Oil and Gas Economy-wide Production, Transport and Storage of Hydrogen

Office of Fossil Energy (FE)
Office of Oil and Natural Gas

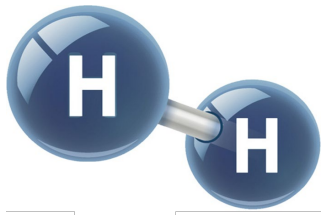
Shawn Bennett
Tim Reinhardt
Evan Frye

July 23, 2020

U.S. DEPARTMENT OF ENERGY

Office of Fossil Energy

Office of Oil and Natural Gas (ONG)



Office of Deputy Assistant Secretary for Oil and Natural Gas
Shawn Bennett

- **Office of Regulation and International Engagement**
- **Office of Research**
  David Alleman
  - **Division of Upstream Research**
    - Onshore
    - Offshore
    - Produced Water
  - **Division of Supply and Delivery**
    Tim Reinhardt
    - Midstream Infrastructure
    - Gas Hydrates
    - Crude Oil Properties

Natural Gas Infrastructure Research

- **Fossil Energy's Midstream Infrastructure Program enhances the safety and efficiency of natural gas production, transmission, and storage infrastructure.**
  - Improve the resiliency and reliability of midstream infrastructure.
  - Support industry efforts to improve transmission and distribution efficiency across the natural gas supply chain.
  - Develop advanced conversion and utilization technologies that will significantly reduce vented or flared natural gas, including R&D on hydrogen production and transportation technologies.

Materials

- Novel coatings
- Sleeves/liners

Transmission and Distribution

- Compressors
- Gathering/Boosting Systems
- Data Science And Management

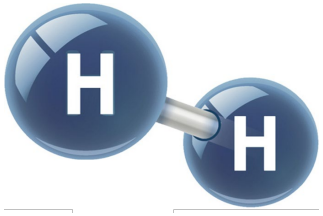
Emissions Mitigation/Quantification

- In-line repair tools
- Emissions monitoring and sensor platforms

Natural Gas Conversion

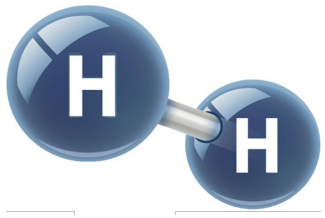
- Single step catalysts
- Process intensification
- Modular solutions

Hydrogen Overview



- Hydrogen is emerging as a low-carbon fuel option for transportation, electricity generation, and manufacturing applications because it could decarbonize these three large sectors of the economy.
- Hydrogen can be produced without a carbon footprint from a variety of sources, including natural gas, coal, biomass, waste materials (i.e., plastics), or splitting water molecules.
- Hydrogen is currently used in several industries, including petroleum refining; ammonia production and fertilizers; metals production; methanol production; food processing; and electronics.
- Applications include energy storage, domestic and industrial heating, fuel cells for transportation, and power generation sectors.
- Technologies already available today enable hydrogen to produce, store, move, and use energy in different ways.

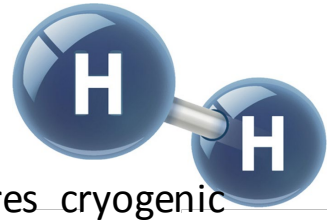
Hydrogen Distribution



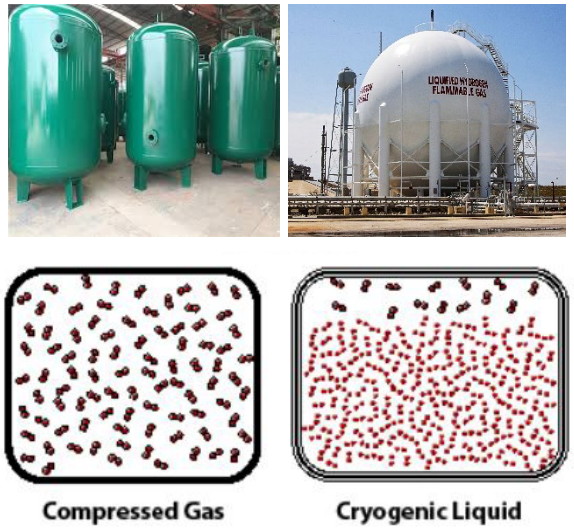
- Hydrogen is currently distributed through three methods:
  - **Pipelines:** While the least-expensive way to transport large volumes of hydrogen, there are only about 1,600 miles of U.S. pipelines dedicated for hydrogen delivery.
  - **High-Pressure Tube Trailers:** Transporting compressed hydrogen gas by truck, railcar, ship, or barge in high-pressure tube trailers is expensive and used primarily for distances of <200 miles.
  - **Liquefied Hydrogen Tankers:** Cryogenic liquefaction is an expensive process that enables hydrogen to be transported more efficiently over longer distances by truck, railcar, ship, or barge.

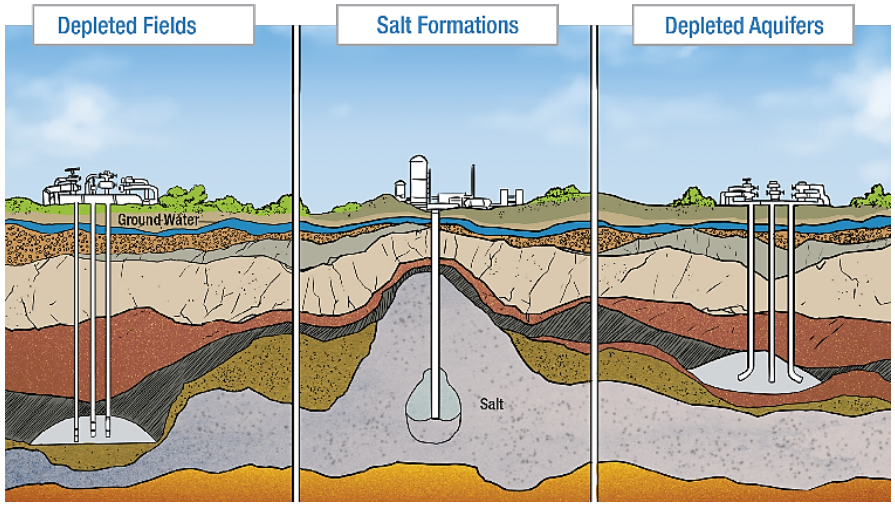
- Existing domestic natural gas pipeline infrastructure (~3 million miles) has the potential to expand the transportation of hydrogen.
  - Blending hydrogen into natural gas pipeline networks is a potential option for delivering pure hydrogen to markets – pipelines can handle up to 30% hydrogen blends without significant modifications or detrimental effects.

Hydrogen Storage

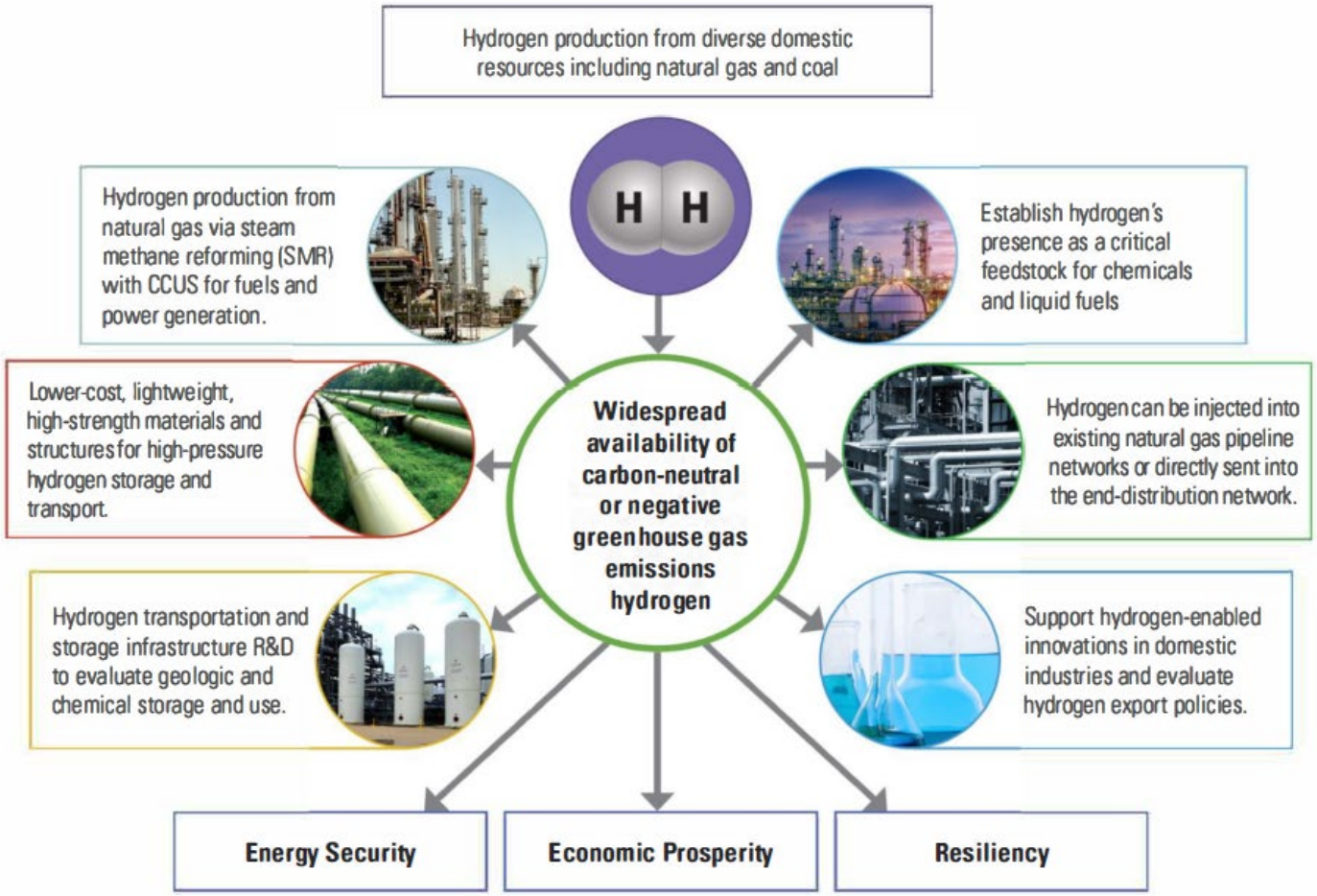


- Storage as a gas typically requires high-pressure tanks and as a liquid requires cryogenic temperatures (-423°F) – physical storage.
- Underground geologic storage of low-pressure gaseous hydrogen is also possible, e.g., in salt caverns, depleted oil and gas reservoirs, aquifers, and hard rock caverns.
- Hydrogen infrastructure could require geologic bulk storage to handle variations in demand throughout the year – geologic cavern storage of hydrogen for industrial use already exists at two locations in Texas.
- Hydrogen can also be stored on the surfaces of solids (by adsorption) or within solids (by absorption) – chemical storage.

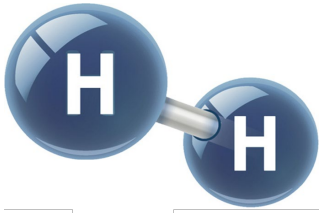




Relationship of FE-ONG Program Elements to Comprehensive Hydrogen Strategy



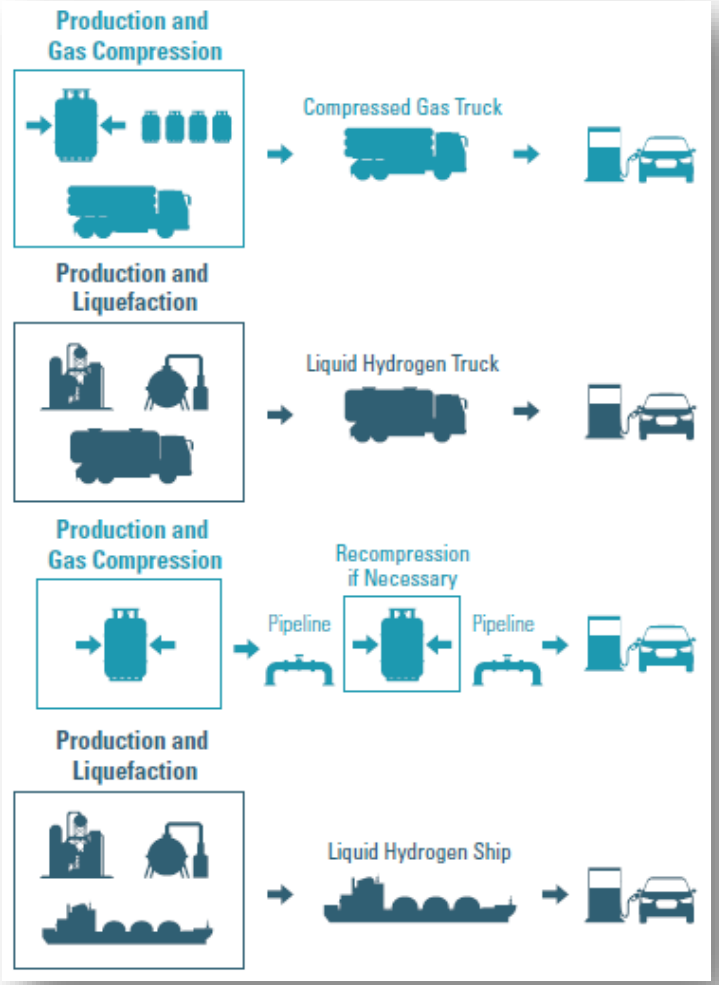
Hydrogen and Natural Gas Infrastructure



- Natural gas networks are well developed in the U.S. and represent infrastructure that could be adopted for conveyance of hydrogen.
- Blending hydrogen into natural gas pipeline networks may be an option for delivering pure hydrogen to markets.
- While converting natural gas infrastructure to hydrogen infrastructure is a long-term proposition, transition strategies call for the introduction of hydrogen into the natural gas infrastructure.
- Hydrogen has high energy density per unit mass, it has low-volumetric energy density at room conditions and an ability to permeate metal-based materials, which can present operational and safety constraints.
- Construction of new pipelines—either natural gas pipelines that will be used for a blended gas or hydrogen dedicated lines—will require consideration of the challenges that hydrogen poses during transportation by pipeline.

Hydrogen and Natural Gas Infrastructure

- Natural gas infrastructure are well positioned in the U.S. to connect sources of production and consumption.
- Blending hydrogen into multimodal capable natural gas pipeline infrastructure may be an option for storing or delivering pure hydrogen to markets and end-users.
- It is necessary to assess multiple factors to safely integrate hydrogen blending into the existing natural gas pipeline systems (e.g., gaseous hydrogen embrittlement).
- Notionally, pipelines can handle from 15%–30% hydrogen blends without modifications or significant detrimental effects.
- While hydrogen compression can be utilized for transport and storage, this compression comes with energy penalties up to 20% of the energy content required for compression.

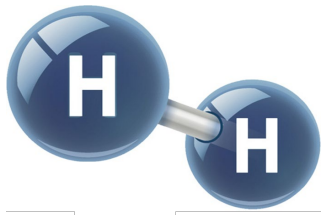


FE Hydrogen R&D Focus

- FE is focused on technological advancements to enable an expanding domestic hydrogen economy.
- FE has the potential to leverage ongoing work and current infrastructure to improve the economics of hydrogen production from natural gas SMR with Carbon Capture, Utilization, and Storage (CCUS).
- FE's depth of experience, previous R&D conducted over the past 30 years, and future efforts can be summarized in four major R&D focus areas:
  1. Carbon-neutral Hydrogen Production using Gasification and Reforming Technologies
  2. Large Scale Hydrogen Transport Infrastructure
  3. Large Scale Onsite and Geological Hydrogen Storage
  4. End Use in Electricity and Other Industrial Sectors

Air Products and Chemicals, Inc. (APCI) Port Arthur, TX Industrial Carbon Capture and Storage (ICCS) project is demonstrating CO_2 capture and storage of steam methane reforming process gas used for large-scale hydrogen production

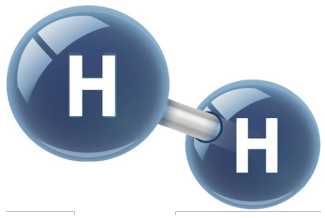
ONG Hydrogen R&D



The proximity and use of hydrogen for industrial processes related to oil and natural gas provides an opportunity for ONG to leverage existing R&D toward enabling the future hydrogen economy, its markets, supply infrastructure, transportation, storage, and use for industrial purposes and power generation.

- ONG is in an ideal position to conduct R&D initiatives that would lead to more efficient and cost-effective technologies for transporting hydrogen between generation facilities and end-use locations.
- ONG can support a larger effort focused on increasing opportunities for the commercialization of hydrogen as a low carbon energy source.
- ONG R&D is underway to develop infrastructure and improve other transportation means to ensure low-cost and low-carbon hydrogen to meet growing demands.
- ONG and its partners have an existing and expanding transportation and storage infrastructure R&D portfolio relevant to a comprehensive hydrogen economy strategy.

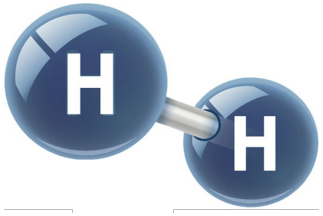
ONG Hydrogen R&D



Specific R&D activities pursued by ONG include the following:

- **Assessing pipeline performance for fatigue and fracture resistance of metallic materials** in natural gas networks as related to the embrittlement issue and ensuring their compliance with appropriate standards and codes.
- **Developing new components, configurations, and sensor technologies** combined with artificial intelligence for real-time operational monitoring and early fault detection for the safe transport of hydrogen in commerce.
- **Developing design requirements and typical operating conditions in natural gas supply infrastructure**, as well as identifying and prioritizing materials performance gaps to avoid leakage within pipeline elements.
- **Conducting hydrogen transportation and storage infrastructure assessments** and R&D (e.g., materials, geology), conducting resource assessments, and establishing field laboratories for hydrogen storage.
- **Evaluating and regulating hydrogen export policies** and procedures.

ONG's Hydrogen Related Ongoing Work

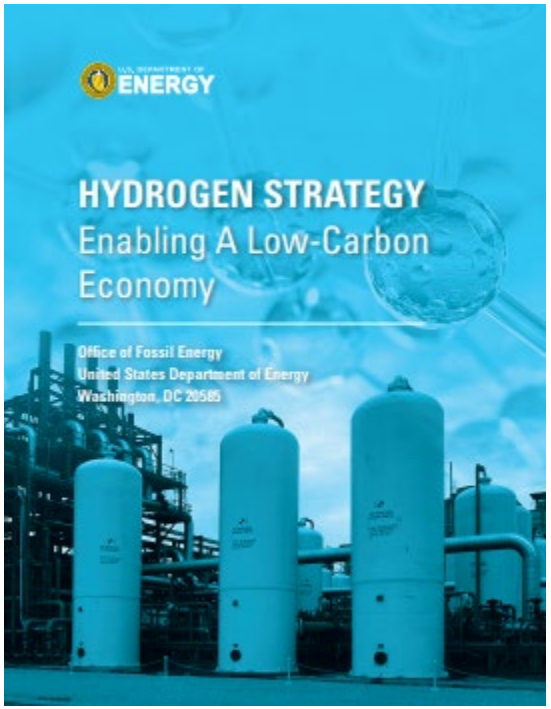


Through a selection made under the Funding Opportunity Announcement (FOA 2006), FE is currently expanding its research program focused on mitigating emissions from midstream natural gas infrastructure.

- **Advanced Natural Gas Infrastructure Technology Development Process-intensified Technologies for the Upcycling of Flare Gas into Transportable, Value-added Products**
  - The goal of AOI 2 is to develop materials, equipment or processes to enable flared, vented, or otherwise rejected gas to be monetized through conversion to transported, value-added products.
    - AOI 2A: Multi-Functional Catalysts
    - AOI 2B: Modular Equipment and Process Intensification Design Concepts for Conversion of Flare Gas to High-Value Carbon Products

Office of Fossil Energy

Office of Oil and Natural Gas



Shawn Bennett

Deputy Assistant Secretary for Oil and Natural Gas

Tim Reinhardt

Director for the Division of Supply and Delivery

Evan Frye

Physical Scientist

Office of Fossil Energy (FE)
U.S. Department of Energy
Forrestal Building
1000 Independence Avenue, SW
Washington, DC 20585

FECommunications@Hq.Doe.Gov

www.energy.gov/fe/science-innovation/oil-gas-research