Federal Perspective on Opportunities for Hydrogen and Natural Gas for Transportation

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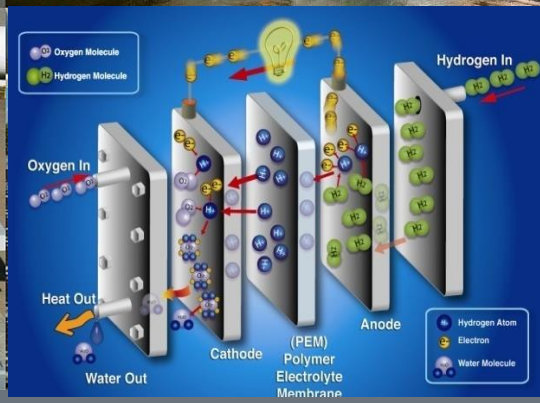

Exploring the Intersection of Hydrogen Fuel Cell and Natural Gas Vehicles - Workshop

American Gas Association, Washington, D.C.
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U.S. Department of Energy

The Potential for Natural Gas in Transportation

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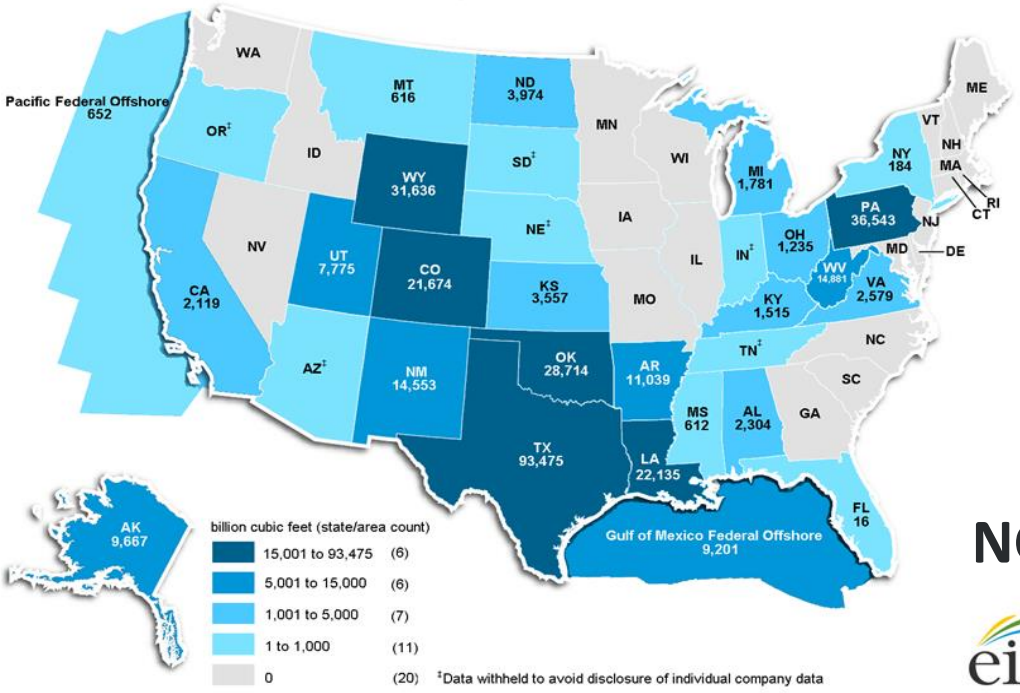
With ample NG resources available , four potential pathways to incorporate NG in transportation are (1) CNG fueling NGV Hybrids (2) Electricity from NG to charge BEVs (3) H_2 produced from NG to fuel FCEVs which offers the highest efficiency and mile driving range and (4) trucks.

Proved Natural Gas (NG) Reserves by State*



322.7 Trillion Cubic Feet of NG Proved Reserves in the U.S.

~2,700 trillion cubic ft. of total technical and economic NG potential

4 Natural Gas Use Pathways**

Compressed Natural Gas (CNG) → Fuels → Trucks

Compressed Natural Gas (CNG) → Fuels → NGV Hybrid

Efficiency 28%
Mile Range 250

NG → Produces → **Electricity** → Fuels → BEV

Efficiency 24%
Mile Range 100

NG → Produces → **H_2** → Fuels → H_2 FCV

Efficiency 36%
Mile Range 400

*Sources: *U.S. EIA, Annual Survey of Domestic Oil and Gas Reserves. Released on April 2014.*
*** ANL Natural Gas and Hydrogen Workshop, Summary Report, 2011.*

Reduced GHG Emissions for H_2 from Natural Gas

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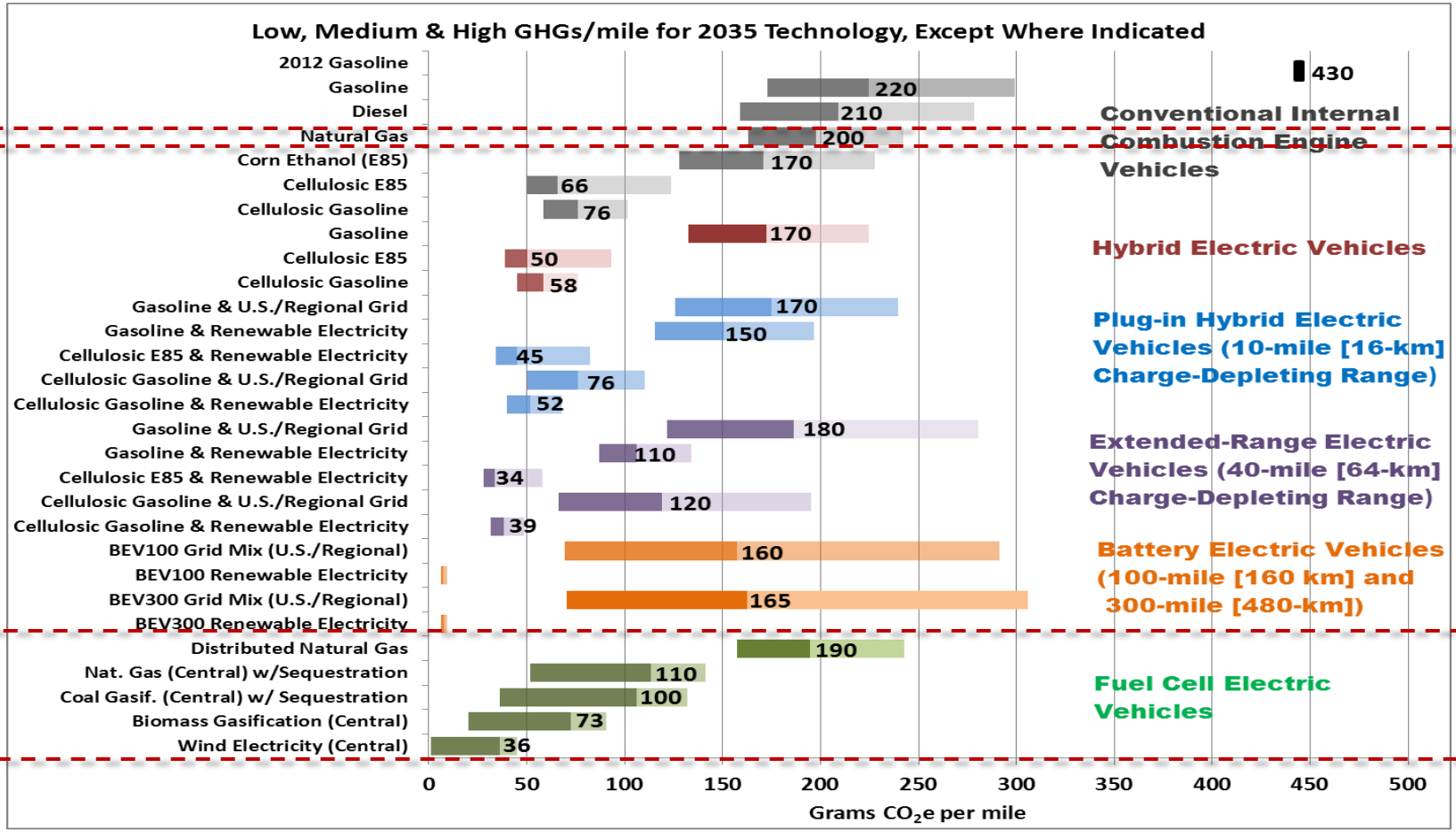
Analysis by ANL, NREL and EERE shows that FCVs fueled by H_2 from NG can reduce GHG emissions by 50%.

Well-to-Wheels Greenhouse Gases Emissions for 2035 Mid-Size Car

(Grams of CO2-equivalent per mile)



Low/medium/high: sensitivity to uncertainties associated with projected fuel economy of vehicles and selected attributes of fuels pathways, e.g., electricity credit for biofuels, electric generation mix, etc.

Source: [Program Record 13005]

Reduced Petroleum Use for H_2 from Natural Gas

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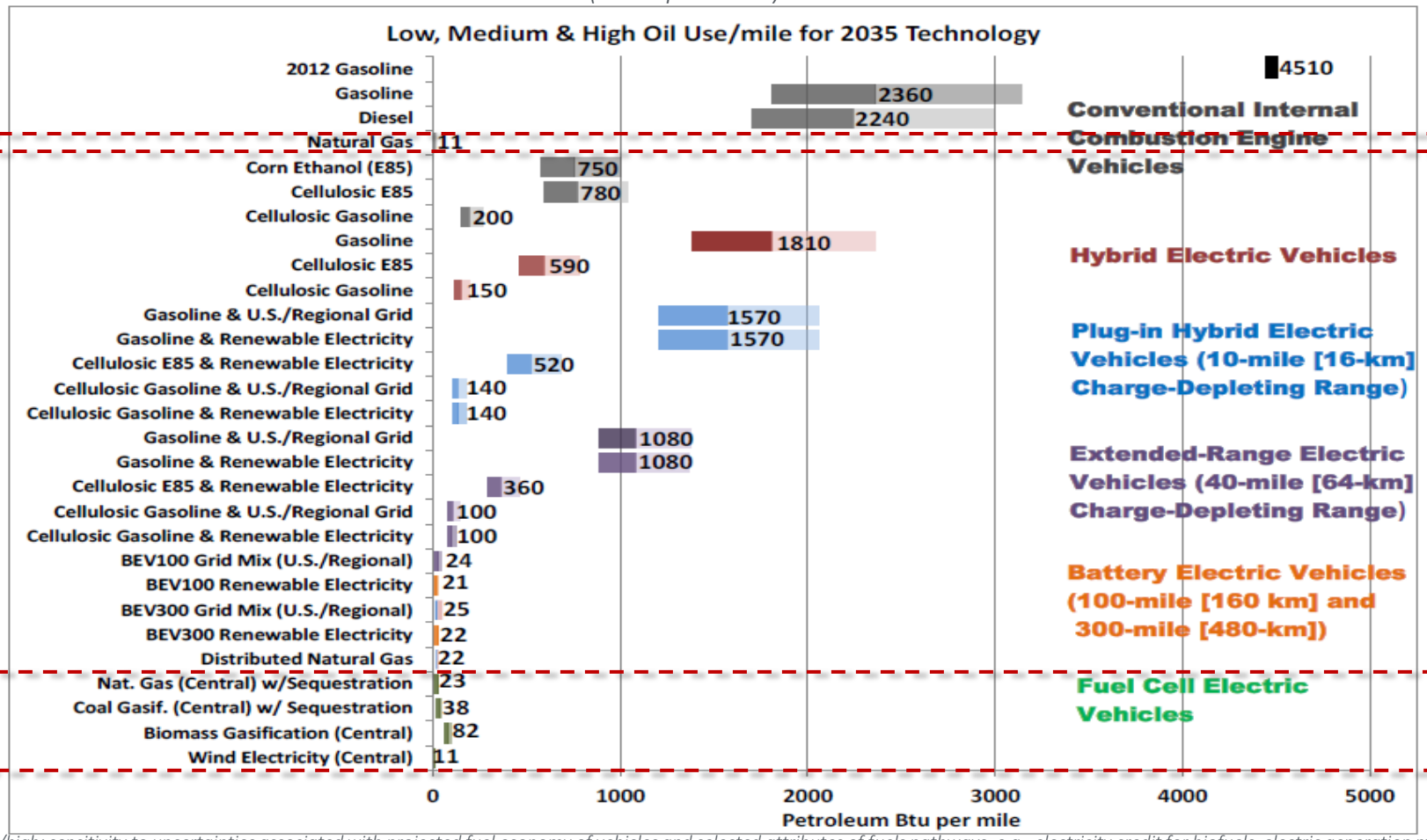
Analysis by ANL, NREL and EERE shows that FCVs fueled by Hydrogen from NG can reduce petroleum use by nearly 100%

Well-to-Wheels Petroleum Energy Use for 2035 Mid-Size Car

(BTUs per mile)



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Options for Early H_2 Infrastructure

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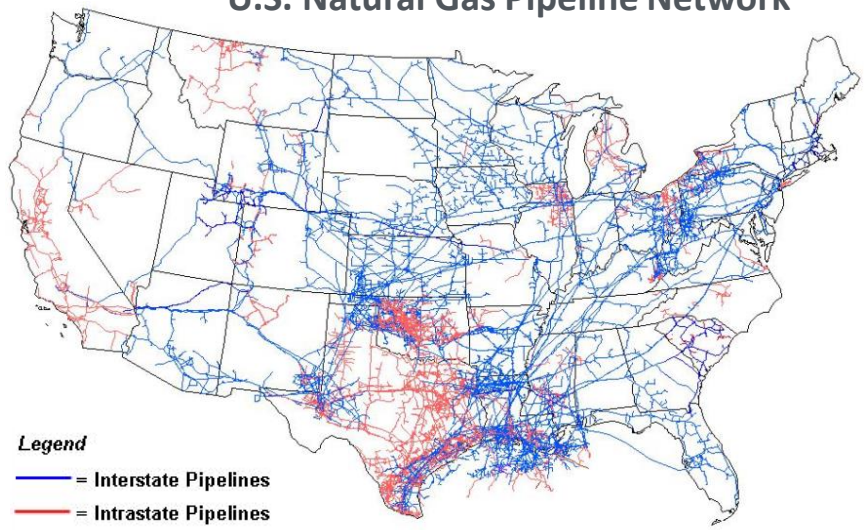
Option for rapidly expanding the H_2 delivery infrastructure is to adapt part of the already existing and robust NG infrastructure to accommodate H_2. Converting NG pipelines to carry a blend of NG and H2 require only modest modifications to pipeline

U.S. Natural Gas Pipeline Network



Current Status

U.S Natural Gas Pipeline Network has **>300,000** mi. of interstate and intrastate transmission lines

Existing **1,200** mi. of H_2 pipelines in use (CA, TX, LA, IL, and IN)

Over **9** MMT of H_2 produced annually

Over **50** fueling stations in the U.S.

Two Main Options for Low-cost Early Infrastructure

- **H_2 delivered from central site:**

Low-volume stations (~200-300 kg/day) would cost <$1M and provide hydrogen for $7/gge *(e.g., high-pressure tube trailers, with pathway to $5/gge at 400–500 kg/day)*

- **Distributed production (e.g. natural gas, electrolysis)**

Other options

- Tri-gen
- H_2 from waste (industrial, wastewater, landfills)

Existing H_2 Production Facilities

Applications for Natural Gas are Numerous

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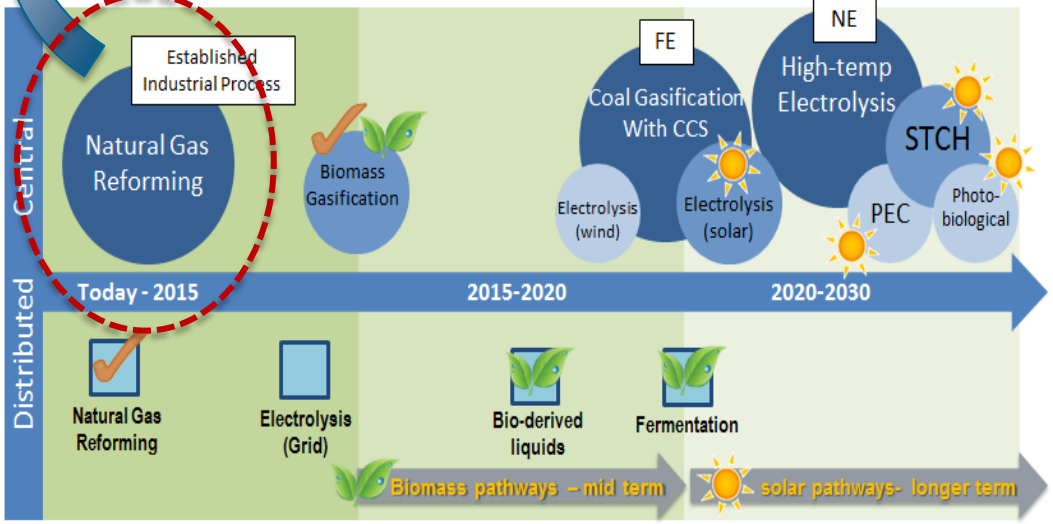
NG applications in the transportation sector include NG use in the heavy duty vehicle segment and H_2 production from NG reforming for FCVs. Other applications include NG use for distributed generation and for various cross-cutting areas such as Trigeneration.

Timeline of Hydrogen Production Options

An example of a NG application and the most immediate strategy for H_2 production

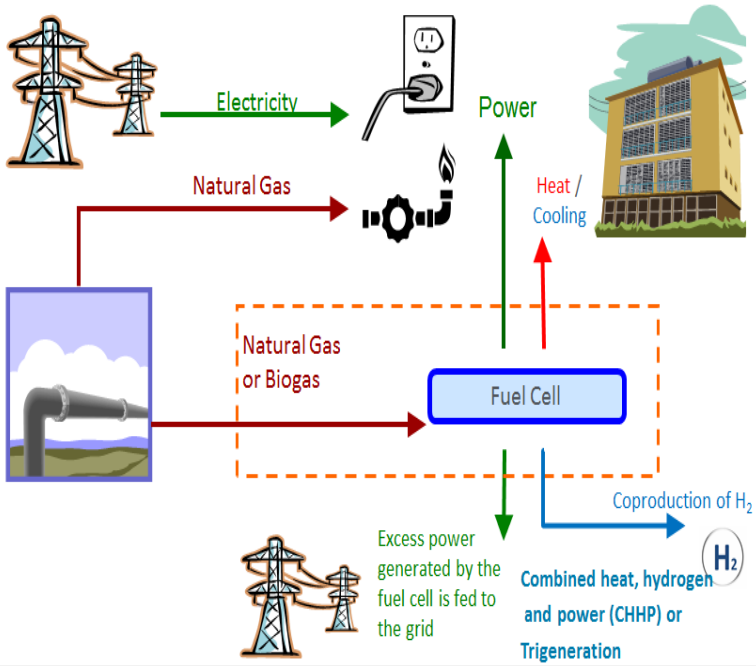


Estimated Plant Capacity (kg/day)

P&D Subprogram R&D efforts successfully concluded

FE, NE: R&D efforts in DOE Offices of Fossil and Nuclear Energy, respectively

The Trigeneration Approach



Trigen from NG co-produces **power**, **heat** and **H_2** and offers fueling/charging opportunities for

and

FCTO R&D Focus and Synergies with Natural Gas

FCTO R&D focus for selected program areas could also be applicable to NG thereby advancing the development of NG technologies and infrastructure

FCTO R&D Efforts	Potential Natural Gas Synergy?
Storage Lower cost precursors for carbon fiber Improved tanks and cold H_2 storage Hydrogen Sorbent Systems Chemical Hydrogen Storage Systems Low-pressure storage for MHE Novel resin manufacturing	✓
Technology Validation Validation of fueling station data (High-pressure Tube Trailer, Compressor Reliability Testing Cryo-compressor testing, etc.) H2FIRST 5 team projects (Station Performance Testing, Dispenser/Components, Reference Station Design, Hydrogen Station Research Team, Hydrogen Contamination Detector) Validation of world's first Tri-Generation station	✓
Safety Codes and Standards Impact of fast fueling (SAE standard J2601) on hydrogen station requirements Performance-based design and liquid release tasks to impact the deployment hydrogen fueling stations Widespread availability and communication of safety-related information	✓
Delivery **Tube trailer** innovations are being deployed in the near term **Liquefaction technologies** and station Compression and Storage improvements in the mid term **New Pipeline materials** and technologies and integration of CSD forecourt innovations in the long term	✓

H_2 and NG face common entry to market barriers

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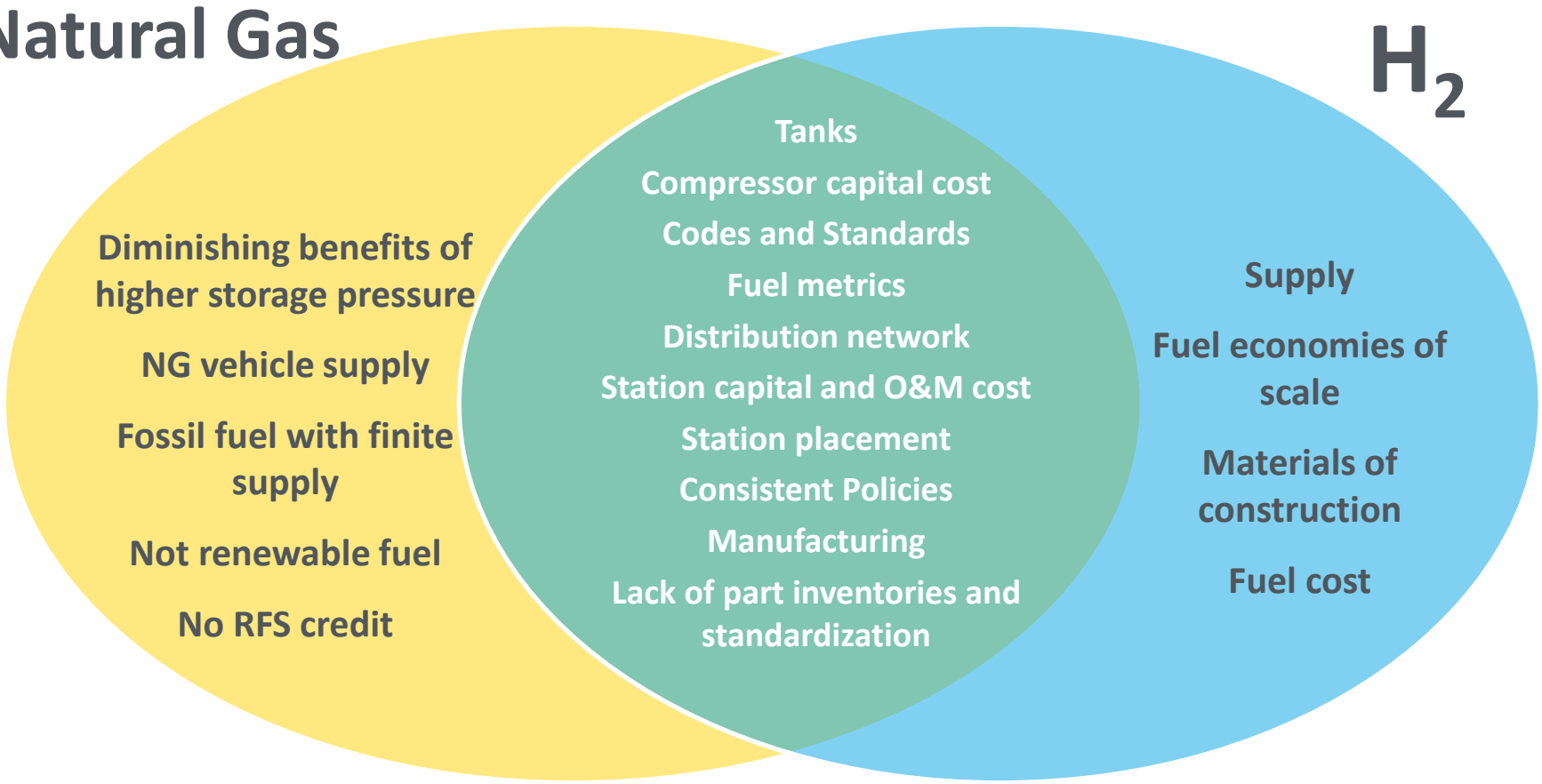
Analyzing in parallel both NG and H_2 can be an useful approach given the commonalities in entry to market barriers faced by both options.



In Conclusion

The complementary nature of H_2 and NG offers opportunities that need to be further explored by relevant stakeholders thereby accelerating the use of both fuels in the transportation sector

- ✓ H_2 and natural gas have synergies as gaseous energy sources
- ✓ H_2 and natural gas are complementary as H_2 can be produced from natural gas reforming
- ✓ Given the synergies and common entry to market barriers faced by H_2 and natural gas, there is potential for mapping out strategies/approaches that address common issues in parallel
- ✓ H_2 and NG Public-Private partnerships currently in place could potentially expand the scope of their efforts by including strategies that leverage the synergies of both fuels

Thank You

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