A Study on the Conversion of Biomass to Bio-Fuel and Assessing It's Applicability as a Fuel Alternative to Fossil Fuel

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Abstract- **The major source of energy comes from fossil fuels and these fuels are used by most industrialized and developing countries. With the rapid growth of population, demand of petroleum fuel or fuel is increasing day by day. But these resources are limited and non-renewable. So, it is necessary to use renewable energy sources to generate fuel. The objective of our study is to assess the prospect of biomass fuel as an alternative to petroleum. The main focus of our work was to give idea about biomass as a fuel and how it can be used as an alternative to petroleum fuel. Biomass is a common and continuously producing form of renewable energy. By using several conversion techniques, biomass can be used as an alternative source of petroleum fuel which can help in fulfilling the increasing demand of petroleum fuel.**

Index Terms- **Biomass, Bio-oil, Bio-fuel, Fossil fuel, Petroleum fuel.**

I. INTRODUCTION

Energy sources are classified as nonrenewable because they do not form or replenish in a short period of time. Renewable energy sources such as solar, wind and bio-fuels which can be replenished naturally in a short period of time. Nonrenewable energy sources come out of the ground as liquids, gases, and solids. We use crude oil to make liquid petroleum products such as gasoline, diesel fuel, and heating oil. Propane and other hydrocarbon gas liquids, such as butane and ethane, are found in natural gas and crude oil. Petroleum fuels make up almost one-third of the global energy demand. These fuels primarily include gasoline, diesel, jet fuel, kerosene and fuel oil. More than 55% of the global demand for petroleum fuels comes from transportation. The remaining 45% demand comes from industrial and power generation sector. According to the 2017 edition of BP's Energy Outlook, global energy demand will increase by around 30% to 2035, an average growth of 1.3%/year, driven by increasing prosperity in developing countries. [1][2][3]

The human population is shifting away from non-renewable energy sources due to the increase in awareness of harmful pollution and depleting resources. The main component of petroleum fuel is CO_2, which is the major contributor to global warming. More than about 50% of CO_2 is emitted from the transport sector and 70% is from the power sector. Now it is necessary to use an alternative approaches to generate energy. On the other hand, Biomass is a renewable resource rich in carbon, tends to be cleaner and less harmful to the environment. Thus, non-fossil fuels are expected to account for half of the growth in energy supplies over the next 20 years. [3][4]

II. BIOMASS

Biomass is organic material that comes from plants and animals, and it is a renewable source of energy. Biomass contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. When biomass is burned, the chemical energy in biomass is released as heat. Biomass can be burned directly or converted to liquid biofuels or biogas that can be burned as fuels. [5]

Wood is still the largest biomass energy resource today, but other sources of biomass can also be used. These include food crops, grassy and woody plants, residues from agriculture or forestry, oil-rich algae, and the organic component of municipal and industrial wastes. Even the fumes from landfills (which are methane, the main component in natural gas) can be used as a biomass energy source. The use of biomass energy has the potential to greatly reduce greenhouse gas emissions. Burning biomass releases about the same amount of carbon dioxide as burning fossil fuels. However, fossil fuels release carbon dioxide captured by photosynthesis millions of years ago—an essentially "new" greenhouse gas. Biomass, on the other hand, releases carbon dioxide that is largely balanced by the carbon dioxide captured in its own growth (depending how much energy was used to grow, harvest, and process the fuel). [6]

Biomass fuels provided about 5% of the primary energy used in the United States in 2016. Of that 5%, about 48% was from biofuels (mainly ethanol), 41% was from wood and wood-derived biomass, and about 11% was from the biomass in municipal waste. Researchers are trying to develop ways to use more biomass for fuel. [5]

III. SOURCES AND PROPERTIES OF BIOMASS OIL

The major biomass sources currently used are sugar cane and corn. Other sources are also used such as sunflower seeds, soybean, canola, peanuts, jatropha, coconut and palm oil, cooking oil, rapeseed, algae, wheat, sugar beet, sweet sorghum and cassava etc. The fuel and energy yields vary with the type of plant material used. [7]

Several issues have been presented on some of the feedstock such as palm oil, jatropha, waste cooking oil and algae which represent the edible and non-edible feedstock with great potential as biofuel feedstock. Animal sources have also been reported to be potential bio-oils feedstock by a number of researchers. Animal fats are formed major from triglycerides and have high energy value. Both animal wastes and their fats that are capable of producing carbon and hydrogen compounds that have the potentials of producing bio-oils directly via pyrolysis or in secondary processes of gasification products. [8]

Sugarcane is currently the most attractive alternative to fossil fuel as it achieves significant GHG emission reductions. It is obtained from renewable biomass: sugarcane and bagasse. Brazil and the United States are the largest producers of ethanol from sugarcane with both countries accounting for about 86% of total bioethanol production in 2010. In Brazil, the introduction of ethanol in automobiles reduced carbon monoxide emissions from 50 g/km in 1980 to 5.8 g/km in 1995. The Brazilian economy has grown its sustainable biofuel production from sugarcane as the government-implemented policies have encouraged the production and consumption of ethanol. [10]

Table 1:Potential oil crop and yield per hectare [9]

Crop	Oil in litres per hectare
Algae	1,000,000
Castor	1413
Coconut	2689
Palm	5950
Safflower	779
Soybean	446
Rapeseed	1190
Sunflower	952

Today, corn grain is one of the primary feedstocks used in the U.S. to produce liquid transportation fuel (ethanol and biodiesel, respectively). Since most of the corn grown in the U.S. is in the Midwest and Upper Midwest, the greatest concentration of ethanol plants is also in the Midwest and Upper Midwest. Biodiesel is an alternative fuel made from vegetable oils. [11]

Soybean is a major feedstock for biofuel production in the U.S and in Latin America. Transesterification and hydro processing have been explored in the utilisation of the biomass oil to petroleum range biofuels commercially. China is also a major producer of soybean; Argentina and Brazil are expected to expand to soy oil for biofuel production due to the availability of land and relatively lower production cost. [8][11]

The production of macroalgae and microalgae utilise established technologies, primarily for waste water treatment and the production of food products for direct consumption, phycocolloids, nutraceuticals and other high value products (HVPs). The production of macroalgae in open ponds and coastal seawaters, and microalgae in high rateponds (HRPs) and photobioreactors (PBRs) can achieve much higher yields than terrestrial crops. [12]

Sunflower seeds are a strong component of oilseed and biofuel cropping systems, because they adapt well to a variety of conditions and often require fewer agricultural inputs than more common crops. Dryland sunflower yields generally average 1,300 pounds/acre, but yields over 2,000 pounds/acre in irrigated or high rainfall conditions are not uncommon. Average oil content is 40 to 42%. Oil yield extracted from the sunflower seed ranges from 35 to 80 gallons per acre. The quantity of oil extracted from the seed varies depending on growing conditions, post-harvest seed handling. [13]

Jatropha is a drought-resistant perennial, growing well in marginal/poor soil and considered as one of the best candidates for future biodiesel production. Jatropha the wonder plant produces seeds with an oil content of around 27%–40%. The oil can be combusted as fuel without being refined. It burns with clear smoke-free flame, tested successfully as fuel for simple diesel engine. It is found to be growing in many parts of the country, is rugged in nature, can survive with minimum inputs, and is easy to propagate, and these growth conditions give this plant the big chance for selection as biofuel sources. [14]

Recycling of waste cooking oils is increasingly being carried out to produce biofuel. Opportunities for businesses and consumers to recycle used cooking oil ("yellow grease") have increased due to the price of waste cooking oils (WCO), which is 2–3 times cheaper than virgin vegetable oils. A significant advantage is that, biofuels derived from waste cooking oil typically burn clean, have low carbon content and do not produce carbon monoxide. This helps communities to reduce their carbon footprints. [13]

Palm oil which is considered as the most efficient oil seed crop in the world due to its high productivity per hectare. Amongst the major oilseeds and oil plants (such as soybean, sunflower, rapeseed, groundnut, cotton) palm oil has a higher production efficiency. Palm oil production is on the rise and the cost of production is relatively lower than other plant oils thus making it one of the most viable biofuel feedstock. Date seeds are commonly considered as a waste product but it possess extractable high value added components. Date seeds, which are low cost agriculture by-products, can be used for production of activated carbon. From date seeds biodiesel can be produced. [8][13]

Most of non-edible biomass has a considerable amount of low-chain fatty acids, which gives special features to biodiesel. The most important advantages of the current biomass are production of biodiesel with high cetane number, low viscosity. These factors can increase engine's output and decrease pollution compared with other biodiesel fuels. [13]

The physical properties of bio-oils are described in several publications. The different physical properties of bio-oils result from the chemical composition of the oils, which is significantly different from that of petroleum- derived oils. Bio-oil is a complex mixture of several hundreds of organic compounds, mainly including acids, alcohols, aldehydes, esters, ketones, phenols, and lignin-derived oligomers. Important parameters that are critical to the properties of bio-oils include their condensation temperature, high heating values, pH, viscosity and water content. These properties are usually affected by the production process. [8][15]

Table 2: Typical Physical and Chemical Properties of Bio-Oil [16]

Physical Properties	Typical Values	Chemical Properties Pine/Spruce 53% wood + 47% bark	Typical Values Bio-Oil Concentrations wt%
Moisture content	25%	Lignin	24.9
pH	2.5	Glyoxal	1.9
Specific gravity	1.20	Hydroxyacetaldehyde	10.2
C	56%	Formaldehyde	3.0
H	6%	Formic acid	3.7
O	38%	Acetic acid	4.2
N	0 to 0.1%	Acetol	4.8
Kinematic Viscosity cSt	@ 20°C 78 @ 80°C 4.4	Cellobiosan	1.9
Calorific Value	16.4MJ/kg (SI units) 7051Btu/lbm (English units)	Levoglucosan	6.3
Density	1.19 kg/L (SI units) 74 lbm/ft3 (English units)	Unlisted	14.8

Table 2 demonstrates the physical and chemical properties of bio oil. For example, it has a very high volume of oxygen and water. Their oxygen contents vary in the range of 35–60 wt% (wet basis), and it highly depend on the kinds of feedstock. Water is the most abundant components and it may vary in the range of 15–30 wt%. [16]

Compared with heavy petroleum fuel oil, the bio-oils have the following undesired properties for fuel applications:
(1) High water content
(2) High viscosity
(3) High ash content
(4) High oxygen content (low heating value)
(5) High corrosiveness (acidity)
These undesired properties have so far limited the range of bio-oil application. The differences in processing conditions and feedstock result in significant differences in the product yield and product composition of bio-oils. [15]

IV. CONVERSION OF BIOMASS INTO BIO-OIL

A number of research projects and companies are developing innovative processes to turn a wide range of biomass (forestry residues, crop residues, waste paper and organic waste) into stable, concentrated bio-oil (biocrude) that is compatible with existing refinery technology and can be converted into advanced biofuels. There is a large variety of thermal and thermochemical processes for converting biomass by combustion, gasification, and liquefaction, and the microbial conversion of biomass to obtain gaseous and liquid fuels by fermentative methods. Breaking down biomass into bio-oil is no easy task. But finding a way to upgrade bio-oil into biofuels that can be plugged into the existing petroleum infrastructure is considered the holy grail of developing renewable transportation fuels. [17][18][19]
Two main types of processes for production of bio-oils from biomass are flash pyrolysis and hydrothermal liquefaction (HTL). The biomass process begins with breaking down biomass into bio-oil through a process called pyrolysis, and then upgrading the oil to hydrocarbon fuel. Pyrolysis uses heat to break down biomass, and the resulting oil contains high levels of oxygen and acids, making it unstable at the high temperatures used in refinery processing. The instability makes it difficult to convert the oil into hydrocarbon fuels and causes the catalysts used in hydroprocessing to be degraded more quickly. HTL is also called direct liquefaction, hydrothermal upgrading/pyrolysis, depolymerization, and solvolysis, which is conducted under elevated pressure and temperature to keep water in either liquid or supercritical state. [15][19]

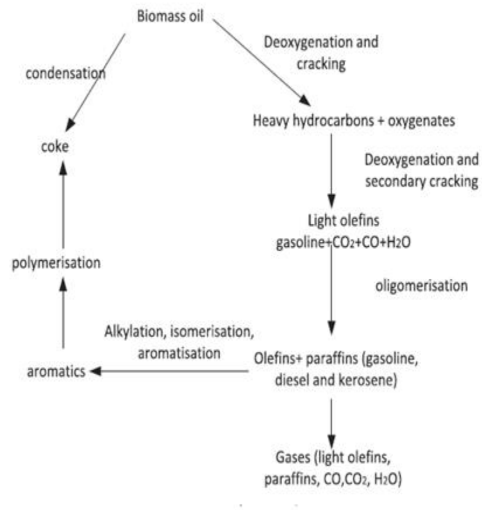

Fig.1: Biomass oil conversion to fuels. [9]

Flash pyrolysis characterized by a short gas residence time (less than 1second) and a relatively high temperature (450–500^{o}C). Hydrothermal liquefaction is usually performed at a low temperature (300–400^{o}C), longer residence time (0.2–1.0 h.). Recently, Venderbosch and Prins reviewed fast pyrolysis technologies, and concluded that challenges for the coming years are (1) improvement of the reliability of pyrolysis reactors and processes; (2) the demonstration of the oil's utilization in boilers, engines and turbines; and (3) the development of technologies for the production of chemicals and biofuels from pyrolysis oils. Unlike flash pyrolysis, technological developments in the area of HTL present new ways to turn wastes to fuel. HTL was initially developed for turning coal into liquid fuels, but recently, the technique has been applied to a number of feedstocks, including woody biomass, agricultural residues, organic wastes (e.g., animal wastes, sewage sludge), and aquatic plants. [15]

V. UPGRADING OF BIO-OIL

There have been intensive studies on bio- oil upgrading research and various technologies have been developed for bio-oil upgrading. Bio-oil can be upgraded in many ways which includes physically, chemically and catalytically. [15][16]
Hot-vapor filtration can reduce the ash content of the oil to less than 0.01% and the alkali content to less than 10 ppm, whereas polar solvents are used to

reduce the viscosity of biomass oils. Hydrogenation is another process to improve stability and fuel quality by decreasing the contents of organic acids and aldehydes. Currently, the most widely used hydrogenation processes for the conversion of petroleum and petroleum products is hydrotreating. Hydrotreating (HDT) is a nondestructive, or simple hydrogenation process that is used for the purpose of improving product quality without appreciable alteration of the boiling range. Hydrogenation without simultaneous cracking is used for saturating olefins or for converting aromatics to naphthenes. It has become the most common process in modern petroleum refineries. Bio-crude may also be processed by a conventional refinery and potentially augmented with petroleum crude. The oxygen in bio-oils can be removed via hydrotreating. The catalysts commonly used for hydrotreating are sulphideCoMo/Al2O3, NiMo/Al2O3 system. [16][18]

Another process is Cracking via hydrocracking or catalytic cracking offers advantages of use of heterogeneous catalysts systems with lower purification and separation cost. Catalytic cracking achieves the removal of oxygen in the form of water and carbon oxides using shape selective catalyst likes zeolites. The catalytic cracking approach offers several potential advantages over hydro-processing such as no or low need for hydrogen, atmospheric pressure processing and a possibility of coupling which makes pyrolysis logistically and economically attractive. Oxygenated organic compounds in contact with zeolite catalyst have been found to undergo a suite of chemical reactions which include dehydration, decarboxylation, cracking, aromatisation, alkylation, condensation and polymerization. [9]

Hydro-cracking is an effective way to make a large amount of light product, but it requires more severe conditions such as higher temperature and hydrogen pressure to deal with acids, which is not economical and energy efficient. [15]

Bio-emulsion is one of the techniques used, when a fuel has to be mixed with another fuel of hygroscopic nature. The emulsification technique has been considered an alternative approach to reduce the production of diesel engine pollutants, as well as the rate of fuel consumption. Emulsion allows for lowering of the viscosity of biomass derived oil to make it useful as fuel with improved combustion and flow properties. Upgrading of bio-oil through emulsification with diesel oil has been investigated by many researchers. A process for producing stable microemulsions, with 5–30% of bio-oil in diesel has been developed at Canmet Energy Technology Centre. Those emulsions are less corrosive and show promising ignition characteristics. Jiang and Ellis investigated the bio-oil emulsification with bio-diesel. A stable bio-oil/bio-diesel emulsion was produced using octanol as an emulsifier. [9][15]

Some other technique includes molecular distillation, Steam reforming and esterification. Molecular distillation is one of the most economically feasible ways to upgrade the oil quality. Fast pyrolysis of biomass followed by catalytic steam reforming and shift conversion of specific fractions to obtain H_2 from bio-oil was presented as an effective way to upgrade biomass pyrolysis oils. Esterification is a way to convert organic acid in bio-oil to their corresponding ester. [15][16]

VI. APPLICABILITY OF BIOMASS AS A FUEL OVER FOSSIL FUELS

Biomass is one of the most abundant resources in the world. By definition, it is the mass of living or recently dead plants and animals, along with their wastes. This means that there is not a single square centimeter of Earth that does not contain some form of biomass that could be converted to energy. Biomass is renewable. If people exercise proper conservation techniques, any form of biomass that is harvested to produce energy can be replaced over a period of time. Fossil fuels, on the other hand exist in finite amounts that will never be replaced. [20]

Biomass can easily be converted from its natural form into concentrated, high energy fuels such as alcohols or a type of gas that is virtually identical to natural gas. These fuels are relatively clean burning when compared with the fossil fuels in use today. It is the main benefit of biomass energy is that biomass can help clean our environment. World population is constantly increasing, and with the increase in population there is also a problem of increased waste which needs to be properly disposed. Many of garbage ends up in rivers, water, streams, oceans harming nearby ecosystems and having negative impact on human health. Instead of pollution our planet with all this garbage we could use it for the production of this energy and it helps cleaning our environment from many different form of pollution. [20] [21]

One of the biggest knocks against fossil fuels is that they give off toxic emissions. These pollutants, called greenhouse gases, trap the sun rays inside our atmosphere. This causes global warming. Biofuels do not release as much carbon as fossil fuels do, and because of this, there are fewer harmful emissions out of biofuels. [22]

Biomass is widely available energy source. With biomass, almost everywhere we look we can find the potential source for the production of biomass energy. This is certainly one of the main benefits of biomass energy over fossil fuels. As we all know that fossil fuels are not going to last forever, and once fossil fuels will be depleted world will need to have relatively cheap, readily available energy source, and this is where biomass should step in and make the difference. Many energy experts agree that when you combine economic and environmental character of energy sources biomass will be on top of your list as one of the best energy sources. [21]

As the world's supplies of fossil fuels are used up, the search for new, renewable energy sources is ongoing. The cost of producing biomass for use as fuels and energy sources is very cheap compared to the cost of finding and extracting fossil fuels. The cost of finding fuel is eliminated when one deliberately plants certain types of plants to be used in the production of biomass fuels. Extraction is generally no more expensive than harvesting crops for food. In some cases, growing and harvesting crops for biomass fuel use is cheaper than raising food crops. [20]

VII. CONCLUSION

The rate of fossil fuel consumption is increasing rapidly and it has a significant effect on environment. When fossil fuel is burned, carbon dioxide releases which add to the greenhouse effect and increases global warming. Greenhouse gases are contributing to global warming because they trap the energy of sun in the Earth's atmosphere. As we are dependent on burning fossil fuels for energy, but by burning they release the carbon stored in them. So, that means we are responsible for adding a lot more carbon dioxide to the air. The use of biomass for generating fuel can reduce dependency on foreign oil because biofuels are the renewable liquid transportation fuels. It is a sustainable fuel which offers significant reduction in net carbon emissions compared with fossil fuels because released carbon dioxide from by fossil fuel burning would absorb by the new plant to produce energy for their own growth. The cost of producing biomass for generation of fuels and energy sources is very cost-effective. Bio-fuels are also cleaner and safer to the environment than fossil fuels. After all this benefits from bio-fuels, it can use an alternative of fossil fuel. There is still a lot of research to be done towards ensuring that biomass derived oils produced fuels or bio-fuels have the capability to meet the standard of fossil derived fuels.

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