimeters or so, the compressed energy consumption is 60 kilowatt hour per ton and the total energy consumption is 80 kilowatt hour per ton. This company has also developed kitchener and heating stove which use straw briquette.

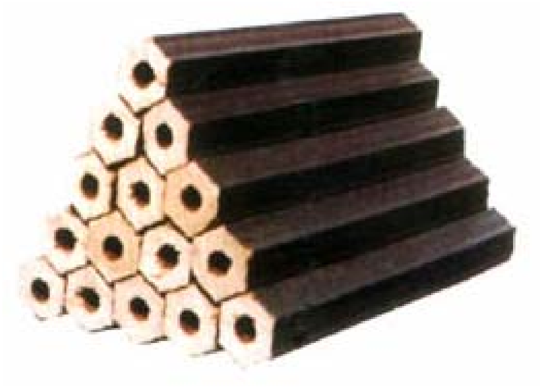
The merits of this technology are: low request to raw material water, low energy consumption, no emission of harmful gases during production process. The shortcomings are: the compressed fuel product storage have a weak ability to resist to moist, the possibility of product mildewing is large, besides, due to no high temperature treatment during processing course, the disease and pest can not be annihilated that may existed in productions.

4.2 Utilization status of biomass compression forming technology

At present, biomass compression forming technology which actually used for energy production is few, the use for energy production in large scale is almost blank, The technology which has been adopted most is spiral compression forming technology and it’s mainly used for producing biomass charcoal, biomass material is molded by compression through spiral compressor and it’s generally hollow rod product, formed biomass material is put in to carbonization furnace for carbonization, the volatile matter in raw material is removed and the production become mechanism charcoal , it is mainly sold to dietary industry as barbecue fuel.

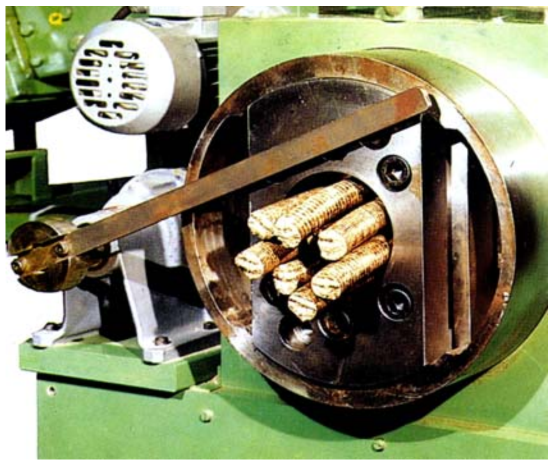
At present, both Ministry of Agriculture and National Development and Reform Commission have plans of developing biomass forming fuel and they have already begun their experimental units. Cold forming technology has arranged experimental units in Huairou Beijing consist of forming and special stoves.






All kinds of biomass formed fuel



All kinds of biomass formed fuel machine

4.3 Technology and economy brief assessment of biomass compression forming

Compression forming technology can increase the per unit volume energy density of biomass 5-6 times compared with natural state, most compression forming technologies need heating during the course of forming, generally heating can kill the disease and pest as well as bacteria of raw material, so the formed fuel can deposit for a long time without rot and metamorphism. These characteristics have greatly improved the performance of biomass energy transportation and storage and it make large-scale utilization possible.

But biomass material need to consume power energy during compression, the consumed power energy is different concerning about the forming technologies, and power energy consumption is generally between 60-100 kWh/ton. Among them, the power energy consumption of spiral compression forming is the highest, while the cold compressed and ring mode rolling are low.

Among all the forming technologies, the price of spiral compression building machine is the lowest while the investment of cold compressed and ring mode rolling building machine is the biggest.

Among all the forming technologies, the cost of biomass compressed process is about 150-200 RMB per ton, calculated according to the cost of biomass raw material of 200 RMB, the cost of formed fuel is close to 400 RMB per ton. Calculated according to the average heating value of raw material of 3500 kcal/kg, the cost of biomass formed fuel of equivalent ton stander coal reaches 800 RMB per ton. Analyzed from economy standpoint, it has no market competitiveness compared with chemical fuel.

There is a big limitation of biomass formed fuel used for peasant’s cooking, for farms that use straw for direct burning formerly, using formed fuel will increase their cash payout, while for peasants who still use straw for direct burning are very poor. The increased cash payout will force farmers to refuse to use this technology even if the technology has a high efficiency. In developed areas, many peasants have used liquefied gas as energy for life use, popularizing biomass formed fuel in these areas will lower peasant’s life qualities, so the difficulty of expansion is huge. The expansion of formed fuel to peasants who use coal will depends on the cost of fuel, if the cost is higher than coal, it’s hard for peasants to accept. The popularization of formed fuel in coal-using household depends on the cost of fuel, if the cost of fuel is higher than coal, and it is difficult for peasantry to accept.

Part Two: Status of Biomass Technology in Denmark

1. Introduction

This document is supplementary to the Survey Report on Biomass Technology Application prepared by ERI. This document focuses on Danish/ European technology.

The introduction chapter serves two objectives:

1. To guide authors of technology surveys in selecting the right data.
2. To assist readers in interpreting the data.

The survey data criteria are briefly presented in sections 0-0.

1.1 Brief technology description

This should include a review of existing studies. The survey report should refer to existing reports to avoid duplication of efforts. Focusing on Danish/European produced technology, including:

High efficient technologies for heat, steam and electricity production and CHP;

- Direct Combustion
    - Grate firing
    - Suspension firing or powder firing
    - Fluid beds
- Co-firing with coal and biomass
- Incineration
- Biogas
- Thermal Gasification

Each technology is allocated one to three pages giving key characteristics of the technology. When drafting new technology sheets, it is recommended to review existing technology sheets for inspiration.

1.2 Input / output

The input includes:

- Possible fuel type(s)
- Supply chain for selected biomass type
- Capital cost

Output includes:

- Available size of plant, divided into 4 categories:
    - o Large scale CHP plant up to 700 MW or District Heating plant up to 50 MW energy output.
    - o Steam boilers 1-20 MW for industrial use
    - o Medium scale heating plant for industries, institutions, hotels up to 15 MW energy output
    - o Small scale boilers for households and farms 10 kW to 1 MW
- Efficiencies, electrical and total
- Need for flue gas cleaning facility (cyclone, bag filter, electrostatic filters) depending on local air pollution regulations.
- Ash handling. Reuse or landfill.

1.3 Utilization status

This includes number of plants in operation, research/development stage and examples of best available technology.

1.4 Brief assessment

This includes specific advantages and disadvantages relative to equivalent technologies. This includes operation, regulation speed, minimum load, etc. Generic advantages are ignored; e.g. renewable energy technologies mitigate climate risk and enhance security of supply.

1.5 Data sheets

Generating capacity for one unit

The capacity, preferably a typical capacity (not maximum capacity), shall be stated for a single boiler/unit. The capacity is given as net generation capacity in continuous operation, i.e. gross capacity (output from generator) minus own consumption (house load), equal to capacity delivered to the grid. For fuel conversion technologies output is stated as tones of converted fuel per day.

1.6 Energy efficiencies

The total efficiency equals the total delivery of electricity plus heat at the fence (i.e. excluded own consumption) divided by the fuel consumption. The electricity efficiency equals the total delivery of electricity to the grid divided by the fuel consumption. The efficiency is stated in per cent.
The efficiencies are determined at full load (100%), continuous operation. If the efficiencies vary much at part load, numbers should be presented at e.g. 50%, 75% and 100% load.

2. Typical Supply Chains for Biomass in Denmark

2.1 Straw

Figure 1 shows the supply chains for straw from the supplier to the energy conversion facility. Straw in Denmark is mainly from wheat and barley.

Properties of straw

	Water content	**Heating value at the given water content**	
	[%]	**[GJ/tons] [MJ/kg]**	**[MWh/tons] [kWh/kg]**
Big bales	14,6	14,4	4,0
Straw pellets	6 - 8	15,5 – 16,5	4,31 – 4,58

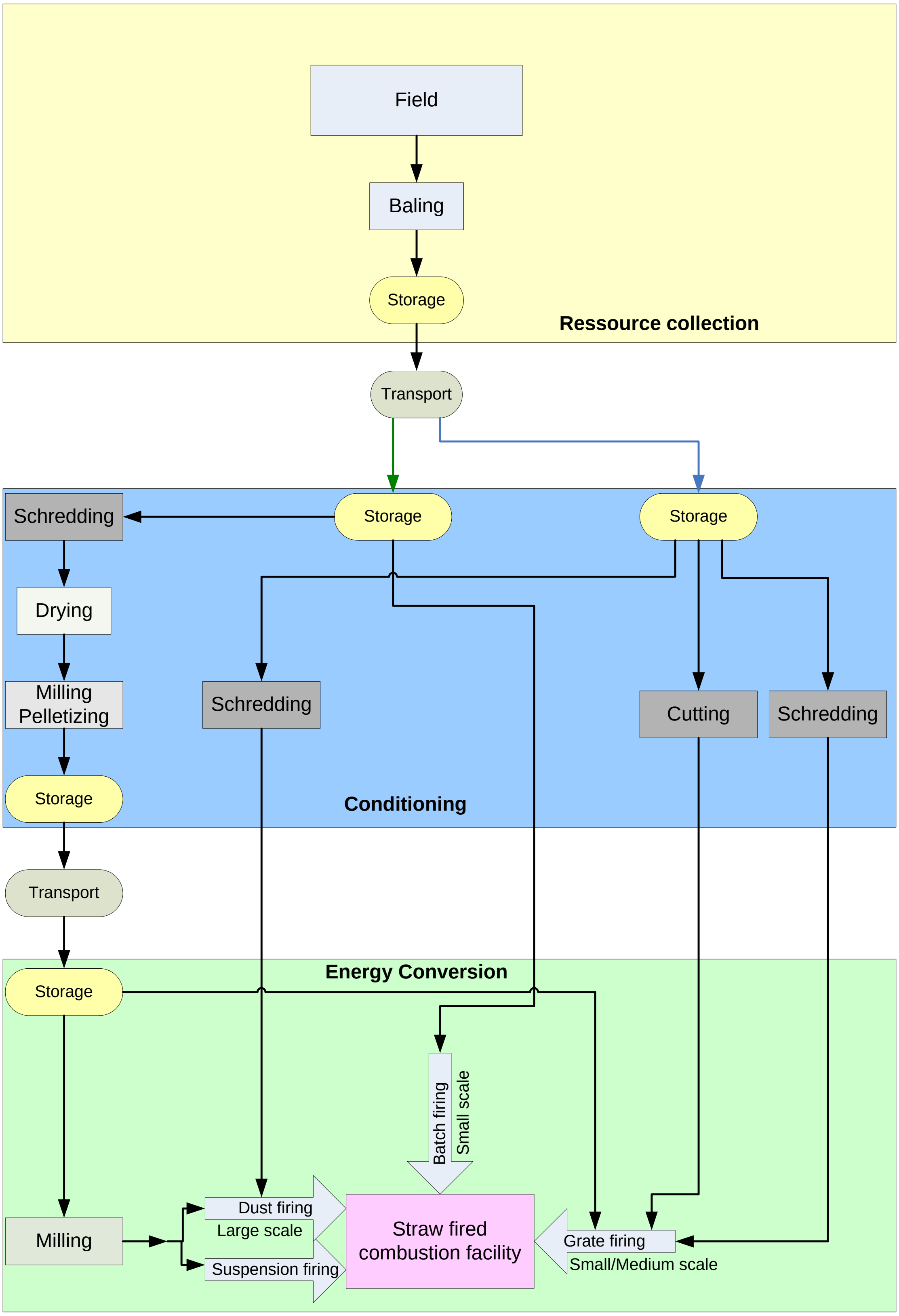


Figure 1 Typical supply chains for straw

2.2 Wood

The below schematic show the supply chains for wood from the supplier to the energy conversion facility.

Properties of Wood

	Water content [%]	Heating value at the given water content	
		[GJ/tons] [MJ/kg]	[MWh/tons] [kWh/kg]
Wood pellets	6 - 8	17,5 – 17,9	4,86 – 4,97
Wood logs	45 - 55	7,3 – 9,5	2,03 – 2,61
Saw dust	20	15,2	4,22
Saw mill chips	40	10,5	2,92
Chips from forest residues	55	7,3	2,03

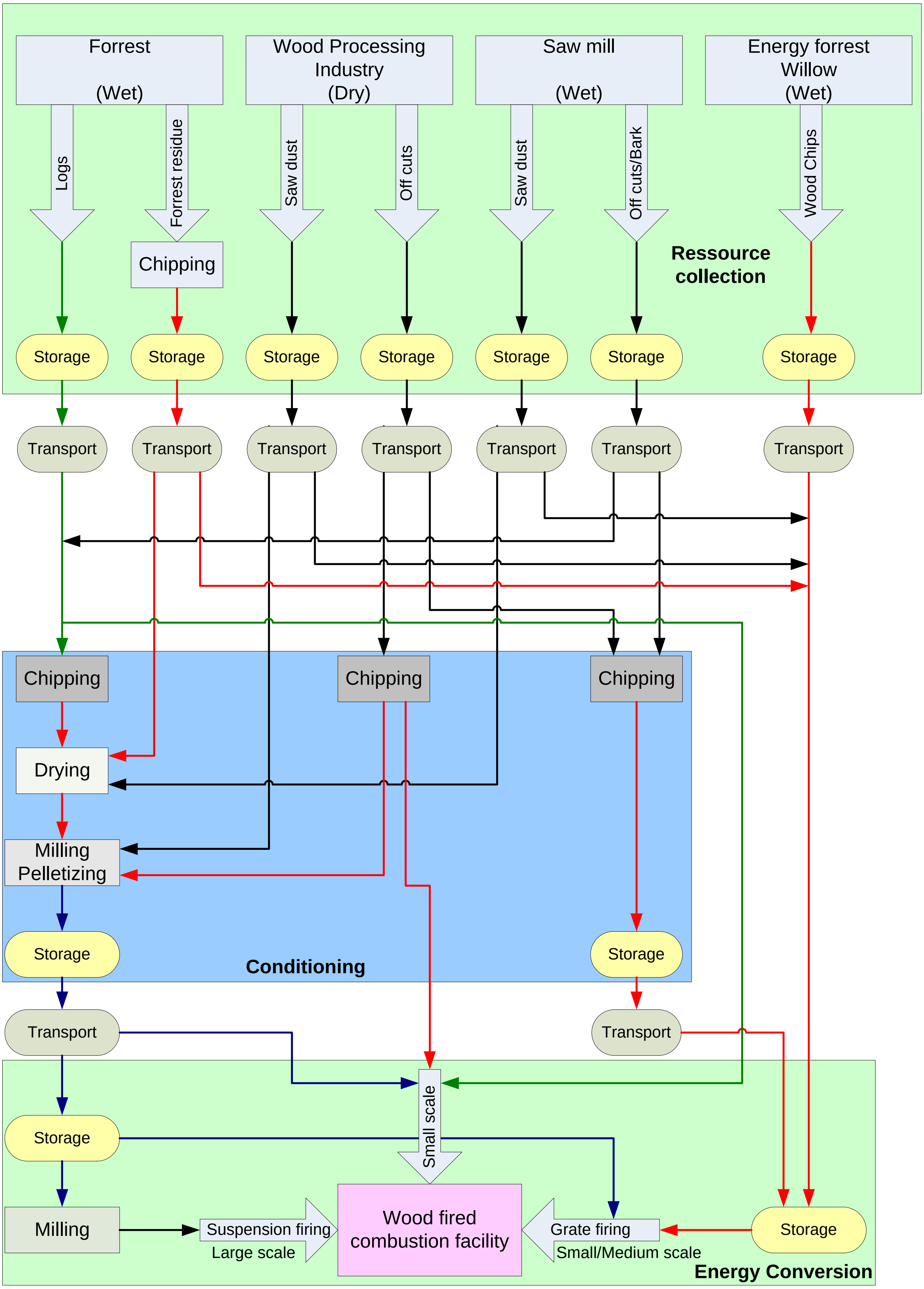


Figure 2 Typical supply chains for wood

3. Biomass power generation technology

3.1 Suspension and dust fired Large Scale Biomass Power Plant

This covers large base-load units with 70-100% biomass. The suspension firing or dust fired boiler may or may not be the main boiler.

3.1.1 Brief technology description

The technology is similar to large pulverized coal power plants. The major components are: Fuel treatment and feed-in system, high-pressure steam boiler, steam turbine, generator and condenser. All fuel is grinded or chipped, burned with dust burners or blown into the furnace for suspension firing, in which case there is also a bottom grate. However pure grate firing is not covered by this technology sheet.

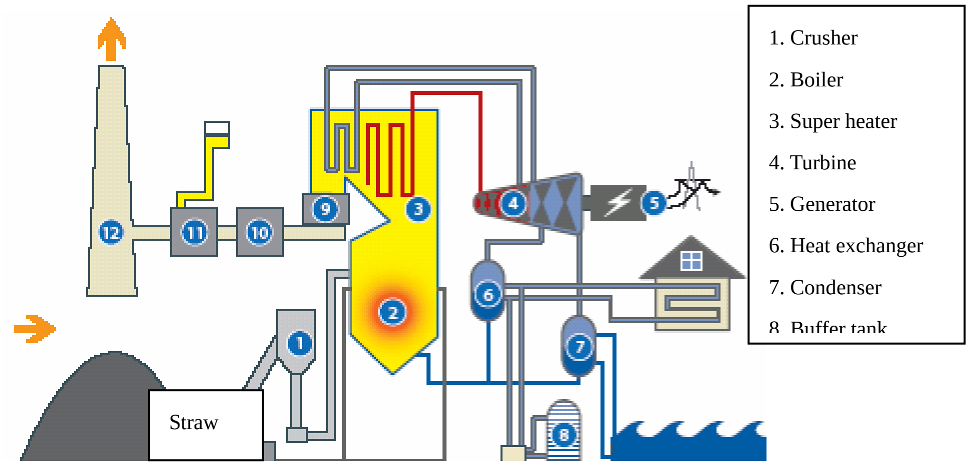


Figure 3 Picture source: Amagerværket, Vattenfall

The steam process can be of different nature:

Condensation
All steam flows all the way through the steam turbine and is fed into a condenser, which is cooled by water at ambient temperature. A condensing steam turbine produces only electricity, no heat.

Back-pressure
Same as condensation, but the steam pressure (and temperature) in the condenser is higher, so that the temperature of the coolant becomes sufficiently high to be used for industrial processes or district heating. A back-pressure turbine produces electricity and heat, at an almost constant ratio.

Extraction
Same as condensation, but steam can be extracted from the turbine to produce heat (equivalent to back-pressure). Very flexible, no fixed ratio between electricity and heat.

3.1.2 Input/output

Input is biomass; e.g. residues from wood industries or forests and residues from agriculture (straw), often delivered as pellets. See Figure 1 and Figure 2.

Support burners uses oil or gas. These must be used for startup but may also cover 30-100% of continuous load.

Wood is usually the most favorable bio fuel for combustion due to its low content of ash and nitrogen. Herbaceous biomass like straw and misc. have higher contents of N, S, K, Cl etc. that leads to higher emissions of NOx and particulates, increased ash, corrosion and slag deposits.

Output is electricity, for back-pressure or extraction plants also heat. The heat may come as steam or hot water. Usually the heat is used for district heating.

Typical capacity is 400 MW_{el}.

Flue gas cleaning includes de-NOx, desulphurization and fly ash filters. Bi-products from ash and desulphurization are reused for production of gypsum and concrete.

3.1.3 Utilization status

The technology is operational.

Focus of the Danish R&D strategy:
Reduce the cost of fuel, by improved pre-treatment, better characterisation and measurement methods.
Reduce corrosion, in particular high-temperature corrosion
Reduce slagging
Reduced emissions
Recycling of ashes
Improved trouble-shooting

Examples of best available technology:

Avedøreværket Power Plant (Copenhagen), Unit 2 main boiler (300000 tons wood pellets per year, 400 MWel output). Dust burners with oil and gas support. Up to 72% wood pellet fuel.

Amagerværket Power Plant, Unit 2, Copenhagen; coal-fired plant from 1972; in 2004 converted to130,000 tons of straw pellets per year; 73 MW in condensation mode and 50 MW + 165 MJ/s in back-pressure mode. Dust burners capable of 100% straw firing after ignition.

3.1.4 Brief assessment

A major advantage with this particular technology is that it can be applied in existing coal-fired power plants at a much lower cost than building new power plants.

Some biomass resources however, in particular straw, contain aggressive components such as chlorine. To avoid or reduce the risk of slagging and corrosion, boiler manufacturers have traditionally deterred from applying steam data to biomass-fired plants at the same level as coal-fired plants. However, recent advances in materials and boiler design constitute a breakthrough, and the newest plants have fairly high steam data and efficiencies.

The plants can be down regulated, but due to high initial investments they should be operated in base load.

3.1.5 Data sheets

Technology	**Steam turbine, 70% biomass**
Energy / Technical data	
Generating capacity	400 MW
Total efficiency	93
Electricity efficiency (%) net – 100% load 75% load 50% load	48.5 48 47

3.2 Grate fired large Scale Biomass Power Plant

This covers large base-load units with 100% biomass. The grate boiler is usually not the main boiler. Suspension firing is not covered by this sheet.

3.2.1 Brief technology description

Grate firing is covered by this technology sheet. The coal boiler in Figure 4 is out of scope. The straw boiler (Item No. 2 in Figure 4) is in focus in this technology description.

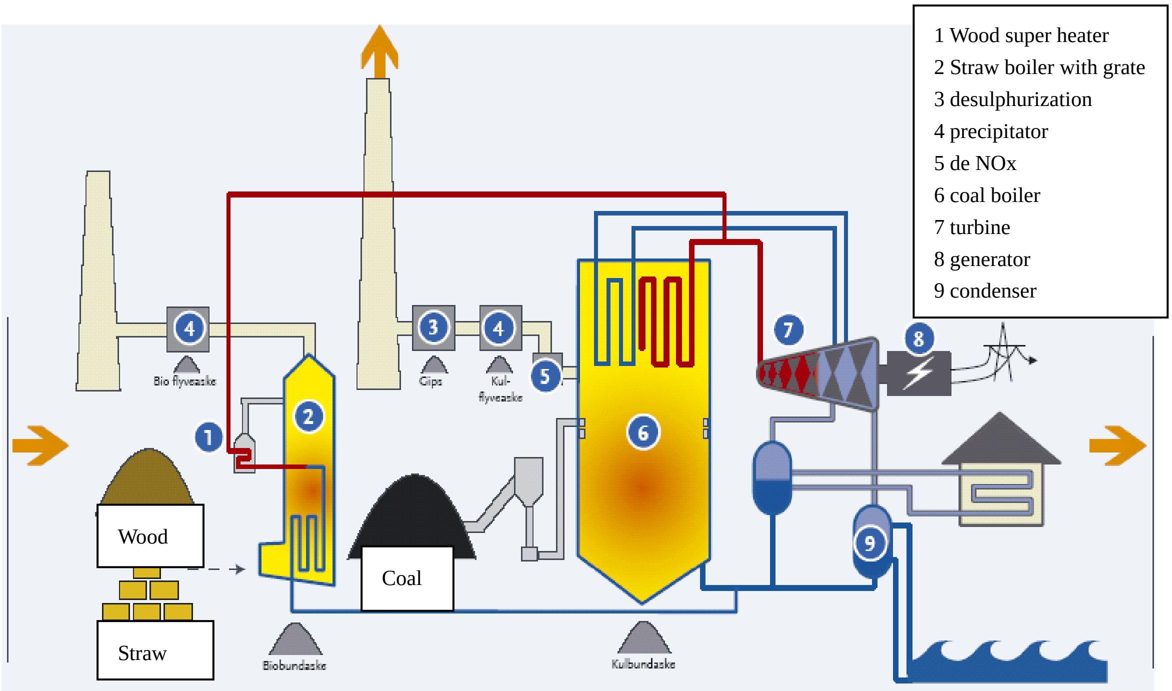


Figure 4 Picture source: Enstedværket, DONG Energy

3.2.2 Input/output

Input is 100% biomass delivered as pellets or straw bales. See Fig 1 and 2. For a 40 MW plant like Enstedværket 50-60 truckloads of straw bales are supplied per day.

Output is electricity, for back-pressure or extraction plants also heat. The heat may come as steam or hot water. Usually the heat it is used for district heating.

Typical capacity is 40 MW_{el}.

Capital cost is relatively high compared to reconFigureed coal boilers.

Flue gas cleaning includes electrostatic precipitators for fly ash. Usually fly ash is sent to landfills due to its content of heavy metals, while bottom ash is used as fertilizer.

3.2.3 Utilization status

The technology is operational.

Examples of best available technology:

Avedøreværket, Copenhagen, secondary straw boiler with grate (165000 tons straw pellets per

year, 45 MW).
Enstedværket, Aabenraa secondary straw boiler with separate wood fired super heater (120000 tons shredded straw and 30000 tons wood chips per year, 40 MW).

3.2.4 Brief assessment

Grate firing is a well proven technology which is suited for low quality fuel. Due to space requirements it is mainly used for boilers up to 50 MW maximum.

3.2.5 Data sheets

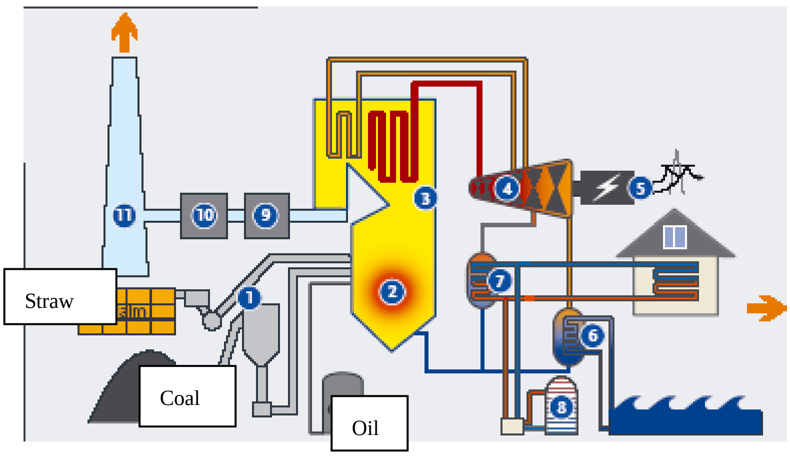
Technology	**Straw fired steam power plant**
	Grate fired boiler
Energy / Technical data	
Generating capacity	40 MW
Total efficiency	93%
Electricity efficiency	48%

3.3 Coal biomass mixed burning

This covers mixed burning in large and medium sized CHP plants.

3.3.1 Brief technology description

Straw and coal is fired in a mixing burner or a fluid bed. Otherwise the plant is a conventional steam turbine CHP plant. Fluid beds are suitable for a wide range of fuels that could normally be difficult to burn such as peat and low quality coal.



1. Crusher
2. Furnace
3. Super heater
4. Turbine
5. Generator
6. Condenser
7. Heat exchagner

Figure 5 Picture Source: Studstrupværket www.dongenergy.com

3.3.2 Input/output

Mainly coal is used but also oil and gas can be mixed with biomass.

Up to 15% straw can be fired in conventional boilers, and somewhat more for fluid bed boilers. If high straw percentage is needed then a separate steam super heater is often necessary.

The Studstrup plant uses 942000 tons of coal (23 000 TJ) and 123000 tons of straw (1850 TJ) per year.

The Studstrup plant produces 700 MW of electricity (2449 GWh/yr) and 910 MW (8982 TJ/yr) of district heating.

Typical capacities range from 20 MW_{el} to 700 MW_{el}.

Flue gas cleaning includes precipitors, de-nox and desulphurization.

Capital cost is moderate due to the fact that most of the plant is conventional, or even an existing coal plant.

3.3.3 Utilization status

The technology is quite mature. However continuous efforts are done in the area of increasing biomass fuel percentage, including other biomass types, NOx modeling and more.

Examples of best available technology

Studstrup Power Plant, Aarhus; chipped straw, up to 10 cm (700 MW_{el}) Studstrup CHP plant uses mixed coal/straw burners since 2002. Straw energy input is 8% of total fuel input.

Grenaa CHP plant (20 MW_{el}) mixes coal and straw in a circulation fluid bed boiler since 1992. Straw energy input is 43% of total fuel input.

Herning CHP plant uses mixed burning of wood chips and natural gas. The mixture depends on the load.

3.3.4 Brief assessment

Mixed burning is less risky than pure bio fuel plants. In case of problems with biofuel supply the plant will still work on pure coal combustion. However the bio fuel to coal ratio is limited.

There is always a risk of corrosion and fouling. Steam temperature may have to be reduced compared to coal fired boiler.

Regulation abilities are like a conventional CHP plant.

3.3.5 Data sheets

Technology	**Coal-Straw mixed burning**
	Studstrup
Energy / Technical data	
Generating capacity	2 x 350 MW electric 2 x 455 MJ/s heat
Total efficiency	85%
Electricity efficiency	42%

3.4 Direct burning Medium-Scale Biomass Cogeneration

This covers mainly steam turbine but also stirling engine, organic rankine cycle and indirect fired gas turbine.

3.4.1 Brief technology description (steam)

The major components are: Fuel treatment and feed-in system, high-pressure steam boiler, steam turbine, generator and condenser.

The furnace technology can be of different nature: Grate firing, suspension firing (where the biomass is pulverized or chopped and blown into the furnace, possibly in combination with a fossil fuel), and fluidized bed. Grate combustion is very robust with regard to using varying types of biomass.

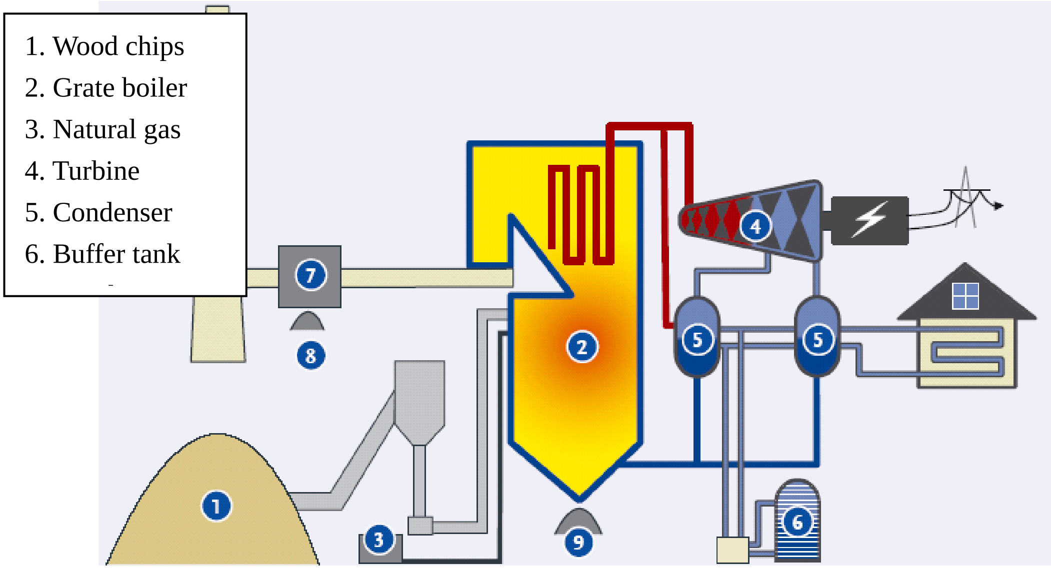


Figure 6 Picture source: Herningværket , DONG Energy

The data sheet describes plants used for combined production of electricity and district heat. These data do not apply for industrial plants, which typically deliver heat at higher temperatures than district heating plants, and therefore they have lower electricity efficiencies. Also, industrial plants are often cheaper in initial investment and O&M, among others because they are designed for shorter technical lifetimes, with less redundancy, low-cost buildings etc.

Co-combustion of biomass with fossil fuels in large power plants is covered by technology sheet section 0.

3.4.2 Input/output

Biomass; e.g. residues from wood industries, wood chips (collected in forests), peat, straw and energy crops. Combustion can be applied for biomass feedstocks with moisture contents up to 60%. Wood is usually the most favorable bio fuel for combustion due to its low content of ash and nitrogen. Herbaceous biomass like straw and miscanthus have higher contents of N, S, K, Cl etc. that leads to higher emissions of NOx and particulates, increased ash, corrosion and slag deposits. Forest residues are typically delivered as wood chips. Both straw and wood residues may also be delivered as pellets. Straw is usually delivered in 500 kg Hesston bales (15 GJ/tonnes) to the CHP plant. Compared to coal the energy density is about 9 times lower. The bales are most commonly shredded and fed by stoker screws.

The fuel is often mixed with coal or co-fired with natural gas.

Output is electricity and heat. The heat may come as steam or hot water. Typically used for district heating.

The capacities of cogeneration plants supplying heat to district heating systems are primarily determined by the heat demands.

In the low capacity range (less than 10 MW) the scale of economics is quite considerable.

3.4.3 Utilization status

The technology is operational. There are 14 biomass fired cogeneration plants in Denmark.

Examples of best available technology (steam):

In Denmark, the most recent small-scale plants are Maribo/Sakskøbing (straw; 11 MW; commissioned in 2000) and Assens (wood chips; 5 MW; commissioned in 1999).

Larger decentralized plants are

- Herningværket 89 MW, grate fired
- Junckers, Køge with several suspension fired boilers producing a total of 133 MW.
- Dalum Paper Mill, 45 MW suspension fired boiler

Stirling engines, ORC and IFGT are at the development and demonstration level.

3.4.4 Brief assessment (steam)

Some biomass resources, in particular straw, contain aggressive components such as chlorine. To avoid or reduce the risk of slagging and corrosion, boiler manufacturers have traditionally deterred from applying steam data to biomass-fired plants at the same level as coal-fired plants. However, recent advances in materials and boiler design constitute a breakthrough, and the newest plants have fairly high steam data and efficiencies.

The plants can be down regulated, but due to high initial investments they should be operated in base load.

3.4.5 Data sheets

Technology	**Small steam turbine, Grate firing, Straw combustion**
	2004
Energy / Technical data	
Generating capacity for one unit (MW)	8 - 10
Total efficiency (%) net	88 - 90

Electricity efficiency (%) net 100% load	29 - 30

Stirling engine (developing)	
Input	50-4000 kW
Electrical efficiency	25-35%
Total efficiency	92-96%
Organic rankine cycle (developing)	
Input	200 – 5000 kW
Electrical efficiency	20-28 %
Total efficiency	93-98 %
Indirect fired gas turbine (experimental)	
Output	4-40 MW
Electrical efficiency	30-38%
Total efficiency	90%

3.5 Biomass Gasification Power Generation

This covers downstream and counter stream fixed bed gasifiers, 2-step and fluid bed gasifiers.

3.5.1 Brief technology description

Solid fuel is converted to a combustible gas by warming with limited air supply in a ceramic lined reactor.

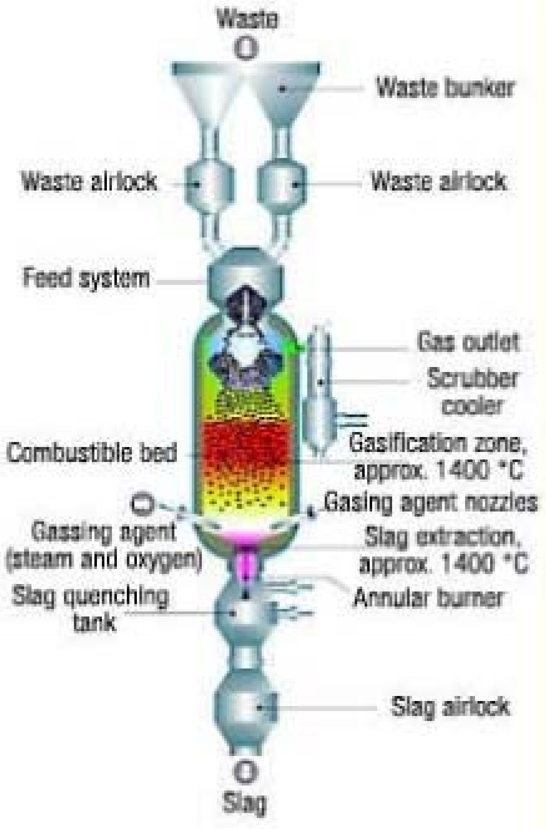


Figure 7 Picture source: Miljøstyrelsen/Danish Environtment protection Agency

3.5.2 Input/output

Wood chips, wood pellets, chunk wood, and possibly straw in fluidbed or 2-step gasifiers. For supply chains se Fig. 1 and 2.

The gas contains CH_4, H_2, CO, CO_2, N_2, H_2O and tar components. Lower heating value is 4,5-6,2 MJ/m^3.

Typical capacities
Downstream 0.2 - 5 MW
Counter stream 2 - 50 MW
Fluid bed 5-100 MW
Pressurized fluid bed 20-500 MW
Two step gasifiers 1-2 MW
Usually there is no flue gas cleaning on the gas engines. In some cases there may be a CO catalyst.

Ash related issues are similar to combustion processes.

The majority of gasification plants in Denmark are not yet competitive in terms of cost.

3.5.3 Utilization status

A lot of activities remain. Tar reduction is a main target but can be solved by externally gas cleaning measures.

Examples of best available technology
The all new Skive gasifier is Europas largest at 28 MW and uses a fluid bed gasifier (not yet fully operational)
The Harboøre demonstration gasifier has 100000 hours of operation.

Babcock Willcox Vølund has resently commissioned two commercial operated gasifiers for Japan.

Other demonstation and experimental gasifiers include: Gjøl, Græsted, Ansager and more.

3.5.4 Brief assessment

The main advantage is that electricity production can be achieved from small biomass based units.

Output can be adjusted quickly. The load range is quite broad.

The main problem is gas cleaning in terms of tar and particles that will otherwise harm the engines.

3.5.5 Data sheets

Technology	**Gasifier**
Energy / Technical data	
Generating capacity for one unit (MW)	0.1-28 MW
Total efficiency (%) net	100-105% (with flue gas condensation)
Electricity efficiency (%) net – 100% load	20-30%

3.6 Municipal solid waste incineration for power generation

This covers solid waste fired CHP plants

3.6.1 Brief technology description

Waste is burned in a grate furnace connected to a steam boiler with steam turbine generator.

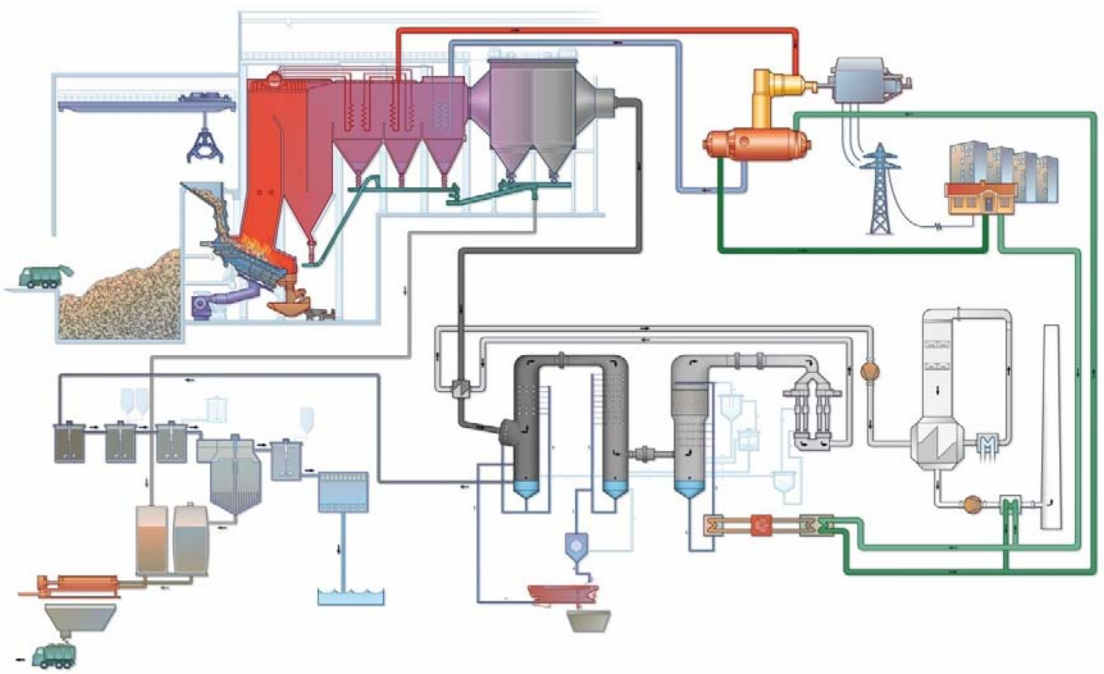


Figure 8 Picture Source: www.affaldsinfo.dk

3.6.2 Input/output

The input is combustible municipal solid waste and fuel oil.

Waste treatment in Denmark is an integrated system of waste prevention, waste collection, waste fractioning, recycling and disposal. Waste is first fractionized at the source then collected by trucks.

Harmful substances such as PVC, electronic equipment and halogenated treated wood should be avoided if possible.

Apart from electricity and heat the output also contains a significant amount of non combustible rest products. This amounts to 0.55 million tons of 2.9 million tons total combustible waste (19%).

Flue gas cleaning is essential and represents a large portion of the plant cost.

3.6.3 Utilization status

There are 32 operational plants in Denmark.

Examples of best available technology
Vestforbrænding 500000 ton/yr
Amagerforbrænding: 400000 ton/yr
Affaldscenter Århus 200000 ton/yr
KARA 160000 ton/yr

3.6.4 Brief assessment

There are significant benefits from incineration, however it should not be chosen as an alternative to recycling.

Extreme care should be taken to control dioxins emissions from incineration.

3.6.5 Data sheets

Technology	**CHP Waste incineration**
	Vestforbrænding
Energy / Technical data	
Generating capacity for one unit (MW)	17 MW electric 75 MJ/s heat
Total efficiency (%) net	87%
Electricity efficiency (%) net – 100% load	20%

4. Biogas technology

4.1 Biogas large scale

This covers municipal biogas projects receiving manure from several farms.

4.1.1 Brief technology description

Manure, organic waste and other biomass is converted to gas via natural bacteriological processes without oxygen supply.

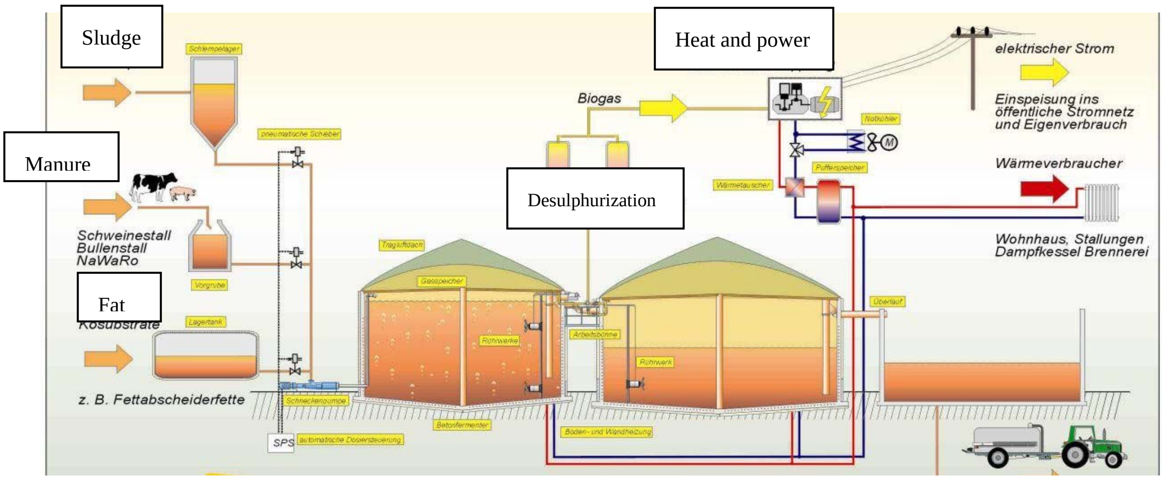


Figure 9 Picture source: Glitz-Ehringhausen Biogas Plant (Germany)

About 50% of dry matter can be converted to gas. It is not economical to convert higher percentage due to residence time. It is important to note, that system efficiencies are based on produced gas, not total heat value of manure.

4.1.2 Input/output

1 ton of manure typically generates 22 m^3 of gas.
1 m^3 of gas equals 21-23 MJ.
1 ton of manure generates roughly 500 MJ.
1 cow generates 22 tons of manure per year
1 feeding pig generates about 0.5 tons of manure per year
1 brood sow with pigs generates about 5 tons of manure per year

It is important that water percentage in manure is not increased due to rain water or water spillage in stables.

Capital cost of large plants is favorable compared to smaller units.

Manure is transported from farms to biogas plant with trucks. Residues are used as fertilizer.

4.1.3 Utilization status

There are about 20 large plants in Denmark each serving several farms.
They produce about 64 million m^3 of gas per year, which is 80% of total biogas production.

Total input is 1.3 million tons of manure and 0,3 million tons of organics waste per year.

Total output from manure is about 0.6 PJ while potential is 26 PJ (3% of national energy demand). Total output from organic waste is about 1.4 PJ while potential is 10 PJ (1% of national energy demand).

This input/output covers both small and large plants. Large plants account for about 80%.

Examples of best available technology are Blåbjerg, Århus, Lemvig, Studsgård, Ribe and Thorsø bio gas plants.

4.1.4 Brief assessment

The technology is quite mature. Most large plants are stable in operation.

A sound operational economy can be difficult to maintain without direct or indirect subsidies. However CO_2 displacement cost is judged to be relatively low. Electricity produced from biogas is currently rewarded with a premium tariff of 0.6 DKK/kWh.

There are benefits in term of reduced odor, enhanced fertilization, and reductions in methane and CO_2.

There is a total biogas potential of about 4% of national energy demand.

4.1.5 Data sheets

Technology	**Biogas plant**
	Municipal serving several farms
Energy / Technical data	
Gas output	1250 - 15000 m^3 gas per day 29 - 345 GJ/day 0.3 – 4.0 MW
Total efficiency (% of produced gas)	80-90%
Electricity efficiency (% of produced gas)	30-38%
Electricity output	0.1 - 1.5 MW
Heat output	0.1 - 2.0 MW

4.2 Biogas medium scale

This covers farm scale biogas plants.

4.2.1 Brief technology description

Manure is converted to gas via natural bacteriological processes without oxygen supply.

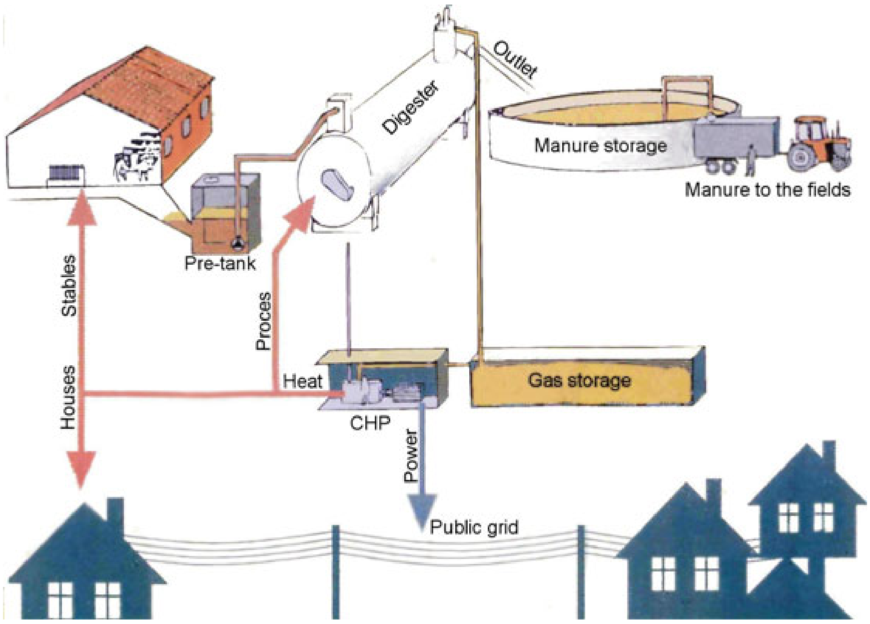


Figure 10 Picture source: Nordic Folkecenter for Renewable Energy

4.2.2 Input output

The input is manure from the farm itself. No extra transportation is needed.

4.2.3 Utilization status

There are about 50 individual farm scale plants in Denmark. They produce about 16 million m^3 of gas per year which is 20% of total biogas production.

4.2.4 Brief assessment

Farm scale biogas projects are not financially viable themselves. However a combination of subsidy schemes allows sound operational economy.

There are benefits in term of reduced odor, enhanced fertilization, and reductions in methane and

CO_2.

There is a total biogas potential of about 4% of national Danish energy demand.

Reference examples of best available technology are available from Xergi, Lundsby and Bioscan.

4.2.5 Data sheets

Technology	**Individual Biogas plant**
	Serving one farm
Energy / Technical data	
Gas output	75 - 1250 m^3 gas per day 1.7 - 29 GJ/day 20 - 300 kW
Total efficiency (% of produced gas)	80 - 90 %
Electricity efficiency (% of produced gas)	25 - 30 %
Electricity output	6 - 100 kW
Heat output	11 – 170 kW

4.3 Biogas household

This covers single family biogas units, smaller than single farm scale.

4.3.1 Brief technology description

Small biogas units have been developed for 3rd world countries.

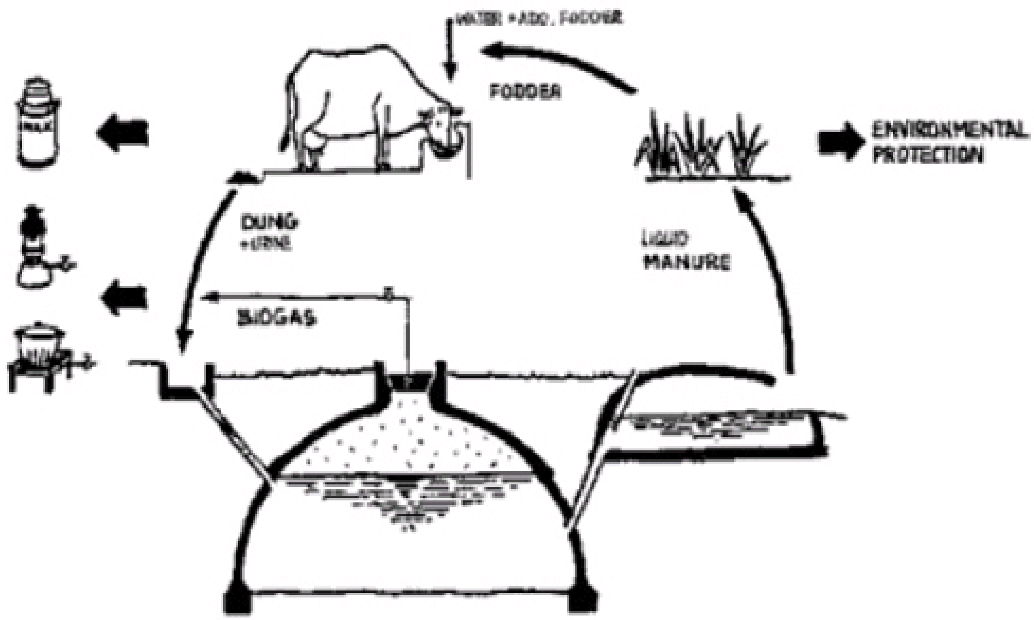


Figure 11 Picture source: Øko-net

4.3.2 Input/output

The units use manure and household waste. No transport is needed. Capital cost is very low.

4.3.3 Utilization status

There are no household biogas units in Denmark, except for farm scale plants.

4.3.4 Brief assessment

Denmark has a well organized waste collection from households, and a good energy infrastructure, so there is no need for household biogas projects. Farms, as opposed to households, are relatively big in Denmark, so they need medium size units.

Examples of available technology: Supergas Project, Cambodia and Sustainable energy Project, Karatu Tanzania.

4.3.5 Data sheets

Not available.

4.4 Landfill gas

This covers gas collection from existing landfills or established with new landfills.

4.4.1 Brief technology description

Waste containing biodegradable organic fractions while stored under oxygen poor conditions will slowly release biogas containing 45-60 % methane.

Gas is collected through a system of perforated plastic pipes drilled into the landfill. It is possible to collect about one third of the gas.

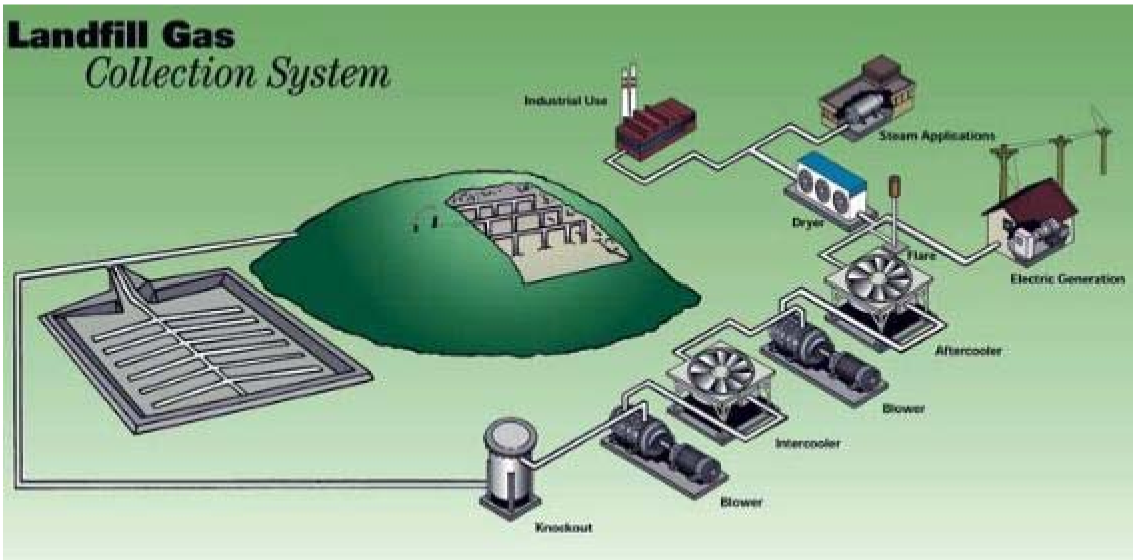


Figure 12 Picture source: City of Ann Arbor, USA

4.4.2 Input/output

1 ton of deposited waste will effectively generate 1.5 - 4.0m^3 of collected gas per year.

The average heating value of the gas is 16 MJ/m^3.

There is no altered supply chain for the landfill. Residues remain at the landfill.

The projects are not necessarily economically attractive.

4.4.3 Utilization status

There are 10 landfill gas projects in Denmark.

4.4.4 Brief assessment

The technology is operational.

Potential in Denmark is 1PJ, about 0.6 PJ is realized. Potential is 0.1% of national energy demand.

4.4.5 Data sheets

Technology	**Landfill gas**
Energy / Technical data	
Gas output	1000 - 25000 m^3 gas per day 16 - 400 GJ/day 0.2 – 4.6 MW
Total efficiency (% of collected gas)	80 - 90 %
Electricity efficiency (% of collected gas)	30 – 38 %
Electricity output	0.1 – 1.7 MW
Heat output	0.1 – 2.0 MW

5. Biofuel technology

5.1 Fuel ethanol from glucose or amylum (starch)

This covers in principle both glucose and amylum processes.

5.1.1 Brief technology description

The starch in wheat, corn, sugar canes etc. is fermented by bacteria into alcohol (ethanol). After fermentation the water and ethanol is separated by distillation. The schematic shows a general overview of production based on starch, and cellulose (dark area). However cellulose is treated separately in chapter 0.

The amylum process is basically the same as the glucose process apart from the cooking and enzymes used to split amylum into glucose.

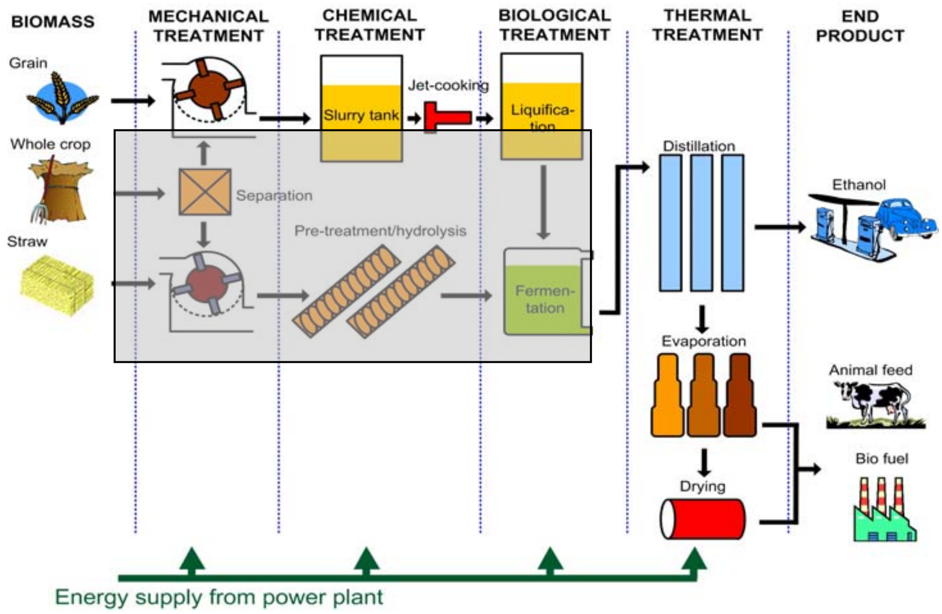


Figure 13 Picture source: ELSAM / DONG Energy

The total energy input necessary to grow and process bio ethanol crops is about equal to the energy content (heating value) of the fuel. However gasoline also requires energy to produce, so a common perception is that bio ethanol saves about half the input energy compared to gasoline.

5.1.2 Input/output

Input is wheat, corn, sugar canes etc.

1 ton of corn yields approximately 330kg of ethanol (416 liters).

5.1.3 Utilization status

Ethanol production from starch and glucose is a simple and well known technique that has been used for thousands of years.

Ethanol fuel is used widely in for instance Sweden. Bio ethanol E85 already accounts for 2.5% of fuel for Swedish road transport.

Denmark will use a total of 5% (energy content) combined bio ethanol and bio diesel by 2010.

Brazil has used bio ethanol for cars since the 1970’s. Today there are over 2 million bio ethanol fuelled cars in Brazil.

5.1.4 Brief assessment

The technology is available. However it requires some kind of intervention to compete with fossil fuels. Some scientists have warned against the use of food crops for bio ethanol. This remains a political issue.

5.1.5 Data sheets

Technology	**Bio ethanol plant**
	Based on starch
Energy / Technical data	
Ethanol output	210 tons per day 5600 GJ/day 65 MW
Electrical consumption	2.5 GJ/ton
Heat consumption	15.3 GJ/ton
Heating value of ethanol	26.5 GJ/ton

5.2 Liquid fuel from cellulose

This covers bioethanol production from straw

5.2.1 Brief technology description

Straw consists mainly of cellulose and hemi cellulose bound together by lignin.

First step is to break down lignin and to convert cellulose into amorf cellulose. This is done by wet oxidation in a heated reactor.

Next step is to break down amorf cellulose and hemi cellulose into glucose. This is done by enzymes.

Finally glucose is fermented by yeast cells that produce ethanol.

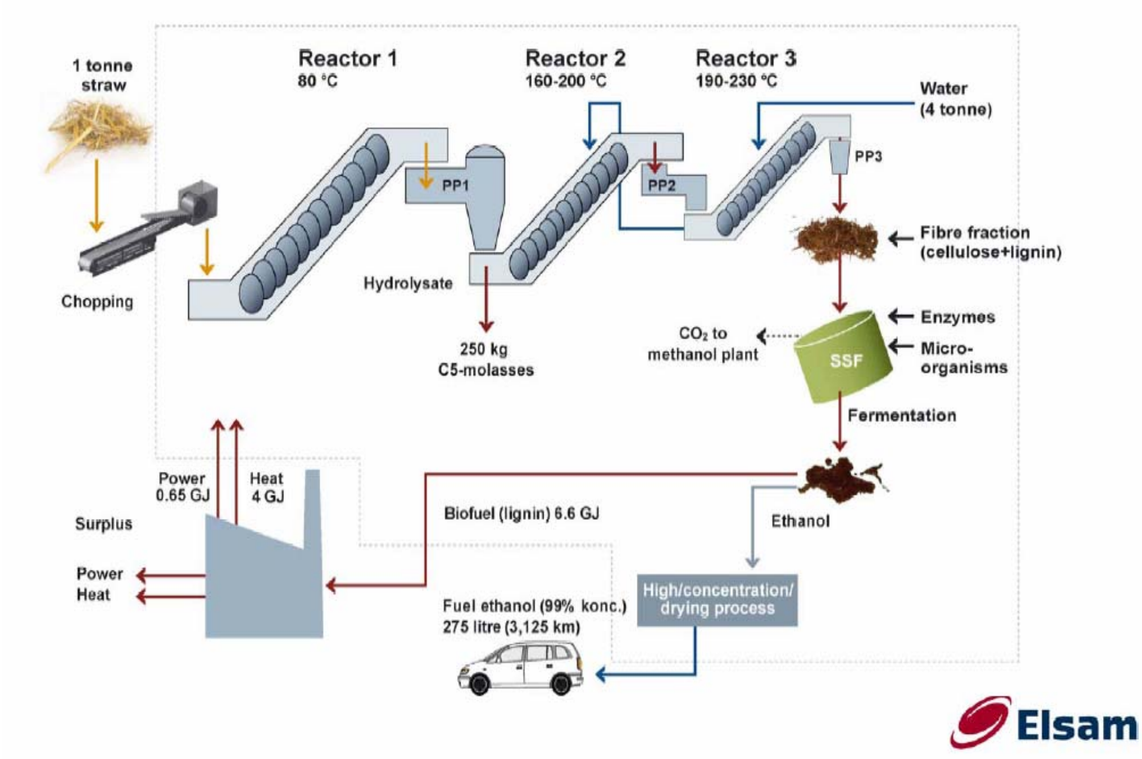


Figure 14 Picture source: IBUS project ELSAM / DONG Energy

5.2.2 Input/output

1 ton of straw will yield approximately 230kg of ethanol (290 liters).

By products include residual lignin and hemi cellulose and other plant components.

The supply chain is similar to Figure 1 and 2.

The capital cost is relatively high compared to starch and glucose processes. Also the energy input is higher. However input fuel is cheaper.

5.2.3 Utilization status

The process is experimental but promising. The problems include acid formation during wet oxidation, which can break down glucose. Furthermore complete decomposition of hemi cellulose is not easily achieved.

5.2.4 Brief assessment

Existing petrol engines can run on 10% bio ethanol without major difficulties. The cost of bio ethanol however has so far been too high.

Bio ethanol from straw may hold a significant potential for the future, since straw is a much cheaper raw material than sugar canes etc.

However the technology is far from mature.

5.2.5 Data sheets

Technology	**Bio ethanol plant**
	Based on cellulose
Energy / Technical data	
Ethanol output	320 tons per day 8600 GJ/day
Electrical consumption	2.9 GJ/ton
Heat consumption	17.5 GJ/ton
Heating value of ethanol	26.5 GJ/ton

5.3 Biodiesel from oil plants

This covers transesterification of rape seed oil or soy bean oil.

5.3.1 Brief technology description

The process called transesterification basically removes glycerin from a vegetable oil by adding methanol.

This results in a product than can be used in traditional diesel engines with only minor modifications.

It is however possible also to run engines on pure vegetable oil without transesterification. This does require engine modifications.

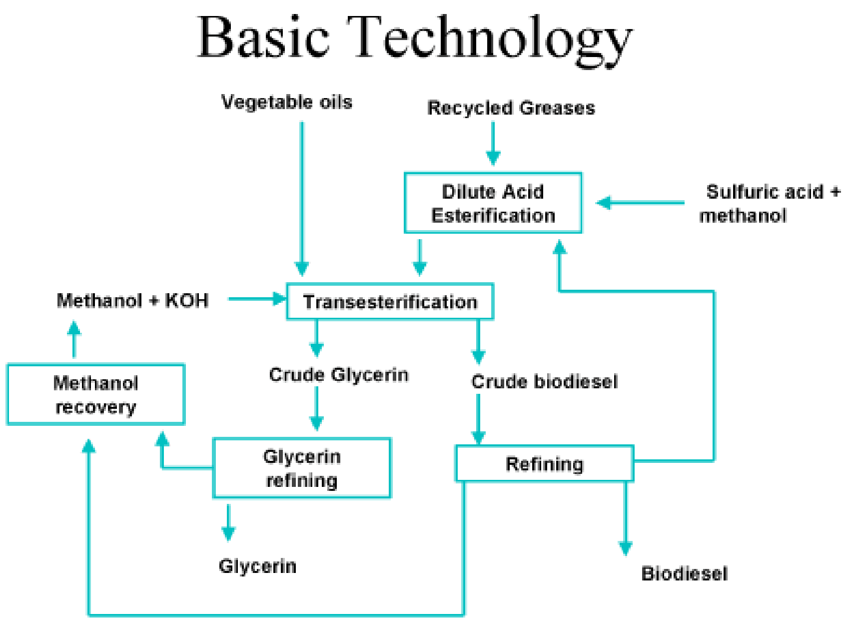
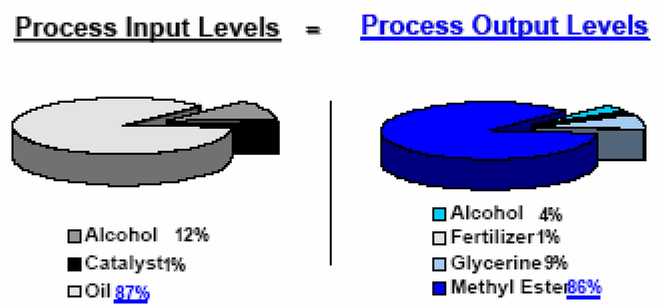


Figure 15 Picture source: US Department of Energy

5.3.2 Input/output

The process input is vegetable oil and methanol. Also recycled grease can be used. Output is mainly methyl ester (bio diesel) and glycerin. 1 input unit of plant oil results in one unit of bio diesel. The oil content of e.g. rape seed is approximately one third of the mass, and represents half the energy content. The rest product can be used as fodder.



Figuree 16 Picture source: www.biodiesel.org

KOH (or NaOH) is used as a catalyst. SO_3 is used to refine recycled grease before transesterification.

It is estimated that total energy input used to grow, harvest and process oil crops is about one third of the energy content (heating value) of the bio diesel.

The supply chain involves raw material growth, harvesting and transportation, oil extraction and transesterification, and final distribution like fossil diesel.

A plant with a yearly production of e.g. 215 000 tons will need to receive approx 100 trucks a day.

Typical capacities are 10-900 m^3 per day.

5.3.3 Utilization status

Bio diesel is widely used in Germany, Austria and the USA.

5.3.4 Brief assessment

The technology is quite mature. Fuel process plants and running vehicles are available. The main problem is that traditional bio diesel is made from high value crops that are sensitive to growing conditions. So the socio-economic and ecological impact is a complex matter.

Most scientists agree that second generation bio diesel made from waste material is a valuable potential resource.

5.3.5 Data sheets

Technology	**Bio diesel plant**
Energy / Technical data	
Rape seeds input	300 000 tons/year
Rape seed oil input	100 000 tons/year
Methanol input	40 000 tons/year
Total input	440 000 tons/year
Fodder material output	190 000 tons/year
Glycerin output	30 000 tons/year
Bio diesel output	215 000 tons/year
Useful output	435 000 tons/year
Energy input	3.67 GJ/ton
Heating value	39.6 GJ/ton

5.4 Pyrolytic oils

This covers oil production from pyrolysis of wood.

5.4.1 Brief technology description

When quickly heating biomass to about 500°C without oxygen supply a pyrolysis gas is formed which contains about 75-80% of the heating value of the input fuel.

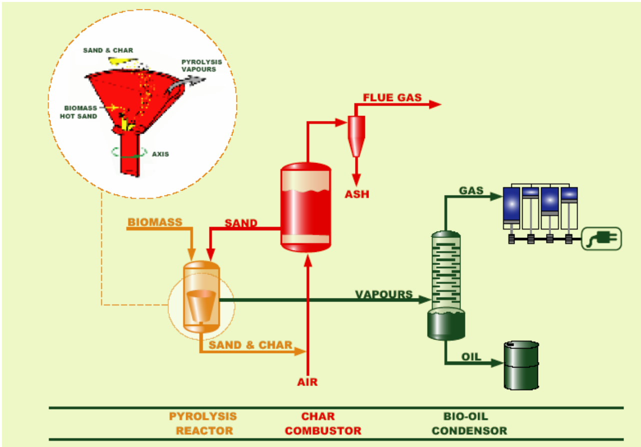


Figure 17 Picture source: BTG, Netherlands

5.4.2 Input/output

Is subsequent cooling is done rapidly the gasses will condense into an oily tar like product called pyrolysis oil. About 60-70% of the energy remains in this oil. Charcoal and gas are by products.

The supply chain for raw material could resemble Figure 2. The product could then be distributed with tank trucks.

Capital cost is expected to be higher that gasification plants due to the necessary gas cooling process.

5.4.3 Utilization status

The stage is experimental although research shows no major difficulties in the process itself. However gas cleaning before condensation is an important issue because the gas contains solid particles. Another problem is that pyrolysis oil is strongly acidic compared to mineral oils.

5.4.4 Brief assessment

Pyrolysis oil is faced with strong competition from other technologies. For boiler/burner applications direct burning is much less complicated. For on-site engine applications gasification is less complicated. For distributed use bio ethanol is a promising alternative.

I any case, pyrolysis oil is not a commercial technology.

5.4.5 Data sheets

Technology	**Flash pyrolysis plant**
	1 MW Experimental
Energy / Technical data	
Wood input	250 kg/hour
Gas output	37 kg/hour
Oil output	175 kg/hour
Char output	37 kg/hour
Lower heating value of oil	15.5 MJ/kg

6. Biomass compressed fuels technology

6.1 Compressed fuels

This covers wood pellets, straw pellets and briquettes.

6.1.1 Brief technology description

Sawdust and cut straw is compressed mechanically into pellets and then distributed.

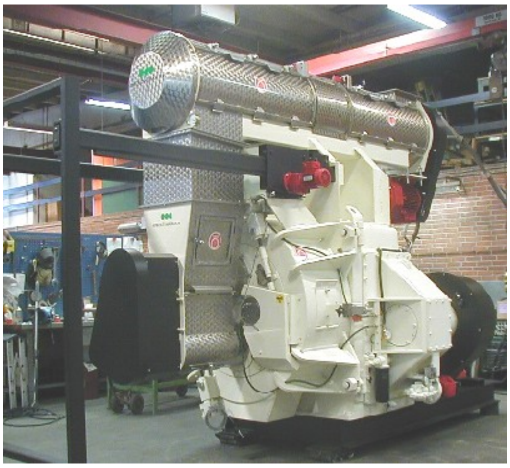


Figure 18 Picture source: Andritz AG

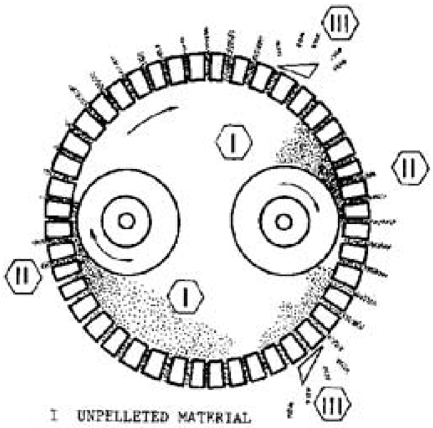


Figure 19 Picture source: Feedmachinery.com

The bulk density of pellets is 650 kg/m^3 whereas wood chips weigh about 200 kg/m^3. A high density is an advantage in distribution.

The main advantage of compressed fuel is that firing is fully automatic even at household scale, whereas household firing with straw bales and firewood is a manual task.

6.1.2 Input/output

Input is mainly sawdust or crushed wood but also straws, whole crops, shells, nuts and kernels can be compressed.

Output is pellets or briquettes.

The compression process requires about 1.5% of the energy content in the fuel.

Distribution of compressed fuel is done in same way as fodder pellets i.e. in sacks and bags or by pneumatics. Also see Figure 1-Figure 2.

6.1.3 Utilization status

The total use of wood pellets in Denmark is 730 000 tons which is about 2% of national energy use

The Avedøre CHP Plant uses 260 000 tons of wood pellets per year. A number of smaller heat and power plants also uses wood pellets or straw pellets.

50% of all wood pellets are used by heat and power plants, while 43% is used in private heating boilers and stoves.

The growth rate in wood pellet consumption was 82% from 2001 to 2004.

Complete production lines for wood pellets are available from e.g. Andritz AG.

6.1.4 Brief assessment

Compressed fuels are probably the best way of distributing solid bio fuels to small scale users. The technology for heat production is quite mature while small scale electricity production is at the development stage. Power plants of any size can also use compressed fuel but wood chips and big straw bales may be cheaper.

6.1.5 Data sheets

Technology	**Compressed fuel mill**
Energy / Technical data	
Capacity	800-5000 kg/h
Electricity consumption, power	50-350 kW
Electricity consumption for pelletizing	50 - 250 kwh/ton pellets
Drying of raw material before pelletizing	0 – 500 kwh / ton pellets
Fuel heating value	4850 kwh/ton

7. Biofuel heating technology

7.1 Small Heating plants

This includes individual household boilers, cookers and stoves below 1 MW.

7.1.1 Brief technology description

The units are based on direct burning. Firing is done automatically with compressed fuel, grains, seeds, shells, cut straw or wood chips, or manually with firewood and straw bales.

Figur 20 Picture source: BAXI

7.1.2 Input/output

Fuels are Wood logs, wood chips, straw bales or compressed fuels. Supply chains are mainly like Figure 2, however in many cases fuel is produced locally.

Some manually fired units can work without electricity supply.

Output is heat in the form of hot air for direct room heating, cooking or baking heat or central heating. Electricity producing units are not yet commercial.

Capital cost is very low due to the simplicity.

Ash can be spread as fertilizer or collected to landfills.

Flue gas cleaning facilities for small scale units are mostly experimental and almost certainly too expensive.

7.1.3 Utilization status

In Denmark there are about 75 000 biomass boilers for central heating and 500 000 room heaters for wood.

Automatic stoves and boilers for compressed fuel are rising in popularity, mainly due to high oil prices.

7.1.4 Brief assessment

The technology is quite mature and the variety of products is huge.

In areas without district heating it is the primary alternative to oil and gas.

7.1.5 Data sheets

Technology	**Small central heating boiler**
Energy / Technical data	
Total efficiency	75-85 %
Electricity efficiency	0 %
Electricity output	0 kW
Heat output	15 - 300 kW

7.2 Industrial Heating and steam plants

This includes steam boilers and hot water boilers up to 20 MW for industry and for institutions.

7.2.1 Brief technology description

Basically this is a traditional industry boiler fitted with bio fuel stoking system.

Figure 21 Picture source: Danstoker

7.2.2 Input/output

Wood chips, cut straw or compressed fuel. Out put is hot water or steam.

7.2.3 Utilization status

Industry and public buildings use about 8% of total wood pellet consumption, about 1 PJ.

The number of bio fuel industrial steam boilers actually installed in Denmark is inhibited due to relatively low oil and gas prices for industries.

Examples of best available technology:

- Velfac A/S, Ringkøbing. 2x950 kW hot water boiler
- Gangsø Furniture, Fårvang. 950 kW hot water boiler

7.2.4 Brief assessment

The technology is quite mature. Although this technology does not produce electricity it saves oil and coal just like an electricity producing plant.

7.2.5 Data sheets

Technology	**Industrial steam boiler**
	Wood chips
Energy / Technical data	
Total efficiency	90 %
Electricity efficiency	0 %
Electricity output	0 MW
Heat output	0.07 – 15 MW

7.3 District heating plants

This includes district heating plants from 1-50 MW. They are mostly grate fired.

7.3.1 Brief technology description

The plants are hot water boilers based on direct burning. The fuel handling and firing systems are mechanical. Different grate systems are used.

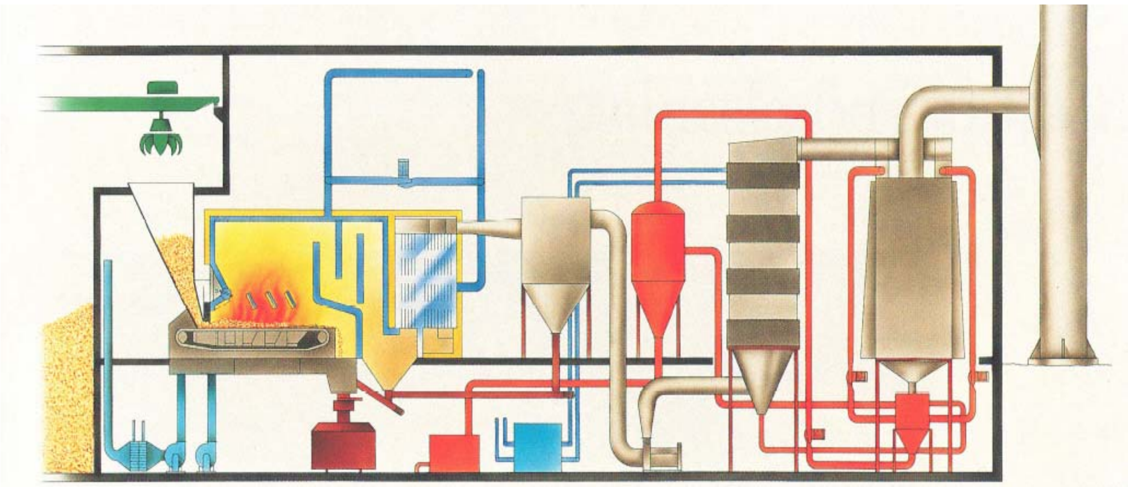


Figure 22 Picture source: Kibæk Varmeværk, Babcock Wilcox Vølund

7.3.2 Input/output

Fuels are big straw bales, wood chips or compressed fuel. Supply chain like Figure 1 and Figure 2.

They produce heat (for district heating) and no electricity.

7.3.3 Utilization status

The smallest plant size is normally private owned and referred to as neighbor heating. This typically serves 2-10 households. Larger plants serve typically 3000 households.

There are approx. 100 public biomass fired district heating plants without electricity production and approx. 20 neighbor heating plants.

Examples of best available technology:

- Ringe District Heating, 4350 kW hot water boiler, wood pellets
- Assens District Heating, 3600 kW hot water boiler
- Farsø District Heating, 6000 kW

7.3.4 Brief assessment

The technology is quite mature and commercially available. Using straw as fuel increases handling cost due to its low density. There may also be dust and odor problems from straw firing depending on the type of gas cleaning.

7.3.5 Data sheets

Technology	**Straw fired district heating plant**
Energy / Technical data	
Heat Output	0.4 - 10 MW
Total efficiency	80 - 90 %
Electricity efficiency	0 %
Electricity output	0 MW