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Impact of green technologies on the production of hydrogen in a sustainable manner

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Abstract

In many countries, hydrogen (H_2) is viewed as a crucial indicator of substitute energy resources and a gateway to a future of sustainable energy resources. An environmentally friendly substitute for fossil fuels now utilized in the general transportation industry might be hydrogen. Our research aims to establish that creating H_2 from bio-mass qualifies as a green technology. Three methods can be used to create hydrogen from biomass. Our major focus must be concentrated on maximizing shift conversions and reforming, as well as on obtaining the most hydrogen economically possible from Pressure Swing Adsorption (PSA). This research reveals that biomass may be used to manufacture hydrogen. The most advantageous economics are found in the pyrolysis-based technology, specifically because of its coproduct potential.

Keywords: Green Technology; H_2 generation; Pressure Swing Adsorption (PSA); Fuel Cells; Sustainable Energy.

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1. Introduction

The key concerns in H_2 economics have undergone a significant transformation in the last ten years. Reducing the demand for fossil fuels is still a major concern for many countries. Photo-biological water splitting and electrolysis, both of which are based on renewable resources, have considerable potential for producing clean hydrogen; nevertheless, upcoming modification is a requisite before these technologies can be considered important for the commercial sector. In the near and medium term, H_2 production from bio-mass is more feasible, comprehensive, and renewable [1]. The International Energy Agency (IEA) program on the Production and Utilization of Hydrogen launched a new task in 2004 called ”Hydrogen from Carbon-Containing Materials” with the intention of bringing together a group of international experts to investigate some of these short-term and long-term options for producing hydrogen with minimal adverse effects on the environment. The effort encompasses both large-scale fossil fuel production in conjunction with carbon sequestration and large-scale biomass production. Small-scale reformation for distributed generation is also a component of the endeavor [2]. Although not all-inclusive, the variety of alternatives for numerous sources with their respective applications presented in Fig. 1 demonstrates how adaptable hydrogen and fuel cell energy systems are.

The trust of the people in the welfare of distinguished power systems, along with the raw material storage infrastructure, is required for the public to accept H_2 as a basic energy holder in numerous power generation technologies [3]. To enable the effective marketing and distribution of H_2 and different fuel cells/oils into the market, suitable technical norms and laws with major levels of welfare and precautions. Moreover, healthy environmental preservation should be taken into consideration. A lack of suitable early-stage requirements may result in technology construction or modification delays, decreased technological acceptance rates, or increased expenses [4].

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This research work emphasizes that hydrogen can be produced inexpensively from biomass without harming the environment.

2. H_2 Generation Techniques

In this paper, we discuss many strategies for converting bio-mass to H_2. The importance of each and every conversion scheme must be evaluated in relation to the availability of adequate feedstock. Since numerous products improve numerous economic options are of special relevance; nevertheless, we did not study co-product creation. The only way to choose exact research strategies in particular complicated and enlightened technical sectors logically is to compare technical and economic elements. Opportunities will differ for central Europe, America, eastern Asia, and the developing globe due to the wide disparity in regional viewpoints [1].

A hydrogen-containing gas is typically created during biomass conversion processes. Current approaches include direct or indirect steam gasification, entrained flow gasification, and more complicated ideas like supercritical water gasification and the use of intermediates (such as CH_3COOH, bio-degraded oil, or torrified wood). For the creation of hydrogen, none of the approaches have touched the implementation stage [5]. H_2 production and the production of biofuels share research and development in biomass gasification.

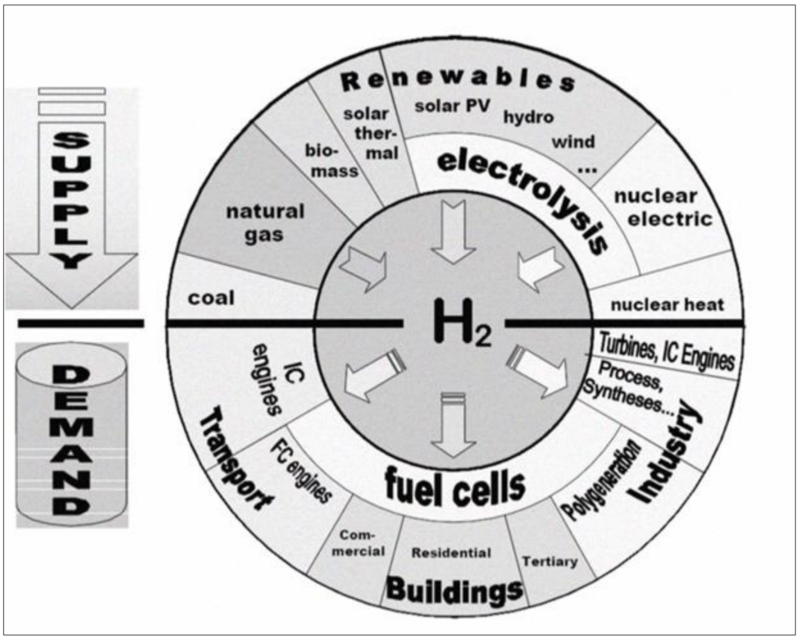


Figure 1 Elementary energy sources and the applications of H_2 [2]

Fig. 2 depicts a flow chart for creating hydrogen from biomass. Other wet biomass-based approaches are being investigated, as energetic drying of biomass may not be justified. Biomass feedstocks are unrefined, unreliable, and poorly regulated products. The crop type, location, and climate changes all affect the different production techniques. Erratic fuels have made it more difficult to innovate technologically since they require more complex conversion systems than less homogeneous and higher-quality fuels. To create more consistent, higher-quality fuels (defined by standards), the production and processing of fuel must be rationalized. Smaller plants typically demand greater fuel features and comparatively better fuel uniformity, whereas larger-scale systems typically suit lower-grade, less expensive fuels.

The initial gasification method (Fig. 3, left) is evaluated on typically low-pressure, warm gasifiers organized at BCL laboratories particularly to gasify biomass [6]. In order to compress the syngas to definite pressure needed for the PSA unit plus the anticipated pressure vanish, the syngas must first be cooled after cleanup. Compressed gas from the gasifier is then the steam reformed. In the PSA, the H_2 is lastly cleaned before being stored and distributed.

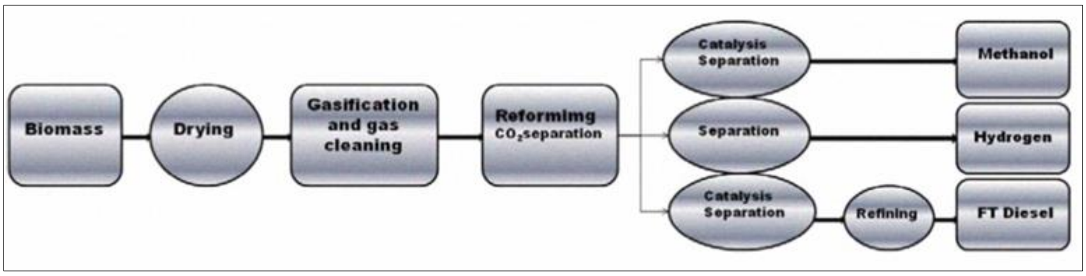


Figure 2 Flow chart of the biomass gasification-based generation of CH_3OH, H_2, or FT diesel

The procedures of the Battelle lFERCO system are duplicated (Fig. 3, middle), which utilizes a gasifier (IGT) [7]. The significant components of the system for the IGT H_2 generating procedure are the processing and drying of biomass, gasification (which requires the use of an air separation unit), shift-conversion, and H_2 purification.

Fast biomass pyrolysis [8], to create H_2 are the next two processes (Fig. 3, right). By briefly being exposed to hot particles in a fluidized bed, biomass is rapidly dried and transformed to produce oil. While the created char and fumes are cooled and condensed, product oils are burned to heat the reactor. These locations then send the bio-oil via truck to the hydrogen-generating facility.

Since bio-oil possesses greater energy density than utilized biomass, it is more cost-effective to manufacture it in far-off places and then ship it. Reform of steam, shift-conversion, and PSA, produce hydrogen from carbohydrate fraction, respectively [9].

3. PSA for H_2 Purification

The PSA process for H_2 separation separates hydrogen from other gases. Fig. 4 provides an illustration of the theory. In an adsorber, contaminations are first simultaneously adsorbed at very large-scaled pressure before being partially desorbed at low pressure. The impurity partial pressure is lowered by "swinging" the adsorber pressure from the feed pressure to the tail gas pressure and by using a high-purity hydrogen purge. There is very little hydrogen adsorbed. The procedure is cyclical in nature. Multiple adsorbers are employed to maintain product, and gas (tail) flows. The partially created pressure differential between the basic feed and the general tail gas acts to separate the two mediums. For hydrogen separation, an optimum ratio of the pressure (4:1) between the basic feed and general tail gas pressures is often needed. For PSA units used in multiple refinery-based applications, the recommended feed pressure range is 205-410 psig. The lowest possible pressure (tail gas) is preferred. Because the PSA removal is much more chromatographic, the lightest contaminants will stay unchanged in the general product first, maintained by impurities that have been more aggressively adsorbed.

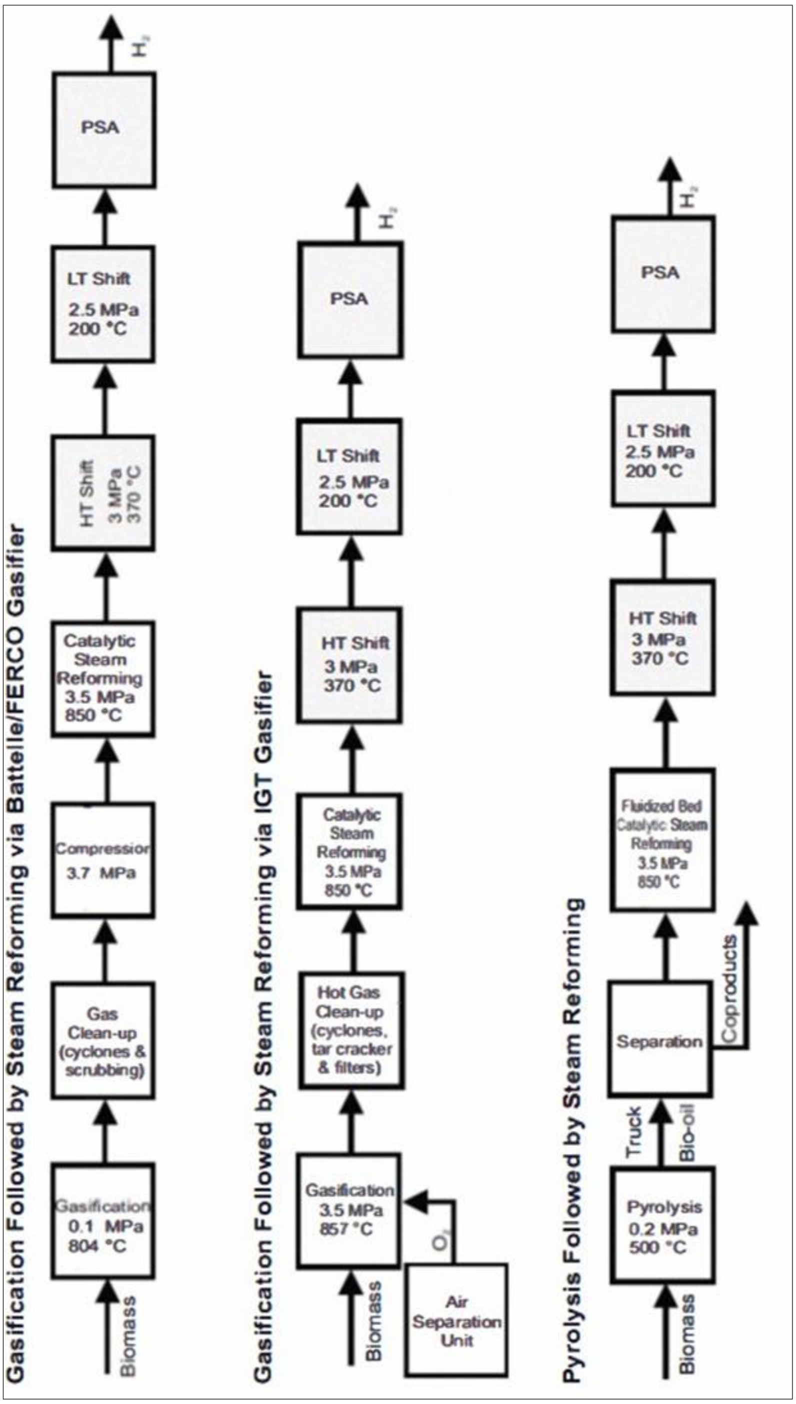


Figure 3 H_2 generation from biomass

The purities of typical PSA H_2 products are 99 to 99.999% volume. Because down-stream processes frequently benefit from high hydrogen purity, a number of major units are built to provide a greater purity. To maximize the extraction for particular flow pressure, rate, and compositions, the system configuration is changed [10]. The level of needed feed pretreatment has an impact on operational productivity, cost, and ease of construction of the deeds. The most cost-effective stream upgrading methods for flows with 70–95% volume H_2 are membrane processes otherwise, PSA, with the choice depending on multiple indicator needs [11]. In the modest flow range, PSA systems offer reasonable capital costs and good economies of scale. The general feeds, and/or gas (tail) compression capital and operational expenses represent a sizable component of the overall separation system costs. Compressor requirements often dictate the most cost-effective scheme. [12].

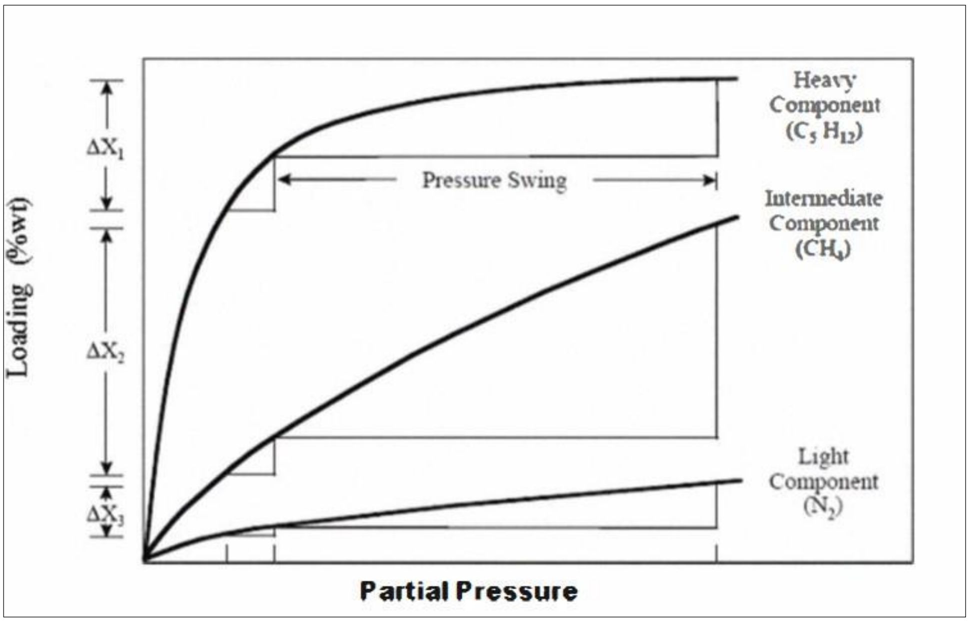
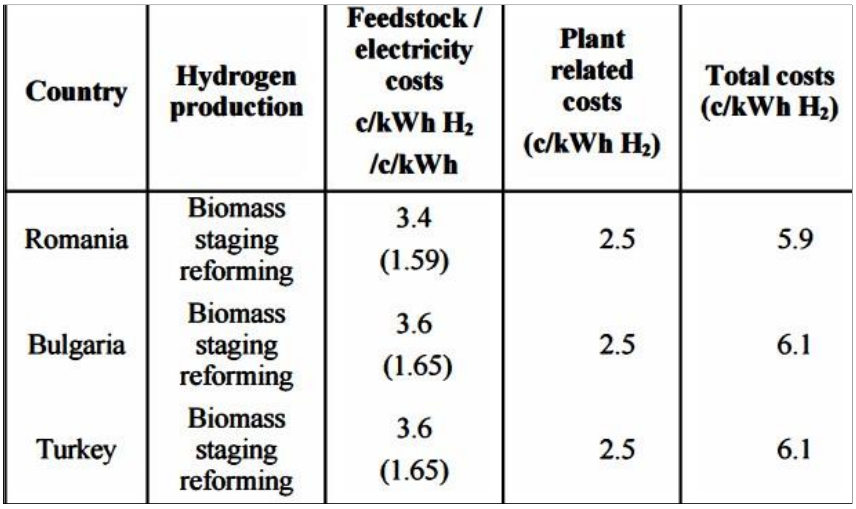


Figure 4 Adsorption isotherms: A plot of partial pressure vs. loading (%wt)

4. Assessment of H_2 Cost

Any type of hydrogen, including biomass-derived hydrogen, can be utilized as a standard resource that is burnt with air into turbines, and engines to produce energy. Additionally, in almost all forms of fuel cells, H_2 can be utilized to generate power in all directions without any restrictions of a basic thermal procedure [13]. However, when hydrogen is utilized as a fuel for combustion along with air, there will be a very small amount of pollutants produced, like NOx, as a result of high-temperature interactions with the nitrogen in the air. In any case, the amounts of these pollutants are lower than those produced by the combustion of typical hydrocarbon fuels. The gas transmission or distribution grid might be supplemented with biomass-derived hydrogen, and the resulting blended gas may be used in the same ways that gas is currently used. The reduced CO_2 emissions from biomass-derived hydrogen could be advantageous. The amount of such ”green hydrogen” added has a direct relationship with the reduction in emissions [14]. The content and characteristics of gas differ significantly between and between nations. Although the gas characteristics can vary significantly, they are controlled. According to some estimates, Romania’s costs for producing hydrogen from biomass are comparable to those of Turkey and Bulgaria (Table I) [15].

Table 1 Hydrogen production cost



Country	Hydrogen production	Feedstock / electricity costs c/kWh H_2 /c/kWh	Plant related costs (c/kWh H_2)	Total costs (c/kWh H_2)
Romania	Biomass staging reforming	3.4 (1.59)	2.5	5.9
Bulgaria	Biomass staging reforming	3.6 (1.65)	2.5	6.1
Turkey	Biomass staging reforming	3.6 (1.65)	2.5	6.1

5. Conclusion

Basically, within many countries, hydrogen is viewed as a crucial indicator of another energy and a pathway towards a future of sustainable sources of energy. Because of its prominent features being an energy holder, that can offer carbon- and other polluted elements-free electricity and other resources for buildings, industrial works, and transportation, hydrogen has the potential to be a vital scheme in our prospective energy sector. The goal of this study emphasized investigating the efficacy of green H_2 generation from numerous biomass with a view to using hydrogen as a source of sustainable energy holder or fuel that reduces NOx, hydrocarbon, CO, and CO_2 emissions significantly.

Compliance with ethical standards

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Disclosure of conflict of interest

There are no conflicts of interest to declare.

References

[1] M. Shahbaz, T. Al-Ansari, M. Aslam, Z. Khan, A. Inayat, M. Athar, S. R. Naqvi, M. A. Ahmed, G. McKay, A state of the art review on biomass processing and conversion technologies to produce hydrogen and its recovery via membrane separation, International Journal of Hydrogen Energy 45 (2020) 15166–15195.

[2] B. Lebrouhi, J. Djoupo, B. Lamrani, K. Benabdelaziz, T. Kousksou, Global hydrogen development technological and geopolitical overview, International Journal of Hydrogen Energy (2022).

[3] O. R. Hansen, Hydrogen infrastructure—efficient risk assessment and design optimization approach to ensure safe and practical solutions, Pro- cess Safety and Environmental Protection 143 (2020) 164–176.

[4] H. T. Hwang, A. Varma, Hydrogen storage for fuel cell vehicles, Current Opinion in Chemical Engineering 5 (2014) 42–48.

[5] S. J. Cooke, Industrial gases, Handbook of Industrial Chemistry and Biotechnology (2017) 1301–1322.

[6] C.-A. Rueda-Duran, M. Ortiz-Sanchez, C. A. Cardona-Alzate, Detailed economic assessment of polylactic acid production by using glucose plat- form: Sugarcane bagasse, coffee cut stems, and plantain peels as possible raw materials, Biomass Conversion and Biorefinery 12 (2022) 4419–4434.

[7] S. Cruz-Manzo, V. Panov, Y. Zhang, Gas path fault and degradation modelling in twin-shaft gas turbines, Machines 6 (2018) 43.

[8] D. Duan, D. Chen, L. Huang, Y. Zhang, Y. Zhang, Q. Wang, G. Xiao,W. Zhang, H. Lei, R. Ruan, Activated carbon from lignocellulosic biomass as catalyst: A review of the applications in fast pyrolysis pro- cess, Journal of Analytical and Applied Pyrolysis 158 (2021) 105246.

[9] A. Mart´ınez-Rodr´ıguez, A. Aba´nades, Comparative analysis of energy and exergy performance of hydrogen production methods, Entropy 22 (2020) 1286.

[10] Y. Long, G. Li, Z. Zhang, W. Wei, J. Liang, Hydrogen-rich gas genera- tion via the exhaust gas-fuel reformer for the marine lng engine, Inter- national Journal of Hydrogen Energy 47 (2022) 14674–14686.

[11] H. M. Sheikh, A. Ullah, K. Hong, M. Zaman, Thermo-economic analysis of integrated gasification combined cycle (igcc) power plant with carbon capture, Chemical Engineering and Processing-Process Intensification 128 (2018) 53–62.

[12] N. Lod´ea, W. Nunes, V. Zanini, M. Sartori, L. Ost, N. Calazans, R. Gari- botti, C. Marcon, Early soft error reliability analysis on risc-v, IEEE Latin America Transactions 20 (2022) 2139–2145.

[13] B. B. Nyakuma, A. Ahmad, A. Johari, T. A. T. Abdullah, Thermo- gravimetric and kinetic analyses of oil palm empty fruit bunch (opefb) pellets using the distributed activation energy model, Journal of Physi- cal Science 27 (2016) 67.

[14] F. Hoehn, M. Dowdy, Feasibility demonstration of a road vehicle fueled with hydrogen-enriched gasoline, in: Intersociety Energy Conversion Engineering Conference, 1974.

[15] F. Taghizadeh-Hesary, Y. Li, E. Rasoulinezhad, A. Mortha, Y. Long, Y. Lan, Z. Zhang, N. Li, X. Zhao, Y. Wang, Green finance and the economic feasibility of hydrogen projects, International Journal of Hy- drogen Energy 47 (2022) 24511–24522.