Hydrogen from Biomass Steam Gasification

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Abstract
Focus has shifted from fossil fuels to renewable sources in order to meet the world's growing energy demand while protecting the environment. Being a flexible fuel, hydrogen is thought to have a big influence on the energy industry. It would soon become the first fuel of choice due to its high energy density, quick burning speed, high octane rating, and zero possibility for injury. Therefore, it is necessary to find a sustainable hydrogen source to take the place of fossil fuels. The majority of hydrogen produced now comes from fossil fuels, which will run out by 2050.One efficient technique for creating renewable hydrogen is steam gasification. In addition to offering a sustainable source of hydrogen, using biomass in hydrogen production will protect the environment. Because it uses CO2 during photosynthesis and doesn't add to the carbon inventory when burned, biomass is considered a carbon neutral emitter. Biomass may be regarded as a negative carbon dioxide emitter if the CO2 generated during the gasification process is captured and not released into the atmosphere. It has been demonstrated that solid-based sorbents, like CaO, have a high CO2 collection efficiency at high temperatures. For sustainable hydrogen production, steam gasification of biomass combined with carbon dioxide capture may therefore be a viable choice. Furthermore, the yield of hydrogen can be greatly boosted by combining the best possible factors that affect its generation.

Keywords: steam gasification, biomass, hydrogen, sustainable, fuel

I. Introduction

A. Hydrogen occurrence

The most prevalent element, hydrogen, makes up roughly 75% of the elemental mass of the planet. In addition, it is the lightest element in the universe. Since hydrogen is lighter than air, it is not readily available in Earthly technologies and is hence a very

B. Hydrogen in energy sector

Among all fuels and energy carriers, hydrogen has the highest energy density. Furthermore, as the only byproduct of burning hydrogen is water, no emissions are produced. Compared to other hydrocarbon fuels, hydrogen has an energy yield of 122 KJ/Kg, which is almost 2.75 times higher. Because 9.5 kg of hydrogen is adequate to replace 25 kg of gasoline, it is consequently thought to be an efficient gasoline substitute [1].

C. Uses of hydrogen

Internal combustion engines and fuel cell technologies are two direct applications for hydrogen. It serves as an intermediate storage fuel in the manufacturing of ethanol, methanol, and gasoline. Hydrogen is a versatile fuel since it can be used as a gas or a liquid. Numerous businesses, including the food, glass, electronics, fertilizer, and metallurgical sectors, use it as well. Despite finding use in a variety of industries, hydrogen is thought to have a major influence on the energy sector. It is estimated that approximately 40 million

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tons of hydrogen would be needed annually if hydrogen were to join the transportation sector. It will soon be the first fuel of choice because to its high energy density, high octane number, quick burning speed, and zero possibility for injury. Since hydrogen is the future of life, it presents a potentially non-polluting, limitless, effective, and affordable energy source. As demonstrated by numerous funded initiatives from numerous national government organizations worldwide, hydrogen is being marketed as the fuel of the future[1].

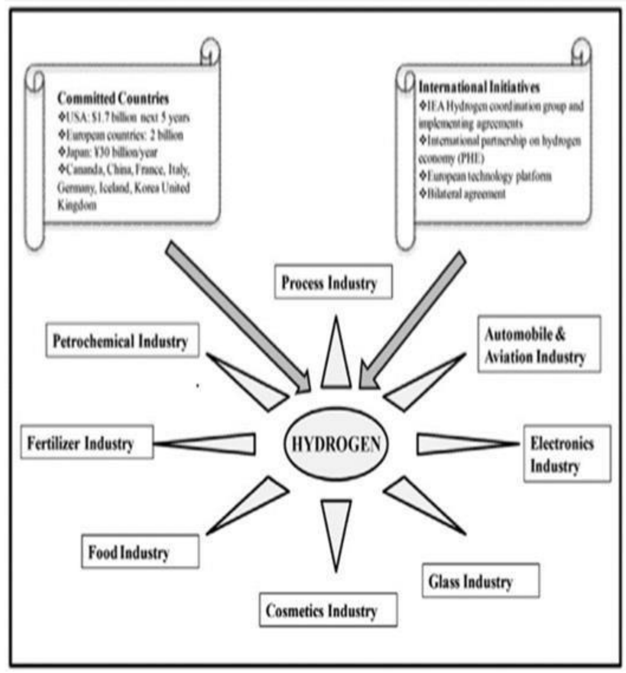
D. Biomass

Biomass is "a non-fossilized and biodegradable organic material originating from plants, animals, and micro-organisms, "according to the 2005 United Nations Framework Convention on Climate Change. The non-fossilized and biodegradable organic fractions of industrial and municipal wastes, as well as products, byproducts, residues, and trash from forestry, agriculture, and allied industries, will also be included in this [2]. By replacing the usage of fossil fuels, biomass is a renewable energy source that will prevent the release of more greenhouse gases into the atmosphere.

II. Hydrogen Production From biomass

Using a range of contemporary methods and technologies, hydrogen can be created from a wide range of sources, including coal, natural gas, oil, and water. Fossil fuels, which will run out by 2050, now produce the largest percentage of hydrogen. There is therefore need to look for alternative source that is renewable suchas biomass, solar, wind, and hydro**.** Biomass utilization seems attractive in comparison to the other renewable sources as it can generate hydrogen directly, whitleathers of the renewable shavetoundergoelectroly sis for hydrogen production. Moreover, it is abundantly available and less reliant on location. If biomass issued for hydrogen generation not only, will it safe guard the environment but will also provide a sustainable source for hydrogen.

As one of the measures to encourage the production of hydrogen from biomass, the International Energy Agency's (IEA) program on the production and use of hydrogen introduced a new aim in 2004: the production of hydrogen from carbon-containing materials [1]. The dedication of countries to the hydrogen and fuel cell effort is depicted in Fig. 1.



Source;OECD/IEA, 2004

III. Steam gasification of Biomass

Through partial oxidation, the thermo chemical process of gasification transforms biomass into a usable gaseous mixture of syngas that includes H2, CO, and CO2. Air, pure oxygen, subcritical steam, CO2, or a combination of these can be used as the gasifying agent for the reaction. The sort of gasifying agent utilized determines the amount of heat in the syngas that is produced

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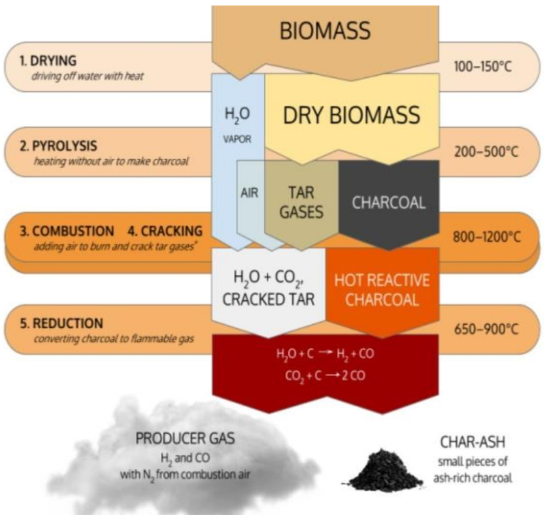
[2]. Different gasification techniques are compared in Fig. 21.



Source: https://www.allpowerlabs.com/gasification-explained

Comparison between different gasification processes.

	Air gasification	Oxygen gasification	Steam gasification
Product heating value, MJ/Nm^3	Low 4–6	High 10–15	High 15–20
Products	CO, H_2, Water, CO_2, HC, Tar, N_2	CO, H_2, HC, CO_2	H_2 CO, CO_2, CH_4 light HC, tar
Average product gas composition	H_2 – 15%, CO – 20%, CH_4 – 2%, CO_2 – 15%, N_2 – 48%, H_2:CO: 0.75	H_2 – 40%, CO – 40%, CO_2 – 20%, H_2:CO: 1	H_2 – 40%, CO – 25%, CH_4 – 8%, CO_2 – 25%, N_2: 2%, H_2:CO: 1
Reactor temperature, °C	900–1100	1000–1400	700–1200
Cost	Cheap	Costly	Medium

A gas enriched in H2 is more likely to be produced when biomass gasification uses steam as the gasifying agent. As a result, it is a well-known and effective method of producing hydrogen. According to research, steam gasification can produce up to three times as much hydrogen than air gasification. Similarly, if the amount of biomass is the same, it has been demonstrated that steam gasification can produce more energy than air gasification. When the tar and char can be used effectively, steam gasification is a superior technology. Biomass with less than 35% moisture content can be processed using this approach. Table 2 lists the series of processes that take place during steam gasification.

Table2:The main reaction during gasification process [11].

Reaction	Chemical reactions	ΔH [kJ/mol]
Primary devolatilisation (pyrolysis)	Biomass → H_2O, CO, CO_2, CH_4, C_2H_4 and C	
Tar cracking and reforming	Primary tar → Secondary tar + H_2, CO, CO_2, CH_4, C_2H_4	
Homogenous gas-phase	Secondary tars → C, CO, H_2	
	$H_2 + 0,5\,O_2 \rightarrow H_2O$	- 242
	$CO + 0,5\,O_2 \rightarrow CO_2$	- 283
	$CH_4 + 0,5\,O_2 \rightarrow CO + 2\,H_2$	- 110
	$CH_4 + CO_2 \rightarrow 2\,CO + 2\,H_2$	+247
	$CH_4 + H_2O \rightarrow CO + 3\,H_2$	+206
	$CO + H_2O \rightarrow CO_2 + H_2$	- 40,9
Heterogeneous	$C + O_2 \rightarrow CO_2$	- 393,5
	$C + 0,5\,O_2 \rightarrow CO$	- 123,1
	$C + CO_2 \rightarrow 2\,CO$	+ 159,9
	$C + H_2O \rightarrow CO + H_2$	+ 118,5
	$C + 2\,H_2 \rightarrow CH_4$	- 87,5

IV. Factors Influencing Hydrogen Yieldinstea Magnification

The kind of biomass, the size of the biomass feed particles, temperature, the ratio of steam to biomass, and the presence of sorbent and catalyst all affect the amount of hydrogen generated during the gasification process.

a) Biomass Type

Lignin, cellulose, and hemicelluloses make up the majority of biomass. These elements are crucial to the breakdown of biomass, and each biomass has a different composition. Large amounts of cellulose and lignin in biomass produce more gaseous products, which raises the possibility of hydrogen recovery[1].

b) Size of Particles

The efficiency of the gasification reaction is greatly increased by small particles because

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they have a large surface area per unit mass, which enhances efficient heat transfer. In addition to increasing the generation of H and CO, the increased efficiency of the gasification reaction also results in a decrease in the production of CO_2, char, and tar. Large particles, on the other hand, are more resistant to heat flow, which causes incomplete pyrolysis and increased char. As a result, reducing particle size increases hydrogen output and carbon conversion efficiency[1].

c) Temperature

The effect of temperature in hydrogen production during steam gasification is very significant. Increase in temperature increases heating rate among particles. Faster heating rate and leads to complete gasification reactions thus small leads to a greater heat generation and les star production.[2]

d) Steam to biomass ratio

Both energy output and gas composition are significantly impacted by the team to biomass ratio. According to research, steam gasification of biomass increases the amount of hydrogen produced. Solid carbon and methane are created at low steam values, and when the steam supply increases, carbon and methane are converted to CO and H_2. While the production of H_2 and CO_2 increases monotonically, solid carbon and methane are further reduced when the amount of steam delivered exceeds the biomass content. Conversely, when steam promotes water gas and hydrocarbon reforming processes, CO decreases monotonically. In biomass gasification, an increase in steam greatly encourages the creation of hydrogen. Excess steam hinders gasification because a drop in temperature encourages the formation of huge amounts of tars[3].

e) Catalysts

Catalysts play a crucial role in gasification by lowering the resistance of particles to mass and heat transfer. Additionally, catalysts aid in the breakdown of tar, which promotes the creation of hydrogen. Dolomite, Ni-based catalysts, alkaline metal, alumina, alumina silicate, K_2CO_2, Na_2CO_3, K_2CO_3, and $ZnCl_2$ are a few of the catalysts that researchers have tried. The presence of CO_2 in the syngas makes its use as a gasifying agent promising. Char, CH_4, and tar can be converted into H_2 and/or CO by combining CO_2 with a catalyst like Ni/Al, increasing the amounts of H_2 and CO.

f) Sorbent to biomass ratio

Because it uses CO_2 during photosynthesis and doesn't add to the carbon inventory when burned, biomass is considered a carbon neutral emitter. Biomass may be regarded as a negative carbon dioxide emitter if the CO_2 generated during the gasification process is captured and not released into the atmosphere. It has been demonstrated that solid-based sorbents are highly effective at capturing CO_2 at high temperatures, where liquid-based sorbents are ineffective. Numerous sorbent materials were investigated, including solid absorbent dolomites based on rhodium, aluminum oxide, and nickel, as well as CaO. Due of their high cost, metal-based sorbents are not commercially viable. On the other hand, calcium oxide is inexpensive, widely available, and can effectively absorb carbon dioxide at extremely high temperatures. Therefore, steam gasification of biomass combined with carbon dioxide extraction during the process may be a viable choice for producing hydrogen sustainably.[3]

V. Conclusion

Energy-rich biomass can be converted into hydrogen using a variety of processes. However, steam gasification is thought to be a successful method of creating renewable

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hydrogen that doesn't release any carbon dioxide into the atmosphere. Steam gasification has several benefits, including being an efficient way to produce hydrogen from biomass, contributing to the largest hydrogen output, and producing a cleaner product with less of an adverse influence on the environment. The kind of biomass, particle size, temperature, steam to biomass ratio, catalyst, and sorbent to biomass ratio all affect hydrogen yield. If the ideal mix of these elements is found, it will encourage the steam gasification process's creation of hydrogen. To create a highly effective, stable, affordable, and reactive catalyst for biomass gasification, much research is needed [1].

Note;Outofthe10readpaper,thesummaryexcludesthe following:[4],[5],[6],[7],[8],[9],[10].

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