AIR LIQUIDE

Creative Oxygen

Hydrogen Initiative

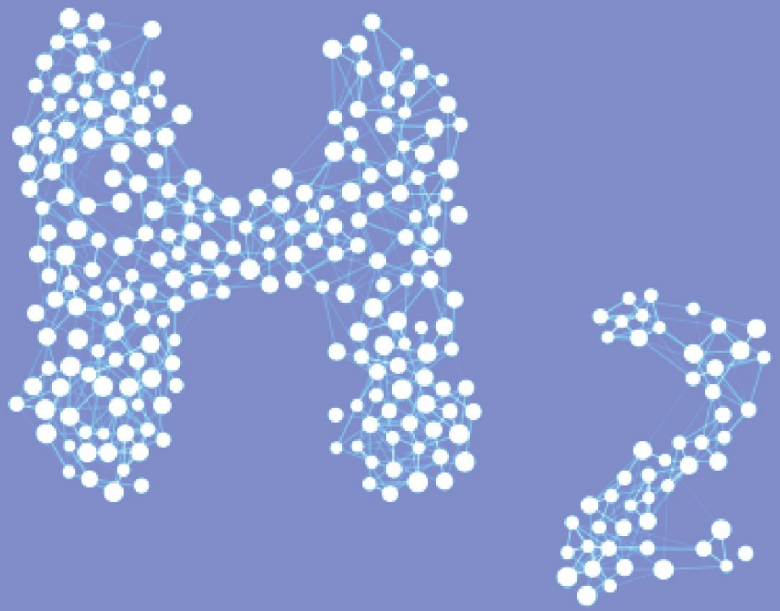
Hydrogen – Transporting the future

November, 22d 2017 I Dr. Alena FARGERE

Accelerating Energy Transition – Agenda

1. Hydrogen – global energy context
2. Why Hydrogen works
3. Why Hydrogen Energy will work
4. Air Liquide's Hydrogen strategy to 2020
5. What is ahead of the game?

1. Hydrogen – global energy context



Global climate change crisis

Must reduce emissions of CO_2 and CH_4

Regulation & Financing

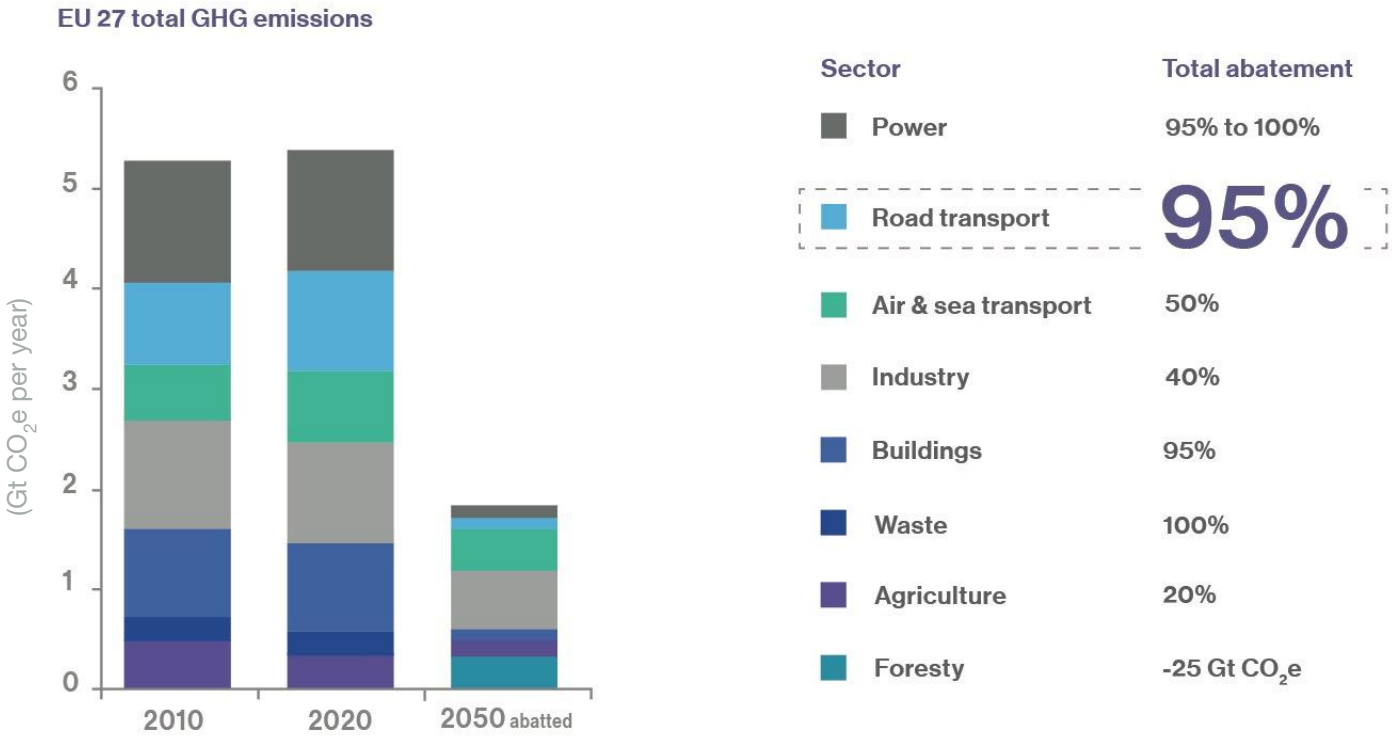
PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

Europe	Japan	U.S.	China
-80%	-80%	-28%	20%
GHG emissions by 2050	by 2050	by 2030	Non-fossil by 2030

Europe's emissions challenge

Aggressive Energy & Climate policies

- Road transport and energy emissions are heavily impacted
- To meet targets we need to abate emissions from transport by 95% by 2050



(1) Large efficiency improvements are already included in the baseline based on the IEA. World Energy Outlook 2009, especially for industry.
(2) Abatement estimates within sector based on Global GHG Cost Curve.
(3) CCS applied to 50% of large industry (cement, chemistry, iron and steel, petroleum and gas, not applied to other industries).
Source: www.roadmap2050.eu

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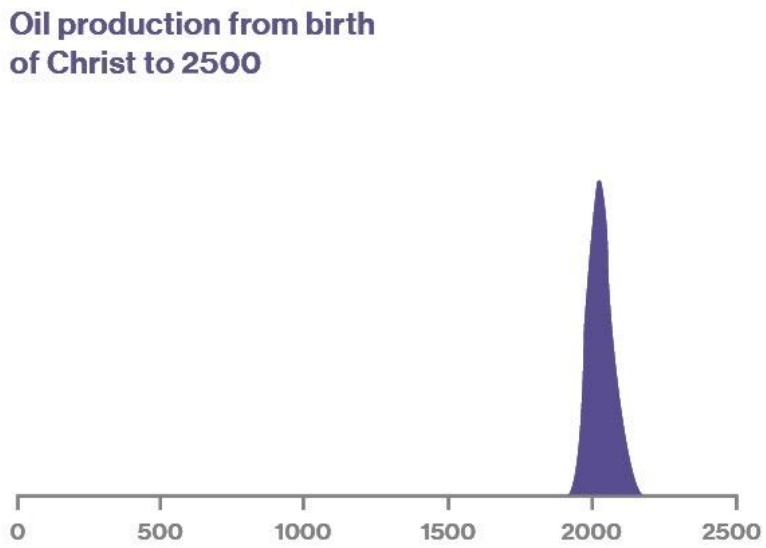
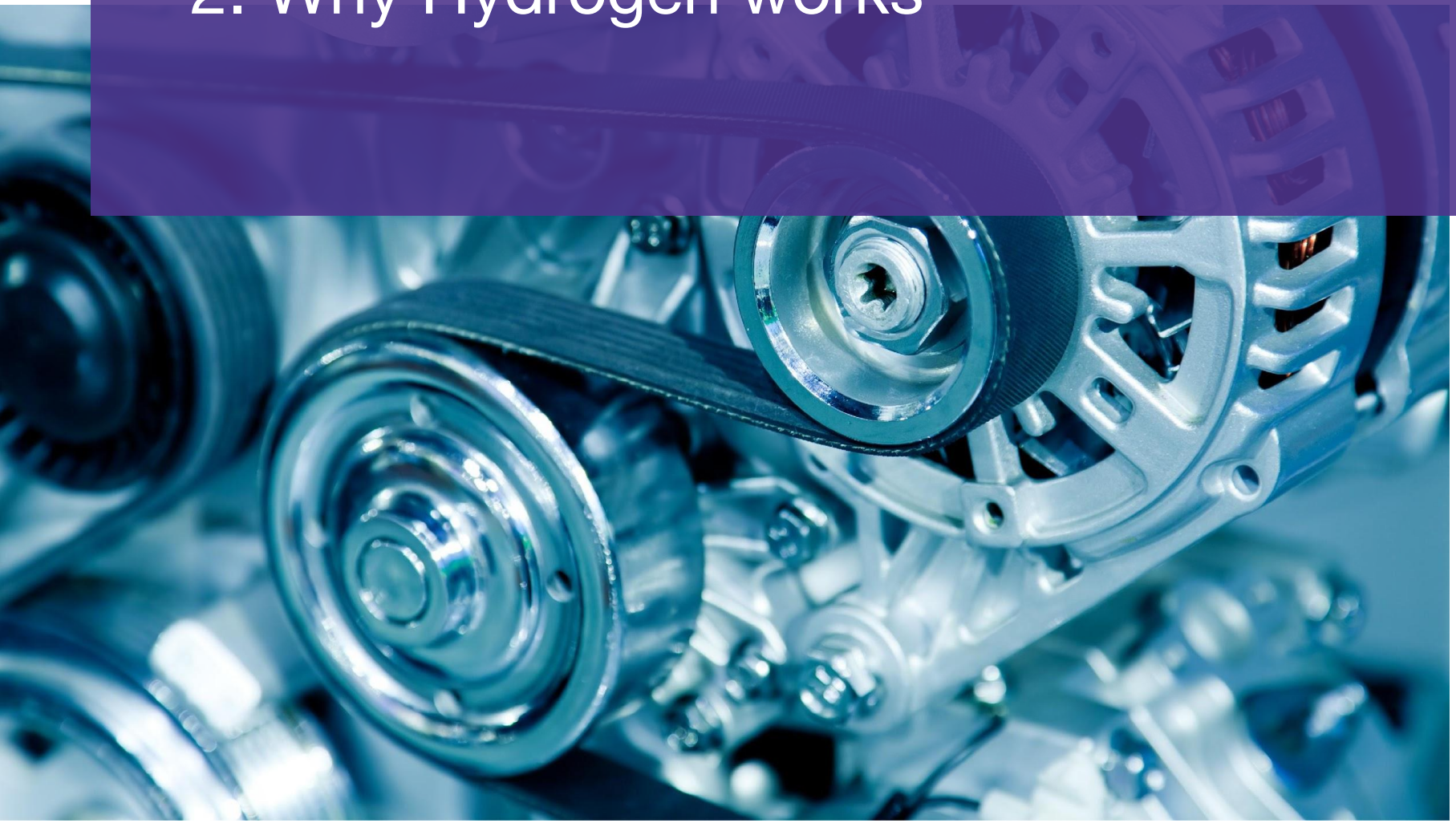
What happens when oil runs out?



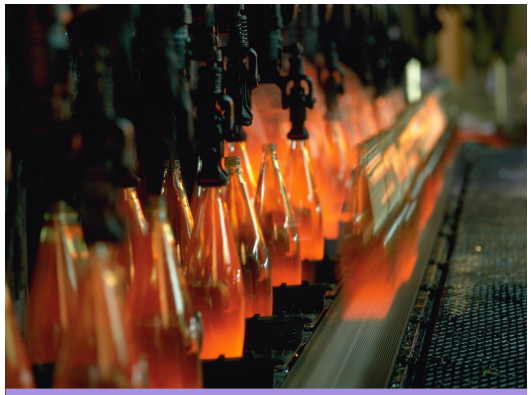
- Cheap and abundant oil has made us an incredibly successful society…
- At stake now is our fundamental mobility, and more…

2. Why Hydrogen works



Hydrogen, many existing applications…

Heat Treatment



Glass

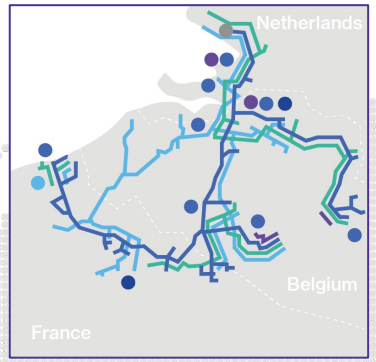
H2 Ultra pure <1ppb

Chemicals & Petroleum refining

Rockets

Fuel cell vehicle

40 years of global investment in Hydrogen



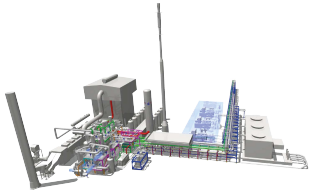
> 14 bn m^3/yr
> 1,850 km H_2 pipeline
> 46 large H_2/CO plants
> 2 bn € sales

year 2015

Hydrogen
Oxygen
Nitrogen
Synthetic gas

Hydrogen and or/carbon monoxide facility and hydrogen source
Oxygen and nitrogen facility
Cogeneration facility
Synthetic gas facility

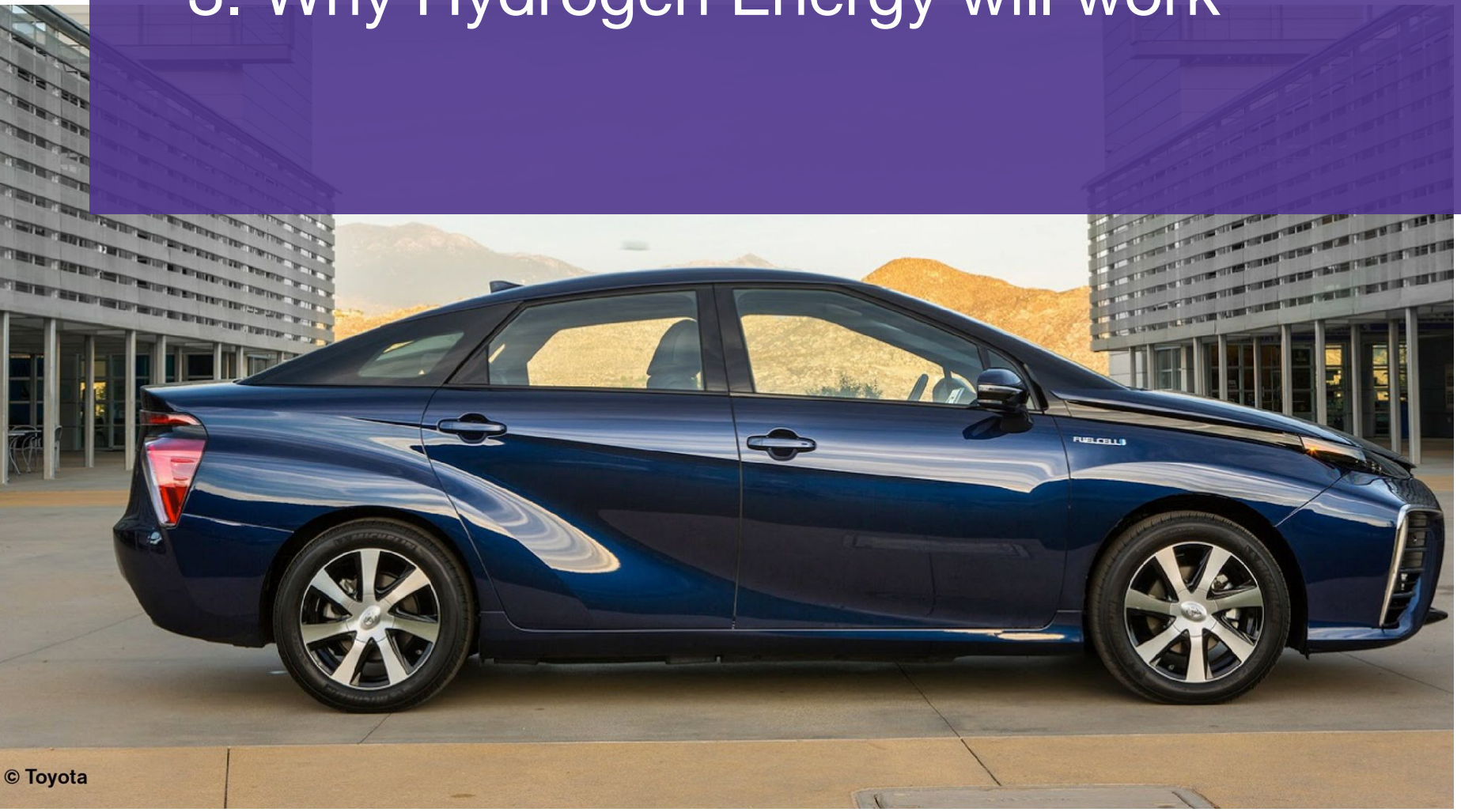
Production



Distribution

Applications

3. Why Hydrogen Energy will work



Hydrogen delivers dramatic transportation solutions

- Hydrogen is everlasting and is the most abundant element in universe
- H_2 produces zero emissions, just water
- Out performs electric battery solutions

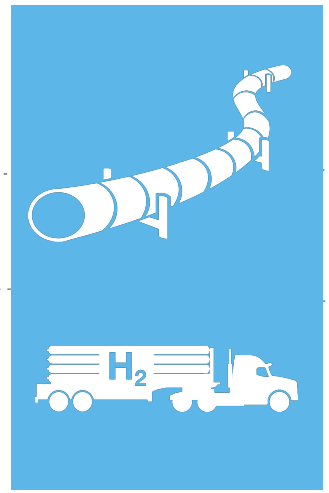
Natural Gas+CCS / Biogas

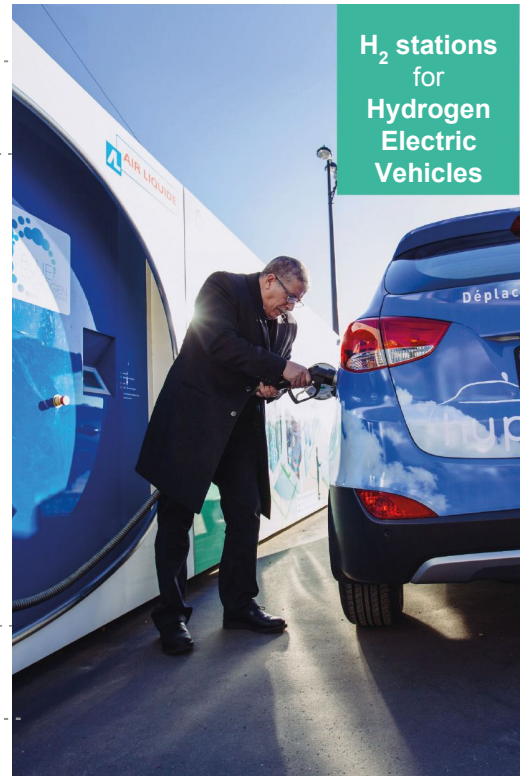
Reformer

BLUE HYDROGEN

Renewable energies

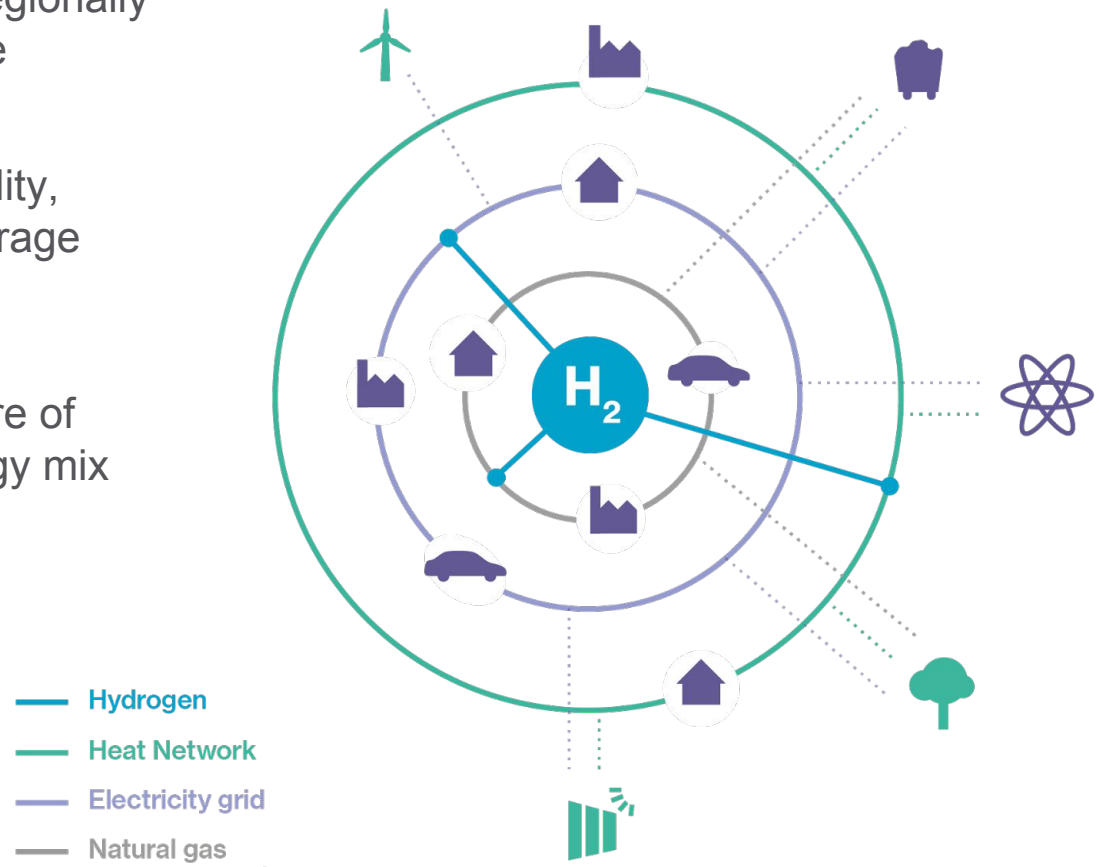
Electrolyser





Beyond mobility, H_2 is *the* energy vector of the future

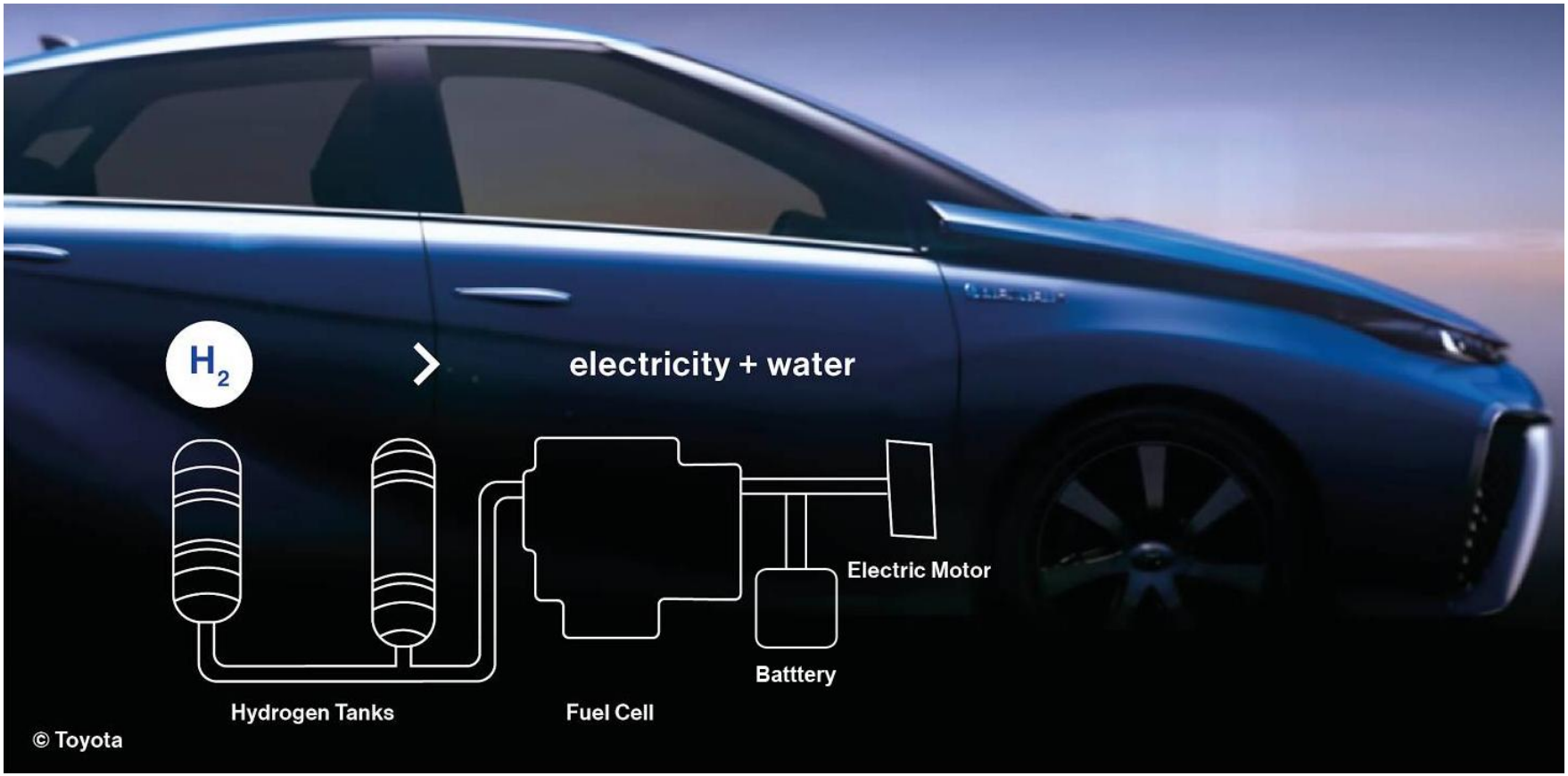
- H_2 can be produced from **any** regionally prevalent primary energy source
- Enhances energy system flexibility, through outstanding Energy Storage capabilites
- H_2 is critical to increase the share of renewable energies in the Energy mix



Reference: IEA Technology roadmap, Hydrogen & Fuel cells, 2015

A fuel cell electric vehicle (FCEV)

Producing electricity from Hydrogen and Oxygen can be applied to any vehicle – cars, buses, forklifts, trucks, trains, aircrafts



Hydrogen out performs all alternatives

PETROL

CO_2 EMISSIONS

Vehicle	150 g/km
Well to wheel	180 g/km
With Hybrid	← ZERO

HYDROGEN

	ZERO
	120 g/km
	← ZERO

With Green H2

ELECTRICAL

AUTONOMY

100 > 300 km

CONVENIENCE

Recharging
30 min < 8 hours

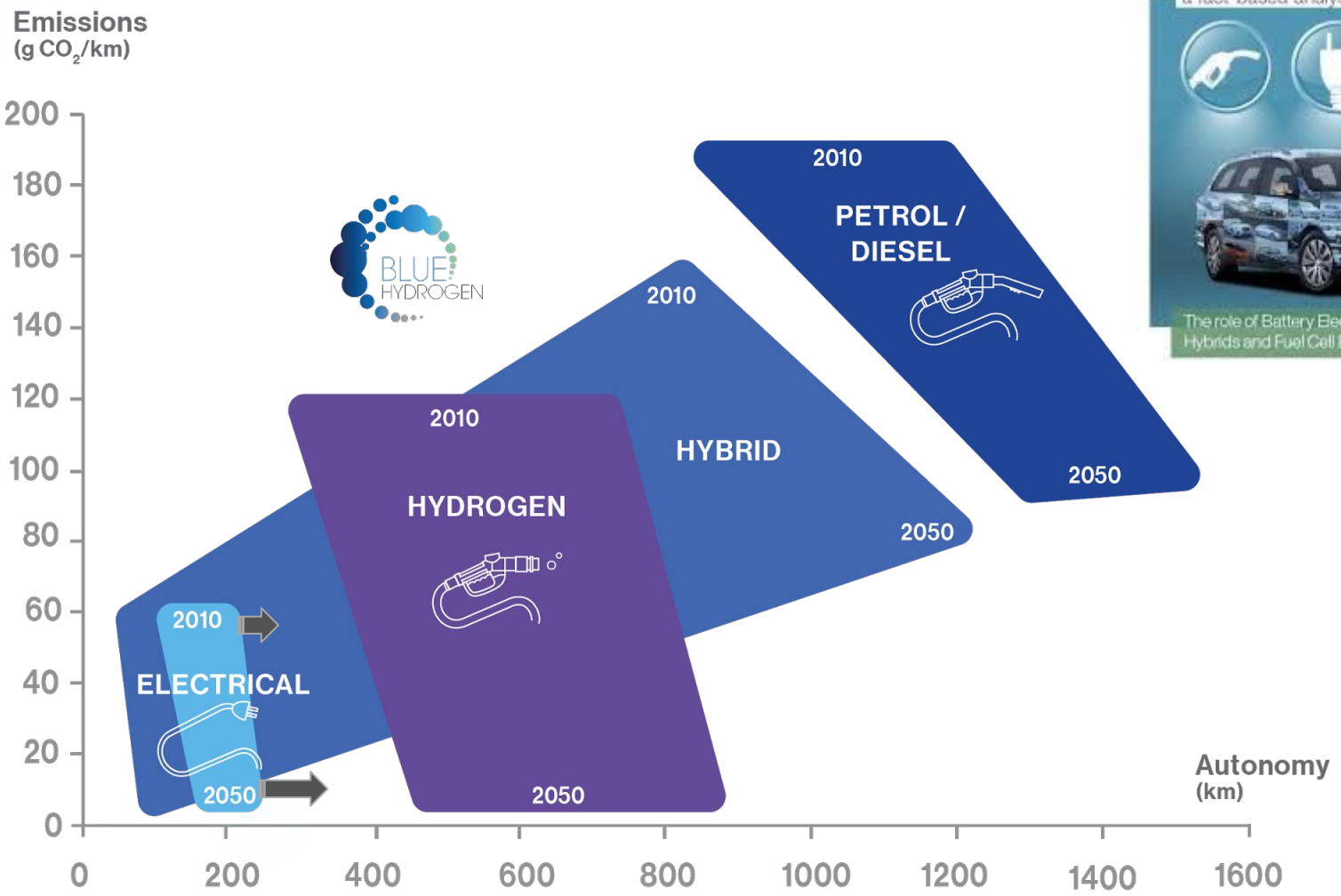
HYDROGEN

500 > 700 km

Refueling
3 < 5 min

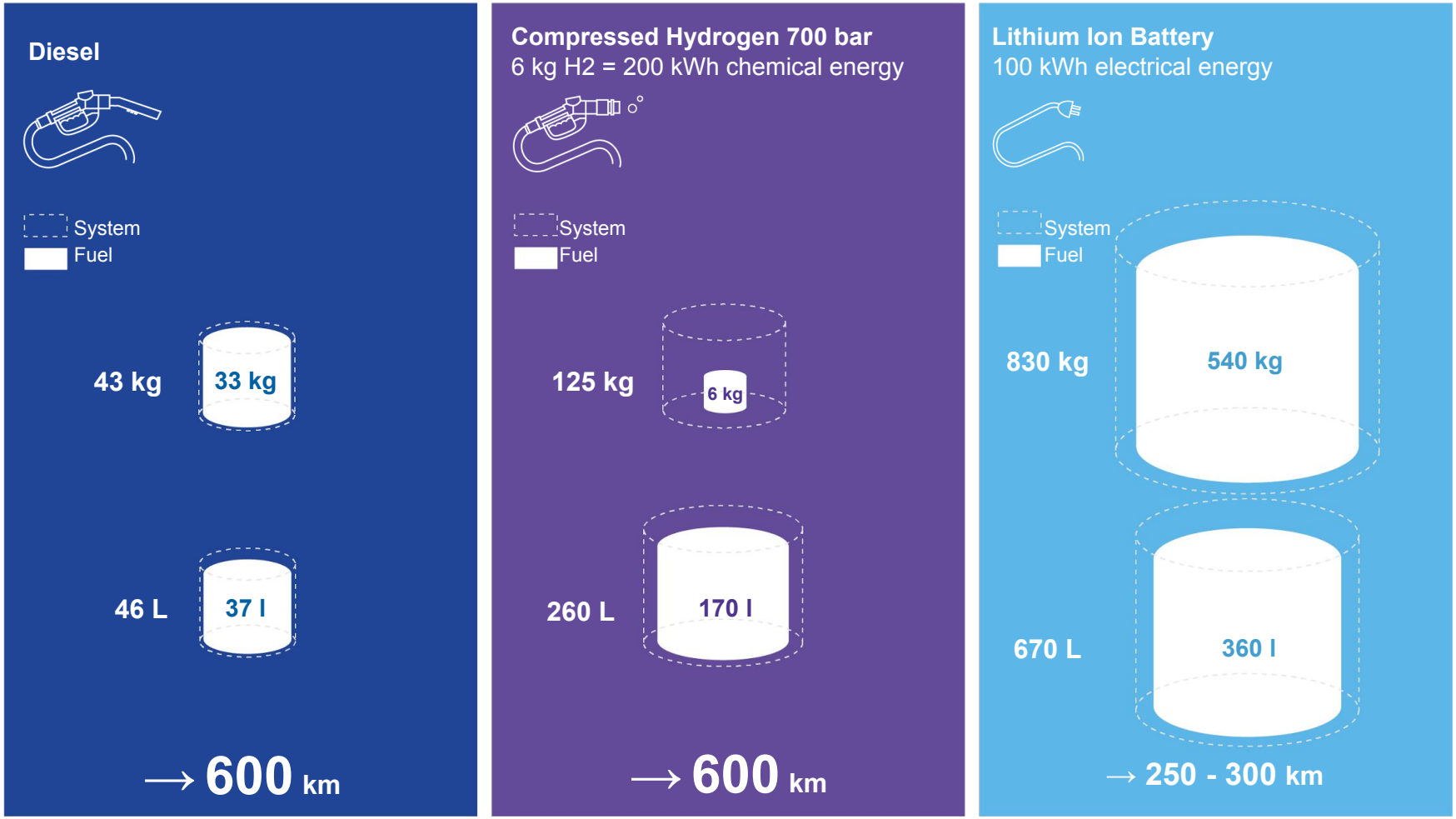
Source : Mc Kinsey, 2011, EU Powertrain Report

Hydrogen out performs all alternatives



Energy density of H_2 packs the ultimate punch

Weight & Volume of Energy Storage Systems



Source: Opel

Major OEM's are leading the way

TOYOTA

- Mirai commercialized since 2015
- Production capacity = 3,000 / yr
- 30,000 / yr from 2020

- Tucson commercialized since 2014
- Production capacity = 1 000 / yr
- 6,000 / yr from 2018

HYUNDAI

HONDA

- Clarity commercialized since 2016
- Production capacity = 1,000 / yr

- New model to be released in 2017

DAIMLER

4. Air Liquide's Hydrogen strategy to 2020

Our ambition: leadership in H_2 Mobility

- Lead **activation of H_2 Energy Markets** in particular H_2 Mobility

- **Be Major Mobility player**
  Maintain leadership across the full value chain from H_2 production to delivery at the pump

Towards leadership in H_2 Mobility – 3 pillars

1
TECHNOLOGY

2
INVESTMENT

3
CUSTOMER EXPERIENCE

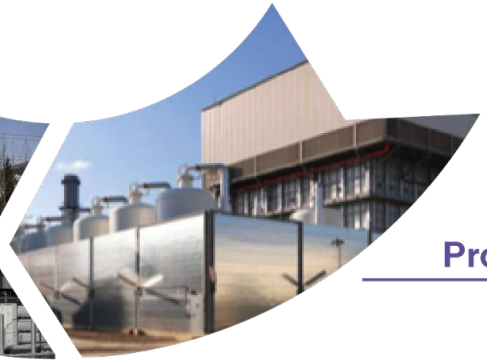
Technology leveraged at every step in the chain

Application

Delivery

Technology covering the whole Hydrogen Energy value chain

Storage & Transport



Production

Efficient
Sustainable
Safe
Reliable
Competitive

Everything we do leads to CO_2- free H_2 mobility

50% of H_2 energy
from carbon-free processes by 2020

A commitment to meet
both **environmental requirements**
and **economic constraints**

Achieving "Blue H_2"

1. Natural gas reforming + CCS
2. Water electrolysis (renewable, nuclear)
3. Biomass gasification
4. Biogas reforming

BLUE HYDROGEN

Towards leadership in H_2 Mobility – 3 pillars

1
TECHNOLOGY

2
INVESTMENT

3
CUSTOMER EXPERIENCE

2015 → 2017: Building up scale all over the world!

Pioneering innovative H_2 mobility projects worldwide

Air Liquide Hydrogen Stations

75 delivered *end 2015*

12 invested and operated by Air Liquide in *2015*

26 in *2016*

40 in *2017*

Americas

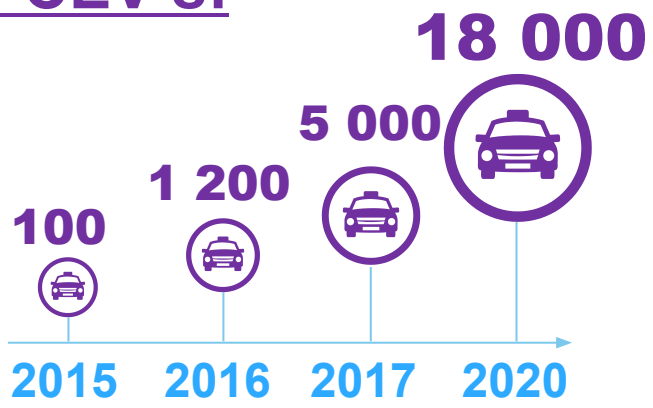
Europe

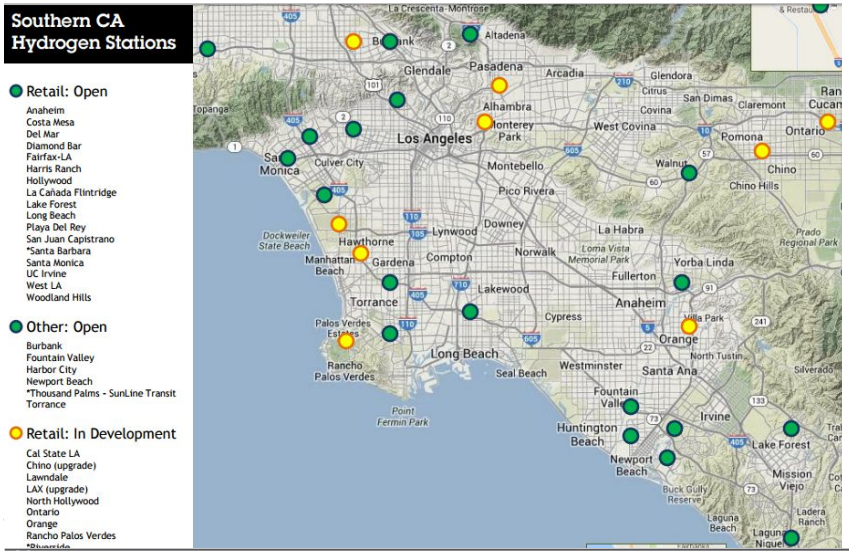
Asia

US / California – the ZEV effect

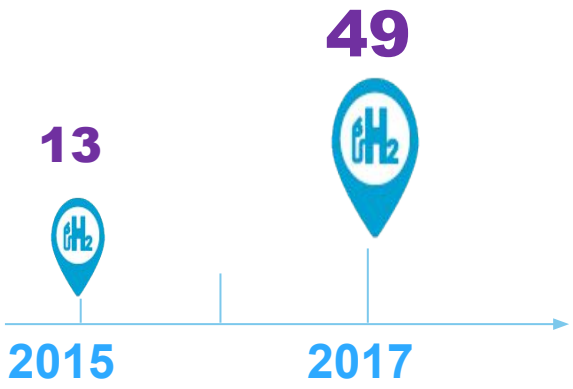
Anaheim H2 station

FCEV's:



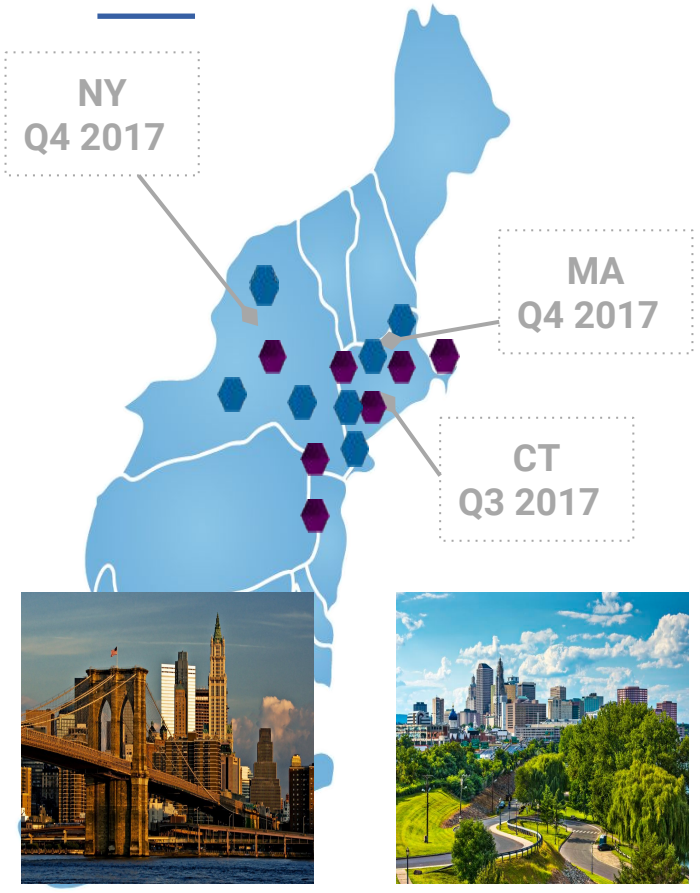


H2 stations:



Air Liquide creative oxygen

US - Conquering the Northeast



Network of 12 Stations

Start-up over Q3-Q4 2017

Dedicated H_2 supply chain by Air Liquide creative oxygen

Project in collaboration with TOYOTA

New York
Bronx, NY
Hempstead, NY
Brooklyn, NY

Connecticut
Hartford, CT

Massachusetts
Braintree, MA
Mansfield, MA

New Jersey
Site location TBA

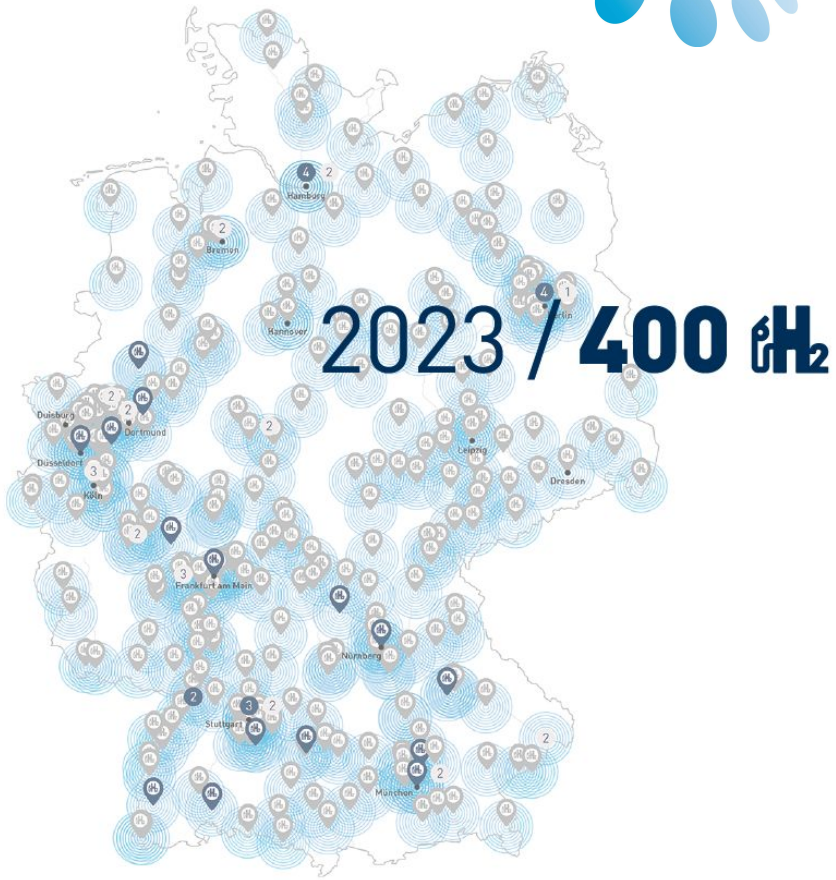
Rhode Island
Site location TBA

Germany – H2 Mobility: Deploying at full speed!

Air Liquide, Daimler, Linde, OMV, Shell and Total have agreed an action plan for the construction of a Hydrogen station network in Germany

- **400 Hydrogen Stations by 2023** (100 by 2017)
- **350m €** investment
- **Max. 90 km distance between each station on motorways**
- **10 Hydrogen Stations** in each metropolitan area

H_2 MOBILITY
FUELLING HYDROGEN



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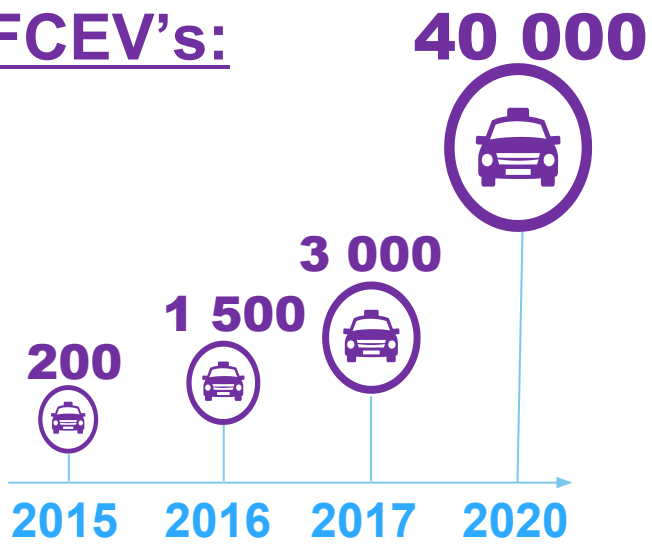
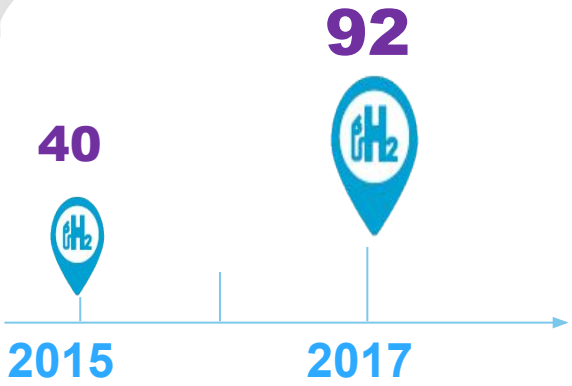
Japan: Largest H2 station infrastructure in the world

FCEV's:



H2 stations:



Nagoya Atsuta

France: Innovative business models for clean mobility

HYPE Taxi Fleet Project - Paris

hype The «taxi of tomorrow»

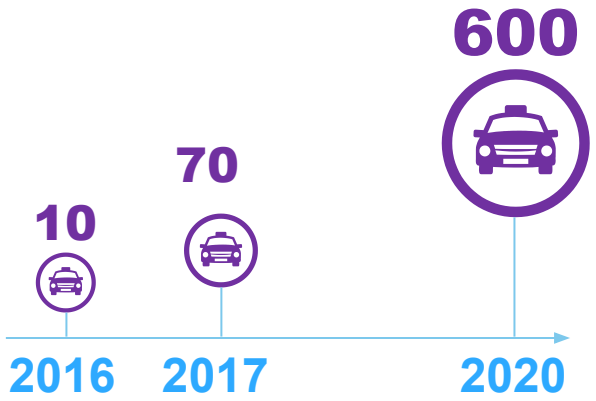
An emission-free Paris

Air Liquide

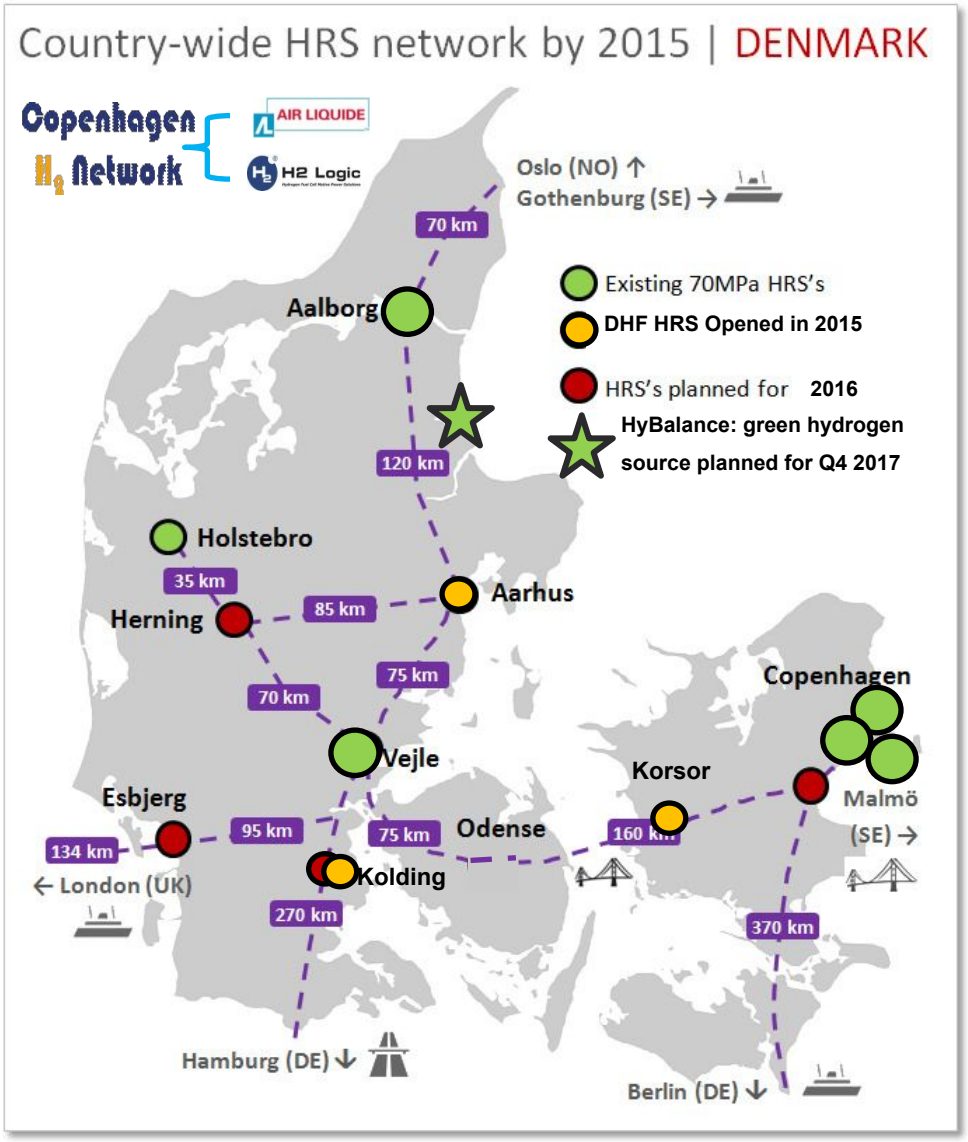
Key Enabler of the project

Launched in Dec. 2015, during COP 21

FCEV taxi fleet



Denmark – A nationwide H2 network powered by wind



Denmark – A nationwide H2 network powered by wind

Industrial Power-to-H2 demonstrator

HyBalance

http://hybalance.eu/

Local industrial customer

Industrial off-takers

H2

H2 @ 200b

Grid services
spot price arbitration

H2

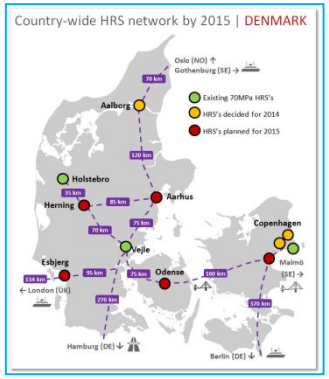
BLUE HYDROGEN

H2

Filling center

1,25 MW PEM Electrolyser

H2 @ high pressure



Refueling stations

Complete Wind-to-H2 supply chain

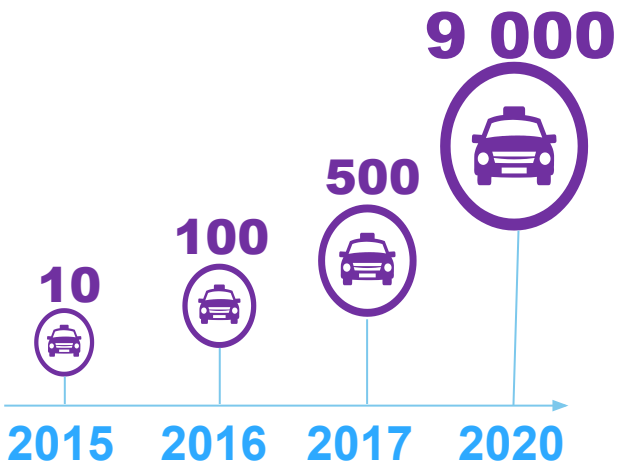
Start-up in October 2017

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

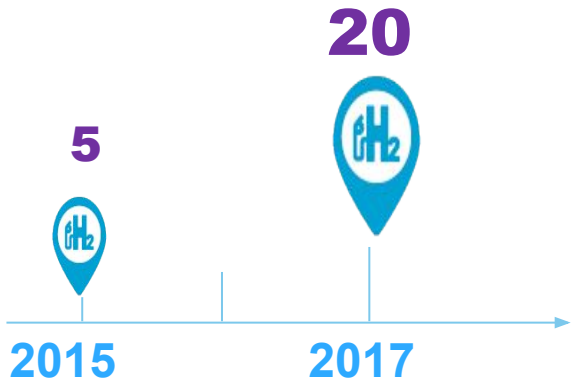
FORSK EL F&U i fremtidens elsystem

Korea – Rolling out an ambitious roadmap!

FCEV's:



H2 stations:



- Green Car roadmap being actively implemented
- Innovative fleet business models
- Creation of H2 Korea to accelerate infrastructure investments

H2KOREA

Middle East – 1st H2 station in Dubai!

- 1st H2 station started in September 2016, with first Mirais deployed
- Scale-up of FCEV deployment in Dubai until 2020 World EXPO
- Collaboration between Air Liquide, ADNOC, Al Futtaim Motors / Toyota & Masdar (green power provider) to develop a H2 mobility roadmap in the USA

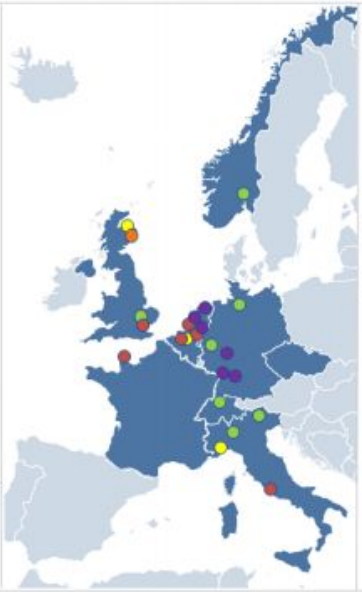
FC Buses: EU and China showing the way

Ongoing EU-funded fuel cell bus projects

CHIC
- Aargau, CH –5 FC buses (2011)
- Bolzano, IT– 5 FC buses (2013)
- London, UK – 8 FC buses (2011)
- Milan, IT – 3 FC buses (2013)
- Oslo, NO – 5 FC buses (2013)
- Cologne, DE* – 4 FC buses (2011/14)
- Hamburg, DE* – 6 FC buses (2011/2015)

High V.LO-City
- San Remo, IT – 5 FC buses (2016)
- Antwerp, BE – 5 FC buses (2015)
- Aberdeen, UK – 4 FC buses (2015)

HyTransit
- Aberdeen, UK – 6 FC buses (2015)



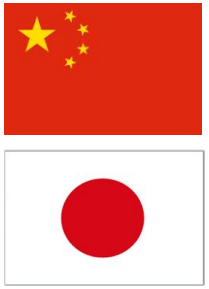
Legend
- Countries with (upcoming) fuel cell buses in operation
- Planned operation
- (2015) Operation start / planned start
- * Co-financed by regional / national funding sources

Ongoing EU-funded fuel cell bus project

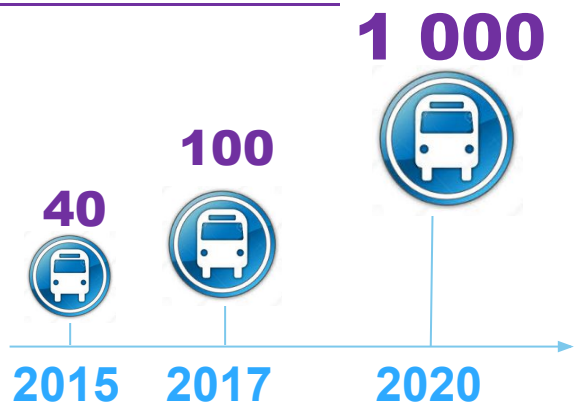
3Emotion
- Cherbourg, FR – 5 FC buses (2017)
- South Rotterdam, NL – 2 FC buses (2017)
- South Holland, NL – 4 FC buses (2017)
- London, UK – 2 FC buses (2017)
- Antwerp, BE – 3 FC buses (2017)
- Rome, IT – 5 FC buses (2017)

Current national/regional-funded fuel cell bus projects
- Karlsruhe, DE * – 2 FC buses (2013)
- Stuttgart, DE * – 4 FC buses (2014)
- Frankfurt, DE * - 1 FC bus (2016)
- Arnhem, NL* – 3 FC buses (2017)
- Groningen, NL* – 2 FC buses (2017)
- Eindhoven, NL* – 2 FC buses (2016)

Next stops:



FC Buses in EU:



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Looking beyond 2017…

- **Hydrogen and Fuel Cell Electric Vehicles are at the Tipping Point !**

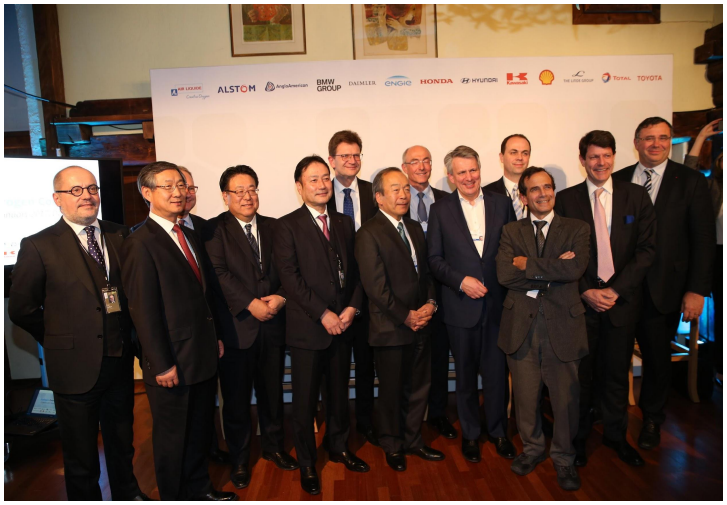
- **Early movers have proven that it is sustainable!**

- **More players need to join the game to further increase the momentum:**
  Car OEM's, Energy companies, financial investors, governments…

Launching oF Hydrogen Council, Jan 2017 in Davos

13 Companies and their CEO's joining forces to voice the vision and the ambitions of the Hydrogen industry
Hydrogen acknowledged as a key solution to empower the energy transition

A further lever to accelerate
H2 infrastructure & FCEV deployments!



Air Liquide ALSTOM AngloAmerican BMW GROUP DAIMLER ENGIE HONDA HYUNDAI Kawasaki THE LINDE GROUP TOTAL TOYOTA

2015 → 2017: Building up scale all over the world!

From 1 000 to 10 000 FCEVs !

From 100 to 300 H2 Stations !

Hydrogen Council

Air Liquide · ALSTOM · AngloAmerican · BMW GROUP · DAIMLER · ENGIE · HONDA · HYUNDAI · Kawasaki · THE LINDE GROUP · TOTAL · TOYOTA

Towards leadership in H_2 Mobility – 3 pillars

1
TECHNOLOGY

2
INVESTMENT

3
CUSTOMER EXPERIENCE

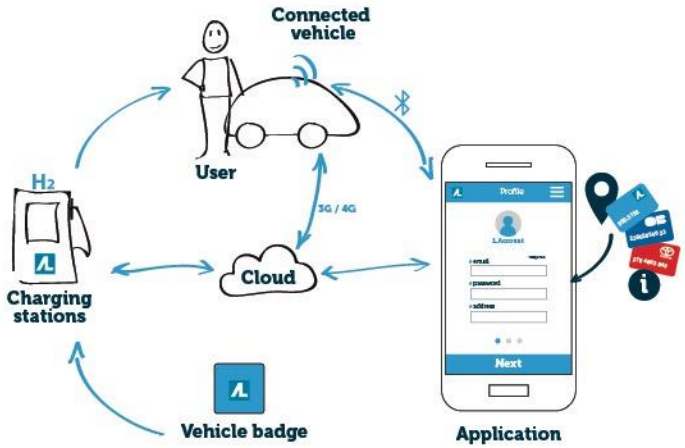
Delivering a new mobility experience…

Enhancing every experience to create a clean and hassle-free future for customers

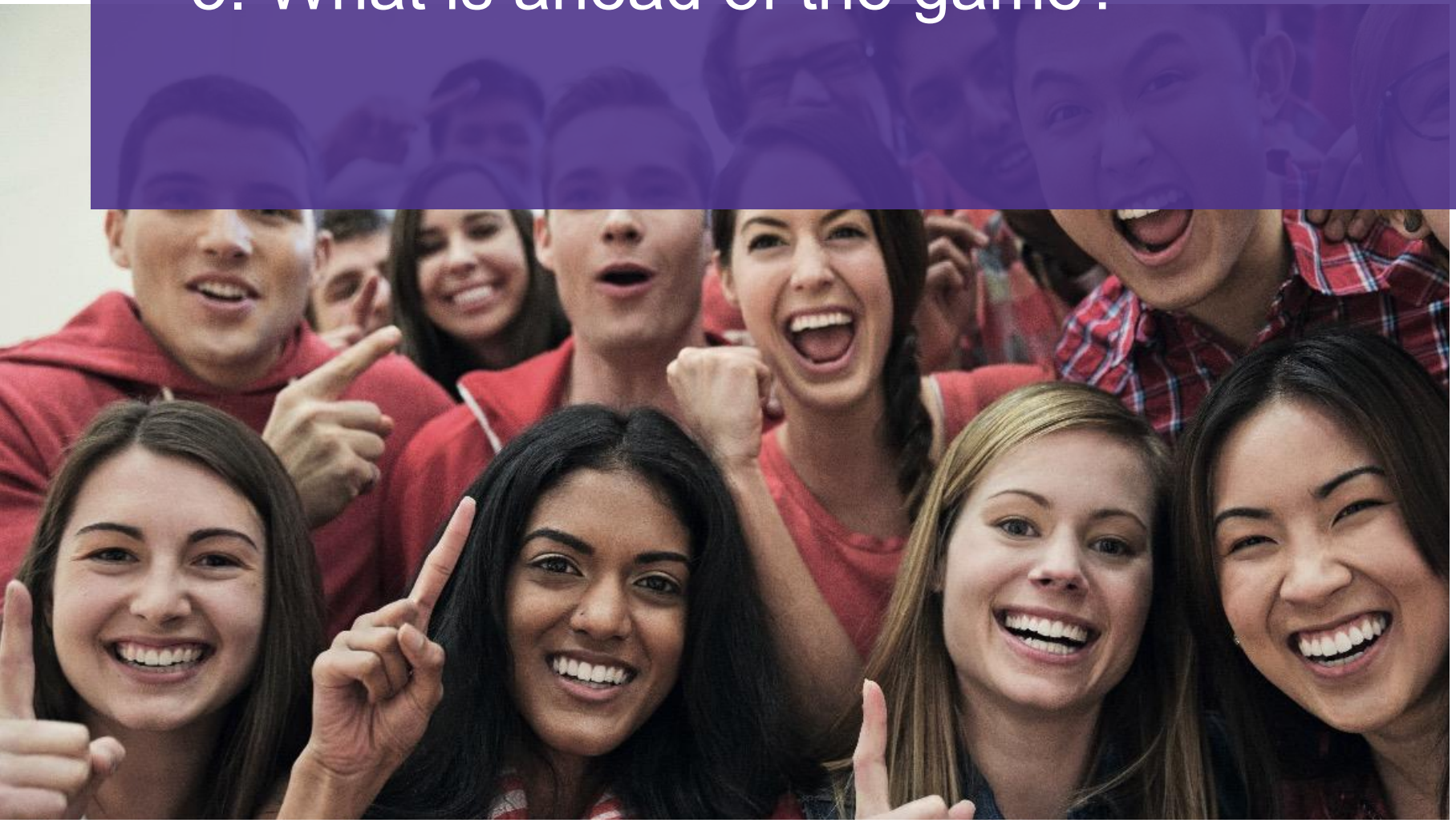
Critical aspects of the experience we deliver

- Accessible and ergonomic stations
- No waiting time, fast charging time
- Convenient payment
- Silent and comfortable cars
- A totally connected experience

Leading towards full freedom in mobility



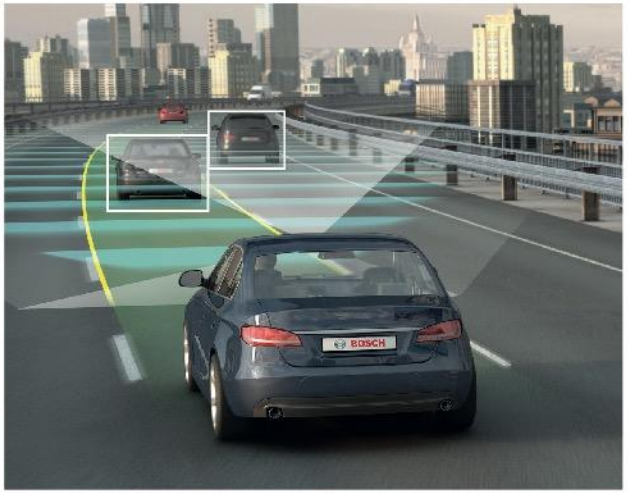
5. What is ahead of the game?



Sustainable mobility is within our grasp

Transition evolving at unprecedented pace

- **Car electrification** (hybrids, battery electric, FCV, e.g. Prius, Mirai…)
- **New mobility models** (Uber, car sharing…)
- **Autonomous vehicles**



Political and economic initiatives are accelerating transition…

Gov. Yoichi Masuzoe – "demotorization" 2020 Olympics

Clear signs of support around the globe

- Japan: M. Abe's commitment towards a H_2 Society
- Korea: New Green Car roadmap (Dec. 2015)
- Europe: EU-funded programs (FCH JU, TEN-T)
- ZEV Allianz : US (California, NE) , Germany, Netherlands

"I have no doubt that Japan comes to the 'Front runner' of hydrogen energy race. I commit to promote hydrogen innovation much harder." - Prime Minister Abe (April 2015)

But need to further incentivize Demand and Offer to accelerate the transition

- Customers
- Car OEMs
- Infrastructure developers

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

Innovative business models to accompany new usages…

Captive fleets are catalysts for take-off

Captive fleet niches: buses, light commercial vehicles, taxis

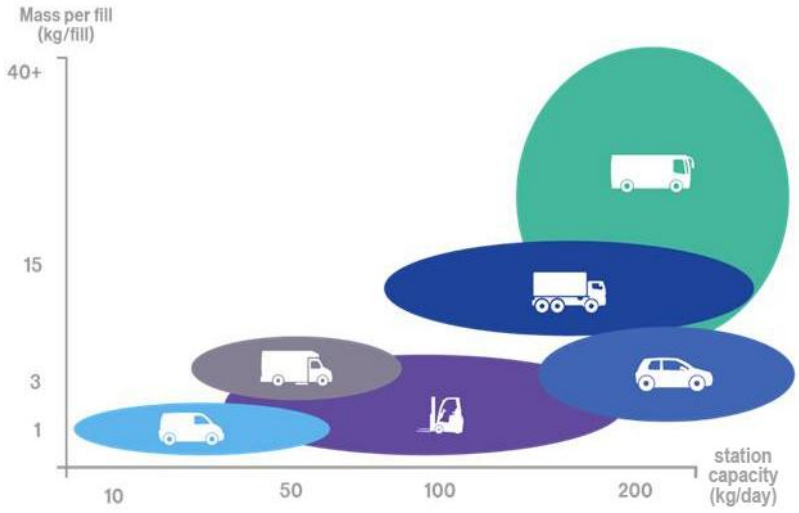
hype The «taxi of tomorrow»

An emission-free Paris

Targeting 70 taxis
by the end of 2016

and 600
within 3 years

Speeding-up energy transition for taxis



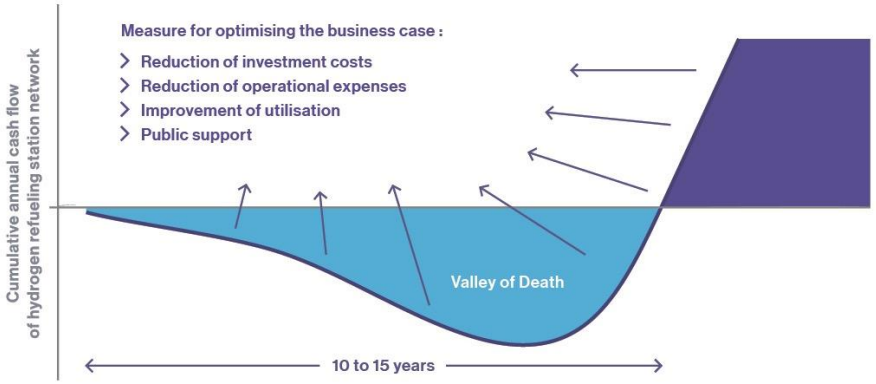
Value is created by mutualising Hydrogen Stations infrastructure with private users

We are finding solutions to infrastructure challenges

Main issue

- Under-utilization of Hydrogen Stations and **"Valley of Death" periods**

H2 Station – cash flow curve



Source : IEA, H2 roadmap 2015

Innovative funding solutions

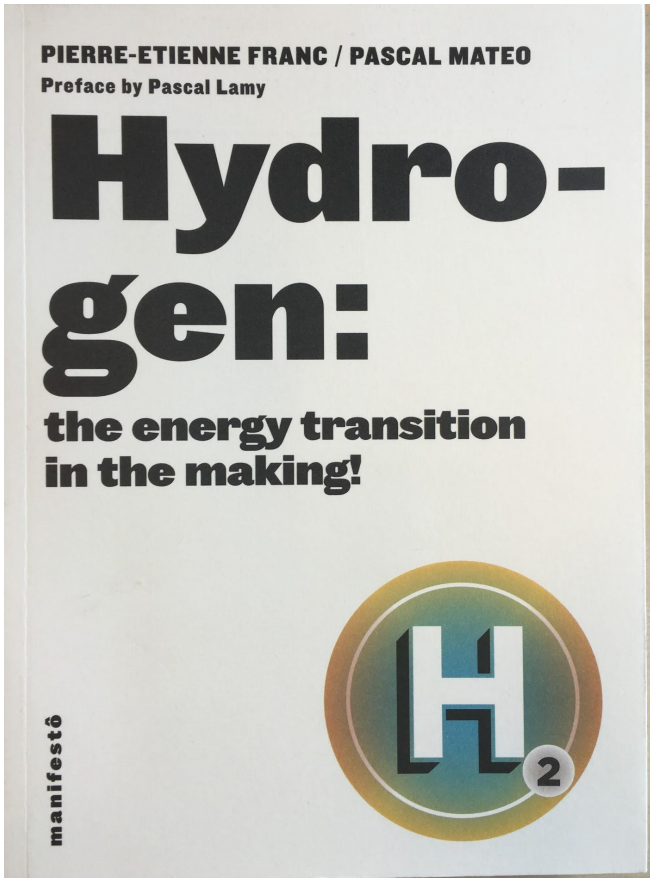
- **Guarantee mechanisms** from Governments attract Private Debt and secure lenders against FCEV ramp-up risk
- Managed through issurance and buy-back of **Carbon Tickets**

Advantages

- **Attract private capital** into H_2 infrastructure development (banks, funds)
- Convergence of interests between **project promoters and Governments**
- Limited impact on budget/public debt → Strong leverage effect

To know more about Hydrogen…

"The energy revolution is in the making and it will involve hydrogen!"



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Thank you