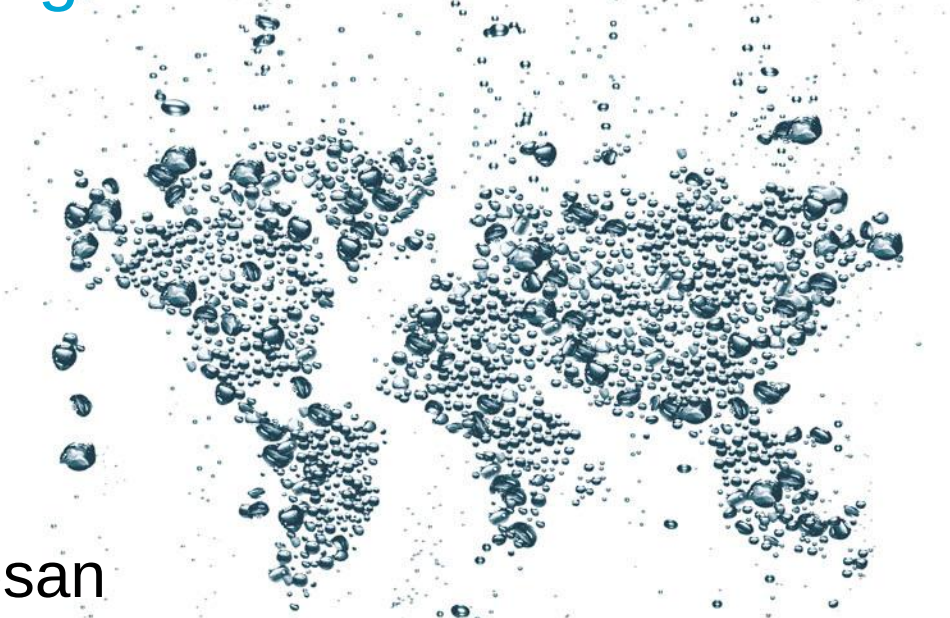
Storage - Challenges and Opportunities.

Workshop on forecourt compression, storage and dispensing RD&D to enable cost reduction.



Nitin Natesan
Chicago, IL - Argonne National Laboratory
March 20-21, 2013

CLEAN TECHNOLOGY BY LINDE

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Linde Covers The Entire Hydrogen Value Chain

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Large-Scale Production

Conventional
(e.g. SMR)

Green
(e.g. BTH)

On-site Supply & Storage

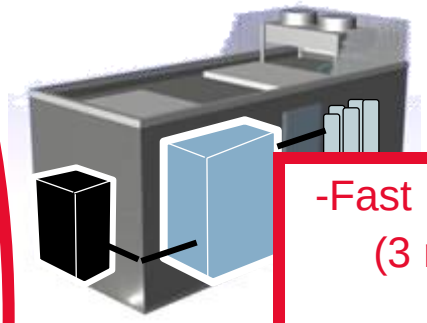
CGH2 storage

LH2 storage

Onsite SMR

Onsite
Electrolyzer

Compression/Transfe



Ionic compr

Cryo pump

Dispenser

350 bar

700 bar

-Fast Fueling
(3 min)

-Back to Back
Peak fueling

-High
Throughput
(>400 kg/day)

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Current Status of Technology

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•Linde has operating fuelling stations with liquid, gaseous and on-site supply options around the world

• Each option presents its advantages and has its drawbacks

• Current technology and established standards exist for each of the different supply technologies

•Industry has met the challenges to fuel fast, peak fuel, and increasing throughput

— Investing only in technologies cannot capture full benefit without improving the hard limit placed on station forecourts by existing codes and standards on storage

— Increased throughput (>200 cars per day) will soon be needed demanding more storage or more deliveries

— Liquid Site = deliveries per week ; Gaseous site = Multiple deliveries per day

• To make a step change in station forecourt competitiveness and viability will require:

— Further RD&D in storage technology

— Further RD&D in site related aspects

— Advancement and industry-wide acceptance of Codes and Standards (will become the limiting factor)

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Current Challenges

Liquid Storage	Gaseous Storage
— Setback distances (75 feet to operable windows / doors / air compressors and 50 ft to flammable objects) = difficulty in finding sites — Area utilization — Ventilation — Other code requirements	— Area utilization — Limited Usable Capacity (need a lot of it or frequent deliveries) — Readily available ASME certified high pressure safety relief devices (>14000 psi) for Hydrogen use — Limited Cycle Life for > 700 bar — Setback distances

Key RD&D Activities Necessary for Cost Reduction

Liquid Storage	Gaseous Storage
— Code Case review to Reduce 75ft, 50 ft and Other key restrictive NFPA setback distances to exposures (reduces cost of slow deployment) — In many areas this a low cost / high density delivery option — Demonstration low cost underground or partially below ground options — Vent stack designs that improve dispersion	— Demonstration project which improves “usable quantity” in gas cascade storage (> 80% usable) — More ASME certified equipment for 700 bar filling (i.e. Safety valves matching vessel MAWP) — Underground options (Cost / Code) — Improved cycle life for > 700 bar — Code Harmonization with Europe

Thank you for your attention.

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