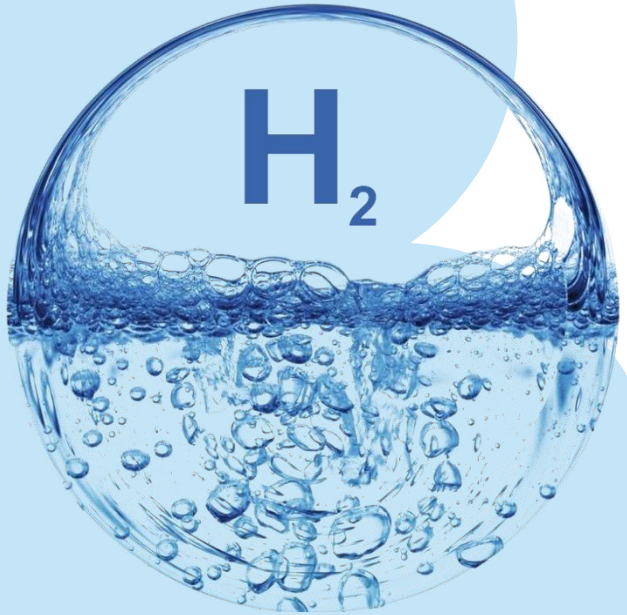
Hydrogen - first mover and cost advantage to drive Portugal strategy



António Bernardo

Webinar *– Business Cases for Fuel Cells and Hydrogen Applications*

ORDEM DOS ENGENHEIROS

July 15, 2020

Portugal has an opportunity to develop a sustainable economy beyond Green Hydrogen production

Key messages

- **Roland Berger has been supporting national strategies** and the **most important hydrogen projects**, which allowed to identify some key lessons learned on the development of Green Hydrogen projects
- **The focus of the deployment** of hydrogen should be in **applications with short and mid term feasibility** such as some of **Fuel Cell mobility end-uses** – buses, trucks and trains
- **Portugal should leverage its first move and cost advantage** to secure a **balanced positioning** in **domestic use vs. international export** of Green Hydrogen

Source: Roland Berger

Roland Berger has been involved in several important projects in hydrogen and fuel cells worldwide…

Roland Berger Hydrogen projects

Non-exhaustive

Governments / public sector

- > Development of **governmental H_2 strategy**
- > Cost benchmark study on **H_2 refuelling stations**
- > **Commercialization strategy** for FCH CHP
- > **Study on H_2** potential in **rail sector**

Technology Screening and Investment Support

- > Develop a storage strategy to pair with their EVSE white label business and get venture funding
- > Find a way to tap into **utility energy efficiency programs**
- > **Commercial feasibility** and **strategic concept**
- > DD of **business cases for H_2 trucks**

Large project setup (project developers with business plan)

- > Development of **business cases for fuel cells** and H_2 applications for European Regions
- > Project development for a **power-to-hydrogen project** with integrated refueling network
- > **Pre-feasibility check for large scale** H_2 project
- > **Corporate strategy development** incl. business model options for a mid and long term engagement H_2 market

Strategy and market entry for industrial players (energy, automotive, etc…)

- > **Market potential assessment** & partnership strategy
- > **Growth strategy** in low emission tech. markets
- > **E-fuel study** & case development
- > **Port strategy** development of a new **business model**
- > Development of strategy with **export market perspective**

Source: Roland Berger

… and has been involved in the Platform for Regional H_2 Valleys, supporting the identification of some key lessons learned

Overview of most major global H_2 projects with direct access by RB (selected)

Netherlands
> HEAVENN
> TSO 2020
> Hydrogen Delta

United Kingdom
> HyNet North West England
> BIG HIT Orkney Island
> H21 North of England

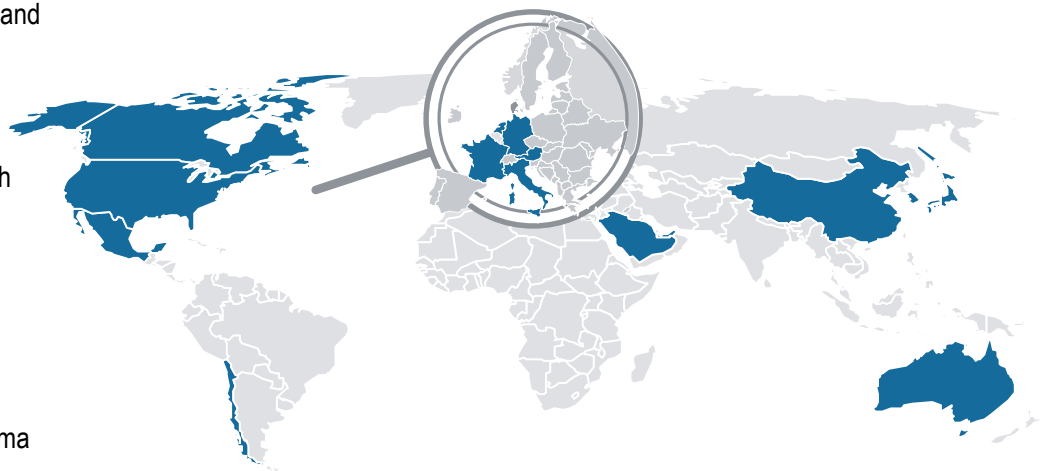
Canada
> Hydrogen Cluster British Columbia

USA
> California Fuel Cell Project

Chile
> Hydrogen Valley Atacama

Europe [IPCEI]
> Blue Danube
> Black Horse
> Green Octopus
> Green Spider
> White Dragon
> Silver Frog
> Rainbow Unhycorn
> Blue Dolphin

Germany
> H2Rivers
> HyBayern
> Hyways4 future
> Norddeutsches Reallabor
> HydroHub Fenne
> eFarm



China
> Pearl River Delta (Foshan)
> Beijing-Zhangjiakou
> Datong
> Rugao

Japan
> Fukuoka Hydrogen Strategy
> Fukushima Plan for New Energy Society

Thailand
> Phi Suea House

Saudi Arabia
> NEOM

UAE
> Mohammed bin Rashid al-Maktoum Solar Park

France
> Zero emission valley Auvergne-Rhône-Alpes
> HyPort
> Normandie

Italy
> South Tyrolean hydrogen valley

Denmark
> HyBalance

Belgium
> Port of Antwerp

Austria
> WIVA P&A

Australia
> South Australia Hydrogen Action Plan
  – Neoen Crystal Brook Energy Park
  – Port Lincoln

Countries with major project activity Countries incl. in wider projects

Source: Roland Berger

Roland Berger's identified 7 lessons learned from the on-going and past hydrogen projects

Key lessons learnt from our projects

1 | **Secure demand from many different sources**, including large single off-takers in the projects to ensure economies of scale (e.g. refinery or natural gas grid injection) and support de-risking the project

2 | **Accelerate the need for regulatory incentives for a Green H_2 early stage market** to promote private initiative and attract investment

3 | **Balance** between production for **local consumption and export** to more industrialized European countries (e.g. Netherlands, Germany)

4 | **Plan technology requirements due to potential constraints on tech supply**, managing risk in terms of time-to-market and drastic increases in price – e.g. wind turbine mills

5 | **Build consortiums with partners with complementary competences –** technology, EPC and off-takers

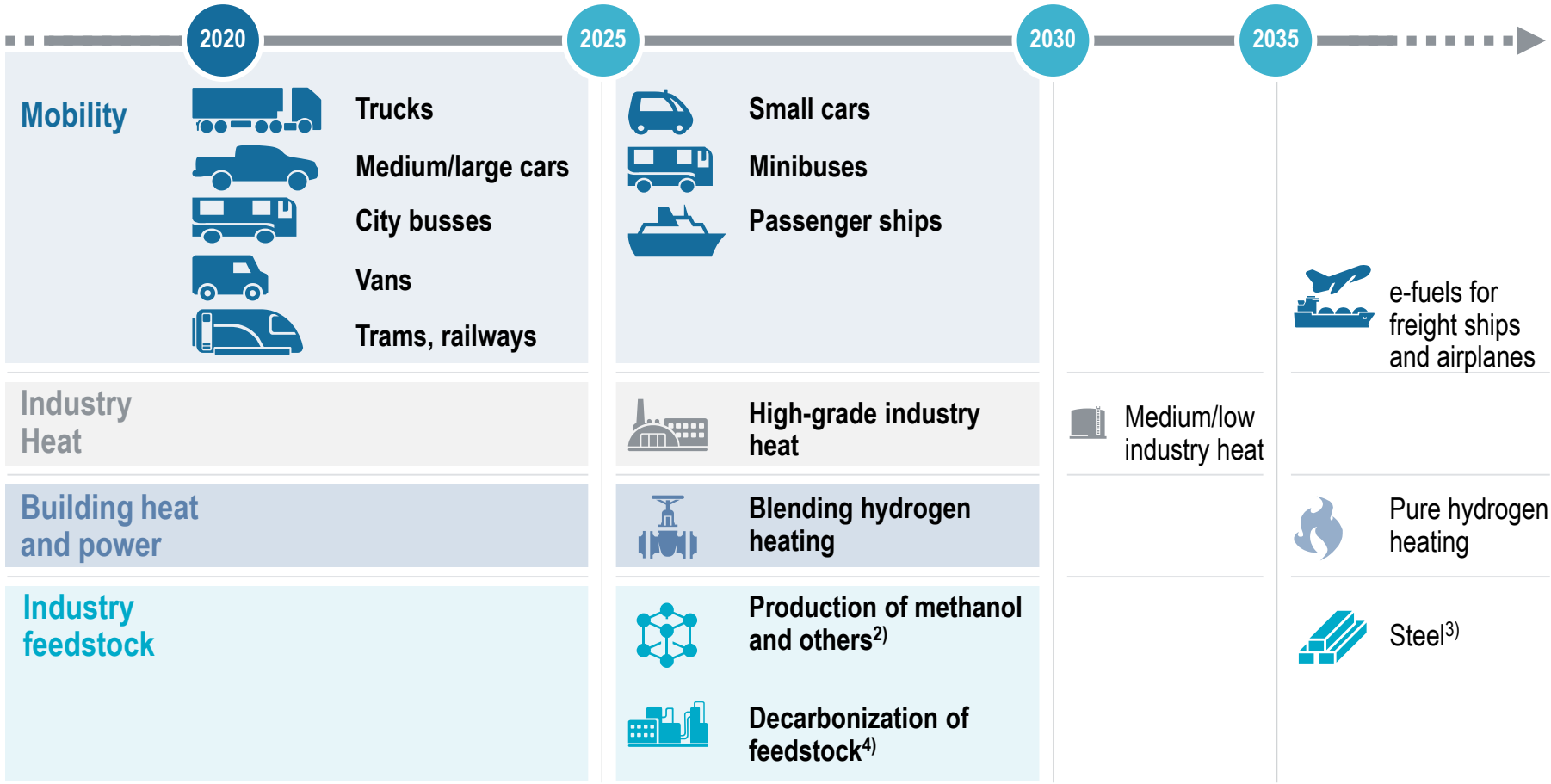
6 | **Rigorous business planning in order to minimize forecasted errors / uncertainty** around pricing, demand and other dimensions of H2 projects (CapEx and OpEx are foreseeable)

7 | **Discipline on project execution** due to the complexity in managing high number of difficult stakeholders, locally and internationally

Source: Roland Berger

Technological readiness levels differ widely – mass market to be expected around 2030 for most mobility end-uses

Hydrogen end-uses – market adoption

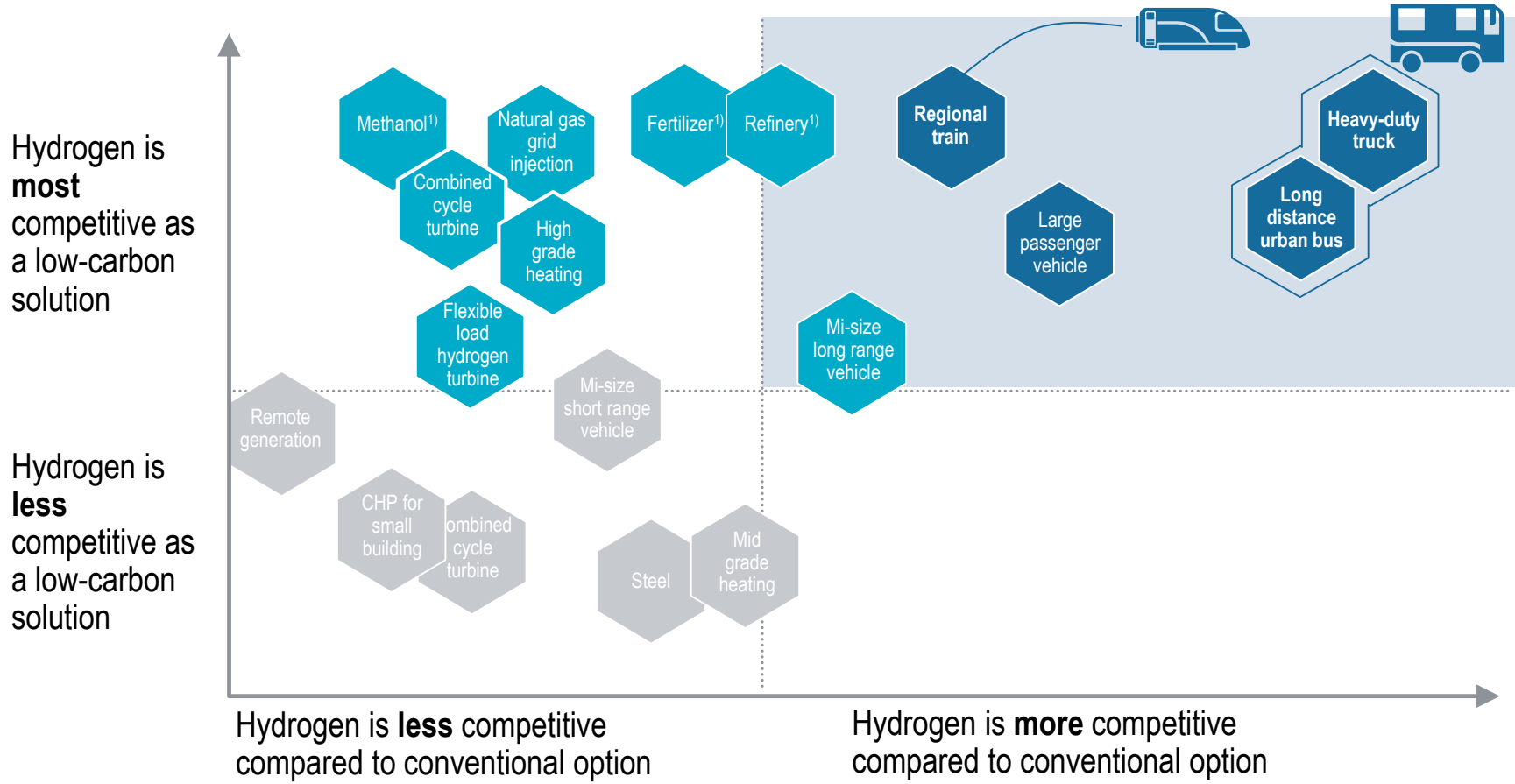


1) Defined as sales >1% within segment in priority markets 2) Market share refers to amount of production that uses hydrogen and captured carbon to replace feedstock 3) DRI with green hydrogen, iron reduction in blast furnaces & other low-carbon steel making processes using H2 4) Market share refers to the amount of feedstock that is produced from low-carbon sources

Source: Hydrogen Council; Roland Berger

By 2030, some H_2 applications are expected to be competitive to both low-carbon and conventional alternatives

2030 competitiveness of selected hydrogen applications



1) Hydrogen is the only alternative and low-carbon renewable hydrogen competing with grey (optimal renewable or low-carbon shown)

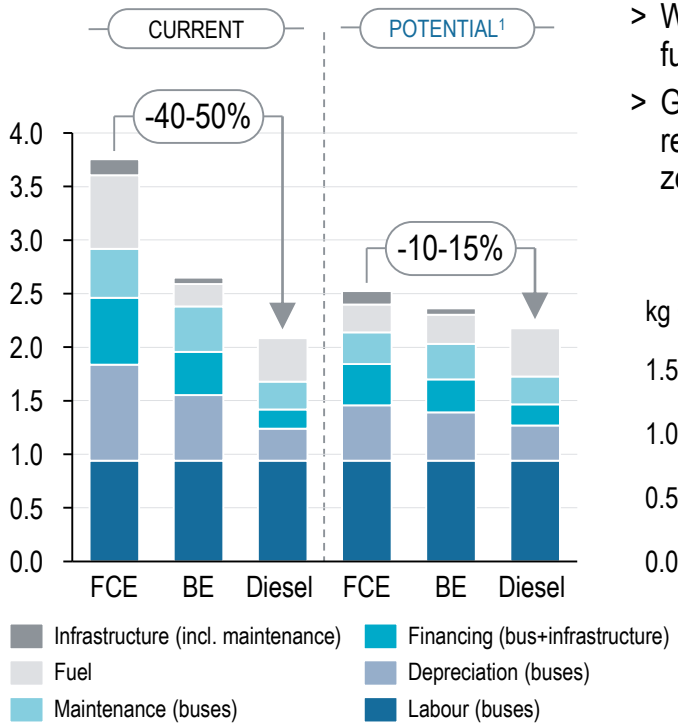
Source: Hydrogen Council, Roland Berger

The cost premium of hydrogen buses might decrease significantly in the medium run, emissions can be drastically reduced

Buses – business case and performance overview

Economic (2 scenarios)

Total Cost of Ownership [EUR/km]

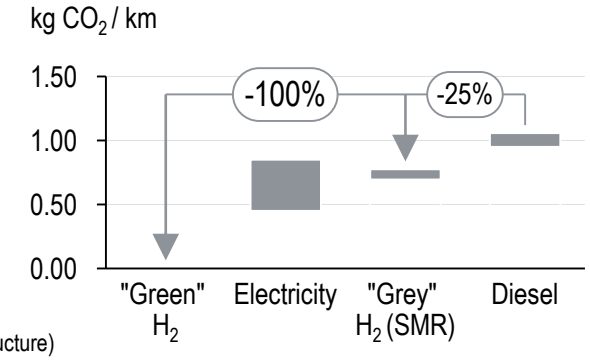


Environmental

> Saving ~100 kg NO_X per bus a year (in this example)

> Well-to-wheel CO_2 emissions depend on fuel source and vehicle efficiency

> Green H_2 or 100% green electricity would reduce well-to-wheel CO_2 emissions to zero

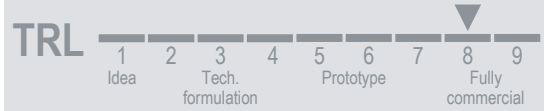


Technical/operational

> Fuel cell electric buses are **entering the commercial phase** with large scale demonstration projects under way

> **Range of FCH buses 250-450 km**; (comparable to diesel buses), BE buses reaching 150-200 km max. guaranteed range

> **Refuelling times of ~7-15 min per bus**; comparable to diesel vs. BE bus several hours charging



1) The "POTENTIAL" scenario requires a number of FCE-related and other factors to fall in place in the medium/long run (please see previous slide)

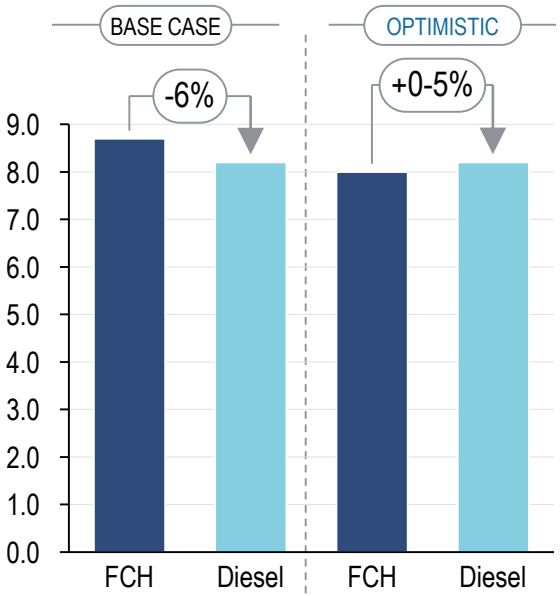
Source: FCH2 JU, Roland Berger

FCH technology has promise in trains – can be competitive with existing technology under certain conditions

Trains – business case and performance overview

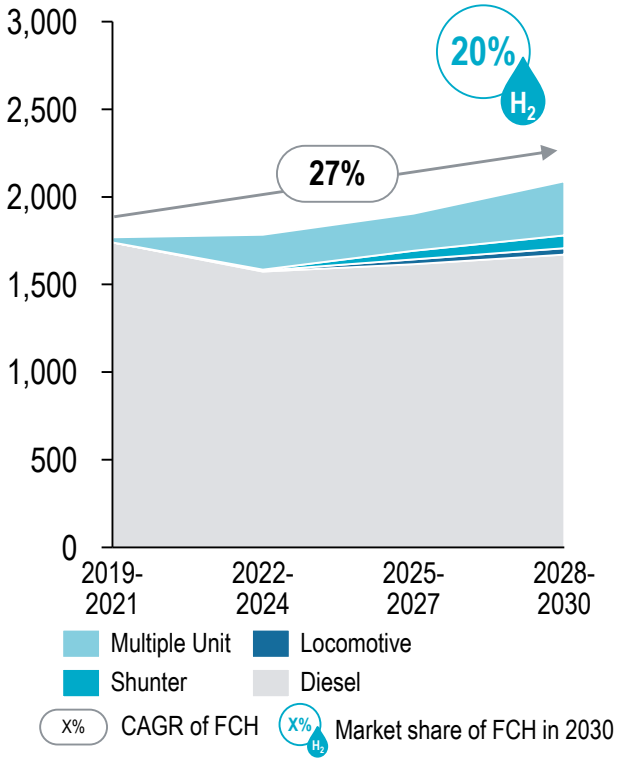
Economic (2 scenarios)

Estimated Multiple Unit Total Cost of Ownership (TCO) [EUR/km]



Market potential

EU Market potential FCH trains – Base scenario [standard units]



Case and barrier analysis

> **10 case studies** demonstrated that **FCH technology** can be **competitive on trains**

– FCH technology competitive on **non-electrified routes ~100 km**

– FCH attractive for **routes with low utilisation**

> No show-stopping barriers for FCH in rail exists but **still optimization potential**

Source: Roland Berger

Heavy-duty vehicles and trains switching to hydrogen will enable de-carbonization without compromising resilience and performance

Benefits of Hydrogen to heavy-duty vehicles

Sustainability

Zero carbon
… full decarbonization with H_2 produced from renewables

Air quality
… no toxic tailpipe emissions/only water vapor

Local value chain
… produced from renewables for local consumption

Operational resilience & performance

Higher autonomy
… vs. other electrical solutions – e.g. buses up to 400 km without refuelling

Strong performance
… comparable to diesel (e.g. acceleration or gradeability)

High passenger comfort
… due to reduced noise levels and smooth driving experience

Full route flexibility
… not bound to any required infrastructure on the route

Fast refuelling
… easy to use and enabling several refuelling cycles per day – e.g. down to 7 min for buses

Technological maturity
… with 15 years and a vast operational experience in Europe

Source: FCH2 JU, Roland Berger

Portugal should implement a first move advantage based on its low cost production to balance domestic use and export of Green Hydrogen

Comparative advantages for domestic and export positioning

Leverage on low Cost of Renewable Energy to…

> **Most competitive European market in producing renewable energy** – the lowest tariff awarded in the country's first solar PV auction (€14.76/MWh)

> **Leading country in** the adoption of **renewable energies – 72% of electricity powered by renewables**

… balance a domestic use…

> **Natural gas grid allows** Portugal **to inject up to 20% hydrogen into the network** without the need for additional investment

> **Commercialization without dependence on other industries** creates immediate incentives for local production

… with international supply

> **Leverage on Sines** as a **logistic platform** with very good accessibility

> Develop know-how in **H_2 conditioning for ship transportation** to gain a sustainable competitive positioning in exports

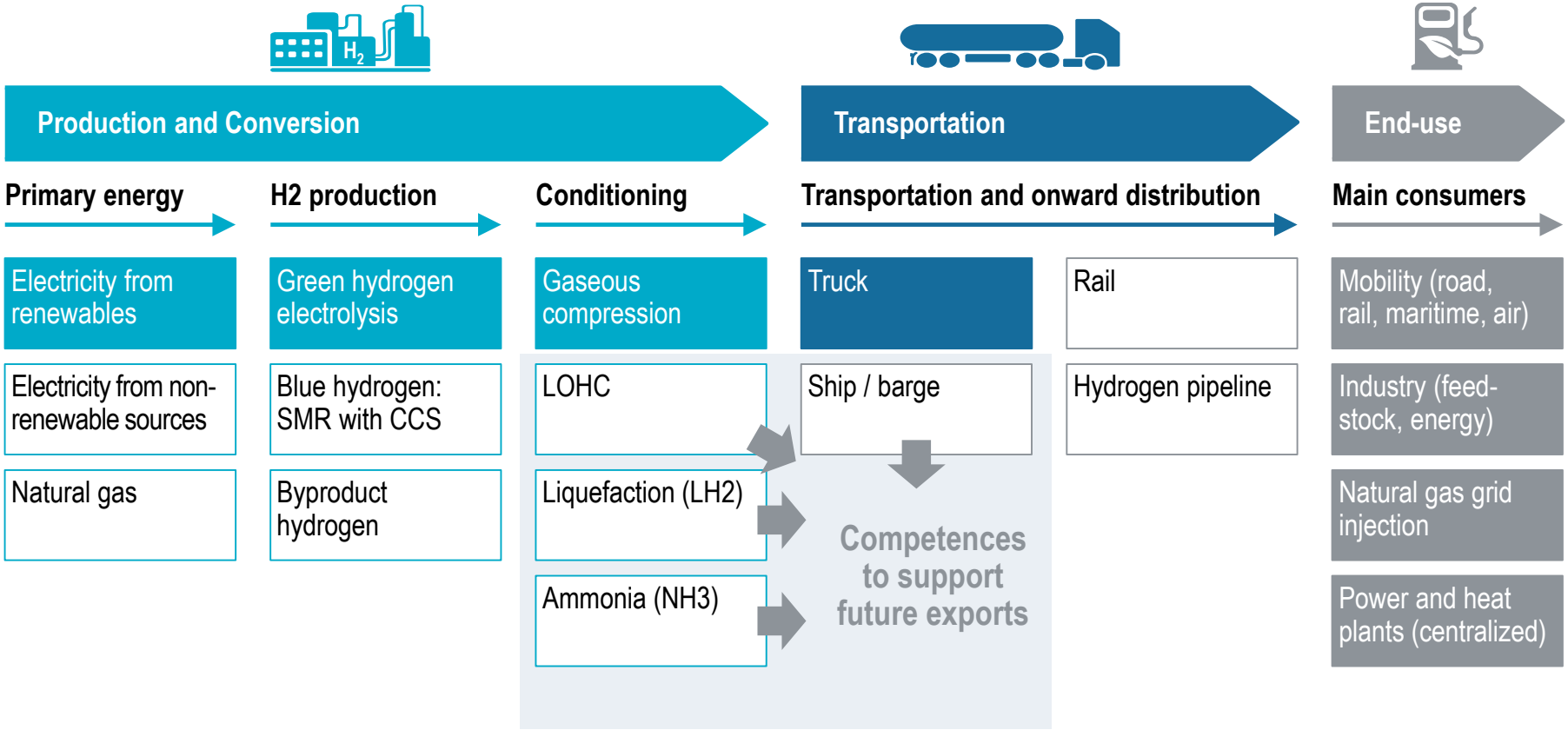
> **Attract Europe funds** to export to other Member States and guarantee a EU energy independence

Source: Roland Berger

In the short-term, Portugal should focus on Green H_2 production and on the market development of its applications (e.g. mobility)

Hydrogen value chain

Non-exhaustive



Prioritize areas of development (short-term)

Source: Roland Berger

Hydrogen has many end-use applications options ranging from mobility to industry feedstocks or blending with natural gas

End-use application details

Road mobility

> **Hydrogen trucks** already available **on** the **market for sale**
> **High speed refueling** compared to electrical trucks
> **Trucks to compete** with **Electrical Vehicles**

Fuel Cells Hydrogen Trains

> **Fuel cells** trains will be used to decarbonize regional diesel trains
> **High speed refueling and lighter battery** are the main advantages compared to Electrical trains

Passenger ships

> **Higher competitive advantage compared with electrical solutions** – still in its developing phase but with potential market adoption before 2030

Natural gas grid injection

> The Portuguese **natural gas network** is modern and **allows hydrogen blending up to 20%**
> **Critical to secure demand** for production players **in the short-term**

Combined heat and power

> Opportunity for **decarbonization of thermoelectric power plants** powered by Green Hydrogen locally produced

Industry feedstock

> **Green hydrogen for industrial players** that already use it **as a feedstock** (e.g. chemical, refinery)

Source: Roland Berger

Along the value chain there are already on going national projects with several green hydrogen applications

Hydrogen value chain – national on going initiatives

Non-exhaustive

Green H_2 Production

Green Flamingo 5GW project powered by wind and PV

Decentralized production for local consumption to support the **reduction of CO2 emissions**

Combined heat and power

Green H_2 for **decarbonization of Combined Cycle Power Plant**

Tests are planned for 2022, from a 1MW installed capacity **and 12 MWh storage capacity**

Natural gas grid injection

The Portuguese Government to **regulate Green H_2 injection** into natural gas grid (**up to 20%**)

Hydrogen Refuel Stations

First HRS to be developed in Gaia (1,5 M€ investment)

Galp is planning to open **one by the end** of the year **2020**

Mobility cluster

Mobility cluster is developing – CaetanoBus already exporting heavy-duty vehicles (in partnership with Toyota)

Industry cluster

Green hydrogen as main **source of feedstock for the industry cluster** (e.g refineries and chemical industry)

Industry player (Confidential)

Source: Roland Berger

Portugal has the strategy and the conditions in place – challenge relies on securing and managing implementation

From strategy to implementation

Strategic vision, large national players and projects already in place

+

Infrastructure of renewables and Natural gas grid

Challenge relies on Implementation

Coordination among different stakeholders (government, large national players, international markets, EU, technology players, …)

Integration corporate strategies with National and European strategies (national, domestic and international players)

Feasibility guarantee through rigorous business planning, equity stories and funding

Discipline through drum-beat project coordination and robust PMO

Source: Roland Berger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