

University of Algiers 3, (Algeria), 19 September 2026

Global Research Collaboration in Green Hydrogen: A Bibliometric Analysis, 2016–2025

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Summary: Green hydrogen has ascended as a pivotal component in the global transition towards sustainable energy, with its advancement increasingly reliant on international scientific and industrial collaboration. This study conducts a bibliometric analysis of the global research landscape pertaining to green hydrogen, utilizing a dataset of 2,324 documents (comprising articles and reviews) indexed in the Scopus database from the period of 2016 to 2025. The documents were sourced through a comprehensive Boolean search incorporating terms like "green hydrogen," "renewable hydrogen," "clean hydrogen," "low-carbon hydrogen," and "green H2." The investigation explores various dimensions including the annual progression of scientific output, leading countries and institutions in research contributions, key authors and prestigious journals, prevalent thematic keywords, and the configuration of international co-authorship networks. The findings reveal nearly a fifty-fold increase in publications during the specified period, with the research arena primarily led by China, India, the United States, Germany, and Italy. A significant aspect of the study is an international co-authorship rate of approximately one-third across the sample, with Saudi Arabia frequently serving as a bridging entity between different nations' research efforts. In contrast, Algeria's presence within this scholarly discourse is minimal, evidenced by just 29 documents that are mostly co-authored with Saudi Arabia, France, and the United Kingdom. The paper reflects on the implications of these outcomes for Algeria's strategic role in international green hydrogen collaborations, particularly in relation to the SouthH2 Corridor initiative, and suggests strategies for enhancing the country's research collaboration frameworks.

Keywords: Green hydrogen; bibliometric analysis; international research collaboration; energy transition; Algeria.

Jel Classification Codes : Q42; Q48 ; C80

Introduction :

The transition from grey to green hydrogen marks one of the most significant shifts currently transforming the global energy landscape. While grey hydrogen is traditionally produced from natural gas via steam methane reforming, green hydrogen is created by electrolyzing water using electricity sourced from renewables. This process positions green hydrogen as a nearly zerocarbon energy carrier, crucial for decarbonizing hard-to-abate sectors like heavy industry, long-distance transportation, and seasonal energy storage. The shift isn't confined to national borders; due to uneven distribution of electrolyser manufacturing, renewable energy generation, storage solutions, and international transport infrastructure, deploying green hydrogen relies fundamentally on international cooperation, setting standards, and sharing technology.

For Algeria, these developments hold particular significance. Participation in initiatives like the SouthH2 Corridor, which aims to link North African green hydrogen production with European demand, positions Algeria at the forefront of a burgeoning global value chain. Understanding global scientific engagement in green hydrogen research, identifying leading countries, and

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discerning prevalent collaboration patterns provide valuable insights into Algeria's current standing and potential international partnerships in this sector.

A bibliometric analysis provides a systematic approach to mapping this scientific field. It quantifies publishing trends, spotlights key authors, institutions, and journals, and unveils collaboration network structures through co-authorship data. This study employs such analysis on globally indexed literature about green hydrogen in Scopus, focusing particularly on the international aspects of scientific partnerships aligning directly with this conference's emphasis on partnerships with leading countries in green hydrogen.

Problem Statement

In the context of Algeria's strategic placement within the burgeoning global green hydrogen economy, this paper seeks to address several critical inquiries:

- How has the global scientific output pertaining to green hydrogen evolved during the period from 2016 to 2025?
- Which nations, academic institutions, researchers, and scholarly journals hold a predominant influence in this area of research?
- What is the scope and organizational framework of international collaborative authorship in green hydrogen studies, and which bilateral partnerships are the most active?
- What is Algeria's current status within this international research network, and what implications does this have for its strategic alliances with leading nations in this field?

I - Literature Review

I.1- Green Hydrogen as a Field of Study

The academic exploration of hydrogen energy extends well before the current surge in interest in green hydrogen, with initial studies focusing on fuel cells, storage solutions, and the economics of steam-methane reforming. What sets apart the literature after 2016, as addressed in this study, is a change in perspective: hydrogen is no longer viewed merely as a generic energy carrier. Instead, it is categorized based on its production method and carbon intensity, labeled as grey, blue, turquoise, or green. This classification has sparked numerous review articles, particularly since policymakers started integrating climate targets into hydrogen strategies. Research like (Yu et al., 2021) explicitly compares these production pathways, while others, such as those by (Shaner et al., 2016) and El-Emam and Özcan (2019), concentrate on the technical and economic feasibility of pairing electrolysis with variable renewable energy sources at larger scales. Technically speaking, (Kojima et al., 2023) analyze how the fluctuations in renewable power impact electrolyser performance, emphasizing that cost assessments for production are heavily influenced by how intermittency is managed. This research field has identified production costs, electrolyser efficiency, and the siting of renewable resources as key technical concerns. These concerns are joined by issues related to storage and large-scale transport, as evidenced by more recent works like (Ma et al., 2024) on large-scale storage and (Zainal et al., 2024), who review advances throughout the entire green hydrogen production chain.

The academic discourse surrounding hydrogen energy significantly precedes the recent surge in green hydrogen interest, initially focusing on aspects such as fuel cells, storage materials, and the economics of steam-methane reforming. However, a distinguishing characteristic of the post-2016 scholarship, as analyzed in this study, is its reframing of hydrogen. It is no longer regarded merely as a generic energy carrier; instead, it is intricately linked to its production methods and associated carbon intensity categorized into grey, blue, turquoise, and green hydrogen. This classification has garnered increasing attention in review articles, especially as policymakers began integrating climate objectives into hydrogen-based strategies. Research efforts have made explicit comparisons among these production pathways (Yu et al., 2021). Concurrently, studies investigate the techno-economic feasibility of integrating electrolysis with variable renewable energy sources (Shaner et al., 2016). This corpus of research has identified key technical priorities for the field, focusing initially on production costs, electrolyser efficiency, and the optimal location for renewable resources. More recent studies have expanded the scope to include challenges related to storage and large-scale hydrogen transport (Ma et al., 2024). on large-scale storage and (Zainal et al., 2024), who review advances across the whole green hydrogen production chain.

A more recent approach focuses on the geography and governance surrounding the deployment of green hydrogen. This includes regional supply evaluations for Europe (Kakoulaki et al., 2021), and applications specific to sectors like shipping (Atilhan et al., 2021). These studies increasingly portray green hydrogen as an internationally traded commodity rather than just a domestic energy solution. This shift in perspective is what drives the current study's emphasis on the collaborative and cross-border nature of the research field itself, rather than solely its technical aspects.

I. 2- Bibliometric Analysis as a Method in Energy Research

Bibliometric analysis has become a vital tool for mapping emerging, interdisciplinary research fields, especially in energy studies where the sheer volume of publications quickly surpasses the capacity of a traditional narrative review. By utilizing structured, quantitative indicators such as publication counts, citation impact, keyword co-occurrence, and co-authorship networks bibliometric studies enable researchers to uncover a field's intellectual framework, its key contributors, and, notably for this paper, the patterns of international collaboration integral to its development. Tools like VOSviewer and the Bibliometrix R package have democratized access to such analyses, while Scopus and Web of Science continue to be the primary databases due to their structured export formats and extensive journal coverage.

In the specific area of hydrogen and renewable energy, bibliometric studies usually target either the technical sub-fields (e.g., electrolysis materials, storage technologies) or broader energy-transition literature. However, research networks focusing on international collaborations specifically in green hydrogen as opposed to general renewable energy are relatively under-explored, particularly from the perspective of a North African or Algerian research system. This study aims to address that gap.

II– Methods and Materials:

This research employs a quantitative bibliometric methodology, utilizing data sourced from the Scopus database (Elsevier). The selection of Scopus is attributed to its expansive multidisciplinary scope concerning energy-related literature, coupled with its organized export format, which facilitates analysis.

II .1- Search Strategy and Data Collection

The following Boolean query was applied to the "Documents" search field of Scopus:

("green hydrogen" OR "renewable hydrogen" OR "clean hydrogen" OR "low-carbon hydrogen" OR "green H2")

The search was restricted to the 2016–2025 period, document types Article and Review, and documents published in English, within the subject areas of Energy, Environmental Science, Business/Management and Accounting, Economics/Econometrics/Finance, Social Sciences and Decision Sciences. This query returned 2,324 documents, exported in full CSV format including author names, affiliations, abstracts, author keywords, citation counts, source titles and DOIs.

II .2- Analytical Procedure:

The analysis began by processing the exported dataset through a programmatic approach to produce descriptive bibliometric indicators. These included annual publication counts, rankings of source and author productivity, frequency of authorkeywords, and citationbased impact rankings. For the collaboration analysis, which is the focus of this paper, we parsed the affiliation field of each document to identify the countries represented among its authors. A document was classified as an international collaboration if it included authors from two or more different countries. We then counted instances where country pairs appeared together in the same document to determine the most frequent bilateral collaboration links. This process follows the standard co-authorship network logic used in tools like VOSviewer and Bibliometrix, which can also create a full visual network map from the same dataset. Although this affiliation parsing approach is systematic, it may result in a slight undercount of countries whose institutional names don't explicitly include the country in the affiliation string; thus, the reported collaboration share should be seen as a conservative estimate.

II .3- Limitations of the Study

There are three important limitations to consider when interpreting the results. First, the analysis is based solely on the Scopus database. This means that coverage might vary slightly if databases like Web of Science or engineering specific repositories such as Compendex were used,

especially regarding conference proceedings. Second, the identification of countries relies on matching strings from a fixed list of country names found in the affiliation field. While this method adequately covers all major contributors to the literature, there may be occasional affiliations from smaller countries that aren't explicitly included in this list. Third, the study presents descriptive, count-based indicators rather than conducting a full social network analysis of the co-authorship graph, such as centrality or betweenness measures. The country-pair frequencies discussed here should be viewed as a preliminary approximation of collaboration structures. For a complete visual map, it would be beneficial to refine these findings using dedicated network-analysis software like VOSviewer.

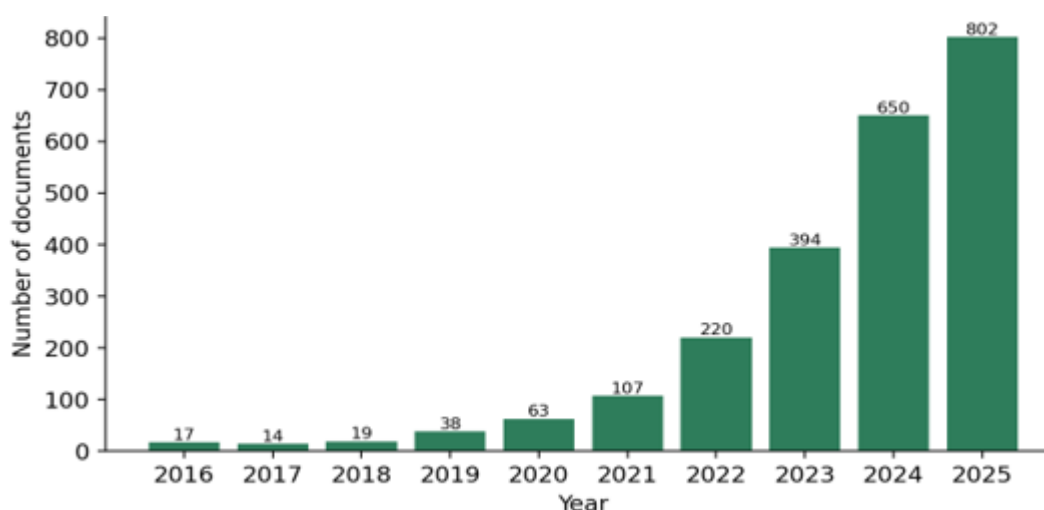
III- Results and discussion :

III. 1- Results

III. 1.1- Growth of Scientific Production

The dataset comprises 1,996 articles (85.9%) and 328 reviews (14.1%). Annual output grew from just 17 documents in 2016 to 802 in 2025 a nearly forty-seven-fold increase over the decade (Figure 1). Growth accelerated sharply from 2021 onward, coinciding with the wave of national hydrogen strategies and large-scale electrolyser announcements made by the European Union, Gulf states and East Asian economies in that period.

Figure (1): Annual scientific production on green hydrogen, 2016–2025 (Scopus, n = 2,324).



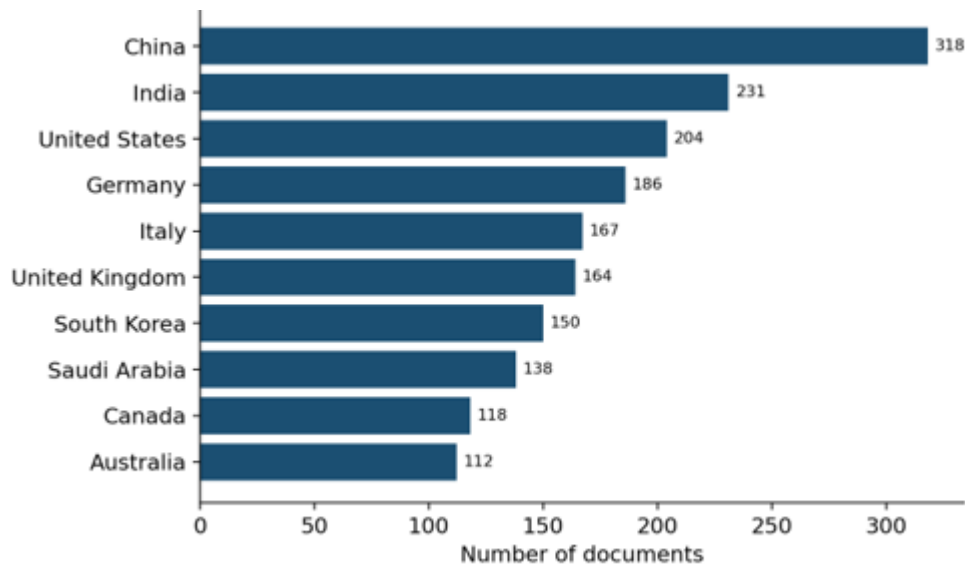
The source: Authors' own elaboration using Scopus database

III. 1.3- Top Contributing Countries

In terms of affiliation-based research output, the leading countries are China (318 documents), India (231), the United States (204), Germany (186), Italy (167), the United Kingdom (164), South Korea (150), Saudi Arabia (138), Canada (118) and Australia/Spain (112 each) as the ten most prolific contributors (Figure 2).

This ranking reflects both large domestic research systems (China, India, the United States) and countries pursuing explicit national hydrogen strategies backed by renewable resource endowments (Saudi Arabia, Australia, Spain). Among MENA countries, the United Arab Emirates (36 documents), Egypt (96) and Morocco (38) are considerably more visible in this literature than Algeria (29), Tunisia (15) or Oman (19).

Figure (2). Top 10 contributing countries by document count.



The source: Authors' own elaboration using Scopus database

III. 1.4- Leading Journals, Authors and Cited Works

The International Journal of Hydrogen Energy leads the field with 612 documents, representing (26.3% of the sample), far ahead of Energies (133), Energy Conversion and Management (92), Renewable Energy (80) and Applied Energy (78). At author level, Ibrahim Dincer is by far the most productive contributor with 46 documents, followed by Qusay Hassan (14), Hamdy Hassan (13) and Mohamed Nasser (13) a concentration that signals a small set of highly active research groups anchoring much of the field's output.

Table (1) : Top 10 journals publishing green hydrogen research.

Rank	Source title	Documents
1	International Journal of Hydrogen Energy	612
2	Energies	133
3	Energy Conversion and Management	92
4	Renewable Energy	80
5	Applied Energy	78
6	Journal of Cleaner Production	69
7	Energy	66
8	Fuel	55
9	Renewable and Sustainable Energy Reviews	54
10	Chemical Engineering Journal	41

The source: Authors' own elaboration using Scopus database

Regarding impact, the sample generated 87,998 citations in total (37.9 citations per document on average). The most cited work is a 2022 Energy Reports overview of water electrolysis technologies (1,315 citations), followed by a 2021 Current Opinion in Chemical Engineering paper on the green hydrogen economy (874 citations) and a 2016 Energy & Environmental Science techno-economic comparison of solar-based hydrogen production (864 citations) see (Table 2).

Table (2): Five most cited documents in the dataset

Rank	Authors	Title	Year	Source	Citations
1	Shiva Kumar S.; Lim H.	An overview of water electrolysis technologies for green hydrogen production.	2022	Energy Reports	1315
2	Oliveira A.M.;	A green hydrogen	2021	Current Opinion	874

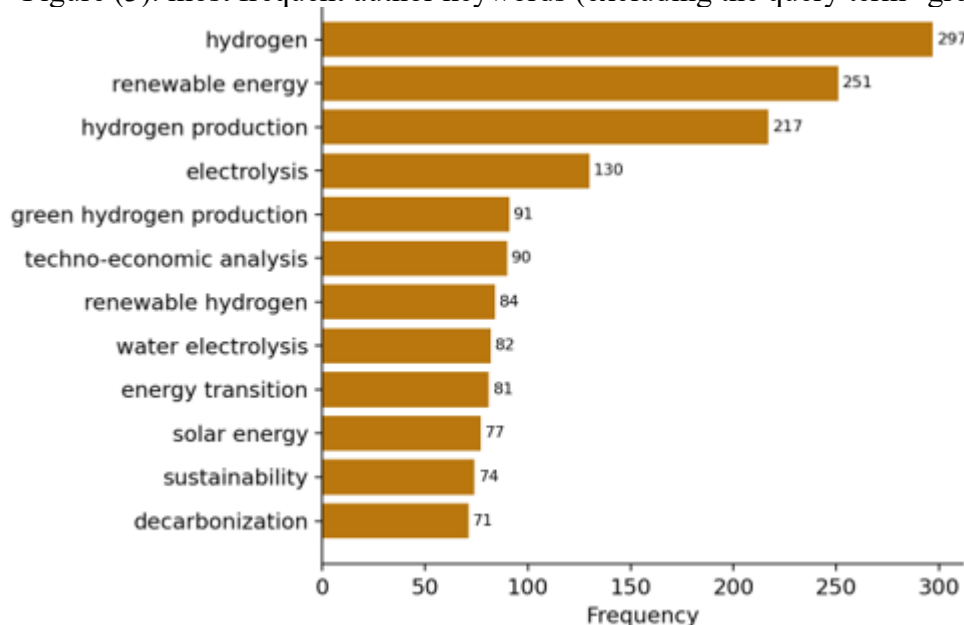
	Beswick R.R.; Yan Y.	economy for a renewable energy society.		in Chemical Engineering	
3	Shaner M.R.; Atwater H.A.; Lewis N.S.; McFarland E.W.	A comparative techno-economic analysis of renewable hydrogen production using solar energy.	2016	Energy & Environmental Science	864
4	Yu M.; Wang K.; Vredenburg H.	Insights into low-carbon hydrogen production methods: Green, blue and aqua hydrogen.	2021	Int. J. Hydrogen Energy	729
5	Miller H.A. et al.	Green hydrogen from anion exchange membrane water electrolysis.	2020	Sustainable Energy & Fuels	728

The source: Authors' own elaboration using Scopus database

III. 1.5- Thematic Structure

Beyond the query terms themselves, the most frequent author keywords are hydrogen (297), renewable energy (251), hydrogen production (217), electrolysis (130), techno-economic analysis (90), renewable hydrogen (84), water electrolysis (82), energy transition (81), solar energy (77) and sustainability (74) (Figure 3). This distribution shows the field is anchored in production technology and techno-economic assessment, with energy-transition and sustainability framing appearing as a secondary, policy-oriented layer a layer directly relevant to the conference's concern with strategies and public policy for the transition to green hydrogen.

Figure (3): most frequent author keywords (excluding the query term "green hydrogen").



The source: Authors' own elaboration using Scopus database

III. 1.6- International Collaboration Networks

Among the 2,310 documents with accessible affiliation data, 752 (32.6%) include contributions from authors affiliated with two or more countries recognized in this study. This denotes that approximately one-third of the publications on green hydrogen within the sample are the result of international co-authorship. The proportion of such collaborations has varied throughout the period under consideration, ranging from approximately 10–15% between 2018 and 2020 to 20–26% in more recent years. This non-monotonic increase indicates that internationalization in green hydrogen research has progressed in an irregular manner rather than following a linear trajectory.

Analyzing specific bilateral collaborations, Saudi Arabia emerges as the most frequent partner country, co-authoring with China (34 joint documents), India (32), Egypt (27), and Pakistan (18). This aligns with the Kingdom's substantial investments in green hydrogen projects such as NEOM and Jazan, which have fostered extensive international research partnerships. Other notable collaboration pairs include Canada–Turkey (30), China–United Kingdom (26), and South Korea–United States (19).

Table (3): Top 10 international country-pair collaborations in green hydrogen research

Rank	Country pair	Joint documents
1	China – Saudi Arabia	34
2	India – Saudi Arabia	32
3	Canada – Turkey	30
4	Egypt – Saudi Arabia	27
5	China – United Kingdom	26
6	South Korea – United States	19
7	Pakistan – Saudi Arabia	18
8	Australia – China	17
9	China – India	17
10	Iraq – Saudi Arabia	16

The source: Authors' own elaboration using Scopus database

III. 1.7- Algeria's Position in the Global Network

Algeria is mentioned in only 29 documents within the sample, which is modest compared to its regional peers like Egypt (96), the United Arab Emirates (36), and Morocco (38). Among the documents co-authored with Algeria, the most frequent international collaborators are Saudi Arabia with 6 joint documents, followed by France and the United Kingdom with 3 each, and Japan, Spain, and India with 2 each. This pattern suggests that Algeria's current scientific partnerships in green hydrogen research are distributed between a Gulf partner involved in large-scale green hydrogen investments and traditional European partners with historical energy-research ties to Algeria, rather than being centered around a single dominant partnership.

III. 1.8- Subject-Area Distribution and the Economics Gap

The subject-area classification by Scopus for the given sample provides valuable insights. Under the applied filters, a significant number of documents are concentrated in Engineering (660 documents) and Physics and Astronomy (624), followed by Chemical Engineering (294) and Chemistry (231). In stark contrast, the categories of Economics, Econometrics and Finance, Social Sciences, and Decision Sciences each show zero documents with the same filter settings (Table 4). This is not due to an error in data extraction but rather highlights how the field has been categorized and who is contributing to it: currently, green hydrogen research indexed in Scopus appears to be an almost exclusively technical and natural-sciences domain.

Table (4): Distribution of the Scopus sample across selected subject areas.

Subject area	Documents
Engineering	660
Physics and Astronomy	624
Chemical Engineering	294
Chemistry	231
Economics, Econometrics and Finance	0
Social Sciences	0
Decision Sciences	0

The source: Authors' own elaboration using Scopus database

The complementary analysis of Scopus index-keyword frequencies underscores a strong technical focus: Hydrogen Production (1,208 mentions), Green Hydrogen (823), Hydrogen (703), Hydrogen Storage (428), and Electrolysis (365) stand out as the primary controlled-vocabulary terms in the sample, mirroring the author-keyword patterns highlighted in Section 4.4. When examined alongside Table 4, this keyword distribution suggests that crucial aspects like economic, financial, and policy-related elements of green hydrogen such as market design, investment evaluation, regulatory standards, and trade governance are notably underrepresented in current literature classifications. These areas are essential for turning a country's technical potential, like

Algeria's, into a functional export value chain. This observation is explored further in the subsequent discussion.

III. 2- Discussion

III. 2.1-Benchmarking with Comparable Research Systems

The global landscape in research is led by a few major systems like China, India, the United States, and Germany, along with nations rich in resources and strategic investment such as Saudi Arabia, Australia, and Spain. For Algeria, aligning with countries like Saudi Arabia and Spain offers a more feasible benchmark and partnership model compared to competing directly with the much larger systems of China or the United States. These nations have similar ambitions to transform their renewable resource wealth into an exportable hydrogen value chain. Algeria's research strategy can benefit more from understanding how these countries developed their green hydrogen research capabilities.

III. 2.2-Collaboration as a Strategic Component

The significant amount of international co-authorship, constituting about a third of the literature, emphasizes collaboration as a key part of maintaining a competitive edge. Saudi Arabia's role as a collaborative hub indicates that joining bilateral or multilateral research partnerships is now standard in this field. Algeria's limited visibility, with only 29 documents, and its modest and scattered partner base suggest an opportunity for growth. This can be achieved by expanding structured research cooperation through initiatives like joint calls, co-supervised doctoral programs, or establishing joint laboratories, especially with partners involved in the SouthH2 Corridor and Gulf countries pursuing similar renewable hydrogen export aspirations.

III. 2.3-Opening for Economics and Management Research

A notable finding is the absence of contributions from Economics, Social Sciences, and Decision Sciences in this area of research. This presents an open disciplinary space for Algerian researchers in management sciences and economics to engage with green hydrogen-related topics such as financing structures, levelized-cost modeling, or regulatory framework design for projects like SouthH2. By entering this relatively untapped field, researchers can help shape a new subfield within international research, offering valuable bibliometric and policy-analytic insights that complement the established engineering literature.

IV- Conclusion:

This bibliometric analysis, encompassing 2,324 documents indexed in Scopus, reveals a rapidly expanding field of green hydrogen research. This expansion is primarily concentrated in a select group of leading countries, with international collaborations comprising approximately one-third of the global scholarly output. Notably, Saudi Arabia emerges as the most active participant in cross-border collaborations. In contrast, Algeria's engagement in this scholarly domain is minimal, both in terms of volume and diversity of international partnerships, despite its strategic involvement in initiatives such as the SouthH2 Corridor.

To enhance Algeria's standing and integration into global green hydrogen research and collaboration networks, the following strategies are recommended:

- Pursuing targeted co-publication and joint supervision agreements with the key partner countries identified in this study, especially those engaged in similar renewable hydrogen export strategies.
- Encouraging Algerian research teams within the fields of economics and management sciences to explore the policy, financing, and governance aspects of green hydrogen. These areas are underrepresented compared to the predominant focus on engineering and techno-economic studies.
- Employing bibliometric monitoring, akin to the approach utilized here, as a regular tool to assess Algeria's evolving position within the international green hydrogen research network. This tool will guide the country's partnership strategy with leading nations in this domain.
- Intentionally positioning Algerian research in economics and management within the identified disciplinary gap, as outlined in Section 4.7. Emphasis should be placed on topics such as financing, regulation, and corridor governance, areas that remain largely unexplored globally rather than replicating existing technical research.

Future investigations could expand this analysis by incorporating a comprehensive co-occurrence network visualization using tools like VOSviewer or Bibliometrix and by integrating institution-level affiliation data. This would aid in identifying specific laboratories and universities as potential collaborators for Algerian research institutions. Furthermore, a longitudinal study, replicating this analysis every two to three years, would enable an assessment of whether Algeria's position within the international green hydrogen research network and the existing disciplinary gap is narrowing or persisting.

Appendices:

Table A1 lists the twenty most productive countries identified through affiliation parsing, and Table A2 lists the twenty-five most frequent author keywords in the sample, extending the summary figures presented in Sections 4.2 and 4.4.

Table A1. Top 20 contributing countries by document count.

Rank	Country	Documents
1	China	318
2	India	231
3	United States	204
4	Germany	186
5	Italy	167
6	United Kingdom	164
7	South Korea	150
8	Saudi Arabia	138
9	Canada	118
10	Australia	112
11	Spain	112
12	Turkey	110
13	Egypt	96
14	Iran	94
15	Brazil	68
16	Japan	62
17	Malaysia	61
18	France	59
19	Netherlands	52
20	Poland	46

Table A2. Top 24 author keywords by frequency (excluding the query term "green hydrogen", 822 occurrences).

Rank	Author keyword	Frequency
1	Hydrogen	297
2	Renewable Energy	251
3	Hydrogen Production	217
4	Electrolysis	130
5	Green Hydrogen Production	91
6	Techno-Economic Analysis	90
7	Renewable Hydrogen	84
8	Water Electrolysis	82
9	Energy Transition	81
10	Solar Energy	77
11	Sustainability	74
12	Decarbonization	71
13	Wind Energy	64
14	Optimization	63
15	Hydrogen Economy	63
16	Electrolyzer	62
17	Energy Storage	56

18	Levelized Cost Of Hydrogen	50
19	Life Cycle Assessment	48
20	Hydrogen Storage	47
21	Energy	46
22	Power-To-Gas	41
23	Fuel Cell	39
24	Water Splitting	37

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