Biomass gasification of carbonaceous feedstock for syngas production: A Review

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Abstract. Biomass is a renewable energy’s most abundant source which includes anything from energy crops or agricultural residue or forestry falls and animal (biogenic) waste. The biomass can be used to produce various products or can be used as an energy source, but utilization of these energy sources should be effective and efficient so the conversion process should be economical, so that it can compete in the market filled from fossil fuel derived products. This paper discusses about the different types of conversion process and the uses of the biomass derived products.

1. Introduction
Biomass has been utilized as fuel for a huge number of years\cite{1}. Advancement of biomass applications has made extraordinary development in the past decades\cite{2}. There is currently an assortment of strategies for changing over biomass into heat and power, from pellets for domestic unit heating and to squander used to deliver power in industrial plants. Biomass and waste gave around 66\% of essential sustainable generation in 2014\cite{3}. Thus, bioenergy is as of now the biggest type of sustainable power source. Biomass is utilized essentially in nations with forest such as branches from trees, wood chips, and sawdust can be utilized to deliver power and heat. Nations with extensive agrarian businesses and ventures that create squander items that can be utilized as biofuels additionally can possibly expand their utilization of biomass\cite{4}.

1.1. Energy Triangle
In providing society with energy, an adjust must be struck between three key measurements: competitiveness for economics, security of supply, and the climate and environment. No single energy source is ideal for all measurements\cite{5}.

Carbon dioxide is discharged into the environment when biomass is combusted, yet when biomass develops as it absorbs carbon dioxide through photosynthesis. So, Biomass is, considered as a carbon neutral source. By utilizing biomass in control generation rather than non-renewable energy sources, CO\textsubscript{2} outflows are fundamental reduced\cite{6}

1.2. Security of Supply
Biomass can be changed over into a steady and solid supply of power and heat. The utilization of biomass will be effective and adaptable combined heat and power plants (chps) can help adjust
discontinuous sustainable power sources like wind and solar based. One imperative advancement is to secure reasonable sourcing volumes and to build up a global trade framework. Biomass assets are topographically diversified and political hazard is minimal[7].

1.3. Competitiveness
Utilizing biomass to deliver energy is at present more costly than utilizing other sources, for example, coal, gas or atomic power. The worldwide biomass supply chain network is developing and, after some time, innovative and calculated upgrades will cut down costs. An expanded CO₂ cost will likewise enhance the financial aggressiveness of biomass[8].

2. Characteristics of biomass feedstock
The Characters of Raw Biomass Feedstock Material and agricultural residue and forest residue are both lignocelluloses, comprising of the following. Other than lignocellulose is starch from food crops, oil extraction from seeds, fats of animals. There is ununiform structure straw is present. The concoction synthesis and type of cellulose are distinctive in stem, dry-leaves, thrones, branch of trees. In the various straw, the skin and dry-leaves are minimal in place, while its core is free[9]

The non-uniformity of structure brings about contrasts in various parts while changing. The change characters and items change as indicated by the distinctive composition and organizations in the straw. In the interim, there are contrasts in enzymoolysis, physical and chemical execution in the company of various sections, tissues-cells[9].

2.1. Lignocellulose
Lignocellulose is a nonexclusive phrase for portraying the principle elements in many vegetation, in particular cellulose, hemicelluloses, and lignin. It is a perplexing grid, involving a wide range of polysaccharides, phenolic polymers and proteins. Cellulose, the real part of cell dividers of ground vegetation, is a glucan polysaccharide has vast repositories of vitality that give genuine prospects to transformation into fuels form biomass. Lignocellulosic biomass comprises an assortment of qualities in particular physical and substance qualities. This type is not made of starch edible foods.
2.2. Problems faced for a biomass feedstock for exploitation

First reason is to work on application of a single technology that should concentrate in extraction of cellulose as there are many ways therefore none of it is used extensively, due to pretreatment framework and major-research into innovation for coupling are inadequate. Accordingly, there are critical issues of natural contamination, misuse of assets and high cost. For instance, amid the creation of ethanol produced from cellulose, the accentuation of using the cellulose part, while alternate divisions, protein from animals, hemicellulose and lignin from plants, are incompletely used. The usage of cellulose alone to create ethanol can expand the cost as well as cause misuse of assets and contamination of the earth. The financial productivity of the cellulose ethanol industry is a trouble critically needs to be explained. The extraction strategies are costly and frightfully polluting[10, 11].

The proportion of matter usage & generation of low yield. The proportion of material usage and creation yield is low. Some extraction techniques utilize refined material keeping in mind the end goal to get items with a high creation yield, however, these strategies additionally making the rate to decrease for multiple purpose materials and increment waste. This increases the generation cost.

2.3. Polygeneration

The point of polygeneration innovation is the most extreme use of asset and aggregate item proficiency with negligible contamination discharge. The improvement and usage of different segments and assembling methods ought to be viewed as a framework, which is the polygeneration arrangement of feedstock. Enhancing the quality of asset use with regards to add up to usage of biomass can bring about financially possible, astute, and effective asset use. This problem can only be combated by ding research in multiple areas [12].

3. Coproducts generated from biomass derived products

Before analyzing the products, one should know the process used for conversion process. The four basic conversions are

(i) Thermal conversion/combustion
(ii) Thermochemical conversion
(iii) Biochemical conversion
(iv) Chemical conversion/ Physical extraction.

3.1. Thermal Conversion/combustion

The thermal conversion is most easily conversion process compared to other, it involves combustion of lignocellulose materials, which consists of lignin, cellulose, hemicellulose.
Combustion of lignocellulose only provides heat as a product which can be used to generate power.

3.2. Thermochemical conversion
This process involves two subtypes which is

(i) Pyrolysis
(ii) Gasification

There is no direct combustion of biomass feedstock, but there is heat given as input along with other additional inputs such as steam air. The main difference between the pyrolysis and gasification is the amount of O₂ given, in pyrolysis the O₂ is completely neglected. As in gasification O₂ content is partially given. Pyrolysis is a procedure of giving the input feedstock at temperatures around 600°C under highly pressurizing conditions and minimum O₂ levels. All the while, biomass experiences fractional combustion. Procedures for pyrolysis will result in fluid energizes and a strong buildup - scorch or biochar. Biochar resembles charcoal which has high carbon content. Liquid stage items result at low temperatures to crush the greater part of the carbon particles resulting in the formation of tar, oil and methanol [15]. Gasification is using higher temperature in a controlled domain which coverts the feedstock into gas. This will happens in two phases: incomplete burning to shape maker gases and charcoals, followed by substance diminishment.

3.3. Gasification process
Gasifier types of gear are for the most part named in view of the flow of air/oxygen stream into the process[13, 14].

(i) Counter-Current gasifier
(ii) Co-Current Gasifier and Gasification
(iii) Cross draft gasifiers

3.3.1. Upward Draft or Counter-Current gasifier  It is most aged & least difficult sort of gasifier. Input air enters from the bottom and created syngas will leave at the highest point of the gasifier. Close to the mesh at the base ignition response happens, over that lessening response happens. Tars and unstable created are delivere amid the response will leave alongside the syngas at the highest point of the gasifier [15, 16].

![Updraft Gasifier with reaction zone](Image)
3.4. Downdraft or Co-Current Gasifier
In counter current gasifier there is an issue of tar formation in the middle of mesh in the output stream. An answer is to have essential gasified gas presented at or above the oxidation zone during the gasification process. The delivered gas is collected from the bottom thus fuel and gas move a similar way. However, by and by once in a while tar-free gas delivered yet the percentage of tar leave in item stream is significantly lowering the amount of tan output [17, 18].

![Downdraft Gasifier with reaction zone](image)

**Figure 5. Downdraft Gasifier with reaction zone**

3.5. Cross draft gasifiers
Cross draft gasifiers having preferences over concurrent and counter current gasifiers, as they are not perfect. The disservices, for example, more leave gas temperature, poor Carbon dioxide lessening, and high gas speed are the results of the plan. Not at all like concurrent and counter current, are the fiery debris container, fire, and diminishment places in cross draft gasifiers independent. These outline attributes constrain the sort of fuel utilization confined to just low fiery debris fills, for example, forest residue. The heap following capacity of the cross-draft gasifiers is very great because of concentrating of many zones, which work at temperatures up as high as 1200 C. Startup time is substantially quicker than that of concurrent and counter current types. The generally high temperatures in cross draft gas maker obviously affects leave gas arrangement, for example, high CO and low H\textsubscript{2} and CH\textsubscript{4} content when dry fuel, for example, charcoal is utilized. Cross draft gasifier works well on dry air impact and dry fuel[19]. The product of gasification is syngas, which has many components, which changes based on the feedstock. The only needed product is CO and H\textsubscript{2}. So, the unneeded gases are filtered out. Or again sent to another reaction where CO\textsubscript{2} to converted to CO with the help of waster gas shift gas reaction.

![Cross draft Gasifier with reaction zone](image)

**Figure 6. Cross draft Gasifier with reaction zone**
3.6. Syngas

3.6.1. Cleaning of syngas The gasification item needs additionally handling so as to accomplish a sufficient combination gas arrangement. Along these lines, contaminants, for example, particulates, tars, salts, nitrogen and, sulfur ought to be wiped out. The sort of contaminant and the level of decontamination rely upon the resulting application; for the generation of energizes a low level of contaminants is ordinarily required while for control age generally high measures of contaminants can be endured[20].

3.6.2. Syngas conversion to low sulfur diesel by Fischer Tropsch (FT) Synthesis reaction The FT procedure are synergist substance response in which Carbon monoxide and Hydrogen in the syngas are changed over into preferred fossil fuels of different atomic weights as indicated by the accompanying condition:

\[(2n + 1)H_2 + nCO \rightarrow C_nH(2n + 2) + nH_2O\] (1)

N is a whole number. In this manner, the response speaks to the development of CH₄, which in most Coal to Liquid or Gas To Liquid applications is viewed as a bothersome side-effect. The FT process conditions for higher value of n, this reaction is preferred for Diesel, and some amount of wax are also formed. During FT synthesis there are other side reactions like water gas shift reaction are also used to maximizes efficiency.

\[CO + H_2O \rightarrow H_2 + CO_2\] (2)

The purified syngas leaving the gasification island will be sent to Fischer Tropsch synthesis island, where the purified moved syngas is changed over into essential results of wax. The wax is sent on to an updating unit for hydrocracking within the sight of H₂, where it is artificially part into littler sub-atomic weight hydrocarbon fluids.

3.6.3. Producing Ethanol and higher order alcohols by catalytic conversion of syngas Normally ethanol can be converted from biomass by two ways. One is by thermochemical conversion by converting products of thermochemical conversions: syngas Another is by biological conversion of biomass. This section will be discussing about thermochemical conversion of biomass products to Ethanol. After syngas cleaning the pure gas is passed into either of the two process[21].

3.6.4. Haldor Topse process Different process setups have been protected for the immediate amalgamation of alcohols. These procedures include a solitary or a couple of central power source units in arrangement for the transformation of syngas to alcohols. The delivered alcohols are, generally, in the scope of C₂-4OH. It ought to be specified that a blend of alcohols is permitted to be mixed with fuel in numerous places. The tree chart of a procedure from Haldor Topse for liquor blend is appeared in underneath figure. This procedure utilizes a central power source unit to change over syngas to alcohols and an optional hydrogenation unit to change over different sorts of oxygenated side-effects (e.g. Ketones, esters, and additionally aldehydes) to the comparing liquor. The subsequent items are sent to a gas fluid separator, from which the gas portion (made for the most part out of methane and unreacted syngas) is sent to a methanation reactor unit to deliver engineered petroleum gas and the fluid division is sent to a stripper unit. In the last unit, short alcohols (generally methanol) are stripped from the fluid division utilizing a surge of new syngas and reused to the primary power source unit. The last is done with a specific end goal to advance the carbon bind development to higher alcohols, by means of liquor homologation or alcohols coupling. The central power source unit works at 20 bar and 270-400 °C and utilizations a cuzno/Al₂O₃ based impetus. The hydrogenation reactor unit works at comparative weight yet in a temperature scope of 100-220 °C utilizing a normal respectable[22].
3.6.5. Enerkem process  The most recent protected process designs for the amalgamation of ethanol utilize different reactor units, this with a specific end goal to expand the general ethanol yield. Different activities with respect to multi-step ethanol combination have been created far and wide by private and state foundations. One of the organizations that has licensed different process arrangements is Enerkem, which in 2014 propelled the main business plant for ethanol creation from civil strong waste (MSW). Despite the fact that the genuine procedure arrangement for this plant isn’t known, it is conceivable in view of a multistep setup like that appeared in Figure below. In a gasification island the MSW is changed over to syngas, which in the wake of molding and cleaning enters to the methanol island. Methanol amalgamation is a develop innovation in the petrochemical segment, and unadulterated methanol can be gotten. The delivered methanol is blended with carbon monoxide in a carbonylation and esterification reactor unit, where methyl acetic acid derivation is created. At that point, methyl acetic acid derivation is hydrogenated to methanol and ethanol, from which ethanol is cleaned.

4. Application of syngas
Furnaces and boilers are mostly used to produce power and heat. This equipment’s works at a relative low efficiency but has a wide range of operating fuels from Natura gas to petroleum products. Biooils may be a suitable fuel for this equipment’s as long as the properties of the fuel are consistent, economically feasible with low emission standards. Therefore, many industries are interested to use this fuel as an alternate. While boilers have a low operating efficiency but diesel engine has efficiency of nearly 35%. So diesel engine can be used for combined cycle plants. Engine with specifically low relative sped is suitable for low grade fuels. The difficulty in ignition of the bio oil is the main concern in operating with bio oil, which has moisture content, and low calorific value and corrosive for the engine parts as there are acids in fuels[23, 24].

5. Conclusion
Among the various strategies for vitality creation from biomass, gasification is considered as the most reasonable choice as it is a straightforward and financially practical procedure to deliver warm vitality or decentralized power age. Downdraft gasifiers are commonly little scale units having most extreme power creation limit up to 5MW. This element makes it progressively appropriate for decentralized power age and dispersion to the remote towns/islands denied of lattice power. To a great extent, it is seen that the survey articles announced in the writing neglect to address the fundamental comprehension of each model kinds and their materialness to structure distinctive gasifiers for a specific feedstock and variety of working parameters.

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