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Green hydrogen production through biomass-powered water electrolysis: A Review

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Abstract. Hydrogen plays a key role in achieving carbon neutrality, particularly in the transport and industrial sectors, where reducing dependence on fossil fuels is a major challenge. This review examines recent systems for producing green hydrogen from biomass, analysing various energy architectures such as electricity–hydrogen cogeneration, multigeneration, polygeneration and hybrid configurations. The systems studied are based on the conversion of biomass via gasification, combustion or other thermal processes, coupled with electricity generation cycles (SRC, ORC, etc.) to power electrolysers. This review describes the operating principles of these systems and the interactions between their components, and compares the architectures according to their hydrogen production performance in order to identify the most promising approaches for sustainable production from biomass.

Introduction

Currently, biomass is primarily utilised for thermal applications, cooling purposes and the generation of electricity production.[1] It is a sustainable and promising energy source thanks to its widespread availability, relatively low cost and renewable nature.[2] The direct co-combustion of biomass and coal remains the predominant conversion pathway and, in the short term, represents the option with the highest potential for large-scale use of energy from biomass. Other thermochemical processes, notably gasification and pyrolysis, offer prospects for higher energy efficiency than conventional combustion. However, despite their technical feasibility, these technologies still suffer from insufficient technological maturity, unproven operational reliability and limited economic viability, which hinders their deployment on an industrial scale.[3] . At the same time bioenergy is growing rapidly within the global energy mix. It can replace fossil fuels.[4]

Among the various energy carriers, hydrogen (H_2) is widely recognised as a sustainable energy solution due to its high energy density approximately 3.5 times higher than that of conventional hydrocarbon fuels, its clean nature and the fact that its combustion produces no CO_2 emissions, as well as the possibility of producing it from biomass.[5]

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In this context, water electrolysis appears to be a key technology for the production of green hydrogen, enabling the dissociation of water molecules into hydrogen and oxygen through the supply of electrical energy[6]. The main electrolysis technologies currently being developed are based on three types of cells: alkaline electrolyzers (AEC)[7] , solid oxide electrolyzers (SOEC) [8]and proton exchange membrane electrolyzers (PEMEC)[9]. Although the contribution of water electrolysis to global hydrogen production remained marginal, accounting for around 0.1% in 2021, its installed capacity grew by a remarkable 70% in the same year, reaching 510 MW in 2022. [10]

In this context, this article focuses on the study of green hydrogen production systems from biomass, in which electricity from biomass conversion is used to power electrolysers. The aim is to present and analyse different system configurations reported in the literature in order to better understand their operating principles and energy performance. To this end, several system architectures are examined, including the Biomass Gas Turbine–Steam Cycle–Electrolyser system,

multi-production systems based on ORC–PEM coupling, high-temperature systems incorporating solid oxide electrolyser cells (SOEC), the S/RC–ORC hybrid system, and hybrid systems combining fuel cells, Stirling engines and electrolysis. Each system is presented in a dedicated subsection to highlight its role in the production of green hydrogen from biomass.

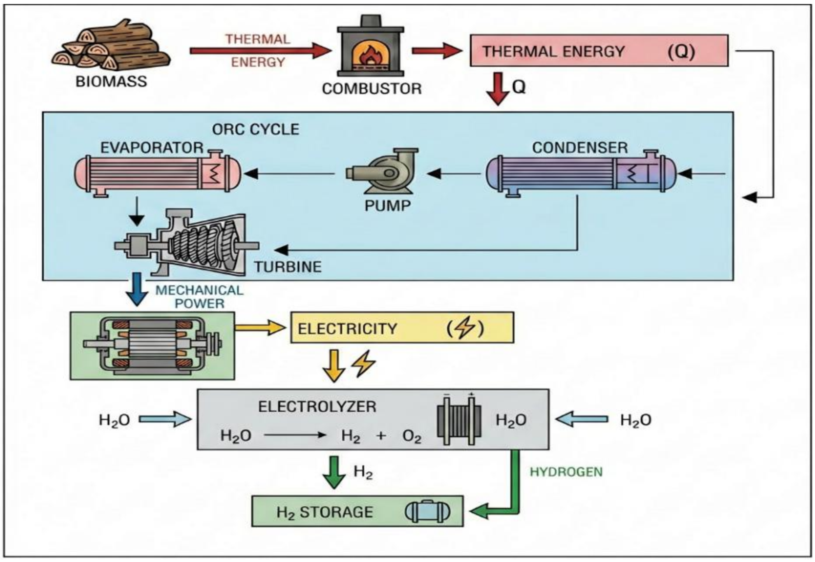

Figure 1: Example of a system for producing hydrogen from biomass

1 Production of green hydrogen by electrolysis of water powered by biomass

1.1 Biomass GT–steam cycle–electrolyser system

In the study by Hai et al.[11] , an innovative biomass-fuelled "power-hydrogen" cogeneration system is proposed, combining three subsystems: a gasification-fuelled gas turbine, a steam flash cycle and a PEM electrolyser. The biomass is first converted into synthesis gas in a gasifier, which feeds the combustion chamber of the gas turbine for electricity generation. The high-temperature exhaust gases from the turbine are then recovered in the steam cycle to maximise residual heat recovery and improve the overall energy efficiency of the system.

Some of the electricity produced by the gas and steam cycles is directed to the PEM electrolyser, which produces hydrogen through water electrolysis. This coupling converts the electrical energy from biomass into a high value-added form of chemical energy, while enhancing the flexibility and versatility of the energy system.

The authors evaluate this system using thermodynamic, exergy, thermoeconomic and environmental analyses, supplemented by single-objective and dual-objective optimisation approaches to identify the optimal operating conditions. The reported results indicate that the gasifier is the main site of exergy destruction, both under reference conditions and under optimal conditions, thus highlighting its decisive role in the future improvement of the system's performance.

1.2 ORC and PEM multi-generation systems

A multi-generation system powered by a biomass combustor has been developed, integrating an organic Rankine cycle (ORC), an absorption chiller, a PEM electrolyser for hydrogen production, and a domestic water heater for hot water supply. In this system, biomass (pine sawdust) is oxidised in the burner, and the thermal energy released is transferred to the ORC cycle to generate electricity. A portion of this electricity is then used for water electrolysis. The results show that, for a biomass flow rate of 0.3 kg/s, it is possible to produce approximately 3.14 kgH_2/day, with an overall exergy efficiency of 22.2%, confirming the feasibility of biomass-electrolysis coupling.[12]

1.3 High-temperature polygeneration systems with SOEC

The study by Xu et al. [13] proposes an innovative polygeneration system combining biomass gasification, Rankine cycle, multi-effect distillation (MED) and solid oxide electrolysis (SOEC). This system aims to simultaneously produce electricity, fresh water and hydrogen, demonstrating the complementarity between biomass thermal recovery and low-carbon hydrogen production processes. In this configuration, biomass (municipal solid waste (MSW), paddy husk, paper, wood, etc.) is first converted into syngas via a downdraft gasifier, a device particularly suited to the production of clean, energy-rich gas. The syngas then feeds a combustion chamber, the heat from which is recovered in a steam generator to drive a Rankine cycle. The electricity generated by the steam turbine is used in part to power the SOEC, a high-temperature electrolyser operating at around 1023 K and offering higher yields than low-temperature electrolysers.

1.4 S/RC-ORC Hybrid System

In an innovative approach to biomass recovery, Ajaj et al. [14] have developed a technoeconomic model combining a steam Rankine cycle (S/RC) and an organic cycle (ORC) to power an alkaline electrolysis (AE) system. Their methodology is based on thermodynamic simulation using Aspen HYSYS of eight distinct configurations, exploiting a thermal cascade where the residual heat from the S/RC activates various ORC architectures (basic, regenerative, recuperative) tested with R245fa and R152a working fluids. Applying algorithmic optimisation in MATLAB to maximise efficiency, the study conducted a comprehensive eco-economic assessment including the levelised cost of hydrogen (LCOH), return on investment time and carbon credit gain (CCG). The results establish the superiority of the regenerative ORC configuration with recuperator RgRc/ORC (Regenerative with Recuperator/ ORC) using the R245fa fluid, which achieves optimal production of 94.65 tons/year with a very competitive LCOH of 1.724~US$/kg, demonstrating the financial and environmental viability of biomass hydrogen coupling compared to conventional methods.

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1.5 Hybrid fuel cell, Stirling and electrolysis systems

Habibollahzade et al. [15] investigated three biomass-based energy conversion systems integrating a solid oxide fuel cell (SOFC) with a gasifier, a Stirling engine, and a proton-exchange membrane electrolyzer (PEME). Their work aimed to simultaneously increase power and exergy efficiency, and reduce environmental emissions and total product cost. They analyzed the systems in terms of energy performance, exergy efficiency, exergy cost optimisation and environmental impact, and applied a multi-objective optimization approach based on a genetic algorithm. The first configuration combined a gasifier with an SOFC, the second reused the SOFC waste heat in a Stirling engine to improve electrical efficiency, and the third used surplus electricity generated by the Stirling engine to produce hydrogen using a proton exchange membrane electrolyser PEME. Their results showed that integrating the Stirling engine significantly improves performance, raising exergy efficiency from 28.5% to 39.5%, while also reducing CO_2 emissions per unit of electricity. The system including the electrolyzer enables additional green hydrogen production (up to 56.5 kg/day at optimal conditions), although with a higher total product cost. Overall, the study demonstrates that hybridization with waste-heat recovery and hydrogen production can substantially enhance the thermodynamic and econonomic performance of biomass-fuelled SOFC systems.

Table 1:Comparative analysis of green hydrogen production systems from biomass

System Configuration	Electrolyzer	H2 Yield (Daily)	Exergy Efficiency	References
Biomass GT–steam cycle–electrolyser system	PEM	86.1 kg	41.40%	**[11]**
ORC and PEM multi-generation systems	PEM	3.14 kg	22.20%	**[12]**
High-temperature polygeneration systems with SOEC	SOEC	289.2 kg	_	**[13]**
S/RC-ORC Hybrid System	ALKALINE	259.3 kg	_	**[14]**
Hybrid fuel cell, Stirling and electrolysis systems	PEM	205.4 kg	38.03%	**[15]**

Table 1 presents a comparison between different configurations of integrated hydrogen production systems in terms of electrolysis technology, exergy efficiency and daily hydrogen production.

Systems based on biomass and conventional thermal cycles, such as the biomass–gas turbine–steam cycle system coupled with a PEM electrolyser, have moderate exergy efficiencies (41.40%) and limited daily hydrogen production. Conversely, multi-generation systems incorporating ORC cycles have lower efficiencies due to the indirect conversion of low-temperature heat, which limits hydrogen production.

High-temperature polygeneration systems using SOEC electrolysers are characterised by significantly higher hydrogen production, thanks to the synergy between high-temperature heat and electrolysis, although their technological maturity and costs remain major challenges.

Finally, hybrid systems combining fuel cells, Stirling engines and electrolysers offer intermediate performance, with acceptable exergy efficiencies but more limited hydrogen production capacity.

It should be noted that the hydrogen production figures reported in the various studies were obtained under different operating conditions, system configurations and types of biomass. Consequently, these results cannot be directly compared. The table provided is primarily intended to give an overview of the different system architectures proposed in the literature and the associated levels of hydrogen production.

Conclusion

This review highlights the strong potential of integrated systems combining biomass and electrolysis for green hydrogen production, through various configurations such as cogeneration, multigeneration, polygeneration and hybrid systems. The work analysed shows that the intelligent integration of energy conversion processes enables optimal valorisation of biomass, while improving the overall performance of the systems and strengthening their technical and economic viability.

Beyond the energy aspects, these systems offer major environmental benefits. By exploiting biomass as a renewable and local resource, they contribute to reducing dependence on fossil fuels and lowering greenhouse gas emissions. When managed sustainably, biomass enables hydrogen production to be carbon neutral, while promoting the recovery of agricultural, forestry and organic residues. In addition, the integration of electrolysers powered by electricity from biomass limits the indirect emissions associated with hydrogen production, further enhancing its clean and sustainable nature.

Hybrid and multigenerational systems also offer significant opportunities for the recovery and use of waste heat, reducing energy losses and the overall environmental impact of the facilities. This approach contributes to improved resource efficiency and reduced thermal emissions into the environment.

Future prospects include the optimisation of integrated architectures, the development of more efficient and environmentally friendly biomass conversion technologies, and coupling with other renewable energy sources such as solar and wind power. These advances could strengthen the role of biomass-electrolysis systems in the transition to a low-carbon, sustainable and resilient energy system, making green hydrogen a key vector for decarbonisation in the energy and industrial sectors.

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References

[1] P. Anselmo Filho et O. Badr, « Biomass resources for energy in North-Eastern Brazil », *Applied Energy*, vol. 77, nº 1, p. 51-67, janv. 2004, doi: 10.1016/S0306-2619(03)00095-3.
[2] M. Wu *et al.*, « Techno-economic analysis of hydrogen-to-power, ammonia-to-power pathway with biomass-to-power integration », *Applied Energy*, vol. 407, p. 127327, mars 2026, doi: 10.1016/j.apenergy.2025.127327.
[3] Z. T. Lian, K. J. Chua, et S. K. Chou, « A thermoeconomic analysis of biomass energy for trigeneration », *Applied Energy*, vol. 87, nº 1, p. 84-95, janv. 2010, doi: 10.1016/j.apenergy.2009.07.003.

[4] G. Fiorese, M. Catenacci, V. Bosetti, et E. Verdolini, « The power of biomass: Experts disclose the potential for success of bioenergy technologies », *Energy Policy*, vol. 65, p. 94-114, févr. 2014, doi: 10.1016/j.enpol.2013.10.015.

[5] H. Lv, J. Chen, W. Zhou, X. Shen, et C. Zhang, « Mechanism analyses and optimization strategies for performance improvement in low-temperature water electrolysis systems via the perspective of mass transfer: A review », *Renewable and Sustainable Energy Reviews*, vol. 183, p. 113394, sept. 2023, doi: 10.1016/j.rser.2023.113394.

[6] I. K. Okakwu, S. O. Ayanlade, A. A. Okubanjo, E. S. Oluwasogo, et E. Noma-Osaghae, « Cost-competitiveness of electrolyser technologies and oxygen sales impact on economic viability of wind-powered green hydrogen production », *Next Research*, vol. 3, p. 101144, janv. 2026, doi: 10.1016/j.nexres.2025.101144.

[7] S. Anwar, F. Khan, Y. Zhang, et A. Djire, « Recent development in electrocatalysts for hydrogen production through water electrolysis », *International Journal of Hydrogen Energy*, vol. 46, nº 63, p. 32284-32317, sept. 2021, doi: 10.1016/j.ijhydene.2021.06.191.

[8] S. A. Grigoriev, V. N. Fateev, D. G. Bessarabov, et P. Millet, « Current status, research trends, and challenges in water electrolysis science and technology », *International Journal of Hydrogen Energy*, vol. 45, nº 49, p. 26036-26058, oct. 2020, doi: 10.1016/j.ijhydene.2020.03.109.

[9] S. P. Sanaka, K. Ramanaiah, et P. Vanni, « Performance analysis of Pem Electrolyser for green hydrogen production », *Sustainable Chemistry for Climate Action*, vol. 7, p. 100162, déc. 2025, doi: 10.1016/j.scca.2025.100162.

[10] S. Ata, A. Kahraman, R. Şahin, et M. Aksoy, « Thermo-enviro-economic analysis of different power cycle configurations for green hydrogen production from waste heat », *Energy Conversion and Management*, vol. 301, p. 118072, févr. 2024, doi: 10.1016/j.enconman.2024.118072.

[11] T. Hai *et al.*, « Design of a biomass-fueled system to produce hydrogen/power: Environmental analyses and Bi-objective optimization », *International Journal of Hydrogen Energy*, vol. 52, p. 154-172, janv. 2024, doi: 10.1016/j.ijhydene.2022.11.279.

[12] P. Ahmadi, I. Dincer, et M. A. Rosen, « Development and assessment of an integrated biomass-based multi-generation energy system », *Energy*, vol. 56, p. 155-166, juill. 2013, doi: 10.1016/j.energy.2013.04.024.

[13] Y.-P. Xu *et al.*, « Optimization of a biomass-driven Rankine cycle integrated with multi-effect desalination, and solid oxide electrolyzer for power, hydrogen, and freshwater production », *Desalination*, vol. 525, p. 115486, mars 2022, doi: 10.1016/j.desal.2021.115486.

[14] Y. Ajaj *et al.*, « Innovative biomass waste heat utilization for green hydrogen production: A comparative and optimization study of steam and organic rankine cycles », *Process Safety and Environmental Protection*, vol. 190, p. 148-174, oct. 2024, doi: 10.1016/j.psep.2024.08.006.

[15] A. Habibollahzade, E. Gholamian, E. Houshfar, et A. Behzadi, « Multi-objective optimization of biomass-based solid oxide fuel cell integrated with Stirling engine and electrolyzer », *Energy Conversion and Management*, vol. 171, p. 1116-1133, sept. 2018, doi: 10.1016/j.enconman.2018.06.061.