Hydrogen Delivery: An Option to Ease the Transition

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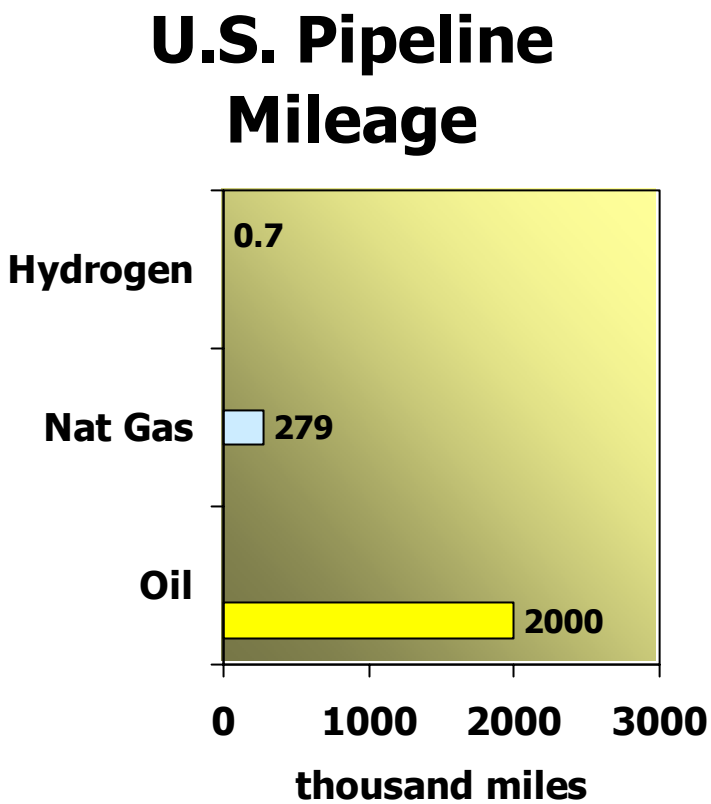
John C. Winslow, Product Manager, Coal Fuels & Hydrogen
National Energy Technology Laboratory

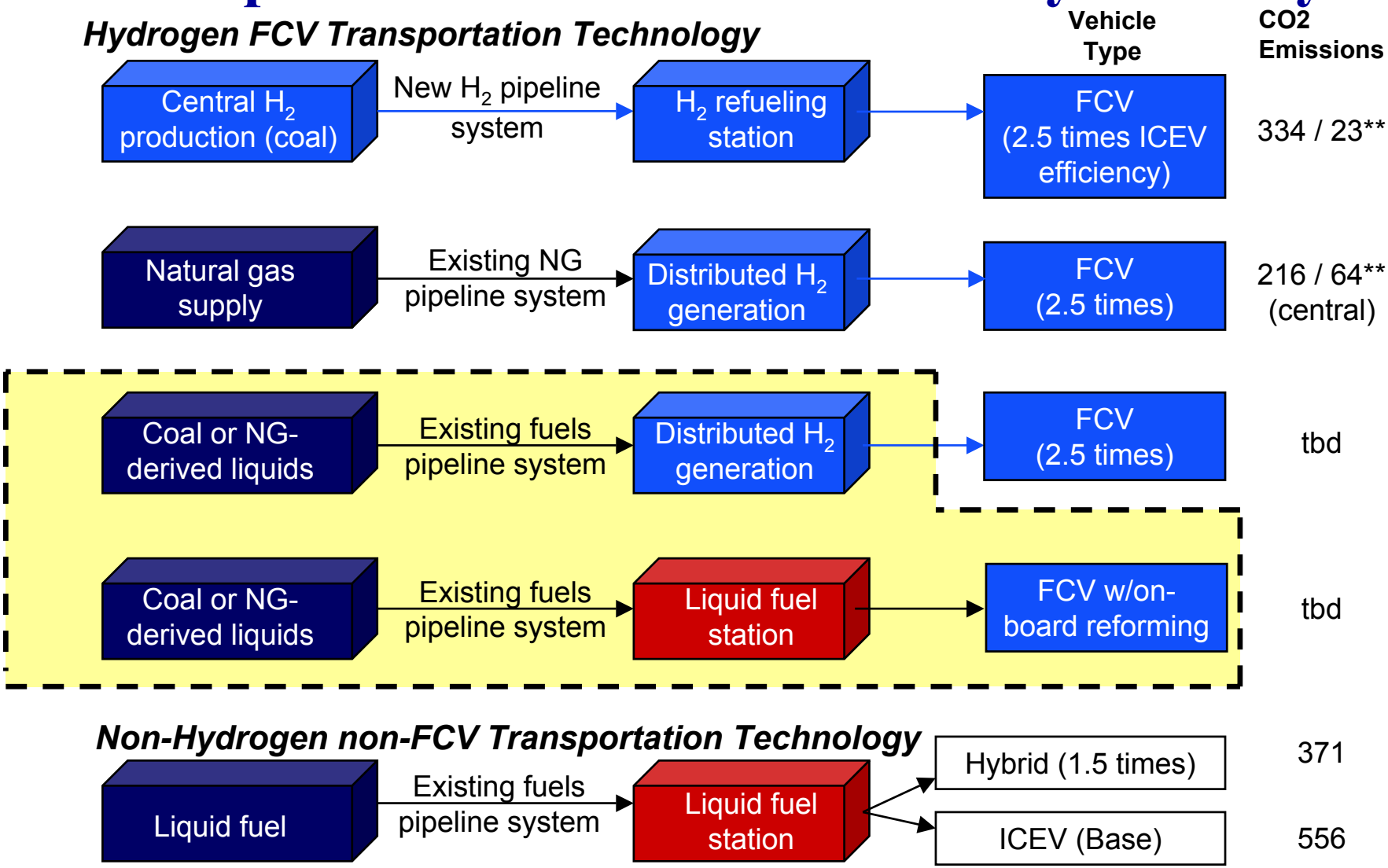
Hydrogen Delivery Today

- Hydrogen infrastructure exists only for small merchant hydrogen markets in the chemical and refining industries
- Current natural gas infrastructure consists of:
  - Pipelines
  - intermediate product storage
  - import terminals
  - rail, barge, and truck delivery



Source: APCI, EIA, NEP

Comparison of Alternative Delivery Pathways



***CO2 emissions in millions of tons per year for each 100 million vehicles**

**** Values are for without and with CO2 sequestration.**

Barriers to Hydrogen Delivery

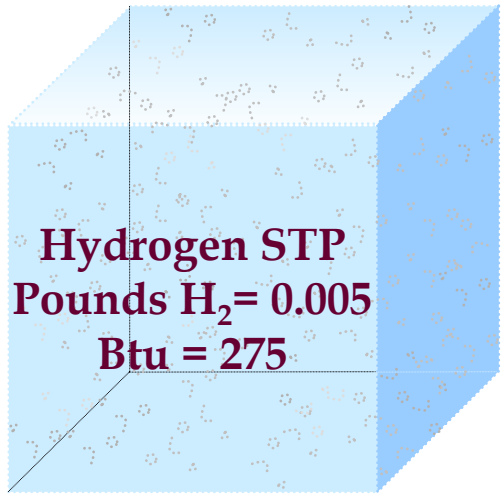
- Hydrogen infrastructure exists only for small merchant hydrogen markets in the chemical and refining industries
- Potential for delivering hydrogen through natural gas infrastructure is likely to be limited: materials; need for separation; safety
- Hydrogen has very low energy density by volume

Hydrogen Storage

Gasoline
#H_2= 7.3, Btu = 853,000

Diesel
#H_2= 8.3, Btu = 949,000

Methanol
#H_2= 6.2, Btu = 430,000



Compressed H_2 (6000 psi)
#H_2= 2, Btu = 110,000

Liquid H_2
#H_2= 4.4, Btu = 229,000

Metal Hydrides
#H_2= 3.0, Btu = 160,000

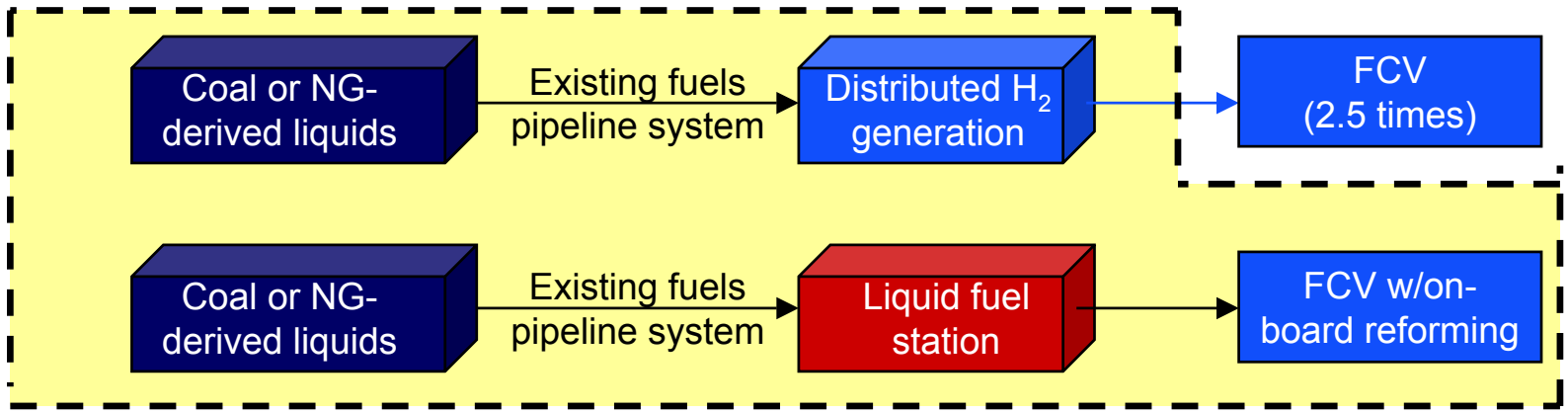
1 Cubic Foot Volume

Air Products & Chemicals, Inc. and Eastman Chemical Liquid Phase Methanol Demonstration, Kingsport, TN

Hydrogen Delivery Via Liquid Hydrocarbons

- **We need to:**
  - Evaluate the potential for coal- (and natural gas-) derived liquids to serve as an interim strategy for delivering hydrogen….and concurrently,
  - Determine the optimum hydrocarbon(s) for delivery and subsequent reforming

FE Hydrogen Liquid Carrier Systems – Analysis Boundaries



Distributed Hydrogen Production Technology: Hydrocarbon Feedstock Alternatives

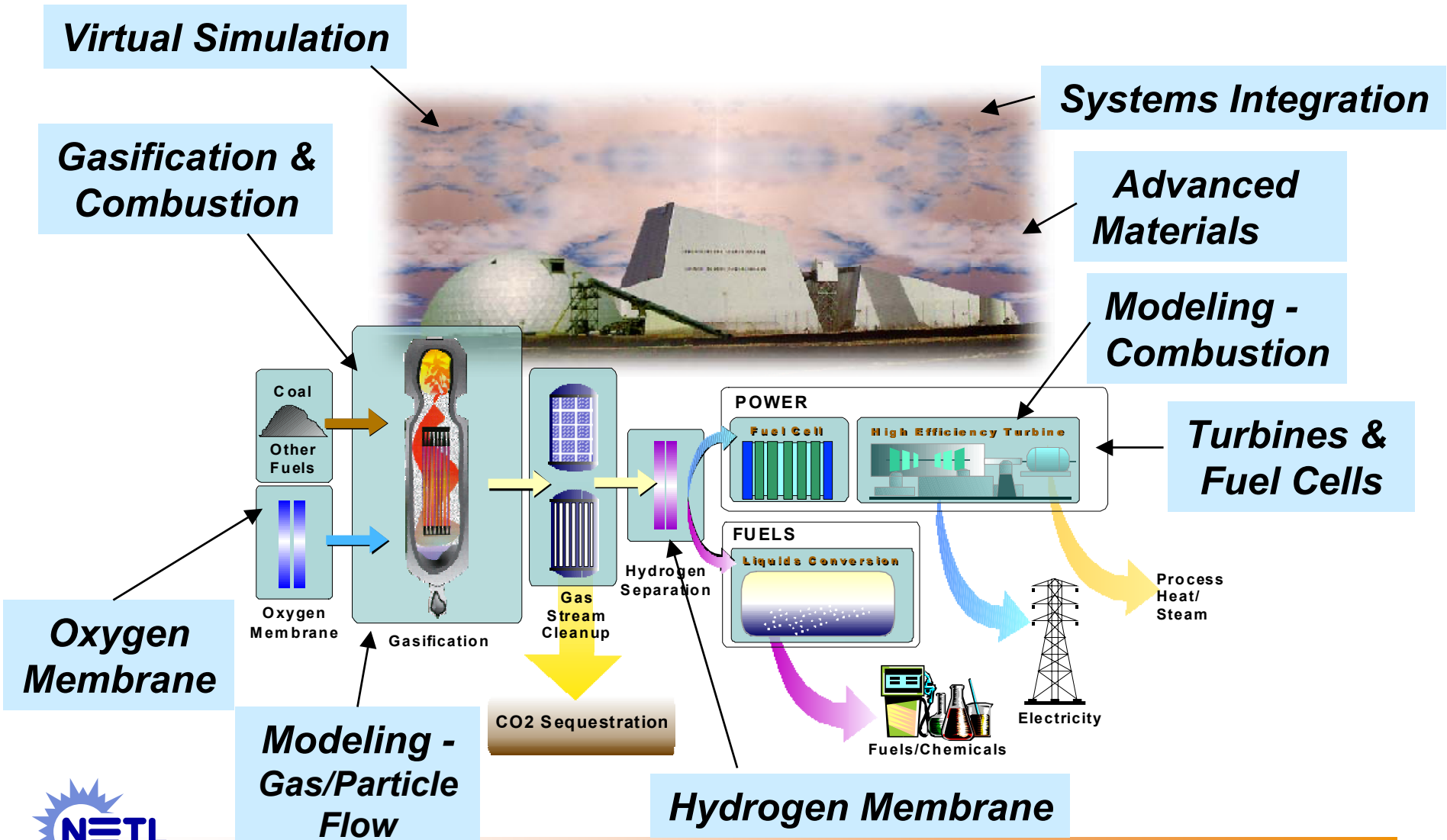
- Service station-sized* hydrogen production facilities based on reforming natural gas or liquid hydrocarbons Service station-sized electrolysis facilities
- On-board reforming of hydrogen-rich, synthesis gas-derived liquid fuel

Benefit: Early introduction of fuel cell technology

Georgetown Univ. 100kw PEM fuel cell-powered bus with H_2 from methanol

•Service station-sized hydrogen production facility is 800 kg per day (360,000 scfd), which is equivalent to the average U.S. gasoline station sales, when adjusted for FCV efficiency at 2.5 times ICEV efficiency.

The Future For Coal: Ultra-Clean Energy Plant



Coal to Hydrogen