Repurposing existing pipelines for hydrogen transport

Materials, welding and economic challenges and solutions

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Hydrogen Welding Workshop

CEM Solutions Co., October 12, 2023

Todays Agenda

- Hydrogen as a Clean Fuel
- Total Value Chain
- Repurposing Existing Infrastructure:
- Technical Challenges in Repurposing:
- Alternative Solutions:
- Technical Readiness:

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Hydrogen as a Clean Fuel:

- Hydrogen is considered a leading clean fuel for the future.
- Realizing the hydrogen economy requires novel engineering and technology solutions.
- Ensuring its techno-economic viability is crucial.

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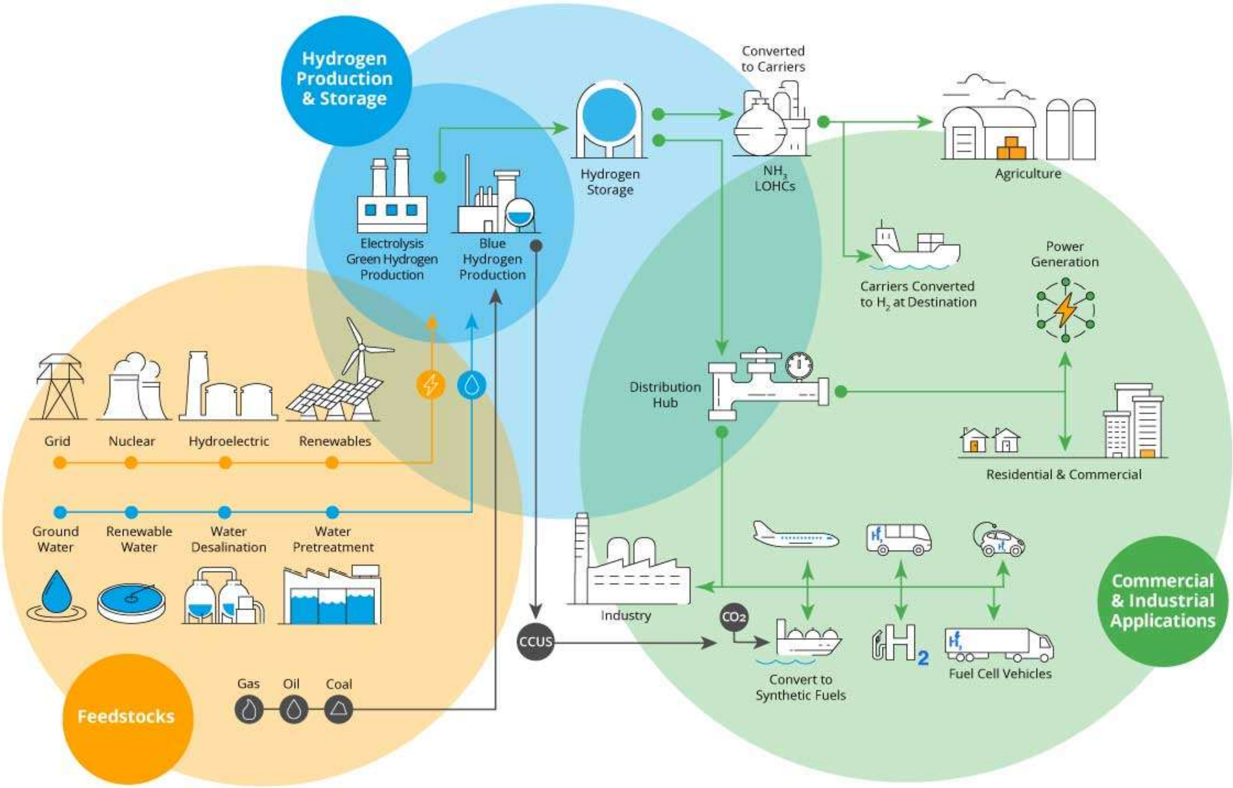
Comprehensive Hydrogen Value Chain



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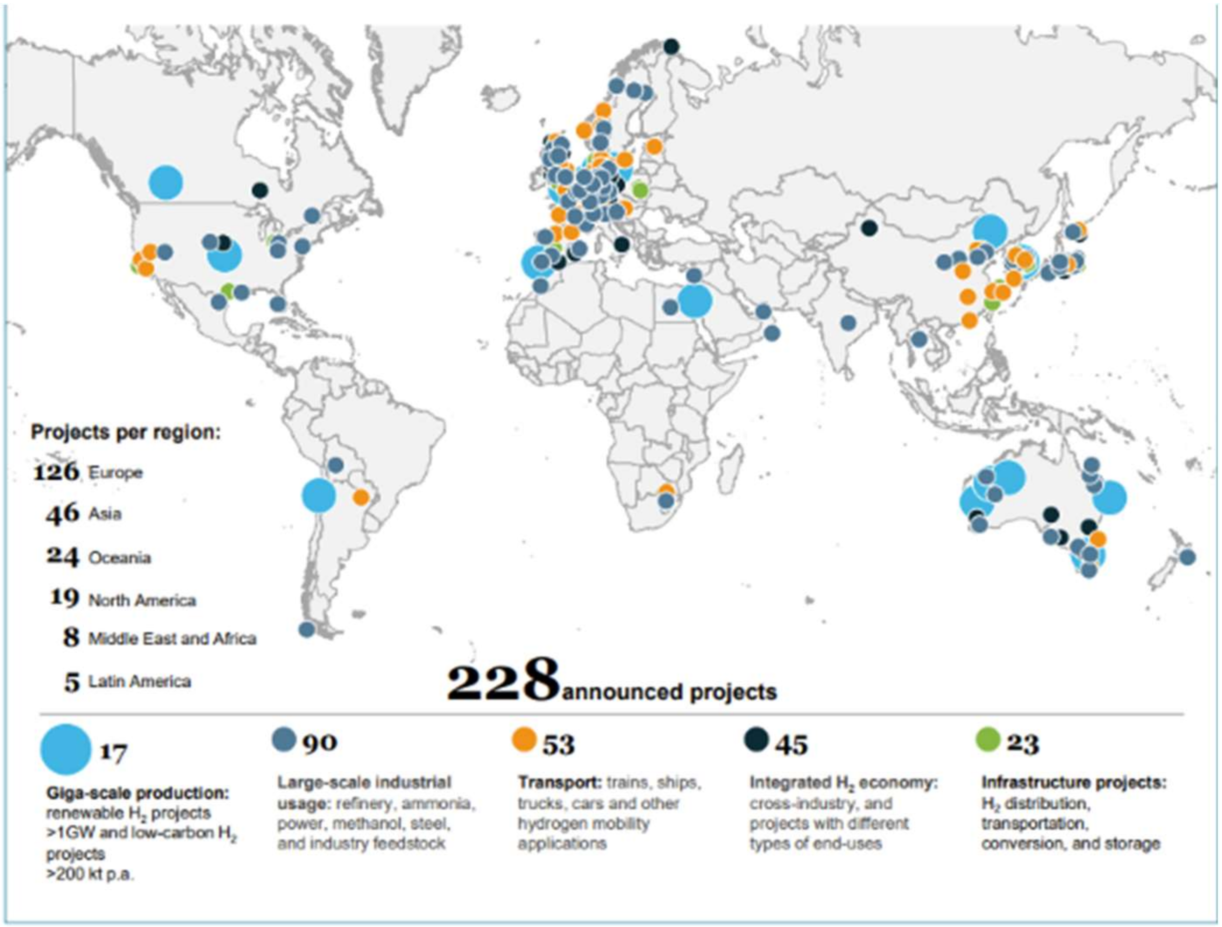
Global Hydrogen Projects



This translates to:

- A growth of tenfold in pipeline infrastructure
- 2500 km to 28000 km in 2030 in US
- 23000 km in EU
- 50% can/may be re-purposed

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Repurposing Exiting Pipelines

- Generally, repurposing existing infrastructure is economically more attractive than building new infrastructure.
- Focuses mainly on the midstream of the hydrogen value chain, which includes thousands of miles of existing natural gas pipelines.

What does retrofitting entail?

Due Diligence & Modifications:

- ❑Pipeline and weld condition and ability to carry pressure
- ❑Upgrading the pipeline's compressor stations to handle hydrogen's lower density
- ❑Replacing certain components, such as gaskets and seals, that are not compatible with hydrogen
- ❑Installing leak detection and safety systems specifically designed for hydrogen
- ❑Regulatory and legal issues-Permits and approvals
- ❑Overall, the repurposing of existing natural gas pipelines has the potential to significantly reduce the cost of developing a hydrogen pipeline network.
- ❑However, it is important to carefully evaluate each pipeline on a case-by-case basis to determine whether it is feasible and cost-effective to repurpose it for hydrogen transport.
- ❑If the repurposing of natural gas pipelines is successful, it could play a major role in accelerating the development of the global hydrogen economy.

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Economics of retrofitting & repurposing

	Retrofitting	New Pipeline
Transmission-onshore	1 X	3.6-3.7 X
Transmission-subsea	1 X	2.2-3.7 X
Distribution	1 X	3.0-3.5 X

- Cost multiplier for new lines versus retrofitting (on a Million $/Km basis)
- Retrofitting is estimated to be 30% of a new bult- and in some cases 10%.
- Retrofitting on onshore lines is more attractive than offshore
- Better retrofitting economics for longer lines

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Ease of retrofitting

	Ease	Challenge
Transmission-onshore High Pressure	Relatively easy	Availability, Contracts, Condition
Transmission-subsea High Pressure	Highly challenged	Compression hardware
Distribution Low Pressure	Medium complexity	High consequence areas

- Onshore lines:
  - Relatively easy to implement
  - Availability of pipelines for conversion is a major concern
    - Those that meet technical requirements
    - Commercial availability-existing contracts, economics

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Repurposing Challenges

Degradation & Defects	Operations & Loading	Materials, Welding & Inspection	Environment	Hydraulics	Commercial & Regulatory
Degradation	Loading condition	Weld, BM Inspections, interval, data	Hydrogen partial pressure	Reduced pressure capacity (energy equivalence)	International boundaries
Material & weld quality-Types of pre-existing cracklike defects	Design factors	Mech. Properties- YS/TS, CVN,	Hydrogen spec	Leak management	Permitting, Licensing, Commissioning
Deformation, wrinkles	Pressure cycling	Fatigue crack growth rate in H2	Inhibitors	Compressor performance	Liability, Legal uncertainty
Residual stress/Installation stress	Gas composition	Microstructure	Temperature	Seals, gaskets, elastomers	Sustainable vs Traditional fuel
	CP status	Residual stress	RoW		Insurance
	Inhibitor	Running fracture (CVN, DWTT)			Metering, Delivery pressure
	Integrity Management	Weld process			Contract and availability

For today, we will discuss the ones marked in "red"

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Welding, NDE and Pipe condition are KEY factors!

- **Pipe vintage and corresponding manufacturing route is key:**
  - SMYS of parent pipe
  - Toughness of parent pipe
  - Toughness of seam weld
  - Inclusions in steel
  - Defects in steel
  - Line pipe inspections in factory
- **Welding and NDE is often overlooked:**
  - Welding technique
  - Weld inspection (X Ray, UT, PT)
  - % of inspection
  - Weld properties from PQR

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What are the repurposing options?

Revalidating the pipeline and weld properties

- Inspection and sampling
  - Prior history
  - ILI inspection data (crack, deformation, corrosion)
  - Selective destructive sampling of pipe and weld (statistical)
  - Nondestructive property evaluation (TS,YS, Kic etc.)
- Pipe and weld condition
  - Vintage and manufacturing route
  - Inspection and %
  - Location
- Analysis

Refurbishing & Replacement Options

- Selective reinforcement using
  - Weld sleeves
  - Composite sleeves
- Crack arrestors to limit extent of release (in non-ECA)
  - This limits the crack length in the event of a failure
- Internal reinforcement liners installed in-situ.
- Composite pipes with embedded sensors
- Selective replacement of steel pipe

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Engineering Risk Management of Hydrogen Infrastructure - Actual analysis

	Transport	Storage
Process/Method	▪ Pipeline ▪ Tanks ▪ Ships	▪ Tanks ▪ Caverns ▪ Depleted gas wells
Needs/Gaps (New infrastructure)	❑ Standards ❑ Welding/Joining ❑ Hydrogen/Fatigue ❑ Inspection/Monitoring ❑ Non-metallics ❑ Low temp. brittleness	❑ Casing integrity management ❑ Cavern inspection methods
Needs/ Gaps (Old infrastructure)	○ Age/Grade/Quality ○ Weld integrity ○ Loss of ductility/toughness ○ Fatigue life ○ Inspection/Monitoring ○ Repair guidelines	○ Casing integrity management ○ Cavern integrity management & inspection methods
Gap closure	➢ <u>**Repurpose guidelines**</u> ➢ Hydrogen permeation-property effects (metals, NM) ➢ Assessing weld integrity ➢ Novel non-intrusive monitoring/ inspection	➢ FMEA of the cavern/well and casing ➢ Brine/contaminant studies on well casing degradation ➢ Hydrogen effects on casing

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Guidelines for Repurposing

- **Inventory of Pipelines**
  - Vintage (pre-1970)
  - LFW, HFI, SAW
  - Grade
  - Location
- **Welding condition**
  - Technique
  - NDE
  - % inspection
- **Pressure containing capacity**
  - Hoop
- **Fracture resistance**
  - Fracture tougness
  - Girth, seam weld, body
  - NDE or DE
- **Cyclic stress (Compression)**
  - Assesment of fatigue
  - Reduced CF life
- **% Hydrogen**
  - PURE Hydrogen
  - Co-transport
  - Literature
- **Hydraulics**

- **Evaluation (weld & BM)**
  - Fracture toughness
  - Fatigue analysis
  - Crack growth-Seam/girth
- **Testing**
  - Sub-scale
  - Full scale
- **Can existing pipeline support Hydrogen ??**
- **Remediation**
  - Liner
  - Crack arrestor
  - Reinforcement

Conclusions

- Techno-economic viability of energy transition, especially Hydrogen hinges on optimizing the Capex.
- A fit for purpose, Re-purposing of existing assets to handle hydrogen is a key enabler.
- Materials, welding and NDE play a key role in ensuring that repurposing is carried out in an efficient and safe manner.
- Repurposing must be carried out with lot of deliberate rigor.
  - A protocol that addresses the current state of the infrastructure, the operating conditions and the technology readiness of solutions must be followed.
- In addition, the Hydrogen value chain presents several novel opportunities in welding and joining, that contribute to the competitive, efficient and safe operation of infrastructure.

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