

Part 1. Benefit of biomass utilization

1.1 Benefit of Biomass

1.1.1 What is biomass?

Generally biomass is the matter that can be derived directly or indirectly from plant which is utilized as energy or materials in a substantial amount. “Indirectly” refers to the products available via animal husbandry and the food industry. Biomass is called as “phytomass” and is often translated bioresource or bio-derived-resource. The resource base includes hundreds of thousands of plant species, terrestrial and aquatic, various agricultural, forestry and industrial residues and process waste, sewage and animal wastes. Energy crops, which make the large scale energy plantation, will be one of the most promising biomass, though it is not yet commercialized at the present moment. Specifically biomass means wood, Napier grass, rape seed, water hyacinth, giant kelp, chlorella, sawdust, wood chip, rice straw, rice husk, kitchen garbage, pulp sludge, animal dung etc. As plantation type biomass, eucalyptus, hybrid poplar, oil palm, sugar cane, switch grass etc. are included in this category.

According to Oxford English Dictionary, it was in 1934 that the term “biomass” appeared first in the literature. In Journal of Marine Biology Association, Russian scientist Bogorov used biomass as nomenclature. He measured the weight of marine plankton (*Calanus finmarchicus*) after drying which he collected in order to investigate the seasonal growth change of plankton. He named this dried plankton biomass.

Biomass is very various and the classification will be reviewed in 2.(1). Biomass specifically means agricultural wastes such as rice straw and rice husk, forestry wastes such as sawdust and saw mill dust, MSW, excrement, animal dung, kitchen garbage, sewage sludge, etc. In the category of plantation type, biomass includes wood such as eucalyptus, hybrid poplar, palm tree, sugar cane, switch grass, kelp etc.

Biomass is renewable resource and the energy derived from biomass is called renewable energy. However, biomass is designated as new energy in Japan and this naming is a legal term peculiar to our country. Law concerning promotion of the use of new energy was enforced in April of 1997. Though biomass was not approved as one of new energies at this moment,

biomass was legally approved when the law was amended in January of 2002.

According to the Law, power generation by photovoltaics, wind energy, fuel cell, wastes, and biomass as well as thermal use of waste are designated as new energy. Legally new energy is provided by the law what should be the production, generation, and utilization of petroleum alternatives, what is insufficiently infiltrated by the economic restriction, and what is specially prescribed in order to promote the use of new energy by the government ordinance. In foreign countries, biomass is usually called and designated as one of renewable energies.

Many studies have suggested that biomass-derived energy will provide a greater share of the overall energy supply as the price of fossil fuels increase over the next several decades. The use of biomass a source of energy is very attractive, since it can be a zero net CO₂ energy source, and therefore does not contribute to increased greenhouse gas emission. It is carbon neutrality of biomass, which is precisely described in 1.(2). The combustion of biomass energy results in the emission of CO₂, however, since nearly all of the carbon in the fuel is converted to CO₂, just as it is during the consumption of fossil fuels. The zero net CO₂ argument relies on the assumption that new trees, or other plants, will be replanted to the extent that they will fix any CO₂ released during the consumption of biomass energy. This may well be true for the properly managed energy plantations, but is not likely to pertain in many developing countries where most of the biomass energy is obtained from forests which are not being replanted, at least not to the same degree that they are being harvested.

The widespread expansion of biomass energy use may result in significant concerns about availability of land, which may otherwise be used for food production, or other commercial use such as timber production. Recent reports showed that a wide range of estimates of future biomass energy potential, ranging from the current level of approximately 42 EJ to nearly 350 EJ close to the current level of total energy production by the year 2100. Consequently, it is desired that biomass energy should be wisely utilized in accordance with the food or valuable material production as well as environmental preservation.

Biomass is quite various and different in its chemical property, physical property, moisture content, mechanical strength etc. and the conversion technologies to materials and energy are also diversified. Researches which make it possible to develop cost effective and environmentally friendly conversion technologies have been done to reduce the dependence on fossil fuels, to suppress CO₂ emission, and to activate rural economies.

1.2 Characteristics of Biomass

1.2.1 General scope

Biomass resource can be utilized substantially in endless number of times, on the basic rail of carbon circulation by photosynthetic process. On the other hand, a fossil resource is limited to a transitory use in principle. Additionally the irreversible emission of CO₂ caused by fossil combustion gives serious influence on global climate (Fig. 1.2.1). R.= resource.

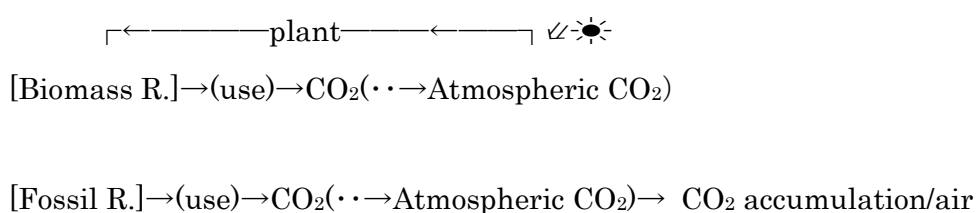


Fig. 1.2.1. Comparison of biomass and fossil system on Carbon cycling.

But the words “renewable” and “sustainable” are not always same meaning. The recycling power of plants is founded on a very delicate base of ecosystem.

The conditions for the bio-system are, maintaining the balance of harvest vs.growing speed, and the environment protection of the farming land. If not, long term sustainability of the biomass system will be fading out.

1.2.2 Renewable

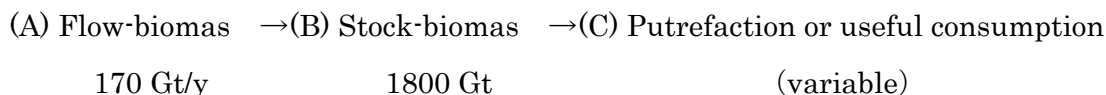
There are two kinds of energy resource: (1)exhaustible resource (=stock type) and (2)renewable resource(flow type; such as solar-,wind-, hydraulic power and biomass). A flow stock is infinitely large, but it should be limited within a given period of time. Excessive utilization such as a deforestation cannot sustain a renewable production system. Biomass has both types of resources.

(A) Flow type Biomass. The net primary productivity 170 Gt/yr (about 7 times as much as world energy demand)

(B) stock type Biomass. Mainly in forest; 1800 Gt (about 80 times as much as world energy demand/yr)

Biomass consumption (C) has two variations, putrefaction and utilizing consumption. In

natural forest, there are nearly equal amounts of growing and the putrefaction, the equilibrium (A)=(C) would be established.



Although we cannot realize (C)>(A), it is capable to get a bigger share of biomass utilization in the distribution among (C), by our policy and technology.

1.2.3 Carbon neutral

Biomass fuel also emits CO₂ by the combustion. But people permit a CO₂ indulgence for biomass, because of the CO₂ absorption during the growing process.

That is, [CO₂ emission] = [CO₂ fixation by the growing process]. However, coal also has a biomass-originated history, the carbon is circulating in long term, several hundred million years. Then under the consideration of term of CO₂-repayment, CO₂ immunity rate should be estimated.

Just after the biomass combustion, none can pay back its CO₂. Therefore, it is estimated that a temperate forest (about 25 years for regeneration time) acquires [CO₂ immunity rate=1], as a standard. At subpolar forest, the regeneration time =100 years case, the immunity rate becomes [25/100=0.25]. In the case of brown coal (the origin was 25 million years before), this immunity rate is only 1 ppm. So fossil fuel has no hope to get the effective CO₂ indulgence.

1.2.4 Sustainable agriculture

At the fuel production from biomass resource, much energy input (E_i) from outside is necessary for the producing process. In addition, a part of biomass becomes biomass waste (E_w) (Fig. 1.2.3). For a energy production system, [E_z-E_i-E_w] should be higher than zero at least. E_z: the gained bio-fuel energy.

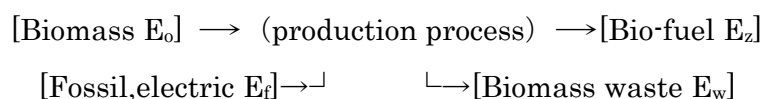


Fig. 1.2.3. Biomass energy balance for the income and expense.

Total energy yield in this system is shown as $E_z/[E_o + E_f]$, if the value is lower than 0.5, the biomass is merely auxiliary fuel. But even small part of biomass can contribute to new energy system if energy balance ratio (products/invested fossil fuel) is over than 1, in the case of coal-biomass mixed combustion generation. When biomass waste can substitute a fossil fuel in the system, the E_f is so decreased that the energy balance ratio is much improved. The typical success example is found at cane sugar industry which uses bagasse as an alternative fossil fuel. Biomass production system with inferior energy balance ratio often loses its carbon-neutral sustainability. In agriculture, production of grain and potatoes, the energy balance ratio is about 1.5~5 (neglected man-power calculation), while lower than 0.5 in almost vegetables that is on loss-making railroad line. In this point, forestry is more excellent than agricultural crops because of a little cultivation energy.

(a) Man-power investment. Increasing of man-power is often able to cut down a fossil and/or electric energy consumption, causing an improvement of apparent energy balance ratio. However, man-power and fossil energy has a trade-off relation. Energy unit for man-power is estimated by 0.073 toe/yr/man (biological standard)~1 toe/yr/man (total life consuming). Labor intensive production often gives a faked saving energy system.

(b) Cycling of N,P,K. N (nitrogen), P (phosphorus), and K (potassium) are main components of fertilizer. They so often disappear by exploitative production that a recycling system is necessary to hold N,P and K in soil. At a woody thermal power station, it is necessary to return the ash for sustaining P and K. Component N cannot stay in the ash, so another N-supply route is indispensable to restore the system. Exceptionally, traditional forestry need not any fertilizer because there is sufficient nitrate-N from rain. But future energy forestry will demand N-fertilizer because the N-balance will collapse.

(c) Conservation of biodiversity. Biodiversity is often fragile by enhancing a biomass production according to the uniformity, the large scale farm, and the intensive process. For example, mixed cropping like agroforestry, is hopeful to have a sustainable soil conservation.

Further information

Sano,H.in “Biomass Handbook”, Japan Institute of Energy Ed., Ohm-sha, 2002, pp.311-323. (in Japanese)

UN Energy “Sustainable Bioenergy: A Framework for Decision Maker”, 2007.

1.3 How to Use Biomass

1.3.1 General scope

For the utilization of biomass, a raw biomaterial is selected among various kinds of biomass by taking into consideration of its utilization purpose, demand and availability. Then, the raw material is converted to new material or energy.

Biomass as bioresource comes mainly from plants and their debris. Animals and microorganisms as well as their organic matters are also important. Many species of plants are useful as biomass. Land biomass mainly consists of herbal biomass from major farm crops, and woody biomass from forest. Many of them are cultivated, converted and utilized for specific purposes. Aquatic biomass from oceans, lakes and rivers can also be cultivated in such a case as kelp. Biomass which is cultivated on farm land or felled from forest for specific purposes is called virgin biomass, whereas the discarded biomaterials in production, conversion and utilization processes are named waste biomass and used for other purposes. For example, bagasse which is the waste of sugarcane processing is used as excellent fuel for the sugar extraction and ethanol distillation processes. Utilization of waste biomass is also important for avoiding the conflict of bioenergy utilization with food and feed. Bagasse is also considered as one of the major raw materials for “the second-generation biofuel”.

Transportation and storage of biomass is not easy because of its bulkiness and degradation. It is, therefore, reasonable to use biomass in the areas where it is produced. For this reason, biomass is used in or nearby regions where biomass supply and demand are balanced. However, when biomass is converted into more transportable form like densified pellet or liquid fuels, it can be utilized in distant regions.

Biomass can be used either as materials or energy. Biomass is utilized as diversified materials such as food, feed,

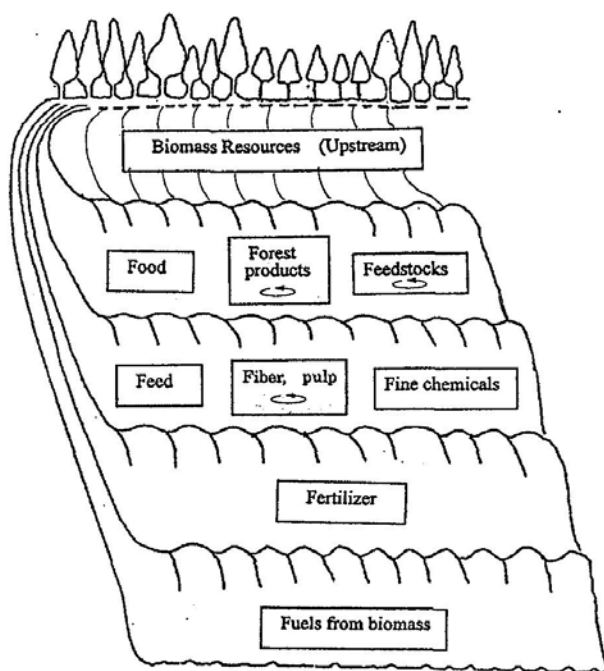


Fig. 1.3.1. Cascade use and recycling of biomass.

fiber, feedstock, forest products, fertilizer and fine chemicals. Utilization as energy in the form of biofuels occurs on the final stage and biomass is decomposed into carbon dioxide or methane and emitted in the air. The diversified use can be called "8F Use" of biomass.

Biomass can be used stepwise like a cascade as its quality is degraded. Fig. 1.3.1. illustrates examples of cascade use of food to feed and then to fertilizer.

Food waste can be treated into good feed. Feed changes into livestock manure which can be fermented into methane. The digested sludge can be used as fertilizer. Forest products such as wood from pulled down houses can be utilized as particleboard or pulp, and as the final step, it can be converted into energy through the combustion of bio-solid fuel.

Recycling is made for paper, fiber, some feedstock and wood products as shown with round-arrows in Fig. 1.3.1. So far as biomass is used as material, its carbon is kept in the material and does not emit any greenhouse effect gas contributing to reduce the ill effect of global warming.

1.3.2 Conversion and utilization

There are many conversion technologies available for changing the quality of biomass to match its utilization purposes. They are physical, chemical and biological techniques. Fig. 1.3.2 illustrates typical conversion technologies.

Physical conversion includes milling, grinding and steam explosion to decompose the biomass structure for increasing its surface areas to accelerate chemical, thermal or biological processes. It also covers separation, extraction, distillation etc. for obtaining useful ingredients of biomass as well as densification, drying or moisture control for making biomass more suitable for transportation and storage. Physical conversion technologies are also often used for the pretreatment to accelerate the main processes.

Chemical conversion includes hydrolysis, partial oxidation, combustion, carbonization, pyrolysis, hydrothermal reactions for decomposing biomass, and also synthesis, polymerization, hydrogenation for constructing new molecules or reforming biomass. Generation of electrons in oxidation process of biomass can be used for fuel cells to generate electricity.

Biological conversion is mainly composed of fermentation processes such as ethanol fermentation, methane fermentation, acetone-butanol fermentation, hydrogen fermentation, and enzymatic treatments which will play more important role to bring the second-generation bioethanol on the practical stage. Application of photosynthesis and photolysis processes will be important to improve biomass systems.

Combustion heat of biomass is converted to mechanical power by means of such heat cycles as Otto cycle (for gasoline engine), Diesel cycle (Diesel engine), Rankine cycle (steam engine), Brayton cycle (gas turbine) and others. Electric generator with electromagnetic induction is used to convert mechanical power into electricity.

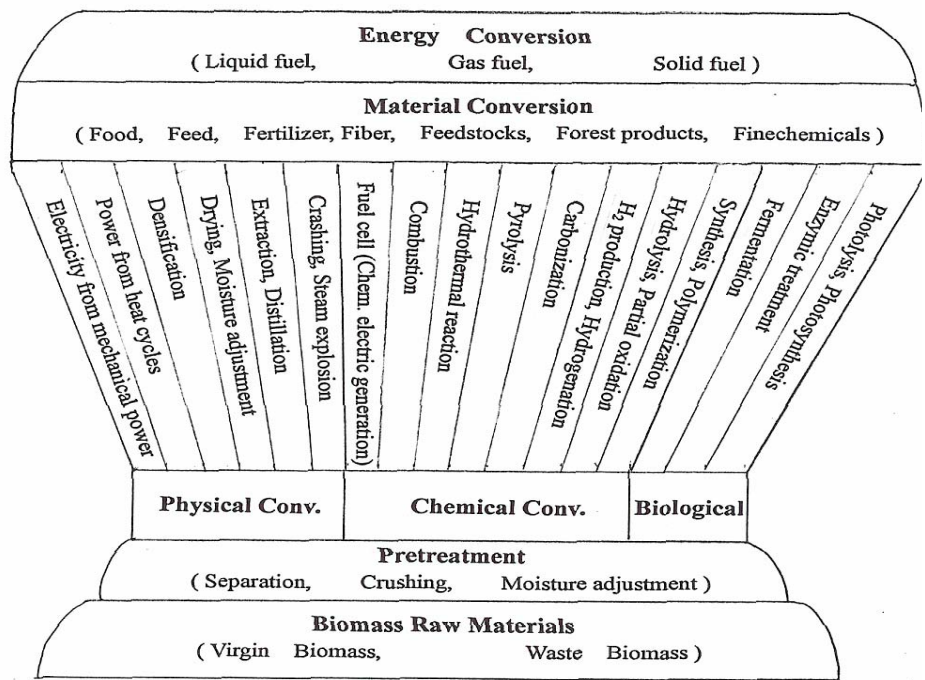


Fig. 1.3.2. Various conversion and pretreatment technologies.

Such pretreatments as separation, extraction, milling, grinding, moisture regulation etc. are often performed before the main conversion processes. Fig. 1.3.2 illustrates so-called a magic box in which biomass is put on the bottom and converted by using various techniques to match its utilization purpose.

Evaluation of the conversion processes is done in terms of product quality, energy efficiency, yield and system economy.

Planning of conversion and utilization system should take the following items into consideration: fluctuation of biomass supply, means and cost of transportation & storage, managing organization and rules which are in harmony with the relevant regulations, as well as the economy of the total system.

1.4 Benefit of Biomass Utilization

1.4.1 General scope

Though energy from biomass is generally not cost-competitive with fossil fuels under current technology and market conditions in many of developed economies, the production of biomass

for materials and energy will produce a variety of benefits. These benefits vary from case to case, however, some noticeable ones include, among others, offsetting greenhouse gas emissions from the combustion of fossil fuels, creating jobs and income through the development of a new industry and the utilization of locally produced raw materials, and enhancing energy security by reducing dependence on imports. Yet, the values of these benefits are far less understood than biomass and bioenergy production costs. Assessing these benefits will provide a more comprehensive picture about the overall competitiveness of biomass and bioenergy, offering implications for bioenergy development and policy formulation.

1.4.2 Oil depletion

Forests and coal resources were in abundance and were sufficient to meet energy demands. However, as human creativity exceeded expectations, producing a more efficient energy technology based on coal and then on oil was needed.

World ultimate conventional oil reserves are estimated at 2000 billion barrels. The global daily consumption of oil equals 71.7 million barrels. It is estimated that around 1000 billion barrels have already been consumed and 1000 billion barrels of proven oil reserves are left in the world (Asifa and Muneer, 2007). The price of petrol and other fuels will rocket with potentially disastrous economic consequences unless people have moved to alternatives to fossil fuels. Increased use of biomass will extend the lifetime of diminishing crude oil supplies. For instance, Carpentieri *et al.* (2005) shows the important environmental advantages of biomass utilization in terms of reduction of natural resource depletion, although an improved impact assessment methodology may better highlight the advantages due to the biomass utilization.

1.4.3 Global warming

Globally, increase in emission rates of greenhouse gases, *e.g.*, CO₂, present a threat to the world climate. As an estimate in the year 2000, over 20 million metric tons of CO₂ were expected to be released in the atmosphere every year (Saxena *et al.*, in press). If this trend continues, some extreme natural calamities are expected such as excessive rainfall and consequent floods, droughts, and local imbalances. Biomass is a carbon neutral resource in its life cycle and the primary contributor of greenhouse effect. Biomass is the fourth largest source of energy in the world after coal, petroleum, and natural gas, providing about 14% of the world's primary energy consumption (Saxena *et al.*, in press). Biomass is being considered as

an important energy resource all over the world.

In order to reduce greenhouse gas emissions from energy consumption, several policy alternatives such as emission taxes and tradable emission permits have been proposed. These mitigation policies are likely to enhance the competitive advantage of biomass energy over fossil fuels as the former can displace CO₂ emissions from the latter. However, it is well understood that the conversion of biomass to bioenergy requires additional energy inputs, most often provided in some form of fossil fuel. The life cycle energy balance of a biomass compared to conventional fossil fuel should be positive, but depending on the processing choices, the cumulative fossil energy demand might, at times, only be marginally lower or even higher than that of liquid fossil fuels. Bioenergy systems should be compared to conventional fuel ones from a point of view of a life cycle basis, or using LCA.

1.4.4 Improving standard of living

Since agriculture is of much importance for the economies under development, it is desirable that sustainable agriculture leads to improvement of farmers' standard of living as well as their income. Education of people is important, since the literacy rate in the rural area of developing countries is expected to be not so high. In this sense, it is important to supply proper information on this technology to the farmers. What is important for the biomass utilization for farmers to be effective is the accessibility of the biomass plant or biomass collecting site from farmers. Even if farmers possess or produce biomass feedstock, it is nothing if they do not have access to the sites where it can be made use of.

1.4.5 Increasing farmers' income

There are mainly two ways to support farmers (The Japan Institute of Energy, 2007). One is to supply energy so that they have the access to useful fuels. In Thailand, small-scale biomethanation provides cooking gas to farmers, so they need not to buy propane gas for cooking. This support to farmers is also effective for sustainable agriculture due to the reduction of fossil fuel utilization. The other support is by cash. When they grow feedstock for ethanol production and sell it at a higher price, they can get money for buying electricity. Since those who use ethanol as fuel are richer compared to farmers, this mechanism can be considered as 'redistribution of wealth.'

1.4.6 Energy security

The economies of all countries, and particularly of the developed countries, are dependent on secure supplies of energy. Energy security means consistent availability of sufficient energy in various forms at affordable prices. These conditions must prevail over the long-term if energy is to contribute to sustainable development. Attention to energy security is critical because of the uneven distribution of the fossil fuel resources on which most countries currently rely. The energy supply could become more vulnerable over the near term due to the growing global reliance on imported oil. Biomass is a domestic resource which is not subject to world price fluctuations or the supply uncertainties as of imported fuels.

1.4.7 Foreign currency

There are opportunities for developing countries to get foreign currency by exporting bioenergy. In the case of cassava production in Thailand, for instance, the cassava production for food and that for ethanol are balanced now. However, the future use of cassava should be carefully determined. In the future, the amount of cassava production for ethanol may increase, while it is often said that bioenergy utilization may be in conflict with food production, i.e., the international growing demand for ethanol may threaten the stability of domestic supply of food.

Further information

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