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Biomass:
A diversity of solutions

Guest Author;
Ahmad Houri, Associate Professor, Lebanese American University. ISES and LSES board member.

1. Introduction

Biomass is one of the oldest used sources of energy, specifically for heating. Biomass accounts for 10% of global primary energy supply (REN21, 2012), higher than all other forms of renewable energy sources, and is growing at a rate of 1.4% annually. However, its contribution to electricity generation is relatively less developed. Biomass has attracted $10.6 billion in new investments in 2011.

Today, biomass is one of the most complex renewable energy sources available and some forms of it like ethanol, biodiesel and pellets are traded in international markets. The complexity stems from the variety of sources, conversion technologies and final uses of biomass. Sources vary widely and they are more easily classified according to their state: solid, liquid, and gas - as shown in Table 1. Various transformation procedures exist and these include pretreatment, purification, compaction, and transformation from one state to another (Table 2). Each of these technologies is used in a specific case. In addition, biomass is used for heating, electricity and transport. Different forms of biomass may be used for each of these applications (Table 3). The distribution of various uses is shown in Figure 1 which illustrates the significant use for heating. This exchange aims at simplifying this complex relationship and to give an idea about its global uses and markets in addition to potential uses in Lebanon.

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Solid	Liquid	Gas
Municipal Solid Waste	Waste vegetable oil	Landfill gas
Wood products	Pure vegetable oil	Gas from animal manure
Corn and starch sources	Algae-based oil	
Crop residues		
Waste water sludge		

Table 1. The various sources of Biomass

Solid	Liquid	Gas
Briquettes	Straight vegetable oil	Biogas
Pellets	Biodiesel	Syngas
Untreated wood products	Ethanol	
Crop residues		

Table 2. Various products resulting from biomass processing

Transportation	Heating	Electricity
Straight vegetable oil	Briquettes	Untreated wood products
Bioethanol	Pellets	Biogas
Biodiesel	Untreated wood products	Crop residues
Biogas	Biogas	Pellets

Table 3. The various uses of biomass

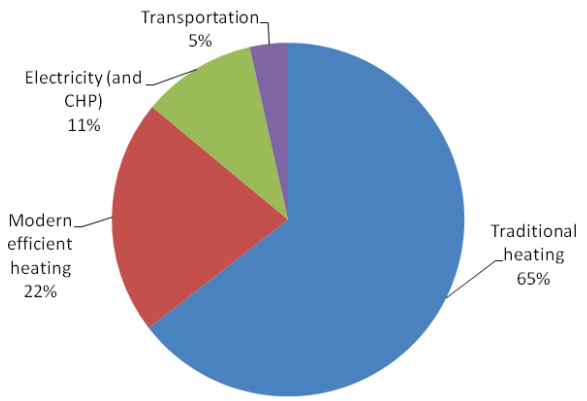

Figure 1. Distribution of Biomass uses globally

Advantages of Biomass

The advantages of using biomass are several and are indicated below.

Lower net CO2 production

Although this has been debated by many scientists, the basic concept is valid. All the energy produced by biomass has originally come from the photosynthetic transformation of solar energy into various types of biomass. Further analysis of the processes of planting, harvesting, transforming and using biomass has led scientists to the conclusion that the overall process is not CO2 neutral. It remains to be determined if biomass use has a lower net CO2 production or not. The answer varies depending on the biomass source and technology used. The advantage in terms of Greenhouse Gas (GHS) reduction are is more visible when waste biomass is being used, where methane can be collected and converted to power, for example.

Can be located on unfarmed and/or unused lands

used in agriculturally unproductive lands. Several improvements of plants like Jatropha have led to lower demands on soil quality and the amount of water needed, thus enabling it to grow on marginal lands.

Large potential supply

Even when waste biomass is considered alone, a small country like Lebanon produces around 4000 tons of municipal solid waste, around 60% of which is organic material. When agricultural bi-products are considered, there is ample supply globally. Examples are abundant with inedible dates being transformed into ethanol, for instance example.

Moderate cost

Due to the variety of available technologies, from the most simple burning of wood to the complex process of producing higher value products, a variety of costs exist. When the proper technology is matched with the proper supply of raw material and demand of the final product, the costs turn out to be rather competitive.

Job creation

Like many other forms of renewable energies, benefits of biomass extend to job creation of generally highly skilled labor although a significant portion of its benefits cover rural economies and farmers. Today, biogas is estimated to create 230,000 jobs while biofuels have created 1.5 million jobs. The remaining forms of biomass are responsible for the creation of 750,000 jobs (REN21, 2012).

Disadvantages of Biomass

On the other hand, the disadvantages of biomass can be considerable, and they are addressed below.

Moderate to high environmental impact

The process of burning biomass may result in undesired emissions if it is not well controlled. In addition, the collection and accumulation of solid wastes, municipal or agricultural, may create some local resistance that is based on the associated smells and/or insects. More importantly, the complete substitution replacement of rain forest; For instance, its replacement with oil palm for the production of biodiesel in Malaysia and Indonesia, for example, have created a major uproar among environmentalists and threatens the extinction of many natural flora and fauna species to extinction.

Plantations could compete with cropland

The lure of biomass production and specifically that of biofuel and biogas is leading farmers in many countries to devote their crop land for the production of rapeseed, corn, or fast growing trees for the production of biodiesel, ethanol and wood pellets respectively. This diversion of agricultural land use from edible crops to energy crops has led many to question whether crops should be “food for people or cars?”

Biomass usually burnt inefficiently

The current use of open burning of biomass in ovens all over the world is highly inefficient. This has been addressed through the use of energy efficient ovens in China and India and rice husk gasification in the Philippines. For the majority of the world population, the inefficient open burning is still a problem.

Competition for energy use

The competition between biomass use for animal feed, bio-chemicals and biomaterials exist. Energy use is only one component of the mix. Sustainability and economics must be taken into account when considering energy uses.

Supply Constraints

The size of any biomass facility is directly linked to the available biomass in a given radius. The further the source is, the more expensive it is to transport it to the facility. The possibility to import pellets has helped the UK establish the world’s largest biomass power plant with 750 MW. However, sustainability issues have to be addressed when long range transportation is required.

Biofuel Production

Biofuels have seen a rapidly increasing market as a result of 25 countries from 5 different continents having established biofuel mix mandates. This means that fuel providers must have a certain amount of biofuel mixed in with their fossil fuel products such as gasoline and diesel to be allowed entry to the market. For example, in Brazil, ethanol must constitute 20% of the gasoline mix whereas in the US refiners were required to add 3.1 billion liters of biodiesel into the diesel supply. In 2011, biofuel constituted 3% of the global road transport fuel (REN21, 2012).

Biofuel has been also used for power plants in Argentina (Biodiesel) and Brazil (ethanol) but this application is almost non-existent in other countries. This is mainly to better added value when used in the transport sector.

Biodiesel is generated from the methanolic treatment of oil and fat. Rapeseed oil, soybean oil, and palm oil are the more commonly

used virgin oils for that purpose while fish oil, animal fat and used oil constitute a significant portion of the biodiesel made from waste products. Biodiesel burning properties and viscosity is similar to that of regular diesel when processed and subjected to strict quality control. A significant increase in viscosity may be a problem in some mixes, depending on the source, for 100% biodiesel under very low temperatures. Accordingly, Biodiesel is normally mixed with diesel to maintain compatibility with normal engines.

Ethanol is usually generated from carbohydrate-rich plants like corn and sugarcane. The fermentation process is well established. In Lebanon, sugar beet can be used instead of sugar cane. It can also be manufactured from wasted food products such as potatoes, dates and other carbohydrate-rich produce unsuitable for human consumption. It is commonly used alone or as mix with gasoline in cars. Regardless, the ethanol must be completely anhydrous. Due to its strong solvating power, special attention should be given to cars using 100% ethanol.

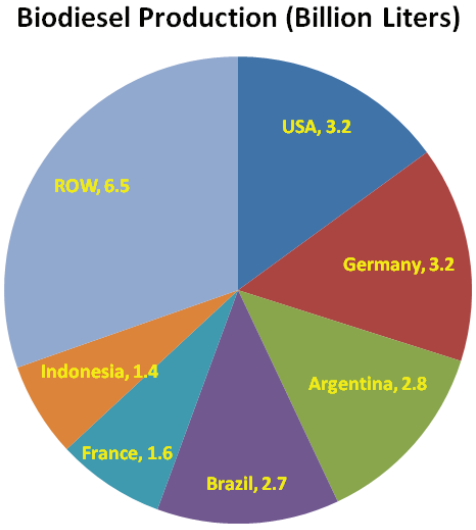

Figure 2. Global biodiesel production by country (2011) [ROW: Rest of the World]

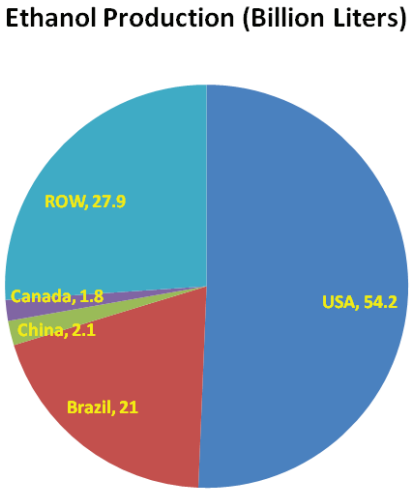

Figure 3. Global ethanol production by country (2011)

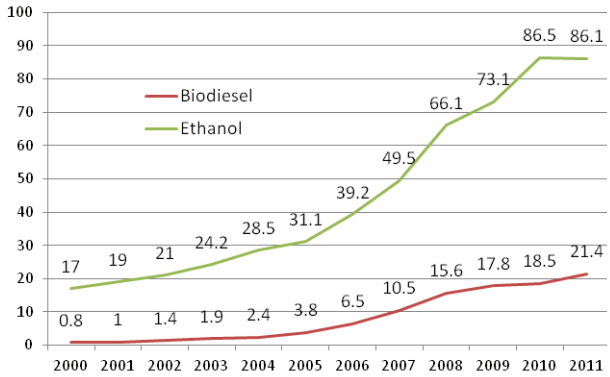

Figure 4. Annual ethanol and biodiesel production (Billion Liters)

Biogas production

Biogas is produced from medium to small-scale bio-digesters in developing countries. They are commonly used for heating and cooking. These systems are efficient and suits perfectly an agrarian economy. Accordingly, China has 43 million digesters, whereas India has installed 4.4 million. Larger bio-digesters have also been developed in these two countries.

In developed countries, biogas is generated from the anaerobic decomposition of organic municipal waste, animal manure from large farms, agricultural products such as whole corn plants, or from municipal waste dumps. It is used to generate electricity for the facility and to supply the grid if feed-in tariffs are in place; or alternatively, used for heating. In countries with an established natural gas network, the generated biogas can be readily pumped into the network after purification. It can also be used in gas-powered cars.

Pellets and briquettes production

Solid biomass is widely used especially in its pellet form, where small condensed uniformly shaped pieces are easy to use with modern boilers and efficiently transported. The use of wood pellet stoves is making great strides with 12 million in USA and 1.56 million in Italy, for example. The global pellet production has reached 18.3 million tons. Russia has the world's largest pellet production plant with an annual capacity of 0.9 million tons per year with even bigger plants planned by Brazil. The top leaders in the pellet production globally are USA, Canada, Germany and Sweden.

Briquettes are the larger form of pellets which are normally 5-10 cm in diameter and 6-25 cm in length. They are normally used to compress loose wood into an easily transportable form and are used to replace logs. They are not an internationally tradable commodity on a large scale yet, but they serve the local population in which the briquettes are made. China alone produces around 0.5 million tons.

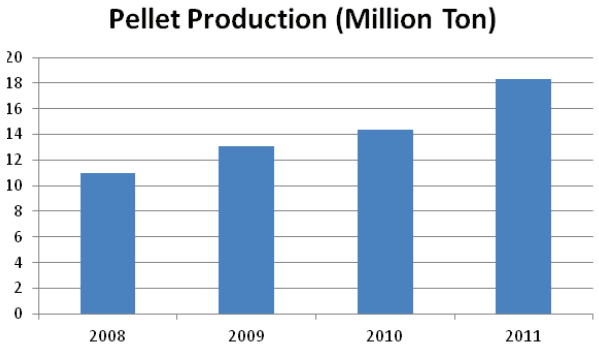

Figure 5. Global pellet production

Innovation in Biomass Use

While the word innovation normally invokes a perception that high-tech solutions are being used, the most effective innovations have been in very simple technologies that have broad applications. Of these applications, clean and energy efficient wood stoves stand out as the best example. Since regular, inefficient and highly polluting cook stoves are used by more than 3 billion people globally, the introduction of energy efficient wood stoves has changed the lives of many. These stoves consume half the amount of wood-fuel saving money, time, pollution and environmental resources.

Another innovation that has been of great service to impoverished communities has been the gasification stove that uses regular biomass but lack the polluting effects of a regular stove. This has been introduced for cooking applications globally and its numbers are increasing.

Growth of biomass to energy

Biomass has witnessed an increase of 5.9 GW in installed electricity capacity in 2010 and has reached a total of 72 GW by the end of 2012. The United States stands at the top with a total electricity production of 13.7 GW. On the other hand, modern biomass use for heating has increased by 10 GWth to reach a total of 290 GWth during the same period. Biodiesel and ethanol are rarely used for electricity despite some exceptions, since they are preferably used as transport fuel.

National Bioenergy Strategy for Lebanon

In 2012, the National Bioenergy Strategy for Lebanon was published in which various biomass resources where assessed and ranked in regard to their potential. Table 4 below summarizes the ranked options in order of importance.

Ranking	Domain	Biomass resources	Primary Energy potential (TJ)
1	Forestry	Residues from felling	1,378-1,771
2	Agriculture	Residues of Fruit and olive trees	2,952 - 3,078
3	Agriculture	Residues of cereals	2,116 -2,233
4	Energy Crops	Jatropha, miscanthus, eucalyptus, sunflower, giant reed	3,574 - 10,164
5	Food Processing Industry	Olive cake by-products	460 - 1,083
6	Municipal Solid Waste	Waste Wood	583

7	Municipal Solid Waste	Municipal sewage sludge	666
8	Food Processing Industry	Animal fat, slaughter house residues	753
9	Municipal Solid Waste	Yellow grease	495 - 562
10	Municipal Solid Waste	Landfill gas recovery	585

Table4. Ranking of potential biomass options according to the National Bioenergy Strategy for Lebanon study

The utilization of the resources mentioned above may be attained by a variety of technologies or conversion options. The applicable technologies in Lebanon and their feedstock are summarized in Table 5.

Feedstock	Conversion technology	Best Use
Vegetable oil, waste oil, animal fat	Biodiesel	Transport fuel, domestic electric generators
Agricultural crops	Ethanol	Transport fuel
Manure, agricultural residues, sewage sludge, slaughter house waste	Anaerobic digestion to biogas	Heat and electricity
Landfill	Landfill gas collection (biogas)	Heat and electricity
Combustible MSW, forestry and agricultural residues, wood from energy crops	Direct combustion	Heat and electricity
Combustible MSW, forestry and agricultural residues, wood from energy crops	Co-combustion with coal	Electricity
Dried woody residues	Pelletization	Heat and electricity

Table 5. Applicable technologies in Lebanon and their feedstock

To these, one might add briquetting and charcoal production from agricultural and forestry residues. Both of these treatments will be used for heating but not electricity production. Another point is that it is unlikely to have enough supply of pellets to operate a power plant so their use might be restricted to heating. Further detailed analysis of potential uses can be obtained by the National Bioenergy Strategy for Lebanon study.

Global Limitations and Recommendations

Since we are far from providing food for everyone globally, and the blame for this is often and partly put, rightly or wrongly, on biofuel production, it appears politically and socially more correct that land allocation should be more focused at the production of staple food products. On the other hand, wastes are abundant and their current modes of disposal are destroying the planet. It sounds only natural that we use the waste resources that we have in order to provide energy to satisfy the constantly increasing needs.

Local Limitations and Recommendations

In addition to the above global limitations and recommendations, Lebanon suffers from the high population density and the high cost of land. Lebanon also is not self-satisfied with crop production, nor with its energy production. Residential land space has completely consumed most of the fertile agricultural coastal plains with the exception of the area of Akkar and some areas in the south. This automatically leads to the exclusion of using agricultural lands for energy crops. For example, diverting the sugar beet crops to ethanol production does not make sense when Lebanon imports its sugar from other countries. Marginal or areas unsuitable for agriculture may hold a great potential for energy crops that are not water intensive.

The opportunity exists for the use of abundant waste products available in the country. Of special interest is the municipal solid waste.

Research and development should be focused in this area where any major breakthrough will provide a solution to get rid of the abundant waste currently occupying large areas and causing various environmental problems. Biogas is generated on its own and it only needs to be collected, purified and burnt to generate electricity. Such a process requires the appropriate legal framework to feed into the grid. Biogas is a “limited time offer” where we suffer from the “use it or lose it” conundrum. The opportunity was already lost in the Borj Hammoud waste dump and we are currently losing the biogas being generated from the Naameh landfill.

The use of certain residues will have to compete with an already existing market for these byproducts. For example, a significant increased value will have to materialize before people shift the use of wood shavings from chicken bedding to pellets or briquettes. Hay produced from wheat and others crops is currently used for animal feed. There is no surplus of animal feed and most of the crop residues generated make their way to animals one way or the other. Again, a careful analysis has to be done to decide whether it is better to channel these by-products to energy use and then import animal feed from the outside.

Although the use of locally produced biomass should be encouraged by the government, it must be made clear that long-term support mechanisms are neither sustainable nor economically feasible for an indebted country like Lebanon. Initial funding through targeted projects could help jump start biomass use, but the applications developed have to be economically viable and locally sourced. Biomass is a renewable energy resource but that does not justify importing pellets or biodiesel from abroad. This would not serve the long term energy independence of the country.

Finally, for the simple economics and efficiency of the systems utilized, biomass for heat should take a priority over biomass for electricity. Heating uses are far more efficient than electricity uses and we lack sufficient resources of each. Today, many Lebanese residents are using either diesel or electricity to heat their houses which is either heavily polluting or extremely inefficient (respectively). A minority is using gas heaters and it is hoped that with the discovery of new gas resources in our sea, this percentage will grow. Biomass is already used for heating in many villages in the simplest woody form. However, in the past few years, an opportunity has presented itself for the use of olive pomace in briquettes for heating. Many olive oil presses has seized the opportunity and are currently transforming all of their generated pomace into briquettes. These are dried and then either used by the immediate community or sold outside. This example indicates that once an economically viable solution is provided, the stakeholders will quickly adopt it.

Conclusion

Biomass is a very diverse potential source of energy. Accordingly, this study discussed some of the more common technologies. Many more are promising and may become cost effective in the short to medium terms. The successful use of the final form for energy use depends on the availability of feedstock and the conversion technology used. Several limitations and sustainability concerns exist, especially in a small densely populated country like Lebanon. Issues like agricultural land use and resource diversion away from traditional uses may result in additional cost for the feedstock. The use of waste products (like MSW and waste cooking oil) for energy is highly promising and strongly encouraged as it provides a cost-efficient solution for unsustainable waste management options available today. The adoption of biomass technologies to treat waste streams will significantly reduce the pressure exerted on ground water, surface water and waste disposal sites which will collectively improve the quality of life for the Lebanese population.

On the economic perspective, heating applications are a priority over electricity generation application due to their higher efficiency. An exception to that would be the biogas generation which is produced year round and might not be needed for heating near the area where it is generated. A better use for this biogas would be for electricity generation. One might consider initiating

heat-intensive industries next to sustainable biogas generating sites in order to benefit from its availability. Direct combustion is more economical than any conversion technology, but some form of pretreatment like pelletization might be economical if the biomass is to be transferred over long distances or packaged for later use.

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Beirut, Maarad street, Building 287 B, 1st floor, Lebanon
T/F: +961-1-981944
info@cedro-undp.org
www.cedro-undp.org