Infrastructure Challenges in the MD/HD Markets

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Start with a few key questions

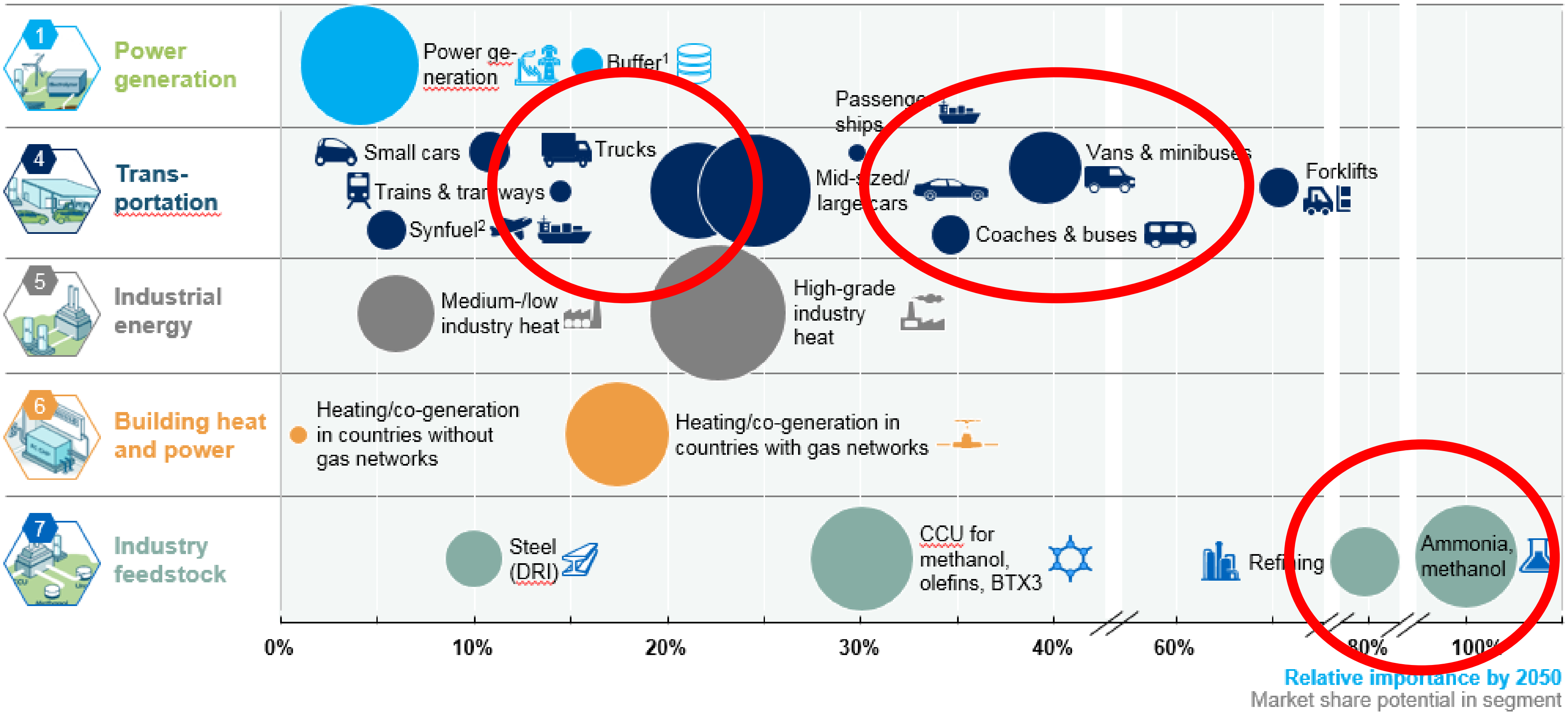
Part I

What can we expect from the MD/HD market?

What does the market expect from us (as an infrastructure provider)?

What might the refueling infrastructure look like?

Market Potential – 2050 Vision from the Hydrogen Council



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Market Requirements – Early Commercial

LD	MD/HD

Vehicle & User Expectations

LD	MD/HD
1-10kg/fill H70 3-5mins per fill partial fills common	30-100kg/fill H35 & H70 & ??? 5-10mins per fill full fills standard

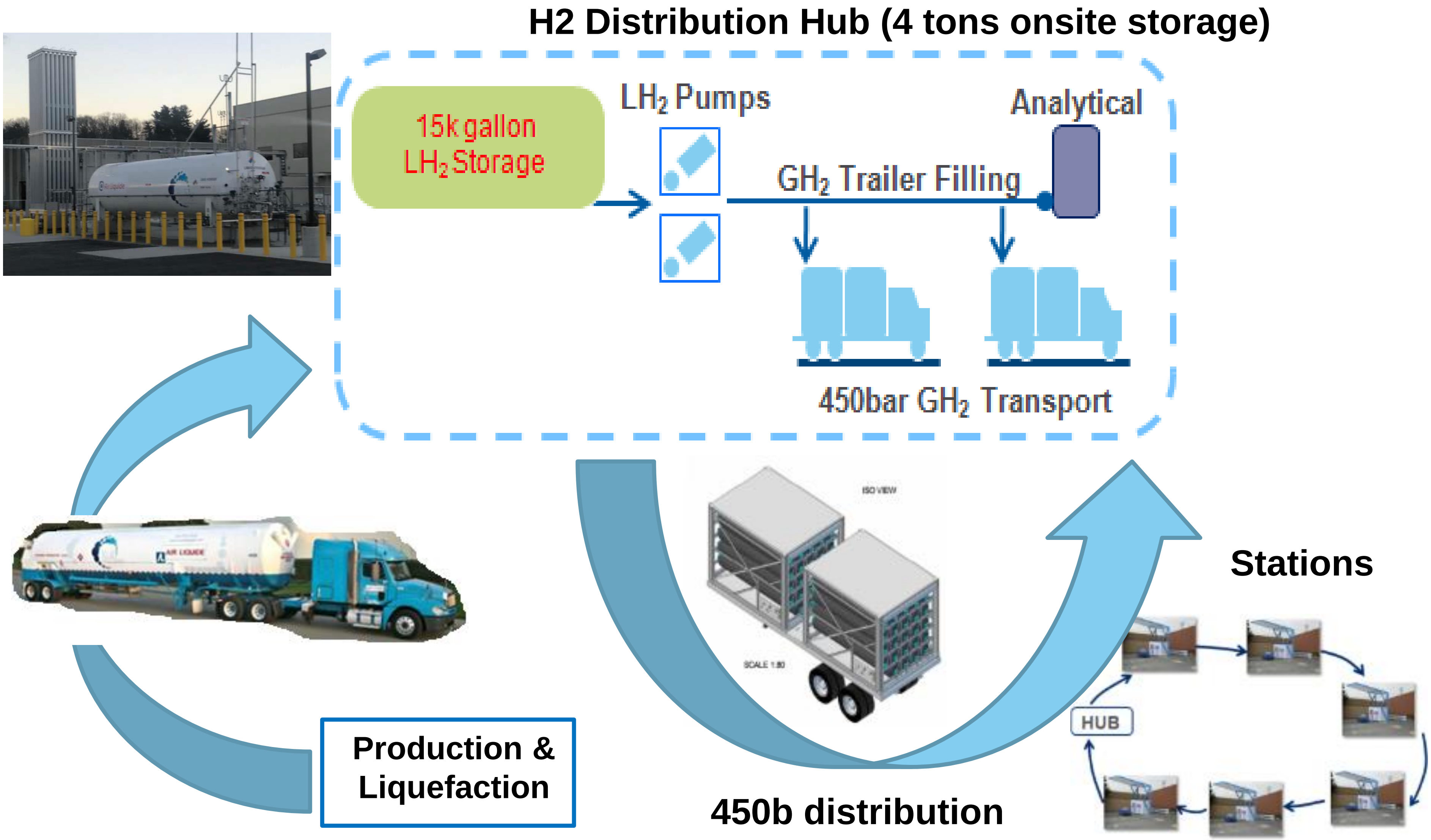
Station Usage

LD	MD/HD
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

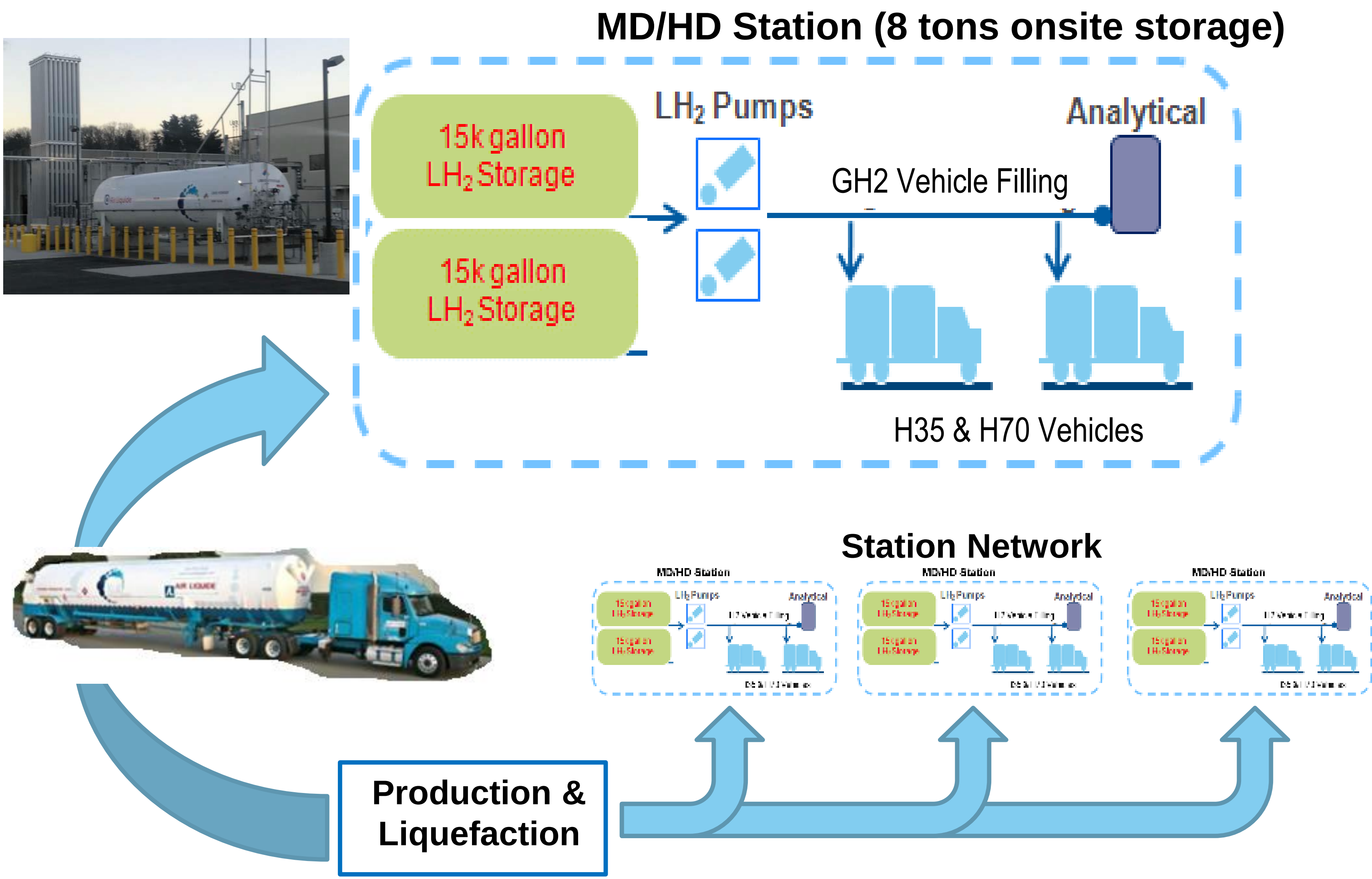
Station Characteristics

LD	MD/HD
100-1000kg/day	3000-10000kg/day (3-10tpd)
I gaseous delivery (300-450bar)	I ~~gaseous delivery~~
II onsite gaseous production	II onsite gaseous production (onsite liquefaction?)
III liquid delivery	III liquid delivery
	IV pipeline stations

Build from Today’s Distribution Model - Hub & Spoke



Tomorrow's MD/HD Station Model – liquid delivery



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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
10-20 tpd

Future
100+ tpd (???)

Leads us to the industry challenges:

Part II

What are the challenges we expect to face?

Simultaneous consideration of protocol and station designs

Fueling protocols (and lack thereof)

- H35 & H70 & ???
- Challenges to status quo
  - Other GH2 pressures (onboard)
  - Onboard liquid
  - Cryo-compressed
  - High flow supply

Station design – high flow

- High flow nozzles, multiple & simultaneous fill points
- Hoses, breakaways, valves, piping
- Cost drives shift from gas compressors to liquid pumping

Station design – high daily capacity

- Shift toward liquid storage & large banks of above ground gaseous
- Does onsite production drive a need for onsite liquefaction?

Station design - reliability

- Customer expectation requires redundancy – does cost drive us to liquid pumping

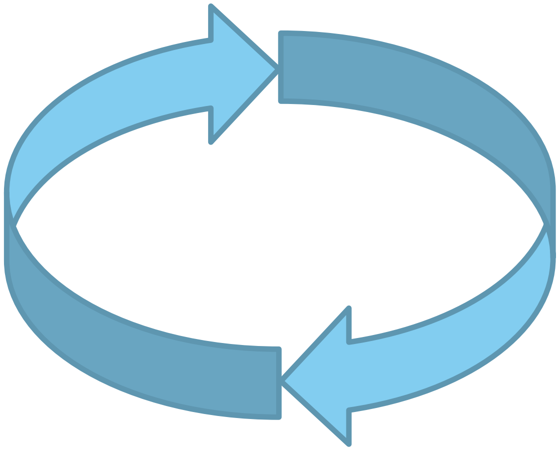
Simultaneous consideration of vehicle and stations

We MUST learn our LDV lessons

Consider impacts on customers, station designers, vehicle OEMs and supply chain (components and H2)

Process

- develop a vehicle standard design reference
- evaluate how this reference impacts station & vehicle cost
- don't forget the customer/user experience
- adapt vehicle storage to optimize total cost of ownership



Protocols and station designs lead to project challenges

Safety offsets and compliance

Drives local permitting

Station footprint

Limiting station locations and potential public access

OSHA PSM requirements

H_2 classified as a highly hazardous chemical

Site with >4.5 tons H_2 requires operating company to meet PSM req'ts

No exceptions for fueling/station operators

No similar req't for traditional liquid fuels (at these volumes)

Homeland Security issues become relevant at this scale

Industry is challenged to address these

The bottom line:

Collaboration is the key

Vehicle OEMs
Station Designers
Owners/Operators
H2 Suppliers
Regulatory Agencies
Technology Developers
DOE

Does this look like LDV did 10-15 years ago?

Thank you

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