WHITE PAPER:
Hydrogen Engine: Market perspectives in Europe

We make **hydrogen**
a practical proposition

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1. Introduction

As governments and corporations are becoming increasingly committed to addressing climate change and reducing emissions, they are placing greater emphasis on the deep decarbonization of the energy sector, promoting the energy transition from fossil fuels to net zero carbon.

As a versatile and sustainable energy carrier, hydrogen is gaining unheard-of political and commercial momentum, and it may be the final piece needed to fully decarbonize a variety of industries over the coming decades and open new opportunities for companies to build a new sustainable and collaborative economy.

1.1 The role of hydrogen in the energy transition

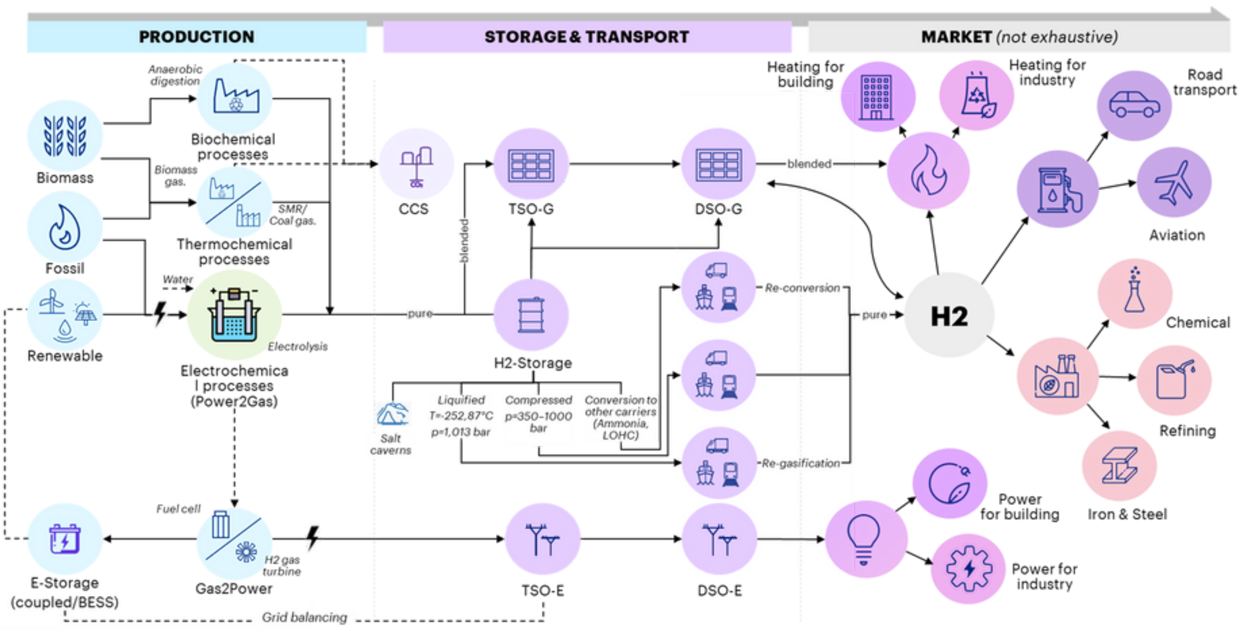
Companies should indeed make a substantial contribution to the energy transition that is occurring throughout the whole energy, resource, and industrial sectors. Organizations in the industrial and energy sectors will need to adapt to the new challenge while remaining resilient and maintaining their presence in the market.

The need to shift to a low-carbon sustainable energy system sets the foundation to evolve, through the creation of complementary businesses, the creation of new markets and the realization of new sources of value from current assets and capabilities.

Hydrogen can be produced from different sources. It is a flexible energy carrier with the capacity to distribute and store enormous amounts of energy rather than being an energy source like natural gas, coal or crude oil.

Electrolysis enables hydrogen production without emitting CO_2. By providing electrical energy to a cathode and an anode, which will produce hydrogen and oxygen respectively, the electrolysis of water is accomplished. When using renewable energy sources, the entire process produces zero CO_2.

No CO_2 is produced using green hydrogen for the decarbonization of our economy, while releasing energy through combustion (burning) or as electricity (fuel cells). Therefore, substituting hydrogen to conventional carriers in a variety of economic sectors, including transportation, domestic and industrial heating, industrial processes, and feedstock has the potential to significantly reduce greenhouse gas emissions.



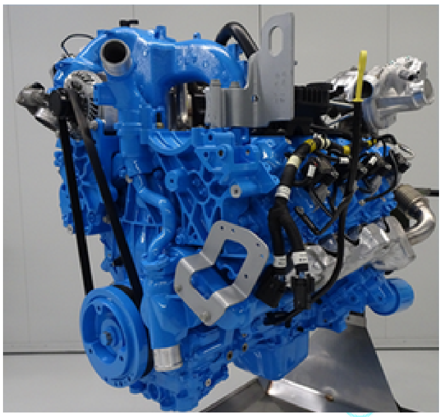
Sources: Accenture Analysis

Figure 1: *Hydrogen Value Chain*

1.2 Hydrogen technologies

Reducing emissions of many end-use applications, such as transport, may include both hydrogen Internal Combustion Engines (H_2-ICE) and Hydrogen Fuel Cell (FC), which could power various uses across the value chain using a zero-carbon fuel, including also on-highway and off-highway applications.

Similarly to an engine powered by spark ignition, hydrogen engines could work with hydrogen as a fuel. On the other hand, in a fuel cell, hydrogen is converted into electricity that is used to power an electric motor, much like in an electric vehicle. In any case, hydrogen fuel cells and engines tend to be complementary since they could thrive in the same ecosystem.



KEY COMPONENTS OF H_2 ENGINES

Injection system & int. manifold	Port Fuel Injection; Direct Injection
Ignition	Spark plug and coil
Specific SW	Specific controls Hydrogen combustion
Air delivery & charging	Improved turbo charging and different valve phasing for lean combustion
Piston & Piston Rings	Specific compression ratio and piston rings optimization
Valves and Valves Seats	Material optimization for dry combustion
Specific H_2 sensors	Detection of H_2 concentration

Figure 2: *PUNCH Hydrocells Hydrogen Engine*

1.3 Opportunities for H_2 Engine

In many of the world's largest markets, regulators are becoming stricter regarding emissions. As an example, European regulators will require manufacturers to reduce their CO_2 emissions for new on-road trucks by 30 percent from 2030, compared with 2019 levels.[1]

Regarding off-highway vehicles, they have historically received less regulatory attention, but OEMs in this market are preparing for growing consumer pressure to reduce carbon emissions. For instance, major mining companies have established ambitious decarbonization goals over the past two years, aiming for Scope 1 and 2 CO_2 neutrality[2], such as Anglo American and Fortescue, which stated their goals of Scope 1 and 2 carbon neutrality by 2040[3]. Other companies such as BHP, Rio Tinto, Teck, and Vale hope to have reached these targets by 2050. To date, diesel engines are primarily found in mining equipment including dump trucks, haul trucks, loaders, dozers, and excavators. A significant switch to zero-emission vehicles will be necessary to drastically reduce the emissions in the mining industry.

Pressure is mounting also to create zero-emissions technologies in other industries, such as construction and agriculture. City-level air-quality restrictions are enforcing decarbonization standards for construction vehicles and directing customers toward zero-emissions excavators, loaders, graders, and lift trucks. Consumer pressure may well induce a quick switch to zero-emission farm tractors and sprayers due to increased social concern about sustainability in the agriculture sectors. In this context, engines powered by hydrogen can help to achieve zero emissions by utilizing already-existing technology, offering a zero CO_2 option for particular use cases, and promoting the development of hydrogen infrastructure.

Hydrogen propulsion technologies could also offer potential for maritime sector. The maritime shipping sector is essential for the global economy, but it represents a significant contributor to worldwide emissions.

However, limits have been set on the sulphur content of the fuel in the existing fleet; Emission Control Areas (ECAs) with stricter restrictions were established to reduce emissions from ships. NOx emission limits were set for new built ships.
All ships built after January 1st, 2021, and entering the Baltic, North Sea, and English Channel Emission Control Areas must meet the Tier III standard established by the IMO.[4]

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[1] "Cutting emissions: Council adopts CO2 standards for trucks," Council of the EU press release, June 13, 2019
[2] Scope 1 emissions are direct greenhouse (GHG) emissions that occur from sources that are controlled or owned by an organization (e.g., emissions associated with fuel combustion in boilers, furnaces, vehicles). Scope 2 emissions are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling. Source: EPA, link
[3] Anglo American and Fortescue announcement
[4] International Maritime Organization (IMO)

TECHNOLOGY	AIR QUALITY	MATURITY	EFFICIENCY[1]	PROs	CONs
CONVENTIONAL ICE Combustion of fuel occurs with an oxidizer (air)	✗ **CO_2, NOx** and hydrocarbons are released when fuel burns in an ICE	**TRL: 9** Fully commercialized technology around the world.	▪ Engines **efficiency value around 27-36%**	▪ Power generator in areas where the other technologies face barriers due to its high reliability ▪ Dual fuel option; ▪ Quick refueling time	▪ Restricted usage in the future due to CO_2 emission reduction imposed by regulation
HYDROGEN ICE No emission version of the traditional ICE	✓ H2 ICEs have no **CO_2 ,CO, HC** and **PM tailpipe emissions. Close to zero tailpipe NOx** is **possible**	**TRL: 6-7** Based on the presence of only one commercialized project	▪ Engine efficiency value **around 27-36%** ▪ Co-generation (electric and thermal) efficiency up to **85-90%**	▪ Reliability to harsh conditions ▪ Low purity H_2 grade acceptable; ▪ Dual fuel option; ▪ Higher efficiency at higher load ▪ Operator capabilities for maintenance like conventional ICE and easier retrofit; ▪ Quick refueling time	▪ Large H_2 storage system required ▪ H_2 fuel infrastructure to be developed
HYDROGEN FUEL CELL Electrochemical cell that converts hydrogen and oxygen into electricity	✓ "Emitting" only **water vapor**, producing no tailpipe emissions	**TRL: 8** Considering PEM small-scale applications in the kW-class.	▪ The energy efficiency of a fuel cell is generally **between 40% and 46%**	▪ Low noise level; ▪ Higher efficiency at lower loads ▪ Easier scalability being a modular product ▪ Quick refueling time	▪ Large H_2 storage system required ▪ H_2 fuel infrastructure to be developed ▪ Required ad-hoc system for integrating in the application
PLUG-IN ELECTRIC MOTOR Electrical machine that converts electrical energy into mechanical energy ***Not applicable to Genset/ CHP***	✓ Running only on electricity have **zero tailpipe emissions**	**TRL: 9** Widespread use of battery electric vehicles around the world.	▪ High efficiency **(~75% of rated load).**	▪ Low noise level; ▪ Maintenance limited to battery inspections	▪ Large battery system required; ▪ Required ad-hoc system for integrating in the application; ▪ Long charging time ▪ High battery weight ▪ Recharging infrastructure (more space required)

Notes: 1. Global efficiency of the product (e.g., vehicle)
Sources: VGB Scientific Advisory Board; International Journal of Green Energy; Ocean Engineering journal; MDPI Sustainability, Accenture Analysis

Figure 3: *Main propulsion technologies comparison*

2. Opportunities of H_2 technologies for on-highway and off-highway applications

2.1 Promising applications for Hydrogen technologies

Hydrogen engine technology has the potential to fill a critical gap by utilizing established supply chains and technological infrastructure.

Despite significant advancements, batteries and fuel-cell technology are still not able to provide the high levels of power required for the challenging environments that many heavy-duty vehicles (particularly in the off-highway category) must operate in. For instance, mining trucks need several megawatts of power to run continuously, are subject to intense vibrations and heat development, as well as airborne dust. These criteria have been satisfied by internal combustion engines for decades and switching from diesel to hydrogen could be an effective approach to decarbonizing these engines with a little amount of additional technological development.

Moreover, hydrogen engines may find use even in areas where batteries and fuel cells are technically feasible; the relative high efficiencies reached by hydrogen engines at high loads, the declining price of hydrogen, and low capex requirements for combustion engines all contribute to the possibility of hydrogen engine as a competitive alternative in regards of Total Cost of Ownership (TCO).

Over and above all these technical features, hydrogen engine technology brings a significant advantage for automotive OEMs and component suppliers to keep leveraging their current engineering know-how, relying on established supply chains, and utilizing existing production facilities.

Hydrogen engine can play their role with multiple applications to provide complementary solutions to FCEVs (Fuel Cell Electric Vehicles) and BEVs (Battery Electric Vehicles), supporting the path to achieving zero emissions across various application segments, including:

On-highway application:
- Heavy-duty vehicles
- Medium-duty vehicles/Bus
- Light-duty vehicles

Off-highway applications:
- Mining and construction vehicles (e.g., excavators, dump trucks, crawler dozers), agricultural vehicles, (e.g., tractors, harvesting machinery) and material handling (e.g., forklift)
- Marine boats (e.g., taxi boats, cargo, cruises, harbor tugs)
- Stationary applications, such as Gensets
- Railway applications (e.g., shunters)

Among applications that could be powered by clean energies, the potential of hydrogen engines against other technologies has been identified by performing, on specific use cases, the Total Cost of Ownership analysis, which represents the complete cost through the entire lifecycle.

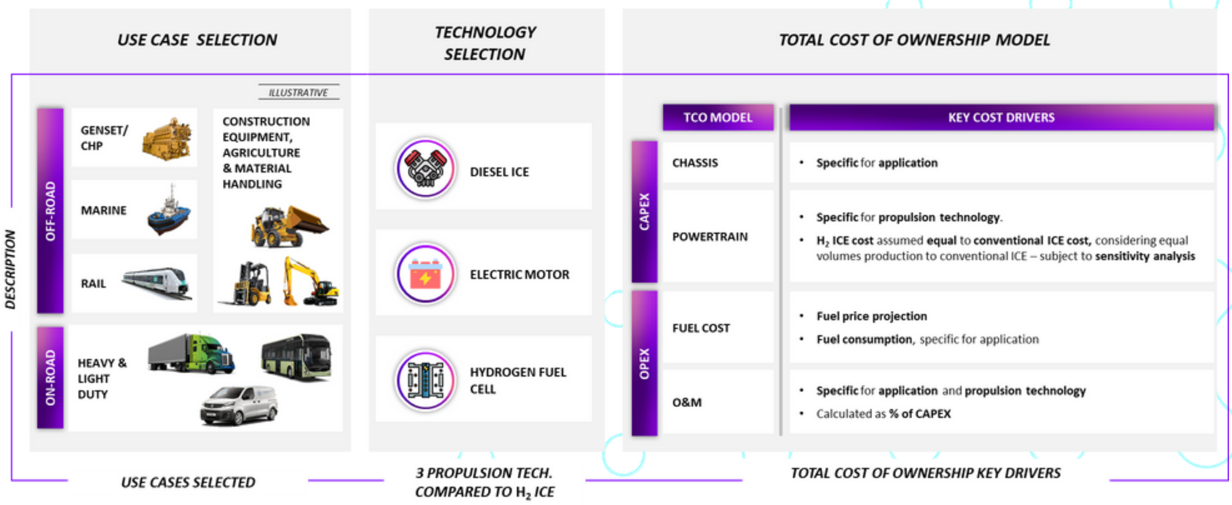


Figure 4: *Methodology for the Total Cost of Ownership model, to compare propulsion technologies on selected use cases*

To come close to a realistic TCO, all direct and indirect costs, have been considered according to the specific features of different use cases. In particular:

> Capital expenditures including:

- Chassis, the frame of the vehicle/device, (including the wheels and other components not related to the powertrain)
- Powertrain, which includes all the necessary components directly linked to the energy used to power the vehicle/device

> Operational expenditures including:

- Fuel Cost, according to the projection of hydrogen, diesel, and electricity in the next years
- Fuel Consumption, driven by the specific technology and application
- O&M costs as a percentage of CAPEX, based on the specific technology considered

	Diesel ICE	ELECTRIC MOTOR	H_2 Fuel Cell	H_2 ICE
CAPEX				
Chassis	• Specific for application	• Specific for application	• Specific for application	• Specific for application
Powertrain	• ICE	• E-drive • Large Battery	• E-drive • PEM Fuel Cell • Small battery • H_2 Tank	• ICE • H_2 Tank
OPEX considering 10 years of application usage				
Fuel cost	• Diesel price 2024-2037 • Carbon tax considered[1]	• Energy price 2024-2037	• Green Hydrogen price 2024-2037. • 2 production models considered: Centralized and Decentralized	
Fuel consumption	Specific for application			
O&M	• 5% of CAPEX, considering high number of parts subject to periodic replacement (e.g., oil filter, engine air filter)	• 1,5% of CAPEX, considering lower number of moving parts and related need of service, compared to Diesel ICE	• 2% of CAPEX, considering higher number of components compared to Electric Motor, and H_2 Tank	• 5% of CAPEX, assumed equal to Diesel ICE, considering H_2 Tank maintenance and the use of less complex engine components (e.g., injection system)

Figure 5: *Key drivers of the Total Cost of Ownership Model - Capex & Opex variables*

The fuel cost represents one of the key drivers for the calculation of the TCO in the period 2023-2028.

The hydrogen price has been estimated for two different models (centralized and decentralized) with different supply chains and different production rates from electrolysis directly connected to RES.

Several key trends, (e.g., decreasing costs of RES and electrolyzer) could make hydrogen cheaper by 2030.

The decline in generation costs could also support reducing electricity costs (which considers base price, grid fees, taxes and surcharges and infrastructure-related costs). Until 2030 the base electricity price is expected to decrease, for both fast and standard charging types.

The market development over the next years is crucial for achieving climate goals and CO_2 -intensive technology such as diesel is set to be replaced across the EU.

Diesel costs soared to record highs in many countries across Europe and are expected to grow due to a demand drop.
Today high green fuel costs represent a barrier to the widespread adoption of alternative technologies, but trends show a cost shift in this pattern.

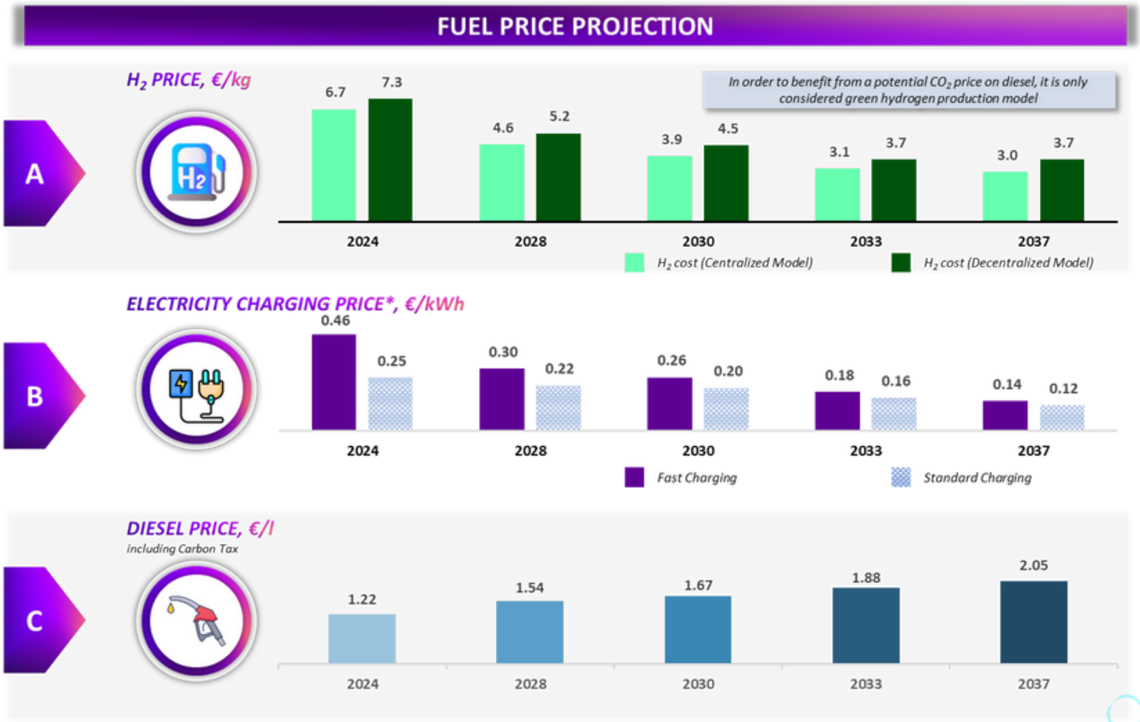


Figure 6: *Fuel Price Trends (2024 – 2037)*

The H_2 production models (decentralized and centralized) are based on the integration of solar photovoltaic plant with electrolyzer to produce green H_2.

A decentralized scenario considers H_2 production near the point of use without the need of an infrastructure for transporting it over long distances.

A centralized scenario considers a decentralized model until 2026 and a large-scale production plant (~ 500 MW) for the next years.

Fuel cost is the main cost driver of TCOs and is expected to support the future competitiveness of electric motors, fuel cells, and H_2-ICE propulsion technologies.

Diesel ICE is expected to decrease market penetration in Europe, due to high TCOs, driven by the expected increasing cost of fuel and increasing value of Carbon Tax.

Based on the 2024-2028 TCO analysis, the H_2-ICE propulsion technology is expected to be competitive in Heavy Duty (Truck and Bus), Genset, Construction Machinery, Marine and Train applications.

2.2 Market perspectives for H_2 technology in Europe

H_2-ICE technology is expected to grow in Europe in the next few years, for Genset, forklift and heavy-duty trucks. The market growth will depend on how the H_2 market and the infrastructure will be developed, and how some applications that today are prototypes (e.g., marine, construction) will increase their penetration in the next years.

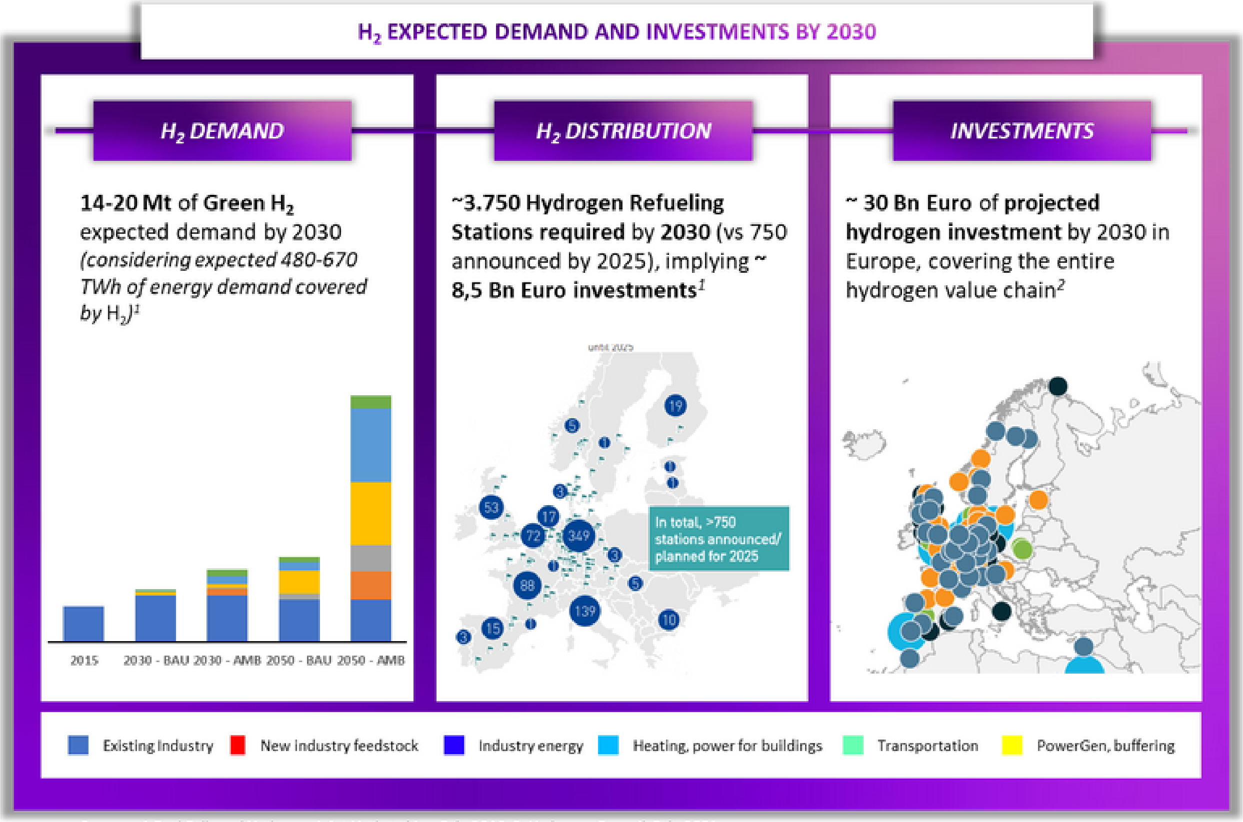
H_2-ICE volumes in Europe have been estimated considering the following drivers:

- Key market trends for considered industries (e.g., market size and expected growth);
- H_2-ICE TCO positioning compared to other technologies;
- Expected volumes of Hydrogen Fuel Cells in selected industries;
- Green hydrogen production forecast in Europe, in 2023-2028; timeframe, considering European Commission 2030 targets;
- Expected regulations on specific topics (CO_2 emissions and hydrogen) in Europe (e.g., On-road);
- OEM ability to transform conventional engines production plant to produce BEV, FC and H_2-ICE.

Hydrogen is expected to cover 4-6% of European energy demand by 2030, driven by:

- EU Commission 2030 targets for Hydrogen production: 40 GW of renewable hydrogen electrolyzers in EU and 10M tonnes of Green Hydrogen produced in Europe[5]
- EU Commission 2030 targets for Hydrogen Delivery Infrastructure: One refueling station will be available every 200 km along the Trans-European Transport Network (TEN-T) and in every urban node[6]
- H_2 Demand: 14-20 Mt of Green H_2 expected demand by 2030 (considering expected 480-670 TWh of energy demand covered by H_2)[7]
- H_2 Distribution: ~3.750 Hydrogen Refueling Stations required by 2030 (vs 750 announced by 2025), implying ~ 8,5 Bn Euro inve stments[8]
- Investments: ~ 30 Bn Euro of projected hydrogen investment by 2030 in Europe, covering the entire hydrogen value chain[9]

[5] European Commission, July 2021
[6] European Commission, July 2021
[7] Fuel Cells and Hydrogen Joint Undertaking, Feb. 2019
[8] Fuel Cells and Hydrogen Joint Undertaking, Feb. 2019
[9] Hydrogen Council, Feb. 2021



Sources: 1.Fuel Cells and Hydrogen Joint Undertaking, Feb. 2019; 2. Hydrogen Council, Feb. 2021

Figure 7: *Hydrogen potential demand and investments by 2030*

On-highway applications

On-highway applications include light commercial vehicles (LCV), medium and heavy-duty vehicles.

H_2-ICE volumes for on-highway applications has been estimated considering expected increase in the cost of Diesel (driven by expected carbon tax introduction in the next few years), the highest estimation of the Diesel TCO in the next years compared to H_2-ICE TCO and the ban on sales of new fossil-fuel vehicles in Europe by 2035.

H_2 technologies are expected to increase at a slower pace than electric motors, considering the H_2 delivery infrastructure to be developed (i.e., 3.750 Hydrogen Refueling Stations required by 2030). Moreover, the Hydrogen ICE is assumed to increase at a slower pace than Fuel Cells, considering the analysis Total Cost of Ownership for selected use cases.

Analysis shows H_2-ICE penetration on new sales in 2028 is expected to be higher for High Duty Vehicles compared to Medium-High Duty Vehicles/Buses and Light Commercial Vehicles, characterized by prototype developments in 2023 and faster growth between 2026-2028.

Marine applications

Marine applications include bulk carriers, tankers, container ships, ferries, motor passenger boats.

H_2-ICE volumes for Marine applications have been estimated in light of an expected decrease of volumes for fossil fuel ships, considering the International Maritime Organization (IMO) GHG strategy to reduce carbon intensity of international shipping by 40% by 2030[10], compared to 2008, as well as the lower TCO of H_2 solutions compared to conventional ones, which is expected to boost the use of Hydrogen for maritime applications.

The H_2-ICE is expected to grow after 2028, considering prototypes currently under construction and the need to develop H_2 infrastructure in European Ports. Pilot initiatives have been already launched (e.g., FCH JU-funded H2PORTS) and some ports have a defined roadmap (e.g., Port of Rotterdam).

Construction equipment & agriculture

Analysis has included vehicles for construction equipment (e.g., excavators, crawlers, backhoes, loaders), material handling (i.e., forklift) and agriculture machinery (e.g., agriculture tractor, harvester).

The construction industry plays a substantial role in the climate crisis globally, contributing to more than 23% of the world's GHG emissions.

Hydrogen refueling can be built on-site, providing enough hydrogen to fuel a fleet of off-highway vehicles.

Material handling is expected to dominate the construction equipment H_2 market, considering fuel cell increasing penetration among large industrial logistic chains.

H_2-ICE in construction applications is expected to grow after 2028, considering the need for developing the H_2 infrastructure, which will be more convenient for industrial district areas, where it can supply several industry players.

Power Generators

The analysis included CHP, residential and commercial Gensets, with a 100kW – 2MW power range.

Considering the TCO analysis, the competitiveness of hydrogen-based gensets,

[10] International Maritime Organization (IMO)

the competitiveness of hydrogen-based gensets, the number of diesels gensets sold in Europe is assumed to continue to decrease in the next years in favor of fuel cells and hydrogen engines.

Hydrogen engine gensets are expected to achieve a relevant market share in new sales by 2028, driven by increasing demand for H_2-ICE Genset by Data Center operators and off-grid applications operators.

Conclusions on H_2 -ICE market perspectives

H_2 -ICE solutions are expected to get a potential market share for genset, trains, construction, agricultural, and some on-highway use cases (especially trucks).

The analysis shows that the market growth will depend on how the H_2 market and the infrastructure will be developed and on how some applications that today are prototypes (e.g., marine, construction) will increase the penetration in the next years.

3. H_2-ICE Ecosystem in Europe

Accelerating the development of H_2-ICE market in Europe in the next years will require to address 3 key challenges:

1. Develop ecosystems to connect hydrogen supply with demand through H_2 valleys: Centralized and decentralized Hydrogen production sites need to be developed in Europe to address expected demand, in line with EU targets in transitioning towards zero-emission fuels
2. Develop specific H_2 infrastructure for different final-use applications: European backbone needs to be developed to guarantee hydrogen supply to key market players across the entire continent
3. Evaluate collaborative business models leveraging key players in the value chain: collaborations with main players engaged in the value chain of hydrogen and final application to accelerate the development of the H_2-ICE market

H_2 valleys under development in Europe are expected to cover regional areas and focus on mobility end-use supply and European Hydrogen infrastructure needs to be developed to address the specific needs of final-use applications.

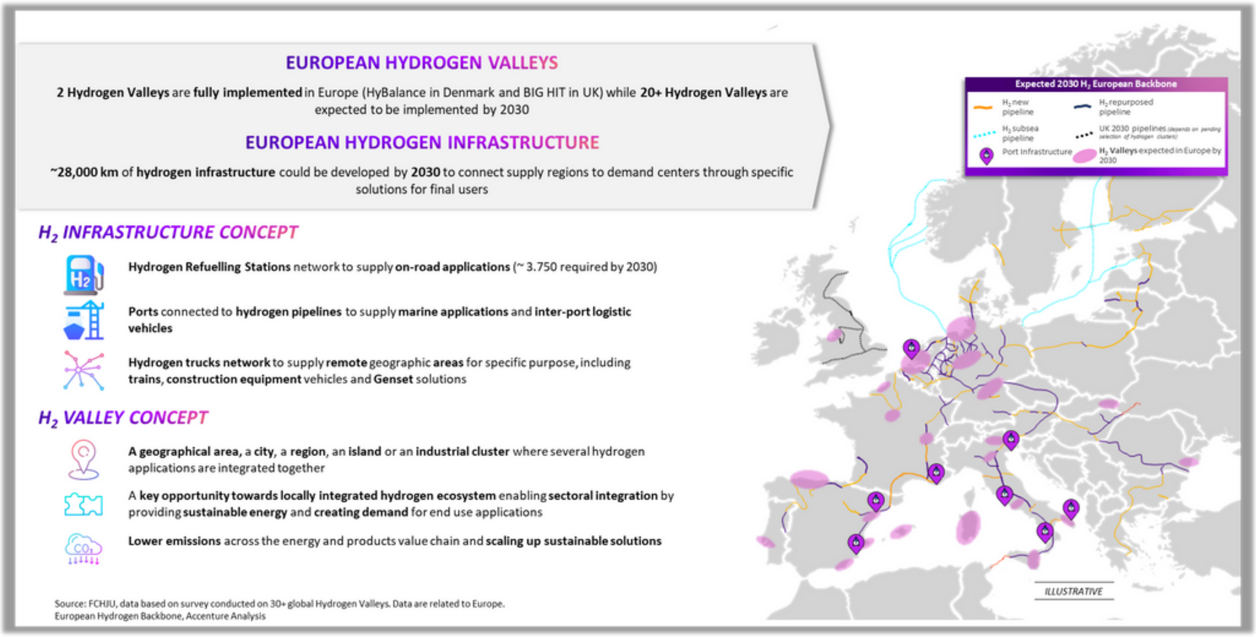


Figure 8: *Potential Hydrogen Backbone and H_2 Valleys*

Projects need to address all barriers to hydrogen valleys highlighted, obtaining public and private funding, securing off-take commitments as well as managing technological readiness...

Effective partnering and stakeholder cooperation are essential to ensure continuous commitment from all parties involved.

Hydrogen valleys are expected to unfold their full potential in the coming years, increasing their commercial maturity and ensuring the success of the energy transition.

The European H_2 infrastructure will become increasingly important as the adoption of hydrogen in the transport, industry and power sectors accelerates.

To support the REPowerEU ambitions, the Hydrogen infrastructure in Europe needs to be developed, by gradually connecting industrial clusters to the emerging infrastructure and growing network to more EU countries.

3.1 H_2-ICE value chain and key players

Three main business areas can be identified in the end-to-end H_2-ICE Value Chain:

H_2 Ecosystem Value Chain:

- H_2 Production: Producer of green hydrogen and enabler of large-scale generation and integration with RES;

- H_2 Handling: Enabler for green hydrogen transport and distribution to end users;

H_2 End-use Value Chain:

- H_2 Powertrain & components: Provider of engines and supplementary components for engine operations (e.g., storage, electrical connections);
- Applications manufacturers: Manufacturer of final application (e.g., vehicle, ship, etc.);

Connected Players:

- Certification's authority: Promoter of the sustainable growth by ensuring compliance with the standards;
- Public & Private authorities: Coordinator of investments, enabler of regulatory framework and research and infrastructure provider and management companies.

In particular, H_2-ICE projects and solutions are being developed by OEMs, including the following:

- **Cummins** has led the project to develop a hydrogen-fuelled engine for commercial transport [11];
- **JCB** has announced an H_2 engine 4.8l PFI for their construction machinery and the Development of Direct Injection solutions[12];
- **Deutz** developed the TCG 7.8 H_2 engine, which has already passed initial tests on the test bench and is scheduled to go into full production in 2024[13];
- **MAN** presented the Zero-Emission Roadmap, where the hydrogen combustion engine, offers a more readily available and robust solution thanks to the well-known basic technology and could thus serve as a bridging technology[14];
- **Yanmar Power Technology**, **Kawasaki Heavy Industries,** and **Japan Engine Corporation** formed a consortium of Japanese engine manufacturers to pursue joint development of hydrogen-fueled marine engines for ocean-going and coastal vessels towards establishing a world-leading position in hydrogen engine technologies to bring to the market by 2025[15];
- **Isuzu Motors**, **DENSO Corporation**, **Toyota Motor Corporation**, **Hino Motors** and **Commercial Japan Partnership Technologies Corporation** (CJPT) have started planning and foundational research on hydrogen engines for heavy-duty commercial vehicles to further utilize internal combustion engines as one option to achieve carbon neutrality[16].

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[11] Cummins, "Cummins receives award from the UK Government to accelerate hydrogen engine development for medium and heavy-duty engines", September 2021 (link);
[12] JCB debuts clean-sheet hydrogen combustion engine, March 2022 (link)
[13] DEUTZ AG: DEUTZ hydrogen engine ready for the market, August 2021 (link)
[14] MAN, "MAN presents Zero-Emission Roadmap", October 2020 (link)
15] Yanmar, Japanese Manufacturers Cooperate on Development of Hydrogen Fueled Marine Engines, May 2021 (link)
[16] Denso, "Isuzu, DENSO, Toyota, Hino, and CJPT to Start Planning and Foundational Research on Hydrogen Engines for Heavy-Duty Commercial Vehicles", Jul 2022 (link)

Each operator in the value chain will be necessary to effectively develop a sustainable hydrogen ecosystem, whose demand will be driven by different end-user applications.

Creating an integrated hydrogen ecosystem will require effective partnering and stakeholder cooperation that will ensure continuous commitment from all parties involved.

Considering the Hydrogen value chain, effective partnering with key players can accelerate the development of the H_2-ICE market by identifying geographical and primary business areas involved in H_2 infrastructure development plans.

Considering the final application value chain, Hydrogen tank manufacturers can play key role to develop E2E offering to OEMs, integrating the H_2 tank with H_2-ICE. Collaborations with certification authorities still represent key enablers for the homologation of the H_2-ICE final applications commercialization in Europe.

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[13] H2 View, “Deutz hydrogen engine ready for market”, August 2021 (link)
[14] Volkswagen website, “MAN presents Zero-Emission Roadmap”, October 2020 (link)
[15] Yanmar, Japanese Manufacturers Cooperate on Development of Hydrogen Fueled Marine Engines, May 2021 (link)
[16] Denso, “Isuzu, DENSO, Toyota, Hino, and CJPT to Start Planning and Foundational Research on Hydrogen Engines for Heavy-Duty Commercial Vehicles”, Jul 2022 (link)

4. Conclusions

The H_2-ICE market in Europe could be valued at around 1Bn Euro in the next 5 years, driven by on-highway and Genset applications.

European hydrogen infrastructure, as well as the effective partnering of players along the value chain, are key success factors to sustain the H_2-ICE market growth in the next few years. All players, from hydrogen producers to vehicle OEMs, engine suppliers, engineering-service companies and start-ups are expected to play a key role in the development of hydrogen and H_2-ICE, investing and collaborating in the scale-up of sustainable solutions.

Some testing and development initiatives have started and over the next few years the H_2-ICE could take on the challenge of delivering zero-carbon fuel while retaining its performance, making a significant contribution to the emission reduction of powertrain technologies.

5. PUNCH Hydrocells offering

PUNCH Hydrocells is the Company of PUNCH Group, located in Torino (Italy), specializing in hydrogen technologies and solutions. Based on more than 15 years spent within General Motors working on the development of propulsion and control systems, the Company is skilled in propulsion and software development, integration and industrialization. Its activities take advantage of dedicated testing facilities capable to run hydrogen engines located on-site.
The hydrogen engine & controller are fully executed in-house leveraging strong capabilities on engine HW&SW development. Both PFI (Port Fuel Injection) and DI (Direct Injection) combustion systems have been developed through CFD simulations optimization and DOE testing techniques. Proprietary advanced engine controller & software is another key element of the offering. This body of work is partially summarized in the references below.
The first product being deployed is a 6.6l V8 PFI hydrogen engine derived from converting a mass-production Diesel engine, with lead applications focusing on power generation, off-highway and marine. On-highway applications will as well be deployed.
Moreover, Direct Injection technology is explored for further performance and efficiency increase.

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- PUNCH Hydrocells website

Bore x Stroke	103 mm x 99 mm	
Dry Weight	450 kg	
Fuel System	PFI	
Ignition	Spark Plug	
Rated Power	250 kW @ 3000 rpm	
Torque	850 Nm @2000 rpm	

This White Paper is provided by:

PUNCH | Hydrocells

PUNCH Hydrocells is a core part of the PUNCH Group, based in Turin in the Cittadella Politecnica and has earned an excellent reputation in part thanks to our rich and storied background in automotive engineering. With more than twenty years of experience in developing diesel engines and control systems, we are now building on that heritage to provide answers to the many problems facing the transition of energy sources which is so vital for tackling climate change. We have the benefit of a world-class team of highly skilled experts across several specialized fields including artificial intelligence, control electronics, and mechanical and electrical engineering. This diverse team allows PUNCH Hydrocells cover the entire value-chain of the hydrogen ecosystem, incorporating: production, storage and distribution, fuel cells and Hydrogen Internal Combustion Engines.
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