U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

Fossil Energy and Carbon Management Hydrogen Program

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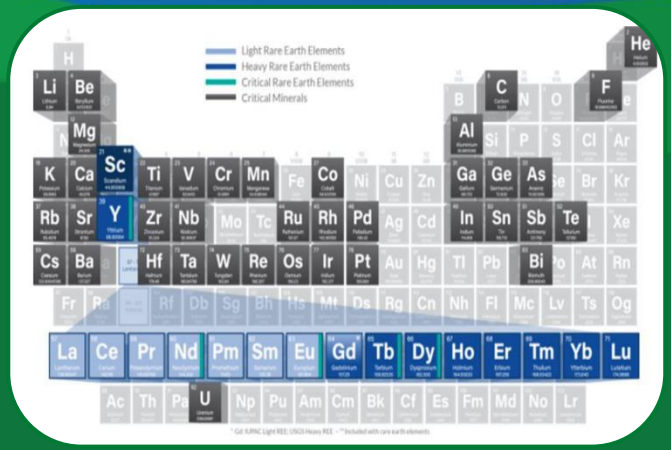
Director, Office of Carbon Management Technologies

April 18, 2023



National Climate Goals

- **2030:** 50% reduction in economy-wide net GHG pollution (from 2005 levels)
- **2035:** Carbon-neutral power sector
- **2050:** Carbon-neutral economy

Addressing Hydrogen Shot and H2@Scale Goals & Challenges

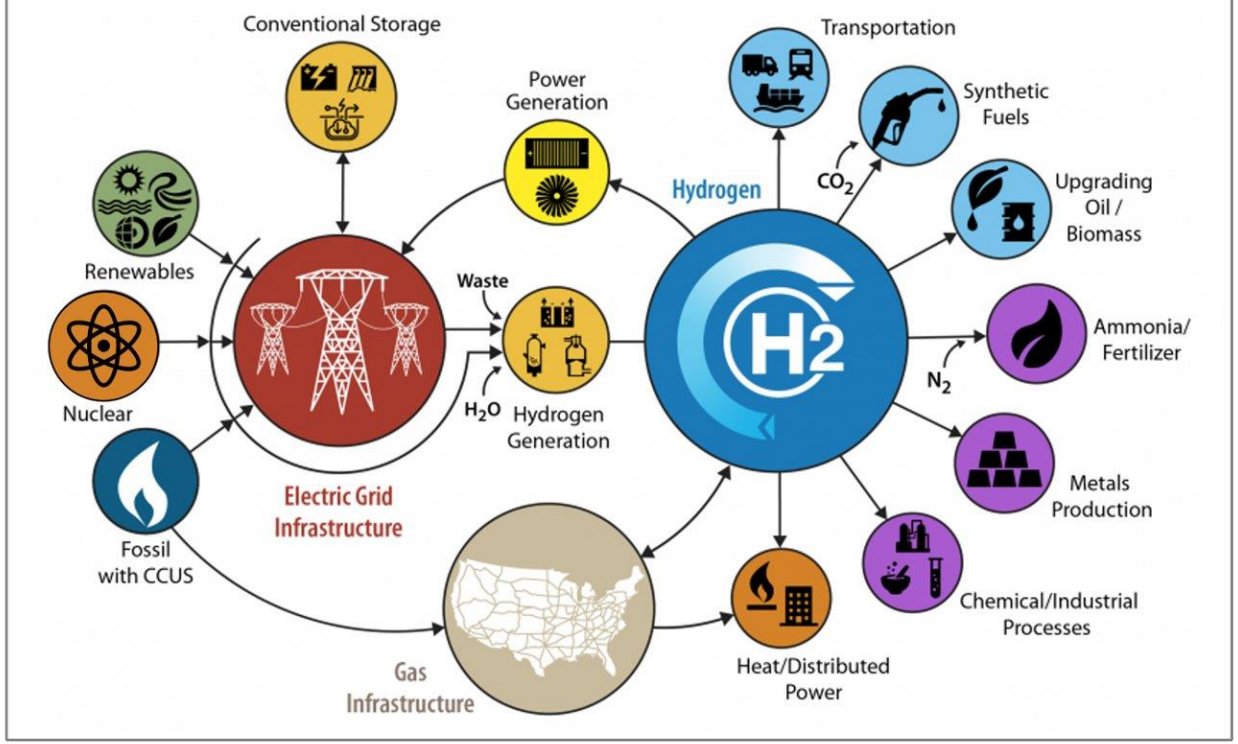
Hydrogen is a key element of a portfolio of solutions to decarbonize the economy

Hydrogen Program

Coordinated across DOE
Focuses on **research, development, demonstration, and deployment (RDD&D)** to address:

- **The entire H_2 value chain** from production through end use
- **H_2 production from all resources** (renewables, nuclear, and fossil + CCS)

H2@Scale provides vision to guide how hydrogen can enable clean-energy pathways across applications and sectors

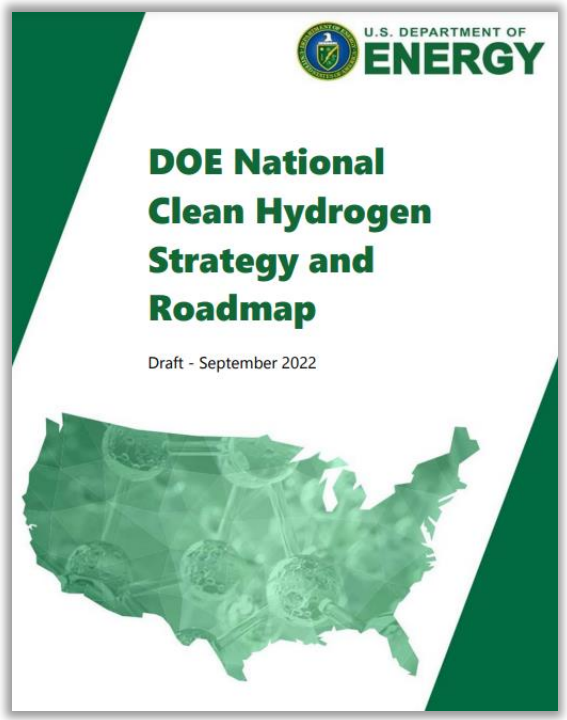


Enabled over
1,200 U.S. patents
>30 commercial technologies

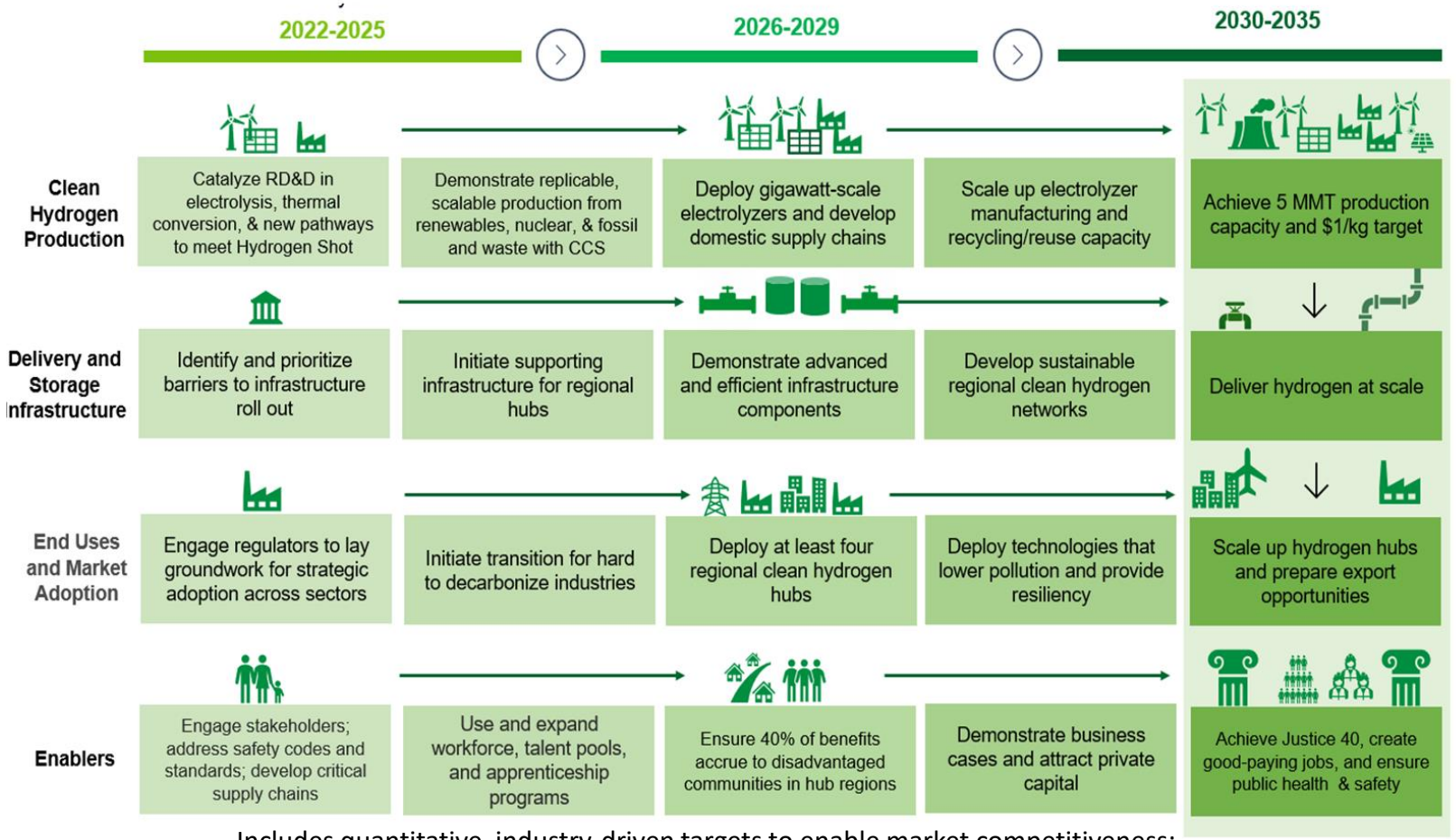
400 projects
200 companies and universities,
15 national labs

www.hydrogen.energy.gov

DOE's National Clean Hydrogen Strategy and Roadmap



Roadmap and Action Plan to Address Barriers

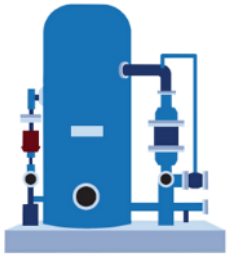


Includes quantitative, industry-driven targets to enable market competitiveness:
Examples include: $1/kg H_2 production, $2/kg delivery, $8/kWh storage, $80/kW fuel cell, etc.

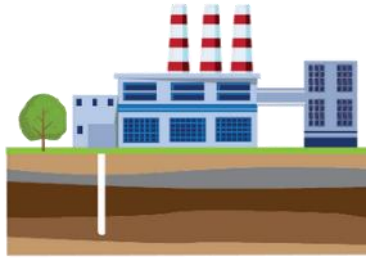
https://www.hydrogen.energy.gov/pdfs/clean-hydrogen-strategy-roadmap.pdf

FECM Strategic Vision

Justice, Labor, and Engagement



Technologies that Lead to Sustainable Energy Resources



Carbon Management Approaches toward Deep Decarbonization

FECM Role Achieving Net-Zero Greenhouse Gases

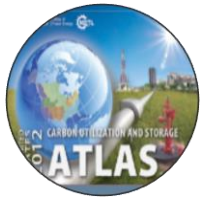
FECM's *Strategic Vision* will enable DOE to make strategic carbon management decisions to ensure that fossil fuel usage is put into proper context with climate change and is designed for a future that achieves and maintains net-zero greenhouse gas emissions.

Read FECM's Entire Strategic Vision by Scanning the Code Above

H_2 with Carbon Management
Conversion of carbon-based feedstocks to H2 coupled with carbon management

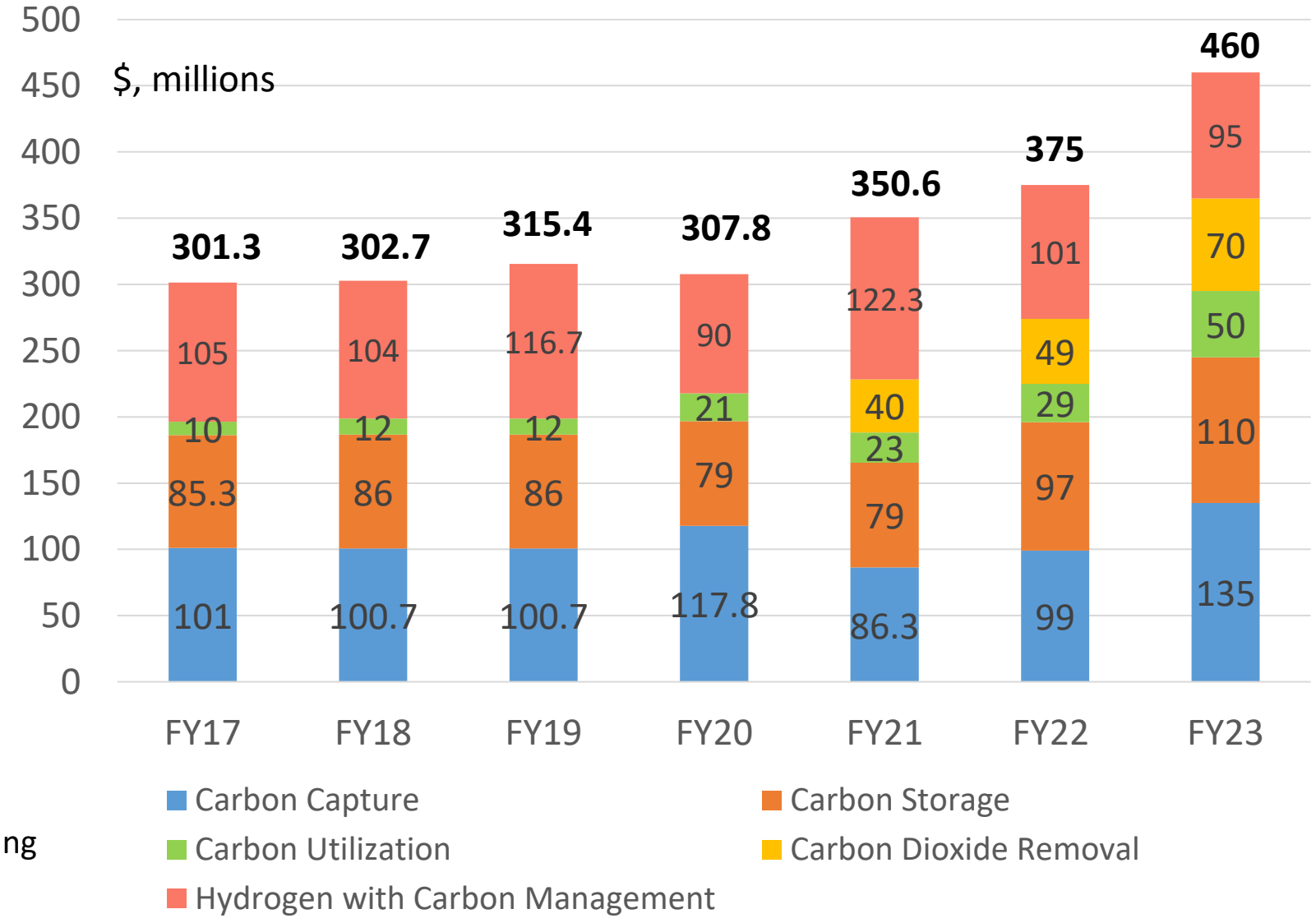
Carbon Dioxide Removal
Removal of atmospheric CO_2 and durable store

Carbon Utilization
Conversion of CO_2 to value-added products



Carbon Storage
Safe, cost- effective, and permanent geologic storage of CO_2

Carbon Capture
Capturing CO_2 from new and existing industrial and power plants



Hydrogen Program in FECM

- Focus is on hydrogen production from fossil resources, waste (e.g., plastics), and available biomass, along with CCUS, to achieve net-zero carbon hydrogen as well as large-scale power generation/energy storage using turbines and large-scale/geological H_2 storage.
- FECM's Methane Mitigation division works to reduce methane flaring/venting/leakage, reducing the CI of hydrogen produced from natural gas.

Hydrogen with Carbon Management

- Program elements include Advanced Gasification, Advanced Turbines, and reversible Solid Oxide Fuel Cells
- The program will not fund R&D specific to traditional fossil power generation, focusing instead on hydrogen-related turbines, fuel cells, CCUS-relevant technologies, and gasification.

Natural Gas Decarbonization and H_2 Technologies

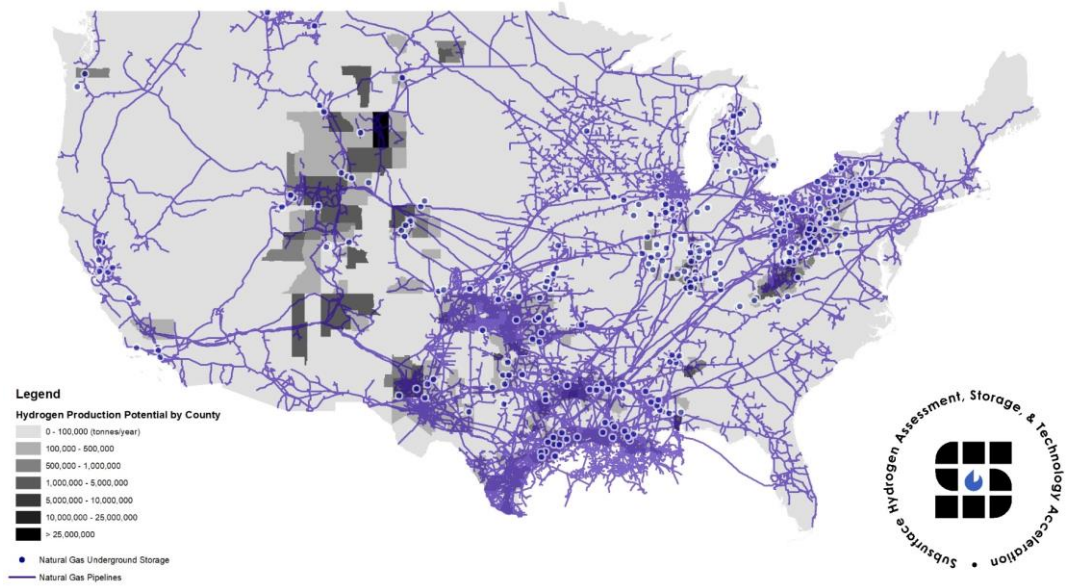
- The Natural Gas Technologies Program is comprised of four subprograms, including the newly-proposed Natural Gas Decarbonization and Hydrogen subprogram.
- Focus areas for the new subprogram include advancing technologies for the carbon-neutral production, transportation, and geologic storage of hydrogen sourced from natural gas.

Hydrogen Pipeline Transportation

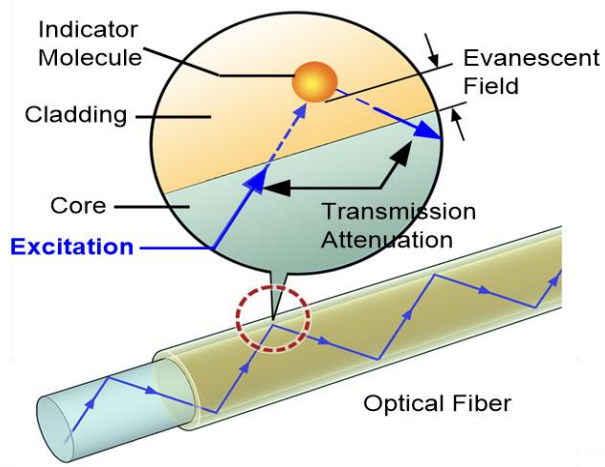
- Characterization of long-term hydrogen impact on piping and pipeline materials and gas blending.
- Life-cycle analysis of emissions from transportation infrastructure.
- Develop advanced sensors, coatings, and materials for hydrogen transportation within blended or dedicated infrastructure.

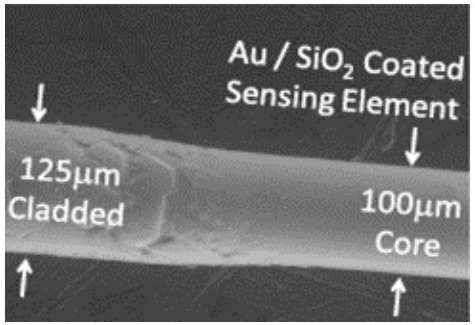
U.S. Natural Gas Pipeline Network
~3 million miles of mainline and other pipelines that link production areas, storage facilities, and consumers.

Dedicated Hydrogen Pipeline System
~1,600 miles, owned by merchant hydrogen producers.



Distributed Fiber Optics Sensors for real-time pipeline monitoring and hydrogen leak detection

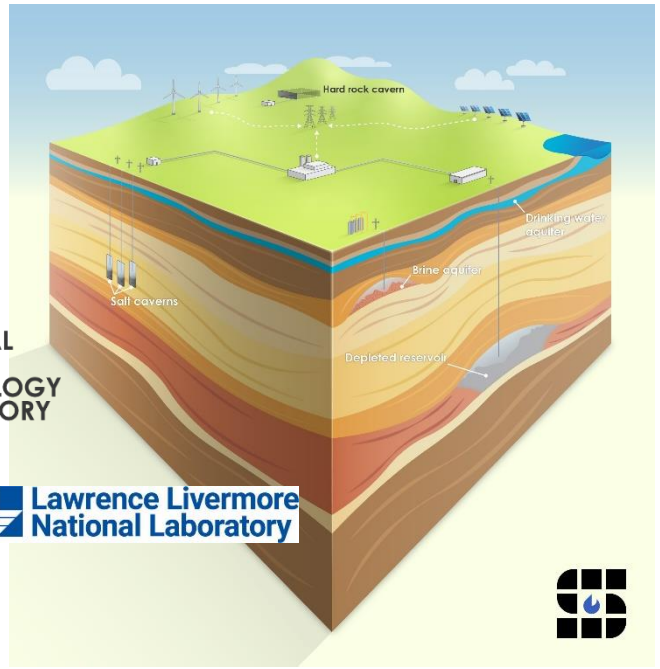




https://publications.anl.gov/anlpubs/2008/02/61034.pdf
https://www.energy.gov/eere/fuelcells/hydrogen-pipelines

Subsurface Hydrogen Storage

SHASTA
Subsurface Hydrogen Assessment, Storage, and Technology Acceleration



NATIONAL ENERGY TECHNOLOGY LABORATORY

Lawrence Livermore National Laboratory

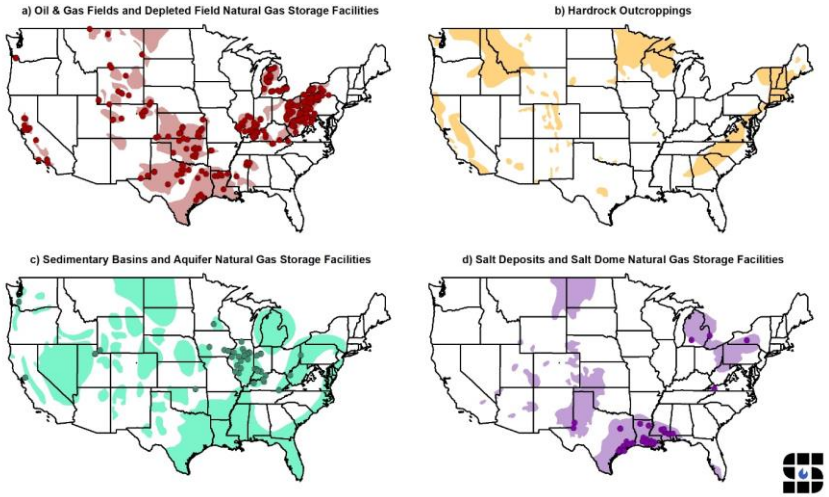
Pacific Northwest NATIONAL LABORATORY

Current Status

- Subsurface hydrogen storage is domestically limited to salt cavern storage facilities.
- Expanding the footprint for subsurface storage to different geologies and geographies is crucial to enabling widespread hydrogen utilization through bulk storage.

Goals & Objectives

- Multi-lab team will 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 or pure hydrogen storage.
- 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.
- Subsurface characterization and validation with respect to potential leakage; long-term effects on reservoir rock; biogeochemical characteristics,; well casing, cement, and transportation infrastructure; and assess overall hydrogen recoverability.
  - Determine viability, safety, and reliability of pure hydrogen or blended gas storage by conducting field demonstrations.



Pre-Commercial.. H_2 Generation (TRL 6+)

Advanced CCS Systems for SMR

Svante VeloxoTherm™ solid adsorbent at Linde SMR H_2 plant

- ~1,100,000 tonnes/year net CO_2 capture
- 90% Capture Efficiency
- Production of "blue" H_2 with 99.97% purity

Gen 1 CCS technology at Phillips 66 refinery in Rodeo, California

- Separate & store ~190,000 tons/year net CO_2 from hydrogen production unit with >90% carbon capture efficiency

Advanced CCUS +for ATR

Tallgrass MLP Operations, LLC

CO2 Capture Unit at Tallgrass MLP Operations LLC's Planned Blue Bison ATR Plant Douglas, WY

- Separate and store 1.66 million tonnes/year of 95% pure CO_2 with >97% carbon capture efficiency
- System combining carbon capture, H_2 production (220 MMSCFD at 99.97% purity), and H_2 combustion in auxiliary burners

Important Hydrogen Provisions in Recent Legislation

Bipartisan Infrastructure Law

- **Covers $9.5B** for clean hydrogen:
  - $1B for electrolysis research, development and demonstration
  - $500M for clean hydrogen technology manufacturing and recycling R&D
  - $8B for at least four regional clean hydrogen hubs
- **Aligns with Hydrogen Shot priorities by directing work to reduce the cost of clean hydrogen to $2 per kilogram by 2026**
- **Requires developing a National Hydrogen Strategy and Roadmap**

President Biden Signs the **Bipartisan Infrastructure Bill** on November 15, 2021. Photo Credit: Kenny Holston/Getty Images

Inflation Reduction Act

➢ **Includes production tax credit for clean Hydrogen**

Inflation Reduction Act – "45Q" Carbon Capture Tax Credit Modifications

	Old	New
Commence Construction	January 1, 2026	January 1, 2033
DAC Facility	100,000 metric tons/year*	1,000 metric tons/year
Electric Generator	500,000 metric tons/year*	18,750 metric tons/year
All other facilities	100,000 metric tons/year*	12,500 metric tons/year
Saline Storage Credit	$50/metric ton	$85/metric ton (industry and power); $180/metric ton (DAC)
EOR and Conversion Credit	$35/metric ton	$60/metric ton (industry and power); $130/metric ton (DAC)

** Non-EOR Conversion facilities were previously 25,000 metric tons/year regardless of facility/source.*

Notes: New Modifications allows up to 5 years for direct pay (up to 12 years certain entities)

Inflation Reduction Act – "45V" Clean H_2 Production Tax Credit

Commence Construction	January 1, 2033
kg of CO_2 per kg of H_2	Credit Value ($/kg)
4 to 2.5	*0.60*
2.5 to 1.5	*0.75*
1.5 to 0.45	*1.00*
0.45 to 0	*3.00*

Clean hydrogen: lifecycle greenhouse gas emissions rate of no greater than 4 kilograms of CO_2 equivalent ("**CO_2e**") gas per kilogram of hydrogen.

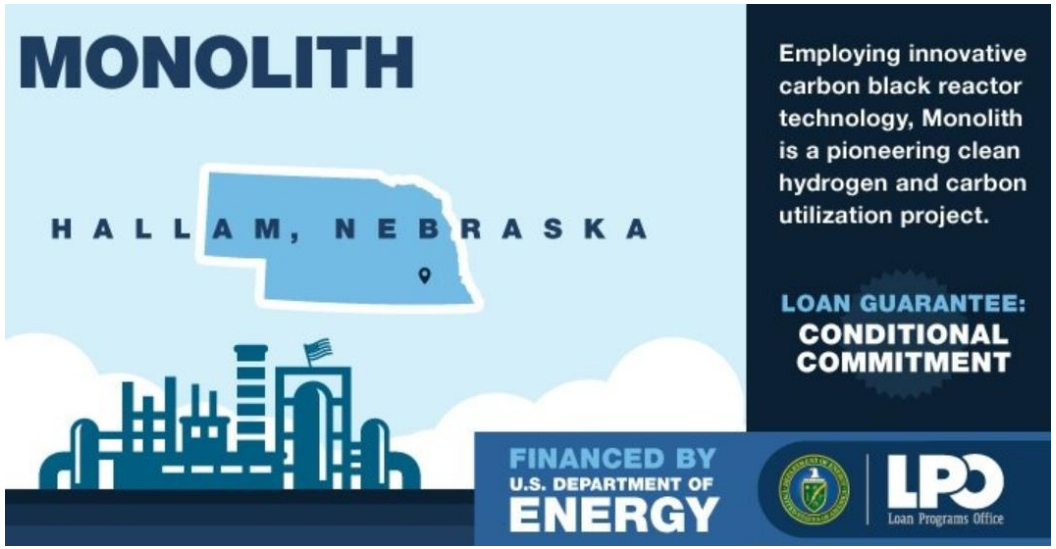
As an alternative to the Clean Hydrogen Production Credit, taxpayers may elect the Section 48 Investment Tax Credit (the "**ITC**") with respect to clean hydrogen production facilities, receiving an ITC of up to 30% depending on the carbon intensity of the production process.

The Clean Hydrogen Production Credit is not available, however, for clean hydrogen produced at a facility that also includes carbon capture equipment for which the Section 45Q carbon capture tax credit is allowed to any taxpayer.

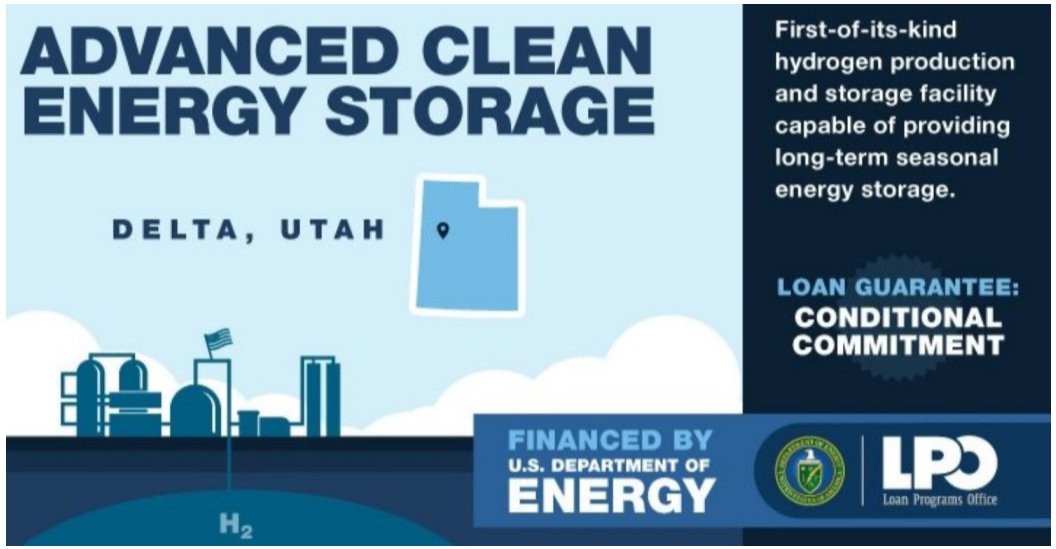
Financing to Enable Deployment at Scale

Loan Programs Office (LPO) has $40 Billion in Available Debt Capital

LPO announced loan guarantee conditional commitments for 2 clean hydrogen projects



$1.04B for the first-ever commercial-scale project to deploy methane pyrolysis technology. Will enable 1,000 construction jobs and 75 operations jobs. (December 2021)



$504.4M for large-scale hydrogen energy storage, 220 MW electrolysis and turbine. Will enable up to 400 construction jobs and 25 operations jobs. (April 2022)

LPO@hq.doe.gov

Energy Justice, Stakeholder Engagement, DEI, Place-Based Engagement Strategies

Strategy: Identify and enable concrete benefits & workforce development with emphasis on EJ, DEI, labor unions, tribal communities, DACs, and those jobs impacted by the energy transition

Challenge: Need to address constructive feedback from stakeholders (non-renewable H_2, siting, NOx, jobs, etc.)

Future Engagement Strategy

- Small, focused meetings, with CBOs, EJ groups, labor unions, tribal groups
- Large, open, public webinars
- Educational materials for dissemination on lessons learned and best practices
- Identify and enable near-, mid- & long-term jobs, registered apprenticeships
- Implement new ideas: e.g., "Dig once"

CENTER FOR 水素安全センター Hydrogen SAFETY
Connecting a Global Community

Center for H_2 Safety (>60 partners) for training

- **H2 and Carbon Matchmaker** - identification
- **H2EDGE** – EPRI FOA project on workforce development
- **Sustainability Tool**
- **Fellowships** (H-Shot, Rose, IPHE fellows)
- **IPHE Early Career Network** (global)
- **HBCU/MSI FOA**
- **H2 Twin Cities** (global)
- **FOA criteria**, policy factors, teaming lists

Use DOE IGEA Regions

H2 Lab & HBCU/MSI to Jobs Pipeline
Expand current Lab program

- LANL hosted approximately 100 students
- ~ 40 involved in LANL Fuel Cell research

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Thank You!