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Biomass: A Source of Energy

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Abstract—*Bioenergy is the main source of energy in many developing countries. It currently represents about 14% of the world's energy supply and potentially as much as 450EJ by mid 21st Century. A major challenge is to provide people with to provide clean, cheap and efficient energy such as electricity, in an environmentally acceptable manner. Bioenergy can be a promising source for rural development. By providing energy at local level, bioenergy can make a significant contribution to social and economic development in rural areas. Farmers need clear market incentives, availability of capital, energy, skills, credit, etc to get energy. The increased use of bioenergy will also bring many environmental benefits. However, bioenergy should not be regarded as the panacea for solving agricultural and energy problems in the rural areas, but as an activity that can play a significant role in improving agricultural productivity, energy supply, the environment and sustainability.*

1. INTRODUCTION

The depleting source of energy has made it necessary to search other sources of energy for sustainability. The increasing environmental pollution has also forced mankind to opt suitable pollution free sources of energy. In these type of energy sources, Biomass power became important these days. It is expected that it is the second-largest renewable source of electricity after hydropower, providing the base load power to utilities. It is estimated that there would be high share of biomass energy in the future energy mixture. Researchers found that biomass has potential to contribute 25-50% of present global energy worldwide by 2050. It is expected that new biomass sources could contribute 45%-50%. Biomass fuels in their unprocessed form comprise wood, straw, animal dung, vegetable matter, agricultural waste, while processed biomass includes methane, charcoal, sawdust and alcohol produced from fermentation processes. Studies shows that the potential availability of primary biomass for energy is influenced by the demand for food as a function of population and diet consumed; food production system that can be adopted worldwide, taken into account the water and nutrient availability; productivity of forest and energy crops and other competing options for land-use like for nature development.

Biomass utilization is more common in rural areas of developing countries (nearly 50% of the world population) as compared to developed countries because of easy availability of wood fuel and charcoal for household purposes. Wood energy is also becoming an increasingly important industrial energy option in the industrialized countries of Western Europe, Asia and the Pacific and North America, as it is based on locally available, renewable and environmentally friendly raw material. Traditional biomass accounts for 35% of primary energy consumption in developing countries, raising the world total to 14% of primary energy consumption

Biomass energy can be produced and converted efficiently and cost-competitively into more convenient forms such as gases, liquids, or electricity. Modern biomass now represents only 3% of primary energy consumption in industrialized countries, and this value has remained steady over recent years.

Biomass energy conversion is possible in other products like inert gases and organic oils, gases, and fuels which can be further used to yield desired energy products using direct combustion processes, thermochemical processes, biochemical processes and agrochemical processes classifies technologies.

The contribution that biomass could make to the energy sector is still considerable, since it creates less carbon dioxide than its fossil-fuel counterpart. Old-fashioned methods of burning wood, field residues, or waste were not environmentally sound because they emitted polluting smoke and volatile organic compounds into the air.

Today, scientists and engineers use improved processes to develop several new methods that cleanly and efficiently convert biomass to electricity. One new method uses biomass to replace a portion of the coal used to fuel a power plant through coal firing. The cost of biomass fuel supply depends on the cost of producing or recovering the ‘feedstock’ – raw materials – and those incurred during its transport and pre-processing prior to use in a power plant.

The utilization of biomass is often presented as a key strategy for reducing greenhouse gases (GHG) emissions from electricity generation and transport. Using biomass potentially provides low carbon transport fuel, heat and power, as biomass crops assimilate carbon from the atmosphere during growth. Therefore, the carbon released back to the atmosphere when the biomass is combusted is that which has been recently captured and should not raise atmospheric concentrations. Burning biomass will not solve the currently unbalanced carbon dioxide problem. Conceptually, the carbon dioxide produced by biomass when it is burned will be sequestered evenly by plants growing to replace the fuel.

2. SOURCES OF BIOENERGY

The bioenergy can be produced from in unprocessed form from wood, straw, animal dung, vegetable matter, agricultural waste, while processed biomass can be methane, charcoal, sawdust and alcohol produced from fermentation processes. There are various residues which can be used as energy :

2.1 Utilization of Residues

There are large and under-exploited potential energy resource from residues as animal feed, erosion control, use as animal bedding; use as fertilisers (dung), etc. and represent many opportunities for better utilization, and thus deserves particular attention. However, there are a number of important factors which need to be addressed when considering the use of residues for energy. The energy variation due to residues is large because of amount of residue assumed necessary for maintaining soil organic, soil erosion control, efficiency in harvesting, losses, non- energy uses, etc.

2.2 Agricultural Residues

It is necessary to remain cautious when dealing with agricultural residues, despite the many attempts carried out to estimate their energy potential. There is no doubt that a large part of the residues are wasted, handled inappropriately, causing undesirable effects from an environmental, ecological and food production viewpoint.

2.3 Forestry Residues

Forestry residues obtained from sound forest management do not deplete the resource base, on the contrary, it can enhance and increase future productivity of forests. One of the difficulties is to estimate, with some degree of accuracy, the potential of residues that can be available for energy use on a national or regional basis, without more data on total standing biomass, plantation density, thinning and pruning practices, current use of residues, MAI, etc. Recoverable residues from forests have been estimated to have an energy potential of about 35 EJ/yr. A considerable advantage of these residues is that large part are generated by the pulp and paper and saw mill industries and thus could be readily available. Currently, a large proportion of such residues is used to generate energy in these industries, but there is no question that the potential is much greater.

2.4 Livestock Residues

The potential of energy from dung alone has been estimated at about 20 EJ worldwide. However, the variations are so large that figures are often meaningless. These variations can be attributed to a lack of a common methodology which is the consequence of variations in livestock type, location, feeding conditions, etc. In addition, it is questionable whether animal manure should be used as an energy source on a large scale, except in specific circumstances.

2.5 Energy Crops

It is difficult to predict at this stage what will be the future role of specifically grown biomass for energy purposes. This is, in many ways, a new concept for the farmer which has got to be fully accepted if large scale energy crops are to form an integral part of farming practices. Currently there are in the world over 100 Mha of plantations. During the past decade over 40 Mha have been planted in developing countries, two-thirds in community woodlots, farms and small holdings, to provide industrial wood, environmental protection and energy.

3. FORMS OF BIO-ENERGY CONVERSION

In general, biomass-to-energy conversion technologies have to deal with a feedstock which can be highly variable in mass and energy density, size, moisture content, and intermittent supply. Therefore, modern industrial technologies are often hybrid fossil-fuel/biomass technologies which use the fossil fuel for drying, preheating and maintaining fuel supply when the biomass supply is interrupted. The bio energy can be obtained from the above mentioned sources can be obtained in five fundamental forms as given below:

(i) The "traditional domestic" use in developing countries (fuel wood, charcoal and agricultural residues) for household cooking (e.g. the "three stone fire"), lighting and space-heating. In this role-the efficiency of conversion of the biomass to useful energy generally lies between 5% and 15%.

(ii) The "traditional industrial" use of biomass for the processing of tobacco, tea, pig iron, bricks & tiles, etc, where the biomass feedstock is often regarded as a "free" energy source. There is generally little incentive to use the biomass efficiently so conversion of the feedstock to useful energy commonly occurs at an efficiency of 15% or less.

(iii) "Modern industrial." Industries are experimenting with technologically advanced thermal conversion technologies which are itemised below. Expected conversion efficiencies are between 30 and 55%.

(iv) Newer "chemical conversion" technologies ("fuel cell") which are capable of by-passing the entropy-dictated Carnot limit which describes the maximum theoretical conversion efficiencies of thermal units.

(v) “Biological conversion" techniques, including anaerobic digestion for biogas production and fermentation for alcohol.

3.1 Direct combustion processes.

Feedstocks used are often residues such as woodchips, sawdust, bark, hogfuel, black liquor, bagasse, straw, municipal solid waste (MSW), and wastes from the food industry. Direct combustion furnaces can be divided into two broad categories and are used for producing either direct heat or steam. More advanced versions of these systems use rotating or vibrating grates to facilitate ash removal, with some requiring water cooling. The second group, include suspension and fluidised bed furnaces which are generally used with fine particle biomass feedstocks and liquids. In suspension furnaces the particles are burnt whilst being kept in suspension by the injection of turbulent preheated air which may already have the biomass particles mixed in it. In fluidised bed combustors, a boiling bed of pre-heated sand (at temperatures of 500 to 900°C) provides the combustion medium, into which the biomass fuel is either dropped (if it is dense enough to sink into the boiling sand) or injected if particulate or fluid. T

3.2 Co-firing

A modern practice which has allowed biomass feedstocks an early and cheap entry point into the energy market is the practice of co-firing a fossil-fuel (usually coal) with a biomass feedstock. Co-firing has a number of advantages, especially where electricity production is an output. Firstly, where the conversion facility is situated near an agro-industrial or forestry product processing plant, large quantities of low cost biomass residues are available. These residues can represent a low cost fuel feedstock although there may be other opportunity costs. Secondly biomass fuel's low sulphur and nitrogen (relative to coal) content and nearly zero net CO_2 emission levels allows biomass to offset the higher sulphur and carbon contents of the fossil fuel. Thirdly, if an agro-industrial or forestry processing plant wishes to make more efficient use of the residues generated by co-producing electricity, but has a highly seasonal component to its operating schedule, co-firing with a fossil fuel may allow the economic generation of electricity all year round. Agro-industrial processors such as the sugarcane sugar industry can produce large amounts of electricity during the harvesting and processing season, however, during the off-season the plant will remain idle.

3.3 Thermo chemical processes

These processes do not necessarily produce useful energy directly, but under controlled temperature and oxygen conditions are used to convert the original biomass feedstock into more convenient forms of energy carriers, such as producer gas, oils or methanol. These carriers are either more energy dense and therefore reduce transport costs, or have more predictable and convenient combustion characteristics allowing them to be used in internal combustion engines and gas turbines.

3.4 Pyrolysis

The biomass feedstock is subjected to high temperatures at low oxygen levels, thus inhibiting complete combustion, and may be carried out under pressure. Biomass is degraded to single carbon molecules (CH_4 and CO) and H_2 producing a gaseous mixture called "producer gas." Carbon dioxide may be produced as well, but under the pyrolytic conditions of the reactor it is reduced back to CO and H_2O; this water further aids the reaction. Liquid phase products result from temperatures which are too low to crack all the long chain carbon molecules so resulting in the production of tars, oils, methanol, acetone, etc. Once all the volatiles have been driven off, the residual biomass is in the form of char which is virtually pure carbon.

3.5 Carbonisation

This is an age old pyrolytic process optimised for the production of charcoal. Traditional methods of charcoal production have centred on the use of earth mounds or covered pits into which the wood is piled. Control of the reaction conditions is often crude and relies heavily on experience. It is estimated that the wood to charcoal conversion rate for conventional techniques ranges from 6 to 12 tonnes of wood per tonne of charcoal. During carbonisation most of the volatile components of the wood are eliminated; this process is also called "dry wood distillation." Carbon accumulates mainly due to a reduction in the levels of hydrogen and oxygen in the wood. There are three basic types of charcoal-making: a) internally heated (by controlled combustion of the raw material), b) externally heated (using fuelwood or fossil fuels), and c) hot circulating gas (retort or converter gas, used for the production of chemicals). Internally heated charcoal kilns are the most common form of charcoal kiln.

3.6 Gasification

High temperatures and a controlled environment leads to virtually all the raw material being converted to gas. This takes place in two stages. In the first stage, the biomass is partially combusted to form producer gas and charcoal. In the second stage, the $C0_2$ and H_2O produced in the first stage is chemically reduced by the charcoal, forming CO and H_2. Gasification requires temperatures of about 800°C and is carried out in closed top or open top gasifiers. These gasifiers can be operated at atmospheric pressure or higher. The energy density of the gas is generally less than 5.6 MJ/m^3, which is low in comparison to natural gas at 38 MJ/m^3. A major future role is envisaged for electricity production from biomass plantations and agricultural residues using large scale gasifiers with direct coupling to gas turbines. Such systems take advantage of low grade and cheap feedstocks (residues and wood produced using short rotation techniques) and the high efficiencies of modern gas turbines to produce electricity at comparable or less cost than fossil-fuel derived electricity.

3.7 Catalytic Liquefaction

This technology has the potential to produce higher quality products of greater energy density. These products should also require less processing to produce marketable products. Catalytic liquefaction is a low temperature, high pressure thermochemical conversion process carried out in the liquid phase. It requires either a catalyst or a high hydrogen partial pressure. Technical problems have so far limited the opportunities of this technology.

3.8 Biochemical processes

The use of micro-organisms for the production of ethanol is an ancient art. However, in more recent times such organisms have become regarded as biochemical "factories" for the treatment and conversion of most forms of human generated organic waste. Microbial engineering has encouraged the use of fermentation technologies (aerobic and anaerobic) for use in the production of energy (biogas) and fertiliser, and for the use in the removal of unwanted products from water and waste streams.

3.9 Anaerobic Fermentation

Anaerobic reactors are generally used for the production of methane rich biogas from manure (human and animal) and crop residues. They utilise mixed methanogenic bacterial cultures which are characterised by defined optimal temperature ranges for growth. These mixed cultures allow digesters to be operated over a wide temperature range i.e. above 0°C up to 60°C. When functioning well, the bacteria convert about 90% of the feedstock energy content into biogas (containing about 55% methane), which is a readily useable energy source for cooking and lighting. The sludge produced after the manure has passed through the digester is non-toxic and odourless. Also, it has lost relatively little of its nitrogen or other nutrients during the digestion process thus, making a good fertiliser. In fact, compared to cattle manure left to dry in the field the digester sludge has a higher nitrogen content; many of the nitrogen compounds in fresh manure become volatised whilst drying in the sun. On the other hand, in the digested sludge little of the nitrogen is volatised, and some of the nitrogen is converted into urea. Urea is more readily accessible by plants than many of the nitrogen compounds found in dung, and thus the fertiliser value of the sludge may actually be higher than that of fresh dung.

4. IMPACTS OF BIOMASS CONVERSION TO ENERGY

Biomass provides a clean, renewable energy source that could dramatically improve the environment, economy and energy security. The use of biomass for energy has effects on all the environmental media i.e. soil, water and air. In addition, these effects may have impacts on human and animal health and welfare, soil quality, water use, biodiversity and public amenity.

4.1 Impact on soil

Environmental impacts of biomass production must be viewed in comparison to the likely alternative land-use activities. At the local or regional level, the relative impacts of producing bioenergy feedstocks depends not only on how the biomass is produced, but also on how the land would have been used otherwise. The use of perennial crops, where they replace annual crops, will result in reduced oil disturbance, greater soil cover and hence lower erosion, improved soil organic matter and soil carbon levels and increased biodiversity, particularly where the change results in a decreased application of inputs (fertilizers and pesticides). Also, plants can selectively and actively absorb toxins, including heavy metals and ash recycling could cause such toxins to be concentrated in the bioenergy plantation’s soils. Soil organic matter and nutrient levels have to be maintained or even improved where bioenergy production is to be based on exploiting agricultural and forestry residues. In many cases, farmers can reduce the risk of nutrient depletion by allowing the most nutrient-rich parts of the plant—small branches, twigs, and leaves to decompose on the field.

4.2 Impact on water

The assessment of direct environmental impacts of energy from biomass for energy for water mainly envisages the following aspects absolute and relative consumption; reuse (consumption/unit produced); discharge of effluents and infiltration; monitoring of contamination by fertilizers, herbicides and insecticides; turbidity; eutrophication; suspended solid particles; environmental suitability of technology used to extract water; use of best available irrigation practices; groundwater depletion; restoration of groundwater etc.

There may also be negative impacts from the introduction of energy crops on local and regional hydrology, because a significant increase in the interception and use of rainfall could result from a wide spread implementation, with potentially substantial reductions in rainfall infiltration and negative impacts of aquifers in the region. Certain practices, like harvesting residues, cultivating tree crops without undergrowth, and planting species that do not generate adequate amounts or types of litter, can reduce the ability of rainfall to infiltrate the soil and restock groundwater supplies, intensifying problems of water overconsumption.

4.3 Impact on atmosphere

Biofuels provide an opportunity for the provision of the modern fuels and services required for development, whilst at the same time avoiding fossil-fuel derived CO_2 emissions. However, present intensive agricultural methods can only be used for the production of liquid fuels e.g. diesel from rapeseed, if the associated residue production is used for energy. Other by-products arising from the production and use of biomass energy are involved in the complex physics and chemistry of the greenhouse effect. These include methane emissions, mainly from rice paddy cultivation and also landfills; however, emissions are directly related to management practices and soil type, and thus have the potential to be reduced substantially. Bioenergy systems emit less sulphur dioxide and nitrous oxides (NO_x) than equivalent fossil-fuel derived energy. SO_2 emissions are implicated in acid rain and increased nutrient depletion from soils. On the other hand, sulphate aerosols, derived from SO_2 emissions to the atmosphere, have been shown to play a role as cloud condensation nuclei, and are thus postulated to moderate the global warming effect. Increases in the levels of all the major greenhouse gases result from land clearing (devegetation), and thus well managed biofuel programmes which lead to revegetation will result in the decrease of greenhouse gases. Land-use changes which result in a permanent increase in the level of the carbon inventory (vegetation) will thus play a role in ameliorating the greenhouse effect

4.4 Impact on Health

Woodfuel use (specifically firewood) has been associated with many respiratory diseases and specifically linked to chronic bronchitis and lung/throat cancer. These are associated with: i) the emission of particulates (large airborne particles) and ii) carcinogens released from the wood through combustion. It is important to note that such health problems are more a result of inefficient cooking conditions and equipment than simply the fuel source.

5. CONCLUSION

Biomass energy systems have a wide range of potential socioeconomic and environmental impacts-both positive and negative. Biomass energy generates far less air emissions than fossil fuels, reduces the amount of waste sent to landfills. Modernized bioenergy systems have environmental impacts associated both with the growing of the biomass and with its conversion to modern energy carriers. Significant impact is expected from bioenergy with respect to mitigation of climate change, development of rural areas and employment options as well as the provision of alternative energy forms. However, the environmental impact induced by using biomass as a source of fuel varies according to the type of conversion technology.

From above it is clear that presently that biomass power is an important alternative for providing energy in the rural sector but in coming years it would play an important role in urban and power plants in a refined manner.

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