WHY HYDROGEN VEHICLES ARE READY FOR THE MAINSTREAM

Whitepaper

KEY VERTICAL MARKETS

JUNIPER RESEARCH

1.1 Introduction

FCVs (Fuel Cell Vehicles) are powered by hydrogen and are more efficient than conventional internal combustion engine vehicles. FCVs do not produce tailpipe emissions, but only emit water vapour and warm air. The fuel cell was demonstrated in the early 19th century by many scientists, including Humphry Davy and Christian Friedrich Schönbein. William Grove, a chemist, physicist, and lawyer, is generally credited with inventing the fuel cell in 1839.

Fuel cell vehicles, also known as hydrogen vehicles, first came to the international limelight in the 1970s, during the oil crisis. Following several years of R&D, Toyota launched the world's first commercialised fuel cell vehicle in 2014. China, the US, Japan, and various European countries have since focused on advancing this technology to pave the way for fuel cell applications to enter the golden era of innovation.

1.2 Definitions & Scope

Juniper Research defines hydrogen vehicles as:

'A vehicle that uses a hydrogen propulsion system as its onboard fuel. The chemical energy of hydrogen and oxygen reacts with the fuel cell and converts the energy to electricity. Hydrogen vehicles produce no harmful tailpipe emissions.'

Fuel cell technology used in hydrogen vehicles is similar to a battery, in that it generates electricity from an electrochemical reaction. It uses an external supply of chemical energy, supplied with a source of hydrogen and a source of oxygen (usually air) – meaning they can run indefinitely. Fuel cells offer clean, efficient, reliable power generation to almost any device requiring electrical power. Hence fuel cells are used in a wide range of transport applications, from hydrogen vehicles to aeroplanes.

1.3 Current Hydrogen Vehicles Landscape and Trends

Due to government initiatives promoting the progress of the fuel cell industry through heavy investment in core technology, since the early 2000s, hydrogen vehicles have been in several prototyping and production stages. Industry players have made further significant advancements in establishing strategic subsidy policies in fuel cell plans, whereby nearly all types of modern vehicles now have fuel cell products or are prototypes. There is a wide range of application types due to hydrogen vehicles' simplicity and flexibility in the current landscape.

The commercial hydrogen vehicle market has been segmented by bus and truck types. Trucks are still in the development stage, but buses are already in operation. Forklifts, buses, and light and medium-sized trucks are at the forefront of fuel cell commercial vehicle applications.

1.3.1 The Environmental & Economic Context

Traditional fuels have significant environmental externalities, including air pollution, water pollution, plastic pollution, and oil spills. The burning of fossil fuels, especially carbon dioxide, to generate electricity and power transportation, has far-reaching effects on the climate and ecosystems. Alternative fuels such as hydrogen reduce carbon dioxide, sulphur dioxide, nitrogen oxides, carbon monoxide, and particulate matter gradually gain popularity and acceptance.

The cost of traditional fuels has increased to its highest in recent months, as illustrated in figure 1. The cold weather in February (2021), hurricanes in August (2021), and the decline in investment among US oil producers since mid-2020 decreased US crude oil production. The low supply ultimately led to the rise in prices. Sanctions imposed on Russia, the second biggest exporter of crude oil, have conversely led to a sharp increase in fuel prices.

Figure 1: Europe Brent Spot Price FOB (Dollars per Barrel), Jan 2018 – May 2022

Source: US Energy Information Administration

1.3.2 Exploration as an Alternative to EVs (Electric Vehicles)

As hydrogen production and infrastructure investments increase, hydrogen-fuelled vehicles will become a more sustainable alternative than electric vehicles. EVs may not depict an effective alternative to ICE (Internal Combustion Engine) vehicles because their emissions potential depends on how the electricity is produced.

The limitations of EVs are highlighted by the existence of hybrid vehicles in many commercial sectors. Buses, trains, and trucks are widely available as diesel-electric hybrids; proving that based on current technology, EVs are not up to the task of providing a mass transit solution. Additionally, hydrogen is being touted as an alternative to EVs because EVs use large, heavy, expensive batteries that require rare earth metals such as cobalt, nickel, and lithium.

As much as hydrogen requires platinum in the production process, it is needed only in production centres and in minimum quantities. Research on finding an alternative to platinum is also at an advanced stage. The rare metals used in EVs are required for every EV battery.

The advantages hydrogen vehicles have over electric vehicles include:

- Hydrogen can be pumped using the existing network of petrol stations.
- Hydrogen vehicles can achieve longer distances because they densely pack their energy storage.
- Filling up a hydrogen vehicle takes a few minutes compared to EVs, which take eight hours.

Major automakers, including BMW and Audi, believe that a change in the political atmosphere could favour hydrogen vehicles over EVs. They are presently developing hydrogen fuel cell passenger vehicle prototypes in addition to their battery cars, as part of preparations to phase out fossil fuels. Before this, Japanese carmakers Toyota, Nissan, Honda, and South Korea's Hyundai were the only manufacturers developing and pushing for hydrogen fuel cell cars for years. Moreover, China is expanding its hydrogen fuelling infrastructure, and the EU wants to build more hydrogen fuelling stations for commercial vehicles. The future of hydrogen vehicles is expected to be expansive based on the latest developments.

1.4 Current Hydrogen Vehicle Initiatives

Mazda has explored the concept of a rotary engine that burns hydrogen in place of petrol – the RENESIS hydrogen rotary engine system. The hydrogen rotary engine is based on Mazda's unique rotary engine technology but adapted to use hydrogen as its fuel, which does not emit CO_2 and offers outstanding environmental performance.

The rotary engine required minimal design changes to operate on hydrogen; enabling Mazda to build hydrogen-fuelled rotary engine vehicles at a low cost. Additionally, a dual-fuel system allows the vehicle to run on either gasoline or hydrogen. Running out of hydrogen is no longer a concern; making the car suitable as it can travel long distances to areas without hydrogen stations. The RENESIS hydrogen rotary engine system draws in air from a side port and directly injects hydrogen using an electronically controlled hydrogen gas injector installed on the top of the rotor housing. The Mazda RX-8 Hydrogen RE is the world's first practical implementation of a hydrogen rotary engine vehicle.

In 2021, Toyota showcased its new hydrogen-powered combustion engine technology in the GR Yaris. In addition, Toyota's experimental hydrogen-powered Corolla Sport performs exceptionally at motorsport events in Japan with near-zero tailpipe emissions. Although hydrogen combustion engine technology is still in the early stages of development and experimentation, it achieves high performance. The hydrogen-powered GR Yaris and the Corolla Sport feature G16E-GTS, 1.6-litre, in-line three-cylinder, turbocharged engine, but with an altered fuel supply and injection system for use with hydrogen as fuel.

The ability to re-use existing ICE technology in hydrogen vehicles is a major positive factor for manufacturers, meaning that while consumer adoption has not yet happened at scale, manufacturers will continue to invest.

The EU has several hydrogen regulatory initiatives in the making. These initiatives will be vital to the development of a vibrant hydrogen market. They include the following:

1.4.1 Proposed Revision of RED II to Include Renewable Hydrogen

RED II (Second Renewable Energy Directive) is a law in the EU that promotes renewable energy across all sectors of the EU economy. RED II establishes common principles and rules to remove barriers, encourage investments and facilitate cost reductions in renewable energy technology. The proposed amendments extend the EU-wide certification system for renewable fuels to include hydrogen. Additionally, in support of the 40GW electrolyser goal in the EU's Hydrogen Strategy, a revised target of 50% renewable share in hydrogen consumption in the industry has been proposed. The adoption of the proposed revision is anticipated to conclude in 2022.

1.4.2 Proposed Revision of the EU Emissions Trading System to Include Renewable and Low-carbon Hydrogen

The EU-ETS (EU Emissions Trading System) contributes to the EU's greenhouse gas reduction targets by setting a cap on the total amount of greenhouse gas emissions from participating entities, such as power stations and industrial plants. The scheme follows the 'polluter pays' principle. Participating entities must buy, through auctions, or receive emissions allowances for each tonne of CO_2 equivalent they emit. The participating entities can also trade emission allowances between each other.

Only fossil-based hydrogen production is part of the scope and receives free allowances under the EU-ETS. The revision proposed by the EC will spread the scope of the EU-ETS to include the production of hydrogen, with electrolysers making renewable and low-carbon facilities eligible for free allowances. Broadening the size of the EU-ETS will protect participating entities switching to renewable or low-carbon technology from competitive disadvantages. Adoption of the revised EU-ETS ended in 2021.

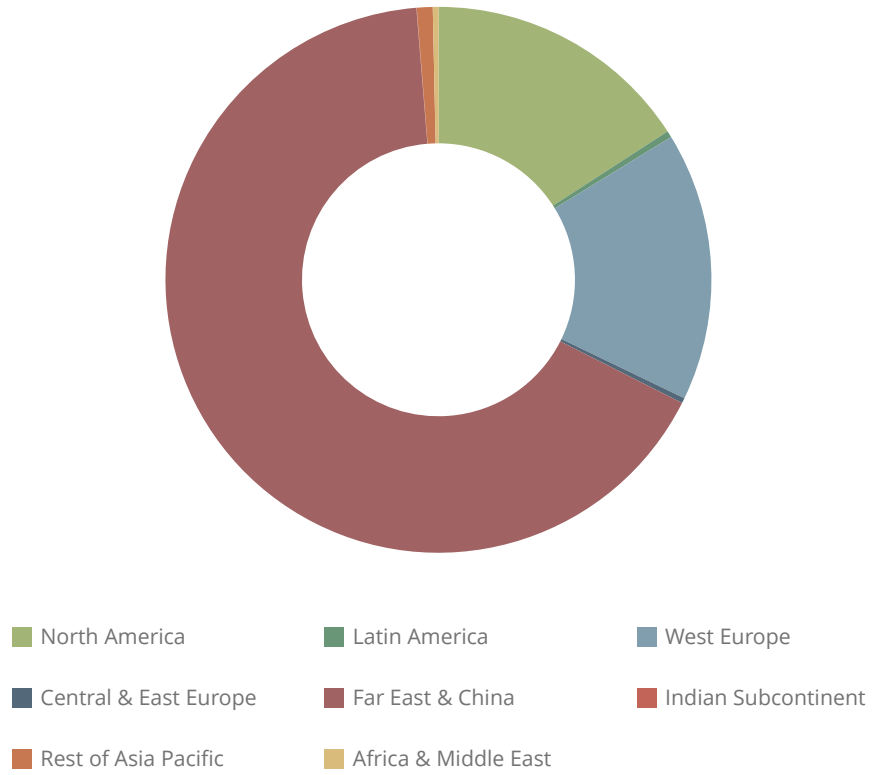
1.4.3 The Ongoing Revision of the EU Secondary Gas Market Legislation

The Gas Directive (Directive 2009/73/EC) and the Gas Regulation (Regulation 715/2009) were under two reviews. Firstly, the gas market legislation was revised to address the emergence of a hydrogen market and hydrogen infrastructure in 2021. Secondly, the gas market legislation was modified to facilitate access to existing gas infrastructure (transmission, distribution, and storage infrastructure) and LNG (Liquified Natural Gas) terminals and markets, subject to what is possible technically.

1.5 Forecast Summary

The number of hydrogen vehicles in service globally will exceed 1 million in 2027, from just over 60,000 in 2022 – a substantial growth of over 1,500%.

Figure 2: Total Number of Hydrogen-powered Vehicles in Service in 2027: 1 Million



Source: Juniper Research

- Hydrogen vehicles are an increasingly viable alternative to BEVs (Battery Electric Vehicles). The potential for enhanced range and rapid refuelling compares favourably with BEVs; reducing customer anxieties around BEV ownership. These positives have led to significant investment by car manufacturers, including Hyundai, Toyota and BMW, and this will translate into an increasingly popular and available product over the next five years.
- The consumer market will lead the hydrogen vehicles space, with consumer vehicles accounting for over 60% of hydrogen vehicles in service globally in 2027. The nascent development stage of many commercial vehicle types and the high average cost of hydrogen-powered commercial vehicles, at over $70,000 globally in 2022, are key factors limiting adoption.
- Additionally, the low availability of fuelling infrastructure is a key challenge for wider adoption, but heavy industry investment is key to reducing this concern over the next five years. Infrastructure vendors must provide 'green' hydrogen, produced using renewable energy sources, to best take advantage of concerns around the environment driving the adoption of alternative fuels.

Order the Full Research

In our brand-new report, discover an invaluable assessment of this early-stage market. Featuring in-depth examination of the different segments critical to the success of hydrogen in new use cases, the research is split out to 2027 for 8 key regions and 60 countries, as well as split by consumer vehicles and commercial vehicles.

Key Features

- **Market Dynamics:** Detailed assessment of how hydrogen vehicles are coming to the fore, including a comparison with battery electric vehicles, an analysis of the technologies involved and an assessment of current areas of success for hydrogen vehicles.
- **Segment Analysis:** Future outlook for the development of five different markets critical to hydrogen development, including::
    - Consumer Hydrogen Vehicles
    - Commercial Hydrogen Vehicles
    - Hydrogen in Aviation
    - Hydrogen Production
    - Hydrogen Fuelling Infrastructure
- **Key Vendor Case Studies:** Case studies on important vendors in the hydrogen vehicles space and their differing approaches to the market, including:
    - Audi
    - BMW
    - Daimler
    - Honda
    - Hyundai
    - Toyota
- **Benchmark Industry Forecasts:** Five-year forecasts provided for the total number of hydrogen vehicles in service, vehicle shipments and accompanying hardware revenue, split by consumer and commercial vehicles. Data is also split by our 8 key regions and 60 countries.

What's in this Research?

1. **Market Trends & Opportunities:** Detailed analysis and strategic recommendations to capitalise on the future growth of the hydrogen vehicle market, including prospects for growth and the trends shaping deployments and developments. These include the context of rising fuel costs, the increasing maturity of hydrogen vehicle technology and initiatives from governments to support development.
2. **Strategic Analysis:** Examines the future outlook for the different segments in the hydrogen vehicles ecosystem and provides comprehensive analysis of the key trends and market disruptions. The report also delivers an assessment of six major players within the hydrogen vehicles market via in-depth case studies.
3. **Interactive Forecast Excel:** Highly granular dataset comprising over 7,300 datapoints; allied to regional and sector analysis tools. Includes regional and country-level analysis, together with 5-year forecasts for the total number of hydrogen vehicles in service, vehicle shipments and accompanying hardware revenue, split by consumer and commercial vehicles.
4. **harvest Digital Markets Intelligence Centre:** Visualises all the data in easy to use and exportable graphs, tables and charts, and features continuous data updates for 12 months.

Publication Details

Publication Date: June 2022

Authors: Nick Maynard & Olivia Williams

Contact: For more information contact info@juniperresearch.com

Juniper Research Ltd, 9 Cedarwood, Chineham Park, Basingstoke, Hampshire, RG24 8WD UK

Tel: UK: +44 (0)1256 830002/475656 USA: +1 408 716 5483 (International answering service)

http://www.juniperresearch.com