

Hydrogen: A Worldwide Status Update

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Director, Air Liquide Hydrogen Energy



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2018

Air Liquide Hydrogen Energy

The world leader in gases, technologies and services for Industry and Health



Today's Presenters

Dave Edwards	Air Liquide Hydrogen Energy
Ed Young	Toyota Motor North America
Charlie Myers	Massachusetts Fuel Cell Electric Vehicle Working Group
Gus Block	Nuvera Fuel Cells
John Finn	Fiba Technologies
Darryl Pollica	IVYS Energy Solutions

Today's Topics

Hydrogen Energy – A global perspective

Hydrogen – Production and Distribution

The Northeast – Status of Projects

Vehicles – An update from Toyota

Hydrogen in Massachusetts – Impacts and opportunities

See the cars – we have vehicles available today

For your consideration

Hydrogen is an energy carrier

- enables a shift to renewables
- addresses key challenges with the power grid and transportation

Fuel Cell Electric Vehicles are complementary to Battery Electric Vehicles

We seek from the commission, recognition that:

- FCEV introductions are imminent and require timely actions
- Outcomes for the state and its citizens are best met with equal treatment in ZEV programs
- Legislation and regulation recommendation and changes sought will be all inclusive for ZEV vehicles

The Role of Hydrogen as an energy vector

Part of the renewable grid

As a transportation fuel



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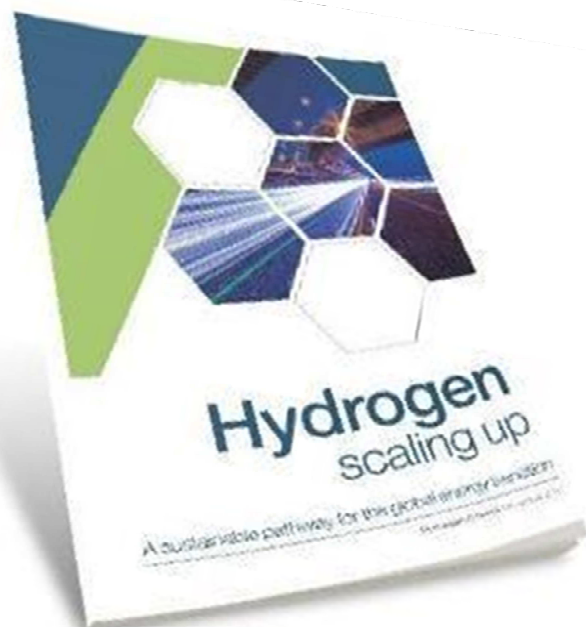
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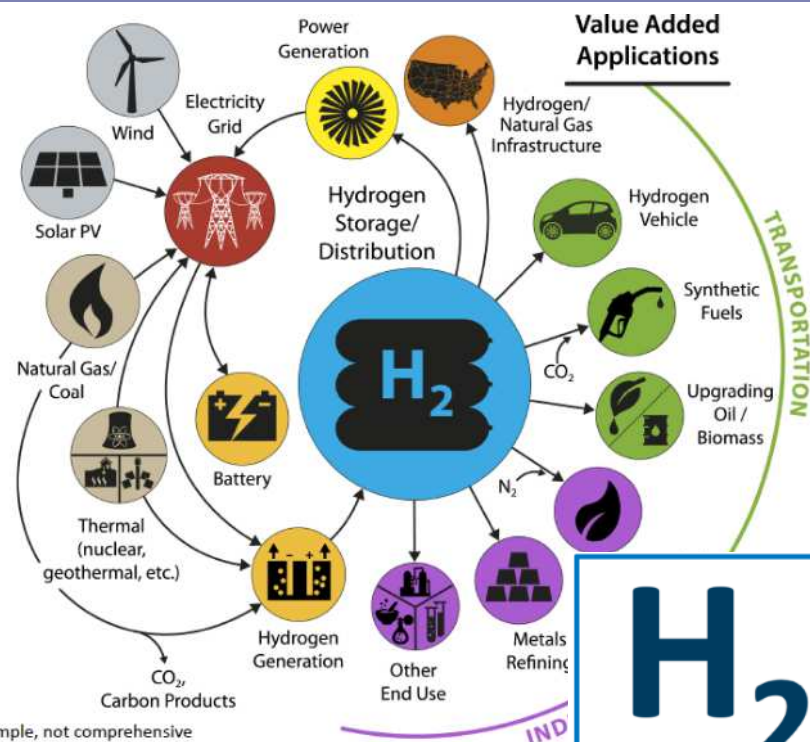
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Hydrogen Council Roadmap

DOE – H2@Scale Program



Hydrogen Council



*Illustrative example, not comprehensive

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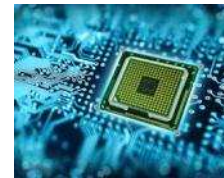
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SOURCE: McKinsey

The History of Hydrogen



1880s

1930s

1950s

1990s

2018

Town Gas

**Fertilizer
Production**

**Space
Programs**

**Refineries and
High Tech**

Power Applications

**Used for its
thermal
properties**

**Used as a
reactant**

**Rocket
propulsion**

**Clean Fuel Regs
Semiconductor
Processing**

**Enabled by fuel cell
technology development
& new ZEV regs**

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Hydrogen Today

Fossil Fuel Sources



Natural Gas Pipeline

Reformation



Traditional Markets

Refining

Fertilizers

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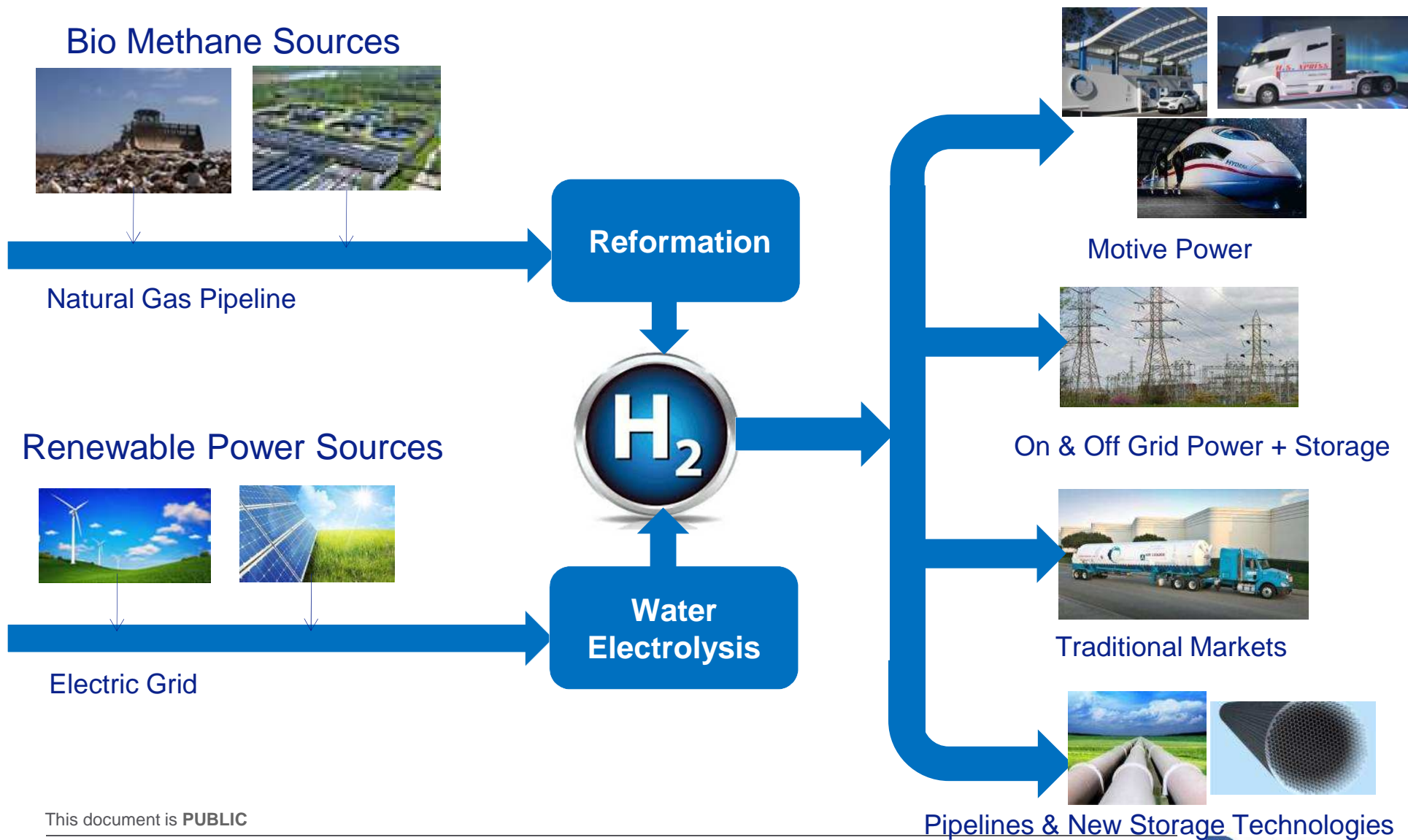
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Hydrogen “The Next 50 years”



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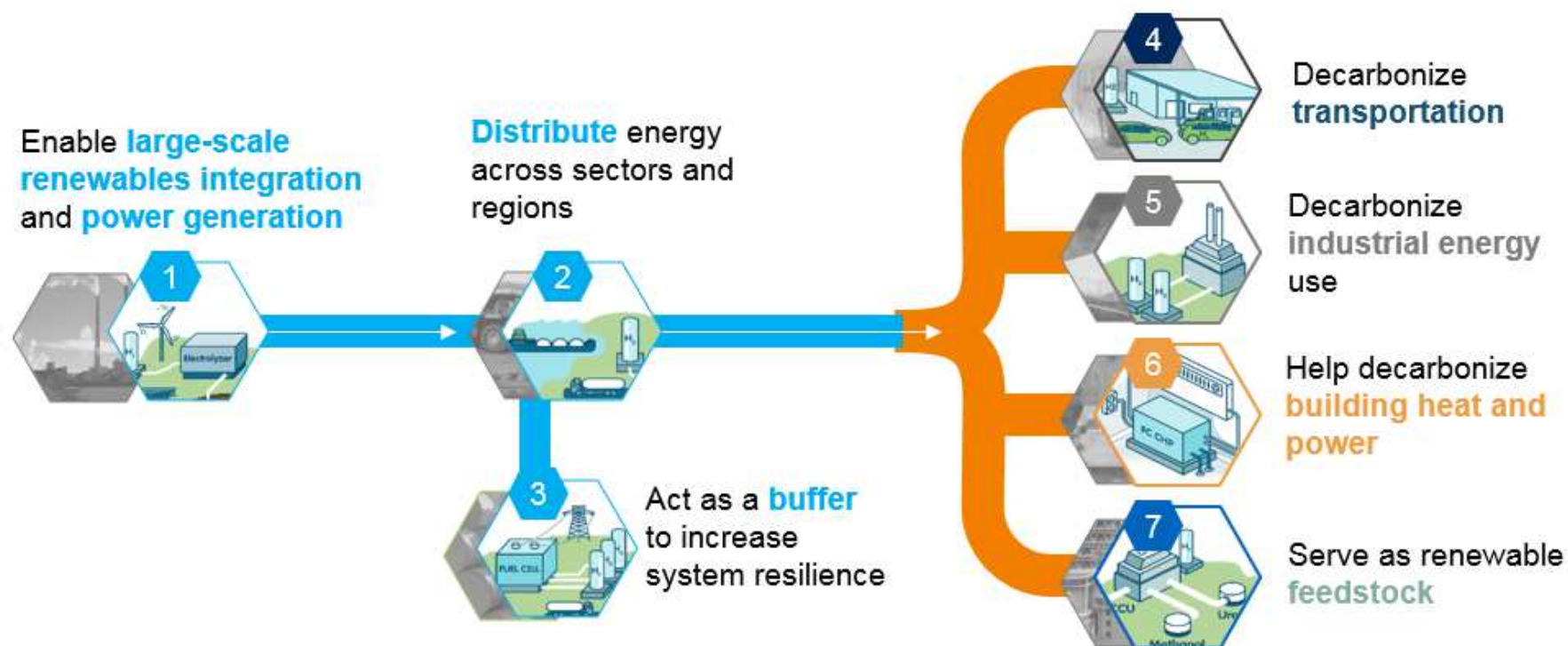
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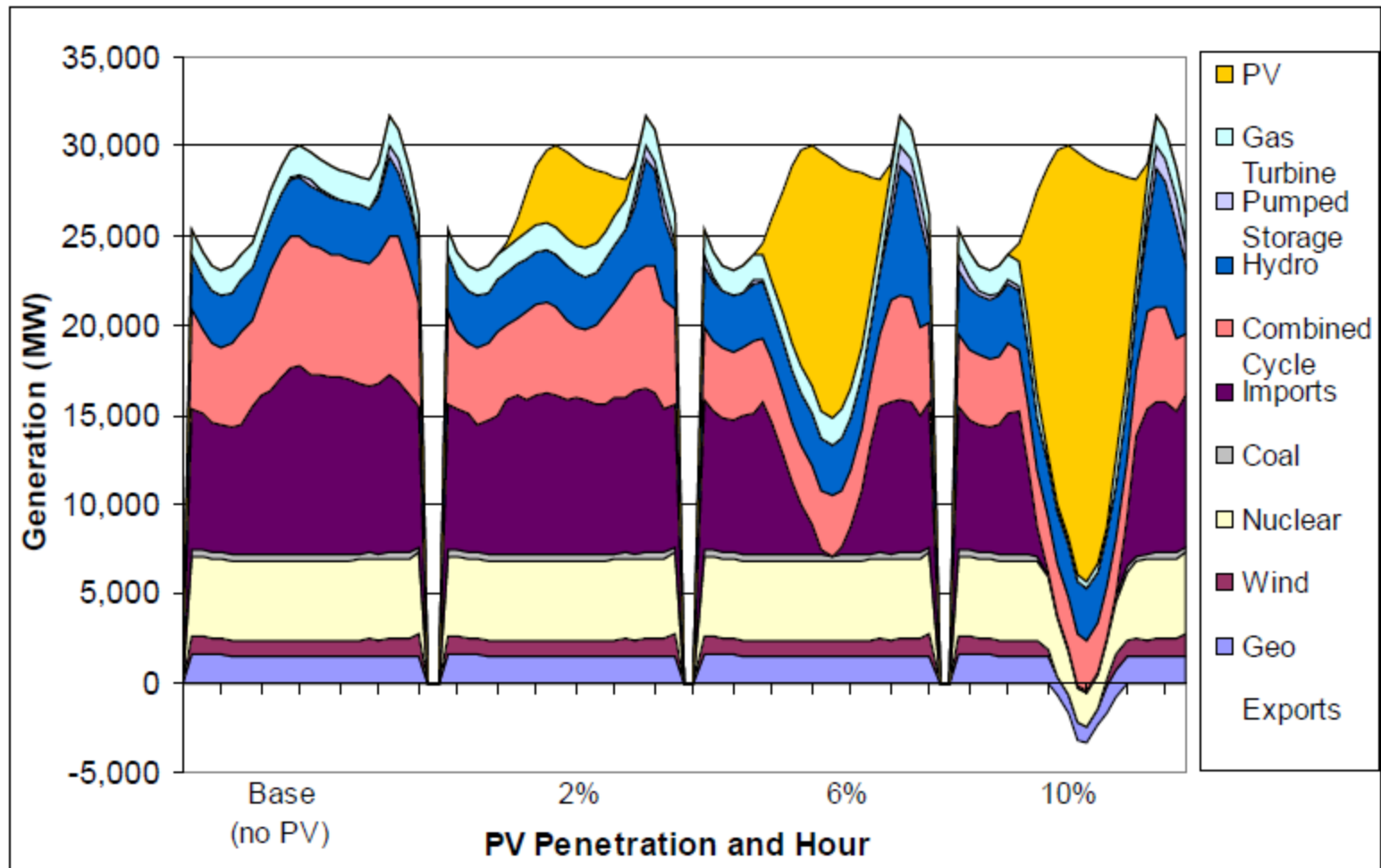
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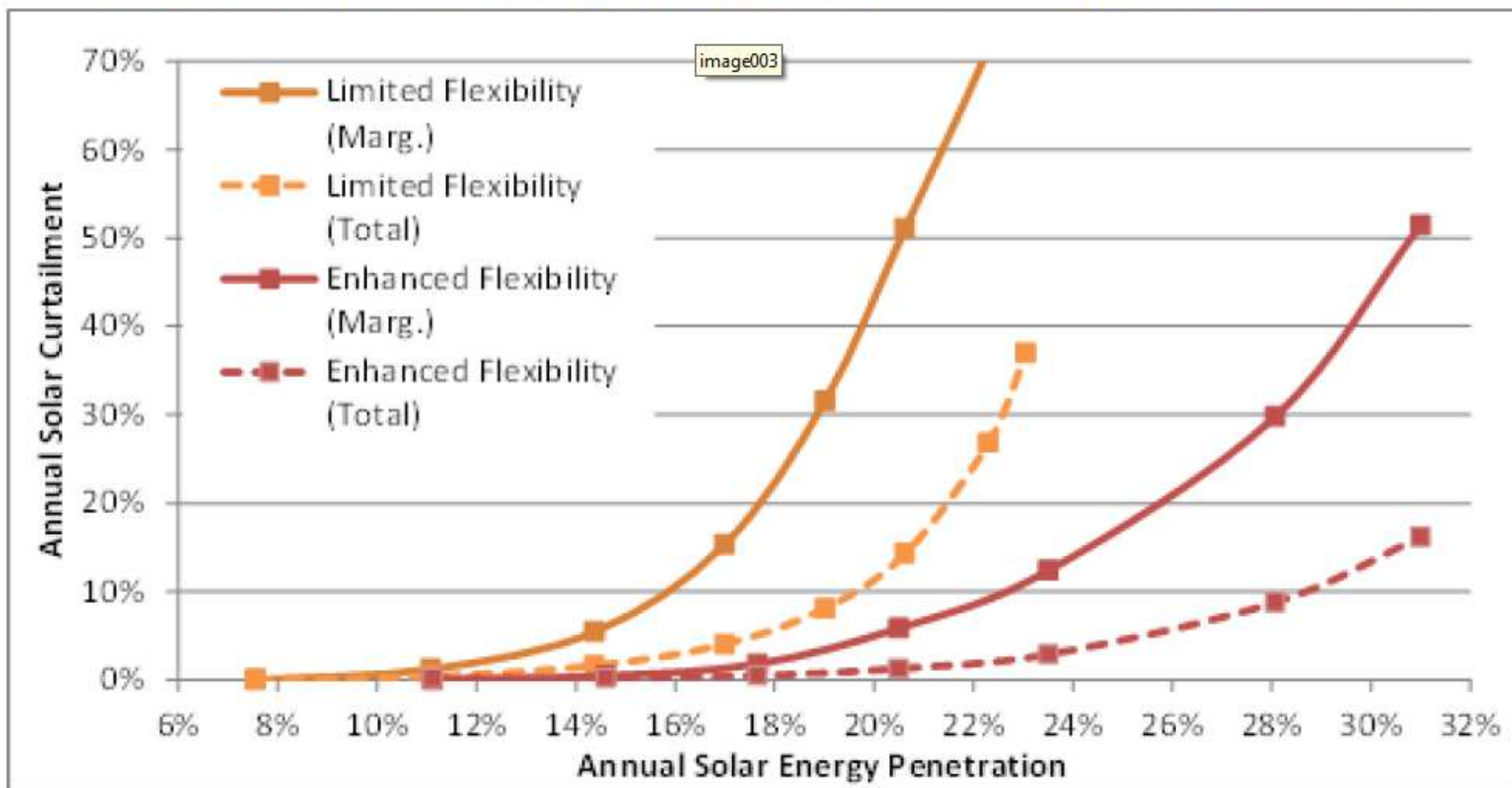
Enable the renewable energy system —————> Decarbonize end uses —



Denholm et al. 2008



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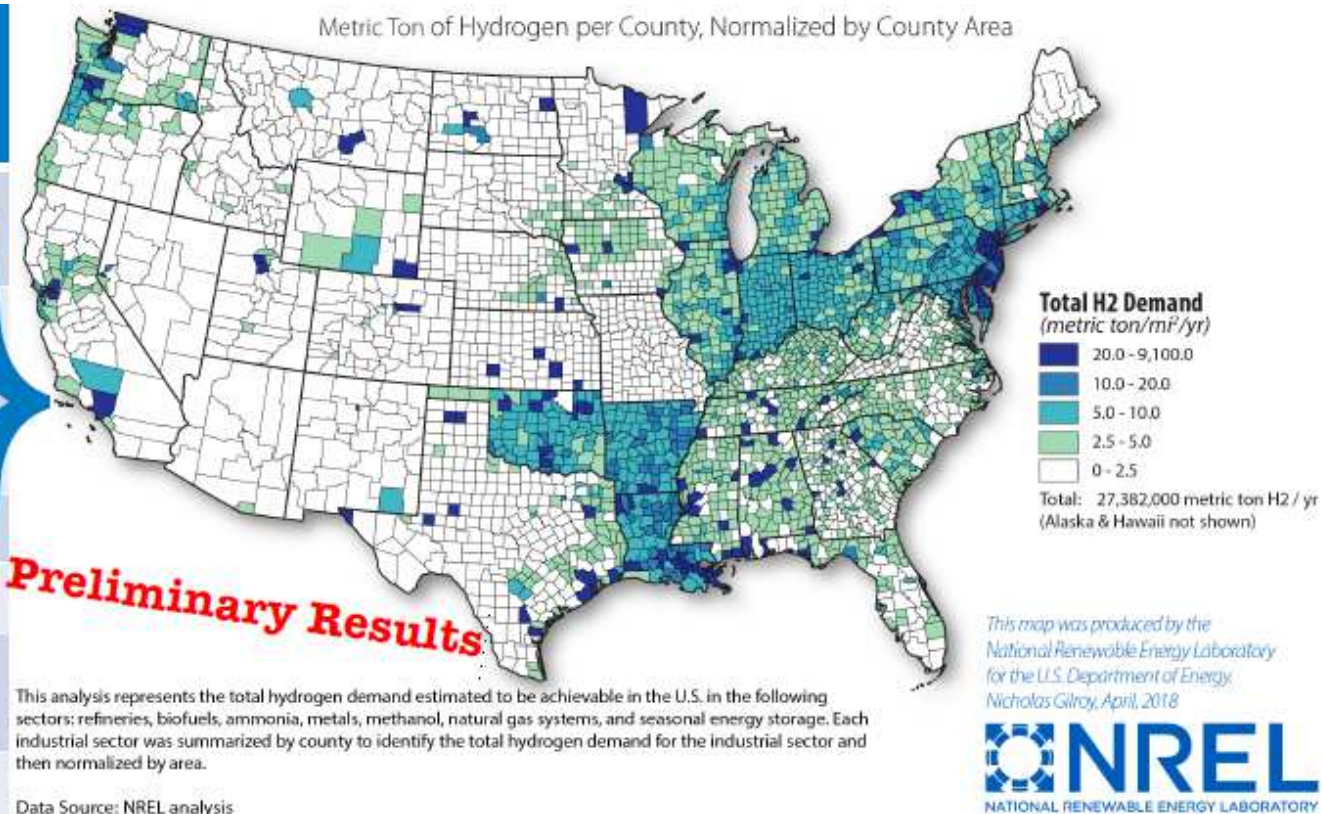
Curtailment will lead to an abundance of low value electrons, and we need solutions that will service our multi-sector demands

What is the potential US market for renewable H2 at scale?

- Refineries
- Ammonia
- Medium- and heavy-duty vehicles
- Light-duty vehicles (LDV)
- Methanol
- Synthetic fuel
- Biofuels
- Seasonal storage for electricity
- Natural gas injection
- Metals

Where will it be used?

Demand	Technical potential (MMT* / year)
Refineries & CPI [§]	8
Metals	6
Ammonia	5
Methanol	1
Biofuels	1
Natural Gas	7
Light Duty Vehicles	28
Other Transport	3
Electricity Storage	28
Total	87



Technical Potential Demand: 87 MMT/yr

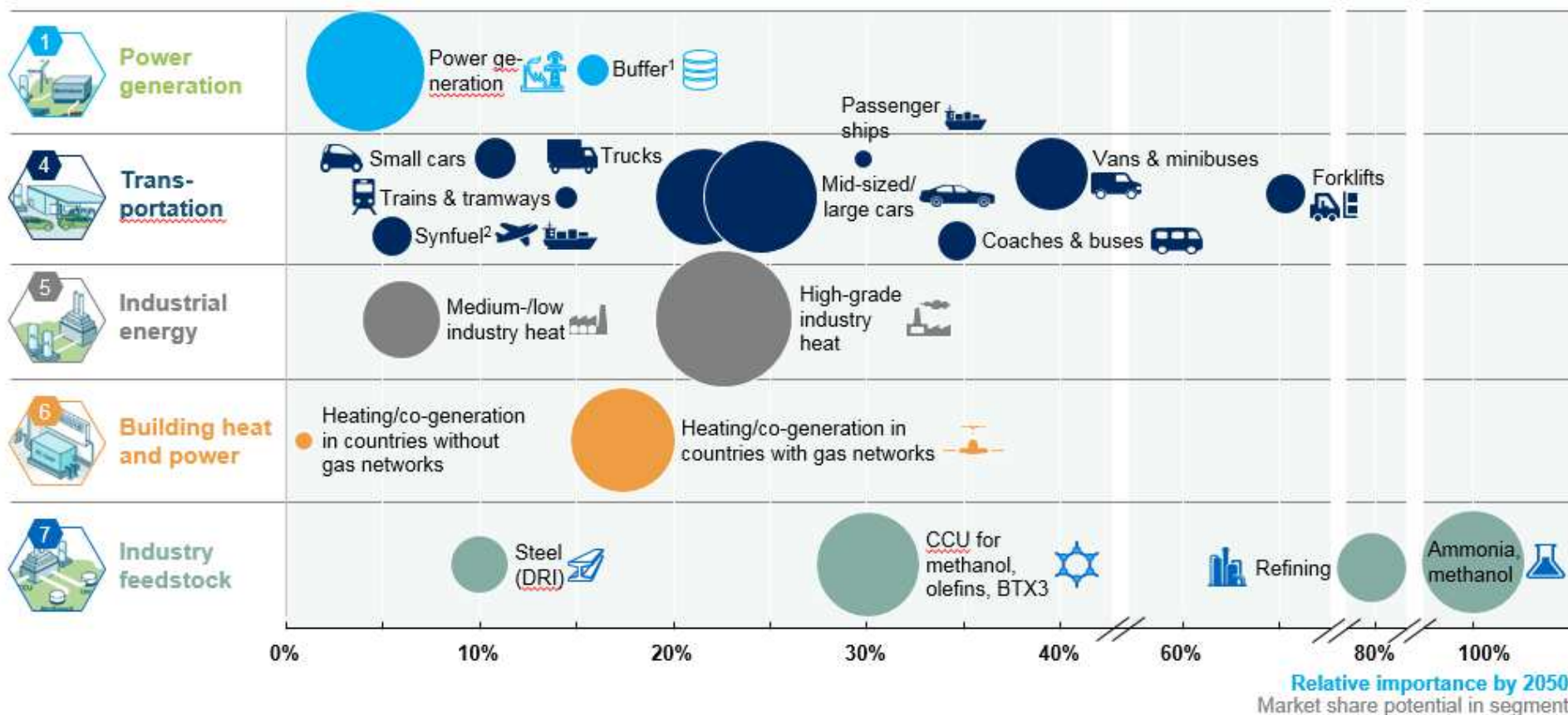
Current U.S. market: ≈ 13 MMT/yr

Including captive generation for ammonia and refining

* MMT: Million metric tonnes

Key results: Hydrogen has significant potential across all applications

○ Bubble size indicates hydrogen potential in 2050 in EJ (1 EJ)



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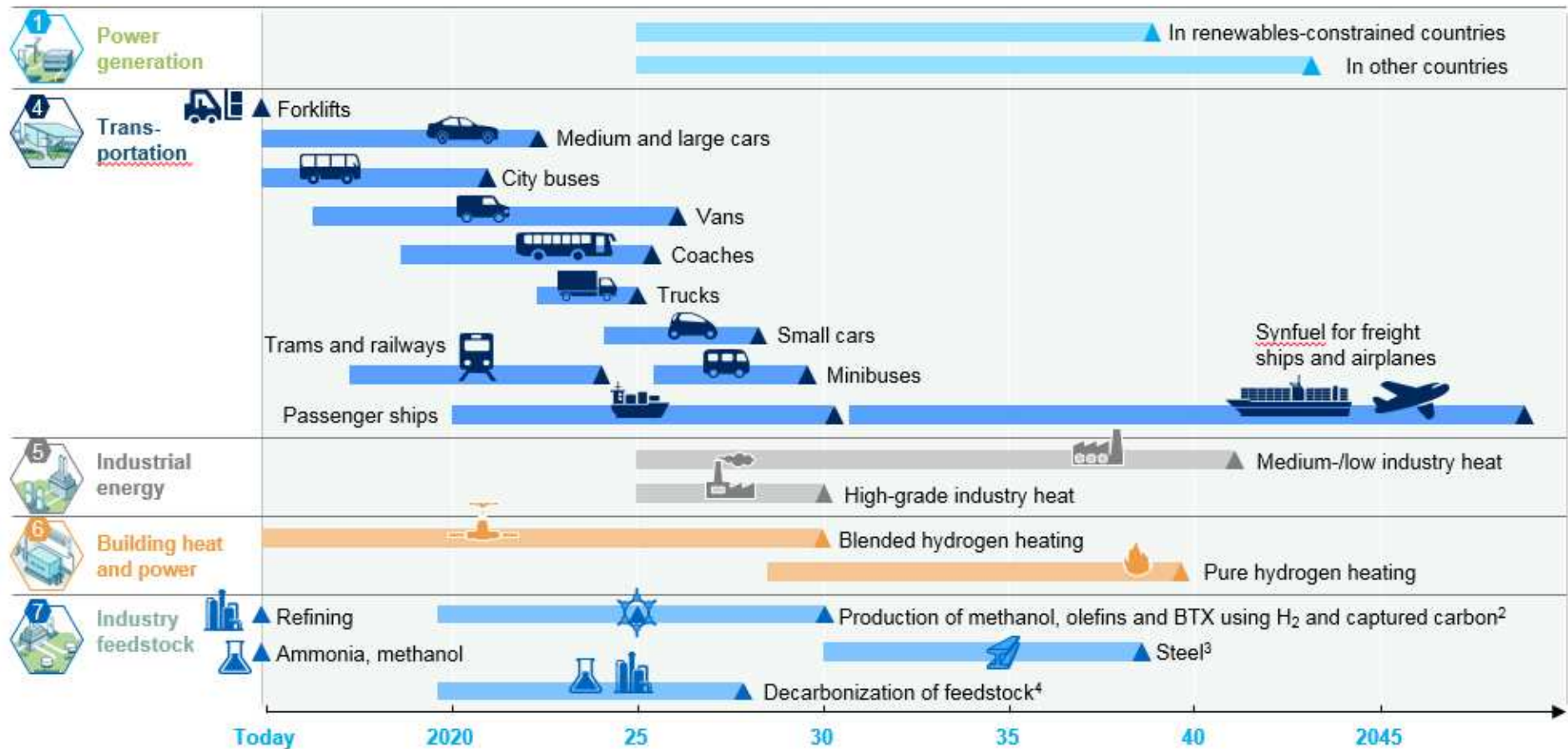
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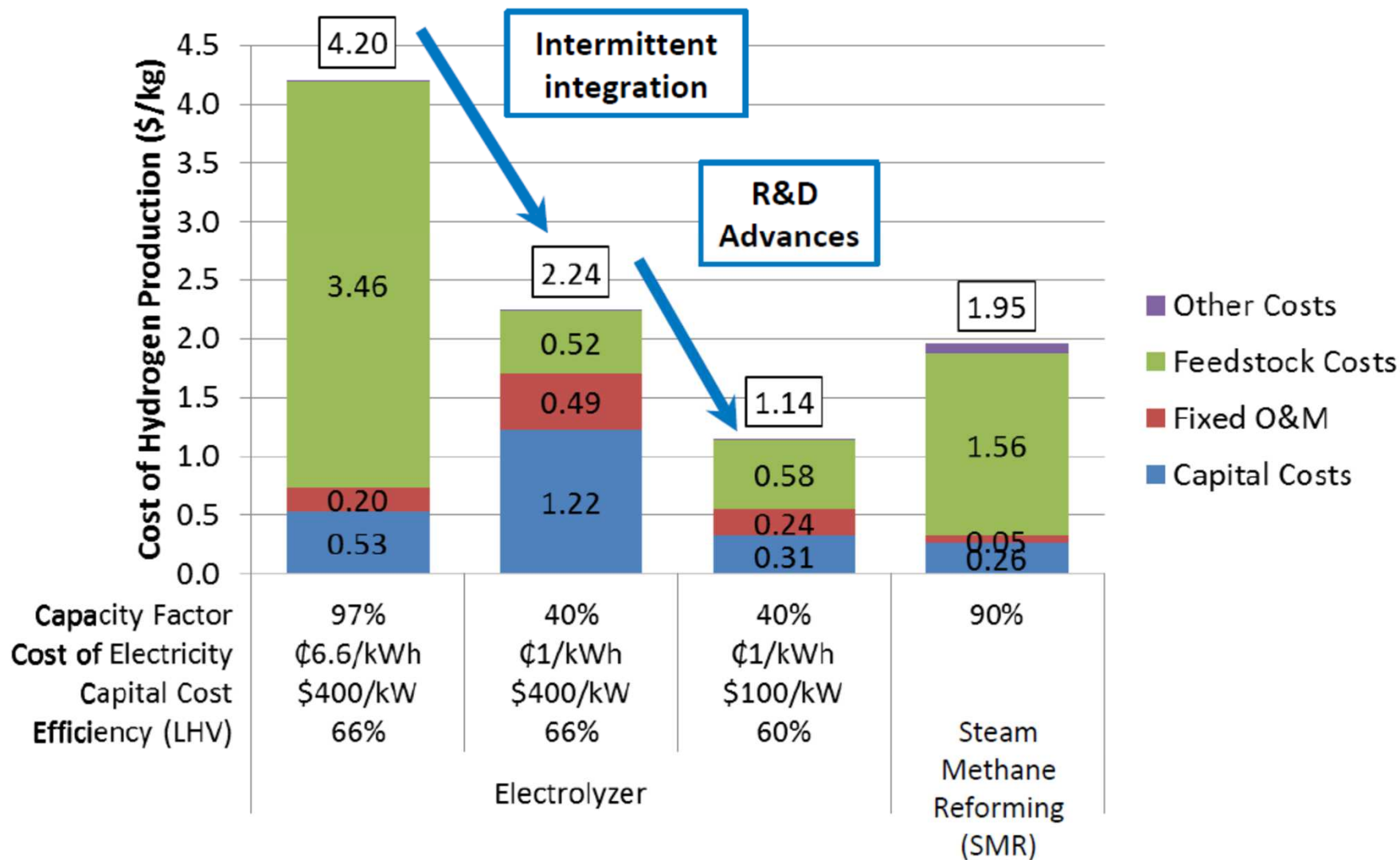
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Key results: Industry sees technology ready to scale

Start of commercialization  Mass market acceptability¹



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Hydrogen: Global Status Update



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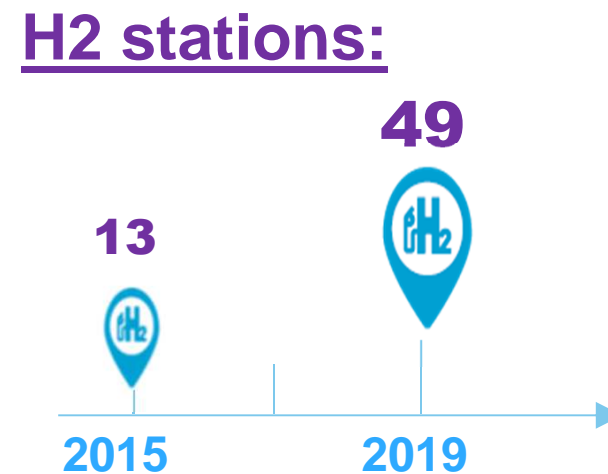
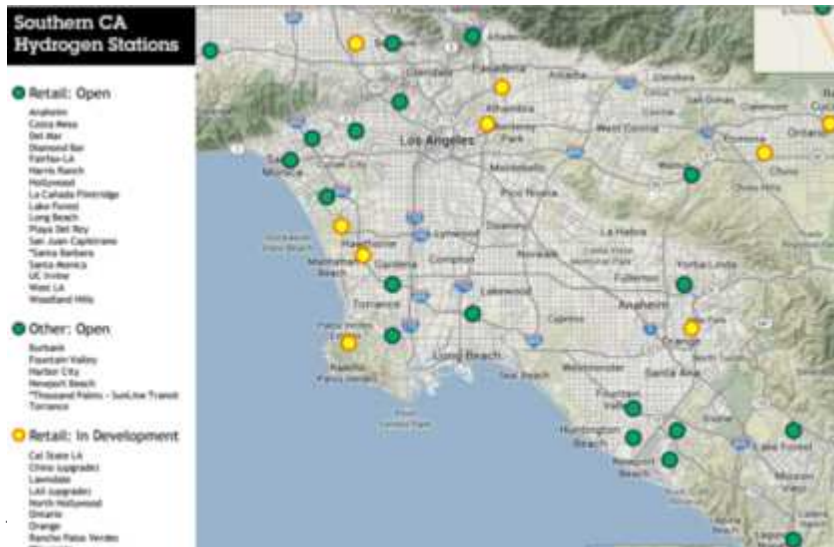
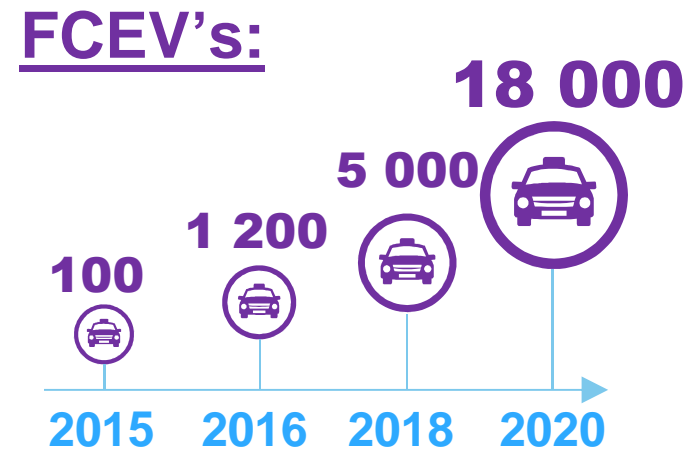
2015 → 2018: Building up scale all over the world!



US / California – the ZEV effect



Anaheim H2 station



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

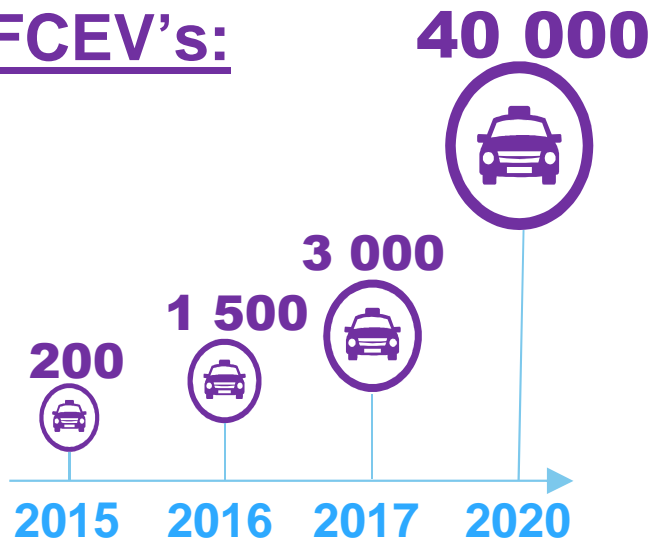
- **400 Hydrogen Stations by 2023** (100 by 2017)
- **350m €** investment
- **Max. 90 km distance between each station on motorways**
- **10 Hydrogen Stations** in each metropolitan area



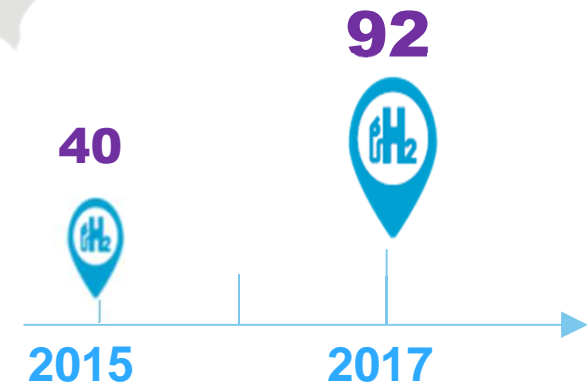
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Japan: Largest H2 station infrastructure in the world

FCEV's:



H2 stations:



Nagoya Atsuta

France: Innovative business models for clean mobility

HYPE Taxi Fleet Project - Paris



An emission-free Paris

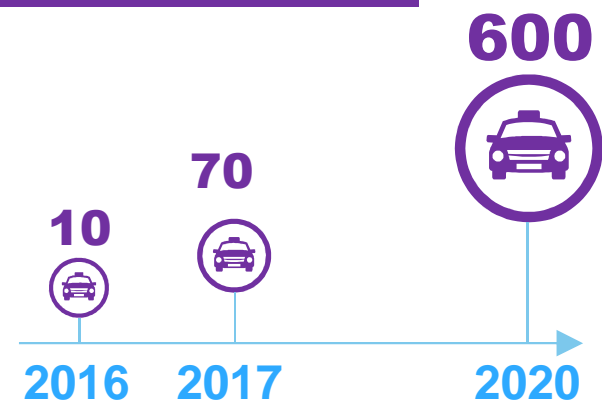


Air Liquide
Key Enabler of the project

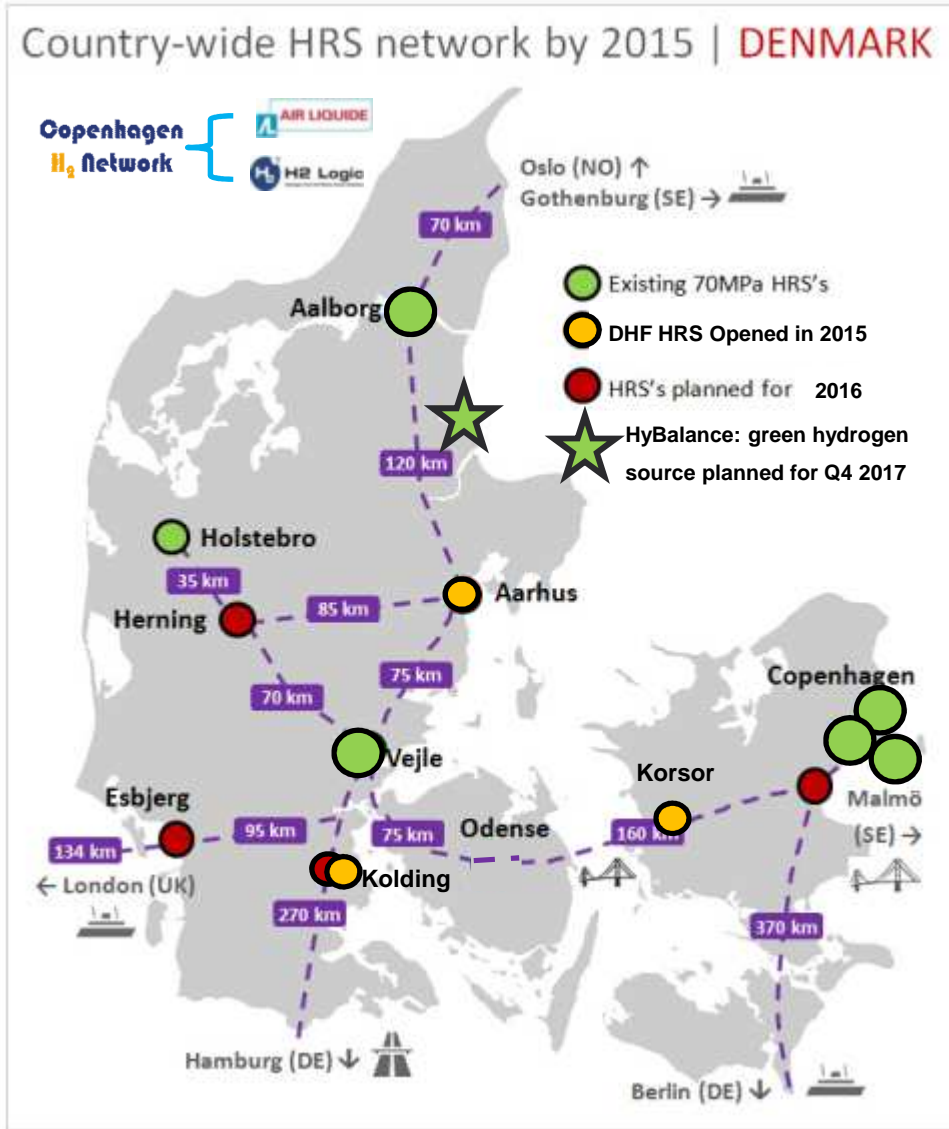
Launched in Dec. 2015, during COP 21



FCEV taxi fleet

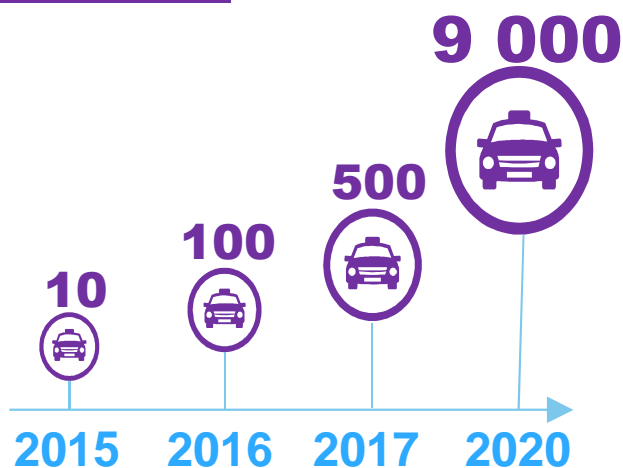


Denmark – A nationwide H2 network powered by wind

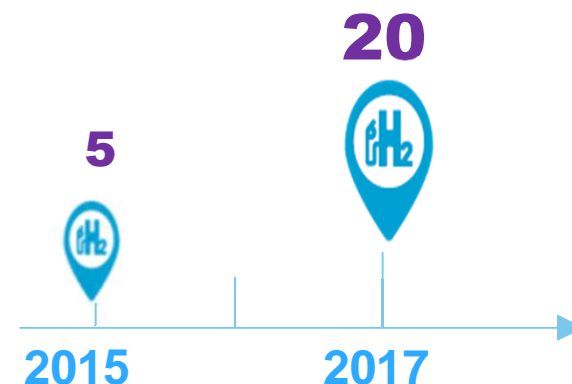


Korea – Rolling out an ambitious roadmap!

FCEV's:



H2 stations:



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



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Massachusetts Status Update



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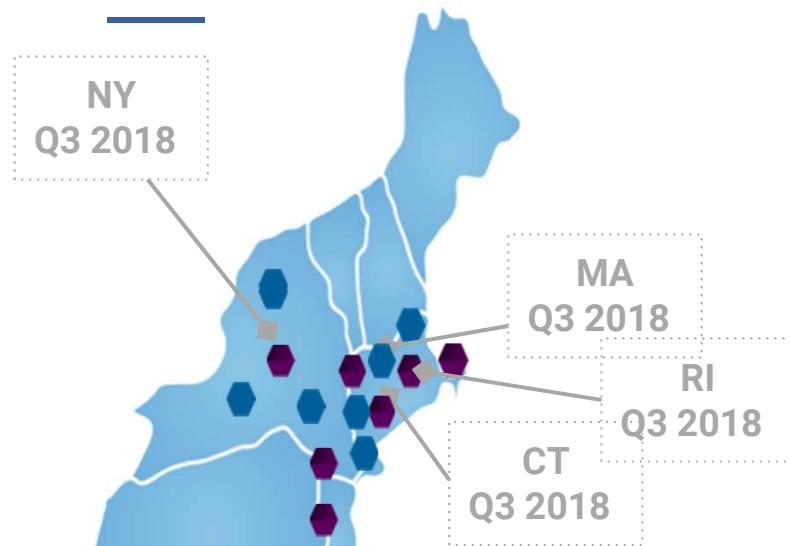
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US – Entering the Northeast



Network of 12 Stations

Start-up over Q3-Q4 2018

**Dedicated H₂ supply chain by
Project in collaboration with**



New York

Hempstead, NY
(3) Site Locations TBA



Connecticut

Hartford, CT



Massachusetts

Braintree, MA
Mansfield, MA
Newton, MA
Lexington, MA



New Jersey

(2) Site locations TBA



Rhode Island

Providence, RI

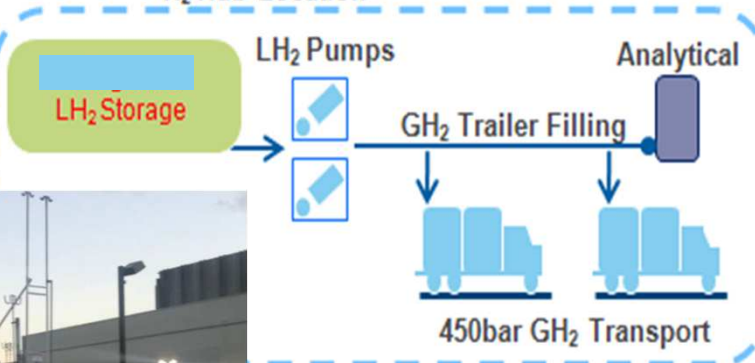
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Distribution Model- Hub & Spoke

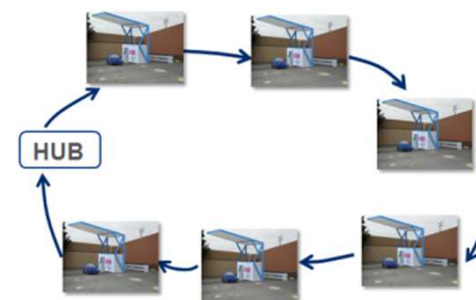
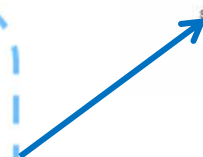
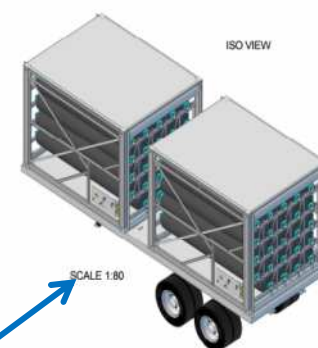
LH₂ Source
Quebec



H₂ Hub Location



Littleton, MA



NE Stations

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East Coast Planned Fueling network- Hubs

2 Hubs to supply the NYC and Boston clusters

- ☐ Delivered liquid from Canada with (5) back-up sources
- ☐ Capacity - 2,100 kg/d (each hub) or 4,200 kg/d total
- ☐ Allows for flexible demand growth
- ☐ Uses proven technology used in forklift applications

Boston Hub – Littleton, MA, colocated at Fiba Technologies

- ☐ Lease signed, approved by planning, and construction completed
- ☐ Room for expansion

NYC Hub

- ☐ Using existing Air Liquide fill facility
- ☐ Other sites being evaluated for planned expansion

Mass – Next steps

Station openings and vehicle introductions are imminent

1. Vehicle access – Mass DOT, access to tunnels
2. Station leases – Mass DOT property signoffs

Summary

Hydrogen - an energy vector that enables renewables and ZEVs

Scale enables transition and cost reductions

Global projects – transitioning from demonstration to market development

Mass - Station openings and vehicle introductions are imminent

Thank you!

For your consideration

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Fuel Cell Electric Vehicles are complementary to Battery Electric Vehicles

We seek from the commission, recognition that:

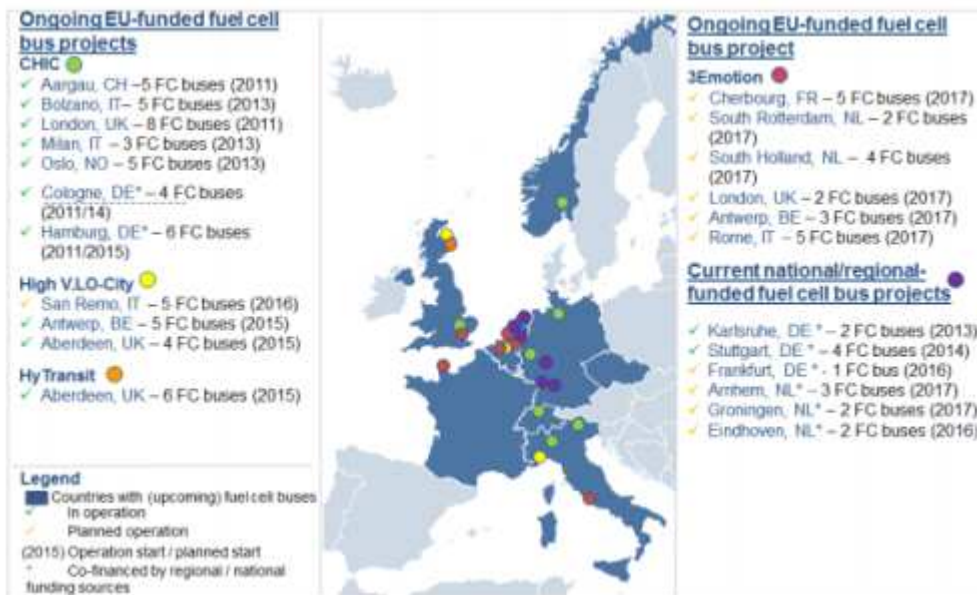
- FCEV introductions are imminent and require timely actions
- Outcomes for the state and its citizens are best met with equal treatment in ZEV programs
- Legislation and regulation recommendation and changes sought will be all inclusive for ZEV vehicles

Backup Slides - Beyond Personal Mobility



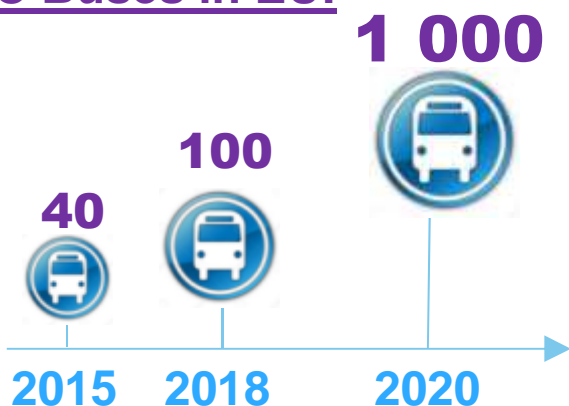
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FC Buses: EU and China showing the way



Next steps:

FC Buses in EU:



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Freight Movement - Nikola

NEWS

Nikola Motor gets \$2.3B worth of preorders for 2,000HP, electric semi-trailer truck



The Nikola One utilizes a fully electric drivetrain powered by high-density lithium batteries. Energy will be supplied on-the-go by a hydrogen fuel cell giving the Nikola One a range of 800 - 1,200 miles while delivering over 1,000 horsepower and 2,000 ft. lbs. of torque – nearly double that of any semi-truck on the road. Never has a production model class 8 truck achieved best-in-class fuel efficiency while also dramatically improving performance over its diesel competition – all with zero-emissions.



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Freight Movement - Toyota

Toyota Opens a Portal to the Future of Zero Emission Trucking

"Project Portal" hydrogen fuel cell system designed for heavy-duty truck at the Port of Los Angeles

Feasibility study will examine potential usage of fuel cell technology in heavy-duty applications

April 2017



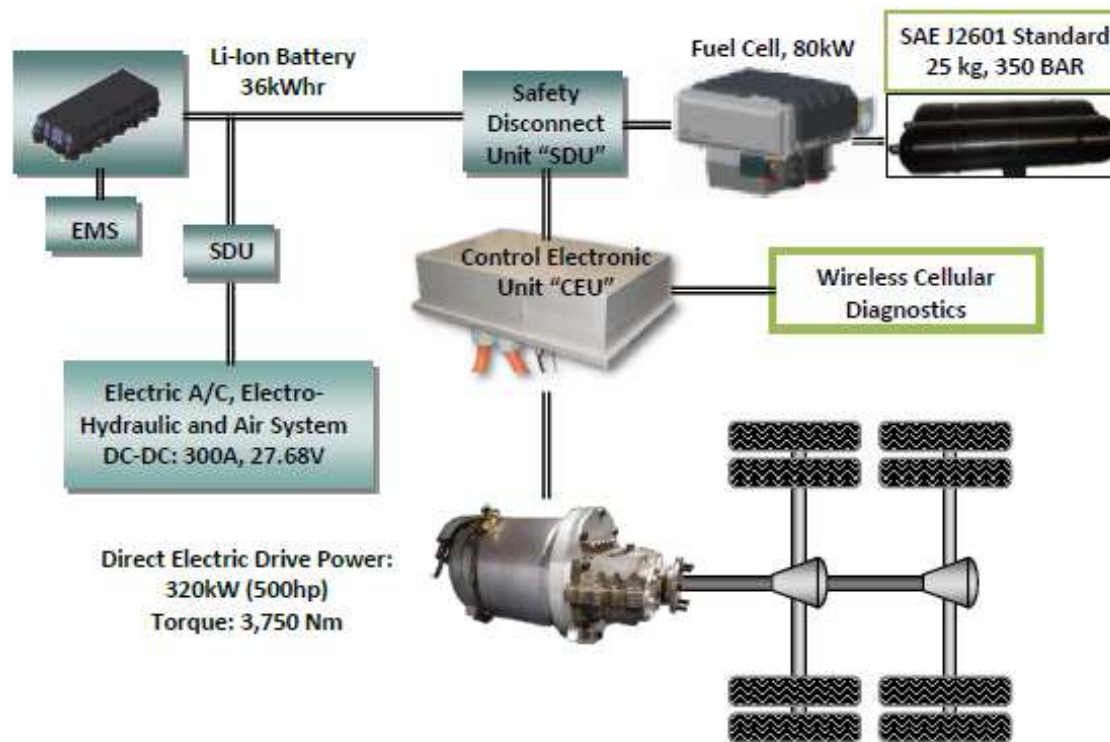
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Freight Movement – US Hybrid

In-Development
Not Released



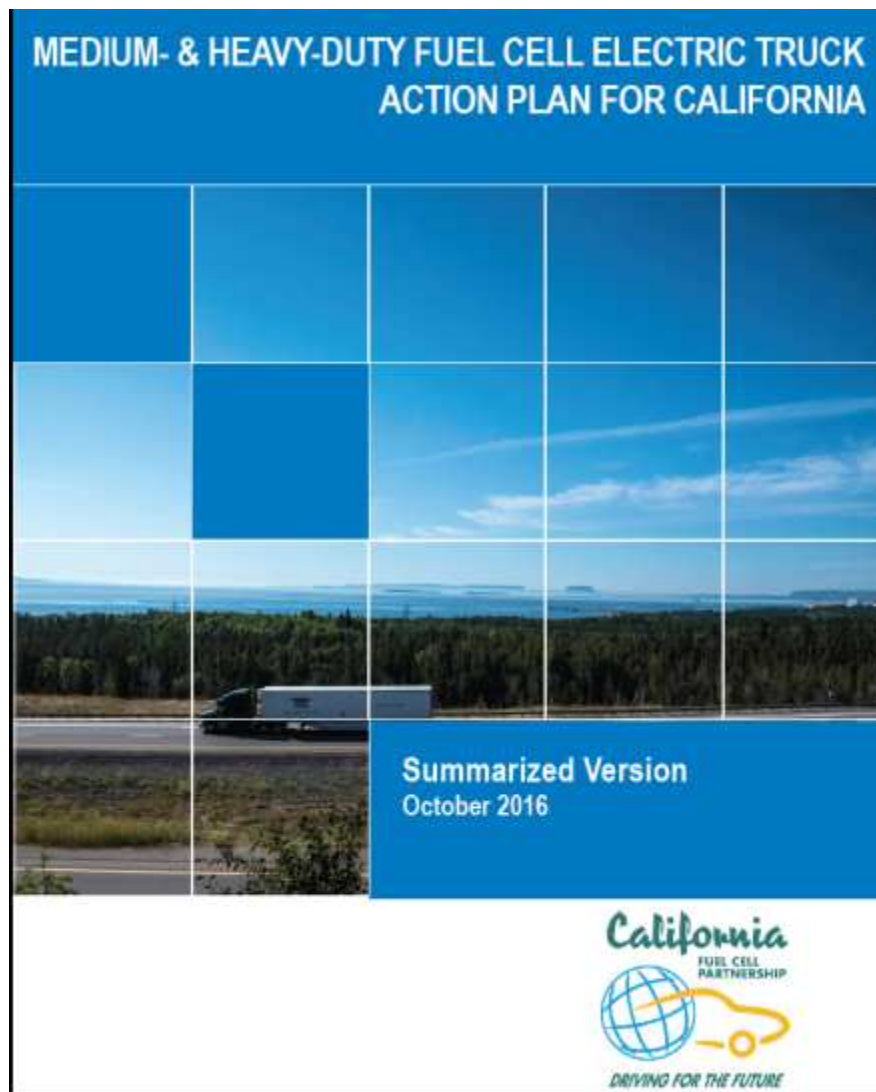
H₂Truck™



Fuel Cell Electric Class-8 Truck Powertrain System Configuration



Freight Movement - California



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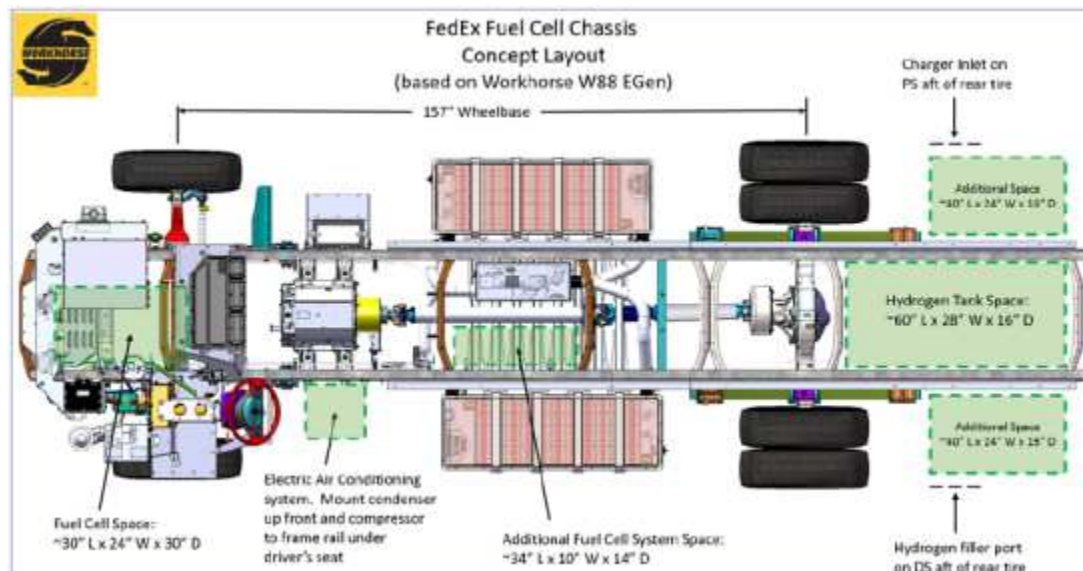
Zero Emission Cargo Transportation Fuel Cell Drayage Truck Project

Current Projects



Kenworth fuel cell truck. (Illustration: Kenworth)

Parcel Delivery



UPS to Deploy Hydrogen Fuel Cell Truck in California

May 02, 2017



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Rail

Ontario studying using hydrogen fuel cells to power GO trains

THE CANADIAN PRESS

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Alstom's hydrogen train Coradia iLint first successful run at 80 km/h

14/03/2017



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