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ECO-MOBILITY 2023

SWEET SPOTTING THE H2 ICE –

AN APPROACH FOR PORTFOLIO DECISIONS FAVORING THE ICE CHARACTERISTICS

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HEADLINES

H_2 mobility and respectively internal combustion engines are on everyone's lips these days

Toyota Abandons Hydrogen Vehicles For Consumers - Focuses On Commerical Vehicles Instead

Toyota Admits Hydrogen-Fueled Mirai Has "Not Been Successful"

Despite slow sales of Toyota's hydrogen sedan, the brand won't give up on the technology.

Toyota's Hydrogen Combustion Engine Has The Potential To Make EVs Obsolete

Toyota is taking a diversified approach to achieve carbon neutrality and it could be a winning formula for the Japanese automaker

Water-injected 2.0-liter turbo-four hydrogen engine spits out 410 hp

AVL debuts 400bhp+ H_2 ICE

Bosch Engineering and Ligier Automotive present Ligier JS2 RH2 with hydrogen engine at Le Mans

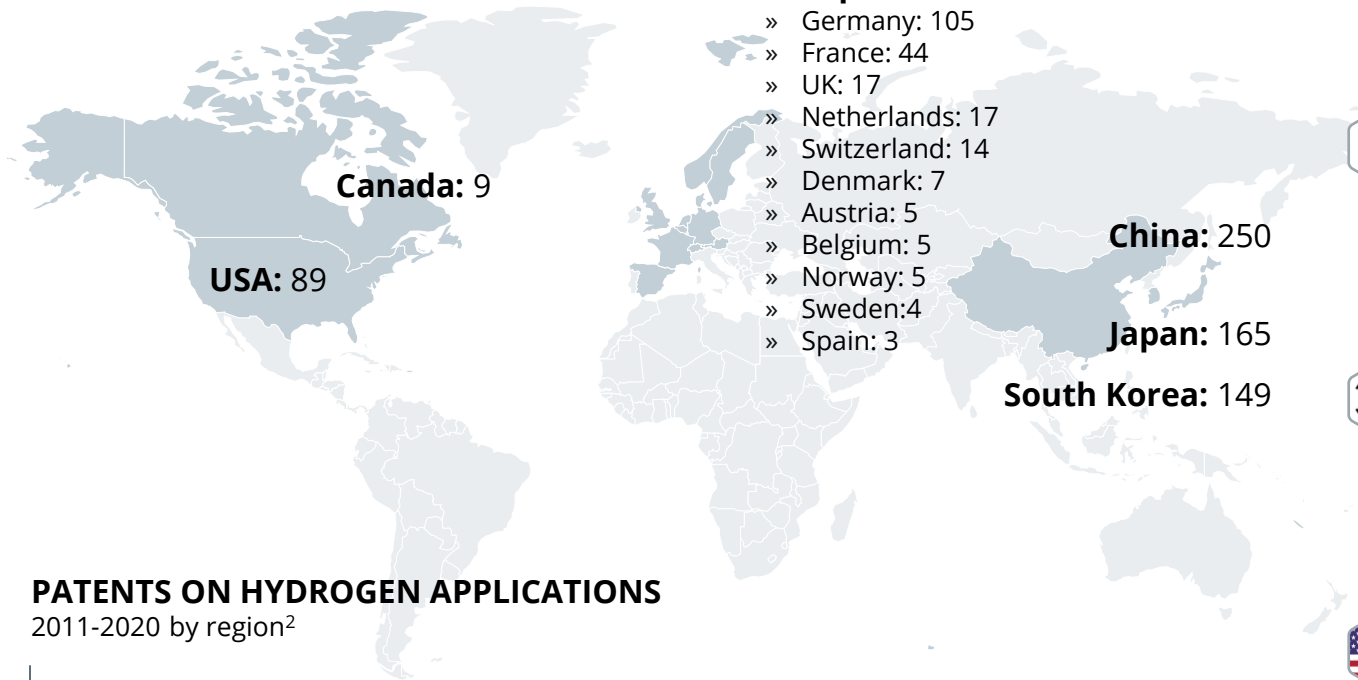
The Era of Hydrogen Cars Opens – Developed The World's Highest Level Hydrogen Engine Technology That Can use 100% Hydrogen Fuel for The First Time in Korea

HYDROGEN INITIATIVES AND INFRASTRUCTURE

Initiatives globally lead into the direction of providing green Hydrogen by utilizing water electrolysis and local production

FUEL STATIONS

Status: 03.11.2023[1]

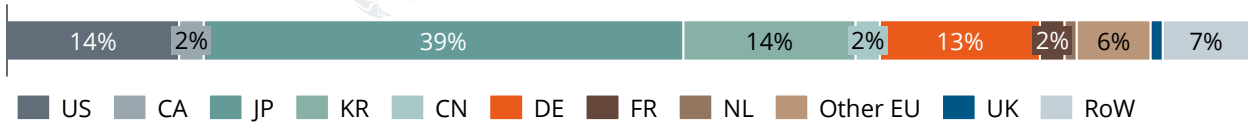


Europe

- Germany: 105
- France: 44
- UK: 17
- Netherlands: 17
- Switzerland: 14
- Denmark: 7
- Austria: 5
- Belgium: 5
- Norway: 5
- Sweden:4
- Spain: 3

PATENTS ON HYDROGEN APPLICATIONS

2011-2020 by region[2]



EUROPEAN UNION

- Hydrogen determined as **strategic pillar** in European Green Deal
- Funding of H_2 **engines** as **retrofit** version of conventional fueled engines to accelerate **technology acceptance**

JAPAN

- Strategic Energy Plan established with focus on Hydrogen utilization for **power generation**
- Decarbonization progress realized through **EV**, **FCV** and **synthetic fuels**

SOUTH KOREA

- Concrete plan to promote clean Hydrogen through regulations and certifications and develop **ecosystem** of **Hydrogen industry**
- Hydrogen Economy Plan foresees the **positioning** as **No. 1** worldwide **producer** of **Hydrogen vehicles** and **manufacturing** of **fuel** cells

USA

- Introduction of roadmap for **clean Hydrogen supply** as well as generation of **regional Hydrogen hubs**
- Priority on **application** of **FCV** in **transport** sector and **off-road** vehicles

[1] Source: https://www.h2stations.org/
[2] Source: „Hydrogen patents for a clean energy future", IEA 2023

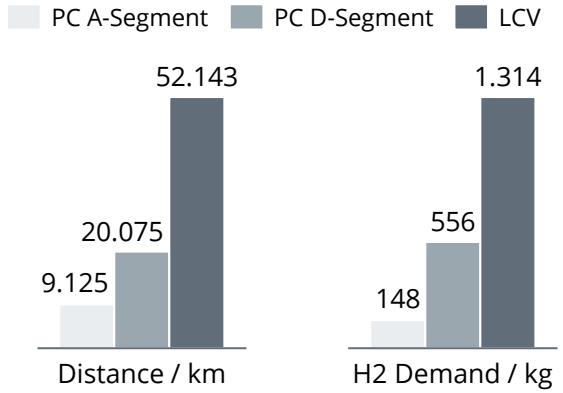
LIGHT-DUTY-VEHICLES ICE CHARACTERISTICS

The diverse operating strategy of LDVs depending on the customer's usage leads to very distinctive performance data

PERFORMANCE DATA

	PASSENGER CAR A-SEGMENT	PASSENGER CAR D-SEGMENT	LIGHT COMMERCIAL VEHICLES
Efficiency TtW	28,5 %	30,5 %	32,1 %
Tank volume	4 kg / 154 L	7 kg / 269 L	10 kg / 385 L
Driving range	320 km	350 km	360 km

UTILIZATION PER YEAR



LDV – ENGINE PERFORMANCE FORECAST

KEY TAKEAWAYS

- Light Duty Vehicles (LDV) have a **broad variety** of **utilization** related to customer profile.
- Passenger cars from **A- to C-segment** show a low travelling range per year and hence a **lower demand of H_2**, while **integration** of **engine** and **EAT** design require high effort.
- Passenger cars above the **D-segment** provide a **more attractive operting strategy for ICE** with **long-distance** travel and also **packaging**.
- Usage of H_2 engines in **LCV** is very favorable in terms of **packaging**, **predictable daily routes** and operation in **areas of high BTE**.
- **NO_x engine-out emissions** are **below Diesel-level** with promising exhaust aftertreatment technologies already introduced.

Source: ITNA (TU Graz), Berylls Strategy Advisors

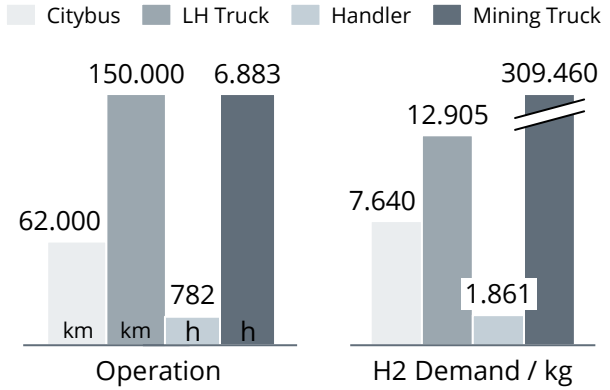
HEAVY-DUTY-VEHICLES ICE CHARACTERISTICS

H_2 engines in HDV face a strong competition with fuel cell applications, while usage to penetrate the market and push H_2 infrastructure is recommendable even to support FCV market

PERFORMANCE DATA

	CITYBUS	LONG HAUL TRUCK	NON-ROAD MOBILE MACHINERY HANDLER	NON-ROAD MOBILE MACHINERY MINING TRUCK
Efficiency TtW	25,8 %	40 %	31,5 %	38,7 %
Tank Volume	25 kg / 962 L	60 kg / 2.308 L	10 kg / 385 L	120 kg / 4.614 L
Operation per day	200 km	600 km	3 h	22 h

UTILIZATION PER YEAR



HDV – ENGINE PERFORMANCE FORECAST

KEY TAKEAWAYS

- Introduction of **H_2 mobility** is already **strongly focused** on **commercial vehicle market.**
- Using H_2 engines in **citybusses** is favorable in terms of **predictable daily routes**, while suffering from **transient operation** at **low loads**.
- **LHT** are **designated** to implement H_2 engines due to **transit routes** and comparably **stationary operating conditions** in fields of **highest BTE**.
- **Small NRMM** like telescopic handler are mostly operated in lower area of engine map, therefore required to be operated with **hybrid strategy**.
- Utilization in **mining trucks** requires **high yearly amount of H_2**, but operation of engine at **high efficiency** is provided.

Source: ITNA (TU Graz), Berylls Strategy Advisors

PORTFOLIO PERSPECTIVES

The technological trends towards a diversification of powertrains in OEMs portfolios require a holistic approach on the decision-making process of their future product portfolio

MARKET

LEGISLATION

Globally diverse emission regulations have a substantial influence on the need of alternative propulsion technologies as well as the speed of implementation

NATIONAL INITIATIVES

Increasing dedication to enhancement of H_2 infrastructure impacts the market penetration

MOBILITY TRENDS

Local spectrum of offerings regarding mobility services influences effect on product portfolio adaptions

CUSTOMER

SOCIAL TRENDS

Individual mobility broadly developing towards green-mindset as well as exclusiveness

VEHICLE TYPE

Underlying vehicle platform provides basis for implementation probability and customer acceptance

TOTAL COST OF OWNERSHIP

Future development of vehicle pricing and fuel costs affect decision making process depending on customer use-case

COMPANY

PROFITABILITY

Arbitrary business opportunities expectedly competing with profit related to pricing and sales volume

BRAND POSITIONING

Unique marketing possibilities facilitate “halo effect” on entire product portfolio

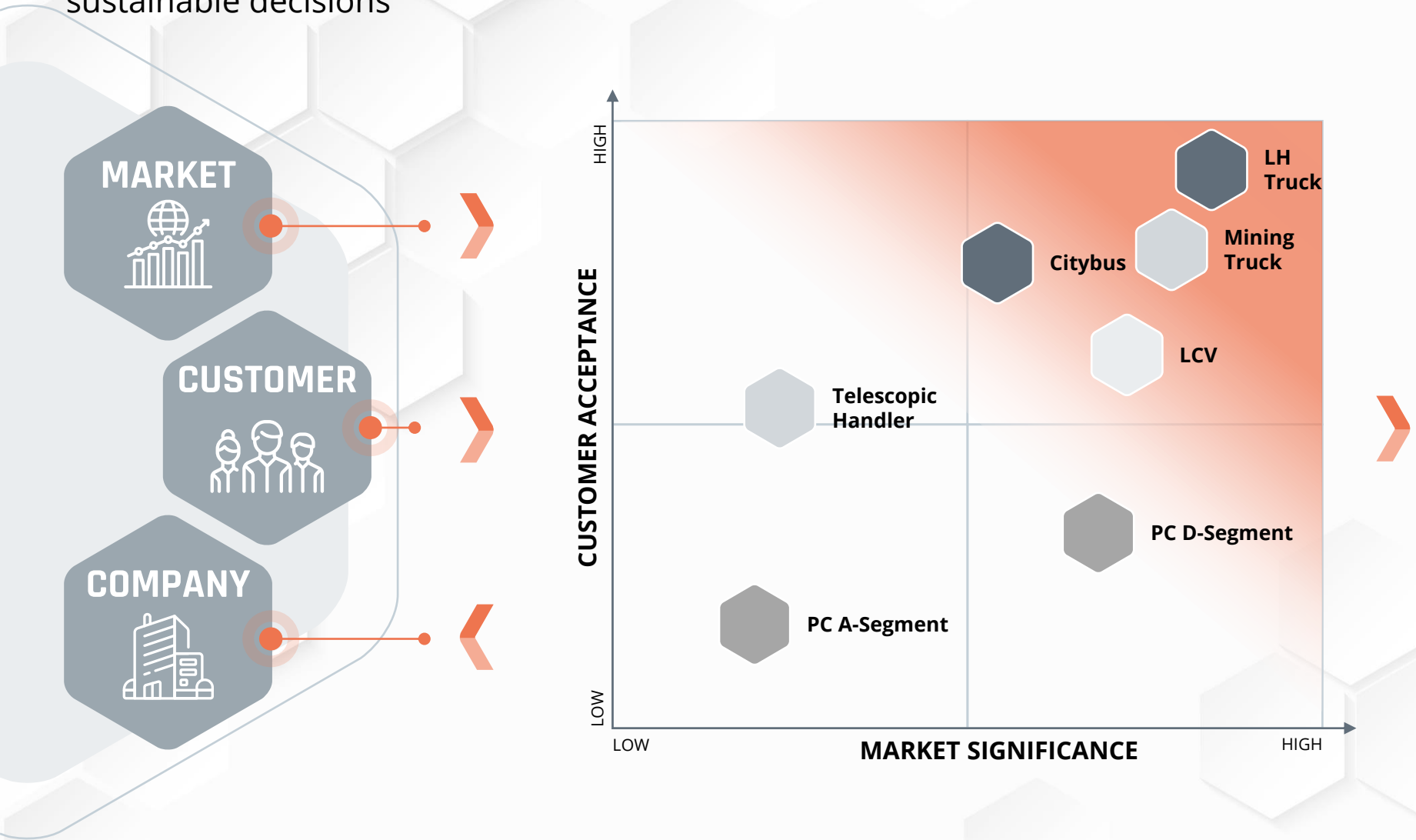
CORPORATE STRATEGY

Deliberate decisions on supporting in-house expertise versus partnerships directly influence value add

Source: Berylls Strategy Advisors

PORTFOLIO SWEET SPOT

Taking different perspectives on the product portfolio gives implications on the strategically right and even more so sustainable decisions

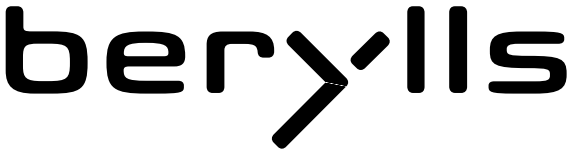


CONCLUSION

- The daily transit routes of **Long-Haul Trucks** can be derived easily and enable a **push** in the establishment of **H_2 infrastructure**.
- **LCV** usage facilitates the **access to urban mobility** with the potential to collaborate with mobility service providers.
- An urgent request for **sustainability in the supply chain** makes H_2 engines in **large NRMM** in combination with power generation of green hydrogen even more attractive.
- In **individual mobility**, the customer acceptance can only be reached via the aspect of **exclusiveness** and a **green mindset**, hence **prioritizing above D-segment**.

Source: Berylls Strategy Advisors


THE FUTURE
WILL BE.
BUT DIFFERENT.
AS ARE WE.



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