

# **Green Hydrogen Market - A Global and Regional Analysis: Focus on Application, Technology, Renewable Energy Source, and Region - Analysis and Forecast, 2023-2033**

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## **Abstracts**

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### **Global Green Hydrogen Market Overview**

The global green hydrogen market was valued at \$828.2 million in 2023, and it is expected to grow with a CAGR of 67.19% during the forecast period 2023-2033 to reach \$141.29 billion by 2033. This growth of the green hydrogen market is likely to be driven by low variable renewable energy (VRE) electricity cost, global plans for net-zero emissions by 2050, and increasing awareness regarding green hydrogen.

### **Introduction to Green Hydrogen**

Green hydrogen represents a significant breakthrough in the field of renewable energy and sustainability. It is a form of hydrogen gas produced using renewable energy sources, distinguishing it from grey or blue hydrogen, which are derived from fossil fuels. The primary method for producing green hydrogen is through the electrolysis of water, a process that utilizes electricity generated from renewable sources such as wind, solar, or hydropower to split water into hydrogen and oxygen. This method is particularly advantageous because it results in zero carbon emissions, making green hydrogen a clean energy source. It is also highly versatile, finding applications in various sectors such as transportation, industry, and energy storage, and can act as a medium for storing surplus renewable energy.

However, the production of green hydrogen is currently faced with several challenges, including high costs and significant energy requirements. Moreover, there is a substantial need for investment in infrastructure to facilitate its production, storage, and distribution.

Despite the current challenges, the outlook for the green hydrogen market is very promising. As technology continues to advance and production costs decrease, the market is expected to expand significantly. This expansion will likely include integration with other renewable energy technologies and sectors, such as transport and industry. Key to this growth will be the support from government policies and international cooperation.

### Market Segmentation:

#### Segmentation 1: by Application

Oil and Gas

Industrial Feedstock

Ammonia

Methanol

Steel

Others

Mobility

Power Generation

Others

### Industrial Feedstock Application to Dominate Global Green Hydrogen Market (by Application)

The application of green hydrogen as an industrial feedstock represents a significant

and transformative segment of the global green hydrogen market. As industries worldwide seek to reduce their carbon footprint and transition toward sustainable practices, green hydrogen emerges as a pivotal player, especially in sectors heavily reliant on traditional hydrocarbon feedstocks. The industrial sector's hunger for clean feedstocks presents a golden opportunity for green hydrogen. Ditching fossil fuels like coal and gas for green hydrogen in chemical production, steelmaking, and other processes promises significant decarbonization without sacrificing progress. Imagine replacing grey ammonia with its green counterpart, made using clean hydrogen, for fertilizers and beyond.

### Segmentation 2: by Technology

Proton Exchange Membrane (PEM) Electrolyzer

Alkaline Electrolyzer

Anion Exchange Membrane

Solid Oxide Electrolyzer

### Alkaline Electrolyzer to Lead the Global Green Hydrogen Market (by Technology)

The alkaline electrolyzer segment held the largest share of the green hydrogen market in 2022. Alkaline electrolyzers were the initial electrolyzers to enter the market for industrial applications, and they remained the sole electrolyzer technology available until the 1970s, when proton exchange membrane (PEM) technology emerged. Unlike PEM electrolyzers, alkaline electrolyzers do not require the use of precious metals, offering a longer operational lifespan and a more cost-effective solution.

### Segmentation 3: by Renewable Energy Source

Wind Energy

Solar Energy

Others

## Solar Energy to Hold Highest Share in Global Green Hydrogen Market (by Renewable Energy Source)

The assertion that solar energy will hold the highest share in the global green hydrogen market is rooted in several key factors. The cost of solar photovoltaic (PV) technology has been decreasing rapidly, making solar energy more economically viable for hydrogen production. This cost-effectiveness is crucial in the context of green hydrogen, where production costs are a significant concern. Solar energy's role in the global green hydrogen market is becoming increasingly prominent, offering a pathway to a sustainable and economically viable hydrogen economy.

### Segmentation 4: by Region

North America - U.S., Canada, and Mexico

Europe - France, Germany, U.K., Spain, Italy, Russia, and Rest-of-Europe

Asia-Pacific - China, India, Japan, Australia, South Korea, and Rest-of-Asia-Pacific

Rest-of-the-World (ROW)

In 2022, Europe is poised to hold the highest share in the global green hydrogen market, a status underscored by its strategic, economic, and policy-driven initiatives. This leadership stems from Europe's aggressive approach toward renewable energy and a strong commitment to reducing carbon emissions. Key to this dominance is Europe's robust policy framework, exemplified by ambitious climate goals such as the European Green Deal and various national strategies explicitly supporting green hydrogen development. The region has witnessed significant public and private investments in green hydrogen, encompassing not just production but also the development of necessary infrastructure for storage and distribution. Technological innovation in Europe is at its peak, with leading renewable energy technology companies spearheading advancements in green hydrogen production.

### Recent Developments in the Global Green Hydrogen Market

In 2023, Linde plc announced plans to increase green hydrogen production capacity in California, responding to growing demand from the mobility market.

In February 2021, Air Liquide and Siemens Energy signed a memorandum of understanding with the objective of combining their expertise in proton exchange membrane (PEM) electrolysis technology. In this collaboration, both companies intend to focus their activities on key areas such as the co-creation of large industrial-scale hydrogen projects in collaboration with customers, laying the ground for manufacturing electrolyzers at large scale in Europe, especially in Germany and France, and R&D activities to co-develop next-generation electrolyzer technologies.

## Demand – Drivers, Challenges, and Opportunities

### Market Drivers: Low Variable Renewable Energy (VRE) Electricity Cost

The convergence of low-cost variable renewable energy (VRE) electricity and the burgeoning green hydrogen market heralds a transformative era in sustainable energy. This fusion, marked by declining costs in VRE sources such as solar and wind power, presents a promising landscape for the widespread adoption and proliferation of green hydrogen technologies. The decreasing costs of variable renewable energy sources, primarily solar and wind power, have been instrumental in reshaping the energy paradigm. Over the past years (2018-2023), significant advancements and economies of scale have driven down the expenses associated with harnessing solar energy through photovoltaic systems. Similarly, innovations in onshore and offshore wind technologies have steadily lowered production costs, making these sources increasingly competitive and cost-effective.

According to reports from esteemed organizations such as the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA), projections indicate a continued downward trajectory in the levelized cost of electricity (LCOE) for VRE sources. By 2026, the LCOE for newly established solar hybrid resources is anticipated to be around \$42.18/MWh, reflecting the remarkable cost-efficiency achieved in solar photovoltaic systems. Similarly, forecasts suggest a substantial decline in onshore wind costs by 45 percent from 2019 levels, with offshore wind costs expected to fall by as much as 50 percent by 2030. This relentless drive toward cost reduction in VRE sources sets the stage for the proliferation of green hydrogen technologies. Green hydrogen, produced through the electrolysis of water using renewable energy sources such as solar and wind power, offers an eco-friendly alternative to conventional hydrogen production methods reliant on fossil fuels. The

reducing costs of VRE electricity significantly impact the economics of green hydrogen production, rendering it increasingly competitive and economically viable.

### Market Challenges: High Cost of Production

The high cost of production stands as a significant restraint in the development of the green hydrogen market, posing challenges to its widespread adoption despite its potential as a sustainable energy solution.

The following are several factors contribute to the high production costs of green hydrogen:

**Electrolysis Technology:** The primary method for producing green hydrogen involves electrolysis, which requires significant energy input. The cost of electrolyzers and the equipment used in this process remains relatively high, impacting the overall production expenses.

**Renewable Energy Infrastructure:** While renewable energy costs have been decreasing, establishing and maintaining the necessary solar or wind power infrastructure for consistent and reliable energy supply adds to the overall cost of green hydrogen production.

**Economies of Scale:** The current scale of green hydrogen production is limited, resulting in higher unit costs. Mass production and widespread adoption are essential to achieving economies of scale that could significantly reduce production costs.

**Storage and Transportation:** Hydrogen has specific storage and transportation requirements, often necessitating additional investments in infrastructure for safe and efficient handling. These costs further contribute to the overall expense of green hydrogen.

Addressing the high cost of production is critical to unlocking the full potential of the green hydrogen market. The following efforts are underway to mitigate these challenges:

**Technological Advancements:** Ongoing research and development aims to improve electrolysis technologies, enhance efficiency, and lower the capital costs of electrolyzers. Breakthroughs in materials and manufacturing processes could drive down the costs of producing green hydrogen.

**Policy Support and Incentives:** Governments are implementing policies, subsidies, and financial incentives to stimulate investment in green hydrogen production. Supportive regulations and funding mechanisms encourage innovation and market competitiveness.

**Collaborations and Investment:** Industry collaborations and partnerships between public and private sectors are fostering innovation and pooling resources to drive down costs through shared research, development, and infrastructure investments.

**Scaling Up Production:** Increasing the scale of green hydrogen production facilities can help achieve economies of scale, driving cost reductions through optimized operations and larger production volumes.

**Market Opportunities: Wide Application of Green Hydrogen**

The expansive range of applications for green hydrogen presents a significant opportunity for the global green hydrogen market, fostering its growth and integration across diverse industries seeking sustainable energy solutions.

The wide-ranging applications of green hydrogen offer a compelling opportunity for market expansion:

**Market Diversification:** The broad applicability of green hydrogen across sectors diversifies its market potential, reducing dependency on specific industries and enhancing its attractiveness to a wider range of stakeholders.

**Technological Innovation:** Increased demand across various sectors stimulates innovation in hydrogen-related technologies, driving advancements in electrolysis, storage, transportation, and utilization, thereby improving efficiency and reducing costs.

**Economic Growth:** The widespread adoption of green hydrogen presents economic opportunities, creating new markets, jobs, and industries within the hydrogen value chain, from production to utilization.

**Climate Mitigation:** Leveraging green hydrogen in various applications contributes significantly to mitigating greenhouse gas emissions, aligning with global climate goals, and fostering sustainable development.



**Global Trade Opportunities:** The international trade of green hydrogen and its derivatives presents opportunities for countries with abundant renewable resources to become key suppliers, fostering global energy security and cooperation.

Overall, the diverse applications of green hydrogen represent a substantial opportunity for market growth. As industries embrace its potential across various sectors, it drives technological innovation, economic development, and environmental sustainability, positioning green hydrogen as a cornerstone in the transition toward a low-carbon and resilient global energy system.

How can this report add value to an organization?

**Product/Innovation Strategy:** In the realm of the global green hydrogen market, technological advancements are transforming agricultural landscapes to create winning products, choose the right unmet needs, target the right customer group, and compete with substitute products. The product segment helps the readers understand the different types of technology used for the green hydrogen market. Also, the study provides the readers with a detailed understanding of the global green hydrogen market based on application and product.

**Growth/Marketing Strategy:** The global green hydrogen market has witnessed remarkable growth strategies by key players. Business expansions, collaborations, and partnerships have been pivotal. Companies are venturing into global markets, forging alliances, and engaging in research collaborations to enhance their technological prowess. Collaborative efforts between hydrogen manufacturers and suppliers' experts are driving the development of cutting-edge monitoring tools. Additionally, strategic joint ventures are fostering the integration of diverse expertise, amplifying the market presence of these solutions. This collaborative approach is instrumental in developing a comprehensive, user-friendly, and efficient green hydrogen market.

**Competitive Strategy:** In the competitive landscape of the green hydrogen market, manufacturers are diversifying their product portfolios to cover various applications. Market segments include application, technology, and renewable energy sources. Competitive benchmarking illuminates the strengths of market players, emphasizing their unique offerings and regional strengths. Partnerships with research institutions and agricultural organizations are driving innovation.

Methodology



## Key Considerations and Assumptions in Market Engineering and Validation

The scope of this report has been focused on various types of applications and technology.

The market revenue has been calculated based on global green hydrogen providers.

The base currency considered for the market analysis is US\$. Currencies other than the US\$ have been converted to the US\$ for all statistical calculations, considering the average conversion rate for that particular year.

The currency conversion rate has been taken from the historical exchange rate of the Oanda website.

Nearly all the recent developments from January 2021 to December 2023 have been considered in this research study.

The information rendered in the report is a result of in-depth primary interviews, surveys, and secondary analysis.

Where relevant information was not available, proxy indicators and extrapolation have been employed.

Any future economic downturn has not been considered for the market estimation and forecast.

Technologies currently used are expected to persist through the forecast with no major technological breakthroughs.

## Primary Research

The primary sources involve green hydrogen market experts and stakeholders such as data suppliers, platform developers, and service providers. Respondents such as vice presidents, CEOs, marketing directors, and technology and innovation directors have been interviewed to verify this research study's qualitative and quantitative aspects.

The key data points taken from primary sources include:

validation and triangulation of all the numbers and graphs

validation of reports segmentation and key qualitative findings

understanding the competitive landscape

validation of the numbers of various markets for market type

percentage split of individual markets for region-wise analysis

## Secondary Research

This research study involves the usage of extensive secondary research, directories, company websites, and annual reports. It also makes use of the paid database to collect useful and effective information for an extensive, technical, market-oriented, and commercial study of the global market. In addition to the aforementioned data sources, the study has been undertaken with the help of other data sources published by different associations.

Secondary research was done to obtain crucial information about the industry's value chain, revenue models, the market's monetary chain, the total pool of key players, and the current and potential use cases and applications.

## Key Market Players and Competition Synopsis

The featured companies have been meticulously chosen, drawing insights from primary experts and thorough evaluations of company coverage, product offerings, and market presence.

Among the prominent players in the global green hydrogen market, the public players dominate, commanding approximately 93.3% of the market share in 2022. The remaining 6.67% is held by private companies.

Some prominent names established in the global green hydrogen market are:

### Company Type 1: Public Companies

Linde plc

Air Liquide

Air Products and Chemicals, Inc.

Engie

Uniper SE

Siemens Energy

Green Hydrogen Systems

Cummins Inc.

Toshiba Energy Systems & Solutions Corporation

Nel ASA

SGH2 Energy Global Corp.

Plug Power Inc.

Aker Horizons

Fusion-Fuel

#### Company Type 2: Private Companies

HY2GEN AG

## Contents

Executive Summary  
Scope and Definition

### 1 MARKETS

- 1.1 Trends: Current and Future Impact Assessment
  - 1.1.1 Trends: Current and Future Impact Assessment
  - 1.1.2 Trend 1: Decarbonization on the Horizon
  - 1.1.3 Trend 2: Infrastructure Development
  - 1.1.4 Trend 3: Falling Renewable Energy Costs
- 1.2 Supply Chain Overview
  - 1.2.1 Market Map
- 1.3 Research and Development Review
  - 1.3.1 Patent Filing Trend (by Country and Company)
- 1.4 Regulatory Landscape
  - 1.4.1 Consortiums and Associations
  - 1.4.2 Regulatory Bodies
  - 1.4.3 Government Programs
  - 1.4.4 Programs by Research Institutions and Universities
- 1.5 Start-Up Landscape
  - 1.5.1 Key Start-Ups in the Ecosystem
- 1.6 Impact Analysis for Key Global Events: COVID-19
- 1.7 Market Dynamics: Overview
  - 1.7.1 Market Drivers
    - 1.7.1.1 Low Variable Renewable Energy (VRE) Electricity Cost
    - 1.7.1.2 Global Plans for Net-Zero Emissions by 2050
    - 1.7.1.3 Increasing Awareness Regarding Green Hydrogen
  - 1.7.2 Market Restraints
    - 1.7.2.1 High Cost of Production
    - 1.7.2.2 Limited Dedicated Transport Infrastructure
  - 1.7.3 Market Opportunities
    - 1.7.3.1 Wide Application of Green Hydrogen
    - 1.7.3.2 Scaling Up of Technologies

### 2 APPLICATION

2.1 Application Segmentation

- 2.2 Application Summary
- 2.3 Green Hydrogen Market (by Application)
  - 2.3.1 Oil and Gas
    - 2.3.1.1 Hydrocracking
    - 2.3.1.2 Hydroisomerization
    - 2.3.1.3 Hydrodealkylation
    - 2.3.1.4 Hydrodesulfurization
  - 2.3.2 Industrial Feedstock
    - 2.3.2.1 Ammonia
    - 2.3.2.2 Methanol
    - 2.3.2.3 Steel
    - 2.3.2.4 Others
  - 2.3.3 Mobility
  - 2.3.4 Power Generation
  - 2.3.5 Others

### **3 PRODUCTS**

- 3.1 Product Segmentation
- 3.2 Product Summary
- 3.3 Global Green Hydrogen Market (by Technology)
  - 3.3.1 Proton Exchange Membrane (PEM) Electrolyzer
  - 3.3.2 Alkaline Electrolyzer
  - 3.3.3 Anion Exchange Membrane
  - 3.3.4 Solid Oxide Electrolyzer
- 3.4 Product Segmentation
- 3.5 Product Summary
- 3.6 Global Green Hydrogen Market (by Renewable Energy Source)
  - 3.6.1 Wind Energy
  - 3.6.2 Solar Energy
  - 3.6.3 Others

### **4 REGIONS**

- 4.1 Regional Summary
- 4.2 Drivers and Restraints
- 4.3 North America
  - 4.3.1 Regional Overview
  - 4.3.2 Driving Factors for Market Growth

- 4.3.3 Factors Challenging the Market
- 4.3.4 Application
- 4.3.5 Product
- 4.3.6 U.S.
  - 4.3.6.1 Application
  - 4.3.6.2 Product
- 4.3.7 Canada
  - 4.3.7.1 Application
  - 4.3.7.2 Product
- 4.3.8 Mexico
  - 4.3.8.1 Application
  - 4.3.8.2 Product
- 4.4 Europe
  - 4.4.1 Regional Overview
  - 4.4.2 Driving Factors for Market Growth
  - 4.4.3 Factors Challenging the Market
  - 4.4.4 Application
  - 4.4.5 Product
  - 4.4.6 France
    - 4.4.6.1 Application
    - 4.4.6.2 Product
  - 4.4.7 Germany
    - 4.4.7.1 Application
    - 4.4.7.2 Product
  - 4.4.8 U.K.
    - 4.4.8.1 Application
    - 4.4.8.2 Product
  - 4.4.9 Spain
    - 4.4.9.1 Application
    - 4.4.9.2 Product
  - 4.4.10 Italy
    - 4.4.10.1 Application
    - 4.4.10.2 Product
  - 4.4.11 Russia
    - 4.4.11.1 Application
    - 4.4.11.2 Product
  - 4.4.12 Rest-of-Europe
    - 4.4.12.1 Application
    - 4.4.12.2 Product

## 4.5 Asia-Pacific

### 4.5.1 Regional Overview

### 4.5.2 Driving Factors for Market Growth

### 4.5.3 Factors Challenging the Market

### 4.5.4 Application

### 4.5.5 Product

### 4.5.6 China

#### 4.5.6.1 Application

#### 4.5.6.2 Product

### 4.5.7 India

#### 4.5.7.1 Application

#### 4.5.7.2 Product

### 4.5.8 South Korea

#### 4.5.8.1 Application

#### 4.5.8.2 Product

### 4.5.9 Australia

#### 4.5.9.1 Application

#### 4.5.9.2 Product

### 4.5.10 Japan

#### 4.5.10.1 Application

#### 4.5.10.2 Product

### 4.5.11 Rest-of-Asia-Pacific

#### 4.5.11.1 Application

#### 4.5.11.2 Product

## 4.6 Rest-of-the-World

### 4.6.1 Regional Overview

### 4.6.2 Driving Factors for Market Growth

### 4.6.3 Factors Challenging the Market

### 4.6.4 Application

### 4.6.5 Product

### 4.6.6 South America

#### 4.6.6.1 Application

#### 4.6.6.2 Product

### 4.6.7 Middle East and Africa (MEA)

#### 4.6.7.1 Application

#### 4.6.7.2 Product

## 5 MARKETS - COMPETITIVE BENCHMARKING & COMPANY PROFILES



## 5.1 Next Frontiers

## 5.2 Geographic Assessment

### 5.2.1 Linde plc

#### 5.2.1.1 Overview

#### 5.2.1.2 Top Products/Product Portfolio

#### 5.2.1.3 Top Competitors

#### 5.2.1.4 Target Customers

#### 5.2.1.5 Key Personnel

#### 5.2.1.6 Analyst View

#### 5.2.1.7 Market Share

### 5.2.2 Air Liquide

#### 5.2.2.1 Overview

#### 5.2.2.2 Top Products/Product Portfolio

#### 5.2.2.3 Top Competitors

#### 5.2.2.4 Target Customers

#### 5.2.2.5 Key Personnel

#### 5.2.2.6 Analyst View

#### 5.2.2.7 Market Share

### 5.2.3 Air Products and Chemicals, Inc.

#### 5.2.3.1 Overview

#### 5.2.3.2 Top Products/Product Portfolio

#### 5.2.3.3 Top Competitors

#### 5.2.3.4 Target Customers

#### 5.2.3.5 Key Personnel

#### 5.2.3.6 Analyst View

#### 5.2.3.7 Market Share

### 5.2.4 Engie

#### 5.2.4.1 Overview

#### 5.2.4.2 Top Products/Product Portfolio

#### 5.2.4.3 Top Competitors

#### 5.2.4.4 Target Customers

#### 5.2.4.5 Key Personnel

#### 5.2.4.6 Analyst View

#### 5.2.4.7 Market Share

### 5.2.5 Uniper SE

#### 5.2.5.1 Overview

#### 5.2.5.2 Top Products/Product Portfolio

#### 5.2.5.3 Top Competitors

#### 5.2.5.4 Target Customers

- 5.2.5.5 Key Personnel
- 5.2.5.6 Analyst View
- 5.2.5.7 Market Share
- 5.2.6 Siemens Energy
  - 5.2.6.1 Overview
  - 5.2.6.2 Top Products/Product Portfolio
  - 5.2.6.3 Top Competitors
  - 5.2.6.4 Target Customers
  - 5.2.6.5 Key Personnel
  - 5.2.6.6 Analyst View
  - 5.2.6.7 Market Share
- 5.2.7 Green Hydrogen Systems
  - 5.2.7.1 Overview
  - 5.2.7.2 Top Products/Product Portfolio
  - 5.2.7.3 Top Competitors
  - 5.2.7.4 Target Customers
  - 5.2.7.5 Key Personnel
  - 5.2.7.6 Analyst View
  - 5.2.7.7 Market Share
- 5.2.8 Cummins Inc.
  - 5.2.8.1 Overview
  - 5.2.8.2 Top Products/Product Portfolio
  - 5.2.8.3 Top Competitors
  - 5.2.8.4 Target Customers
  - 5.2.8.5 Key Personnel
  - 5.2.8.6 Analyst View
  - 5.2.8.7 Market Share
- 5.2.9 Toshiba Energy Systems & Solutions Corporation
  - 5.2.9.1 Overview
  - 5.2.9.2 Top Products/Product Portfolio
  - 5.2.9.3 Top Competitors
  - 5.2.9.4 Target Customers
  - 5.2.9.5 Analyst View
  - 5.2.9.6 Market Share
- 5.2.10 Nel ASA
  - 5.2.10.1 Overview
  - 5.2.10.2 Top Products/Product Portfolio
  - 5.2.10.3 Top Competitors
  - 5.2.10.4 Target Customers

- 5.2.10.5 Key Personnel
- 5.2.10.6 Analyst View
- 5.2.10.7 Market Share
- 5.2.11 SGH2 Energy Global Corp.
  - 5.2.11.1 Overview
  - 5.2.11.2 Top Products/Product Portfolio
  - 5.2.11.3 Top Competitors
  - 5.2.11.4 Target Customers
  - 5.2.11.5 Analyst View
  - 5.2.11.6 Market Share
- 5.2.12 Plug Power Inc.
  - 5.2.12.1 Overview
  - 5.2.12.2 Top Products/Product Portfolio
  - 5.2.12.3 Top Competitors
  - 5.2.12.4 Target Customers
  - 5.2.12.5 Key Personnel
  - 5.2.12.6 Analyst View
  - 5.2.12.7 Market Share
- 5.2.13 Aker Horizons
  - 5.2.13.1 Overview
  - 5.2.13.2 Top Products/Product Portfolio
  - 5.2.13.3 Top Competitors
  - 5.2.13.4 Target Customers
  - 5.2.13.5 Key Personnel
  - 5.2.13.6 Analyst View
  - 5.2.13.7 Market Share
- 5.2.14 HY2GEN AG
  - 5.2.14.1 Overview
  - 5.2.14.2 Top Products/Product Portfolio
  - 5.2.14.3 Top Competitors
  - 5.2.14.4 Target Customers
  - 5.2.14.5 Analyst View
  - 5.2.14.6 Market Share
- 5.2.15 Fusion-Fuel
  - 5.2.15.1 Overview
  - 5.2.15.2 Top Products/Product Portfolio
  - 5.2.15.3 Top Competitors
  - 5.2.15.4 Target Customers
  - 5.2.15.5 Key Personnel

5.2.15.6 Analyst View

5.2.15.7 Market Share

## **6 RESEARCH METHODOLOGY**

6.1 Data Sources

6.1.1 Primary Data Sources

6.1.2 Secondary Data Sources

6.1.3 Data Triangulation

6.2 Market Estimation and Forecast

## List Of Figures

### LIST OF FIGURES

Figure 1: Global Green Hydrogen Market (by Region), 2022, 2026, and 2033

Figure 2: Global Green Hydrogen Market (by Application), \$Million, 2022, 2026, and 2033

Figure 3: Global Green Hydrogen Market (by Technology), \$Million, 2022, 2026, and 2033

Figure 4: Green Hydrogen, Recent Developments

Figure 5: Supply Chain and Risks within the Supply Chain

Figure 6: Patent Analysis (by Country), January 2020-December 2023

Figure 7: Patent Analysis (by Company), January 2020-December 2023

Figure 8: Impact Analysis of Market Navigating Factors, 2023-2033

Figure 9: Strategic Initiatives, 2020-2023

Figure 10: Share of Strategic Initiatives

Figure 11: Data Triangulation

Figure 12: Top-Down and Bottom-Up Approach

Figure 13: Assumptions and Limitations

## List Of Tables

### LIST OF TABLES

Table 1: Global Green Hydrogen Market Snapshot

Table 2: Green Hydrogen Opportunities across Regions

Table 3: 12. List of Key Oil and Gas Projects Utilizing Green Hydrogen

Table 4: 12. List of Key Ammonia Projects Utilizing Green Hydrogen

Table 5: 12. List of Key Methanol Projects Utilizing Green Hydrogen

Table 6: Global Green Hydrogen Market (by Region), \$Million, 2022-2033

Table 7: North America Green Hydrogen Market (by Application), \$Million, 2022-2033

Table 8: North America Green Hydrogen Market (by Technology), \$Million, 2022-2033

Table 9: North America Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033

Table 10: U.S. Green Hydrogen Market (by Application), \$Million, 2022-2033

Table 11: U.S. Green Hydrogen Market (by Technology), \$Million, 2022-2033

Table 12: U.S. Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033

Table 13: Canada Green Hydrogen Market (by Application), \$Million, 2022-2033

Table 14: Canada Green Hydrogen Market (by Technology), \$Million, 2022-2033

Table 15: Canada Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033

Table 16: Mexico Green Hydrogen Market (by Application), \$Million, 2022-2033

Table 17: Mexico Green Hydrogen Market (by Technology), \$Million, 2022-2033

Table 18: Mexico Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033

Table 19: Europe Green Hydrogen Market (by Application), \$Million, 2022-2033

Table 20: Europe Green Hydrogen Market (by Technology), \$Million, 2022-2033

Table 21: Europe Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033

Table 22: France Green Hydrogen Market (by Application), \$Million, 2022-2033

Table 23: France Green Hydrogen Market (by Technology), \$Million, 2022-2033

Table 24: France Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033

Table 25: Germany Green Hydrogen Market (by Application), \$Million, 2022-2033

Table 26: Germany Green Hydrogen Market (by Technology), \$Million, 2022-2033

Table 27: Germany Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033

Table 28: U.K. Green Hydrogen Market (by Application), \$Million, 2022-2033

- Table 29: U.K. Green Hydrogen Market (by Technology), \$Million, 2022-2033
- Table 30: U.K. Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033
- Table 31: Spain Green Hydrogen Market (by Application), \$Million, 2022-2033
- Table 32: Spain Green Hydrogen Market (by Technology), \$Million, 2022-2033
- Table 33: Spain Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033
- Table 34: Italy Green Hydrogen Market (by Application), \$Million, 2022-2033
- Table 35: Italy Green Hydrogen Market (by Technology), \$Million, 2022-2033
- Table 36: Italy Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033
- Table 37: Russia Green Hydrogen Market (by Application), \$Million, 2022-2033
- Table 38: Russia Green Hydrogen Market (by Technology), \$Million, 2022-2033
- Table 39: Russia Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033
- Table 40: Rest-of-Europe Green Hydrogen Market (by Application), \$Million, 2022-2033
- Table 41: Rest-of-Europe Green Hydrogen Market (by Technology), \$Million, 2022-2033
- Table 42: Rest-of-Europe Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033
- Table 43: Asia-Pacific Green Hydrogen Market (by Application), \$Million, 2022-2033
- Table 44: Asia-Pacific Green Hydrogen Market (by Technology), \$Million, 2022-2033
- Table 45: Asia-Pacific Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033
- Table 46: China Green Hydrogen Market (by Application), \$Million, 2022-2033
- Table 47: China Green Hydrogen Market (by Technology), \$Million, 2022-2033
- Table 48: China Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033
- Table 49: India Green Hydrogen Market (by Application), \$Million, 2022-2033
- Table 50: India Green Hydrogen Market (by Technology), \$Million, 2022-2033
- Table 51: India Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033
- Table 52: South Korea Green Hydrogen Market (by Application), \$Million, 2022-2033
- Table 53: South Korea Green Hydrogen Market (by Technology), \$Million, 2022-2033
- Table 54: South Korea Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033
- Table 55: Australia Green Hydrogen Market (by Application), \$Million, 2022-2033
- Table 56: Australia Green Hydrogen Market (by Technology), \$Million, 2022-2033
- Table 57: Australia Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033



Table 58: Japan Green Hydrogen Market (by Application), \$Million, 2022-2033

Table 59: Japan Green Hydrogen Market (by Technology), \$Million, 2022-2033

Table 60: Japan Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033

Table 61: Rest-of-Asia-Pacific Green Hydrogen Market (by Application), \$Million, 2022-2033

Table 62: Rest-of-Asia-Pacific Green Hydrogen Market (by Technology), \$Million, 2022-2033

Table 63: Rest-of-Asia-Pacific Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033

Table 64: Rest-of-the-World Green Hydrogen Market (by Application), \$Million, 2022-2033

Table 65: Rest-of-the-World Green Hydrogen Market (by Technology), \$Million, 2022-2033

Table 66: Rest-of-the-World Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033

Table 67: South America Green Hydrogen Market (by Application), \$Million, 2022-2033

Table 68: South America Green Hydrogen Market (by Technology), \$Million, 2022-2033

Table 69: South America Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033

Table 70: Middle East and Africa Green Hydrogen Market (by Application), \$Million, 2022-2033

Table 71: Middle East and Africa Green Hydrogen Market (by Technology), \$Million, 2022-2033

Table 72: Middle East and Africa Green Hydrogen Market (by Renewable Energy Source), \$Million, 2022-2033

Table 73: Market Share, 2022

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