Hydrogen Infrastructure in Germany: Status, Developments, Sources

LeadIng.

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Hamburg, June 7, 2011
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Expectations towards a H2 Infrastructure

H2-Infrastructure: Production – Distribution - Fuelling

Key initiatives in Germany

Everyday products ...

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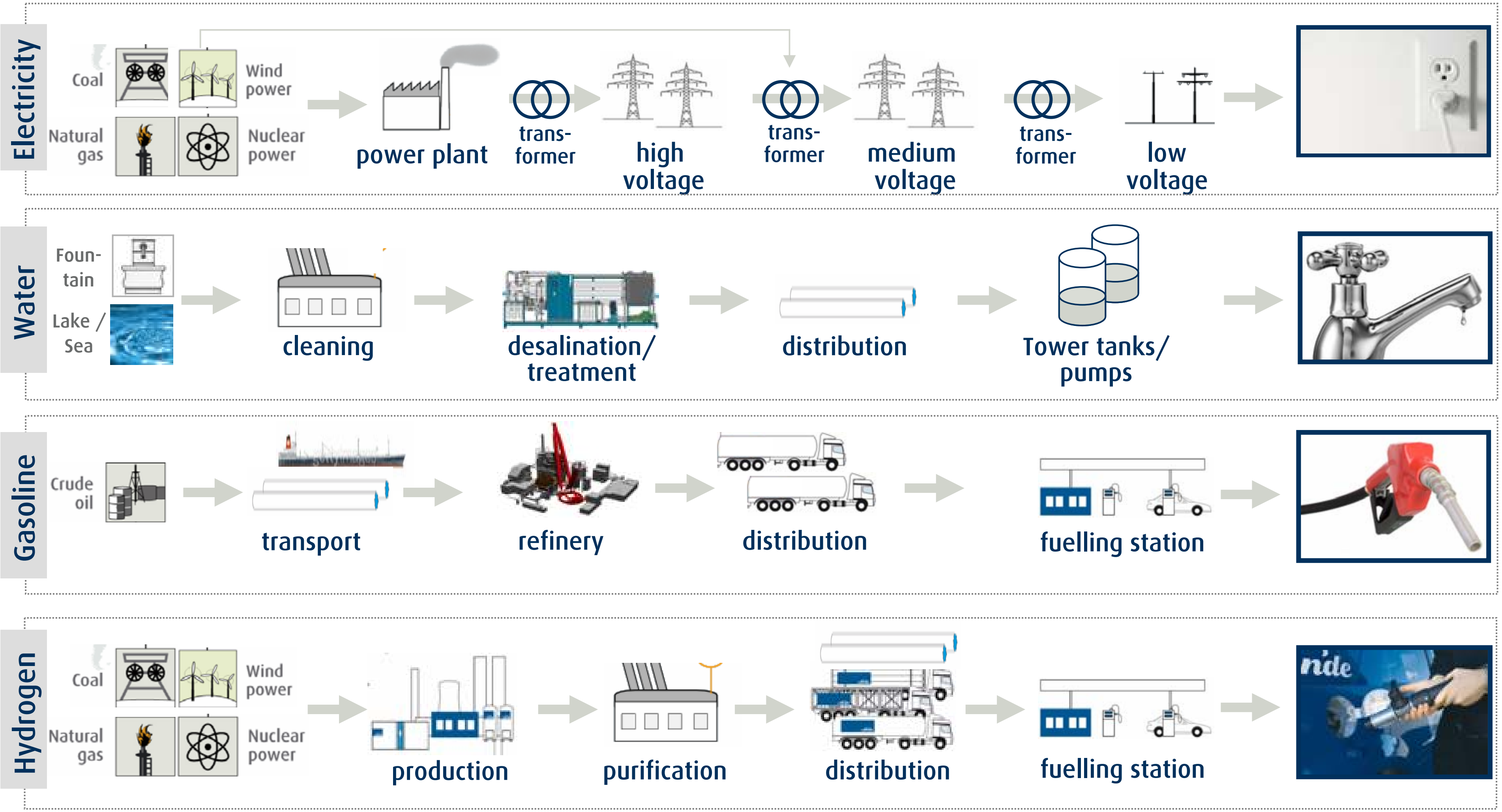
...need a solid infrastructure behind the scenes

Our customers only see final products...



...that need a complex infrastructure

A hydrogen infrastructure is demanding…

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Costs for..

— **exploitation of new oil reserves** in 2011[5]:	**92**	**B€**
— **extension of the european electricity grid** bis 2015[1]:	**28**	**B€**
— **car-scrap** bonus (direct costs):	**5**	**B€**
— construction of a **90 km** high-speed rail line**:**	**3,6**	**B€**
— **18 Eurofighters** incl. logistic and training[2]:	**1,9**	**B€**
— Build-up of a public **charging infrastructure for BEVs**[3]**:**	**1 – 2**	**B€**
— Build-up of a public **hydrogen infrastructure for FCEV** [4]:	**1,5 – 2**	**B€**

1 Mio cars

…but absolutely doable

[1] Beinhaltet den Ausbau von 18,700 km Leitungsnetz
[2] Publizierte Kosten für das österreichische Bundesheer für deren Eurofighter Auftrag.
[3] Abhängig vom Anteil an Schnellladestationen. Investitionskosten pro Ladestation zwischen 2.000 - 25.000 €
[4] 1000 Tankstellen innerhalb Deutschlands
[5] Handelsblatt, 16.03.2011, Exxon Mobil, Shell, BP; Chevron, Total, Conoco Phillips
Source: tagesschau.de, wikipedia.de, bahn.de

Seven success factors for the infrastructure build up

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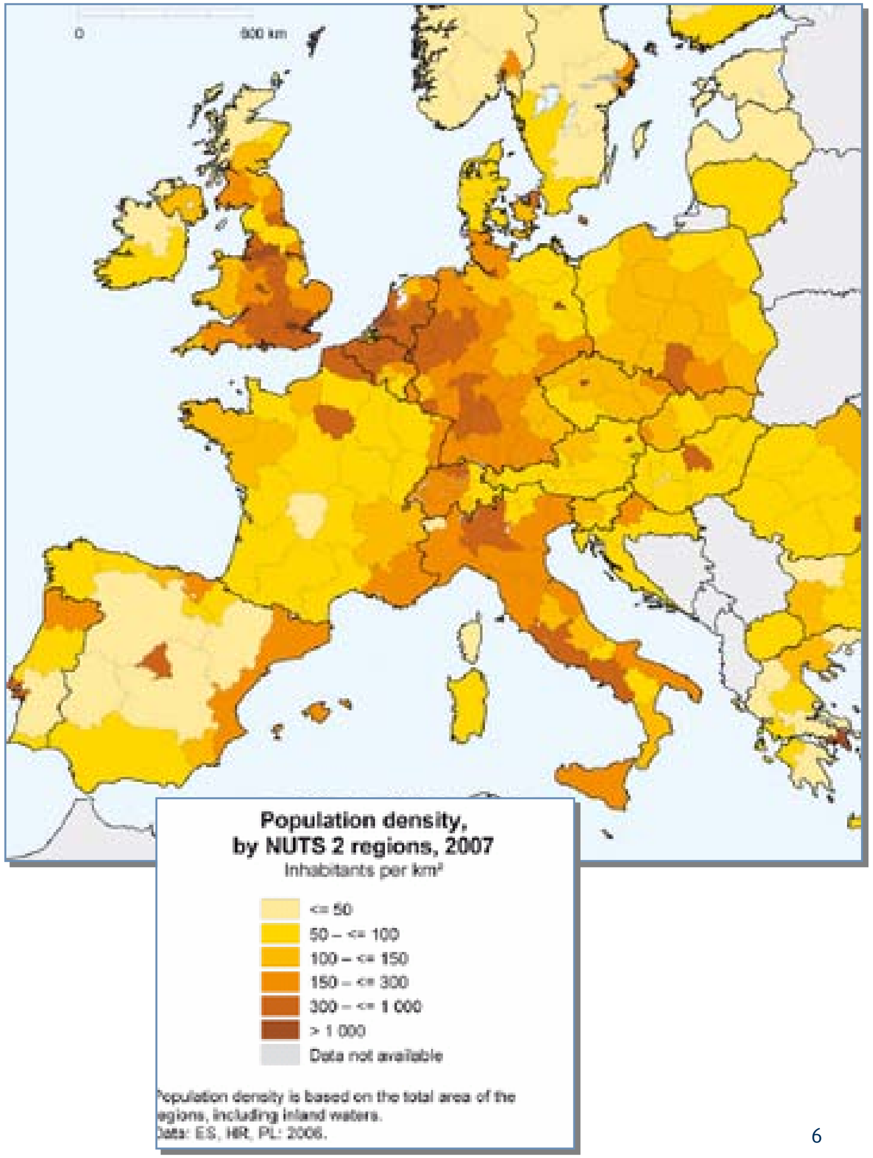
1. Population density
2. Private and public wealth
3. Environmental awareness
4. Technology and infrastructure competence
5. Collaboration of industry and government
6. Hydrogen demand:
   Cars, busses, forklifts, ships etc
7. Attractiveness for investors



Source: Eurostat

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Linde covers the entire hydrogen value chain

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Production

Conventional
(e.g. SMR)

Green
(e.g., BTH)

Supply/Storage

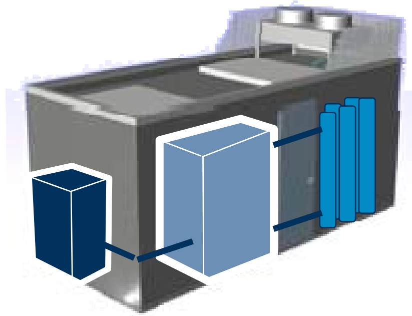
CGH2 storage

LH2 storage

Onsite SMR

Onsite Electrolysis

Compression/Transfer



Ionic compressor

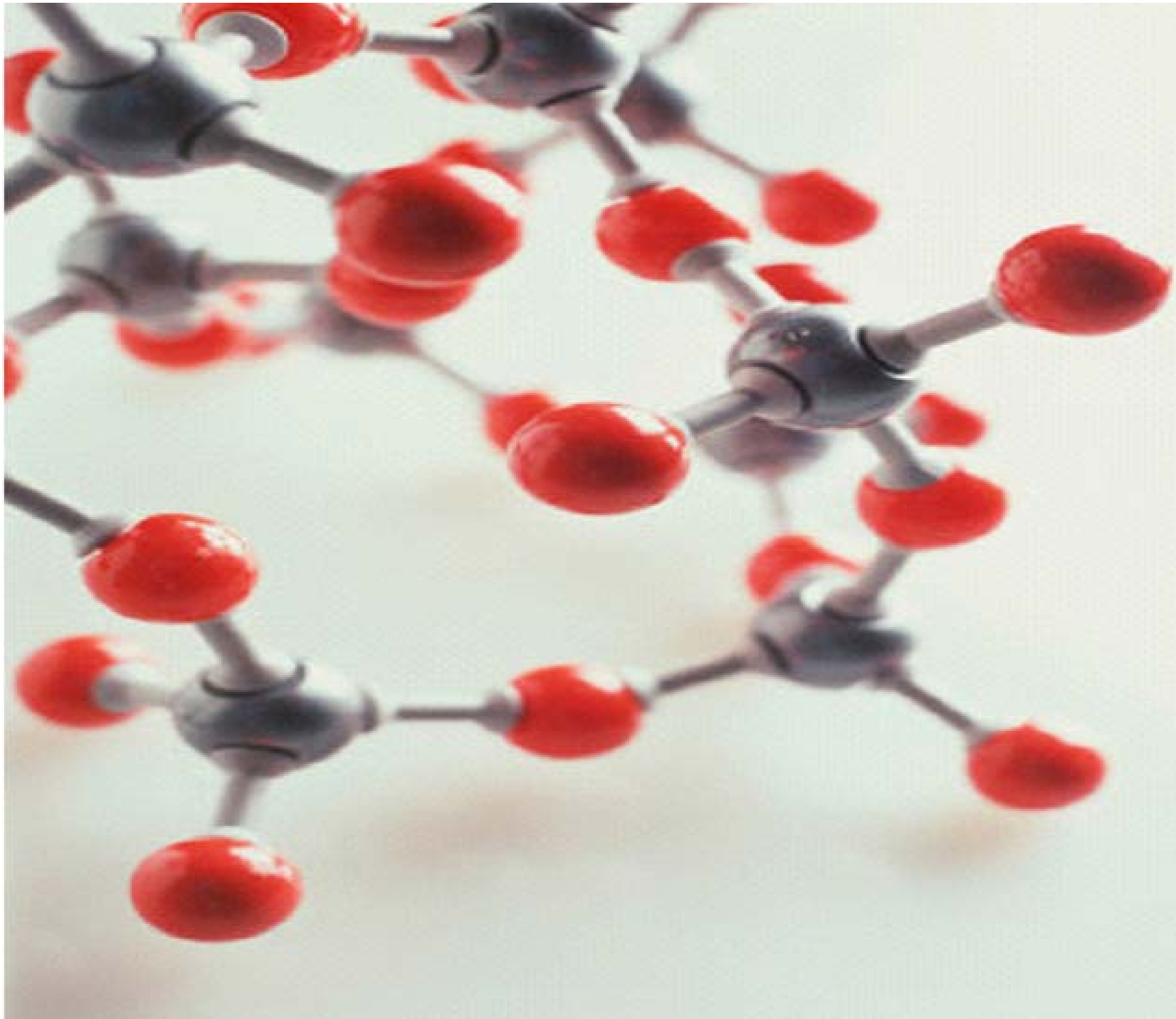
Cryo pump

Dispenser

350 bar

700 bar

A large variety of feedstock can be used to produce hydrogen..



Water: H_2O

Methane: CH_4

Butane: C_4H_{10}

Ethanol: C_2H_6O

Sugar: $C_6H_{12}O_6$

Wood: $C_{12}H_{22}O_{11}$*

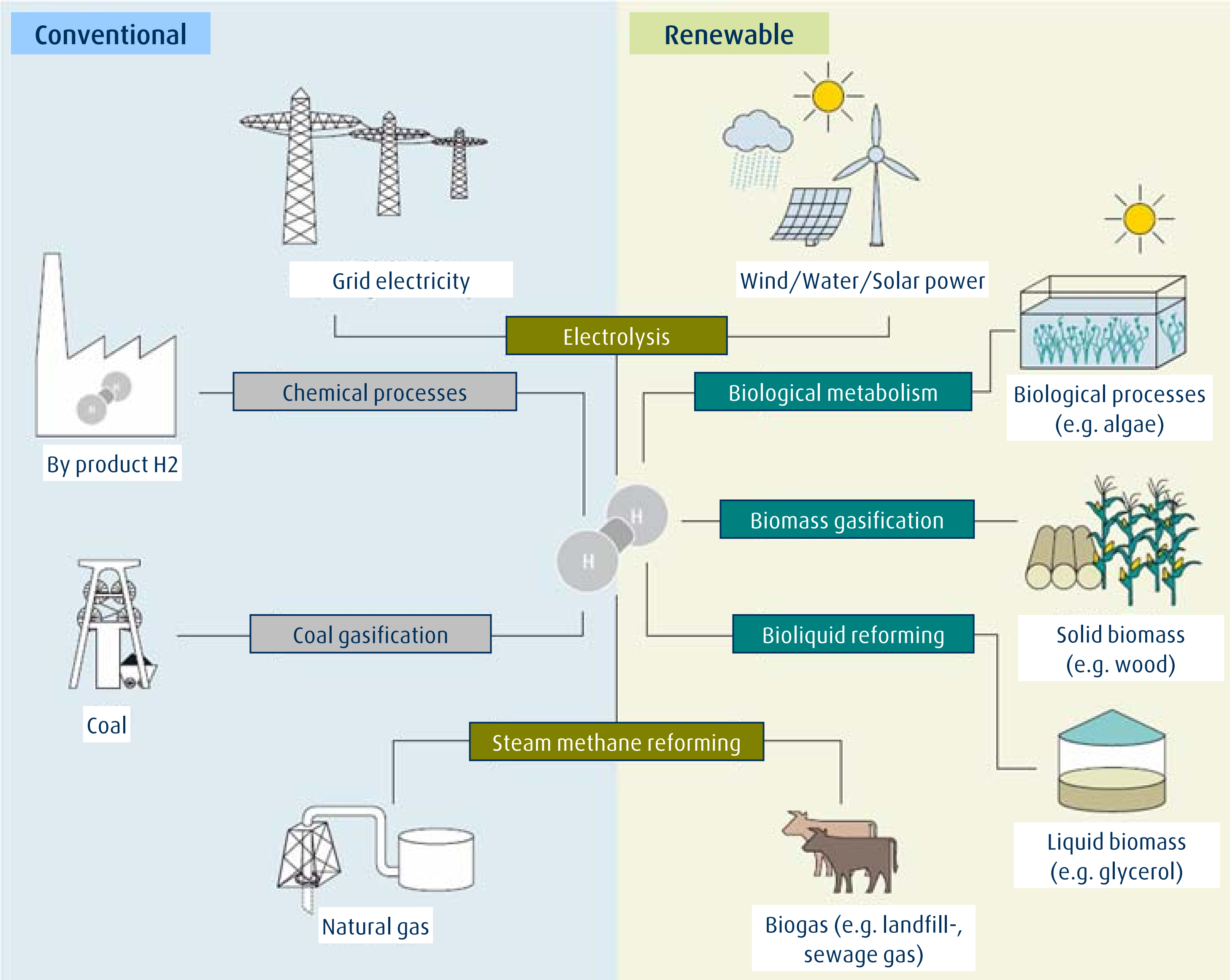
Petroleum: C_nH_{2n+2}

Cole: $C_{135}H_{96}O_9NS$

....

* Approximation

Hydrogen production: Variety of feedstock allow for a broad diversification and CO2 reduction



Hydrogen distribution: Different solutions for different demands and distances

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	Facts	Advantages	Disadvantages
	- Transport @ 200 bar - Capacity (varies): **ca. 330 kg – 630 kg CGH2** [2]	- Economical transport for distances < ~ 250 km	- Comparatively low capacity → High demand requires high level of deliveries - Comparatively High footprint
	- Transport @ -253 °C - High capacity: **ca. 3.500 kg LH2** [1]	- Economical transport for distances > ~ 250 km - High capacity allows flexibility in delivery - Allows comparatively small footprints	- Comparatively high energy requirements
	- Transport @ 20 - 100 bar - H2 capacity: **10.000 – 100.000 Nm^3/h** [3]	- Economics depend on steady delivery rates and distances - Very high capacities	- Comparatively high invest

[1] equals approx. 700 vehicles / Trailer; [2] equals approx. 66 – 126 vehicles/ Trailer; [3] equals approx. 180 – 1.800 vehicles/hour (assuming 5kg/vehicles)

Linde's advanced hydrogen fuelling technologies

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The Ionic Compressor

- High throughput of 35 kg/h at 900 bar[1]
- Energy consumption reduced by 25%[2]
- Very small number of moving parts (liquid piston)
- Reduced wear and long service life
- Four times longer maintenance intervals*
- Fulfils industry standard SAE J 2601

The Cryo Pump

- Very high throughput of up to 120 kg/h at 900 bar
- Energy consumption reduced by 70%[2]
- Hydrogen with highest purities
- No additional cooling system
- High reliability, little maintenance effort and low costs
- Fulfils industry standard SAE J 2601

[1] For one system. Modular setup allows for higher throughputs.
[2] In comparison to a conventional piston compressor

Cost of production is projected to reduce by 70% at the dispenser

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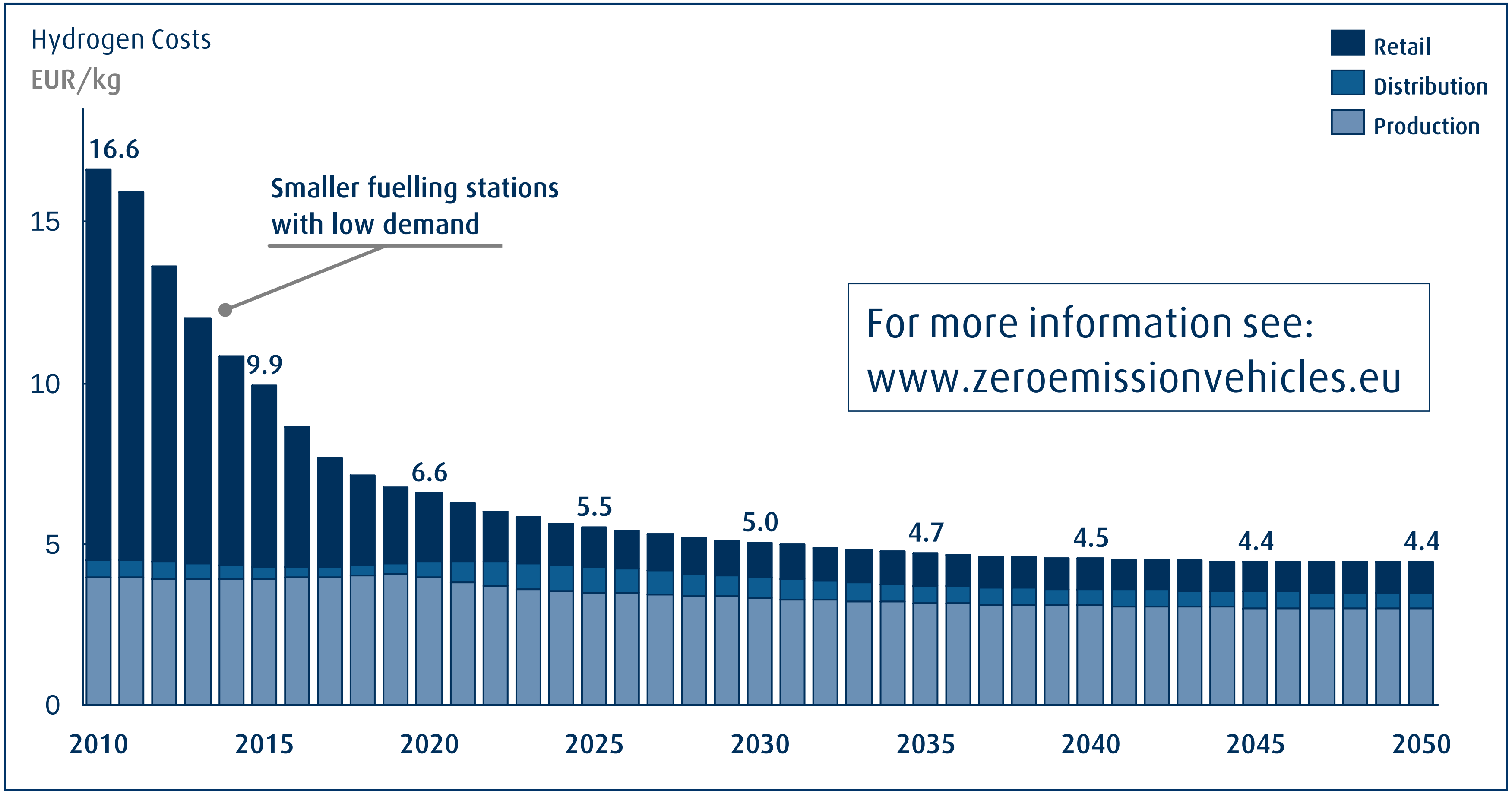
w/o taxes

25% FCEV WORLD



Quelle: EU Study analysis “A portfolio of powertrains for Europe: a fact-based analysis”, 2010

Reference projects prove technological maturity

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Linde reference projects

Key facts

— More than 70 hydrogen stations equipped in 15 countries

— More than 200,000 successful fuellings

— Leading supplier of hydrogen fuelling technologies

Key Learnings

- Technological maturity reached
- High level of standardisation reached
  - Standardised fuelling protocol
  - Standardised H2 quality
- Comparable fuelling experience
  - 3 min / fuelling
  - Touch & feel like conventional stations
  - Integration into existing infrastructure

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Key initiatives in Germany

Clean Energy Partnership

CEP

Clean Energy Partnership CEP

Ein Leuchtturmprojekt des Nationalen Innovationsprogramms Wasserstoff- und Brennstoffzellentechnologie (NIP)

Federal Government

Energy and Technology:
Air Liquide
Linde
Shell Hydrogen
StatoilHydro
TOTAL
Vattenfall Europe

Car OEMs:
BMW
Daimler
Ford
GM/Opel
Honda
Toyota
Volkswagen

Public Transport:
Berlin: BVG
Hamburg: Hochbahn

H_2 Mobility is a second step in evaluating the commercialization of a hydrogen infrastructure and FCEVs

	Factual comparison of FCEV within a portfolio of power-trains	H_2 Mobility – Fact-based analysis of roll-out scenarios	H_2 Mobility infrastructure roll-out
Status	Results published Nov 2010	Ongoing	Parties to be defined (from 2011)
Objec-tive	• **Fact-based evaluation** of the **market potential** of **FCEV** compared to **BEV**, **PHEV**, **ICE** • Development of an **integrated perspective** across the **H_2 value chain** based on **proprietary industry data**	• Assessment of hydrogen retail infrastructure roll-out in GER • Definition of an integrated **roll-out scenario** for **FCEV** market penetration with major car OEMs	• Establishment of a **future consortium** for the **H_2 infrastructure** roll-out • Implementation of a **business case**

Linde and Daimler initiative to reach the next level: "20 additional hydrogen fuelling stations for Germany"

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DAIMLER

<u>Key facts</u>

- Initiative by Daimler and Linde
- Bridge the gap between demonstration (CEP) and commercialization (H2 Mobility)
- 20 additional public hydrogen stations in Germany
- Build-up in 2012, 2013, and 2014
- Strengthen existing cluster and establish links
- Will allow to drive through Germany with hydrogen cars

Summary

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- Hydrogen is an attractive fuel
- The hydrogen infrastructure build-up is demanding but doable.
- Hydrogen can be produced from a variety of primary energy sources.
  It will lead to a zero emission mobility
- Cooperation is key – key initiatives are on the way.