Hydrogen as key enabler for the Heavy-Duty transport system decarbonization

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Key drivers & trends

Next decade evolution

Key Market Trends

DECARBONIZATION / EV	HYDROGEN	MARKET CONSOLIDATION	SUPPLY CHAIN CHALLENGE
▪ Switch to **zero tailpipe emission**, driven by Regulations, challenged by external constraints (e.g., autonomy, infrastructure, cost) ▪ **PWT mix** still in favor of **ICE (~80% @ 2030), including net-zero fuels**; **EV acceleration** in specific markets / segments	▪ With **Hydrogen** as future energy carrier, two potential technologies co-exist: H2-ICE and Fuel Cells ▪ **EU** Commission "opening" to **H2-ICE as ZE solution** for the scope of M&HDV CO_2 emission standards, driving research and development activities on the technology	▪ Due to uncertainties, OEMs / PWT players need to invest into multiple technologies to secure **multipower line-up**, rising the overall effort and potentially leading **to industry consolidation** in the long term	▪ **Supply chain challenge**, driven by Passenger Car Diesel Engine phase out, shrinking industry with cost pressure for key PWT components

Next coming CO_2 and pollutant emissions Regulations will drive an unprecedented change in Powertrain Mix

FPT Industrial: a Multi-Energy strategy

Sustaining leadership in Diesel and Natural Gas while investing into new zero-emission solutions

Sustainable internal combustion engines (Diesel, NG, H_2)

- Line-up extension and **continuous improvement**, state of the art technology and competitive solution, matching new customer needs
- Alternative fuels focused approach: leadership in **Natural Gas** and technology transfer to sustainable circular models
- **H_2 Internal Combustion Engines** as viable solution

Position as *Zero Emissions* solution provider

Extend FPT value chain into the Electrification area

Primary focus on Propulsion (**eAxles**), complemented by **Battery** Solutions, **Software** Management capabilities and fuel cell systems

TURIN PLANT: 15.000 m^2 dedicated to ELECTRIFICATION

Approx. 200 employees

Front + Rear eAxles
Hi-Perf. Passenger Car

Rear eAxle
HCV 44t

Central Drive
LCV-Minibus 8t

Battery Pack
LCV-Minibus 37 kWh

Battery Pack
BUS 69 kWh

Introducing hydrogen with Fuel Cells technologies

H_2 ICE – A new player complementing FC technologies

ICE integration on conventional vehicle architecture

Less stringent requirements towards **hydrogen purity grade**

More flexible and adapted for **hard operating conditions**

Well established **supply chain** and **manufacturing** processes

Synergies with FC technologies wrt **hydrogen infrastructure**

Energy conversion efficiency «normally» lower vs FC (→ fuel operating cost)

Local pollutants (NOx, PM/PN) still present even if at ultralow level

Acoustic emissions in line with SI engine

TCO vs FC strongly affected by H_2 price and technology evolution (efficiency/system cost).

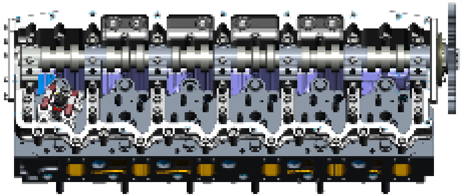
H_2 ICE development – Technology approach

from
Natural Gas Spark Ignited PFI
Stoichio + 3way cat

to
H2 ICE Spark Ignited DI/PFI
Lean burn + DeNOx ATS

Hardware

Dedicated (CNG derived) Cylinder Head and Camshaft



New FIE and ignition system

New pistons design

Turbocharger

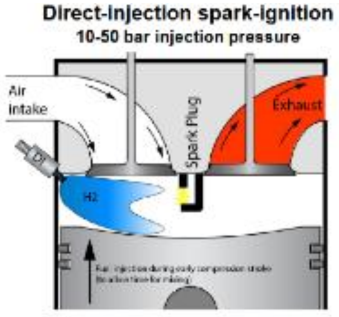
Simplified ATS*

Software

Dedicated SW and controls with specific calibrations

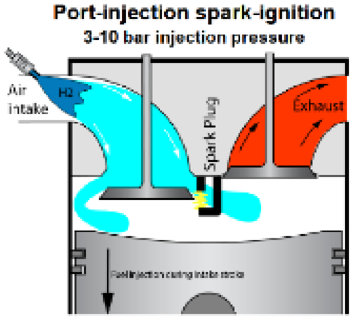
** Simplified ATS compared to Diesel, targeting NOx reduction and ultrafine PN*

H_2 ICE – Technology approach: PFI vs DI systems



Direct Injection (DI) system

- Suitable to achieve **higher engine power density** (25-27 kW/l, similar to Natural Gas PFI)
  → current mainstream for engine displacement > 12 litres
- **Preventing any risk of backfire** during transient operations
- **Operating pressure up to 30 bar**
- **DI system components under development**



Port Fuel Injection (PFI) system

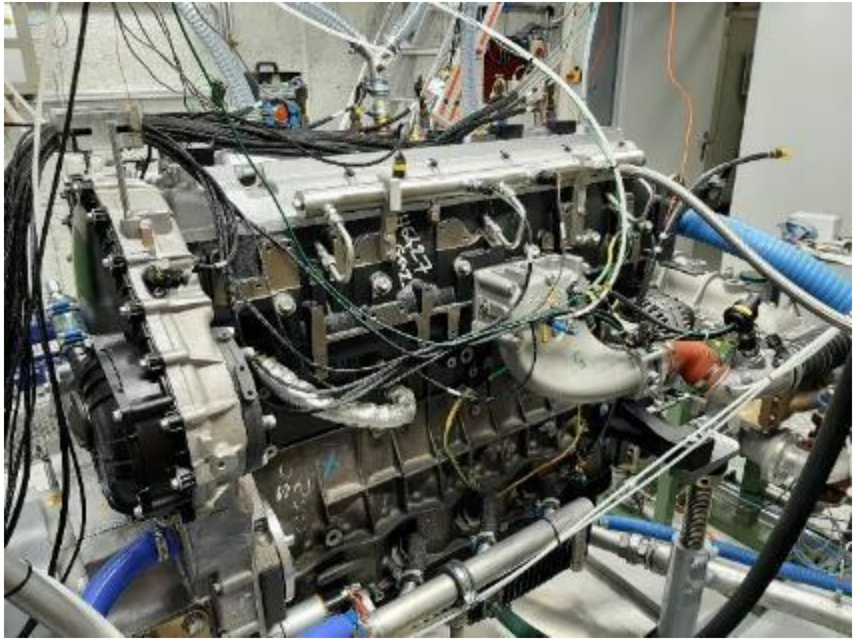
- **Lower engine power density** compared to DI systems (approx. –20%)
- Suitable in case of **limited transient requirements** (e.g. power generation, series hybrid)
- **Operating pressure up to 15 bar**
- PFI technologies **closer to production readiness**

H_2 ICE - Main technical challenges and solutions

CHALLENGE	APPROACH	TECHNOLOGY
Controlling A/F mixing to optimize combustion process Preventing abnormal combustion (knocking, pre-ignition) Avoiding back-fire phenomena Tackling low power density	Direct injection under lean burn conditions	H_2 DI injectors technology Air handling: turbocharging Engine design Dedicated ignition system Lube oil formulation DeNOx ATS
Avoiding explosive mixtures inside the crankcase	Crankcase ventilation system	Dedicated scavenging circuit
Hydrogen embrittlement	Materials compatibility	Special materials

FPT H_2 ICE: from engine test bed to white fields

Proof of Concept of Cursor13 H_2 460HP on Snowgroomer



Cursor13 H2 on engine dyno at FPT Arbon

Prinoth *Snowgroomer powered by FPT C13 H2*

Will H_2 mobility fly?

Key supporting elements

Onboard energy storage capacity

"Green" H_2 production and cost

Refuelling infrastructure

TCO

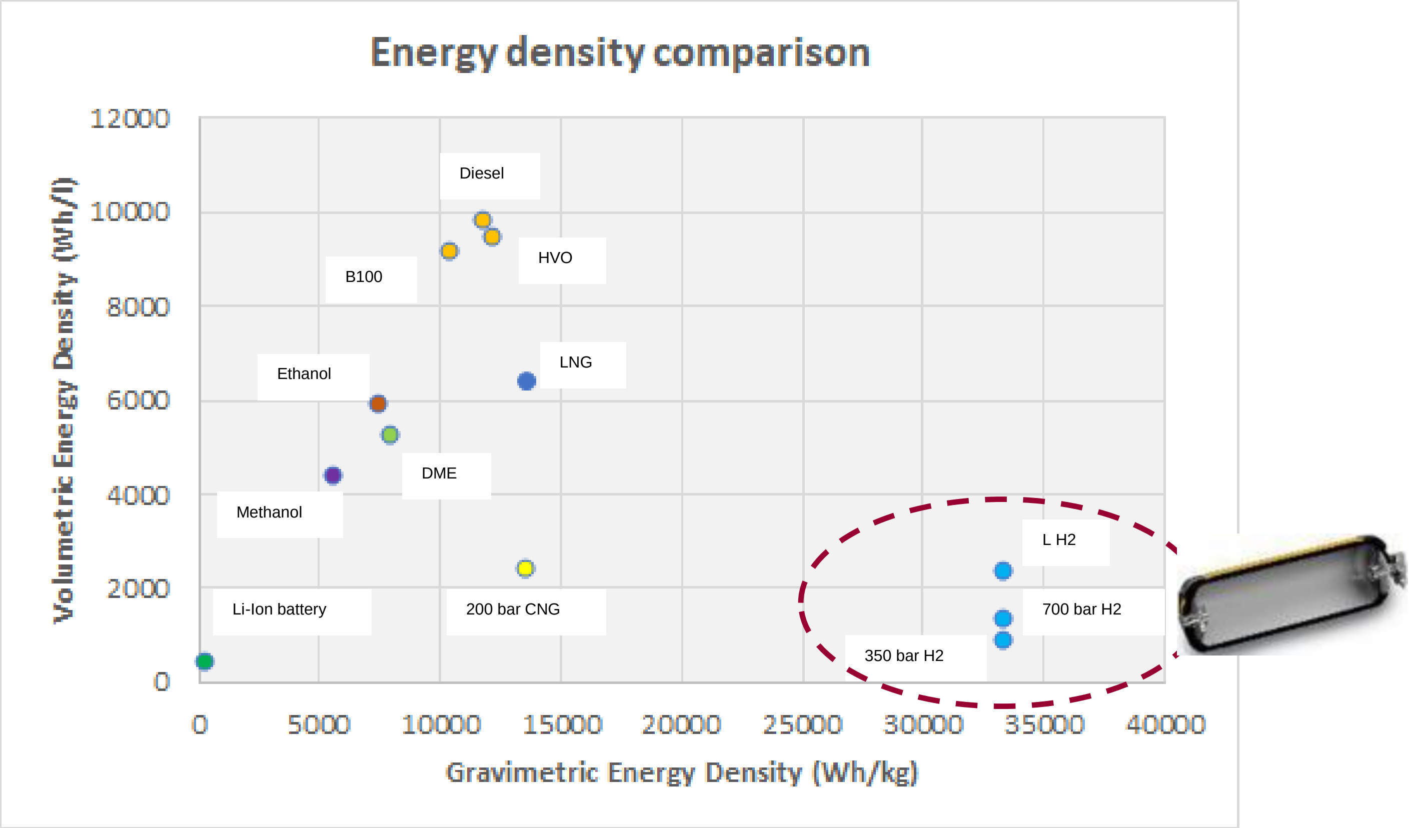
Customer needs & Mission

Customer acceptance

Technology maturity & Reliability

Energy density is crucial especially for off-road applications

Fuel energy density comparison



H_2 refuelling infrastructure development in EU

Recent agreement from EU Institutions on AFIR, setting minimum target for MS for AF infrastructures:

1. Member States to assess the best locations for HRS (H_2 Refueling Station) deployment. HRS should **preliminary focus on heavy-duty segment**
2. Best locations to be considered as “along the **TEN-T network**” a HRS can be located within a radius of 10km from the neares TEN-T road exit
3. **Density of 200km along the TEN-T** core by 31 December 2030
4. At least **one HRS per urban node** by the same date
5. HRS have to be designed for a **minimum cumulative capacity of 1 tonne a day**
6. **At least one 700 bar refuelling dispenser**
7. **Comprehensive network** (connecting urban nodes, ports, airports) and **liquid hydrogen** are **not** included

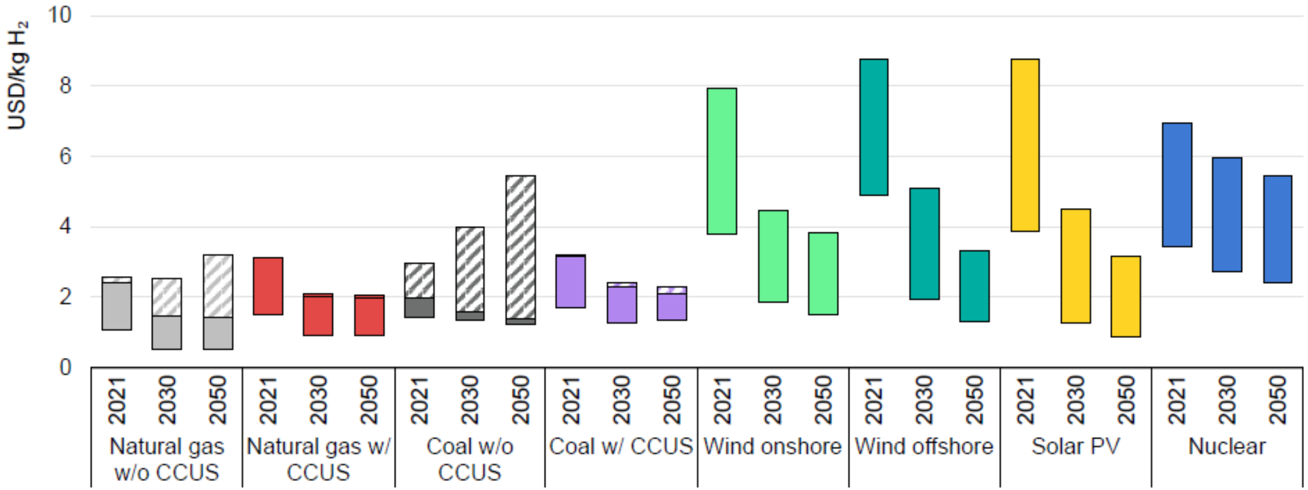
https://h2-map.eu/

Production cost for green hydrogen

Crucial role especially for the Long Haul segment

Opportunities for cost reductions to produce low-emission hydrogen

Levelised cost of hydrogen production by technology in 2021 and in the Net Zero Emissions by 2050 Scenario, 2030 and 2050



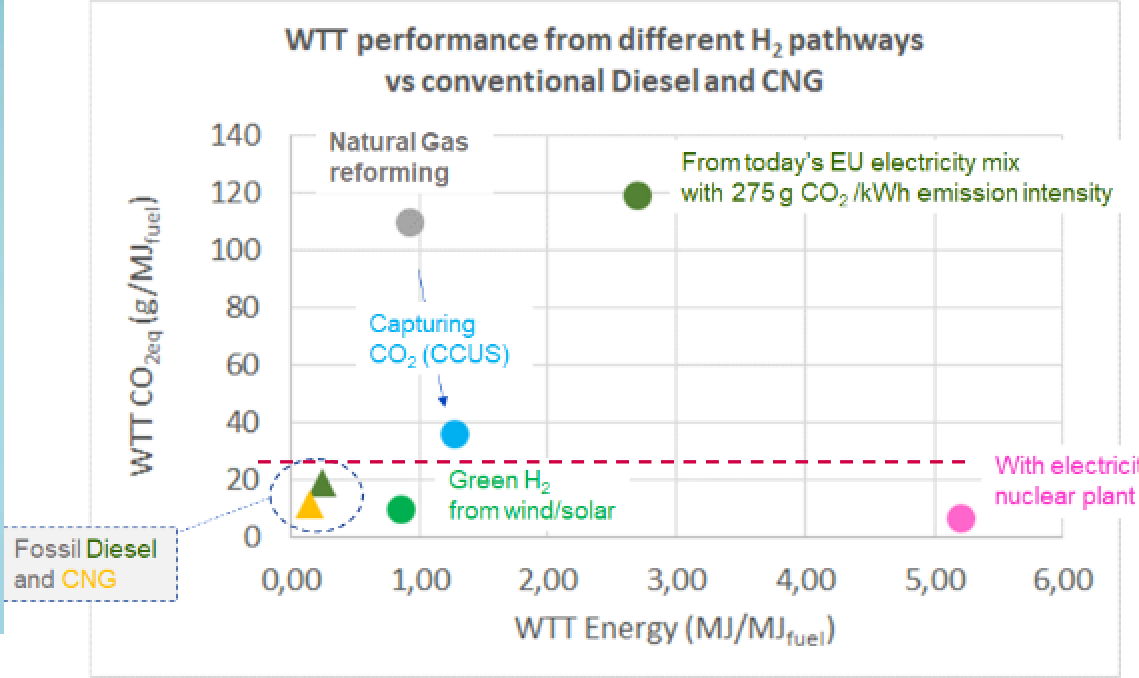
Notes: Ranges of production cost estimates reflect regional variations in costs and renewable resource conditions. The dashed areas reflect the CO_2 price impact, based on CO_2 prices ranging from USD 15/tonne CO_2 to USD 140/tonne CO_2 between regions in 2030 and USD 55/ tonne CO_2 to USD 250/ tonne CO_2 in 2050.

Sources: Based on data from McKinsey & Company and the Hydrogen Council; Council; IRENA (2020); IEA GHG (2014); IEA GHG (2017); E4Tech (2015); Kawasaki Heavy Industries; Element Energy (2018).

https://iea.blob.core.windows.net/assets/c5bc75b1-9e4d-460d-9056-6e8e626a11c4/GlobalHydrogenReview2022.pdf

Why colors matter…

H_2 production CO_2 and energy footprint



Source JEC WtW Study v5 - https://publications.jrc.ec.europa.eu/repository/handle/JRC121213

2022 IEA data

95 Mt H_2 produced worldwide

- 62% from NG SRM
- 21% from coal
- 16% from naphta reforming
- 1% as low emissions H_2, mainly through CCS

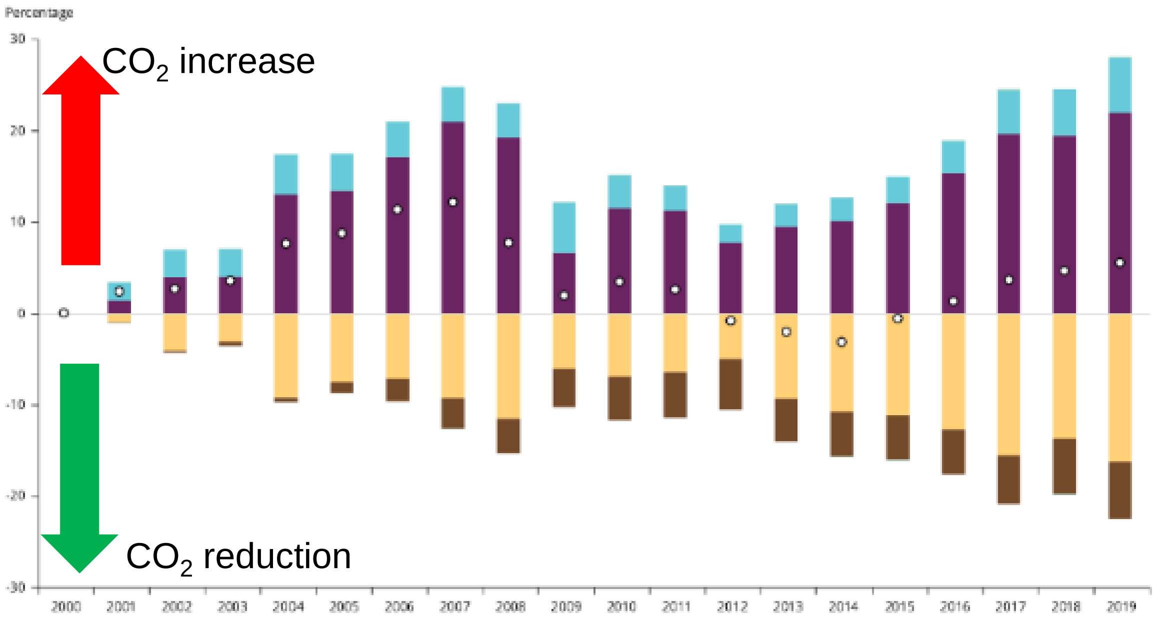
100kt as green hydrogen

https://www.iea.org/reports/global-hydrogen-review-2023

Threshold from EU Delegated Regulation 2021/2139 (linked to Taxonomy) considers hydrogen “sustainable” if < 3 $kgCO_2/kgH_2$ (25 gCO_2/MJ)

What we have done to reduce GHG emissions from HD transport

Key elements driving the HD CO_2 emissions evolution



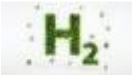
https://www.eea.europa.eu/publications/co2-emissions-of-new-heavy

HOW to ACT:

Transport demand & logistic optimization
→ digitalization & connectivity

Vehicle efficiency
→ reducing vehicle energy demand

Moving from fossil to carbon free energy sources

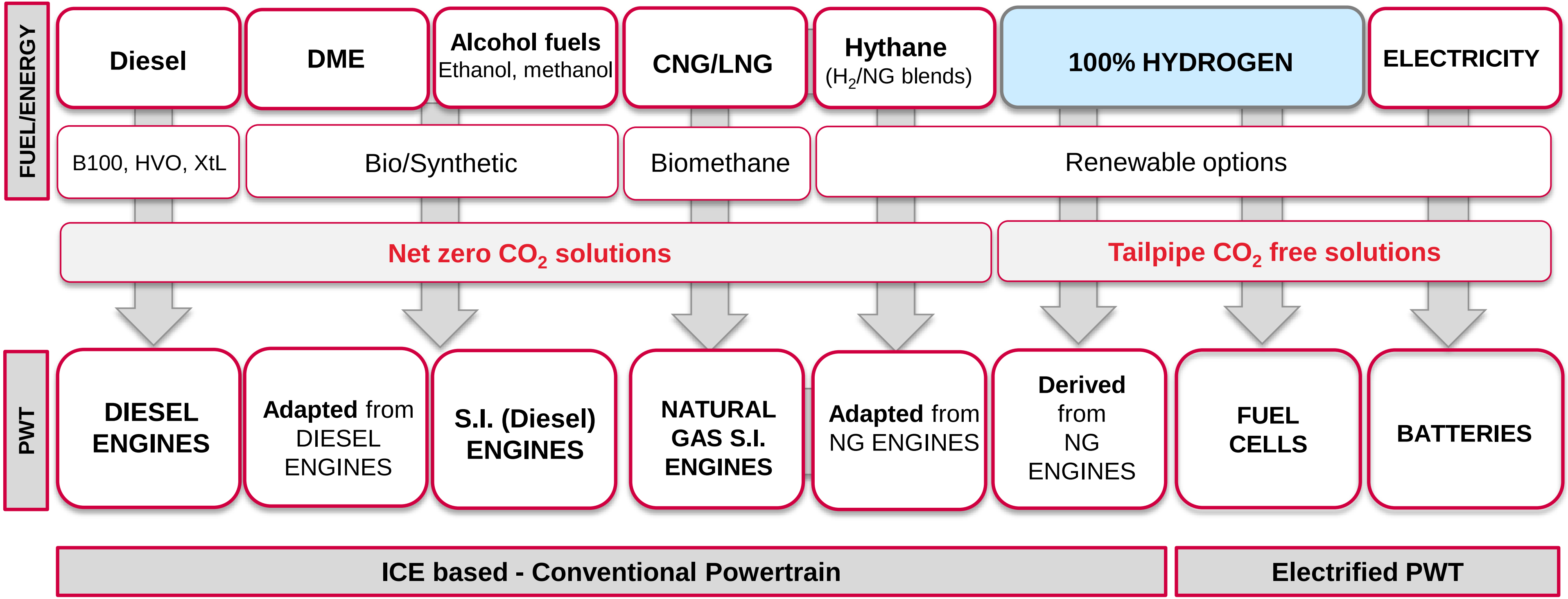


Moving from fossil to renewable energy sources

Advanced biofuels (e.g. BioCNG/LNG HVO)

Going beyond zero tailpipe CO_2 emissions

Net-zero solutions are key to complement and accelerate the decarbonization process



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