Green hydrogen production: a bibliometric analysis (O-4H)

F. Posso[1,*,**], A. Aguilera[2], M. Galeano[3]

[1] *Universidad de Santander. Facultad de Ingenierías y Tecnologías. Instituto de Investigación Xerira. Campus Universitario Lagos del Cacique. Calle 70 N 55-210. Bucaramanga. Colombia*

[2] *Consultor y Docente en Vigilancia Tecnológica y Prospectiva, Cali. Colombia*

[3] *Universidad Nacional de Asunción. Facultad de Ciencias Químicas. San Lorenzo. Paraguay*

(*) Pres. author: directormgcti@udes.edu.co (**) Corresp. author: directormgcti@udes.edu.co

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1. Introduction

The intervention of hydrogen of renewable origin, green H_2, in the energy mix of a country is a topic of great interest today as it is emerging as an energy vector conducive to the decarbonization of the economy and the energy transition from a fossil energy system to one based on renewable energies [1]. Thus, in the context of the Hydrogen Economy, green H_2 is produced, stored, transported and distributed for use as energy vector or chemical input. The diversity of pathways of production, with different levels of scientific advancement and technological maturity, motivates the realization of this work, which proposes to carry out a systematic bibliographic review, supported by bibliometric methods, of the scientific literature and the registration of patents on the production of green H_2, in the period 2010-2020.

2. Method

The method used is carried out in three stages. The first involves identifying the pathways and processes to produce green H_2; the second, to carry out a bibliographic search on the pathways and processes identified; and the third, to carry out the bibliometric analysis of the bibliographic exploration results. These stages are associated with a set of activities, namely: analysis of review articles on green H_2 production processes; selection of production pathways and processes to study; construction of keywords and search equations; consulting selected scientific and patent databases; review, debugging and validation of the results; downloading and processing of information in specialized software (Vantage Point and VosViewer); generation of bibliometric indicators and their corresponding analysis and dynamic interpretation. Based on the maximum length of this summary, the results of the two H_2 production processes with the highest activity in scientific and patent publications are presented: electrolysis and gasification, although the full study covers nine processes from the three selected production pathways.

3. Results and discussions

The preliminary bibliographic review of the production processes of green H_2 allows identifying the prioritized renewable primary sources (RPS), their ways of conversion and the production processes associated with the greatest activity and relevance at present. Thus, the selected RPSs are biomass energy, direct solar energy, wind energy and hydropower; while its derived energies are thermal, biochemical, photonic, and electrical energy, from whose individual or joint conversion 14 green H_2 production processes are obtained on which a systematic bibliographic search is carried out in the Scopus databse, following the general procedure used in bibliometric studies in the knowledge field of energy [2].

Based on the bibliometric indicators generated, Figure 1 shows the green H_2 production pathway for the five processes with the highest activity, having a scientific production of more than 300 articles in the study period. Conventional electrolysis is seen to be the process with the most access pathways, while biomass energy is the most versatile of all types of energy. Also, one of the emerging technologies to produce green H_2, photoelectrochemistry, is included in this group and with promising development prospects [3].

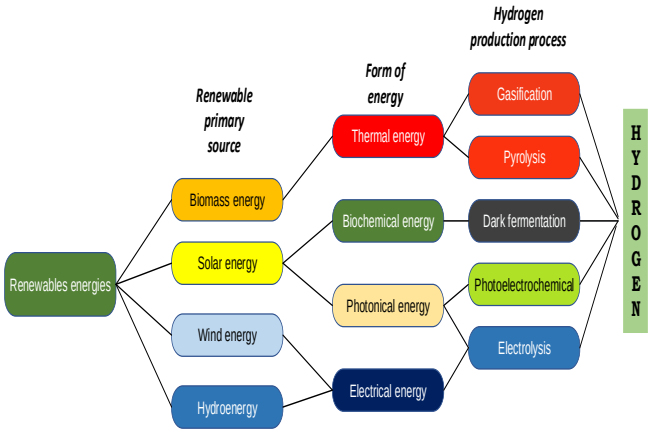

Fig. 1. Pathways of selected processes for green H_2 production.

In Figure 2, the evolution of the five aforementioned processes is presented, it can be seen that gasification and electrolysis are the processes that lead, in that order, the statistics for all the years of the study period. This result is not accidental, since both are well known processes in their structure and behavior, with mature technologies and widely used in the process industry. In the context of the Hydrogen Economy, its participation has two distinctive aspects, the primary energy source that is the base of the process and its final uses.

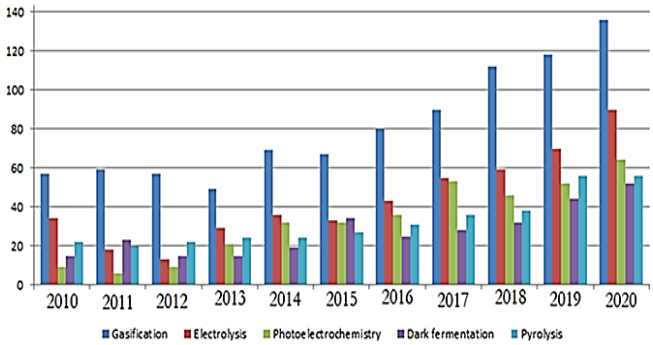

Fig. 2. Evolution of scientific publications of selected processes

In keeping with this result, the technological development of both processes is presented, measured by the number of patents registered annually, Fig. 3 (a, b).

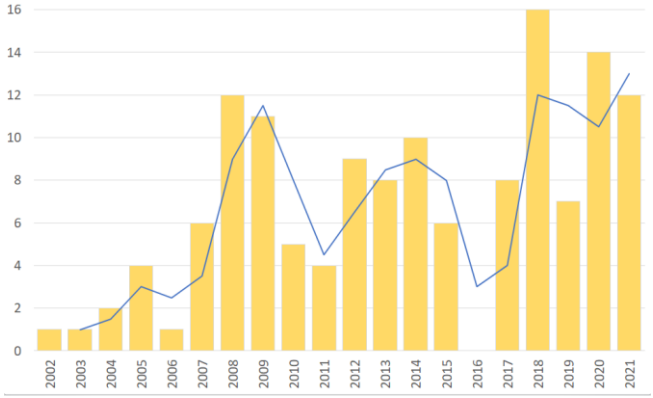

Fig. 3a. Evolution of patents for gasification.

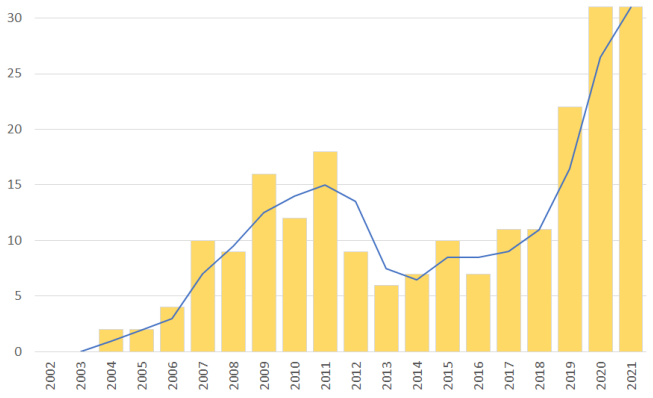

Fig. 3b. Evolution of patents for electrolysis.

The technological innovation curves show the usual behavior, with peaks and valleys in correspondence with the behavior of the scientific literature. There is also a more pronounced growth in electrolysis in the last 4 years (Fig. 3a), which could be attributed to its qualification as the main green H_2 generation process [4].

4. Conclusions

A retrospective and current state of the development, scientific and technological, of the production of green H_2 is presented, through a bibliometric analysis of the scientific literature and patent registration in the period 2010-2020. There is a growing trend in scientific publications, with the leadership of gasification and electrolysis processes, and an important participation of photoelectrochemistry. Regarding technological development, electrolysis has experienced high growth in the last five years and gasification has a pendular behavior. The results indicate the preponderance of conventional H_2 production processes, but with the sustained advance of emerging technologies, such as photoelectrochemistry and dark fermentation. It is concluded that the production of green H_2 constitutes a stage in the value chain of the Hydrogen Economy in full scientific progress and technological development, combining mature processes with new processes based on the use of innovative types of RPS conversion. The results help to identify the current state and interpret the trends in the generation of knowledge, technological development and innovation in the production of green H_2 that support the formulation of policies and actions for the incorporation of the Hydrogen Economy in a given context.

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