Hydrogen: Transition to Scale

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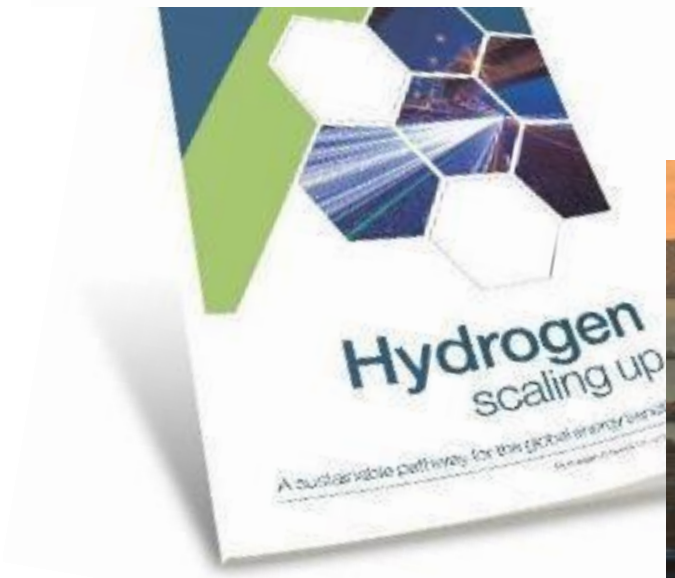
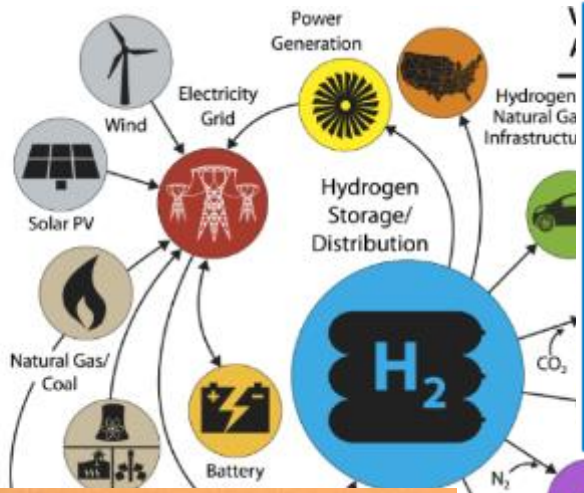
Sources – Hydrogen Roadmapping

Hydrogen Council Roadmap

Hydrogen Council



DOE – H2@Scale Program

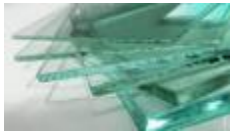


H_2 @Scale:
Energy system-wide benefits of increased H_2 implementation

CaFCP Vision for 2030

SOURCE: McKinsey

The History of Hydrogen = Transitions



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**

The Hydrogen Production Transition

Fossil Fuel Sources

Natural Gas Pipeline

Reformation

H_2

Traditional Markets

Refining

Fertilizers

Renewable Hydrogen “The Next 50 years”

Bio Methane Sources

Natural Gas Pipeline

Renewable Power Sources

Electric Grid

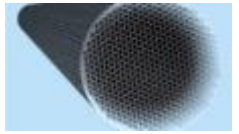
Reformation

Water Electrolysis

Motive Power

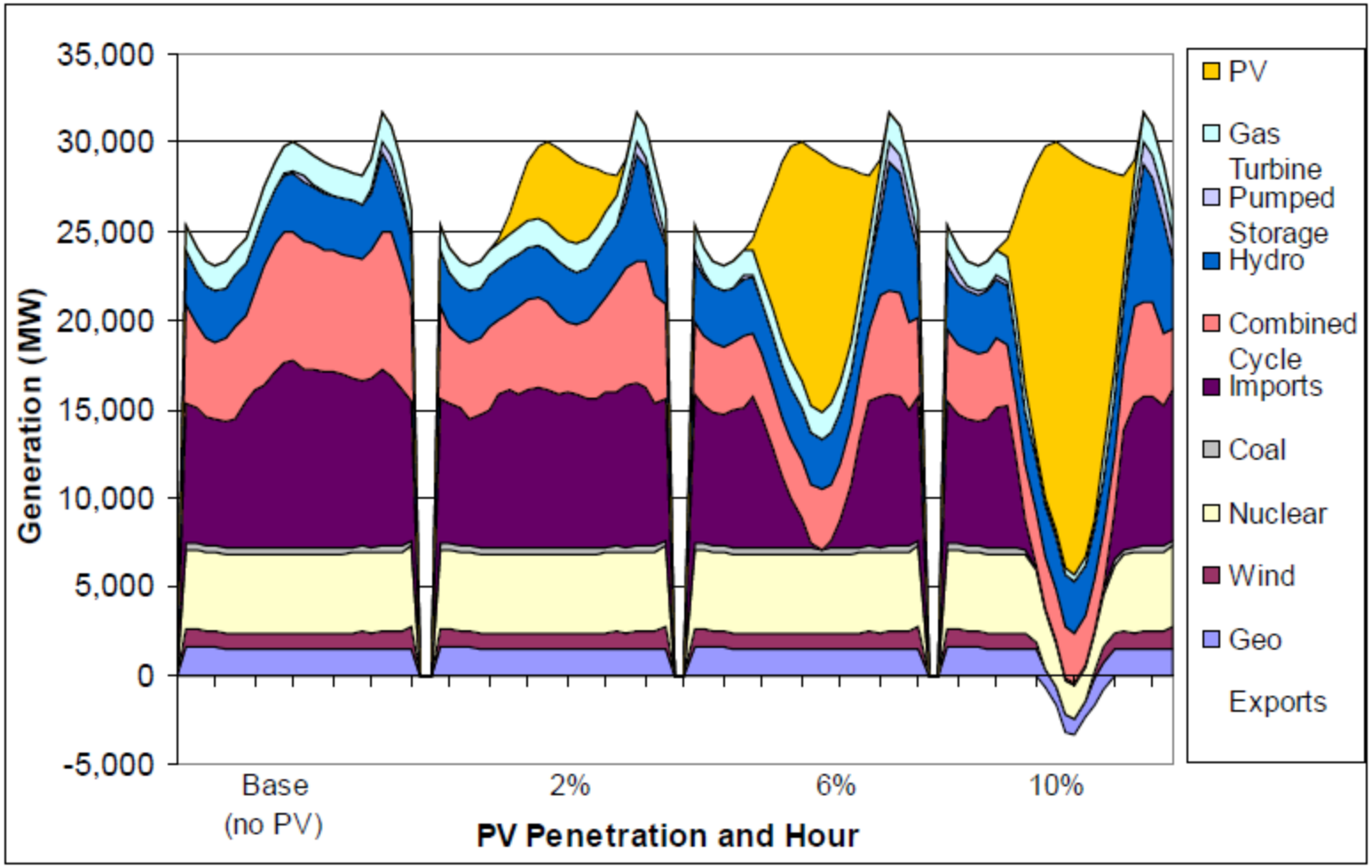
On & Off Grid Power + Storage

Traditional Markets

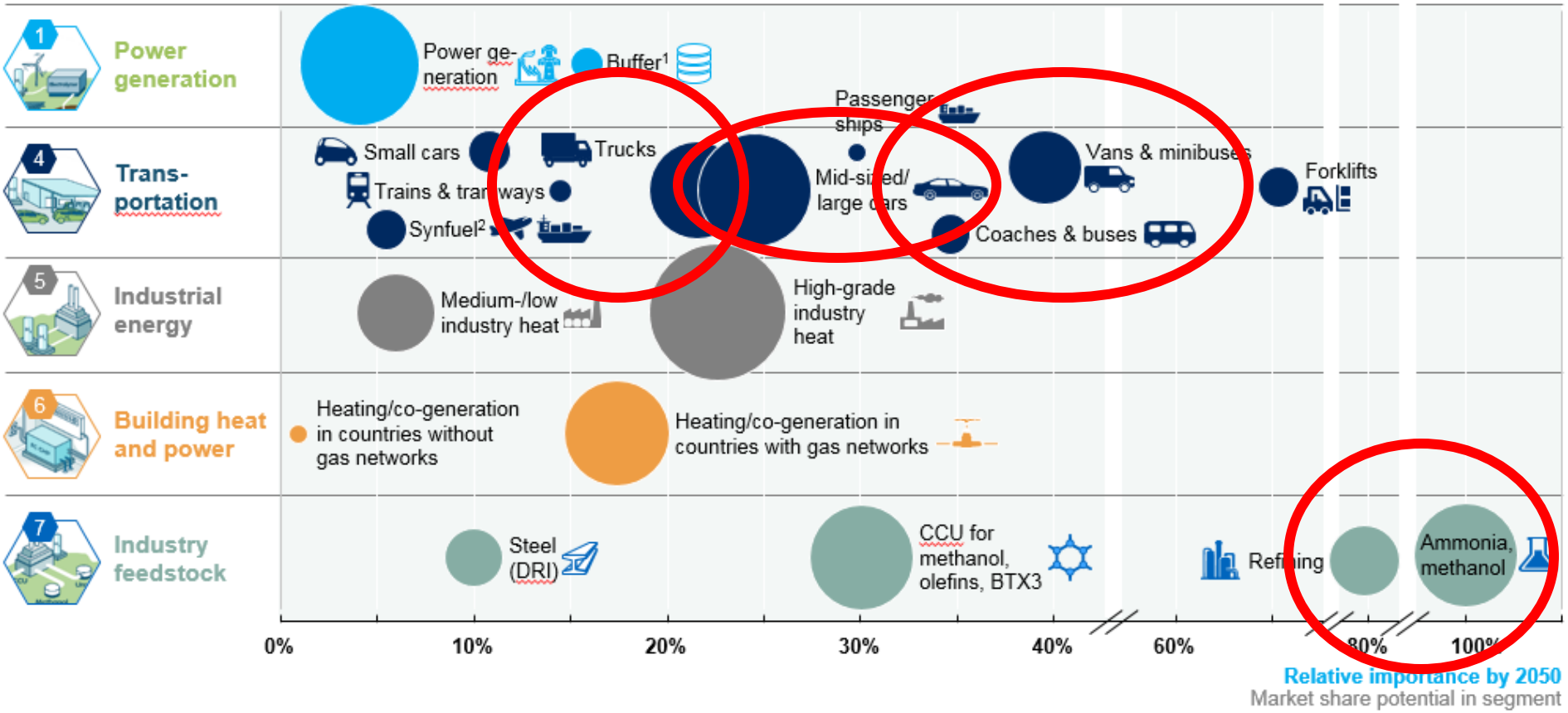


Pipelines & New Storage Technologies

Denholm et al. 2008



Market Potential – 2050 Vision from the Hydrogen Council



CA: 2030 Vision for On-Road Transportation

LD	MD/HD
1,000,000 Vehicles 1000 stations 700tpd H2	10,000 Vehicles 100 stations 700tpd H2

<u>As a reference:</u>

Today in CA there are 7 large refineries consuming approximately 3000tpd H2

The “merchant” business in CA is about 50tpd LH2

Market Requirements – Early Commercial

LD	MD/HD
Vehicle & User Expectations	
1-10kg/fill H70 3-5mins per fill partial fills common	30-100kg/fill H35 & H70 & ??? 5-10mins per fill full fills standard
Station Usage	
100+ vehicles/day/position 1-4 fueling positions/station 1 nozzle/fueling position	50+ vehicles/day/position 2-4 fueling positions/station 2 nozzle/fueling position

Station Characteristics

LD

100-1000kg/day

I gaseous delivery (300-450bar)

II onsite gaseous production

III liquid delivery

MD/HD

3000-10000kg/day (3-10tpd)

I ~~gaseous delivery~~

II onsite gaseous production (onsite liquefaction?)

III liquid delivery

IV pipeline stations

Build from Today's Distribution Model - Hub & Spoke

H2 Distribution Hub (4 tons onsite storage)

15k gallon LH_2 Storage

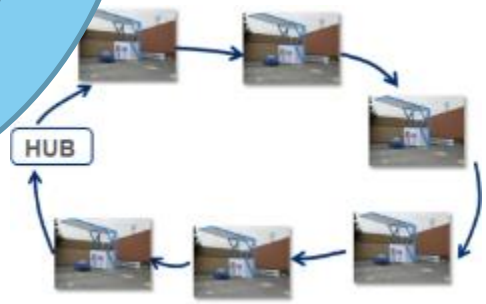
LH_2 Pumps

Analytical

GH_2 Trailer Filling

450bar GH_2 Transport

Stations

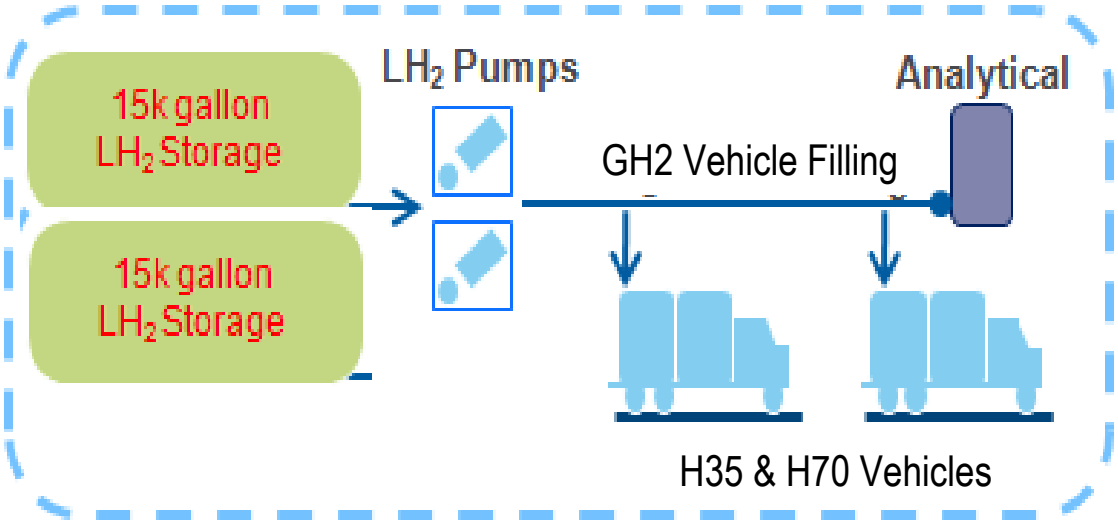


Production & Liquefaction

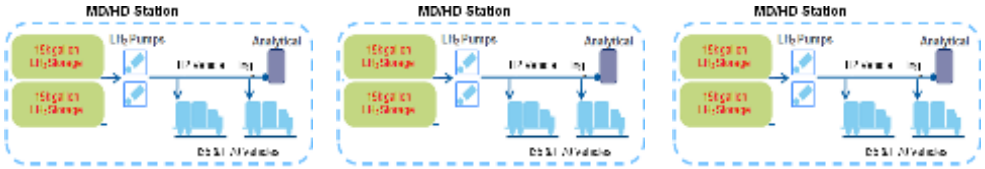
450b distribution

Tomorrow's MD/HD Station Model – liquid delivery

MD/HD Station (8 tons onsite storage)



Station Network



Production & Liquefaction

LH2 Storage

Onsite liquid storage
15,000gal typical = 4 tons

Liquid delivery tanker
13,000gal typical = 3.5 tons

NASA Sphere
850,000gal = 230 tons

Roughly to Scale

H2 LIQUEFACTION

Onsite liquefaction
1-3 tpd

Typical industrial liquefier
10-20 tpd

Future
100+ tpd (???)

Where can NH3 play a role in this transition

Storage - H2 options are limited

Liquid – individual tanks, large spheres

Gaseous - Caverns

Transportation – H2 transportation is impractical over large distances

Liquid – trailers are the only option, rail does not exist (yet?) – economical up to 500 miles

Gaseous – Pipelines are effective but location locked and timely/expensive to build
Trailers are limited in capacity (~500kg max) – economical up to 100 miles

Cost reductions – market growth requires access to low cost & renewable hydrogen

Liquid – cost reduction with scale

Gaseous – cost reduction with onsite production

Thank you

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