Energy Utilization and Conversion in Modern Biomass Conversion Technologies

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Abstract – This paper provides a review on the current state of biomass conversion technologies that are in use and those that could play a significant role in the future, such as those that might be linked to carbon dioxide (CO_2) collection and sequestered technology. Since the transportation industry is poised to become the most important new market for large-scale efficient biomass usage, here is where most of the focus will be placed. Bio-energy contribution, now estimated at 40EJ to 55 EJ per year, is expected to expand significantly in the future. Nevertheless, the precise objective of bio-energy will be dependent on the competitiveness aspect with bio-fuels and on agriculture policy globally. For the rest of this century as least, observations suggest a range of 200–300 EJ, rendering biomass a more significant alternatives of energy supply compared to mineral oil. The need to update bio-energy practices so they are compatible with sustainable development strategies is a major concern. It is expected that within the next two to three decades, the cost of electricity generated using sophisticated conversion concepts (such as gasification and contemporary co-firing and gasification) and contemporary biomass sourced fuels (e.g., hydrogen, methanol, and ethyl alcohol from the lignocellulosic biomass) will be competitive with conventional energy sources (partly based on price development with petroleum). An even more efficient and cost-effective biofuel production system may be developed from sugarcane-centric ethanol within the tropical climates.

Keywords – Biomass conversion, co-firing, combustion, bio-oil extraction, gasification, digestion.

I. INTRODUCTION

The development of large-scale biomass raw materials supply frameworks may be facilitated by flexible energy systems that allow for the use of both biomass and fossil fuels. This might result in a reduced-cost, reduced-carbon, and reduced-risk emission of energy in supply systems. The gasification pathway provides unique opportunities to couple this with low-cost CO_2 storage (and collection), leading to ideas that are versatile in terms of primary fuel input and product mix and have the potential to achieve zero or negative carbon emissions. This can only be accomplished by persistent research and development (R&D) initiatives, biomass market growth, sustained legislative support, and international cooperation. At the present day, bio-fuels account for the significant portion of the globe's energy distribution (about 80% of the total usage, or more than 400 EJ annually). Biomass resources, however, meet 10-15% (or 45±10 EJ) of this need, making biomass the most major renewable energy source to date. Biomass accounts for around 9-13% of overall energy sources in developed nations, but as much as 25%-33% in poor countries [1].

In certain nations, biomass provides as much as 50-90% of the country's overall energy requirement. Yet, much of this biomass use is domestic, with the poor relying on it for cooking and warmth. As a result, it is difficult to quantify biomass's role in the energy supply, since its non-industrial application is poorly documented. Certain traditional uses are also unsustainable since they deplete local soils of nutrients, lead to air and water pollution, and negatively affect people's health. In case biomass is collected for pwer without compensatory reforestation and other practices for conservations, it might potentially increase greenhouse gas emissions and have an impact on ecosystems. Even though some of this use is commercial—for example, residential firewood in industrialized nations and charcoal (bio-char) and wood in urbanized and commercial regions in developing nations—almost little information is available on the extent of these markets. There are around 9.6 expected joules worth of stuff in these markets.

Commercial power generation from biomass for application in energy production, industry, or transport fuel accounts for a smaller but rising portion of modern bio-energy (some 7 EJ/yr in 2000). A total of around 40 GWe of biomass-produced electricity production capabilities (generating 160 TWh annually) and over 200 GW of heat generation capabilities (generating >700 TWh annually) were built across the globe by the expiration of the 19th century [2]. It is projected that over 18 billion liters of biofuels were generated worldwide in 2016 (mostly ethanol made sugarcane and cereals and maize surpluses, and to a much smaller level bio-fuels produced from the oil seed crop). This amounts to around 0.5 EJ as transportation fuels (approximately 2000), although output of bio-ethanol across the globe is increasing quickly. Bio-energy has the (technical) potential to make a significant contribution to the future global energy supply. With expected technical advancements, energy cultivation on present farming land might theoretically make significant contribution more than 800 EJ without threatening global food supplies. Another 40-170 EJ might come from organic wastes and residues, with forest residues likely contributing the least and organic waste playing a potentially huge part, particularly when biological materials are exploited on a grander scaling. The maximum potential for bioenergy may be more than 1000 EJ (per annum) [3]. This is significantly more than the present world energy usage of approximately 400 EJ.

Although Sub-Saharan Africa, Eastern Europe, and South America are the most immediately attractive locations, Oceania and Northeast, and East Asia all stand out as prospective sites for biomass generation in the long-term future. The latter is mostly explicable by demographic trends (China's population is expected to decline after 2020) and rapid technical advancement in agriculture, which has resulted in significant productivity gains. These studies also reveal that substantial portions of the biomass industry's technological potential may be realized at moderate production costs, on the order of 2 US dollars per gigajoule (GJ). However, significant changes are needed to fully tap into its bio-energy potential. Increasing crop outputs per hectare is one measure of agricultural efficiency that is particularly important in developing nations. To what degree and how quickly such transformations may be implemented in various places remains unknown. The (area) bio-energy potentials could be significantly lower if circumstances are not optimal.

It is important to highlight that technology advancements (in conversions, including long-term supply chains of biomass (i.e.., global transportation of biomass produced energy transporters) may greatly increase the efficiency and competitiveness of bio-energy. One obvious motivator to explore the production possibilities of bio-energy is the need to increase competitiveness. This paper provides a critical review of the current status of biomass conversion advancements that are in use and innovations, which have a significant role to play in the near future, such as those linked to CO_2 Collection and Sequestration (CCS). The generation of biodiesel for the transport sector is dignified to become the most promising new marketplace for the widespread adoption of sustainable biomass practices. The rest of the paper is organized as follows: Section II focuses on defining the technological background of biomass conversion. Section III provides a critical discussion of combustion, bio-oil extraction, gasification, and digestion for heat and power. Section IV is about the production of transport fuels through the method of gasification. Section V concludes the paper by providing final remarks.

II. TECHNOLOGY BACKGROUND OF BIOMASS CONVERSION

Technological evaluation into the establishment of alternative sources of energy from bio-materials has been stimulated by the environmental impacts of continuous fossil fuel consumption and Greenhouse Gases (GHGs). Carbon dioxide (CO_2) is the primary contributor to the increasing levels of greenhouse gas emissions in the atmosphere. In addition, the globe's energy consumption is rising quickly, with bio-fuels contributing for more than 87% of all power production right now.

Most organic energy resources (such as gas and oil reserves) are located in politically unstable locations, making energy security a major concern. Thus, biogas from trash and leftovers may be an important part of the future energy picture. Renewable and versatile, biogas may be used in lieu of fossil fuels in the production of power and heat and as a gas fuel in vehicles. Moreover, biomethane (improved biogas) may replace natural gas in chemical manufacturing. Anaerobic digestion (AD) is an energy-efficient and ecologically beneficial technique, and recent assessments have shown that the biogas it produces has substantial benefits over other sources of bioenergy [4].

By making use of readily accessible resources, AD technology may lower GHG emissions in contrast to fossil fuels. The technology's waste product, digestate, may be used as a high-value alternative to mineral fertilizers in crop production. As of 2014, the total amount of biogas produced in Europe was 1.35 × 107 t. As a result of the significant development of agricultural biogas farm plants, Germany is the frontrunner in worldwide biogas generation, with approximately 25% of the total integrated capacity. More than 8,000 installations for producing agricultural biogas were active in Germany by the end of 2014 [5]. Numerous nations are now investing in research into alternative methods of creating biogas from agricultural byproducts and municipal solid waste. The infrastructure in several European nations is now conducive to the generation of biogas-powered energy. Remarkably, in Europe there is as much as 1.5 × 109 t of agro-biomass accessible for AD.

Biogas from cellulosic resources is a promising new energy source, and the United States, China, and India are all investing in alternative production systems. While waste-derived biogas (and/or biomethane) shows promise as a supplement to or replacement for the natural gas infrastructure, current production levels are insufficient to meet the world's yearly demand. The question of what feedstock is most suited for the biogas economy is not easily answered. Proteins, lipids, and carbohydrates all have several potential uses. Alternative fuels derived from agro-waste and biowaste have attracted the attention of researchers due to the pressing need for environmentally responsible waste disposal on a worldwide scale.

There is a plethora of potential pathways for converting biomass into energy carriers. The primary conversion paths utilized or being developed for the production of power, heat and transportation fuels are shown in **Fig 1**. In Section III, we will review the available or developing conversion advancements for generating heat and power (gasification, combustion, and digestion), and in Section IV, we will do the same for transport biofuels (gasification, fermentation, and extraction), differentiating between the two in terms of their potential and current availability.

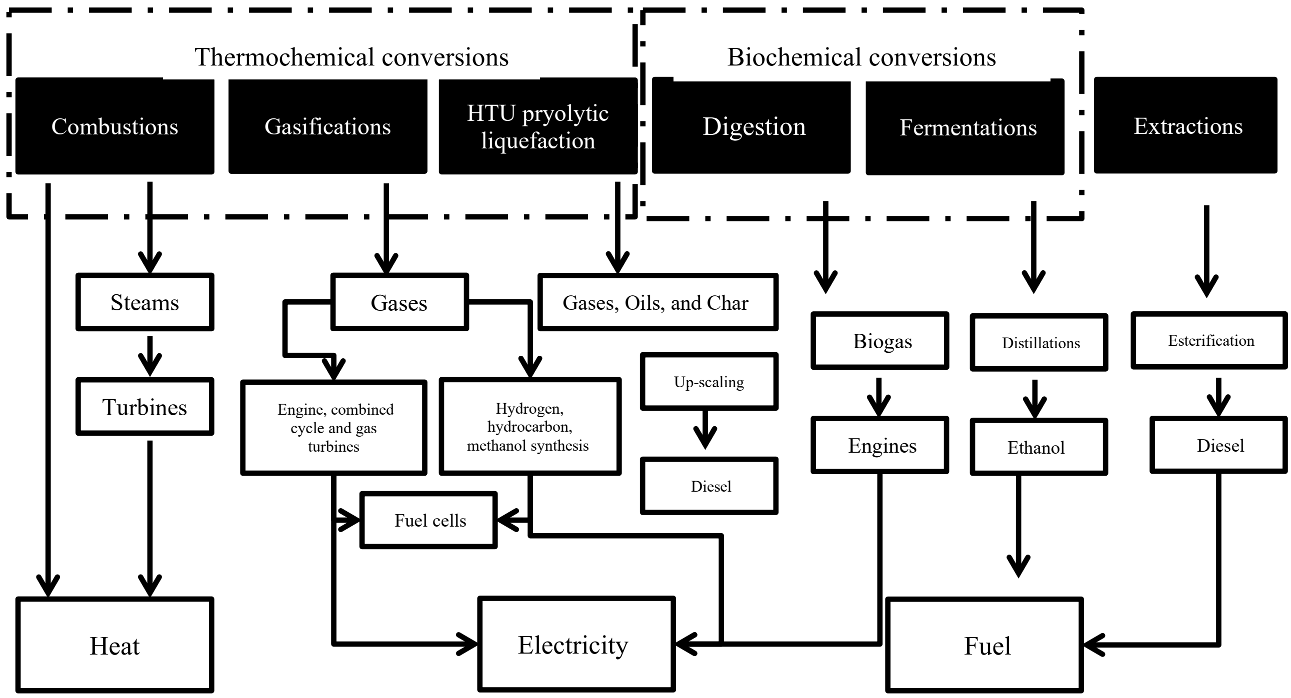

Fig 1. Conventional Methods for Biomass Conversion into Alternative Energy Sources

Fig 1 expands on several categories, which reflect a broad variety of technology ideas and deployment capability ranges.

III. COMBUSTION, BIO-OIL EXTRACTION, GASIFICATION, AND DIGESTION FOR HEAT AND POWER

Different alternatives exist for producing heat (industrial and domestic), Combined Heat and Power (CHP), and electricity. In this section, we will examine the most prominent technologies that are now in use or have been used so far, analyzing their function, current state, and baseline performance. Key choices now under development that may be pivotal in the next decades are also highlighted. There is a focus on the European setting since so many cutting-edge bio-energy technologies have been developed and implemented there. The technologies that may help nations in development with low incomes are very briefly discussed.

Combustion

Domestic Heating

Producing heat for domestic usage is an ancient application of biomass combustion [6]. Domestic heating of biomass is still a fundamental market for biomass in a significant portion of countries such as Germany, France, Sweden and Austria. In most countries, there is no hard data on how much wood is actually burned in fireplaces and stoves, although it is likely that these sources contribute significantly to meeting the heat demand in the nations where it is mentioned. Using wood in its traditional form is inefficient (as low as 10%) and produces large amounts of pollutants, such as dust and soot. Heating systems have come a long way thanks to technological advancements, with many now being automated, including catalytic gas purification, and using conventional fuels (e.g., pellets). The effectiveness value over the open fireplace is vital; whereas the open fireplace could have a negative efficiency over the entire year (considering the loss of heat within the chimney), modernized heaters could reach effectiveness of approximately 70% to 90% with significantly reduced emissions. Such methods have found extensive use in nations such as Germany, Sweden and Austria. In Sweden, for instance, the market for biomass pellets has grown rapidly due to the widespread use of automated firing systems.

District Heating and CHP

Large-scale implementations of biomass-based district heating may be found in the Nordic nations and Austria. Because of national climate and energy policy, biomass fuelled CHP models took off in the 1980s across Scandinavia. To begin, many people opted to upgrade their already-existing coal-fired boilers. With the clear benefits of increased electrical efficiency and reduced costs, there has been a rising trend in the size of CHP systems over time. This was coupled with the expansion of the biomass market, which increased the accessibility and competitiveness of biomass resources sourced from greater distances (especially forest residues). Denmark launched a comprehensive plan to put straw to use in the 1990s. Cigar burners and other effectual straw baling, storage, and transportation chains were among the many technological innovations developed and put into practice. Straw's high alkali and chlorine content made traditional combustion methods inefficient, therefore new approaches were required. These developments necessitated not just innovative pre-treatment methods like straw washing, but also more sophisticated boiler ideas like two-stage combustion. While Austria is a global leader in the deployment of biomass powered CHP, the majority of their systems are on the smaller scale of the village level and are often integrated with local fuel delivery networks. All of these locations have colder winters than the United States, making CHP a more viable option. In addition, it has been shown that community participation is crucial. Typically, CHP-plant owners are either local governments or forest owners. The energy expenses of such systems are often greater. The local population backs the project very strongly, though, because of the jobs and money it brings into the area. High labor expenses, however, have also resulted in extensive automation, with many modern plants operating entirely without human oversight.

Larger-scale Combustion of Biomass

Burning biomass is the simplest definition of biomass combustion. Humans have utilized this simple technology for thousands of years to produce heat and, subsequently, to produce electricity via steam. Wood may be the most frequent feedstock, but many other substances may also be burnt efficiently. Straw, sawdust, bark residuals, and shavings from sawmills are all examples of byproducts and scraps that may be used as feedstock, as can "energy crops" like switchgrass, poplar, and willow that are planted for that purpose. The pelletization of agricultural and wood leftovers is gaining popularity as a convenient alternative. To save money, many rural residents, including farmers, are turning to biomass heating systems instead of propane or heating oil. Direct space heating from a stove or fireplace is possible, or a back boiler may be connected to provide hot water to radiators throughout the property. Pellet stoves are a relatively new invention that utilizes an electrically powered auger to continuously feed compressed pellets of wood or other biomass into the fire. It is possible to leave these stoves running for at least twenty-four hours without checking on them. Boilers fueled by biomass may be used on a bigger scale to provide hot water, heat a building, or produce steam to operate machinery. Several farmers now rely on them as their only greenhouse heating source.

Combustion of biomass at industrial scales is used all over the world to generate power (along with heat and process steam). Throughout time, several variations on plant layouts have been created and put into use. The fundamentals of combustion include pile burning, grate firing (vibrating, stationary, and moving), fluidized bed, and suspension firing ideas. The Paper and Pulp (P&P) industry has been a pioneer in the usage of biomass combustion for power generation via the burning of black liquor and waste incineration. For the most part, the P&P industry uses the conventional boiler for the generation of electricity and steams as well as the recovery of pulping chemicals. From 1980s, countries such as the Netherlands and Germany began widespread deployment of waste incinera tors with extremely tight emission rules. Such facilities typically feature low stream temperatures and pressure (to deal with corrosion), high degrees of flue gas purification, and enormous capabilities (i.e., approximately 1 Mtonne/plant/year).

Current electrical efficiencies range from the high teens to the low thirties, and more effective models (attaining about 30% power effectiveness) are being put into service. Mass burning has replaced landfills as the primary waste-to-energy technique in Europe; however its high treatment costs of 50 to 150 Euros per tonne are offset by increased tipping costs. Independent plants for biomass combustion (by use of wood like forest left-overs as fuels) generally have capacities between 20 MWe and 50 MWe, with the same power effectiveness in the range of 25% to 30%. Low prices of fuels, a feed-in tariff, or a carbon tax for renewable power are necessary for such facilities to be profitable. Several cutting-edge combustion ideas have been making their way into the mainstream in recent years. Producing both electricity (and heat) and water from biomass is made possible by fluid bed technology and cutting-edge gas purification. Electrical efficiency of 30% to 40% are feasible on a scale of around 50 MWe to 80 MWe. With their innovative CFB (Circulating Fluidized Bed) and BFB (Bubbling Fluidized Bed) boilers, Finland is at the forefront of this sector. These boilers have great flexibility of fuels, minimal investment expenses, high efficiency, and have been implemented on a massive scale. Finland's newest plant, with a 500 MWth capacity, is co-fired with different bio-fuels, some of which are delivered by boat.

Co-combustion

In several European Union (EU) nations (such as the Netherlands, Spain, and Germany), biomass co-combustion, mostly in coal-generated energy facilities, is the single most drastically advancing options of conversion for biomass. Co-benefits firings are easy to see: when fuels of high quality such as pellets are utilized, the investment costs are cheap or nonexistent, and the total electrical effectiveness is high (typically about 40%) [7]. Also, direct substitution of coal results in a significant amount of reduced emissions. Moreover, many currently operating coal-fired power facilities have reached full depreciation, making co-firing a particularly advantageous GHG mitigation alternative. Biomass fire also reduces emissions of sulphur dioxide and other gases. Nonetheless, in certain nations, switching from coal to biomass might save money on costly flue gas cleaning infrastructure upgrades. As a rule, boiler performance and upkeep are unaffected by low co-firing shares.

As many plants already have at least some co-firing capability, there is growing demand for even greater co-firing shares (e.g., 40%). Nevertheless, there are more serious technical ramifications, such as for feeding lines and boiler performance, and these are the ones that are now being developed to address. To take advantage of economies of scale and decrease fuel supply threats, Denmark is constructing power plants (like the Avedore plant) that can combine natural gas or coal with several types of biomass streams. Straw is widely used as a fuel source in Denmark. Problems with corrosion and slagging in traditional combustion systems were brought on by the alkaline and chlorine rich straw. Straw, however, may be used in multi-fuel systems to generate low-temperature steam, which can then be superheated using fossil fuels. These issues are mitigated to a large extent by using this method.

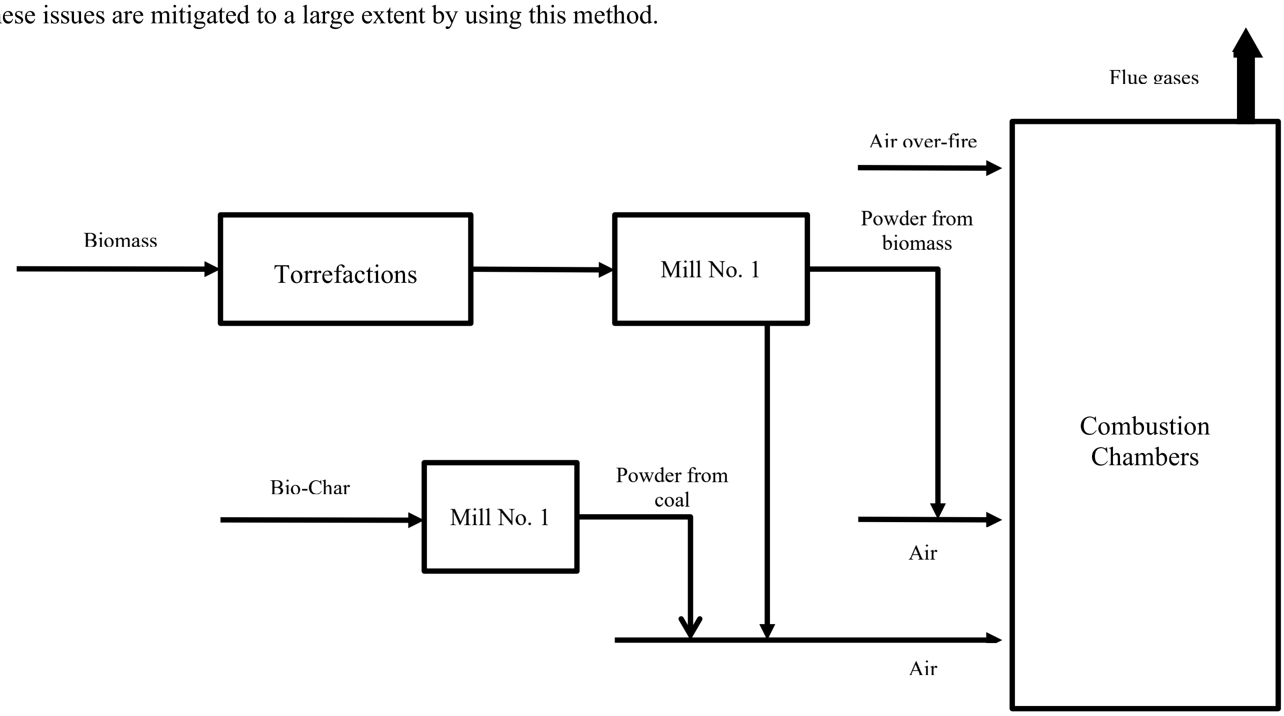

Fig 2. Torrefaction-Based Co-Firing Framework

Co-firing Technologies

By burning both fossil fuels and biomass like coal or natural gas together in one power plant, known as "biomass co-firing," more energy may be produced with less environmental impact. In the power industries, co-firing technologies may be segmented into three distinct categories as shown in **Table 1**.

Table 1. Categories of Co-Firing Technologies	
Direct co-firing	For existing coal-fired boilers, especially pulverized bio-coal boilers, direct co-firing is the most popular and cost-effective way of co-firing biomass with coal. Dependent on the biomass's fuel properties and co-firing ratio, the bioenergy and coal are burnt together in the coal boilers furnace using the same or different mills and burners.
Indirect co-firing	Gasification, pyrolyzation or torrefaction of biomass produces upgraded solid biomass, gas fuel, and liquid fuel, which are then co-fired in the furnace. Hence, there are three types of co-firing systems: those based on torrefaction (which is what this thesis study focuses on), those based on gasification, and those based on pyrolysis.
Parallel co-firing	To increase the conversion efficiency of the coal-fired energy plant, a biomass boiler may be installed beside the existing boiler in a parallel co-firing arrangement.

Direct co-firing has been the most common alternative for industrial biomass applications because of the cheap investment cost of converting an existing coal power plant into a co-firing plant; nevertheless, high volatile content, low density, and the high water content of biomass complicate its combustion behavior, restricting its co-firing ratios. Since it may utilize coal, oil, or natural gas as its base fuel, indirect co-firing provides a great deal of fuel flexibility. Since specialized biomass burners may be operated in parallel with the conventional boiler unit, the degree of business risks is lowered and dependability is improved with parallel co-firing.

Co-firing Solution for 100% Fuel Switching

Biomass is distinct from coal when it comes to combustion. Biomass loses a substantially larger percentage of its mass via devolatilization than coal does; but, if the biomass nanoparticles are too big or thick, they may not be pressurized into the flue gas, instead entering the bottom ash stream and undergoing minimal conversion beyond dehydration if the biomass injection is not properly coordinated. Moreover, the biomass particles' low densities allow for oxidation at rates far greater than those for coal. Moreover, striated flows are prevalent during biomass-coal combustion if the boilers fail to adequately mix the flue gases in the furnace Chamber. While it is theoretically possible to co-fire with 20% biomass depending on the energy content, most plants are only co-firing at 5- 10% levels at now. In most parts of the globe, pulverized fuel plants have the highest installed capacity for burning coal. As a result, pulverized coal plants are the best candidate for co-firing. Hence, to achieve high levels of bioenergy co-firing in current pulverized coal boilers, a reliable biofuel co-firing solution is necessary.

Concept of Torrefaction based Co-firing System

Torrefaction greatly improves biomass's use and combustibility in combustion chambers (see **Fig 2**). One such pre-treatment method that has showed promise and potential in recent years is torrefaction, which may be used to improve the quality of biomass. Thermo-chemical fermentation process occurs between 200 and 300 ˚C, with a standard residence time of 1 hour; during this time, biomass partly decomposes, releasing volatiles and generating the solid end products. During thermal decomposition, the hemicellulose matrix that holds the raw biomass's cellulose fibers together is broken down, resulting in shorter fibers and a loss of the raw biomass's tenacity. First, the weight and energy content of torrefied biomass usually remain constant at 70% and 90%, respectively, compared to the original. In addition, the raw sample is both challenging and energy-intensive to ground due to the higher fiber content of raw biomass. To assist the insertion of wood powder into boiler furnaces, torrefied woody particles have a greater flowability and superior fluidization behavior than raw biomass. Lastly, the quality of torrefied biomass is consistent between batches. After torrefaction, the physical and chemical qualities of woodcuttings, destruction wood, and woody biomass are all the same, allowing for a wider range of fuel options and mitigating the effects of seasonality.

Gasification

In the 1980s, both the United States and Europe paid a lot of attention to gasification as an approach to convert a wide variety of solid bio-fuels into combustible syngas or gas [8]. When biomass has been gasified, the fuel gas may be further processed or purified before being burned (for example, in gas turbines; whenever integrated with collective cycles, this amounts in Biomass Integrated Gasification/ Combined Cycle (BIG/CC) plant). For further information on gasification's role in the fuels industry, see Section IV. In the section, biomass gasification for the generation of heat and electricity will be discussed first. We shall differentiate between gasification on a lesser scale (in several kW^{th} to approximately 1 MWth range of capacity and typically incorporating fixed-bed gasifications ideology) and large-scale gasification (often associated with Fluid Bed perceptions).

Small-Scale Gasification

Small-scale gasification was heavily supported in the 1980s and 1990s. Small scaled power and power production using gas or diesel engines led to the creation and testing of downdraft and updraft, fixed-bed gasifier with capabilities ranging from under 100 kWth to several MWth. Commercial uses of tiny gasifiers for heat generation is well-established. Small-scale (Bioneer) gasifiers for heating were widely used in Finland in the 1980s with great success. Nonetheless, combustion is a formidable rival to gasification as a heat source. Using agricultural wastes near to their point of production has been a central idea for quite some time. Several different gasifier, gas cleaning, and system integration ideas were developed and put to the test under various situations. Under the help of organizations like the World Bank, technology was also sold to other underdeveloped nations. Both rural electrification and economic growth were major factors.

Small-scale gasification integrated with diesel or gas engines has not taken off despite significant research and development efforts, financial expenditures, and a larger number of demonstration components. It is possible to purchase small (fixed beds) gasifiers, which are integrated to gas/diesel engines (typically for 100 kWe to 200 kWe models with an estimated, moderate, electrical effectiveness of 15% to 25%). Implementation has been successful, especially in India. Nevertheless, their widespread implementation in the EU has been delayed by the critical necessity of small-scale glasifiers based on the quality of fuels (ideally conventional and hence more expensive fuels such as pellets) and cautious operations, as well as high prices, notably for adequate gas cleaning given the stringent emission limits. Standardized gasification models that are pre-packaged using micro-turbines and hydrogen fuels might be a game-changer for small-scale power production from biomass in the long run, but such systems need further research and development, as well as inexpensive and dependable fuel cells and, significant breakthroughs in small-scale gas cleansing.

Larger-scale Biomass Gasification

Gasifiers with a capacity of many tens of megawatts of thermal energy (MW^{th}) are often connected with Circulating Fluidized Bed conceptions that provide critical fuel efficiency. It is true that gasifiers operating at ambient conditions (ACFB) are employed in certain countries (such Italy, Austria, Sweden, and Germany) to generate (raw) producer gases and process heat, but this is not a widespread practice. Biomass Power generation from Integrated Gasification/Combined Cycle (BIG/CC) systems is very efficient and adaptable with regard to fuel characteristics [9]. Around 30 MWe is the size at which 40% electrical efficiency (LHV basis) is achievable in the near future. Throughout the early part of the 1990s, BIG/CC was the focus of several European Union (EU) and state projects. Research and demonstration projects have been launched because of the potential of this technology to achieve great electrical efficiency at small scales with minimal capital expenditures. In addition, the fuel gas must be rigorously cleaned before burning in order to fulfill gas turbine criteria, hence BIG/CC ideas may reach minimal emission to air levels.

Some nations and gasification approaches have seen demonstration projects get off the ground. For example, in Brazil, a World Bank/GEF financed initiative was established to showcase an ACFB BIG/CC unit with 30 MWe fueled with grown Eucalyptus. During the same space of time, the first Swedish BIG/CC units (BIOFLOW piloted project) has logged thousands of hours of operation using a pressurized gasification process. In 2000, the Yorkshire, UK facility that had been testing an atmospheric BIG/CC cataloging switched to using natural gas instead of bio-fuels. The implementation of the indirect FERCO concept of gasification in power plant in Burlington is a noteworthy project in the United States. There have also been several national projects developed (especially in the EU) to create pre-commercial or demonstrator units utilizing BIG/CC technologies. Nonetheless, putting the demonstration projects into action proved challenging. First generation units were relatively expensive.

Unit capital expenses are substantial for the initial generation of BIG/CC systems. Prices of between €5000 and €3,500/kWe are quoted, which is still much over the target range of €1500 to €2000/kWe that would put BIG/CC in a competitive position. There are still a number of technical challenges to be overcome, such as those associated with pre-treatment and tar removal. Rapid market liberalisation in the energy industry in the late 1990s made it difficult for many utilities to undertake costly demonstration programs. Recently, several of the demonstration units were decommissioned. The energy industry, which is notoriously risk adverse, tends to favor co-firing and established combustion technology (which, of course, continues to advance over time). As a result, progress on a technology that, in the not-too-distant future, will be able to generate electricity from biomass at market-competitive prices, has stagnated. Many studies have analyzed the cost-efficient potentials of the BIG/CC model, and at considerably higher scale (above 100 MWe) and according to the continual advancement of gas turbine technologies, it is substantial. Use of grown biomass as fuel may be economically viable in many parts of the globe due to the confluence of high electrical effectiveness and relatively cheaper unit capital expenses. But, its progress has been modest thus far.

Gasification for Co-firing

Larger co-firing conventional ratios in power stations may also be achieved by gasification, which eliminates the necessity for additional solid fuel inputs and enhances control over the combustor. Recent evidence from co-firing systems demonstrates the viability of CFB gasifier deployment (e.g. Amer in the Netherlands). Gasifier from gasification might be used as a co-fuel in already-existing or newly-built combined cycles that utilize natural gas as their primary fuel source. Using economies of scale, one may achieve both relatively higher efficiencies and cheaper costs (presently up-to 60% for NG fired cogeneration) while still having a reliable fuel supply, since the proportion of fuel gas to natural gas burnt can be adjusted. While this has not yet been proved anywhere around the world, there has been an increase in study into it, and it may prove to be of critical relevance in the near future as co-firing possibilities at unambiguous coal-fired energy plants are progressively exploited.

Bio-Oil Extraction

Pyrolysis and Liquefaction Processes

Biomass may be pyrolyzed at 500 ˚C temperature in the deficiency of oxygen to generate bio-oils, biogas and bio-char. The liquid fraction (70% or more of the biomass used for heating) may be optimized by the use of flash pyrolysis methods (rapid pyrolysis). Oxygen makes up around 40% of bio-weight; oil's making it caustic and acidic. Engines and turbines might theoretically be fueled by crude bio-oil (with some tweaks and only for higher grade oils). Upgrading the oil (through hydrogenation) may also lower the oil's oxygen level. Nonetheless, there are costs associated with upgrades in terms of money and energy. The majority of upgrading and pyrolysis technologies is still in the stage of demonstration. Other methods for creating 'raw intermediate' liquids from biomass include liquefaction (pressured conversion) and HTU (Hydrothermal Upgrading) that convert high pressured biomass in moderate temperatures and water to bio-fuel (technique in its early stages, developed first by Shell).

In comparison to gasification, pyrolysis has seen less development thus far (and liquefaction options even more so). Potential small-scale technological deployment in rural surroundings and as feed-stock for the chemical sector has attracted a lot of interest since the late 1980s and early 1990s. It was also argued that bio-higher oil's energy density compared to untreated biomass would reduce transportation costs. While a lot of knowledge has been amassed over the years, only a few of demonstration units have been fully implemented (Fortum, a Finnish oil firm, and Dynamotive, a Canadian company at the forefront of commercializing pyrolysis technology, are excellent case studies). Market implementation is still in its early stages. More and more people are looking at pyrolysis as a way to prepare bio-oil for long-distance transport and subsequent conversion (refers to a wide range of applications, from (entrained flow) gasification for syngas biosynthesis to efficient energy production).

The term "pyrolysis" refers to a thermal cracking process used for biomass feedstock that either does not contain oxygen or contains just a small amount of oxygen. In normal use, it is subjected to temperatures between 300 and 700 ˚C. The process of pyrolysis amounts to three major products: gas, solid char, and liquid oil. An essential component of the method is a thermal reactor used to generate heat. Ablation involves applying pressure to a substance while moving it rapidly over a heated surface. Using this novel quick heating method, big pieces of biomass may be heated directly without being crushed beforehand. Further cracking processes, repolymerization, and bio-oil formation may be avoided if the pyrolytic volatiles are quickly evacuated from the reactors and condensed, mostly in cooling systems. To create useful reactive intermediates, a vacuum pyrolysis technology may be used instead of a carrier gas. The features of the biomass and the operation settings determine the comparative yield and attributes of the liquid product. Biochemicals and biofuels may be made from the liquid bio-oil that is produced when biomass is pyrolyzed. The impact of pyrolysis contexts of solid products and the physio chemical characteristics of the chars have been studied in a number of publications that pyrolyzed tobacco wastes in order to establish high-value products such as biochar.

Using TG-Fourier transform infrared (FTIR) and thermogravimetric (TG) analysis spectroscopy methods, some researchers e.g., Ramsay [10] has studied the influence of temperatures and heating frequency on the products, uncovering the possibilities of pyrolysis for the valorization of tobacco. In contrast to quick pyrolysis, which always results in a high output of liquid oil, slow pyrolysis is known to produce a high yield of char. The yields and biochemical composition of slow and quick pyrolysis were studied by Zaoui et al. [11]. They discovered that the operating parameters were just as important as the biomass type when it came to determining the yields and featuring the liquid oils.

Wijayanti, Musyaroh, and Sasongko [12], the best liquid oil yields were generated at 600 ˚C. This was determined by studying the influence of higher temperatures vacillating from 500 ˚C to 700 ˚C. The dispersal of chemical components in the pyrolytic liquid oil was studied by Ourak et al., [13], who looked at the impact of temperatures (400 ˚C to 700 ˚C) and additions (ZnCl2 and MgCl2). They discovered that the liquid oil could be converted into an easily ignitable fuel. Oil from pyrolysis procedures and the resulting product are typically analyzed for chemical components using a 1D gas GC-MS (chromatography-mass spectrometry). Modifying the procedure for py-GC-MS procedure, the TG-MS, and the TG-FTIR might provide more understanding of chemical substances.

Tobacco leaves and stems were analyzed for their chemical constituents by Sun and Sun [14]. They found that secondary breakdown occurred at temperatures over 350 ˚C, resulting in the fragmentation of aromatic components into smaller molecules. Nitrogen-containing compounds, phenols and nicotine are only some of the other chemical substances that have been investigated. While one-dimensional GC has been in use for quite some time, it still has some minor limitations when it comes to achieving the greatest possible compound separation. Higher-dimensional GC methods might improve the detectability and resolution of liquid oils, enabling the identification of more chemicals. Many organic molecules with the organic fractions may be identified using 2D, TOF/GCxGC MS evaluation as opposed to standard GC-MS. Despite the abundance of research on 2D GC evaluation of bio-fuels and tobacco bio-oils is still uncommon.

Digestion

Biogas

A wide range of feedstocks, including organic household waste, organic industrial by-products, manure sludges, etc., have been shown to be suitable for anaerobic biomass digestion, and this method has been successfully utilized in commercial settings. Whenever a digested gas is employed to energy gas engine-based generators, the total electrical efficiency is poor (about 10-15%). Digestion is best for wet biomass sources. It is estimated that the maximum efficiency of converting biomass into gas depends on the feedstock, but it is about 35%. In order to break down the large amounts of organic material found in their wastewater, the food and beverage sector has traditionally relied on the process of digestion. Co-digestion of manures as well as other wet organic wastes, for example, is proving to be especially successful in today's market for sophisticated, large-scale models for wet industrial wastes. In the field of wet waste processing, nations such as Denmark and Germany stand out because to their sophisticated digesting systems.

Landfill Gas Utilization

The microorganisms living in a landfill produce a wide variety of gases known as landfill gas (LFG). Landfills that are just not properly managed may release large amounts of LFGs like CH4 and CO_2 into the atmosphere, causing significant climate change; emit unpleasant odors, trash, and dust into the surrounding area; and allow leachate generated in the landfill to leak into nearby ground and surface water. At 17.7% of the total CH4 released by the United States in 2011, 1908 landfills were responsible for producing roughly 1.03±108 metric tons of carbon equivalent of CH4. China has 580 landfills in 2013; 13 percent of the country's total CH4 emissions came from these sites. Estimated CH4 emissions from waste disposal facilities in Europe made about 22% of the total, making them the second greatest source of CH4 generated from human activity. If LFG emissions are allowed to continue unchecked, they will have the greatest impact on the continent of Africa. Managing the created LFG is crucial since the total potential methane from Africa in 2012 was 10,496106 m^3 (assuming all wastegenerated is landfilled).

The term "LFG utilization" refers to the process of gathering and processing LFG obtained from the breakdown of solidwaste from a landfill for the purpose of creating power, fuel, heat, and different valuable chemical compounds. An expanding suite of LFG utilization technologies is now being put to use in a variety of contexts. Africa is home to just around 1% of the world's LFG utilisation technology, and the continent is seeing a relatively slow pace of growth in this area over the years. Africa is home to around 15% of the population within the globe, or more than 1.2 billion individuals. However, Africa relies heavily on landfilling for its Waste disposal. Hence, as MSW output is anticipated to rise as

Africa's population rises, an expansion in landfill sites is anticipated. The continent has not been able to make good use of the LFG it generates from landfills, and neither African policymakers nor academics have paid much attention to the process of enriching the LFG that is released from African landfills. Gases produced from landfills may provide viable options for the supply of energy in several African nations. According to estimates, the conversion of LFG to electricity in Kampala (Uganda) reached 31,000 MWh in 2009 and 26,600 MWh in 2011 [15]. It is being considered as a significant source of power in South Africa, Nigeria, and other African nations.

Landfills are one particular location from which biogas may be extracted. Landfill sites are a major source of methane emissions since they produce methane-rich landfill gas. Profitability has led to the widespread implementation of systems for collecting landfill gas and turning it into power using gas engines. It is easy to see the advantages: This process diverts methane gas, which has increased global warming potentials compared to carbon dioxide (CO_2), from landfills and converts it into usable energy carriers. As a result, reusing landfill gas has become a popular strategy for reducing greenhouse gas emissions in many parts of the globe, including the United States (US), European Union (EU), and increasingly other parts of the world.

IV. PRODUCTION OF TRANSPORT FUELS THROUGH GASIFICATION

Fig 1 shows the three primary pathways to generate transportation fuels from biomass. Gasification may provide syngas, which can then be transformed into methanol, DiMethylEther (DME), Fischer-Tropsch liquids, and hydrogen. The most common method for making biofuels involves hydrolysis procedures to convert ligno-cellulosic biomass into sugars before the biomass is fermented into ethanol. Last but not least, oil seeds (such as rapeseed or palmoil) may be extracted for their oil, which can then be esterified to create biodiesel for use as a biofuel. Despite its small weight, hydrogen needs a complex infrastructure to transport and store. Except for DME, all of the other potential fuels are liquids that may be stored and supplied using existing facilities.

As ethanol and methanol in particular have a lower power density than gasoline, more mass must be carried on board to achieve the same level of energy output. The fuels' potential toxicity and disaster-related environmental effects are also important considerations. Benzene and other carcinogenic aromates are present in gasoline and diesel. Although methanol does not cause cancer, it is more harmful to human skin than gasoline. Closed filling systems and other precautions are needed to make the fuel safer for consumers to handle than gasoline and diesel (e.g. as employed for LPG). Investment expenses will go up as a consequence of this. As compared to traditional fuels like gasoline and diesel, Fischer-Tropsch liquid and ethanol have significant benefits, including a negligible toxicity as well as a complete absence of sulphur and aromates. As an added bonus, we can use the gasoline and diesel distribution networks already in place.

Methanol, Hydrocarbons and Hydrogen via Gasification

Liquid-phase methanol production, Fischer-Tropsch synthesizing (integrated with energy production), and new gas separation and cleansing technologies are all examples of cutting-edge technical ideas that might lead to reduced production costs and greater overall efficiency in the long run. Nevertheless, further Research and development (R&D) efforts over a significant duration of time are needed to accomplish such as state of affairs. The efforts to enhance gasification technologies for the production of syngas are on the increase in nations like Sweden, the Netherlands, and Germany. Energy efficiency in somewhat "standard" manufacturing plants may approach 60% (on a 400 MW^{th} input scale). Deployment, in large-scale, (e.g., above 1000 MWth) is necessary to fully take advantage of the economies-of-scale intrinsic to these kinds of projects. From an economic and efficiency standpoint, however, this choice (or group of options) stands out as a clear winner.

By gasifying biomass, we may get methanol, hydrogen, and Fischer-Tropsch diesel. Prior to producing the secondary power carrier by relatively typical gas processing technologies, all approaches need very pure syngas. SNG (Synthetic Natural Gas), and DME (DiMethylEther) could be established from syngas in addition to MeOH, hydrogen, and FT-liquids. Many approaches using either already available technology or cutting-edge, experimental ones are feasible. A typical conversion flowchart for such procedures is shown in **Fig 3**. Before the formaldehyde or FT reactor, or hydrogen separation, there is a sequence of operations to convert the biomass to the desired gas requirements.

Syngas, which includes carbon monoxide (CO), hydrogen (H2), and a few other chemicals, is what comes out of the gasifier. There follows a chain of biochemical processes on the syngas. Except the gas cleaning train, the machinery required to produce hydrogen gas, methanol, and fuel-grade diesel from natural gas is identical. Gas turbines, boilers, and steam turbines may all be used to co-generate electricity from the remaining unconverted gas fractions. Even though there hasn't been any commercial biofuels production using gasification yet, there has been a lot of research and development into the process over the previous several decades. For the purpose of creating transportation fuels (like methanol), interest in syngas made from biomass emerged in the 1980s, in part as a response to the escalating price of oil. French and Swedish researchers have been working to perfect the process of pressured gasification for creating methanol from biomass.

Large-scale CFB gasifiers were structured in Finland by fertilizer manufacturer Kemira to generate syngas for use in the city's ammonia plant (which was shut down). Important industrial experience with this technique can be found at Schwarze Pumpe (East Germany), where gasification capabilities (entrained flow) has been built to produce methanol from waste streams. Advanced gasification techniques for widespread use are in a precarious position due to low energy costs. There has been a resurgence of interest in gasification technology for the manufacture of transportation fuels ever since e.g., Sharma, Antil, and Sachdeva in [16].

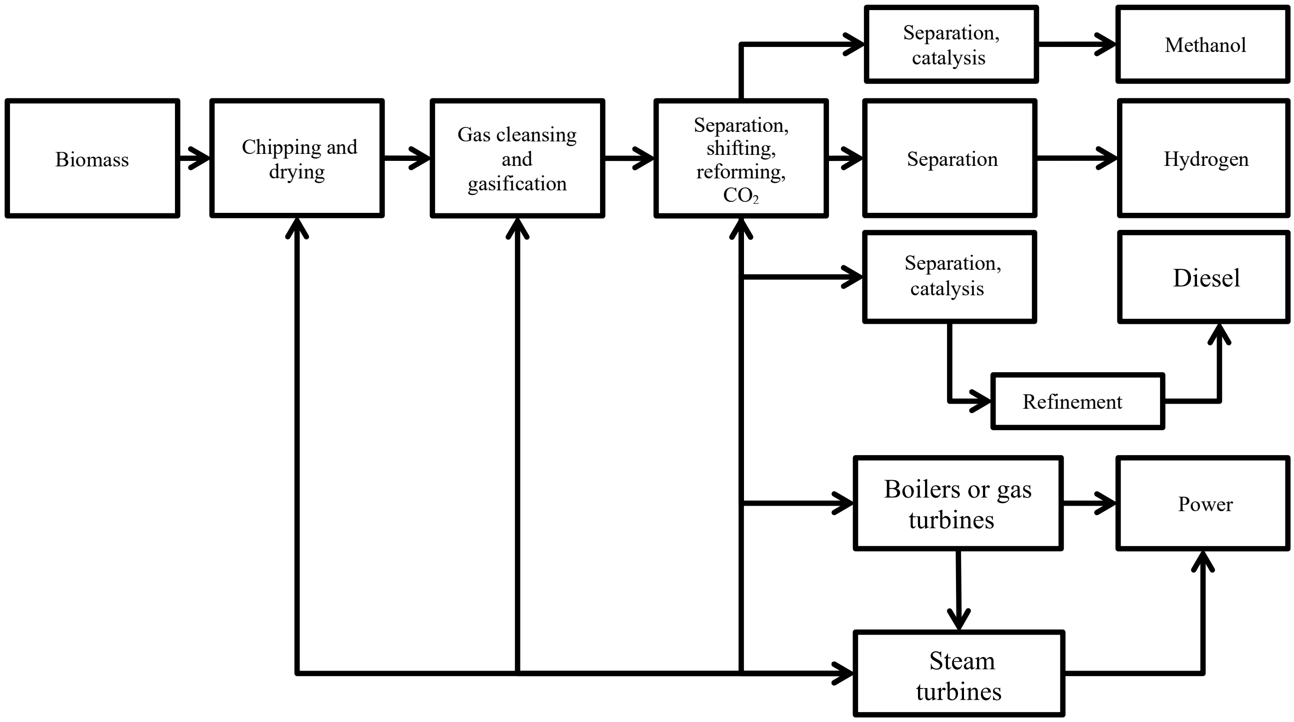

Fig 3. Using plant matter for production of fuels including hydrogen, methanol, and FT diesel by gasification

Choren, a German business, has shown how to make FT-diesel from biomass gasification in Freiburg. Even though the technological and economic promise of such ideas is significant, their implementation seems feasible. However, technological hurdles remain, and they are most probably becoming challenging compared to those facing BIG/CC ideologies. This is due to the fact that more complex gas cleansing is required to safeguard downstream catalytic gaseous production equipment. Once pure syngas is readily accessible, established methods for making FT-liquids, methanol, hydrogen, and DME may be put into practice. Gas purification, process scaling, and integration into existing infrastructure are the primary obstacles to progress.

V. CONCLUSION

Throughout the 1990s and 1980s, bio-energy and biomass were mostly considered at the regional and local levels; however, this is becoming a global issue. The internationalization of biomass markets has led to an increase in the export of biomass and biomass-retrieved energy transferors. In addition, it becomes more challenging to keep extremely distinct national policies due to carbon and certificate trading, including projects employed as under the Clean Growth Approach or the Joint Operational Activities. An enthralling example of the pan-European objective with potentially significant implications for a European bio-energy marketplace is the new EC biofuel regulation, which mandates biomass resource generation and transportation of high-quality fuels. More competitive, sophisticated and efficient conversion capabilities, particularly, for the production of heat and power, must be commercialized, and similar considerations apply to technological advancements and the RDD&D trends required doing so. Biomass is one renewable power source that may significantly contribute to the globe's power production in the future. Bioenergy's exact role will be determined by its rivalry with fossil fuels and by agriculture policy across the globe, although it appears reasonable to predict a significant rise from the present contribution of 40-55 EJ per year. With possible observations of 200–300 EJ lasting far beyond this century, biomass has surpassed mineral oil as a viable energy supply source. Bio-energy has serious challenges, one of which is the need for its usage to be updated so that it may be integrated into sustainable development strategies.

Data Availability

No data was used to support this study.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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