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# Review of the Planning and Distribution Methodologies to Locate Hydrogen Infrastructure in the Territory

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**Abstract:** The member countries of the European Union (EU) have prioritized the incorporation of hydrogen as a key component of their energy objectives. As the world moves towards reducing its dependence on fossil fuels, alternative sources of energy have gained prominence. With the growing development of Fuel Cell Electric Vehicles (FCEVs), the establishment of an infrastructure for hydrogen production and the creation of a network of service stations have become essential. This article's purpose is to conduct a methodical review of literature regarding the use of green hydrogen for transportation and the planning of imperative infrastructure in the territory of the EU, specifically Hydrogen Refueling Stations (HRS). In order to increase the acceptance of fuel cell vehicles, a comprehensive network of hydrogen refueling stations (HRS) must be built that enable drivers to refuel their vehicles quickly and easily, similar to gasoline or diesel vehicles. The literature review on this topic was conducted using the Web of Science database (WOS), with a variety of search terms proposed to cover all the key components of green hydrogen production and refueling infrastructure. The implementation of HRS powered by renewable energy sources is an important step in the adoption of fuel cell vehicles, and overcoming the obstacles that come with their implementation will require cooperation and innovation from governments, private businesses, and other stakeholders.

**Keywords:** green hydrogen; electrolysis; storage; refueling; fuel cell; location

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## 1. Introduction

A significant stride in curbing greenhouse gas (GHG) emissions within the transportation sector involves the advancement and promotion of zero-emission vehicles. Among these, Fuel Cell Electric Vehicles (FCEVs) represent a crucial model currently under development. The reduction of GHG emissions in the transportation sector is a lofty goal set by the European Union, and the widespread adoption of FCEVs is considered indispensable for meeting these ambitious targets. To support this endeavor, manufacturers are heavily investing in the research and development of FCEVs, along with the necessary infrastructure, such as hydrogen refueling stations. FCEVs utilize hydrogen stored in tanks, utilizing a fuel cell (FC) to generate electricity through an electrochemical process. This process combines hydrogen with oxygen from the air, powering the FCEV and producing only water ($H_2O$) as waste. FCEVs emerge as a sustainable transportation option due to various factors, with the key considerations being the following: (1) reduction in the weight of the hydrogen tank compared to a battery; (2) extended range and quicker refueling times compared to Battery Electric Vehicles (BEVs); (3) addressing the shortage of materials in battery production, such as lithium. Collectively, Fuel Cell Electric Vehicles exhibit several advantages over traditional vehicles.

These attributes render FCEVs an appealing choice for sustainable mobility. As this technology undergoes further development and expansion, its feasibility and widespread adoption are anticipated to increase. Consequently, the European Union (EU) has put forth initiatives to usher in a hydrogen-based economy, aiming to mitigate greenhouse gas (GHG) emissions. Notably, the International Renewable Energy Agency (IRENA) deems hydrogen the paramount energy source for the future [1].

In September 2015, the United Nations General Assembly (UNGA) adopted the 2030 Agenda for Sustainable Development, a comprehensive action plan addressing people, planet, and prosperity. Central to this agenda are the 17 Sustainable Development Goals (SDGs), accompanied by 169 targets. These goals serve as a global call to action, aiming to eradicate poverty, safeguard the planet, and promote peace and prosperity for all by the year 2030. Encompassing a wide array of issues—from poverty and hunger to health, education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, innovation and infrastructure, reduced inequality, sustainable cities and communities, responsible consumption and production, climate protection, life below water, life on land, peace, justice, and strong institutions—the SDGs underscore the need for collaborative efforts and partnerships to achieve them.

To realize these goals, resilient infrastructure must be developed, inclusive and sustainable industrialization promoted, and innovation nurtured [2]. Recognizing the importance of these objectives, the European Union (EU) has launched various programs in alignment with the 2030 Agenda.

The Energy and Climate Strategic Framework sets out the Hydrogen Roadmap [3], a strategic plan that describes the steps and milestones required to develop and use hydrogen as an energy carrier. The objectives of the strategy are aligned with the measures planned in the European context. One of the main policies to address this issue is the inclusion of renewable hydrogen in Directive 2018/2001 of 11 December 2018 [4] and the European Green Deal [5]. Its main goal is to make the European Union (EU) a climate-neutral continent by 2050, lined with the goals of the Paris Climate Agreement.

The EU Hydrogen Strategy is considered a core part of the European Green Deal and is expected to bring significant investment in hydrogen technology and infrastructure in the coming years. The plan is based on the three periods (2020–2024, 2025–2030, and 2030–2050) described in Table 1. The table also includes different goals and sectors for each period.

**Table 1.** EU Hydrogen Strategy Temporary framework (European Green Deal). Data from European Green Deal [5].

| Period | Objective | Sector |
|---|---|---|
| 2020–2024 | Installation of at least 6 GW of electrolyzers in the EU and the production of up to 1 million tons of renewable hydrogen | In industrial processes and in heavy transport, in addition, electrolyzers and hydrogen plants will be needed for FC bus and truck refueling |
| 2025–2030 | Installation of 40 GW of electrolyzers by 2030 and the production of up to 10 million tons of renewable hydrogen in the EU | Manufacture of steel, trucks, railways, some maritime transport applications, and other modes of transportation |
| 2030–2050 | Renewable hydrogen technologies should reach maturity and be deployed on a large scale | Aviation, maritime transport, industrial and construction sector |

In the realm of transportation, the Hydrogen Refueling Station (HRS) stands out as the critical infrastructure for hydrogen utilization, akin to conventional gas stations for hydrogen fuel cell vehicles. HRSs play a pivotal role by supplying compressed hydrogen to refill the fuel tanks of these vehicles. The success of this technology hinges on strategic location planning across territories and the integration of renewable energy sources into hydrogen production.

Currently, the FCEV model market is significantly low, primarily attributed to the scarcity of hydrogen refueling stations (HRS). Therefore, it is imperative for vehicle manufacturers, institutions, and infrastructure managers to collaborate on a comprehensive and coordinated plan aimed at promoting the adoption of this technology in EU. This plan should encompass various aspects, including vehicle transformation, necessary infrastructure planning, and construction.

Hence, the Important Projects of Common European Interest (IPCEI) in the hydrogen sector was initiated in 2020 with the aim of expediting the development of the green hydrogen economy across European countries and Norway. Nevertheless, accurately determining the size and distribution of hydrogen infrastructure design poses a challenge due to the inherent uncertainty in forecasting.

The purpose of this paper is to offer a comprehensive overview of the present status of hydrogen infrastructure research within the transportation sector. The intention is to highlight the key areas of research that hold the utmost significance in formulating a well-planned hydrogen logistics system, encompassing distribution, storage logistics, energy sources, and supply chains.

According to the information provided, Section 2 of the paper will offer a concise overview of hydrogen technology in the transportation sector, shedding light on key topics and pertinent research criteria.

Moving forward, Section 3 will detail the methodology employed for conducting hydrogen research, utilizing the Web of Science (WOS).

Subsequently, the search results will be presented and analyzed in Section 4, with a specific focus on two interconnected topics: green hydrogen and hydrogen refueling stations (HRSs).

Section 5 will then engage in a discussion of the results, extracting potential research opportunities across various facets of this field. Lastly, the paper will draw conclusions in Section 6.

## 2. Hydrogen in the Transportation Field

As of 2023, the transportation sector stands as the second-largest contributor to greenhouse gas (GHG) emissions, accounting for 21.3% of the total, following closely behind the energy supply sector. In response, the European Union has established a strategy for reducing GHG emissions in the transportation field, emphasizing the utilization of green hydrogen as an alternative to other vehicle energy sources.

For elucidation, hydrogen is primarily categorized into three main types based on the energy sources used in their production: (1) Grey hydrogen: produced using natural gas or methane through steam methane reforming (SMR). Grey hydrogen is the most common type but is not considered sustainable due to the greenhouse gas emissions generated during production. (2) Blue hydrogen: this hydrogen is produced with natural gas and carbon capture and storage (CCS) technology to capture and store the carbon emissions generated during production. Blue hydrogen is considered a transitional option towards a sustainable hydrogen economy because it reduces GHG emissions compared to grey hydrogen. (3) Green hydrogen: produced through water electrolysis, splitting water into hydrogen and oxygen using renewable energy sources (RES) such as wind or solar power. Green hydrogen is considered the most sustainable option, as it generates no greenhouse gas emissions.

On the other hand, there are other types of hydrogen, such as turquoise hydrogen generated with natural gas through methane pyrolysis with CCS; purple or pink hydrogen, produced through water electrolysis with nuclear energy; and brown hydrogen, produced from lignite through coal gasification. Figure 1 shows different hydrogen technologies from the most sustainable to the most polluting. This classification is related to the EU

Taxonomy [6], which categorizes various hydrogen production processes based on their degree of sustainability.

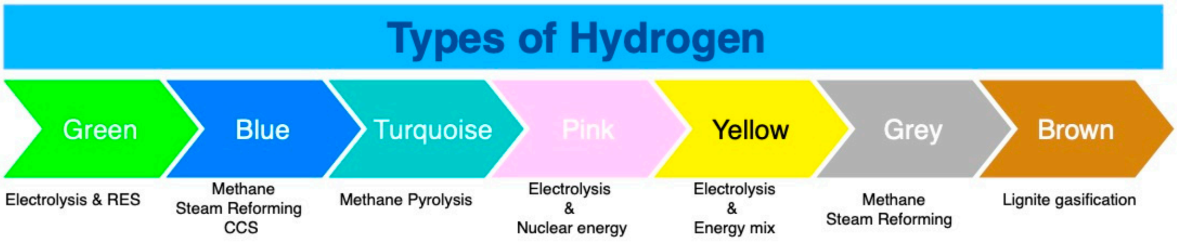


**Figure 1.** Hydrogen types (according to their production resources).

However, sustainability needs to be considered throughout the entire hydrogen value chain, graphically represented in Figure 2. This underscores the importance of not only considering hydrogen production but also accounting for all associated elements, including distribution, storage, compression, refueling, supply, and the consumption of Fuel Cell Electric Vehicles (FCEVs).

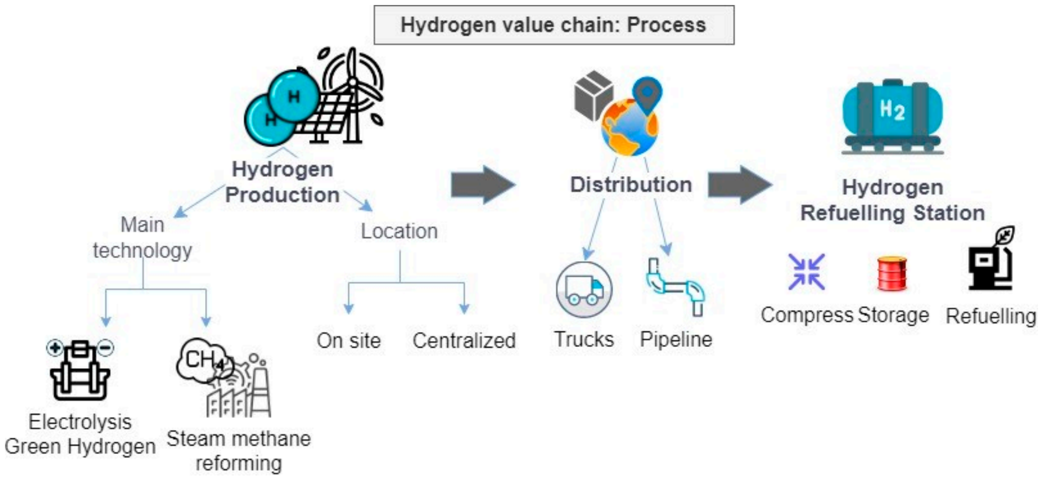


**Figure 2.** Hydrogen value chain for use in transportation.

Hence, the initial insight gleaned from the paper is that energy consumption and GHG emissions are intricately linked, not only to hydrogen production but also to all associated phases, including the distribution model, the location of hydrogen refueling stations, compression, storage, and refueling processes.

From a sustainability standpoint, the hydrogen value chain in transportation should consider specific ideal concepts or proposals:

- Hydrogen production can take place in two ways: through on-site plants connected to hydrogen refueling stations (HRS) or locations where hydrogen is needed, as well as large-scale production facilities linked to energy plant production.
- The distribution of hydrogen relies on various factors, including the infrastructure used, such as pipelines, trucks, freight trains, and marine transportation, as well as the initial and final delivery points (hydrogen network).
- Hydrogen consumption sites, which are frequently shown in refueling stations (HRS), need to specify the following characteristics: location, size, storage capacity and typology, compression technology, and refueling type and technique.

As for end-user devices (FCEVs), it is clear how important it is to recognize the current market position and trend. Therefore, we will now present our own global analysis (not solely focused on scientific publications) of the growth and commercialization of FCEVs.

Recently, fully functional FCEVs for both passenger and freight transport have appeared on the market, such as the Mercedes-Benz Gen H2 truck with 1000 km of autonomy [7] or the Hyundai Xcient fuel cell model with a transport range of 400 km for its 4 × 2 Tractor and 18-ton trailer [8]. Therefore, vehicle manufacturers (particularly heavy truck manufacturers) are slowly starting FCEV production with the aim of being able to mass produce when the institutions, users, and infrastructure are ready. For example, the Hyundai Hydrogen Mobility (HHM) program has launched a paid truck-as-you-go truck rental program in Switzerland that also includes hydrogen supply [9]. Based on the previously mentioned points, we can assert that the analysis of hydrogen implementation must be multifaceted and global in its approach. The fundamental pillars of hydrogen development in terms of supply, technology, and distribution are the end user and the accompanying location and consumption characteristics.

Figure 3 illustrates how end-user locations and demand are the primary determinants of HRS placement. As a result, HRS location takes precedence over associated infrastructure, distribution, and manufacturing.

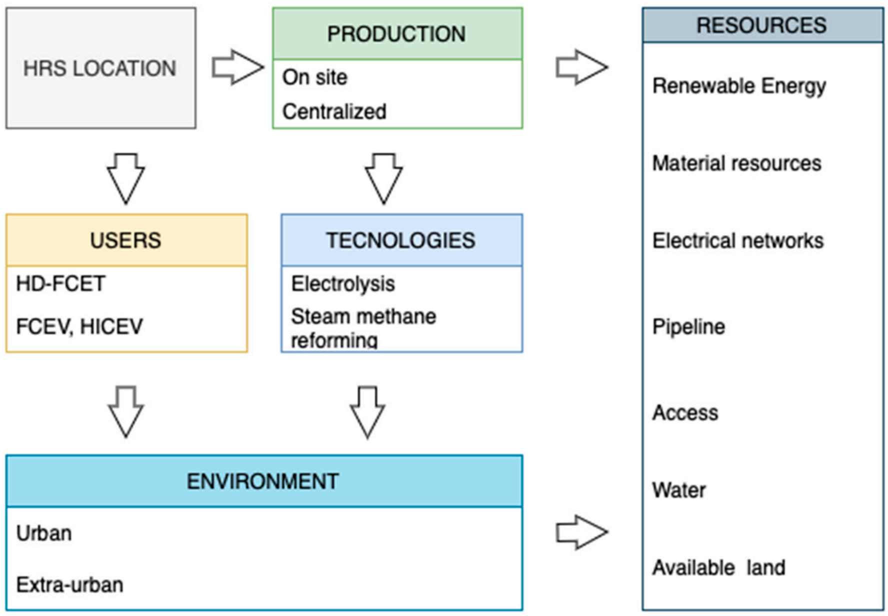


**Figure 3.** Hydrogen Refueling Station (HRS) location planning scheme.

Consequently, the purpose of this study is to examine the current state of the art regarding hydrogen refueling stations (HRS), one of the essential components of the required infrastructure. As a result, the authors analyze the technical articles that have been released up to this point on HRS site planning, green hydrogen, and related subjects, mostly in the EU.

## 3. Review Methodology

With an aim to accomplish a proper, state-of-the-art analysis of hydrogen infrastructure planning, both quantitative and qualitative results of the publications carried out should be obtained. Thus, a literature review with the Web of Science (WOS) database following the scheme Figure 3 proves to be essential.

The search process involved the use of various related keywords (such as hydrogen production, distribution, supply, compression, storage, or refueling) and their combinations, utilizing Boolean operators. This approach enabled the authors to obtain targeted results and conduct cluster analysis. Consequently, the primary conclusions of this review were derived from the most relevant publications.

### 3.1. Research Consultation

Initially, a comprehensive review of publications was undertaken to discern the impact of factors related to hydrogen infrastructure and the value chain. While the initial focus of the review was on the EU territory, a global assessment was subsequently conducted to encompass a broader perspective and to appreciate variations among different regions.

At the outset, a specific set of keywords was identified: (1) fuel (hydrogen); (2) end users (FCEV); (3) production technology (electrolysis); (4) supply infrastructure, HRS (refueling); (5) storage (hydrogen storage). Following this, these keywords were integrated with technical and energy criteria to derive the primary topics for the literature review, as illustrated in Figure 4. It is important to note that the literature review was conducted in July 2023.

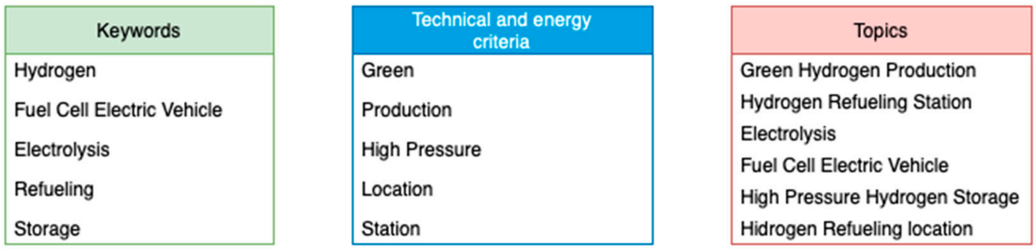


**Figure 4.** Topics obtained after combining keywords and technical and energy criteria.

In essence, the review aims to identify both knowledge gaps or potential research areas and to achieve a comprehensive understanding of the research landscape related to hydrogen refueling infrastructure, particularly in the EU.

### 3.2. Item Selection Process

The review was conducted in three sequential stages, supplemented by a thorough analysis of the results. In the initial stage, literature identification was performed based on the key topics outlined in Figure 4. Subsequently, a comprehensive review of literature impact was conducted, addressing the interconnected topics. Further refinement was achieved through topic clustering and focused searches in energy and transport journals. Finally, the authors conducted a comprehensive analysis of the most pertinent publications in the field. Next, we provide a detailed description of these four steps, including the analysis step.

Step 1. Keywords and Main Topics Review.

Initially, the number of publications came to a total of 214,001 in the last twenty years. The following numbers of results emerged from the main keywords: electrolysis (178,611 publications), production of green hydrogen (7115 publications), FCEV (19,650 publications), and HRS (669 publications); in addition, highly related topics were reviewed, such as plants for the production of green hydrogen (7115 publications) and HRS location (109 publications).

Step 2. Combination of Keywords and Technical and Energy Criteria.

The results were subsequently interconnected using the Boolean operator AND for a more focused search. This operator was applied by connecting 'Main Topic' AND 'Green Hydrogen Topic,' effectively combining keywords (main topics) with factors from the hydrogen value chain. In this phase, the primary focus of the search, specifically the location of hydrogen refueling, was also incorporated. Figure 4 shows how the themes were combined. The following were the different searching combinations:

TS = (green hydrogen production*) AND TS = (electrolysis*)
TS = (green hydrogen*) AND TS = (FCEV*)
TS = (green hydrogen*) AND TS = (hydrogen refueling*)
TS = (Hydrogen refueling location)
TS = (green hydrogen*) AND TS = (hydrogen refueling location*)

TS = (high pressure hydrogen storage*) AND TS = (hydrogen refueling location*)

Step 3. Refined Clusters of Interest and Combinations' Results

Due to the significantly high volume of results in the second stage, stemming from the combined topics search, the outcomes of the review were refined in this third stage. Specifically, the focus was narrowed to a cluster of energy, fuels, and transport journals, as depicted in Figure 5.

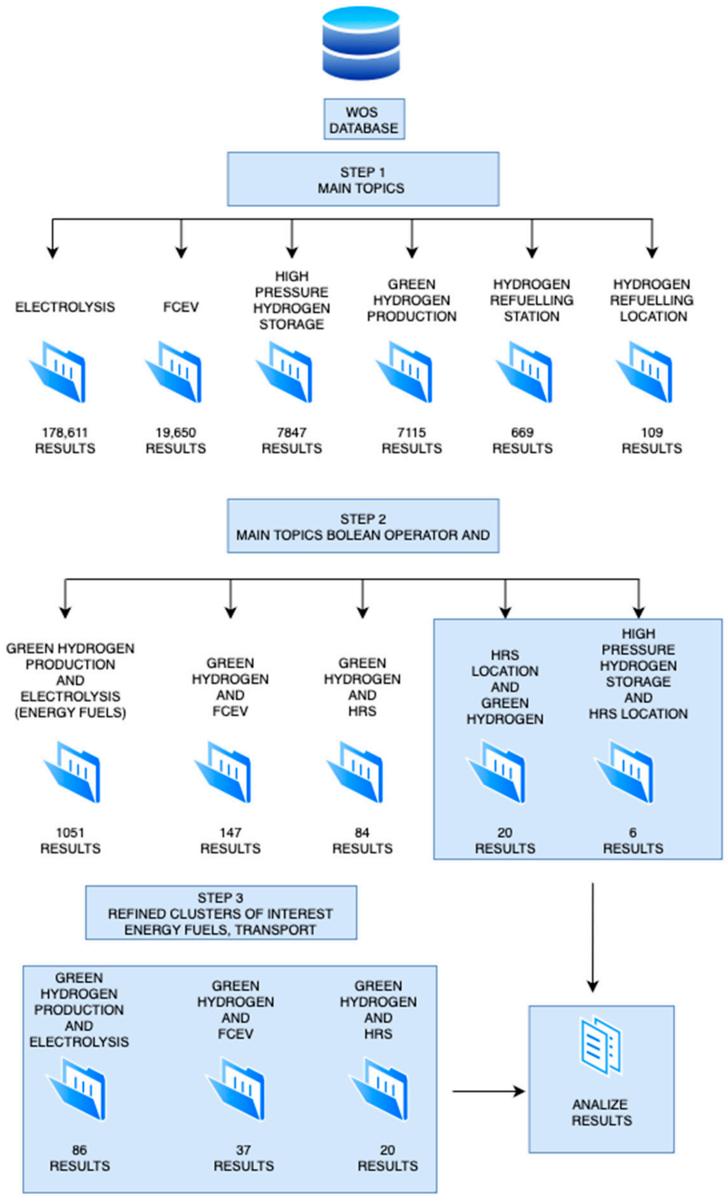


**Figure 5.** Searching result diagram.

In Table 2, the results of the paper search are presented. The first column displays the different combinations of topics, the second lists the clusters associated with them, and the third enumerates the number of documents found.

**Table 2.** Reviewed articles results. Data from WOS July 2023.

| Topic | Clusters | Analyzed |
|---|---|---|
| Green hydrogen production and electrolysis | Energy, fuels, and transport | 86 |
| Green hydrogen and FCEV | Energy, fuels, and transport | 37 |
| Green hydrogen and HRS | Energy, fuels, and transport | 20 |
| Green hydrogen and hydrogen refueling location | All articles | 20 |
| High pressure hydrogen storage and HRS location | All articles | 6 |

### *3.3. Results Analysis*

In the concluding step, a thorough analysis of the obtained articles was conducted, yielding a total of 74 reviewed articles, accounting for instances where some of the earlier searches resulted in duplicated articles.

For a better understanding of the entire methodology described above, the idea is presented graphically in Figure 6, the green rows depict the progress diagram of review methodology.

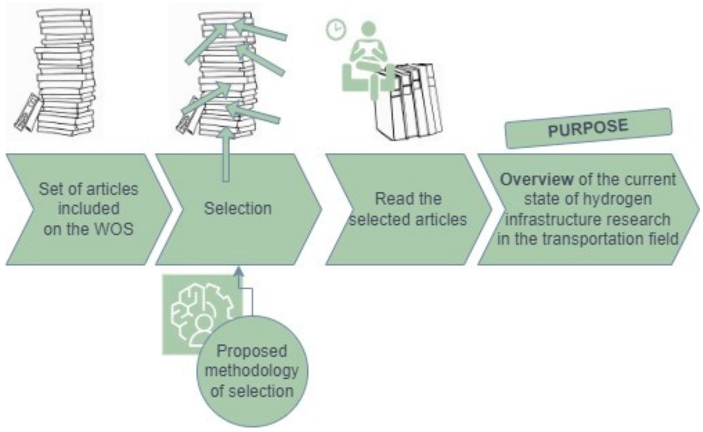


**Figure 6.** Proposed review methodology.

Therefore, as a preliminary analysis of these identified works, it is worth noting that there is a considerable amount of research on green hydrogen production, its core technology, and end-user devices (such as Fuel Cell Electric Vehicles, FCEVs). However, there is a noticeable gap in knowledge, indicating a potential for improvement in research, particularly concerning the location of Hydrogen Refueling Stations (HRS) and hydrogen storage. Essentially, there is a need for more research on the associated infrastructure of hydrogen supply.

## 4. Results Review

Related to the previous section, the authors considered that HRS, particularly their location, green hydrogen distribution, and storage therein, could likely be interesting for in-depth analysis. Therefore, this chapter aims to describe the main conclusions and objectives derived from the 74 articles most related to the review process developed.

The EU's 2025 zero emissions targets are set out in [3,5], but oil and gas companies need to be included through research and innovation investments to ensure proper delivery in the energy sector, as Hunt et al. emphasized [10]. Indeed, Spanish energy companies are presently undertaking substantial investments in various decarbonization projects centered around green hydrogen production, such as Naturgy [11], Repsol [12], Endesa [13], and Iberdrola [14].

As an alternative, Su et al. [15] introduces the possibility of using green methanol, made from green hydrogen, as another sustainable transportation fuel, similar to how it is used in many other applications, including powering internal engines.

Furthermore, numerous authors emphasize the decarbonization of transportation through green hydrogen, including works by Capurso et al. [16], Lebrouhi et al. [17], Gu et al. [18], Zhang et al. [19], Boudries [20], Park S. et al. [21], Tabandeh et al. [22], Zhou et al. [23], and Nugroho et al. [24]. This is because green hydrogen plays a pivotal role in advancing the energy transition and reducing greenhouse gas emissions.

A primary constraint in green hydrogen production lies in the limited availability of water resources. Consequently, various alternatives are proposed, including the use of seawater proposed by Haussmann et al. [25], or atmospheric water as proposed by Thimmappa et al. [26], which allows the electrical production stations to potentially be placed anywhere.

With the aim of evaluating the environmental and economic impacts of FCEVs, life cycle analysis (LCA) is compared between fossil fuel engines and hydrogen engines. In this regard, Iannuzi et al. [27] analyzed costs and emissions between FC and conventional buses in Rosario (Argentina), and Muñoz et al. [28] compared the emissions of diesel, natural gas, and FCEV city buses.

Lu et al. [29] studied the energy efficiency of FCEVs compared to conventional vehicles and concluded that green hydrogen is more efficient (21.9–29.2%) than conventional gasoline vehicles (CGVs) (14%) and still slightly more efficient than diesel vehicles (CDVs) is (23%); Additionally, FCEVs emit fewer greenhouse gases.

Caponi et al. [30] evaluated the levelized cost of hydrogen (LCOH) between (1) on-site hydrogen production at an HRS and (2) the delivery of hydrogen to an HRS. The results suggest that on-site LCOH production at the HRS is 35% lower than hydrogen supply. Ababneh et al. [31] assume that the cost of electric fuels depends on the cost of the power source. They also add that electricity prices influence the operational costs linked to on-site production. Hence, they conclude that green hydrogen production may emerge as a competitive option for extensive systems, particularly when aligned with affordable electricity prices.

In the context of feasibility studies and the potential benefits of increasing green hydrogen infrastructures in China, Gu et al. [18] identified the economic, energy, and environmental aspects of integrated green hydrogen supply networks. The authors delved into the economic implications, assessed the energy considerations, and explored the environmental impacts of such networks.

Furthermore, Wang et al. [32] focused on the necessary energy security planning, especially during notable events such as the 2022 Beijing Winter Olympics.

Finally, a further analysis was conducted by Li and Kimura [33], in which an economic feasibility study of FCEVs and hydrogen production was developed for the member states of the Association of Southeast Asian Nations (ASEAN). This study compared energy consumption, emissions, infrastructure costs, and FCEV investments against other alternative fuel vehicles, and included an economic feasibility study of FCEVs and hydrogen production. Their findings revealed that the adoption of FCEVs by users is more significantly influenced by the high costs associated with FCEVs than the cost of hydrogen as a fuel. The study emphasized the potential impact of policies supporting clean energy, as they can contribute to enhancing the competitiveness of FCEVs in the market. Furthermore, the research highlighted that emissions could be substantially reduced through the utilization of hydrogen produced from renewable energy sources.

In summary, the aforementioned studies underscore the significance of conducting feasibility studies, considering both the emerging challenges and potential benefits associated with the green hydrogen director plan. As a result, these findings are valuable for assessing infrastructure and policy investment strategies aimed at realizing sustainable and carbon-free transportation.

It is worth mentioning that comprehensive infrastructure planning is becoming crucial, especially given the location and size of Hydrogen Refueling Stations (HRS). Thus, Rose and Neumann [34] present an infrastructure location model and an energy optimization system model with the aim of connecting both systems (HRS and energy system), which is crucial for creating an efficient and effective network in which hydrogen production and distribution come together with FCEV demand.

In a similar manner to the previous studies, Crönert and Minner [35] formulated a location problem for hydrogen filling stations as a competitive model for location and allocation of flow capture. This approach can help identify optimal locations for HRS based on factors such as accessibility, demand, or competition. Other studies also used mathematical programming to determine the best locations to build alternative fuel stations. For example, Shukla et al. [36] developed a model that uses mathematical programming to determine the best locations for alternative gas stations, taking into account factors such as demand, cost, and accessibility. Such studies are important to optimize the location and allocation of fuel stations and ensure that the infrastructure is efficient and effective to meet the demand for environmentally friendly fuels.

Hence, the review results show the necessary research core of the hydrogen infrastructure plan with the aim of fulfilling a suitable green hydrogen supply network. Therefore, the following sections describe the outstanding studies of green hydrogen in transportation, both in freight and passenger transport, as well as in HRS planning.

### *4.1. Green Hydrogen*

Hydrogen, the most plentiful element in the universe, holds significant promise as a clean and sustainable energy source. The European Hydrogen Strategy seeks to champion the utilization of hydrogen as an energy carrier, particularly when derived from renewable sources. This initiative aims to curtail greenhouse gas emissions and play a pivotal role in the ongoing decarbonization of the energy sector.

As presented in the previous section, various processes currently exist for hydrogen production, each categorized by distinct colors, namely green, blue, turquoise, and grey hydrogen. One method involves steam methane reforming, utilizing natural gas as a feedstock. Although this is not classified as green hydrogen production, it can be deemed a clean technology if the ensuing carbon dioxide emissions are captured and stored, resulting in the creation of "Blue Hydrogen." The key is to ensure the use of renewable energy sources in the production process.

Many researchers have begun studying green hydrogen, such as Lagiola et al., who conducted a literature review focusing on the production methods of green and blue hydrogen to align with the European Union's decarbonization targets for 2030 [37]. Pruvost et al. not only explore green and blue hydrogen but also identify turquoise hydrogen as a promising technology for hydrogen production, particularly when the by-product (pure carbon in a solid state) is valorized [38]. Hermesmann and Müller [39] assess the level of development in hydrogen production by evaluating various production technologies, including grey, turquoise, blue, and green. Notably, steam methane reforming (SMR) has the highest environmental impact. On the other hand, Proton Exchange Membrane (PEM) is identified as a promising solution for minimizing the overall environmental impact in hydrogen production, although it necessitates a substantial proportion of Renewable Energy Sources (RES). This perspective is also explored by Ajanovic et al. [40], who assert that only green hydrogen achieves genuinely low greenhouse gas emissions. Mohideen et al. [41] conducted a comparison of various hydrogen production methods to investigate the Life Cycle Assessment (LCA) of hydrogen. Their findings indicate that grey hydrogen is the most cost-effective, with green hydrogen being twice as expensive as blue hydrogen. Additionally, the authors highlight that the main obstacle to expanding the use of Fuel Cell Electric Vehicles (FCEV) is the location of Hydrogen Refueling Stations (HRS), primarily due to insufficient refueling infrastructure.

Currently, the majority of hydrogen is derived from fossil fuels, resulting in greenhouse gas emissions and contributing to climate change. However, there are more sustainable methods of hydrogen production, such as electrolysis of water using Renewable Energy Sources (RES). Hydrogen produced through RES-powered electrolysis is termed 'Green Hydrogen'. In recent years, there has been a growing interest in both the production and application of green hydrogen, driven by its potential to decrease greenhouse gas emissions and contribute to the transition towards a more sustainable energy system. In this sense, Figure 6, which depicts the changing number of articles published in the Web of Science (WOS) database, provides a clear indicator of the growing trend. As can be seen from Figure 7, the number of articles related to green hydrogen has been increasing steadily over the past decade, with a significant uptick in the last few years. Overall, the trend towards greater interest in green hydrogen is a positive development, as it suggests that there is growing recognition of the need to transition towards a more sustainable energy system, and that hydrogen can play an important role in this transition.

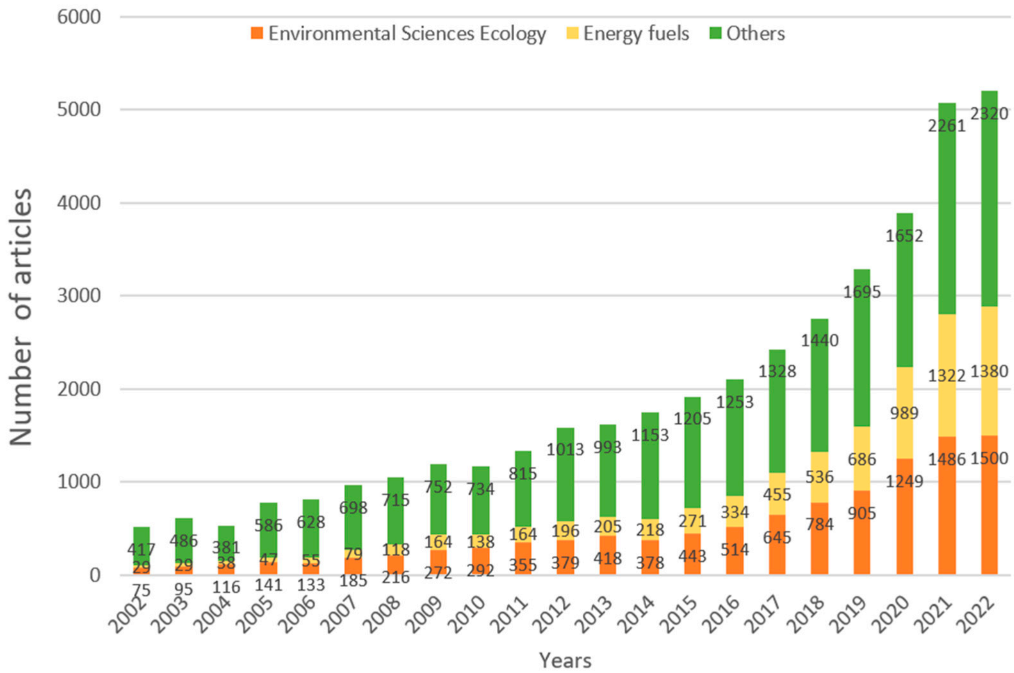


**Figure 7.** Number of articles found per year, topic "Green Hydrogen". Source WOS database.

In addition, Table 3 presents a comparative analysis of the consumption and efficiency of the main electrolysis technologies. Those technologies are the following: (1) Proton Exchange Membrane (PEM): This technology uses a solid polymer electrolyte membrane to separate the hydrogen and oxygen gases. PEM electrolysis is suitable for small-scale applications, such as residential or automotive use, as it has a low operating temperature and can respond quickly to changes in electrical demand. (2) Alkaline Electrolysis (AEL): This technology uses a liquid alkaline electrolyte (typically potassium or sodium hydroxide) to conduct the electricity and separate the hydrogen and oxygen gases. AEL has been used for several decades and is well-established, with relatively low capital costs and high efficiency. It is suitable for large-scale industrial applications. (3) Anionic Exchange Membrane (AEM): This technology is similar to PEM electrolysis but uses a solid anion exchange membrane instead of a proton exchange membrane. AEM has the potential to be more efficient than PEM, as it can operate at higher current densities, but is still in the development stage. (4) Solid Oxide Electrolysis (SOE): This technology uses a solid oxide ceramic electrolyte to separate the hydrogen and oxygen gases. SOE has the potential to be highly efficient, as it can operate at high temperatures and utilize waste heat from other industrial processes. However, SOE is still in the development stage and has high costs due to the premature wear of materials subjected to high temperatures. In order to obtain best results of durability and performance, Nechache and Hody investigated this topic; the main objective of the study was to examine the progress of next-generation materials in achieving durability goals and reducing electrode degradation during long-term operation at high current densities [42].

The challenge lies in identifying the optimal method and materials for water electrolysis, a topic explored by various authors including Liu et al. [43], Stiber et al. [44], Park, E. et al. [45], and Teuku et al. [46]. Panah et al. [47] used an economic analysis to compare AEL, PEM, and SOE electrolysis using the Danish electricity market.

**Table 3.** Comparative between electrolysis technologies. Data from MHydrogen [48].

| Technology | Units | PEM | AEL | AEM | SOE |
|---|---|---|---|---|---|
| Producer | | Siemens | ThissenKrupp | MHydrogen | MHydrogen |
| Rated Elect Power | | 6 MW | 20 MW | 10 MW | 10 MW |
| H2-Production Rate | $Nm^3/h$ | 1200 | 4000 | 2086 | 3077 |
| H2-Production Rate | kg/h | 108 | 360 | 188 | 277 |
| Spec. Electrical Consumption | $KWh/Nm^3$ | 5.0 | 5.0 | 4.8 | 3.3 |
| Spec. Electrical Consumption | KWh/kg | 55.6 | 55.6 | 53.3 | 36.2 |
| Minimum Operation load | % | 3 | 45 | 3 | 5 |
| Electrolyzer Efficiency | % | 60 | 60 | 63 | 93 |

To identify the optimal electrolysis technology, various factors must be considered, including the specific application, scale, efficiency, and cost. Achieving efficient hydrogen production requires the implementation of processes that guarantee effectiveness. A crucial aspect is understanding the minimum operational load of the electrolyzer to ensure maximum efficiency. This knowledge becomes particularly important when determining the duration of hydrogen production, especially in cases where reliance on substantial renewable energy, particularly solar power, is in place. Given the solar-dependent nature of this energy source, it is reasonable to anticipate that operational load will align with increased solar exposure. This consideration should inform the design of Hydrogen Refueling Stations (HRS) and the overall hydrogen production process, with the aim of mitigating infrastructure costs associated with hydrogen production equipment, storage, and renewable energy generators. In this regard, it is worth mentioning that it is possible to produce green hydrogen using different RES such as wind, solar, or hydropower. The literature review highlights the challenge of integrating hydrogen production into the national energy mix, as discussed by Nastasi and Lo Basso [49] and Capurso et al. [16]. On the contrary, other authors emphasize the positive impact of green hydrogen storage in balancing renewable energy systems. This contributes to aligning the supply and demand of energy, particularly in the face of variability in renewable energy sources, as discussed by Ajanovic et al. [40], Cloete et al. [50], and Jang et al. [51].

Simultaneously, green hydrogen assumes a pivotal role as both a fuel and an energy storage medium, as highlighted by Capurso et al. [16]. This contribution is integral to the overall energy transition, as emphasized by Lebrouhi et al. [17] and Aprea et al. [52], while also aiding in the reduction of greenhouse gas emissions.

Awaleh et al. [53], conducted a comparison of green hydrogen production using wind power and geothermal energy in Djibouti. Their findings indicate that producing hydrogen with wind power is the most cost-effective option. Additionally, they assert that the cost of electro-fuels is contingent upon the cost of the electricity source.

Ibraim et al. [54] explore the production of green hydrogen through offshore wind farms in deep waters, leveraging their high capacity for wind power production. The study considers two approaches: electric energy transmission and onshore electrolysis, as well as offshore electrolysis with a hydrogen pipeline. The utilization of renewable energy sources in hydrogen production not only reduces costs but also lowers $CO_2$ emissions, a viewpoint supported by various authors, including Zhang et al. [19].

The European Union (EU) has set ambitious targets to achieve 32% renewable energy in the electricity sector by 2030. This substantial increase in renewable energy capacity is poised to provide a stable and sustainable source for electricity generation through the electrolysis process, facilitating the production of green hydrogen. However, to unlock the full potential of green hydrogen, it becomes imperative to localize its production, leveraging on-site renewable energy sources whenever feasible. This approach not only minimizes the impact on the electrical system but also ensures a dependable supply of hydrogen for local industries and transportation. Furthermore, the utilization of green hydrogen holds promise in contributing to the broader decarbonization efforts, particularly in sectors like heating and industry, where it can replace fossil fuels as a clean energy alternative. Such a transition is pivotal in advancing the EU's overarching goal of achieving net-zero greenhouse gas emissions by 2050.

The study by Shiva and Lim [55] is a comprehensive overview of water electrolysis technologies for green hydrogen production. They found that proton exchange membrane (PEM) technology has some advantages over alkaline (AEL) and anionic exchange membrane (AEM) technologies, but the main challenge with PEM technology is the high cost of materials required for its construction. On the other hand, the study found that sodium oxide (SOE) technology has the highest efficiency, with an efficiency rate of 93%. However, the main disadvantage of SOE technology is the high operating temperature range required for its operation, which is typically between 700 and 850 °C. This high temperature range can lead to reduced durability of components and may require additional cooling measures, which can add to the overall cost of the system. Despite the challenges associated with each technology, the study concludes that water electrolysis is a promising method for producing green hydrogen, and that continued research and development is needed to optimize the efficiency and reduce the cost of the various electrolysis technologies.

More efficient methods and materials that reduce the production costs of green hydrogen are currently being developed. The use of green hydrogen to generate electricity in FCEVs should not only make ecological and ecological sense, but also have a direct impact on costs. Hydrogen production and the exploitation of HRS in regions with the greatest renewable energy potential reduces costs. These data are confirmed by the International Renewable Energy Agency (IRENA) [1].

The study by Wolff et al. [56] highlights the importance of using green hydrogen in Fuel Cell Electric Vehicles (FCEVs) to reduce the environmental impact of transportation. The study found that operating battery electric vehicles (BEVs) with the current mix of electricity production has a higher environmental impact than diesel vehicles. However, operating FCEVs with green hydrogen produced from renewable energy sources significantly reduces the environmental impact of transportation.

The study by Sheng et al. [57] compares the greenhouse gas emissions associated with different types of electric vehicles (EVs) in New Zealand. The study found that BEVs have the lowest greenhouse gas emissions, emitting 90% less GHGs than conventional vehicles and 40% less GHGs than FCEVs. However, as more green hydrogen is produced, FCEVs are becoming a more viable option, with the second-lowest greenhouse gas emissions among EVs. Pasini et al. [58] conducted an analysis of current and future technologies for e-fuels. They contend that if electricity production is not completely decarbonized, it could result in higher emissions than those produced by fossil fuels.

Table 4 underscores the significance of green hydrogen in the transportation sector, a point emphasized by the authors in their respective conclusions. The studies consistently indicate that the environmental impact diminishes when renewable energies are employed in hydrogen production. The table includes key findings from various authors.

**Table 4.** Featured search results. Data from Web of Science (WOC).

| Authors | Title | Abstract |
|---|---|---|
| Wolff, S. et al. [56] | Multi-disciplinary design optimization of life cycle eco-efficiency for heavy-duty vehicles using a genetic algorithm | With the current electricity mix, the environmental impact of Battery Electric Vehicles (BEVs) is 313% higher than that of diesel. Nevertheless, as the proportion of renewable energy in the mix rises, the performance of battery electric vehicles surpasses that of diesel, showing a notable improvement of −65%. Furthermore, employing green hydrogen to operate fuel cells contributes to a reduction in environmental impact by −27%. |
| Sheng, M. et al. [57] | Well-to-Wheel analysis of greenhouse gas emissions and energy consumption for electric vehicles: A comparative study in Oceania | Fuel Cell Electric Vehicles (FCEVs) become a fundamental pillar of "green hydrogen" production promotion with the emissions decreasing goal. |
| Capurso, T. et al. [16] | Perspective of the role of hydrogen in the 21st century energy transition | This study underscores the potential sustainability of hydrogen when produced through electrolysis powered by renewable energies. However, it also highlights that, in the realm of mobility, the current efficiency of fuel cells is eclipsed by the adoption of Li-ion batteries. |
| Muñoz P. et al. [28] | Comparative analysis of cost, emissions and fuel consumption of diesel, natural gas, electric and hydrogen urban buses | The transition of the entire urban bus fleet in Argentina to zero-emission technologies is anticipated to yield benefits in terms of energy consumption, environmental emissions, and the economy. If the transition involves adopting Hydrogen fuel cell buses for the entire fleet, it has the potential to reduce approximately 1.3 million tons of carbon dioxide equivalent emissions. |
| Pasini, Gianluca et al. [58] | Renewable Electricity for Decarbonization of Road Transport: Batteries or E-Fuels? | E-fuels demand 3–5 times more input energy and result in 3–5 times higher equivalent vehicle $CO_2$ emissions when the electricity used is not completely decarbonized. |

The comprehensive review conducted by Panchenko et al. [59] offers insights into the future outlook of the hydrogen industry, encompassing strategic planning for diverse hydrogen production technologies and their applications across different regions. The authors emphasize that countries are actively formulating hydrogen roadmaps, recognizing the strategic and economic significance of the industry in domains such as electricity production and transportation. While the review acknowledges the maturity of hydrogen production technologies, it underscores the industry's primary challenge—cost reduction to enhance economic viability. Despite this hurdle, there is a burgeoning interest in hydrogen as an energy source, particularly in regions with abundant photovoltaic potential. Establishing a hydrogen economy in these areas holds the promise of reducing reliance on fossil fuels and enhancing overall economic sustainability. The review underscores the potential of hydrogen as a clean and sustainable energy source, underscoring the ongoing imperative for continued research and development efforts. These endeavors aim to enhance the cost-effectiveness and scalability of hydrogen, paving the way for its widespread adoption.

The utilization of renewable energy in electricity production serves to prevent the surpassing of electricity transmission line capacities and contributes to cost reduction. The development of renewable generators has reached a commendable stage, with photovoltaic systems and onshore as well as offshore wind farms emerging as the primary renewable energy production technologies within the EU territory. This leads to the consideration that the principal challenge lies in strategically planning and effectively distributing infrastructure, particularly Hydrogen Refueling Stations (HRS), across the territory.

Given that HRS is a pivotal infrastructure for the application of hydrogen in transportation and is currently underdeveloped, the ensuing section will delve into the existing literature on this topic.

*4.2. Hydrogen Refueling Station (HRS)*

The requirement for the HRS location is mainly the capture of vehicle flow in a growing market. At the same time, increasing the number of HRS will increase the degree of penetration in the FCEV market. Consequently, there is an initial need to devise a methodology for identifying areas with the highest likelihood of FCEV introduction. To facilitate the strategic implementation of this infrastructure, the Italian Recovery and Resilience Plan advocates for the development of refueling stations catering to freight transport, anticipating a 5–7% penetration rate, as outlined by Gallo et al. [60]. The authors argue that the impact of this initiative could potentially lead to a reduction of approximately 9 to 16,5 tons of $CO_2$.

As shown in Figure 8, it is interesting to note that there has been a significant increase in the number of studies on hydrogen refueling in the last 20 years, particularly since 2017. This reflects the growing interest and importance of hydrogen as a fuel source, and the need for research and development in the area of hydrogen infrastructure and refueling technologies. It also highlights the increasing recognition of hydrogen as a key component of a low-carbon energy system, and the need to establish a reliable and efficient hydrogen supply chain to support the deployment of fuel cell vehicles and other hydrogen-based applications.

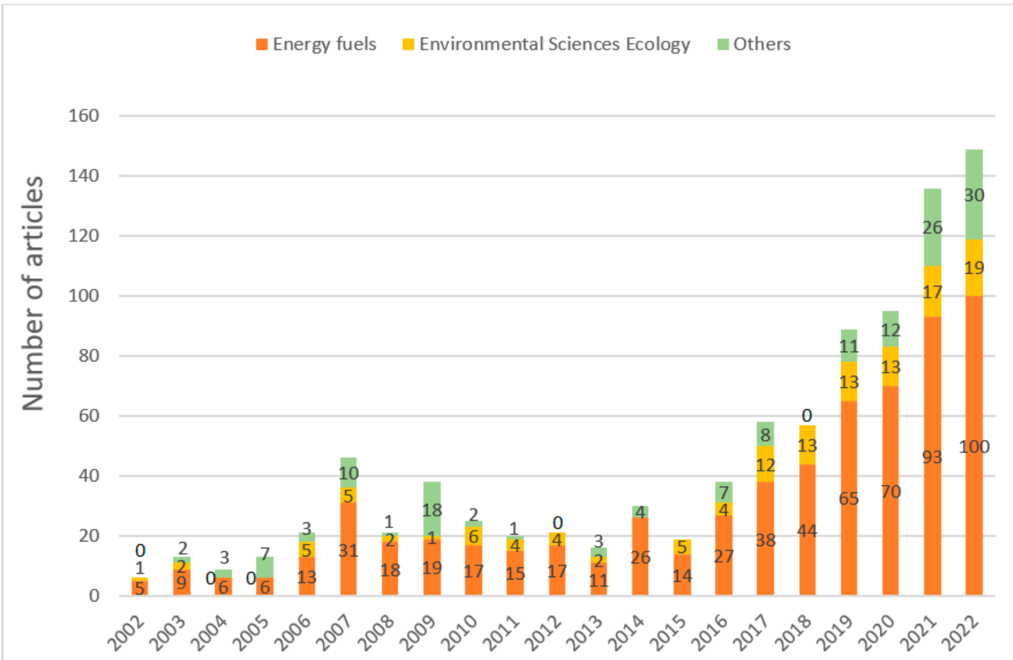


**Figure 8.** Number of articles found per year, topic "HRS". Source from WOS database.

The EU's photovoltaic potential provides the opportunity to use renewable energy sources to produce and refuel hydrogen. In regions of Europe with low photovoltaic potential, other renewable energy sources are used. For example, studies such as the one published by Kavadias et al. [61] highlight the importance of considering the demand for Fuel Cell Electric Vehicles (FCEVs) and the infrastructure needed to support them when planning for hydrogen production from renewable energy sources. They conducted a case study to investigate the economic feasibility of producing hydrogen from surplus energy generated by a wind farm for a Hydrogen Refueling Station (HRS) and for the storage of excess energy. The study found that in scenarios with low penetration of FCEVs, the economic profitability of such a system is low.

Viesi et al. [62] described the methodology and the main scenarios in terms of hydrogen mobility, Mobility Hydrogen Italy (MH2IT), the sizing of the FCEV fleet, and hydrogen demand in HRS.

The successful integration of Hydrogen Refueling Stations (HRS) with green hydrogen production requires an optimal design and sizing of the infrastructure. In the context of determining the Levelized Hydrogen Cost (LHC), El Manaa Barhoumi et al. [63] conducted a study focusing on its application in Oman. The research explores three methods for implementing a photovoltaic (PV) system to produce hydrogen: a PV grid-connected system, a stand-alone system with batteries, and a stand-alone PV system with fuel cells, all centered around Green Hydrogen Refueling Stations. The study employs HOMER software (https://www.homerenergy.com) to assess the cost of energy and determine the most viable technical solutions.

Zhang C et al. [19] investigate the influence on hydrogen refueling in electric systems under various assumptions of sizing and flexibility to obtain hydrogen through electrolysis. They concluded that the flexibility of electrolysis reduces the cost and helps to stabilize the energetic network.

The hydrogen supply standards for light vehicles necessitate a pressure of 700 bar, while heavy vehicles such as buses and trucks require 350 bar. Achieving these standards involves elevating the pressure of produced hydrogen and storing it at high pressure. Subsequently, vehicles are refueled following the SAE refueling protocols [64].

The current technology allows for the elevation of hydrogen pressure to 1000 bar. The high working pressures required in Hydrogen Refueling Stations (HRS) necessitate storage in Type IV tube bundles, specifically designed for such pressures. The purity of hydrogen is crucial for its transformation into electricity through Fuel Cells (FC). Initially, compressors were made with membranes to prevent hydrogen contamination; however, newer dry-piston compressors now effectively prevent such contamination [65]. To ensure a sustainable refueling process, the compression of hydrogen at the necessary working pressures will require energy from renewable sources. In the context of hydrogen refueling, considerations such as costs, demand, flow capture, and location play a prominent role.

In their study, Park S. et al. [21] examined consumer preferences regarding Hydrogen Refueling Stations (HRS), taking into account production methods, the likelihood of refueling failure, and associated costs. The findings revealed that, following price, supply stability emerged as the second most crucial attribute. Security was identified as a key stakeholder requirement. Tanaka et al. [66] conducted a study to identify the hazardous area within a hydrogen storage and dispenser site (HRS), along with determining the tolerable limit for hydrogen concentration. In a separate study, Serdaroglu et al. [67] investigated the impact of temperature on pressure tanks to establish an optimal design that factors in environmental conditions. These considerations are integral to the overall design of Hydrogen Refueling Stations (HRS). In conclusion, addressing these factors is crucial for ensuring the safety and efficiency of HRS installations.

Another critical consideration is the positioning of Hydrogen Refueling Stations (HRS). Thabandeh et al. [23] advocate for a comprehensive approach to expansion planning for green hydrogen, encompassing the integration of HRS, Renewable Energy Sources (RES), and power distribution networks. They have presented a coordinated plan for investing in these infrastructures and put forth a mathematical framework to aid system operators in decision-making. This framework facilitates the modeling of photovoltaic (PV) systems and green HRS to enhance strategic decision support. Simunovic et al. [68] examined the capacity and location of Hydrogen Refueling Stations (HRS) based on their intended uses. Their study delved into various configurations for siting hydrogen production, utilizing the available energy sources within an existing wind farm, and the subsequent placement of HRS. The study concluded that determining the optimal configuration remains challenging until potential users are identified. To address this, the authors proposed a sizing method that considers the worst-case scenario—factoring in the maximum demand for hydrogen, minimum electricity production in the wind farm, and the development of an algorithm to model stochastic hourly load profiles. Zhou et al. [24] assert that the location of Hydrogen Refueling Stations (HRS) significantly influences costs, operational modes, services, and profits, underscoring its utmost importance. In response to this, they introduced a model for location optimization based on Geographic Information System (GIS).

Hernandez et al. [69] proposed a mathematical model to guide the planning of the hydrogen infrastructure for long-distance travel using a GIS to determine the location and optimal number of HRS, comparing sources of hydrogen production. This study is a case analysis conducted in the coastal region on the west coast of the United States.

Greene et al. [70] conducted a review focusing on the challenges associated with designing and planning the deployment of essential infrastructure. Their assessment includes a comparative analysis of factors such as cost, demand, and distance. The study proposes location methods employing a p-median model.

Nugroho et al. [24] keep in mind that for the HDFC-HRS network it is necessary to determine the optimal location, determine the cost of infrastructure and determine the most efficient method of producing green hydrogen.

HRS, in combination with green hydrogen production, needs an optimum design and sizing appropriate to the infrastructure in order to determine the Levelized Cost Analysis (LCA).

Chen et al. [71] use an LCA to assess the feasibility of using hydrogen for FCEVs on four possible supply routes in Shanghai, they considered both on-site renewable energy production and off-site hydrogen production. Caponi et al. [30] examined the Levelized Cost of Hydrogen (LCOH) in various large-scale applications, considering different case studies involving hydrogen production at Hydrogen Refueling Station (HRS) locations and hydrogen supply to HRS. The study concludes that on-site hydrogen production could be a viable solution, especially in scenarios with low electricity prices.

Bethoux et al. [72] focused on FCEV, highlighting the necessary advances for its implantation and the infrastructure necessary for achieving a large-scale use of hydrogen in transport.

Ogden et al. [73] conducted a literature review to suggest the use of natural gas (NG) as a transitional means for transporting hydrogen. The transportation of hydrogen via pipelines, in a partial to total volume, is already a practical reality. In a separate study, Nakayama et al. [74] concentrated on a qualitative risk analysis of hydrogen pipelines. They identified potential risk scenarios and scrutinized effective safety measures.

All these studies suggest that the development of HRS infrastructure should prioritize sustainability, reliability, security, and affordability.

In the United States, regulatory institutions like the California Air Resources Board (CARB) play a crucial role in safeguarding the public from the adverse effects of air pollution and spearheading initiatives to combat climate change. Among these efforts, the California Hydrogen Infrastructure Tool (CHIT) stands out as a web-based mapping tool designed to aid in pinpointing optimal locations for hydrogen refueling stations (HRS) in California. The tool encompasses data on both existing and planned HRS, along with the locations of hydrogen production facilities, existing and planned hydrogen pipelines, and the potential demand for hydrogen fuel cell vehicles across various regions of the state. The CHIT tool empowers users to explore diverse scenarios for HRS deployment in California, enabling the evaluation of costs and benefits associated with different strategies for expanding the state's hydrogen infrastructure. Its primary objective is to support California's ambitious goal of establishing a network of 1000 HRS by 2030, thereby facilitating the commercialization of fuel cell vehicles. [75].

In Spain, the hydrogen road map, published in March 2021 by the Spanish Ministry for the Ecological Transition and the Demographic Challenge, underscores heavy vehicle transportation as a pivotal sector for the widespread adoption of hydrogen as a fuel. The roadmap delineates key focus areas, including the promotion of green hydrogen production through renewable energy sources, the establishment of a network of hydrogen refueling stations for fuel cell vehicles, and the encouragement of hydrogen utilization in industrial processes. The plan encompasses substantial investments in research and development, measures to attract private investments, and initiatives to foster international cooperation in hydrogen technology. Various initiatives have been implemented to integrate hydrogen buses, such as those by ALSA in the community of Madrid, or the Metropolitan Transport of Barcelona (TMB), along with the construction of an HRS and a green hydrogen production plant in this city. Moreover, the Hydrogen Roadmap of Spain includes specific legislation for the construction of hydrogen refueling stations (HRS) and provides incentives for the acquisition of hydrogen-powered vehicles and the implementation of necessary infrastructure in vehicle fleets. It also supports the automotive industry in producing Fuel Cell Electric Vehicles (FCEV). The roadmap equates the construction of HRS to traditional service stations and includes the construction of HRS in the c, which is a program that promotes sustainable mobility in Spain. These measures aim to encourage the consumption of renewable hydrogen and promote the development of a hydrogen economy in Spain. These promote the use of renewable hydrogen in different sectors, such as transport, industry, and energy. The strategy aims to install a renewable hydrogen production capacity of 4 GW by 2030, with an investment of 8.9 billion euros. Additionally, it envisions the establishment of a regulatory framework to facilitate industry development, the promotion of research and development, and the fostering of public–private partnerships to propel the sector forward [3].

The studies addressing Hydrogen Refueling Station (HRS) implementation are presented in Table 5. In the Spanish context, these studies concentrate on urban environments. Brey J. et al. introduced an optimization model to strategically plan the deployment of HRS in urban settings [76], examining consumer preferences regarding HRS design [77]. Elsewhere, Ala G. et al. scrutinized future strategies for implementing Fuel Cell Electric Vehicles (FCEV) in Portugal [78].

**Table 5.** Outstanding search results. Hydrogen Refueling Station location data from Web of Science (WOC).

| Authors | Title | Abstract |
|---|---|---|
| Rose and Neumann [34] | Hydrogen refueling station networks for heavy-duty vehicles in future power systems | This paper delves into the interplay between Heavy-Duty Vehicle (HDV) Hydrogen Refueling Stations (HRS) that locally produce hydrogen and the power system. It achieves this by combining an infrastructure location planning model with an electricity system optimization model |
| Cröeert and Minner [35] | Location selection for hydrogen fuel stations under emerging provider competition | They formulate a location problem for hydrogen fuel stations as a competitive model for location and flow capture assignment. |
| Shukla et al. [36] | An optimization framework for cost effective design of refueling station infrastructure for alternative fuel vehicles | This study employs mathematical programming to identify optimal locations for establishing alternative transportation fuel stations. The primary objective is to position refueling stations in a way that maximizes the number of vehicles served while adhering to budget constraints. |
| Kavadias et al. [61] | Sizing, Optimization, and Financial Analysis of a Green Hydrogen Refueling Station in Remote Regions | Fuel Cell Electric Vehicles (FCEVs) have the potential to mitigate air pollution and diminish greenhouse gas emissions, particularly when hydrogen (H2) production is sourced from Renewable Energy Sources. This positive impact is further amplified when coupled with a widespread network of Hydrogen Refueling Stations (HRSs), enhancing accessibility and adoption. |
| Viesi et al. [62] | The Italian hydrogen mobility scenario implementing the European directive on alternative fuels infrastructure (DAFI 2014/94/EU) | A significant milestone in the context of alternative fuels infrastructure in the European Union is the DAFI Directive 2014/94/EU. In the realm of hydrogen mobility, this paper outlines the methodology and key findings of the Scenario MobilitàH2IT. |

**Table 5.** *Cont.*

| Authors | Title | Abstract |
|---|---|---|
| Park, S. et al. [21] | Preference Structure on the Design of Hydrogen Refueling Stations to Activate Energy Transition | This study conducts an analysis and presents a consumer preference structure for hydrogen refueling stations. The assessment considers factors such as the production method, distance, the likelihood of not refueling, the number of dispensers, and fuel costs as the primary attributes. |
| Hernandez, B. et al. [69] | Mathematical Model for the Placement of Hydrogen Refueling Stations to Support Future Fuel Cell Trucks | This document introduces a mathematical model designed to inform the planning of hydrogen infrastructure, particularly in support of future long-term Fuel Cell Technologies (FCTs). |
| Greene, D. et al. [70] | Challenges in the designing, planning and deployment of hydrogen refueling infrastructure for Fuel Cell Electric Vehicles | This paper provides a thorough review of the challenges associated with designing, planning, and deploying hydrogen refueling infrastructure. It assesses progress to date and offers insights into future prospects. |

Additionally, a search was conducted to identify the current number and locations of existing Hydrogen Refueling Stations (HRS). This was done to ascertain the level of implementation of this infrastructure. Currently the implantation of HRS is scarce. According to the latest data from the H2Stations [79], there were 814 operational hydrogen refueling stations worldwide at the end of 2022, with the majority located in Asia and Europe. Most of these correspond to fleets of vehicles and urban passenger transport. Among the HRS, there are 7 in Spain, and 15 more are planned to be developed in the near future. Due to the investment necessary for HRS and the shortage of commercialized vehicles, the majority of the existing HRS are indeed used to refuel fleets of short-distance freight vehicles and public service vehicles, such as buses or taxis, as well as for personal use by owners of FCEVs. This is because these types of vehicles are well-suited to the current limitations of FCEV technology, such as their limited driving range compared to traditional gasoline-powered vehicles. However, there are ongoing efforts to expand the use of FCEVs to other types of vehicles, such as long-haul trucks and trains. Erdogan and Millery formulate the problem of refueling vehicles using alternative fuels and develop solution techniques to help organizations with fleets of alternative fuel vehicles [80].

From the analysis of the results according to the methodology given in Section 3, the works related to the final goal of the search, the location of the HRS, are selected. Table 5 shows a selection of the search results for green hydrogen and hydrogen refueling location.

Furthermore, Table 6 shows the results on the Iberian Peninsula. Based on these publications, the authors assert that Hydrogen Refueling Stations (HRS) emerge as the primary infrastructure for hydrogen utilization in transportation, although their current state of development is suboptimal. Conversely, hydrogen production techniques are deemed well-established.

**Table 6.** Hydrogen refueling station (Iberian Peninsula) data from Web of Science (WOC).

| Authors | Title | Abstract |
|---|---|---|
| Brey, J. et al. [76] | Incorporating refueling behavior and drivers' preferences in the design of alternative fuels infrastructure in a city | The aim of this article is to introduce an optimization model designed for planning the deployment strategy of hydrogen refueling stations in a city where Origin-Destination (OD) data is unavailable. The model is dual-objective, seeking to maximize the coverage of traffic by the selected hydrogen refueling stations while simultaneously minimizing the average distance of the city's inhabitants to the nearest hydrogen refueling station. |

**Table 6.** *Cont.*

| Authors | Title | Abstract |
| --- | --- | --- |
| Brey, J. et al. [77] | Eliciting preferences on the design of hydrogen refueling infrastructure | This paper investigates consumer preferences concerning the design of urban hydrogen refueling infrastructure. The study utilizes survey results obtained in Andalusia to analyze and draw insights into consumer attitudes and choices related to hydrogen refueling in urban areas. |
| Ala, G. et al. [78] | Electric Mobility in Portugal: Current Situation and Forecasts for Fuel Cell Vehicles | This paper offers an overview of the present status of electric mobility in Portugal, outlining the strategies implemented by the country. The objective of this work is to explore the future prospects of Fuel Cell Electric Vehicles (FCEVs) in Portugal, employing a dynamic model known as SERA (Scenario Evaluation and Regionalization Analysis. |
| Cardona et al. [81] | Model predictive control of an on-site green hydrogen production and refueling station | This article outlines the layout and specifications for a Hydrogen Refueling Station (HRS) in the case study of Zaragoza (Spain). |

Additionally, Table 7 compiles noteworthy articles that make significant contributions to the field of hydrogen transport. However, these contributions do not align with the themes covered in the preceding tables.

**Table 7.** Other reviewed articles data from Web of Science (WOC).

| Authors | Title | Abstract |
| --- | --- | --- |
| Hosseini and Waid [82] | Hydrogen production from renewable and sustainable energy resources: Promising green energy carrier for clean development | This article offers an overview of state-of-the-art hydrogen production technologies that utilize renewable and sustainable energy resources. |
| Çabukoglu et al. [83] | Fuel cell electric vehicles: An option to decarbonize heavy-duty transport? Results from a Swiss case-study | In this study, the researchers investigate the maximum penetration depth of fuel cell powertrain technology within the heavy-duty fleet and assess to what extent it can contribute to the decarbonization of freight transport. |
| Sánchez et al. [84] | Impact of Spanish electricity mix, over the period 2008–2030, on the Life Cycle energy consumption and GHG emissions of Electric, Hybrid Diesel-Electric, Fuel Cell Hybrid and Diesel Bus of the Madrid Transportation System | In this paper, the fundamental question posed is: which combination of technology and fuel proves to be more efficient in terms of energy consumption and greenhouse gas (GHG) emissions? To comprehensively answer this question, a life cycle assessment is deemed necessary. |
| Tang, R. and Cering [85] | Levelized cost of hydrogen for refueling stations with solar PV and wind in Sweden: On-grid or off-grid? | This study delves into the feasibility of producing hydrogen using renewable electricity in refueling stations in Sweden. The analysis incorporates hourly solar radiation data, wind speed data, and electricity prices to assess the viability of such hydrogen production. |

## 5. Discussion

Research endeavors focused on energy transition and the replacement of fossil fuels with greenhouse gas-free alternatives in the transportation sector are extensive. Nowadays, vehicular mobility characterized by zero-emission technologies encompasses Battery Electric Vehicles (BEV), Range-Extended Electric Vehicles (REEV), Plug-in Hybrid Electric Vehicles (PHEV), Fuel Cell Electric Vehicles (FCEV), Fuel Cell Hybrid Vehicles (FCHV), and Hydrogen Internal Combustion Engine Vehicles (HICEV). This state-of-the-art study discusses the significant progress made in addressing greenhouse gas (GHG) emissions in the transportation sector by promoting vehicles with zero-emission technologies, such as Fuel Cell Electric Vehicles (FCEVs) or (FCHVs). The focus then shifts to the challenges faced by the FCEV market, primarily the scarcity of Hydrogen Refueling Stations (HRS). It highlights, therefore, the importance of HRS in promoting hydrogen fuel cell vehicles, along with the need for collaboration among stakeholders for comprehensive planning and execution.

Hence, research endeavors have been focused on the development and expansion of hydrogen infrastructure, encompassing the production, storage, transportation, and dispensing of hydrogen fuel. In addition to conventional processes like natural gas reforming and other fossil fuel-based methods, there is a growing interest in the production of green hydrogen through water electrolysis. This process is powered by renewable electricity sources such as wind, solar, or hydropower. Various studies have assessed the feasibility and economic viability of different hydrogen production pathways, recognizing that the choice of production method can significantly impact the overall sustainability and carbon footprint of the hydrogen supply chain. A key determinant in this regard is the technology employed for the decomposition of the water molecule, including AEL, PEM, AEM, or SOE. The selection of one technology over another influences costs, as well as the availability of renewable energy sources for their production.

Another factor addressed in the studies is the location of green hydrogen production. It can be centralized or situated adjacent to HRSs. In the former scenario, a challenge arises concerning the method used for transporting hydrogen to the HRS, either through pipelines or via road transport. The primary technologies for hydrogen transport and storage include gaseous compressed hydrogen (CGH2), liquid hydrogen (LH2), liquid organic hydrogen carriers (LOHC), Metal Organic Frameworks (MOF), hybrids, and ammonia. Transporting hydrogen via pipelines is viable due to existing networks in the United States and European countries. However, this infrastructure is limited and can be supplemented by the extensive natural gas network.

The HRS infrastructure is accompanied by a storage and compression system at standard supply pressures of 700 and 350 bar. This supply pressure may vary based on the temperature reached inside the tank, depending on the storage standard. One reason why HRS for bus fleet service is more prevalent is the use of 350-bar pressure, significantly lower than the 700-bar pressure for light vehicles. Both are technically developed but come with significantly different costs.

Energy consumption directly influences operational costs and investments. Within HRS, energy consumption is primarily attributed to the compression system and hydrogen cooling. This is crucial for the optimal filling of vehicle tanks, directly impacting vehicle autonomy.

Studies conducted on HRS location highlight the diverse challenges associated with implementing this infrastructure. These challenges encompass costs, demand, distance, FCEV market penetration, and other factors, including navigating within a competitive market. The location of hydrogen production, storage, and supply facilities will consider the strategic requirements of the national transport network, essential technical factors, access to energy resources, and the water needed for electrolysis. Achieving this will necessitate the development of a mathematical model that incorporates all parameters, accounting for the variability of environmental factors.

The hydrogen roadmap aligns research, investment, and governance to achieve the objectives outlined in various European programs and national plans. The primary goal is the decarbonization of industrial sectors, households, and the transportation sector.

## 6. Conclusions

In this paper, an overview is presented on the current state of research regarding hydrogen infrastructure in the transportation field. The aim is to illustrate the most relevant research areas in the planning of overall hydrogen logistics distribution, storage logistics, energy sources, and supply chains. The deployment of HRS in the transportation sector faces several challenges, including variability in the origin and destination of hydrogen demand. This variability reflects fluctuations in the points where vehicles require refueling and their subsequent travel destinations. Additionally, the profitability of HRS is intricately tied to their ability to attract hydrogen refueling demand, especially in competitive markets with multiple refueling station options. Moreover, the efficiency of HRS is influenced by the technological capabilities deployed and the energy requirements associated with their operation. Different technologies present varying energy demands and operational capacities. Presently, existing HRS primarily serve fleets of public transport vehicles and short-distance goods, prioritizing services in areas where demand is more predictable and commercially viable.

Moreover, it is important to highlight that operational expenses are experiencing a decline in areas where the potential for renewable energy sources is most significant. This reduction in operating costs is a direct result of the increasing availability and affordability of clean energy. As a result, the advancement and adoption of hydrogen fuel production technologies, coupled with the establishment of clean refueling infrastructure, play a crucial role in streamlining the commercialization of FCEVs. This is due, among other reasons, to the synergistic effect of reduced operational costs and the promotion of environmentally sustainable practices; the strengthening of the commercial position and acceptance of FCEVs in the market is due to their alignment with current environmental concerns. The state-of-the-art subject of this study is addressed in the literature, taking into account factors such as cost, demand, used technologies, and security, but not all at the same time. Hence, we consider that the parameters and restrictions needed to determine the optimum sizing and best location for HRS need to be further researched, as well as the determination of an appropriate HRS distribution network methodology.

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## References

1. IRENA. Hydrogen: A Renewable Energy Perspective, International Renewable Energy Agency. Report. 2019. Available online: www.irena.org (accessed on 26 July 2023).
2. Transforming Our World: The 2030 Agenda for Sustainable Development, United Nations. 2015. Available online: https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf (accessed on 26 July 2023).
3. Hydrogen. (n.d.). Available online: https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen_en (accessed on 26 July 2023).
4. Directive (Eu) 2018/2001 of the European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Sources, Official Journal of the European Union. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001 (accessed on 26 July 2023).
5. European Green Deal. (n.d.). Available online: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (accessed on 26 July 2023).
6. EU Taxonomy for Sustainable Activities. (n.d.). Available online: https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en (accessed on 26 July 2023).
7. GenH2 Truck-Daimler Truck Media Site. (n.d.). Available online: https://media.daimlertruck.com/marsMediaSite/en/instance/ko/GenH2-Truck.xhtml?oid=47469461 (accessed on 26 July 2023).
8. Hydrogen Vehicles | Hyundai XCIENT Fuel Cell Truck | Hyundai Fuel Cell Truck & Bus. (n.d.). Available online: https://trucknbus.hyundai.com/hydrogen/en/hydrogen-vehicles/xcient-fuel-cell-truck (accessed on 26 July 2023).
9. Hyundai Hydrogen Mobility. (n.d.). Available online: https://hyundai-hm.com/ (accessed on 26 July 2023).
10. Hunt, J.D.; Nascimento, A.; Nascimento, N.; Vieira, L.W.; Romero, O.J. Possible pathways for oil and gas companies in a sustainable future: From the perspective of a hydrogen economy. *Renew. Sustain. Energy Rev.* **2022**, *160*, 112291. [CrossRef]
11. El Hidrógeno Verde Clave Para Alcanzar la Neutralidad Climática. (n.d.). Available online: https://www.naturgy.es/blog/negocios_y_autonomos/hidrogeno_verde_clave_para_la_neutralidad_climatica (accessed on 26 July 2023).
12. Compromiso "Cero Emisiones Netas en 2050" | Repsol. (n.d.). Available online: https://www.repsol.com/es/sostenibilidad/cambio-climatico/cero-emisiones-netas-2050/index.cshtml (accessed on 26 July 2023).

13. El Hidrógeno Renovable y Verde | Endesa. (n.d.). Available online: https://www.endesa.com/es/proyectos/todos-los-proyectos/transicion-energetica/hidrogeno-verde (accessed on 26 July 2023).
14. Pioneros en Hidrógeno Verde-Iberdrola. (n.d.). Available online: https://www.iberdrola.com/conocenos/nuestra-actividad/hidrogeno-verde (accessed on 26 July 2023).
15. Su, C.; Wei, H.; Wang, Z.; Ayed, H.; Mouldi, A.; Shayesteh, A.A. Economic accounting and high-tech strategy for sustainable production: A case study of methanol production from $CO_2$ hydrogenation. *Int. J. Hydrogen Energy* **2022**, *47*, 25929–25944. [CrossRef]
16. Capurso, T.; Stefanizzi, M.; Torresi, M.; Camporeale, S.M. Perspective of the role of hydrogen in the 21st century energy transition. *Energy Convers. Manag.* **2022**, *251*, 114898. [CrossRef]
17. Lebrouhi, B.E.; Djoupo, J.J.; Lamrani, B.; Benabdelaziz, K.; Kousksou, T. Global hydrogen development—A technological and geopolitical overview. *Int. J. Hydrogen Energy* **2022**, *47*, 7016–7048. [CrossRef]
18. Gu, Y.; Chen, Q.; Xue, J.; Tang, Z.; Sun, Y.; Wu, Q. Comparative techno-economic study of solar energy integrated hydrogen supply pathways for hydrogen refueling stations in China. *Energy Convers. Manag.* **2020**, *223*, 113240. [CrossRef]
19. Zhang, C.; Greenblatt, J.B.; Wei, M.; Eichman, J.; Saxena, S.; Muratori, M.; Guerra, O.J. Flexible grid-based electrolysis hydrogen production for fuel cell vehicles reduces costs and greenhouse gas emissions. *Appl. Energy* **2020**, *278*, 115651. [CrossRef]
20. Boudries, R. Hydrogen as a fuel in the transport sector in Algeria. *Int. J. Hydrogen Energy* **2014**, *39*, 15215–15223. [CrossRef]
21. Park, S.; Nam, S.; Oh, M.; Choi, I.J.; Shin, J. Preference Structure on the Design of Hydrogen Refueling Stations to Activate Energy Transition. *Energies* **2020**, *13*, 3959. [CrossRef]
22. Tabandeh, A.; Hossain, M.J.; Li, L. Integrated multi-stage and multi-zone distribution network expansion planning with renewable energy sources and hydrogen refuelling stations for fuel cell vehicles. *Appl. Energy* **2022**, *319*, 119242. [CrossRef]
23. Zhou, J.; Wu, Y.; Tao, Y.; Gao, J.; Zhong, Z.; Xu, C. Geographic information big data-driven two-stage optimization model for location decision of hydrogen refueling stations: An empirical study in China. *Energy* **2021**, *225*, 120330. [CrossRef]
24. Nugroho, R.; Rose, P.K.; Gnann, T.; Wei, M. Cost of a potential hydrogen-refueling network for heavy-duty vehicles with long-haul application in Germany 2050. *Int. J. Hydrogen Energy* **2021**, *46*, 35459–35478. [CrossRef]
25. Hausmann, J.N.; Schlö, R.; Menezes, P.W.; Driess, M. Open Access Article. *Energy Environ. Sci.* **2021**, *14*, 3679. [CrossRef]
26. Thimmappa, R.; Gautam, M.; Bhat, Z.M.; Thodika AR, A.; Devendrachari, M.C.; Mukhopadhyay, S.; Dargily, N.C.; Thotiyl, M.O. An atmospheric water electrolyzer for decentralized green hydrogen production. *Cell Rep. Phys. Sci.* **2021**, *2*, 100627. [CrossRef]
27. Iannuzzi, L.; Hilbert, J.A.; Silva Lora, E.E. Life Cycle Assessment (LCA) for use on renewable sourced hydrogen fuel cell buses vs diesel engines buses in the city of Rosario, Argentina. *Int. J. Hydrogen Energy* **2021**, *46*, 29694–29705. [CrossRef]
28. Muñoz, P.; Franceschini, E.A.; Levitan, D.; Rodriguez, C.R.; Humana, T.; Correa Perelmuter, G. Comparative analysis of cost, emissions and fuel consumption of diesel, natural gas, electric and hydrogen urban buses. *Energy Convers. Manag.* **2022**, *257*, 115412. [CrossRef]
29. Lu, Q.; Zhang, B.; Yang, S.; Peng, Z. Life cycle assessment on energy efficiency of hydrogen fuel cell vehicle in China. *Energy* **2022**, *257*, 124731. [CrossRef]
30. Caponi, R.; Bocci, E.; del Zotto, L. Techno-Economic Model for Scaling Up of Hydrogen Refueling Stations. *Energies* **2022**, *15*, 7518. [CrossRef]
31. Ababneh, H.; Hameed, B.H. Electrofuels as emerging new green alternative fuel: A review of recent literature. *Energy Convers. Manag.* **2022**, *254*, 115213. [CrossRef]
32. Wang, P.; Xue, Q.; Yang, J.; Ma, H.; Li, Y.; Zhao, X. Energy Security Planning for Hydrogen Fuel Cell Vehicles in Large-Scale Events: A Case Study of Beijing 2022 Winter Olympics. *Automot. Innov.* **2022**, *5*, 209–220. [CrossRef]
33. Li, Y.; Kimura, S. Economic competitiveness and environmental implications of hydrogen energy and fuel cell electric vehicles in ASEAN countries: The current and future scenarios. *Energy Policy* **2021**, *148*, 111980. [CrossRef]
34. Rose, P.K.; Neumann, F. Hydrogen refueling station networks for heavy-duty vehicles in future power systems. *Transp. Res. Part D Transp. Environ.* **2020**, *83*, 102358. [CrossRef]
35. Crönert, T.; Minner, S. Location selection for hydrogen fuel stations under emerging provider competition. *Transp. Res. Part C Emerg. Technol.* **2021**, *133*, 103426. [CrossRef]
36. Shukla, A.; Pekny, J.; Venkatasubramanian, V. An optimization framework for cost effective design of refueling station infrastructure for alternative fuel vehicles. *Comput. Chem. Eng.* **2011**, *35*, 1431–1438. [CrossRef]
37. Lagioia, G.; Spinelli, M.P.; Amicarelli, V. Blue and green hydrogen energy to meet European Union decarbonisation objectives. An overview of perspectives and the current state of affairs. *Int. J. Hydrogen Energy* **2023**, *48*, 1304–1322. [CrossRef]
38. Pruvost, F.; Cloete, S.; Hendrik Cloete, J.; Dhoke, C.; Zaabout, A. Techno-Economic assessment of natural gas pyrolysis in molten salts. *Energy Convers. Manag.* **2022**, *253*, 115187. [CrossRef]
39. Hermesmann, M.; Müller, T.E. Green, Turquoise, Blue, or Grey? Environmentally friendly Hydrogen Production in Transforming Energy Systems. *Prog. Energy Combust. Sci.* **2022**, *90*, 100996. [CrossRef]
40. Ajanovic, A.; Sayer, M.; Haas, R. The economics and the environmental benignity of different colors of hydrogen. *Int. J. Hydrogen Energy* **2022**, *47*, 24136–24154. [CrossRef]
41. Mohideen, M.M.; Subramanian, B.; Sun, J.; Ge, J.; Guo, H.; Radhamani, A.V.; Ramakrishna, S.; Liu, Y. Techno-economic analysis of different shades of renewable and non-renewable energy-based hydrogen for fuel cell electric vehicles. *Renew. Sustain. Energy Rev.* **2023**, *174*, 113153. [CrossRef]

42. Nechache, A.; Hody, S. Alternative and innovative solid oxide electrolysis cell materials: A short review. *Renew. Sustain. Energy Rev.* **2021**, *149*, 111322. [CrossRef]
43. Liu, J.; Yang, H.; Zhou, Y. Peer-to-peer trading optimizations on net-zero energy communities with energy storage of hydrogen and battery vehicles. *Appl. Energy* **2021**, *302*, 117578. [CrossRef]
44. Stiber, S.; Sata, N.; Morawietz, T.; Ansar, S.A.; Jahnke, T.; Lee, J.K.; Bazylak, A.; Fallisch, A.; Gago, A.S.; Friedrich, K.A. A high-performance, durable and low-cost proton exchange membrane electrolyser with stainless steel components. *Energy Environ. Sci.* **2022**, *15*, 109–122. [CrossRef]
45. Park, E.J.; Arges, C.G.; Xu, H.; Kim, Y.S. Membrane Strategies for Water Electrolysis. *ACS Energy Lett.* **2022**, *7*, 3447–3457. [CrossRef]
46. Teuku, H.; Alshami, I.; Goh, J.; Masdar, M.S.; Loh, K.S. Review on bipolar plates for low-temperature polymer electrolyte membrane water electrolyzer. *Int. J. Energy Res.* **2021**, *45*, 20583–20600. [CrossRef]
47. Ghaebi Panah, P.; Cui, X.; Bornapour, M.; Hooshmand, R.A.; Guerrero, J.M. Marketability analysis of green hydrogen production in Denmark: Scale-up effects on grid-connected electrolysis. *Int. J. Hydrogen Energy* **2022**, *47*, 12443–12455. [CrossRef]
48. Chebli, E.; Fledersbacher, P. Green Hydrogen Production in Spain MHydrogen Perspective and Contribution. Available online: https://mhydrogen.com/ (accessed on 12 January 2022).
49. Nastasi, B.; lo Basso, G. Hydrogen to link heat and electricity in the transition towards future Smart Energy Systems. *Energy* **2016**, *110*, 5–22. [CrossRef]
50. Cloete, S.; Ruhnau, O.; Hirth, L. On capital utilization in the hydrogen economy: The quest to minimize idle capacity in renewables-rich energy systems. *Int. J. Hydrogen Energy* **2021**, *46*, 169–188. [CrossRef]
51. Jang, D.; Kim, K.; Kim, K.H.; Kang, S. Techno-economic analysis and Monte Carlo simulation for green hydrogen production using offshore wind power plant. *Energy Convers. Manag.* **2022**, *263*, 115695. [CrossRef]
52. Aprea, J.L.; Bolcich, J.C. The energy transition towards hydrogen utilization for green life and sustainable human development in Patagonia. *Int. J. Hydrogen Energy* **2020**, *45*, 25627–25645. [CrossRef]
53. Awaleh, M.O.; Adan, A.B.; Dabar, O.A.; Jalludin, M.; Ahmed, M.M.; Guirreh, I.A. Economic feasibility of green hydrogen production by water electrolysis using wind and geothermal energy resources in asal-ghoubbet rift (Republic of Djibouti): A comparative evaluation. *Energies* **2022**, *15*, 138. [CrossRef]
54. Ibrahim, O.S.; Singlitico, A.; Proskovics, R.; McDonagh, S.; Desmond, C.; Murphy, J.D. Dedicated large-scale floating offshore wind to hydrogen: Assessing design variables in proposed typologies. *Renew. Sustain. Energy Rev.* **2022**, *160*, 112310. [CrossRef]
55. Shiva Kumar, S.; Lim, H. An overview of water electrolysis technologies for green hydrogen production. *Energy Rep.* **2022**, *8*, 13793–13813. [CrossRef]
56. Wolff, S.; Seidenfus, M.; Brönner, M.; Lienkamp, M. Multi-disciplinary design optimization of life cycle eco-efficiency for heavy-duty vehicles using a genetic algorithm. *J. Clean. Prod.* **2021**, *318*, 128505. [CrossRef]
57. Sheng, M.S.; Sreenivasan, A.V.; Sharp, B.; Du, B. Well-to-wheel analysis of greenhouse gas emissions and energy consumption for electric vehicles: A comparative study in Oceania. *Energy Policy* **2021**, *158*, 112552. [CrossRef]
58. Pasini, G.; Lutzemberger, G.; Ferrari, L. Renewable Electricity for Decarbonisation of Road Transport: Batteries or E-Fuels? *Batteries* **2023**, *9*, 135. [CrossRef]
59. Panchenko, V.A.; Daus, Y.V.; Kovalev, A.A.; Yudaev, I.V.; Litti, Y.V. Prospects for the production of green hydrogen: Review of countries with high potential. *Int. J. Hydrogen Energy* **2023**, *48*, 4551–4571. [CrossRef]
60. Gallo, M.; Marinelli, M. The Use of Hydrogen for Traction in Freight Transport: Estimating the Reduction in Fuel Consumption and Emissions in a Regional Context. *Energies* **2023**, *16*, 508. [CrossRef]
61. Kavadias, K.A.; Kosmas, V.; Tzelepis, S. Sizing, Optimization, and Financial Analysis of a Green Hydrogen Refueling Station in Remote Regions. *Energies* **2022**, *15*, 547. [CrossRef]
62. Viesi, D.; Crema, L.; Testi, M. The Italian hydrogen mobility scenario implementing the European directive on alternative fuels infrastructure (DAFI 2014/94/EU). *Int. J. Hydrogen Energy* **2017**, *42*, 27354–27373. [CrossRef]
63. Barhoumi, E.M.; Okonkwo, P.C.; Farhani, S.; ben Belgacem, I.; Zghaibeh, M.; Mansir, I.B.; Bacha, F. Techno-economic analysis of photovoltaic-hydrogen refueling station case study: A transport company Tunis-Tunisia. *Int. J. Hydrogen Energy* **2022**, *47*, 24523–24532. [CrossRef]
64. J2601_202005: Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles-SAE International. (n.d.). Available online: https://www.sae.org/standards/content/j2601_202005/ (accessed on 26 July 2023).
65. Infinity Dry-Running Piston Compressors With Electro-Hydrostatic Drive | Sera GmbH. (n.d.). Available online: https://www.sera-web.com/trockenlaufender-kolbenkompressor (accessed on 26 July 2023).
66. Tanaka, T.; Azuma, T.; Evans, J.A.; Cronin, P.M.; Johnson, D.M.; Cleaver, R.P. Experimental study on hydrogen explosions in a full-scale hydrogen filling station model. *Int. J. Hydrogen Energy* **2007**, *32*, 2162–2170. [CrossRef]
67. Serdaroglu, G.; Khzouz, M.; Gillott, M.; Shields, A.; Walker, G.S. The effect of environmental conditions on the operation of a hydrogen refuelling station. *Int. J. Hydrogen Energy* **2015**, *40*, 17153–17162. [CrossRef]
68. Šimunović, J.; Pivac, I.; Barbir, F. Techno-economic assessment of hydrogen refueling station: A case study in Croatia. *Int. J. Hydrogen Energy* **2022**, *47*, 24155–24168. [CrossRef]
69. Hernández, B.; Alkayas, A.; Azar, E.; Mayyas, A.T. Mathematical model for the placement of hydrogen refueling stations to support future fuel cell trucks. *IEEE Access* **2021**, *9*, 148118–148131. [CrossRef]

70. Greene, D.L.; Ogden, J.M.; Lin, Z. Challenges in the designing, planning and deployment of hydrogen refueling infrastructure for fuel cell electric vehicles. *eTransportation* **2020**, *6*, 100086. [CrossRef]
71. Chen, Q.; Gu, Y.; Tang, Z.; Wang, D.; Wu, Q. Optimal design and techno-economic assessment of low-carbon hydrogen supply pathways for a refueling station located in Shanghai. *Energy* **2021**, *237*, 121584. [CrossRef]
72. Bethoux, O. Hydrogen Fuel Cell Road Vehicles and Their Infrastructure: An Option towards an Environmentally Friendly Energy Transition. *Energies* **2020**, *13*, 6132. [CrossRef]
73. Ogden, J.; Jaffe, A.M.; Scheitrum, D.; McDonald, Z.; Miller, M. Natural gas as a bridge to hydrogen transportation fuel: Insights from the literature. *Energy Policy* **2018**, *115*, 317–329. [CrossRef]
74. Nakayama, J.; Suzuki, T.; Owada, S.; Shiota, K.; Izato, Y.I.; Noguchi, K.; Miyake, A. Qualitative risk analysis of the overhead hydrogen piping at the conceptual process design stage. *Int. J. Hydrogen Energy* **2022**, *47*, 11725–11738. [CrossRef]
75. California Hydrogen Infrastructure Tool (CHIT) | California Air Resources Board. (n.d.). Available online: https://ww2.arb.ca.gov/es/resources/documents/california-hydrogen-infrastructure-tool-chit (accessed on 25 January 2023).
76. Brey, J.J.; Brey, R.; Carazo, A.F.; Ruiz-Montero, M.J.; Tejada, M. Incorporating refuelling behaviour and drivers' preferences in the design of alternative fuels infrastructure in a city. *Transp. Res. Part C Emerg. Technol.* **2016**, *65*, 144–155. [CrossRef]
77. Brey, J.J.; Brey, R.; Carazo, A.F. Eliciting preferences on the design of hydrogen refueling infrastructure. *Int. J. Hydrogen Energy* **2017**, *42*, 13382–13388. [CrossRef]
78. Ala, G.; Colak, I.; di Filippo, G.; Miceli, R.; Romano, P.; Silva, C.; Valtchev, S.; Viola, F. Electric Mobility in Portugal: Current Situation and Forecasts for Fuel Cell Vehicles. *Energies* **2021**, *14*, 7945. [CrossRef]
79. Stations Map-H2Stations.org. (n.d.). Available online: https://www.h2stations.org/stations-map/ (accessed on 26 July 2023).
80. Erdoĝan, S.; Miller-Hooks, E. A Green Vehicle Routing Problem. *Transp. Res. Part E Logist. Transp. Rev.* **2012**, *48*, 100–114. [CrossRef]
81. Cardona, P.; Costa-Castelló, R.; Roda, V.; Carroquino, J.; Valiño, L.; Serra, M. Model predictive control of an on-site green hydrogen production and refuelling station. *Int. J. Hydrogen Energy* **2023**, *48*, 17995–18010. [CrossRef]
82. Hosseini, S.E.; Wahid, M.A. Hydrogen production from renewable and sustainable energy resources: Promising green energy carrier for clean development. *Renew. Sustain. Energy Rev.* **2016**, *57*, 850–866. [CrossRef]
83. Çabukoglu, E.; Georges, G.; Küng, L.; Pareschi, G.; Boulouchos, K. Fuel cell electric vehicles: An option to decarbonize heavy-duty transport? Results from a Swiss case-study. *Transp. Res. Part D Transp. Environ.* **2019**, *70*, 35–48. [CrossRef]
84. García Sánchez, J.A.; López Martínez, J.M.; Lumbreras Martín, J.; Flores Holgado, M.N.; Aguilar Morales, H. Impact of Spanish electricity mix, over the period 2008–2030, on the Life Cycle energy consumption and GHG emissions of Electric, Hybrid Diesel-Electric, Fuel Cell Hybrid and Diesel Bus of the Madrid Transportation System. *Energy Convers. Manag.* **2013**, *74*, 332–343. [CrossRef]
85. Tang, O.; Rehme, J.; Cerin, P. Levelized cost of hydrogen for refueling stations with solar PV and wind in Sweden: On-grid or off-grid? *Energy* **2022**, *241*, 122906. [CrossRef]