Barriers to scaling heavy duty hydrogen infrastructure

World Hydrogen Energy Summit 2021

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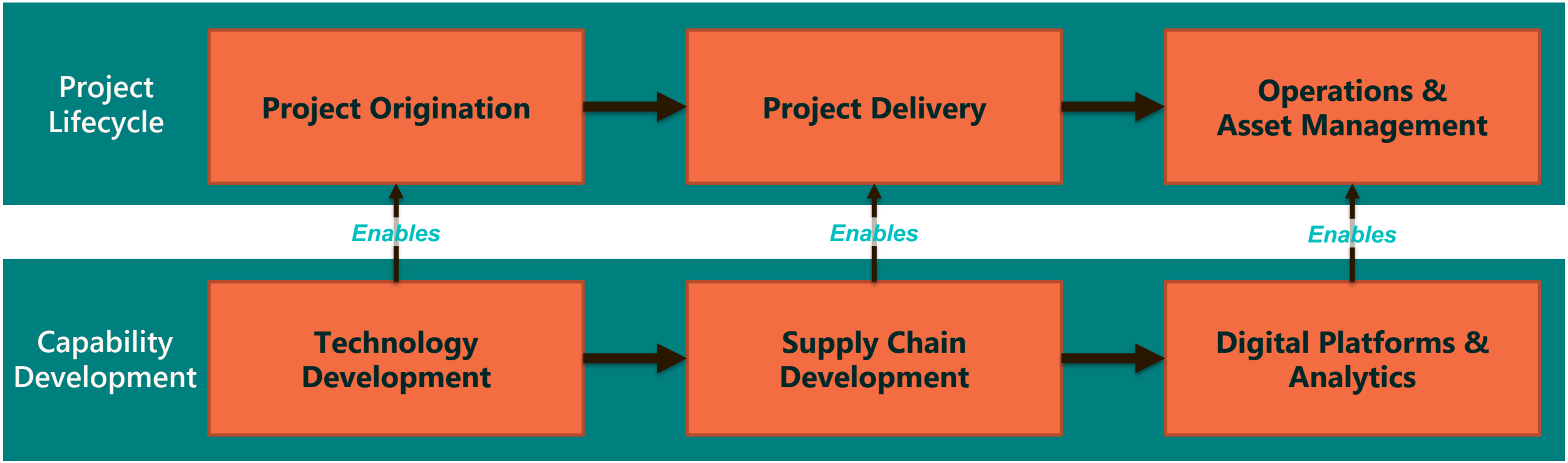
The unseen barrier: Bankable hydrogen mobility projects and supply chain development are highly interdependent



Defining Heavy Duty Mobility

20-35 kg tanks
15-35 kg daily consumption
35 MPa
refuel rates depend on cycle times

Medium Duty

50-80 kg tanks
30-70 kg daily consumption
35-70 MPa
8 kg/min refuel rates

Heavy Duty

300-500 kg tanks
800-1200 kg daily consumption
35-70 MPa
15 kg/min refuel rates

Ultra Heavy Duty

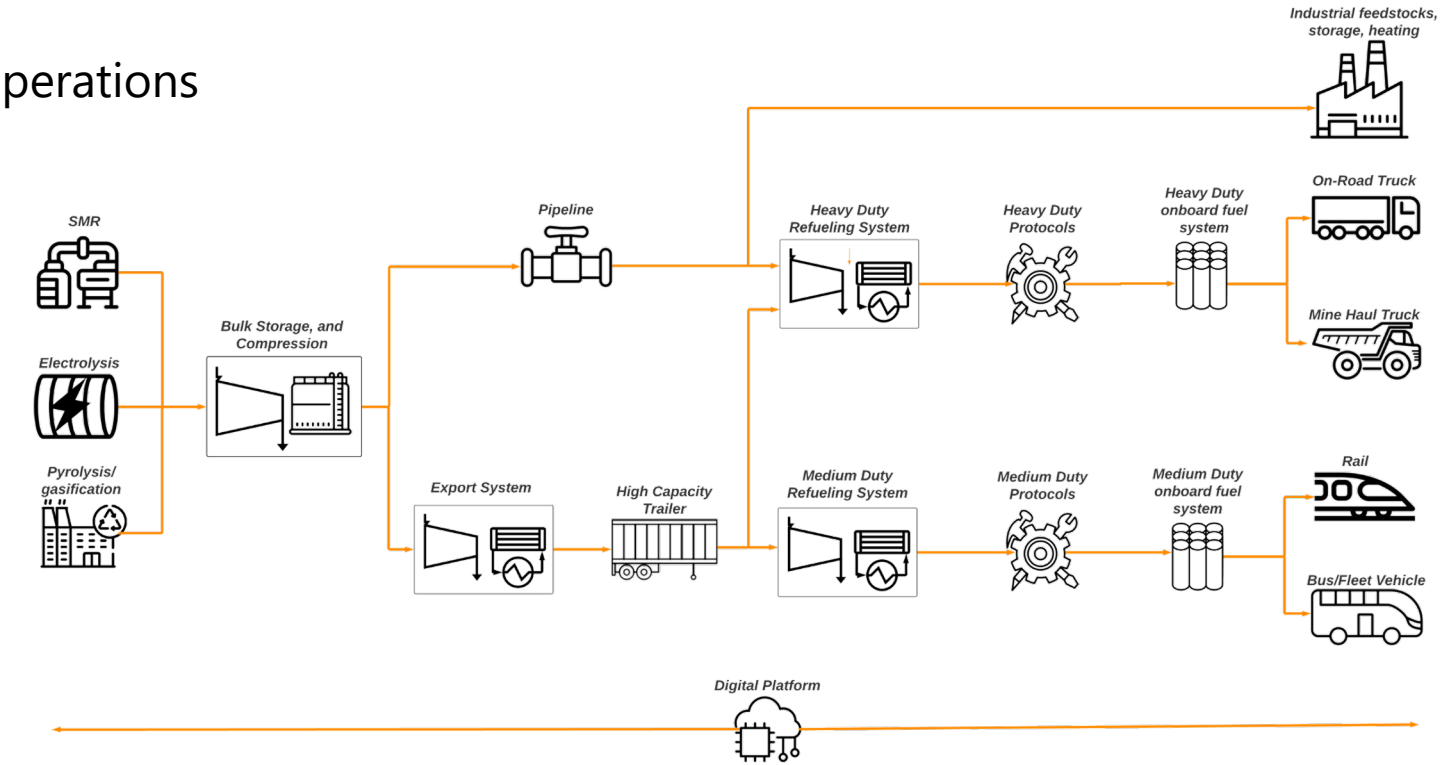
H2 Supply Chains are a System of Systems

The supply chain needs design, safety management, and operation as a single system of systems to achieve:

- ***$/kg*** that is bankable
- ***Availability*** that delights customers
- ***Safety*** that the public deserves
- ***Performance*** that meets the needs of operations

Common reasons supply chains are not well integrated:

- *Interfaces between technologies are not designed, or managed throughout the project lifecycle*
- *Competencies and experience in hydrogen equipment & operations is rare*
- *Modifying technologies and associated interfaces has no payback for a single project. Needs a portfolio and roadmap approach.*



H2 technology needs scaling for HD & UHD

Supply Chain Element	Current State Of The Art	Required for Scaled Deployment
Refueling Stations (70 Mpa)	1-2 HD truck per hour, with long recovery periods	• 5-10 HD truck per hour, back to back fill • 2 UHD vehicles per hour, back to back fill
Refueling Protocols	• 3 kg/min @ 35 MPa best available • Early prototypes for 3-5 kg/min @ 70 MPa in controlled environments	• For HD: 10 kg/min @ 70 MPa, 100 kg tanks • For UHD: 15 kg/min @ 70 MPa, 500 kg tanks
Export Compression	• 25 kg/h @ 65 MPa • 50 kg/h @ 45 MPa	• 2500 kg/h @ 65 MPa (trailer export) • 4500 kg/h @ 10 Mpa (pipeline export)
GH2 Trailers	1100 kg capacity @ 500 bar ~1.5-1.8 million USD per trailer	1500 kg capacity @ 550+bar 60% cost reduction
Liquefiers	80-100% turndown capability 11,000,000 USD/TPD 13-15 kWh/kg	0-100% turndown 50% cost reduction <8 kWh/kg
Refueling components	60 g/s @ 70 Mpa, -40C 120 g/s @ 35 Mpa, -10C	For HD: 180 g/s @ 70 MPa, -40C For UHD: 250 g/s @ 70 MPa, -40C
Chilling	30-50 kW @ -40C	300 kW @ -40C for GH2 refueling stations 600-800 kW @ -20C for GH2 trailer export systems
Transfer losses	LH2: 10-20% loss GH2: 5-10% loss	<3 %

Other barriers to scaling

Barrier	Options to enable growth
Limited access to hydrogen experience	• ***Investment in talent engines*** • *Attract talent from other technology industries such as high tech, biotech, automotive, oil and gas.*
Lack of firm hydrogen demand	• *Demand, H2 production & infrastructure/operations integrated deals* • ***Cheaper and available vehicles!!!***
Products are unreliable, cost too much, and not fit for purpose	• *Investment in continuous improvement ecosystems* • ***Investment in higher capacity products***
Poor asset management & maintenance	• *Digital operations & training* • *Reliability growth programs, analytics engines*
Incumbents have a vertical integration business model	• *Decouple technology access from molecule supply* • *Differentiate from the merchant gas, or capitalized lease models of IGCs*
Technical standardization is low	• *Tightly couple lighthouse commercial project needs and schedules to standards committee agendas*
Supply Chains are commercially weak and not integrated	• ***Move from transactional procurement to open technology ecosystems*** • *Move away from focus on individual technologies to the supply chain as a product*

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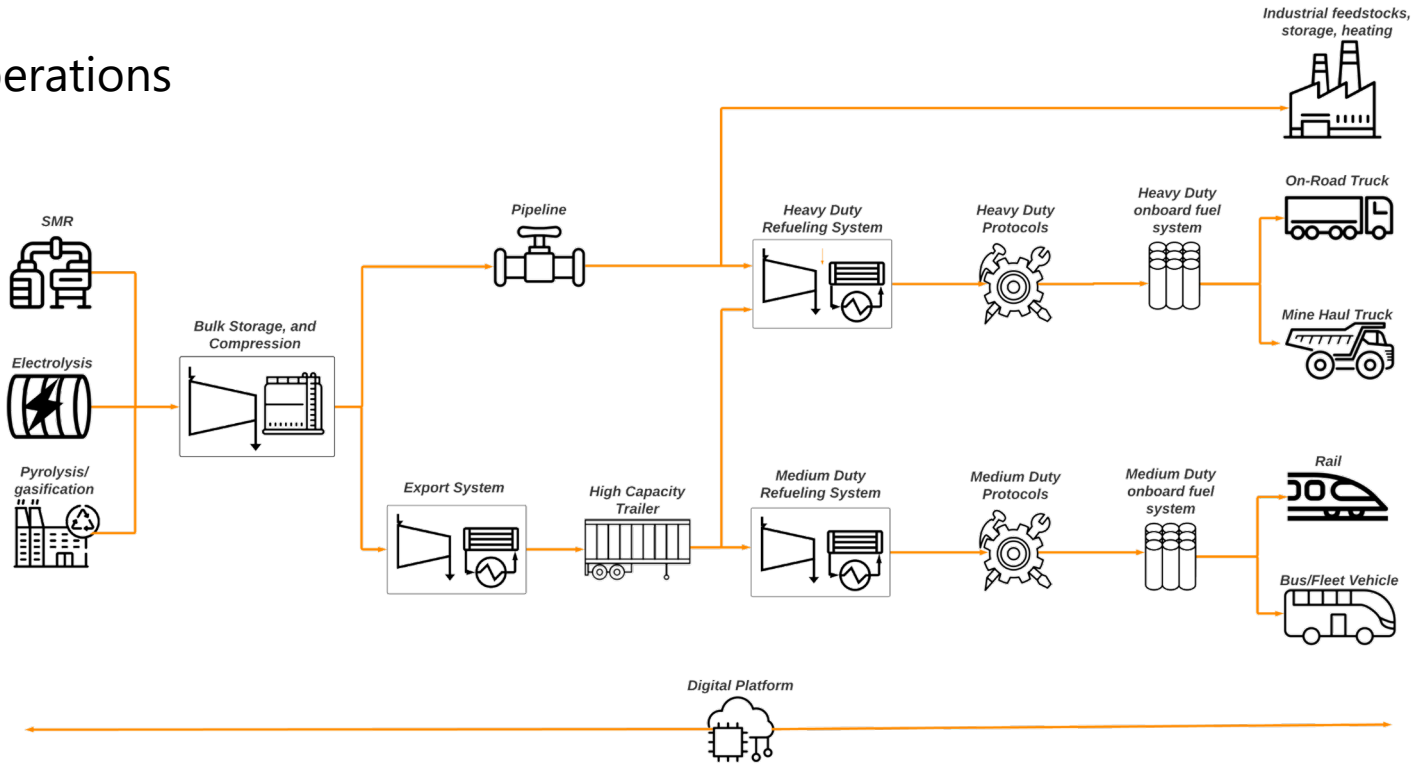

What is LIFTE H2?

GLOBAL
SUPPLY CHAIN INTEGRATION
PRODUCT DEVELOPMENT
DIGITAL PLATFORM

Scalable & Profitable Hydrogen Projects

REGIONAL
PROJECT DEVELOPMENT
OPERATIONS