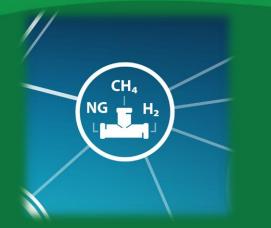


Fossil Energy and Carbon Management

Fossil Energy and Carbon Management: Clean Hydrogen Perspectives

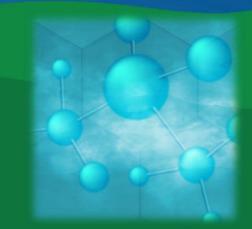
Tim Reinhardt Director, Division of Methane Mitigation Technologies Office of Resource Sustainability



February 10, 2022







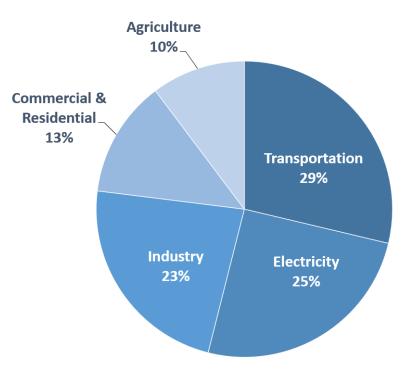
Fossil Energy and Carbon Management (FECM)

Office of Fossil Energy and Carbon Management DOE-FE is now DOE-FECM

New name for our office reflects our **<u>new vision</u>** to achieve decarbonization and carbon management

- Administration Goals:
 - \circ 50% emissions reduction by 2030
 - \circ CO₂ emissions-free power sector by 2035
 - Net zero emissions economy by no later than 2050





U.S. Environmental Protection Agency (2021). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019



Fossil Energy and Carbon Management

FECM Mission: Deep Decarbonization and Environmental Justice

Minimize environmental impacts of fossil fuels; achieve net-zero emissions.

Priority Technology Areas

- 1. Point source carbon capture
- 2. Carbon dioxide (CO₂) removal
- 3. CO₂ conversion into products
- 4. Reliable CO₂ storage
- 5. Hydrogen production (non-electrolytic)
- 6. Critical mineral production from industrial and mining waste
- 7. Methane mitigation

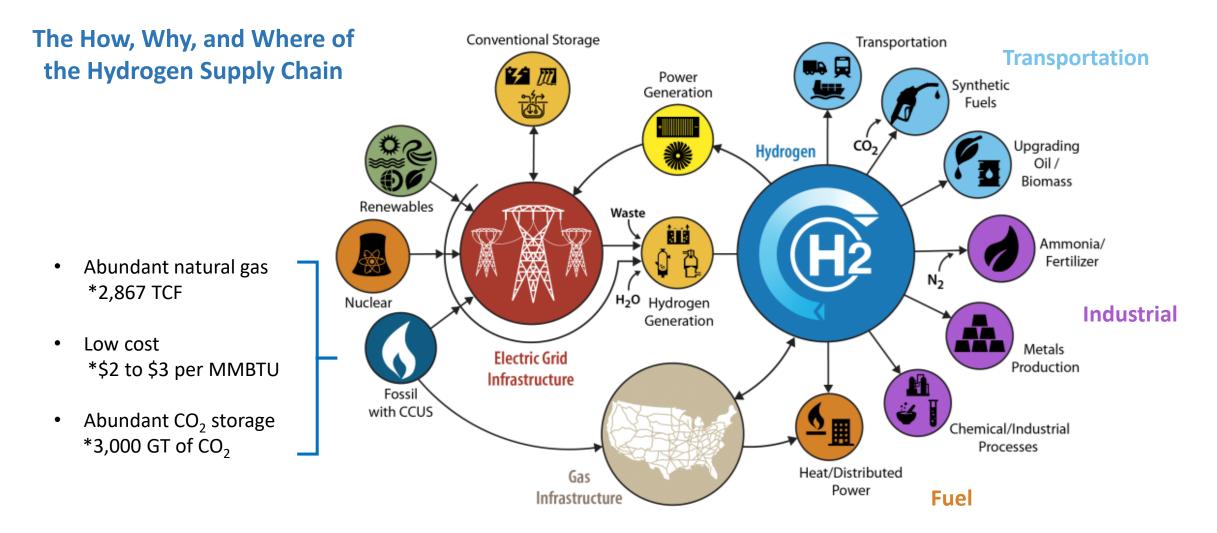
Office of Carbon Management (FECM-20)

Office of Resource Sustainability (FECM-30) Supporting Legacy Communities (Justice)

- Good-paying jobs
- Job growth acceleration
- Healthy economic transitions
- Improve community conditions

Address hardest-to-decarbonize applications in the electricity and industrial sectors

Hydrogen Supply Chain





Fossil Energy and Carbon Management

Driving Towards Net-Zero Together

EERE Hydrogen

Feedstocks:

Renewables and Water

Technologies:

- Electrolysis—Low- and High-Temperature
- Advanced Water Splitting—Solar/High-Temp Thermochemical, Photoelectrochemical
- Biological Approaches

FECM Hydrogen

Feedstocks:

Fossil Fuels—Coal and Natural Gas

Technologies:

- Gasification, Reforming, Pyrolysis
- Advanced Approaches—Co-firing and Modular Systems
- Natural Gas to Solid Carbon plus Hydrogen

Areas of Collaboration

Reversible Fuel Cells, Biomass, Municipal Solid Waste, Plastics

Polygeneration including Co-Gasification with Biomass

High-Temperature Electrolysis, System Integration

Feedstocks:

Nuclear Fuels and Water

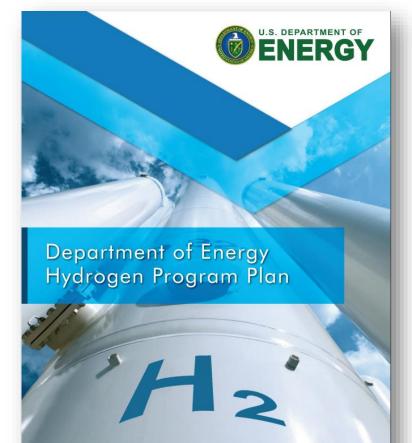
Technologies:

- Electrolysis Systems for Nuclear
- Advanced Nuclear Reactors
- System Integration and Controls LWRs and Advanced Reactors

NE Hydrogen

Crosscutting R&D Offices: Office of Science (SC) and ARPA-E

Fundamental Science and Advanced Innovative Concepts



https://www.hydrogen.energy.gov/pdfs/ hydrogen-program-plan-2020.pdf



Fossil Energy and Carbon Management

Why Hydrogen?

- Versatile fuel that offers a path to sustainable long-term economic growth (potential to meet 14% of U.S. total energy demand by 2050).
- Serves as a sustainable fuel for transportation, production of electricity, and heat for homes.
- Enable zero or near-zero emissions in transportation, stationary or remote power, and portable power applications.
- Integrated approach from all energy sectors (fossil, nuclear, and renewable energy systems) to realize the full potential and benefits of hydrogen
- **NEED**: Provide clean hydrogen at competitive cost to decarbonize power, transportation and industry.

Department of Energy Hydrogen Program Plan 2020

Vision

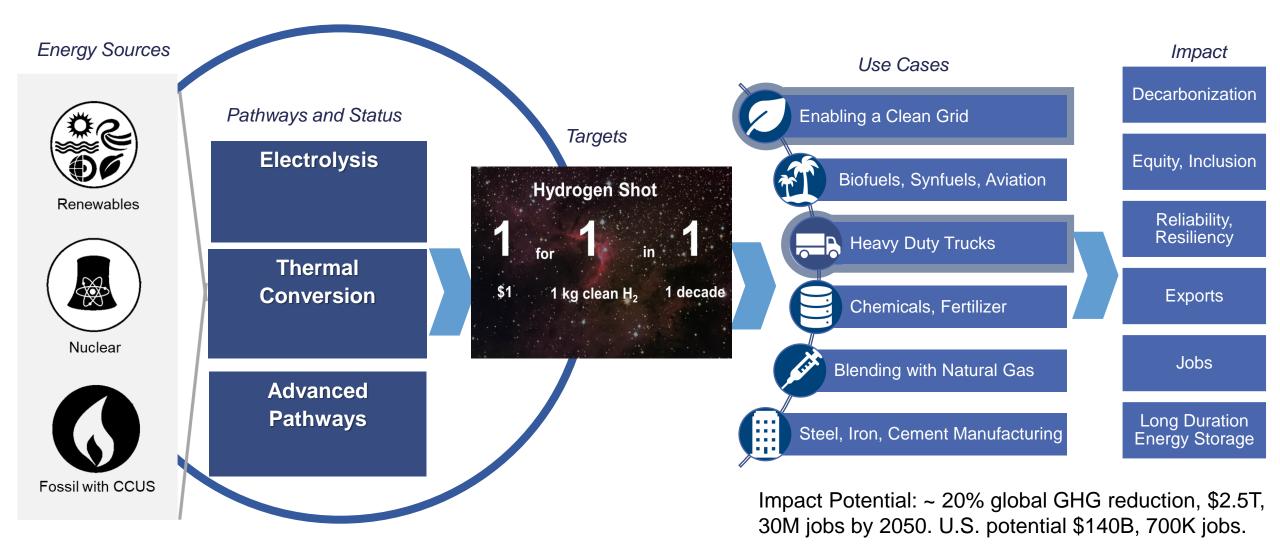
The Program's vision is a prosperous future for the nation, in which clean hydrogen energy technologies are affordable, widely available and reliable, and are an integral part of multiple sectors of the economy across the country.

	NEAR-TER	t L	LONGER-TERM	
Production	Gasification of coal, biomass, and waste with carbon capture, utilization, and storage Advanced fossil and biomass reforming/conversion Advanced biological/microbial conversion Electrolysis (low-temperature, high-temperature) Advanced thermo/photoelectro-chemical H_O splitting			
Delivery	Distribution from on-site production Tube trailers (gaseous H ₂) Widespread pipeline transmission and distribut Cryogenic trucks (liquid H ₂) Chemical H ₂ carriers		eline transmission and distribution	
Storage	Pressurized tanks (gaseous H ₂) Cryogenic vessels (liquid H ₂)	Geologic H ₂ storage (e.g., caverns, depleted oil/gas reservoirs) Cryo-compressed Chemical H ₂ carriers Materials-based H ₂ storage		
Conversion	Turbine combustion Fuel cells	Advanced combustion Next generation fuel cells	Fuel cell/combustion hybrids Reversible fuel cells	
Applications	Fuel refining Space applications Portable power	Blending in natural gas pipelines Distributed stationary power Transportation Distributed CHP Industrial and chemical processes Defense, security, and logistics applications	Utility systems Integrated energy systems	

Figure 2. Key hydrogen technology options

Source: https://www.hydrogen.energy.gov/pdfs/hydrogen-program-plan-2020.pdf

Hydrogen Production Pathways and Targets for Impact





Fossil Energy and Carbon Management

www.energy.gov/fecm

FECM's Clean Hydrogen Strategy



- technoanalysis on all fossilbased hydrogen production pathways Regional analyses
- Hydrogen safety studies

Mid-Term

- Implement recommendations of regional analyses Subsurface
- storage R&D · Large demos/
- hydrogen hubs

Long-Term

 Deployment of advanced hydrogen production methods Special projects for U.S. hydrogen

economy



Fossil Energy and **Carbon Management**

Program Mission and Challenges

- Enable decarbonization of natural gas conversion, transportation, and storage
- Produce carbon-neutral hydrogen from natural gas
 - Produce higher value liquids and gases
- Enhance natural gas infrastructure for hydrogen transportation
 - Characterization with sensors, coatings, and component development
- Determine viability, safety, and reliability of subsurface storage

	Near-Term	Long-Term
Conversion	NG Upcycling	Widespread transformational natural gas reforming / conversion
Transportation	Distribution from on-site produc Geographic Assessment	Mieles a singling the provision and distribution
Storage	H2 Recoverability	Geologic H2 storage (e.g., caverns, depleted oil/gas reservoirs)Chemical H2 barriersMaterials-based H2 storage



Natural Gas Decarbonization & Hydrogen Technologies Research Program

Hydrogen Production from Natural Gas

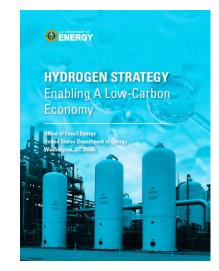
- Natural gas is the **"bridge fuel**" to enable a hydrogen economy and transformational methods will maintain its relevance as a feedstock even as green hydrogen become cost-competitive.
- Improved methods of **decarbonization** drive disruption of existing hydrogen production.
- Widespread industrial adoption means even incremental **hydrogen production efficiency** improvements can have a large impact in the near term.

Hydrogen Transportation in Existing Infrastructure

- Near-term improvements in materials to reduce fatigue and embrittlement will enable an improvement in transport capacity from legacy systems.
- Enhanced safety measures (leak detection and mitigation) along with "real-time" in-pipe sensing (blend composition and component integrity) are vital to ensuring resiliency of the transport system.

Hydrogen Storage within the Subsurface

- Existing storage mechanisms at refineries or **end-use locations** are commercial technologies, but safety considerations remain key, particularly at **larger volumes**.
- Subsurface storage can utilize depleted oil and natural gas reservoirs, as well as salt domes, but long-term storage permanence must be effectively demonstrated through **rigorous characterization**.





Production & Utilization

Decarbonization

of Methane &

Utilization of

Infrastructure

Underground

Storage

Design modular technologies to upcycle flare gas into transportable, value-added products

Ensure suitability of existing natural gas pipelines and infrastructure for hydrogen transport

OAK RIDGE

Pipeline Transportation Transformational concepts for decarbonized, clean hydrogen from domestic natural gas resources

> Identify underground storage infrastructure to handle highvolume fractions of hydrogen

> > Lawrence Livermore National Laboratory Pacific Northwest

Transformative Natural Gas to Hydrogen Production

Natural Gas Feedstock

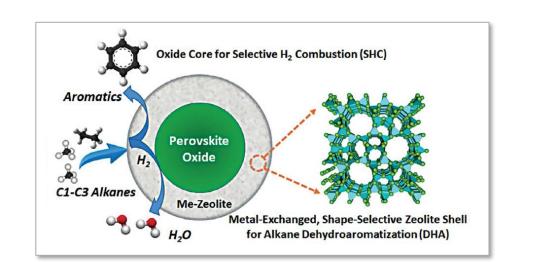
Transformational Hydrogen <u>Production</u>

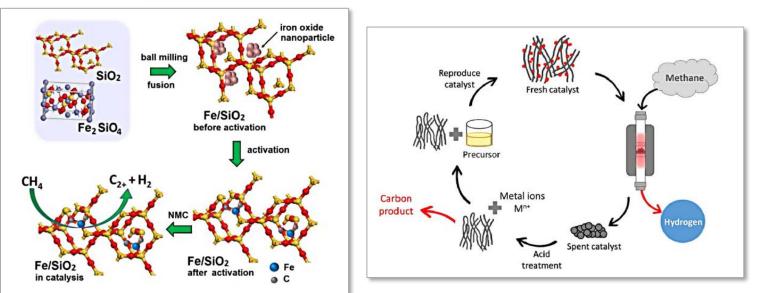
- Cyclical Chemical Looping Reforming
- Electrochemical Conversion
- Microwave Assisted Conversion
- NEQ Plasma Reforming
- Mechanochemical Conversion
- Thermochemical/Biological In Reservoir Conversion
- Non oxidative Coupling of Methane
- Methane Pyrolysis

DEPARTMENT OF



Carbon Management





Fossil Energy and

Natural Gas Pipeline Infrastructure and Hydrogen

Goals:

- Validate the utilization potential of existing natural gas infrastructure as a potential means to expedite increased transport of hydrogen, ammonia, and carbon dioxide.
 - Efficient and flexible transport requires pipelines capable of handling both single components and blended mixtures, as well as intermittent and alternating gas chemistries.
- Determine material compatibility of natural gas pipeline materials with hydrogen, carbon dioxide, and ammonia for current pipeline routes to guide decisions on introducing non-traditional gases in these pipes.
- Address design challenges of hydrogen transport and compression, including:
 - Materials and coatings
 - Light gas compression
 - o Sealing
 - o Safety
 - Control of hydrogen content variability
- Investigate regional uncertainties regarding pipeline materials, methods of construction, their location of use, and other relevant characteristics.
 - o Identify, preclude, or limit the introduction of hydrogen and other gases into established natural gas pipelines.

Greater predictability and management of pure hydrogen vs. hyblends

- Hydrogen is ~9 times lighter than natural gas
- Different viscosity
- Higher speed of sound
- Carries less energy per unit volume
- Carries more energy per unit mass
- Higher heat capacity
- Higher flame temperature
- Wider flammability range
- Lower autoignition temperature
- Lower ignition energy

Hydrogen Storage R&D Needs

Either at production or end-use locations

Goals

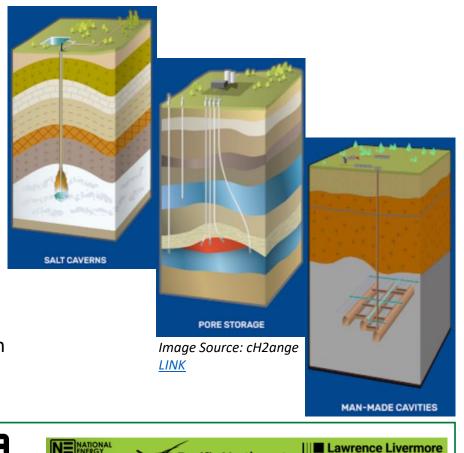
Identify and address key technological hurdles and develop tools and technologies to enable broad public acceptance for **subsurface storage** of hydrogen blended with natural gas and pure hydrogen.

Current Status

 Subsurface hydrogen storage is limited to smaller scale salt dome facilities. Expanding the footprint for subsurface storage is crucial to enabling widespread hydrogen utilization.

Objectives

- Subsurface geologic characterization efforts to demonstrate storage permanence and adequate demonstration of minimal risk to sensitive receptors, including drinking water resources.
 - Determine geophysical and geochemical interactions between pure hydrogen and blended gas storage and effects on structural integrity and microbial communities.
- Salt dome or depleted oil and natural gas reservoir characterization and validation with respect to potential leakage and long-term effects on reservoir rock, casing and cement.
 - Determine viability, safety, and reliability of pure hydrogen or blended gas storage by conducting field demonstrations.
 - Depleted oil and natural gas reservoirs
 - Saline reservoirs
 - Mined storage caverns in impermeable igneous and metamorphic rocks



Pacific Northwest



Fossil Energy and Carbon Management

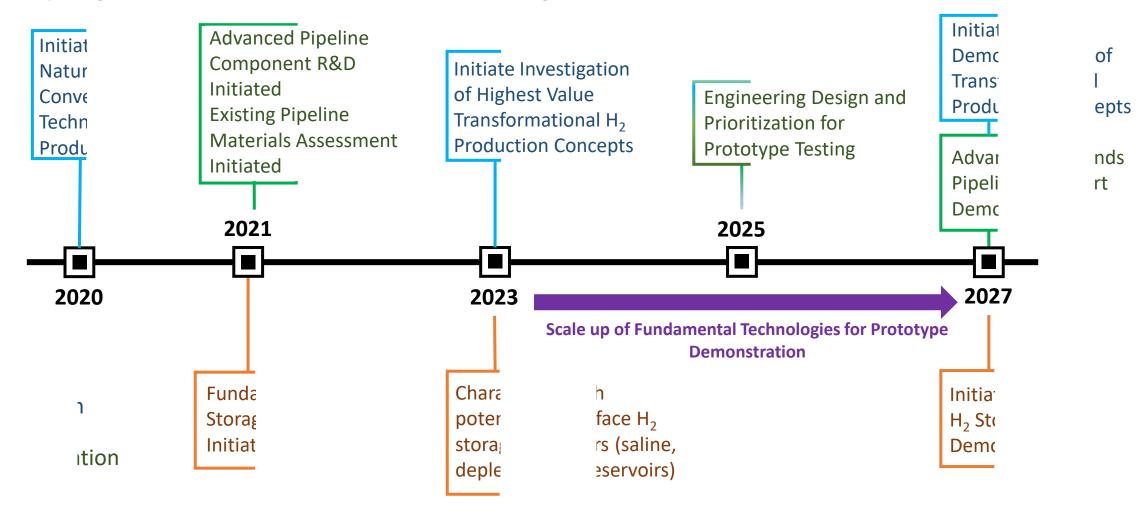
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and Technology Acceleration

National Laboratory

Conversion, Transportation, and Storage Timeline

Hydrogen Production, Transportation, and Storage





Questions?

Timothy Reinhardt Office of Fossil Energy and Carbon Management



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