Hydrogen Production: Transition and Scale

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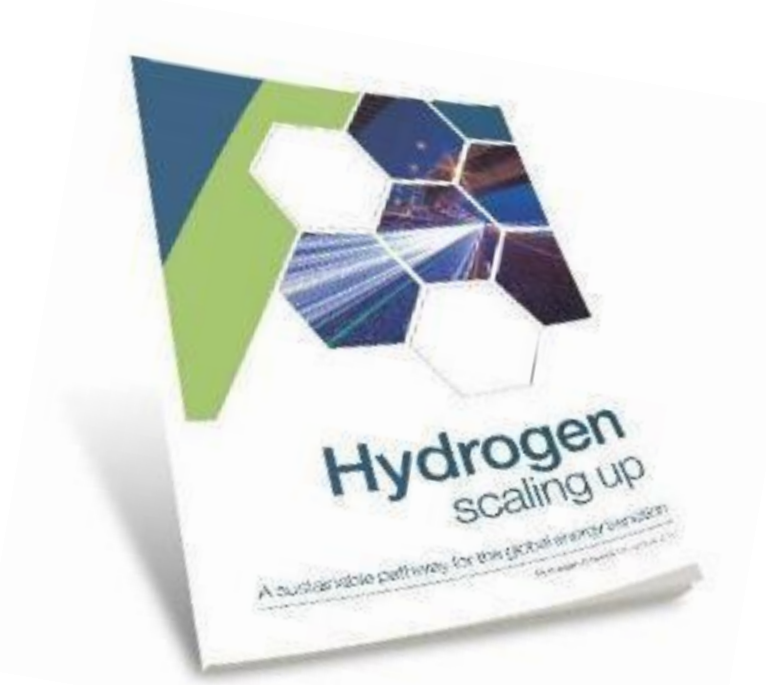
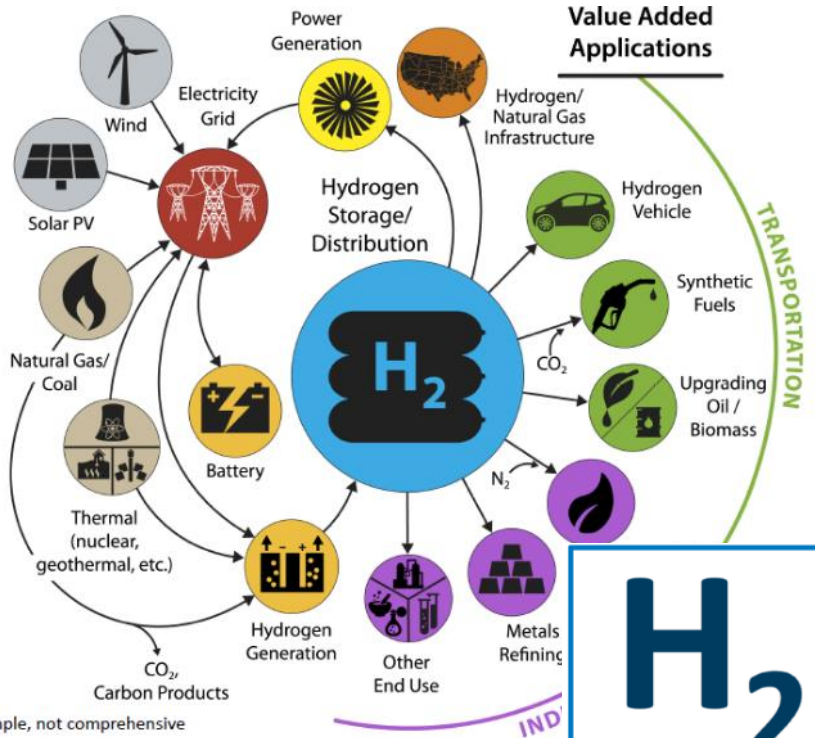
Hydrogen Council Roadmap



Hydrogen Council

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

DOE – H2@Scale Program

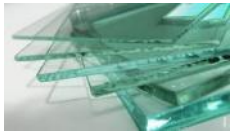


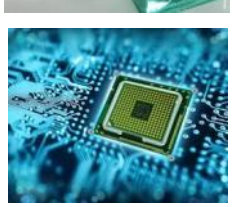
H_2 @Scale:
Energy system-wide benefits of increased H_2 implementation

Air Liquide creative oxygen

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**

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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

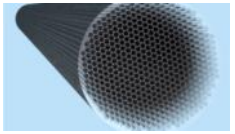
Reformation

Water Electrolysis

Motive Power

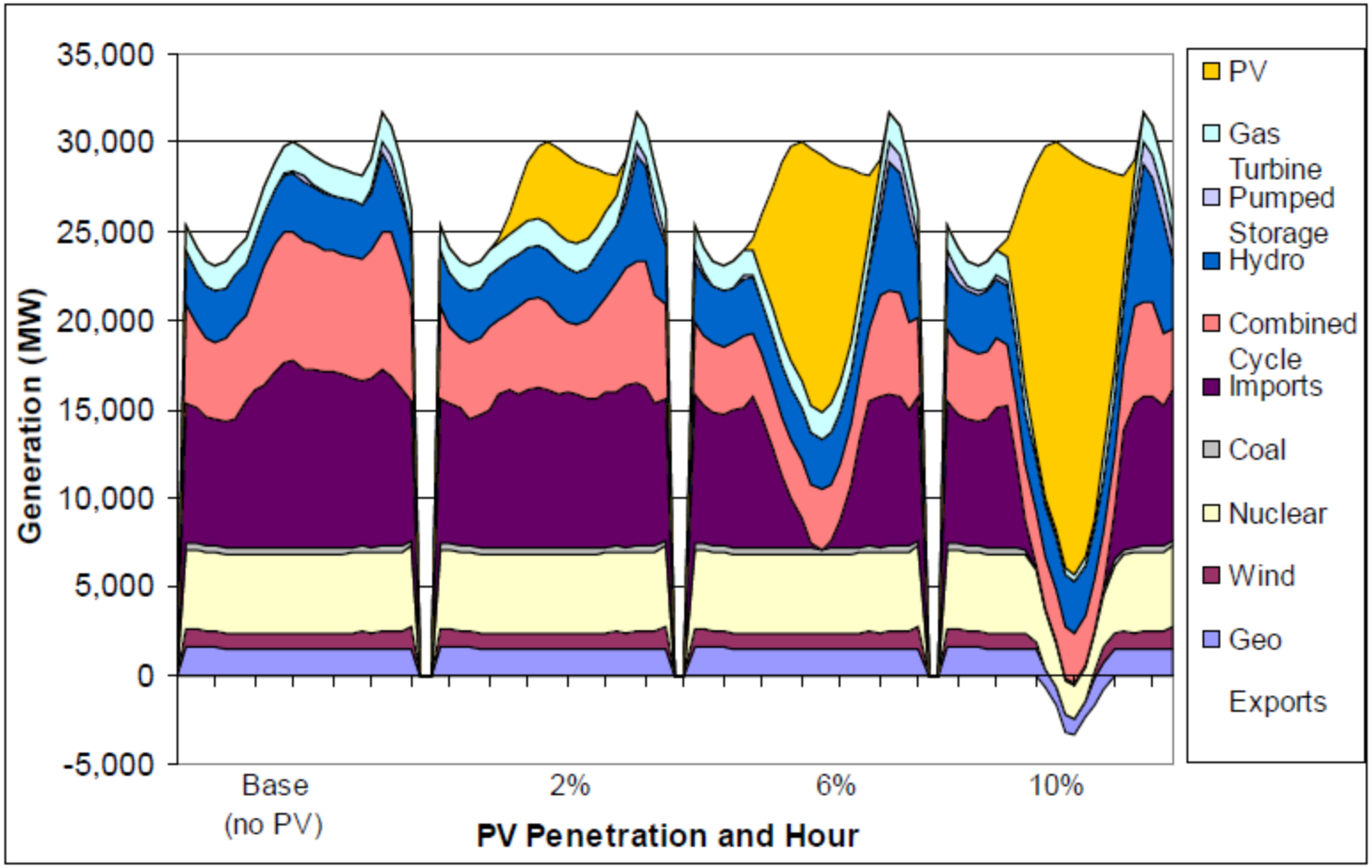
On & Off Grid Power + Storage

Traditional Markets



Pipelines & New Storage Technologies

Denholm et al. 2008



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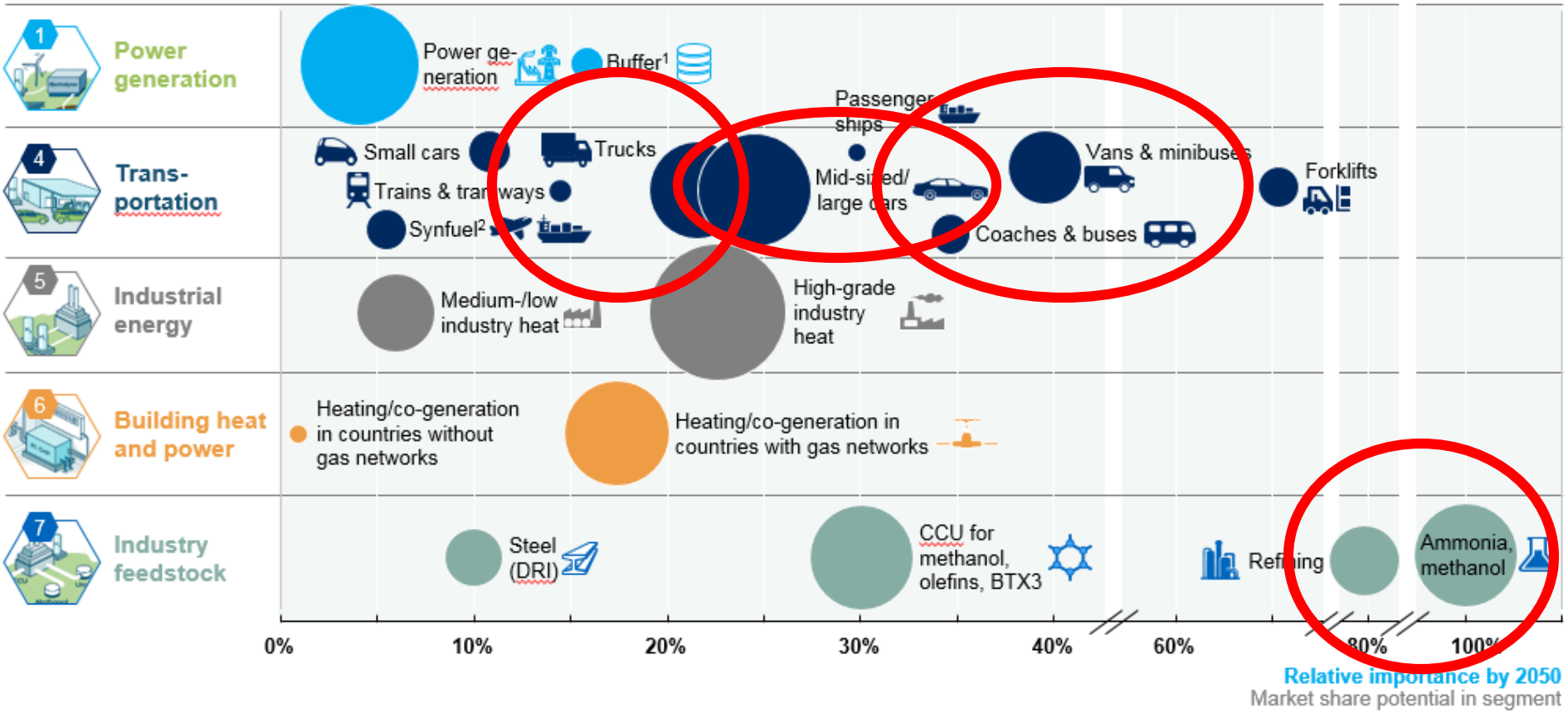
Market Potential – 2050 Vision from the Hydrogen Council



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Market activation

- transition to incentivize private investment
- how do we define and then drive toward a viable market
- the price/cost of hydrogen – gating success

Renewables

- timing, cost, scale vs fossil sources
- messaging and policy positions - shift in emphasis from fuel to energy
    - HC position – 2030 decarbonization targets
    - state commitment(s) in transportation and energy
- valuation of grid services

Challenges of scale

- Shortages (production and supply lagging demand)
- Technology challenges
    - Liquefaction (example)
    - Large scale electrolysis
    - Pipeline conversion/development
    - Grid integration
    - Storage

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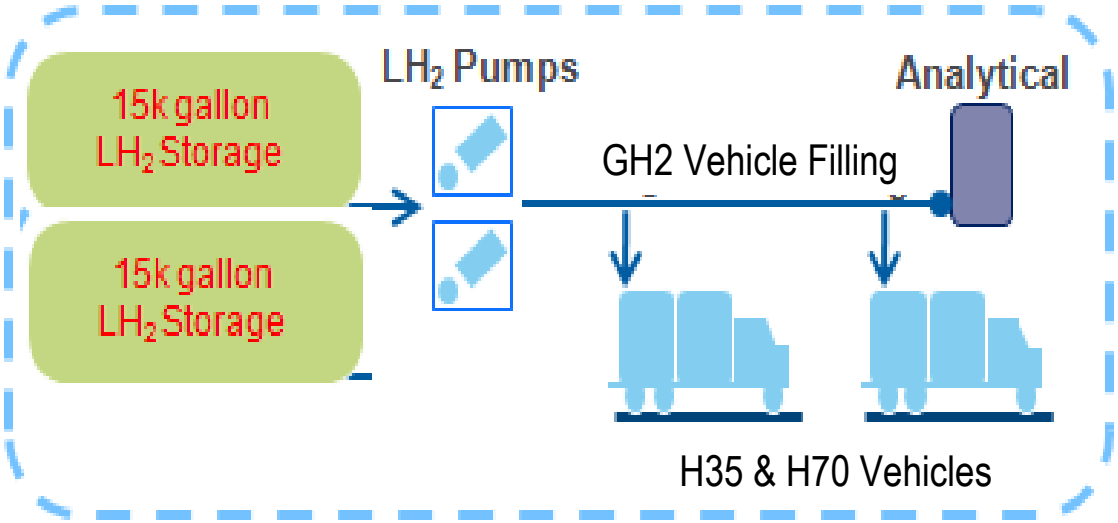
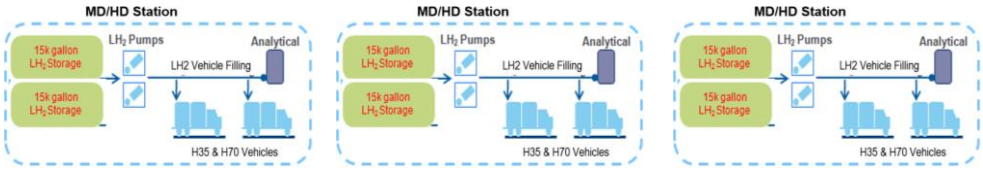
Tomorrow's MD/HD Station Model – liquid delivery

MD/HD Station (8 tons onsite storage)



Station Network



Production & Liquefaction

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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

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H2 LIQUEFACTION

Onsite liquefaction
1-3 tpd

Typical industrial liquefier
10-30 tpd

Future
100+ tpd (???)

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Thanks!

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