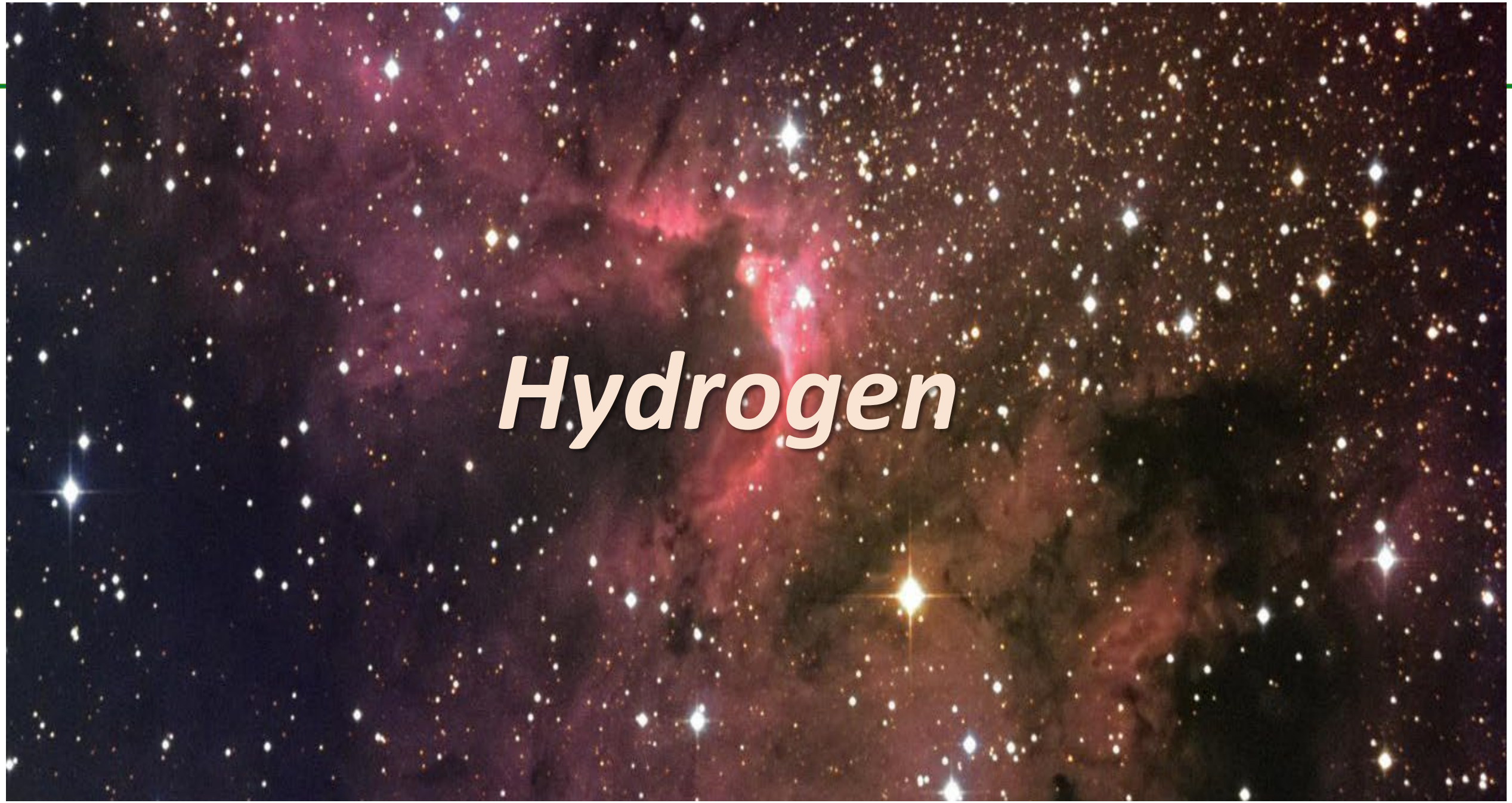
Tribal Energy Summit

Dr. Eric Miller, Chief Scientist, Hydrogen and Fuel Cell Technologies Office,
Bob Schrecengost, Senior Program Manager, Division of Hydrogen with Carbon Management
Mark Ackiewicz, Director, Office of Carbon Management Technologies, Office of Fossil Energy and Carbon Management
Todd Shrader, Deputy Director for Project Management, Office of Clean Energy Demonstrations

U.S. Department of Energy

October 5, 2022


Hydrogen

Key Hydrogen Facts:

- Most abundant element in the universe
- Present in common substances (water, sugar, methane)
- Very high energy by weight (3x more than gasoline)
- Can be used to make fertilizer, steel, as a fuel in trucks, trains, ships, and more
- Can be used to store energy and make electricity, with only water as byproduct
- Can be produced from multiple abundant fuel sources in the U.S.

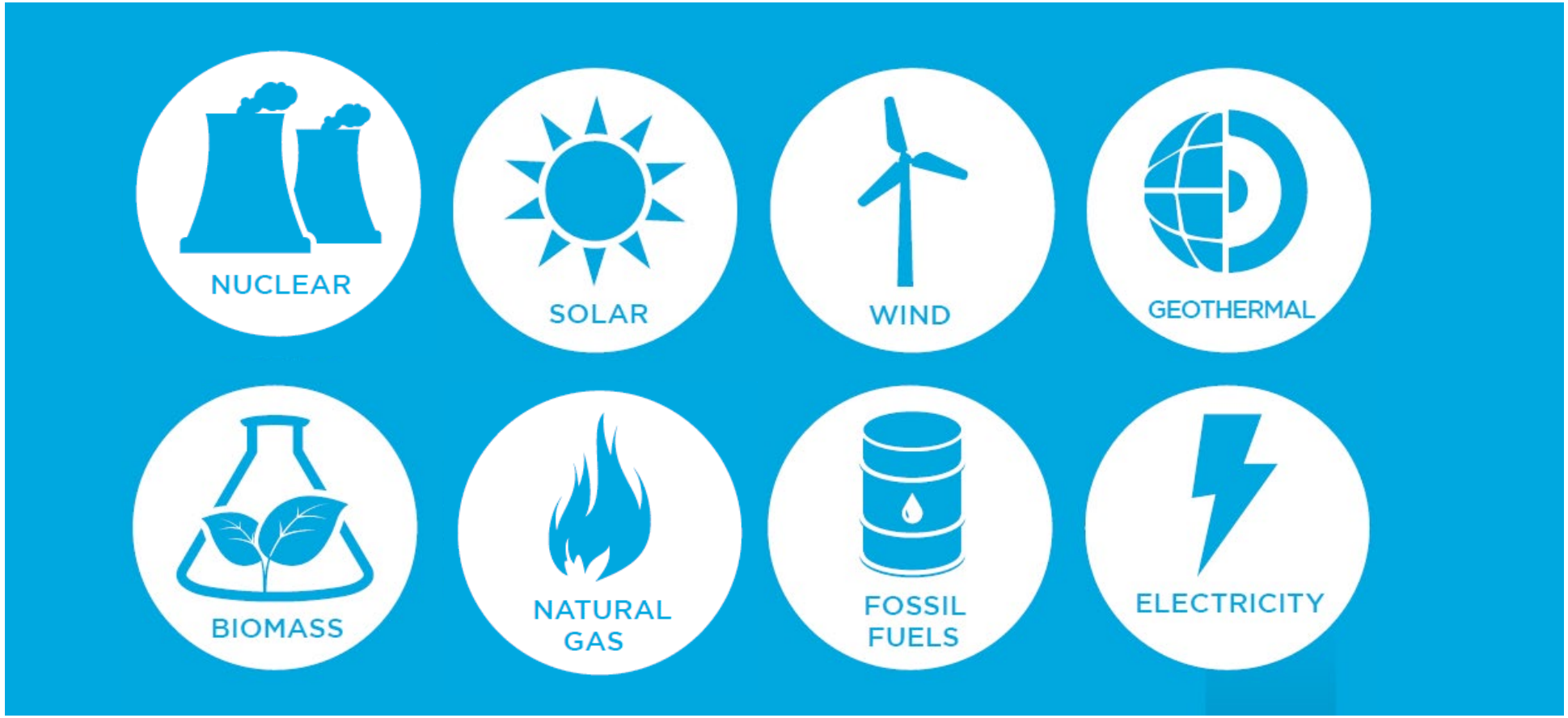
Key Hydrogen Benefits

- Reduced greenhouse gas emissions
- Reduced oil consumption
- Ability to store renewable power
- Ability to use for industry and transportation
- Reduced air pollution
- Reliable grid support

Hydrogen Sources

Clean and domestic energy sources can be used to produce hydrogen

Most of today's hydrogen comes from natural gas



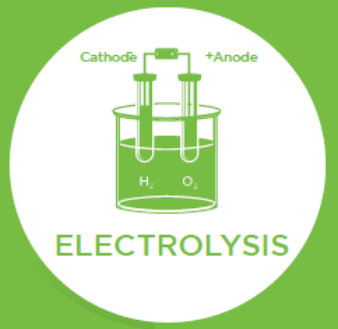
10 million metric tons of hydrogen

produced annually in the United States, mostly for oil refining and fertilizer production

Learn more at: http://www.energy.gov/eere/fuelcells/hydrogen-resources

Hydrogen Production

Diverse clean domestic energy sources can produce hydrogen through these processes



Electricity separates water into oxygen and hydrogen

Microbes or enzymes break down plants and produce hydrogen

Energy from direct sunlight and sun heat splits molecules

Steam and hydrocarbons come together under high temperature

Learn more at: http://www.energy.gov/eere/fuelcells/hydrogen-production-processes

Hydrogen Uses

Multiple industries

Multiple applications

Including steel, cement ammonia industries

For heavy-duty applications including trucks, trains and at ports

Good for long-term energy storage; improved electric grid efficiency

Electricity production for cell phone towers, data centers, hospitals and supermarkets

Largest use of hydrogen produced today

Second largest use of hydrogen produced today

Learn more at: https://energy.gov/eere/fuelcells/fuel-cell-technologies-educational-publications

Hydrogen Energy Earthshot

“Hydrogen Shot”

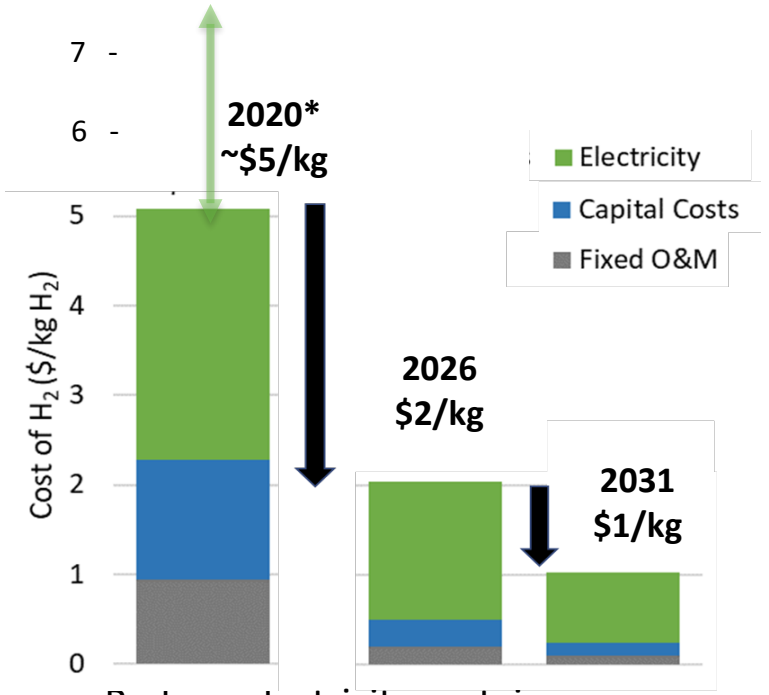
“1 1 1”
$1 for 1 kg clean hydrogen in 1 decade

Launched June 7, 2021
Summit Aug 31-Sept 1, 2021

Hydrogen Shot: $1 for 1 kg of clean H_2 in 1 decade (2031)

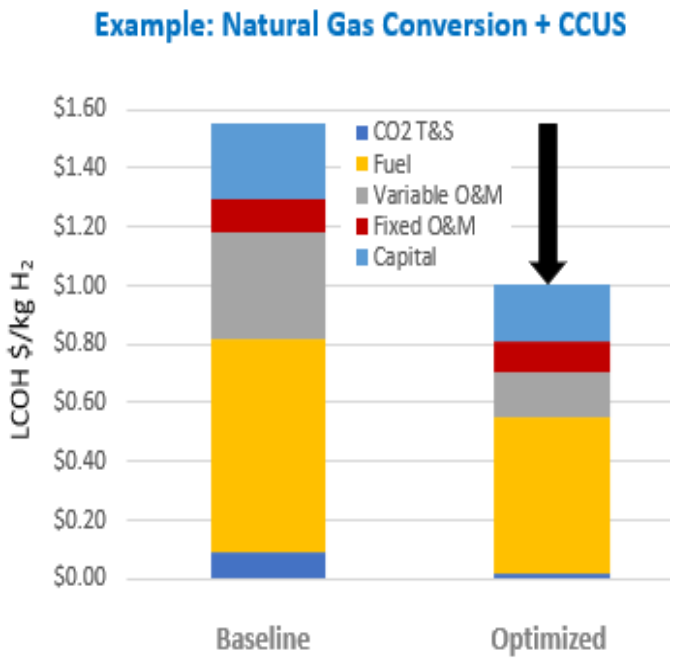
Strategies and scenarios being developed to reduce cost and emissions across pathways

H_2 from Electrolysis



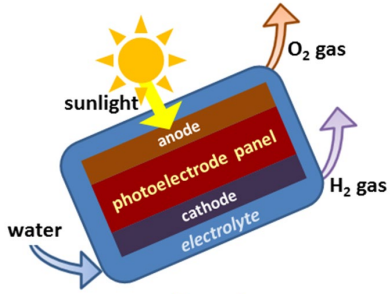
- Reduce electricity cost, improve efficiency and utilization
- Reduce capital cost >80%; operating & maintenance cost >90%

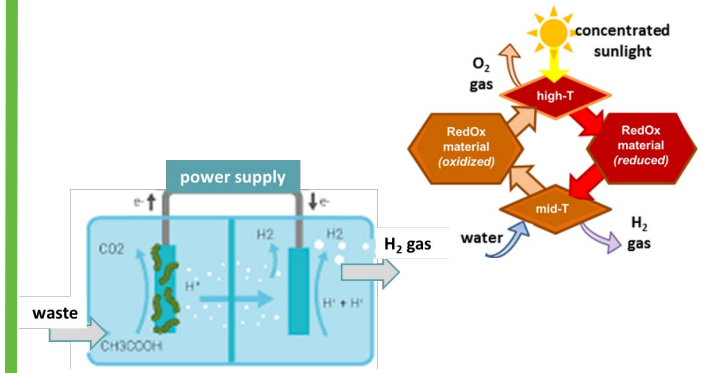
Thermal Conversion



- Reforming, pyrolysis, air separation, catalysts, Carbon Capture and Storage (CCS), upstream emissions

Advanced Pathways





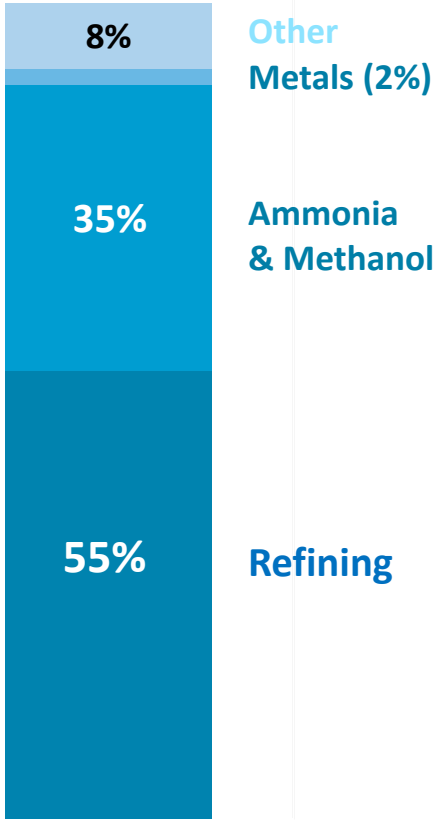
- Photelectrochemical (PEC), thermochemical, biological, etc.

*2020 Baseline: PEM (Polymer Electrolyte Membrane) low volume capital cost ~$1,500/kW, electricity at $50/MWh. Pathways to targets include capital cost <$300/kW by 2025, < $150/kW by 2030 (at scale). Assumes $50/MWh in 2020, $30/MWh in 2025, $20/MWh in 2030

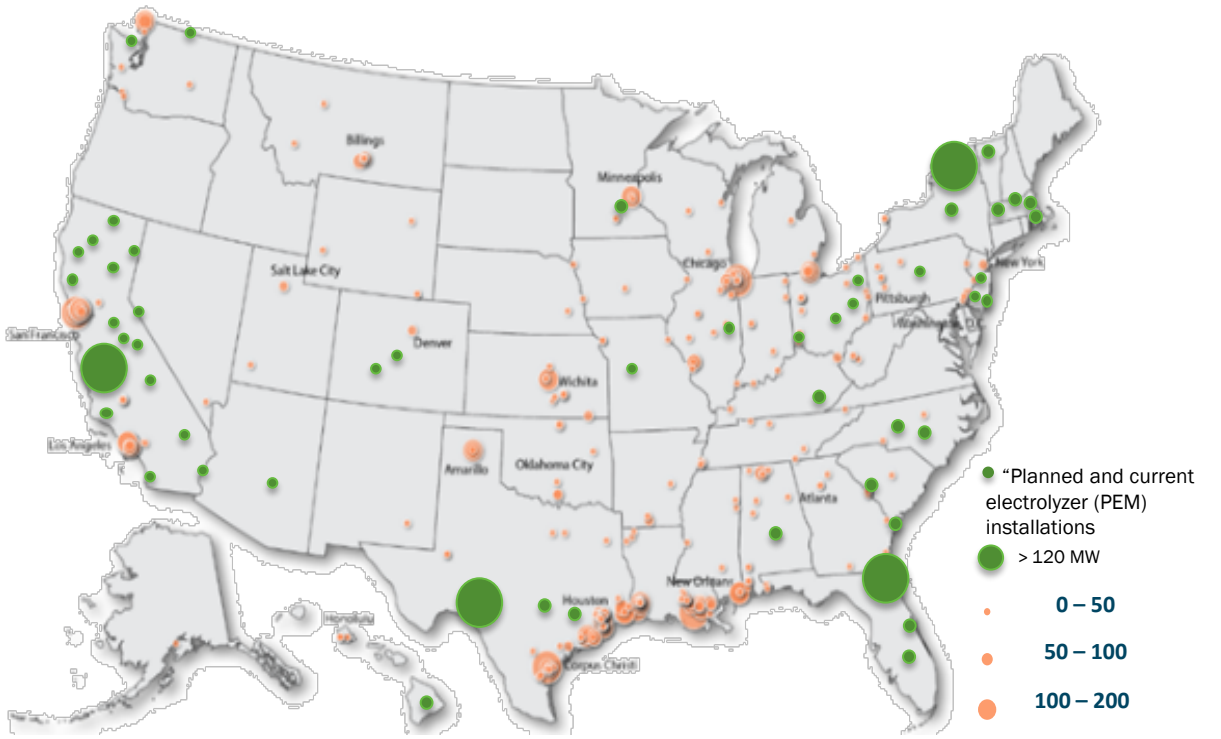
Snapshot of Hydrogen and Fuel Cells in the U.S.

- 10 million metric tons produced annually
- More than 1,600 miles of H_2 pipeline
- World's largest H_2 storage cavern

Use of Hydrogen in the U.S. Today



Examples of Hydrogen Production Locations



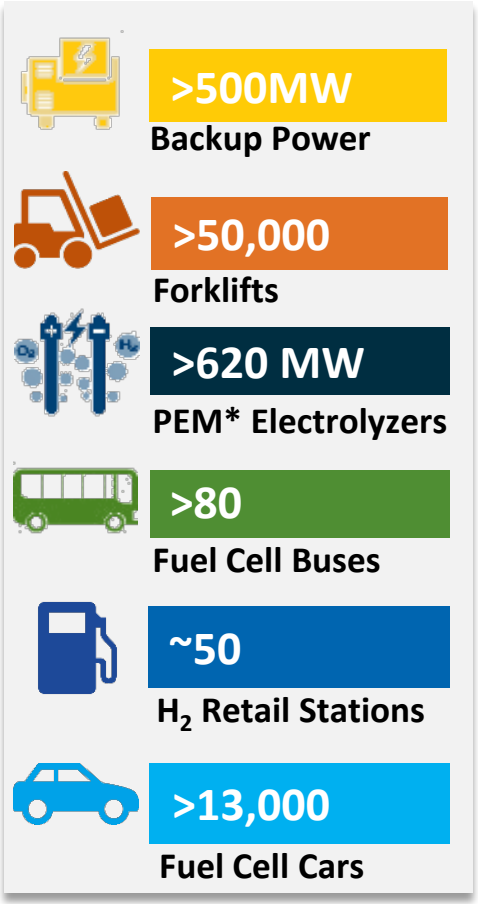
"Planned and current electrolyzer (PEM) installations

- > 120 MW
- 0 – 50
- 50 – 100
- 100 – 200
- 200 – 400
- 400 – 800

Hydrogen Production Units using natural gas Gaseous Metric Tons/Day

>620 MW of PEM* electrolysis in the U.S.
>3X increase since 2021

Examples of Deployments



*Proton exchange membrane

Hydrogen Challenges

- Cost of clean hydrogen
- Needs energy (like solar, wind, nuclear) or fuel to produce
- Storage and transport challenges
- Limited infrastructure to move and use hydrogen

U.S. DEPARTMENT OF ENERGY

The U.S. DOE Hydrogen Program

Dr. Eric L. Miller

Chief Scientist, U.S. Department of Energy Hydrogen and Fuel Cell Technologies Office

October 5, 2022

Addressing Hydrogen Shot and H2@Scale Goals & Challenges

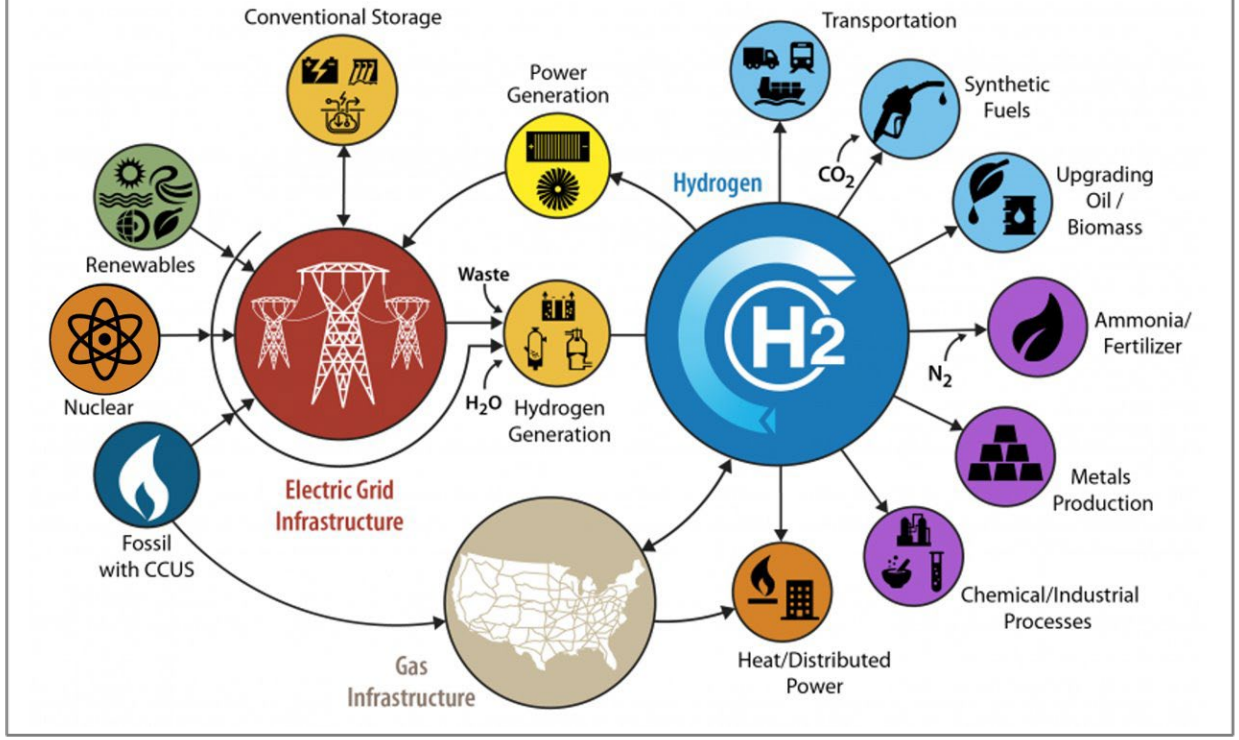
Hydrogen is a key element of a portfolio of solutions to decarbonize the economy

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



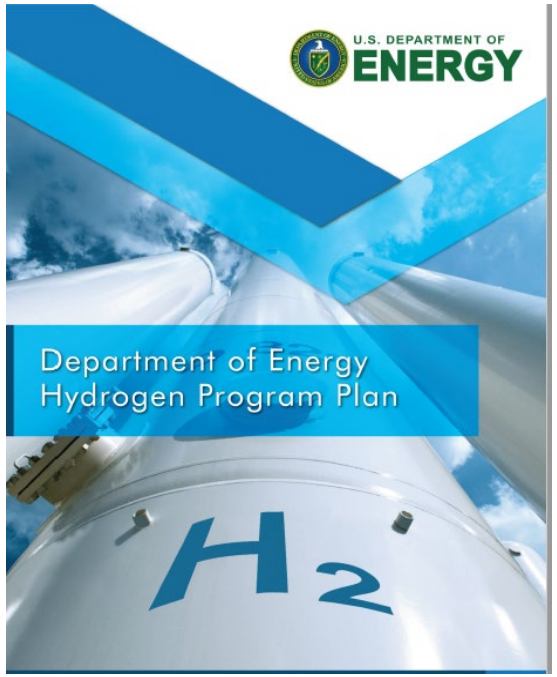
Enabled over
1,200 U.S. patents
>30 commercial technologies

400 projects
200 companies and universities,
15 national labs

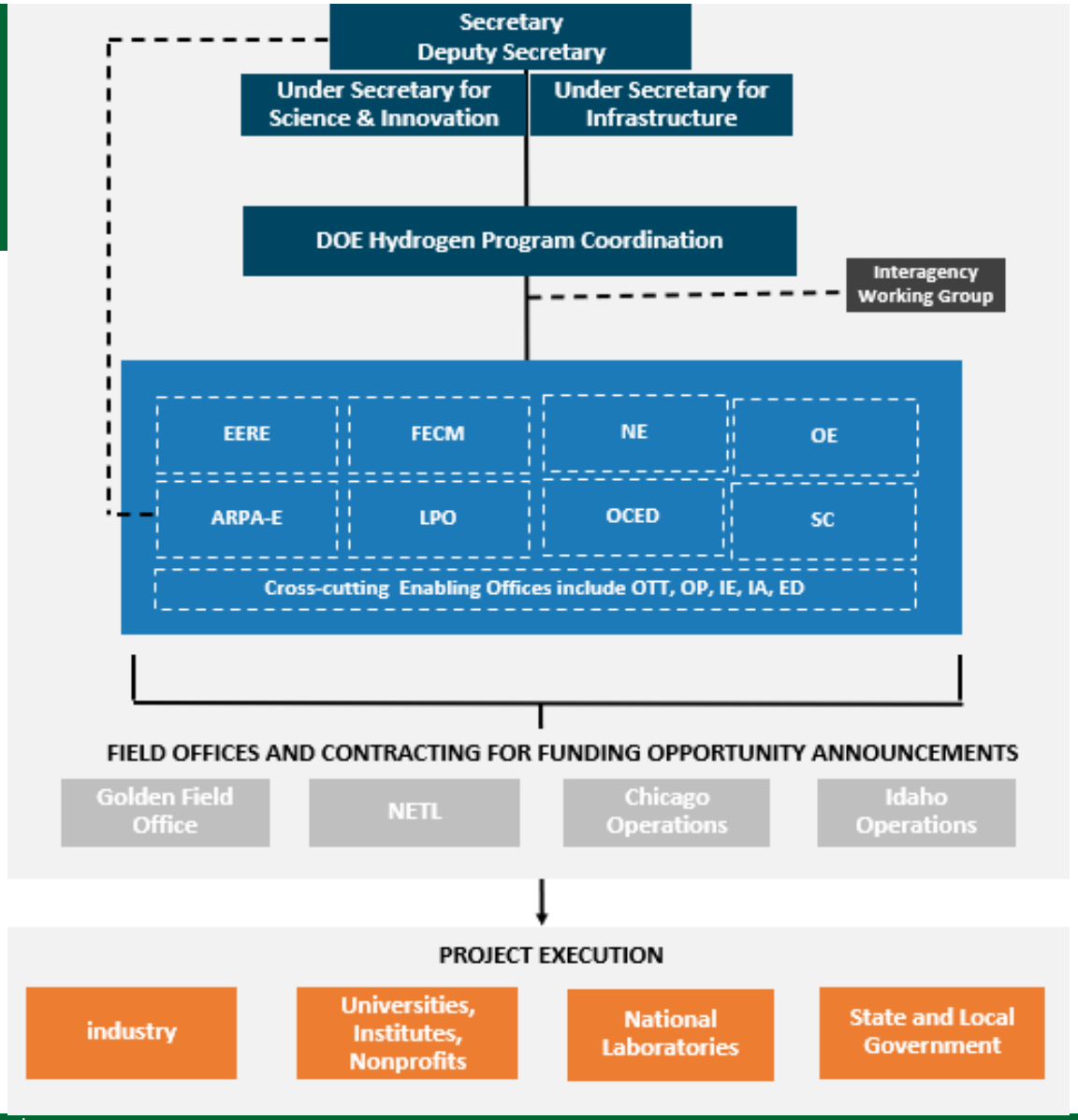
www.hydrogen.energy.gov

The U.S. DOE Hydrogen Program Framework

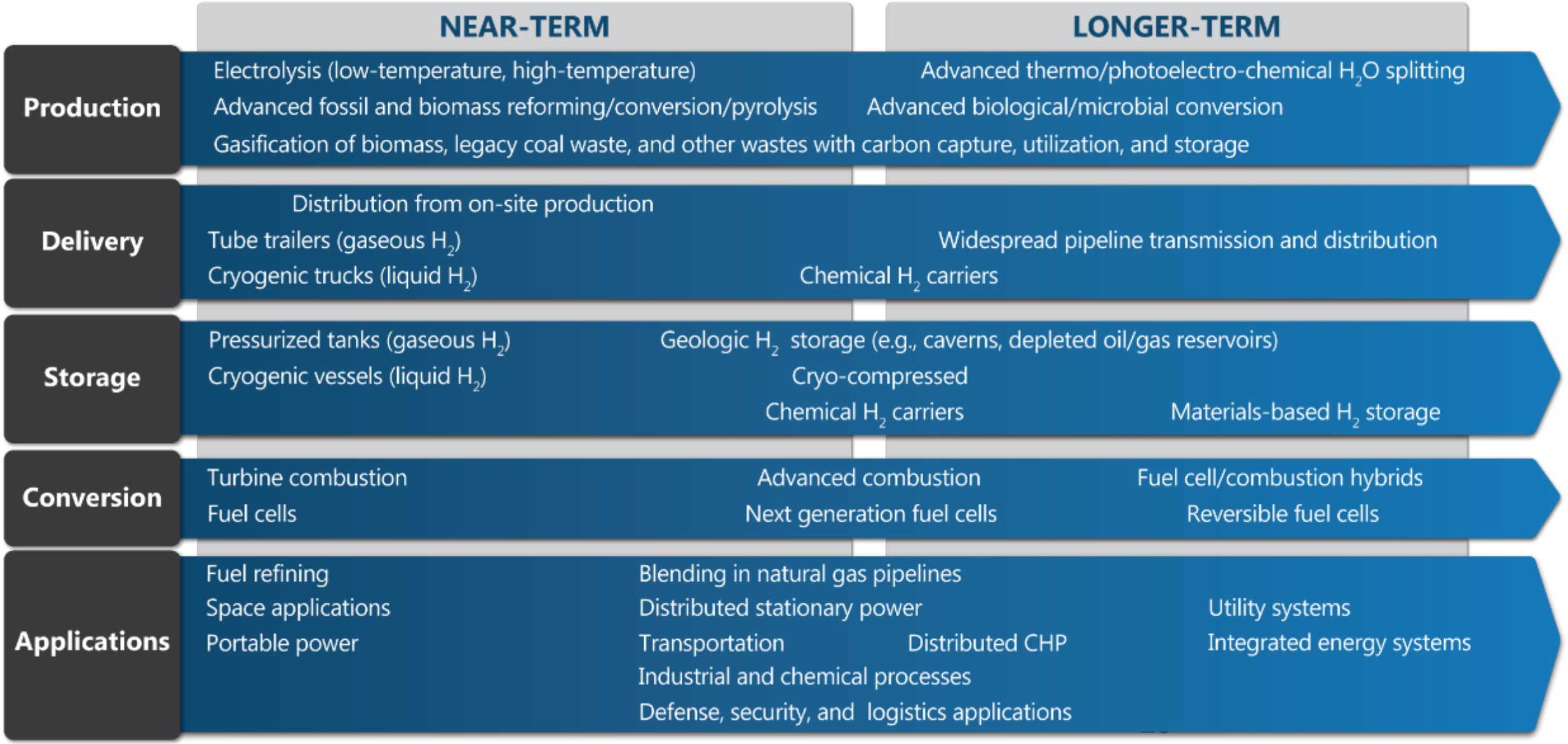
Hydrogen is one part of a broad portfolio of activities
Includes multiple offices and the entire RDD&D value chain from production through end use



www.hydrogen.energy.gov

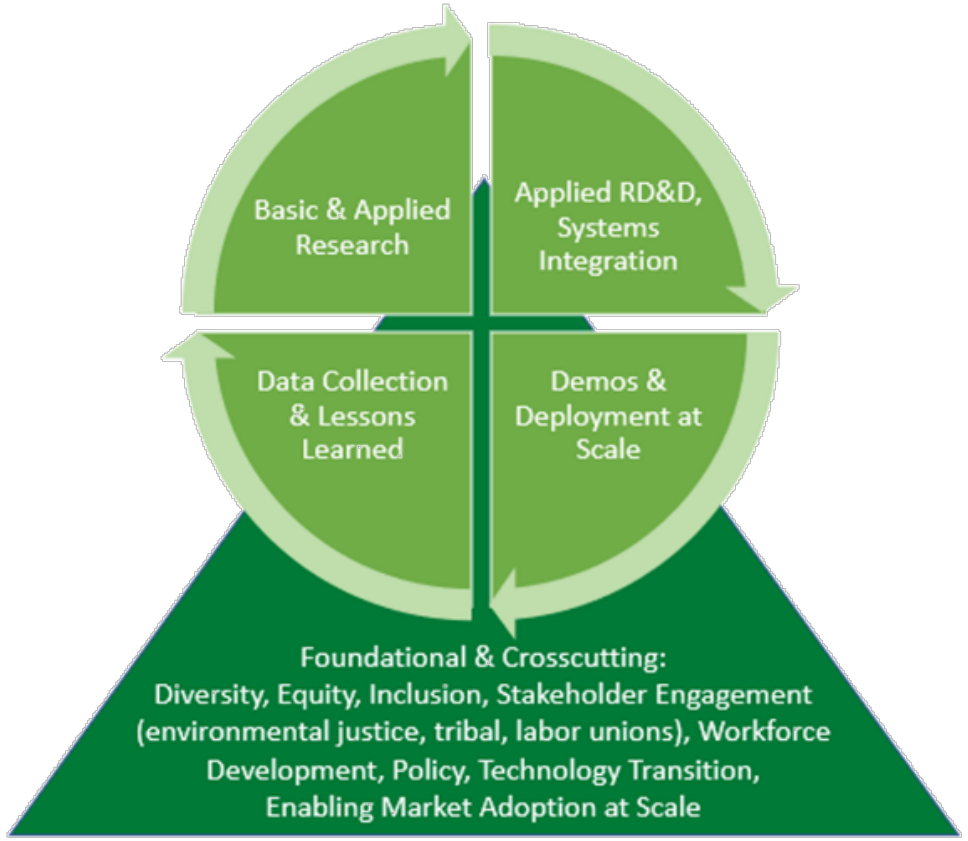


Comprehensive DOE Strategy Across the Hydrogen Value Chain



Coordinated RDD&D Strategy with Diverse Stakeholder

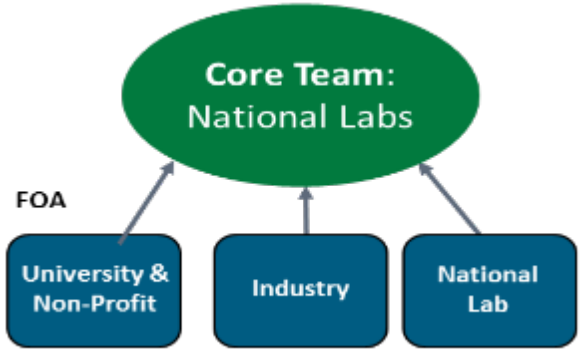
Includes more than **400 projects** with more than **200 companies & universities** and **15 National Labs**



Mechanisms include:

- **Consortia – national labs, industry, and academia**
- **Lab-industry projects (CRADAs)**
- **Small business innovation projects**
- **Single project recipients & subrecipients**
- **Direct projects at/with labs**
- **Energy Frontier Research Centers (Science)**
- **Prize competitions – e.g., Hydrogen Shot Incubator Prize**

Consortia Framework



Example Initiatives*

H2NEW U.S. DEPARTMENT OF ENERGY

HydroGEN Advanced Water Splitting Materials

ElectroCat Electrocatalysis Consortium

H-Mat

SHASTA Subsurface Hydrogen Assessment, Storage, and Technology Acceleration

CABES an Energy Frontiers Research Center

**includes initiatives in H_2 production and utilization as well as leveraging & expanding H_2 infrastructure*

Science: Advancing Foundational Science for Carbon-Neutral H_2 Technologies

Discover and Control Materials and Chemical Processes to Revolutionize Electrolysis Systems

– How do we co-design multiple components that work together to enable stable, efficient electrolysis for the carbon-free production of hydrogen from water?

Manipulate Hydrogen Interactions to Harness the Full Potential of Hydrogen as an Energy Carrier

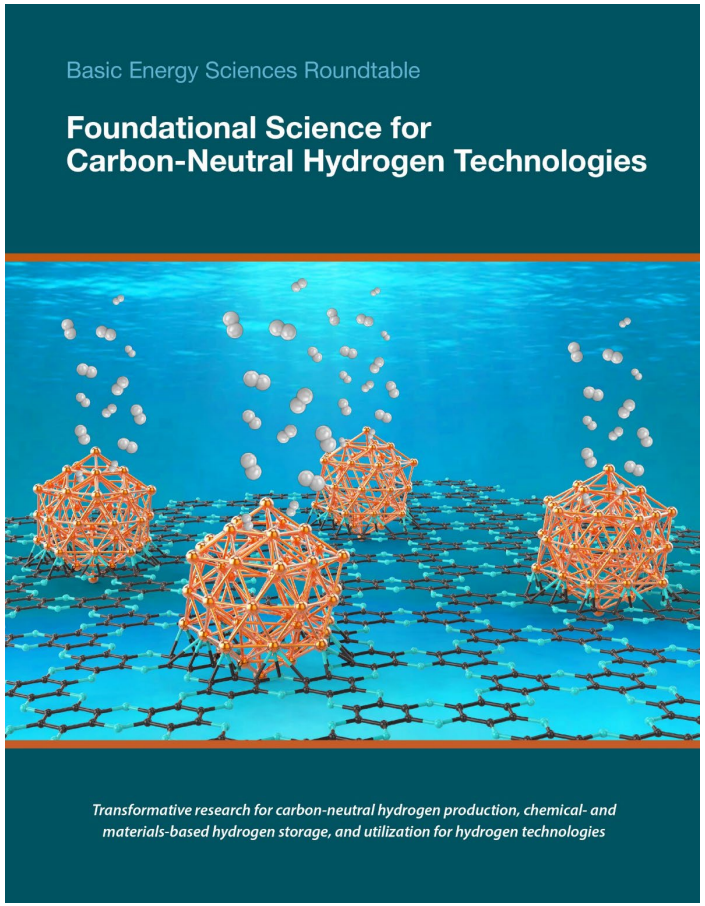
– How do we acquire fundamental insights across the entire range of energies to allow selective tuning of hydrogen interactions with molecules and materials?

Elucidate the Structure, Evolution, and Chemistry of Complex Interfaces for Energy and Atom Efficiency

- How can co-existing and evolving interfaces be tailored at multiple length scales to achieve energy-efficient, selective processes and enable carbon-neutral hydrogen technologies?

Understand and Limit Degradation Processes to Enhance the Durability of Hydrogen Systems

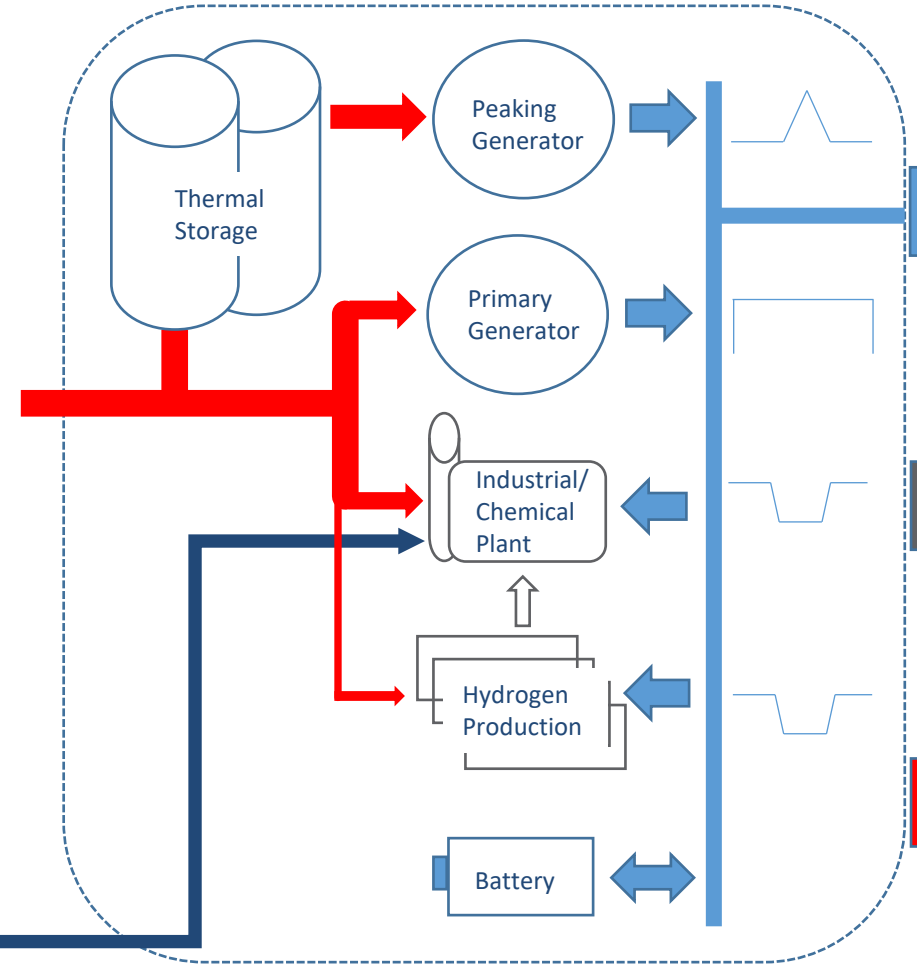
- How do we identify and understand the complex mechanisms of degradation to obtain foundational knowledge that enables the predictive design of robust hydrogen systems?



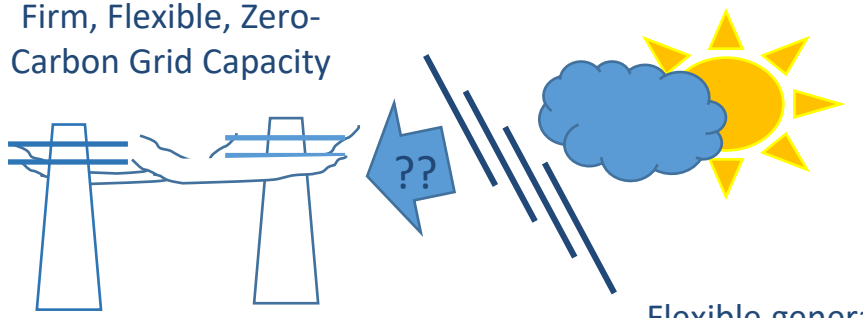
Available at:
https://science.osti.gov/bes/Community-Resources/Reports

Nuclear Energy: Integrated Energy System Concept with Hydrogen

Flexible Scale Reactors



Firm, Flexible, Zero-Carbon Grid Capacity



Flexible generation enables more renewable power to the grid

Transportation Fuels
Steel Production
Fertilizer / Ammonia
Polymers/ Chemicals
Hydrogen

Refineries/Oil Production
Minerals
Wood/Paper plants
District Heating

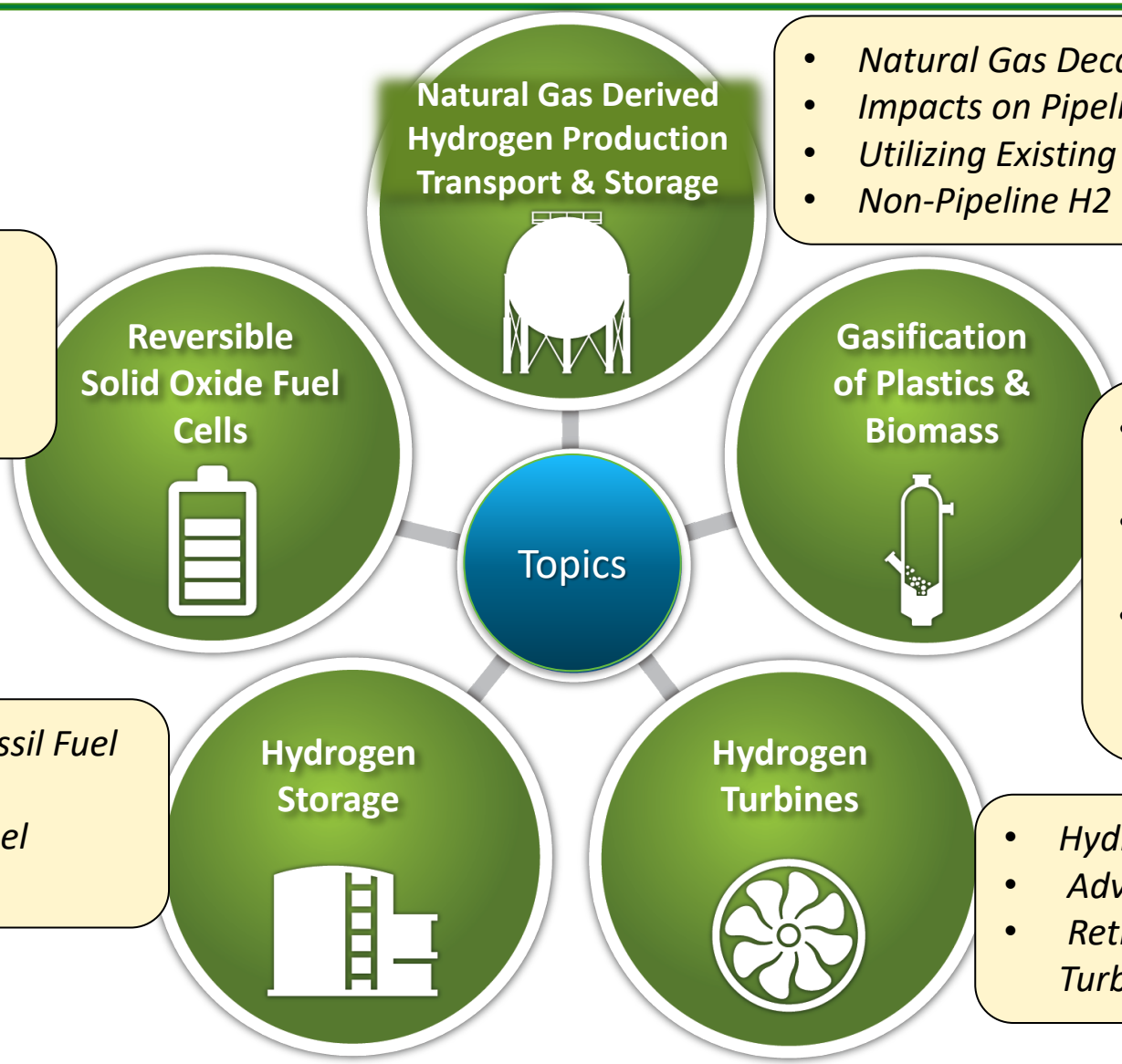
CO_2 / Carbon Sources

- Ethanol plants
- NG generators
- Cement plants
- Biomass
- Polymer/Chemical Waste

Flexible Reactor Siting

Data centers
Manufacturing plants
Biofuel plants/processing
Desalination
Industrial parks/plants
Fueling Stations

Fossil Energy and Carbon Management: *more to come from FECM*



- *Natural Gas Decarbonization*
- *Impacts on Pipeline / Equipment Materials*
- *Utilizing Existing Natural Gas Pipelines for H_2*
- *Non-Pipeline H2 Transport and Storage*

- *Cell Development*
- *Improve Core Technologies*
- *Systems Development*

- *Waste gasification in retrofitted systems*
- *Novel waste gasifier technologies*
- *Enabling waste plastics for use in gasification systems and allied equipment*

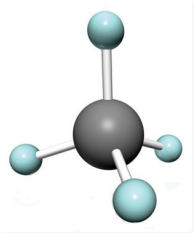
- *For Improving Existing Fossil Fuel Systems*
- *For New Flexible Fossil-Fuel Systems*

- *Hydrogen Combustion Fundamentals*
- *Advanced Hydrogen Turbines*
- *Retrofit Packages for Deployed Gas Turbines*

ARPA-E Example: Methane Pyrolysis to Produce H_2 and Solid Carbon

Cracking Methane:
Two Product Process

- *converts natural gas into hydrogen plus solid carbon products*
- *potential carbon markets include cement, asphalt, soil & sequestration*



750 - 1200 °C

Gaseous hydrogen

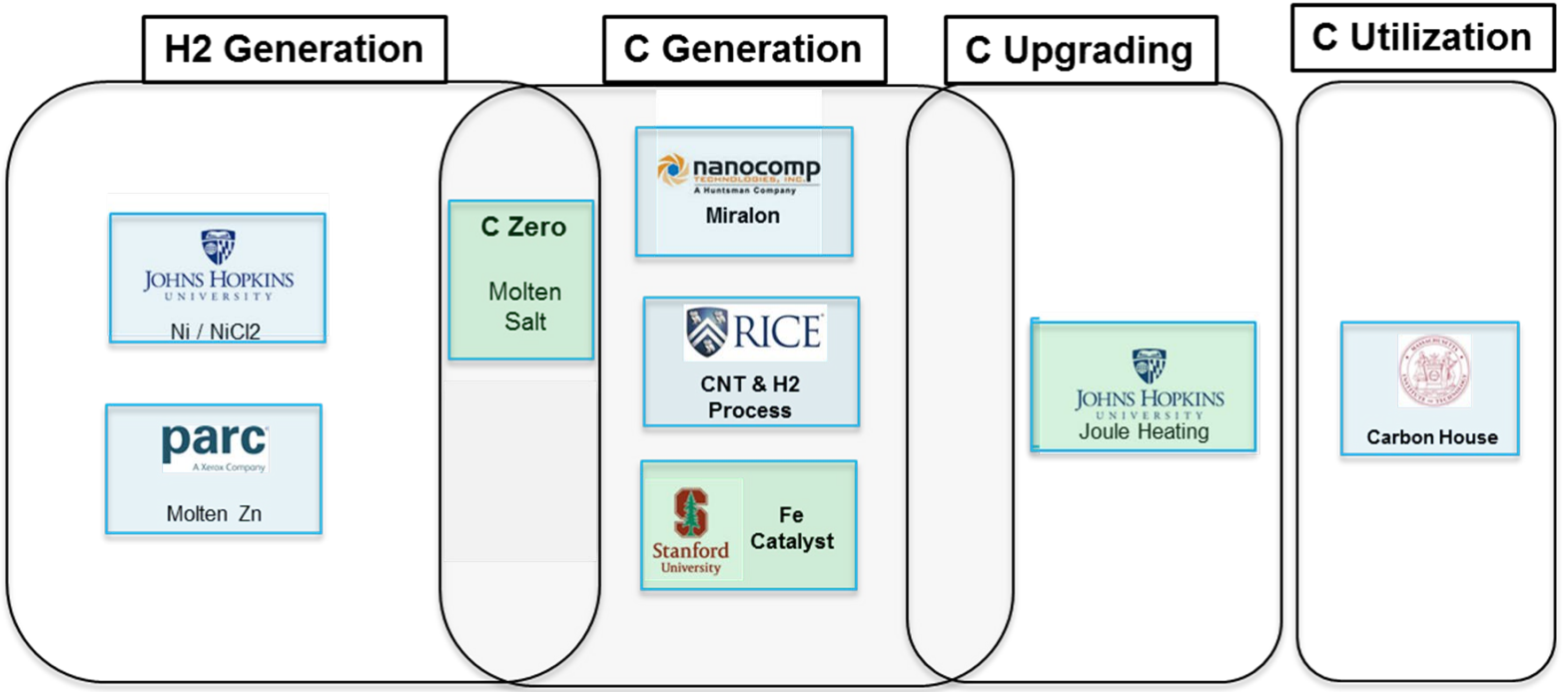
+

Solid carbon

CH_4 → $2\ H_2$ + C (s)

¼ weight
½ energy

3 X weight H_2



Methane Pyrolysis Cohort

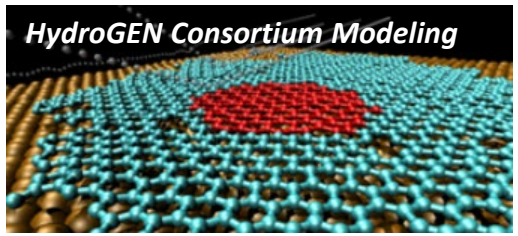
- *projects addressing the different aspects of the two-product process*

Supporting RDD&D to Enable Achieve Scale and Market Success
and address energy and environmental justice

Research and Development

Basic and applied research through individual projects and lab consortia

Examples:

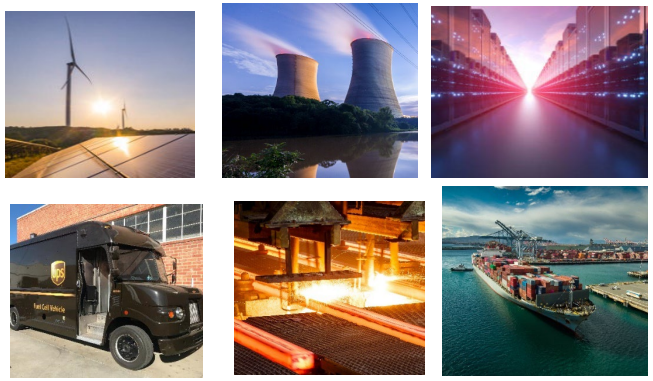


Basic science user facilities, theory, modeling

Technology Integration, Validation, Demos

1st of a kind demonstrations and systems integration to de-risk deployments

Examples:



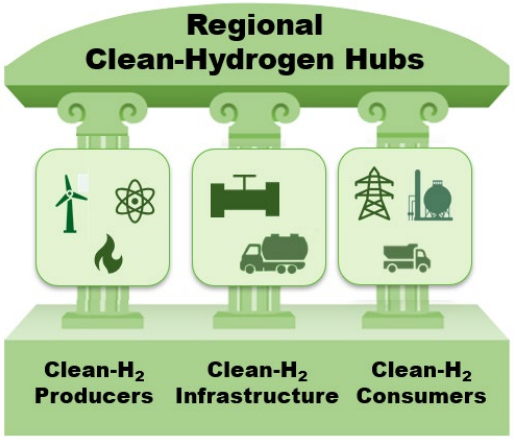
Renewables and nuclear to H_2, 15 delivery trucks in disadvantaged area, 3 Super Truck projects, data center, fueling for passenger ferry, energy storage, H_2 for steel

Deployment and Financing

H2 Hubs, loan guarantee program, workforce development

Example:

$8 billion for at least 4 hubs: Renewables, fossil w/CCS, nuclear; multiple end-uses



2 new loan guarantee projects ($1.5B total) on pyrolysis and large-scale electrolysis, H_2 energy storage and power generation

Enabling Activities

- Analysis and tools
- Safety, codes & standards
- Manufacturing
- Workforce development

H2EDGE Hydrogen Education for a Decarbonized Global Economy

CENTER FOR Hydrogen SAFETY Connecting a Global Community

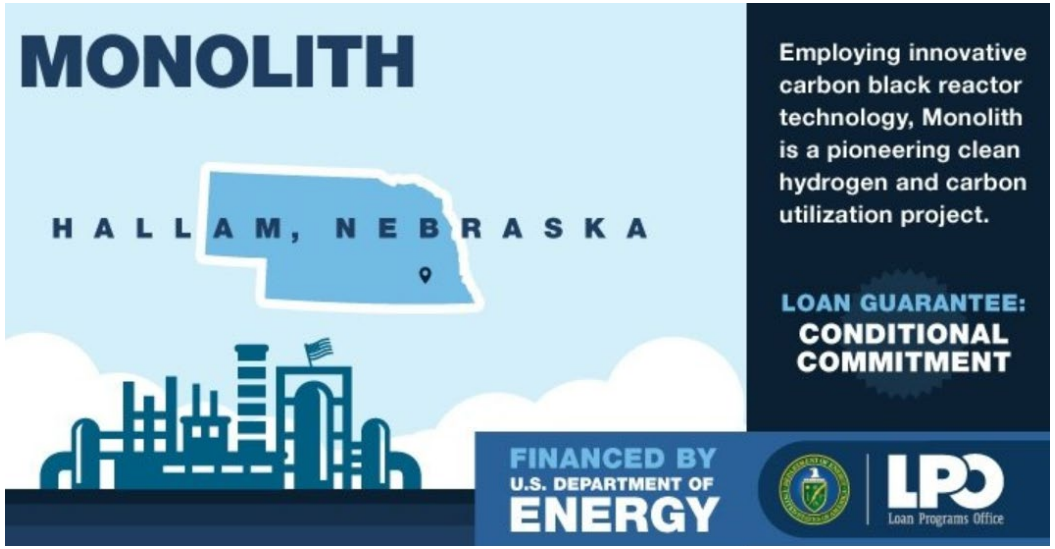
HyBlend U.S. DEPARTMENT OF ENERGY

H2 Matchmaker

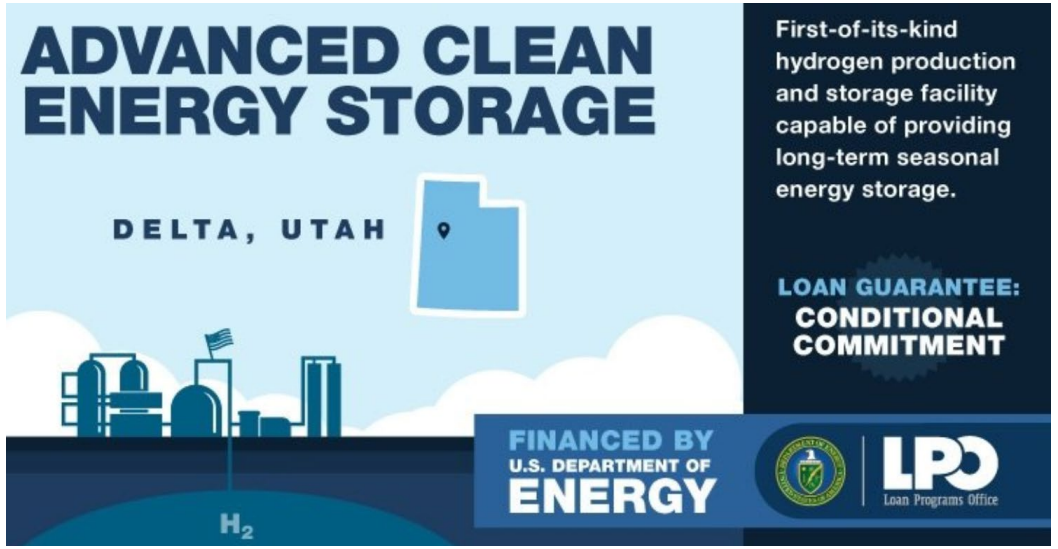
Financing to Enable Deployment at Scale

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


The Bipartisan Infrastructure Law
a.k.a Infrastructure Investment and Jobs Act (IIJA)
and
Inflation Reduction Act

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**

BIL Hydrogen Provisions cover Range of RDD&D

Manufacturing RD&D across H_2 and fuel cell technologies

Raw Materials → Processed Materials → Subcomponents → End Product

Includes end of life (EOL) & recycling RD&D

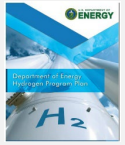
Sec. 40314 (EPACT Sec 815): Clean Hydrogen Manufacturing & Recycling **$0.5 Billion over 5 years**

Electrolysis RD&D: BIL Includes RD&D across multiple electrolysis technologies, compression, storage, drying, integrated systems, etc.

Sec. 40314 (EPACT Sec 816): Clean Hydrogen Electrolysis Program; **$1 Billion over 5 years. Goal $2/kg by 2026**

Regional Clean H_2 Hubs: At least 4 Hubs, geographic diversity, includes renewables, fossil + CCS, nuclear, for clean hydrogen production, multiple end use applications

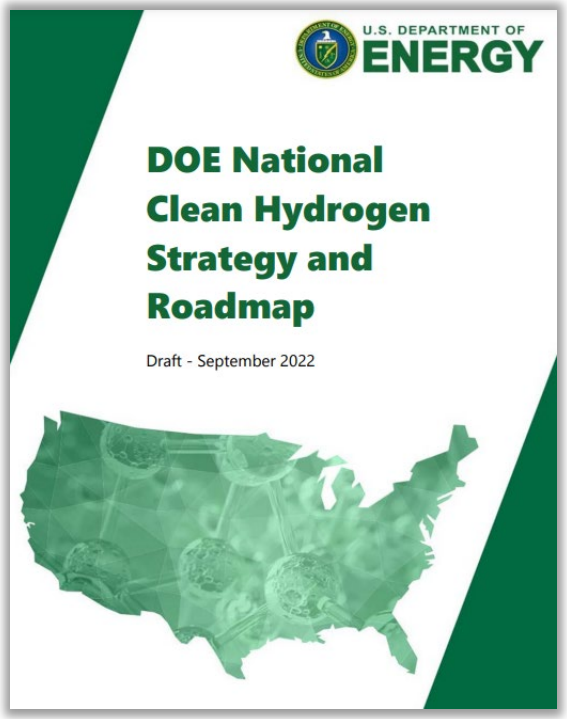
Sec. 40314 (EPACT Sec 813): Regional Clean Hydrogen Hubs; **$8 Billion over 5 years**



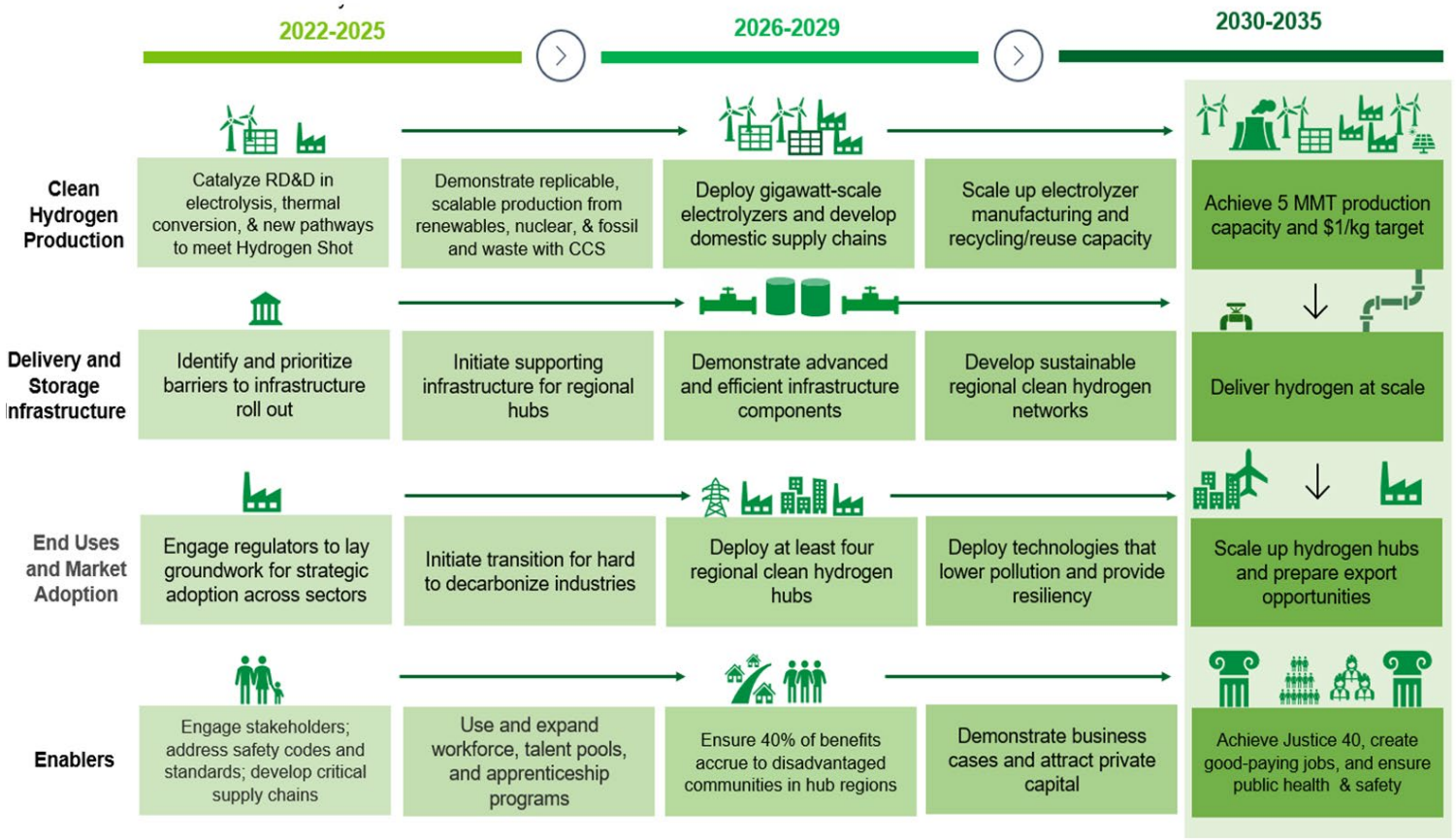
National Hydrogen Strategy and Roadmap: Within 180 days
Clean Hydrogen Standard: 2 kg CO_2e/kg H_2, update within 5 yrs

Sec. 40314 (EPACT Sec 814: Strategy & Roadmap and **Sec. 40315 (EPACT Sec 822)**: Clean Hydrogen Production Qualifications)

DOE's National Clean Hydrogen Strategy and Roadmap



Roadmap and Action Plan to Address Barriers



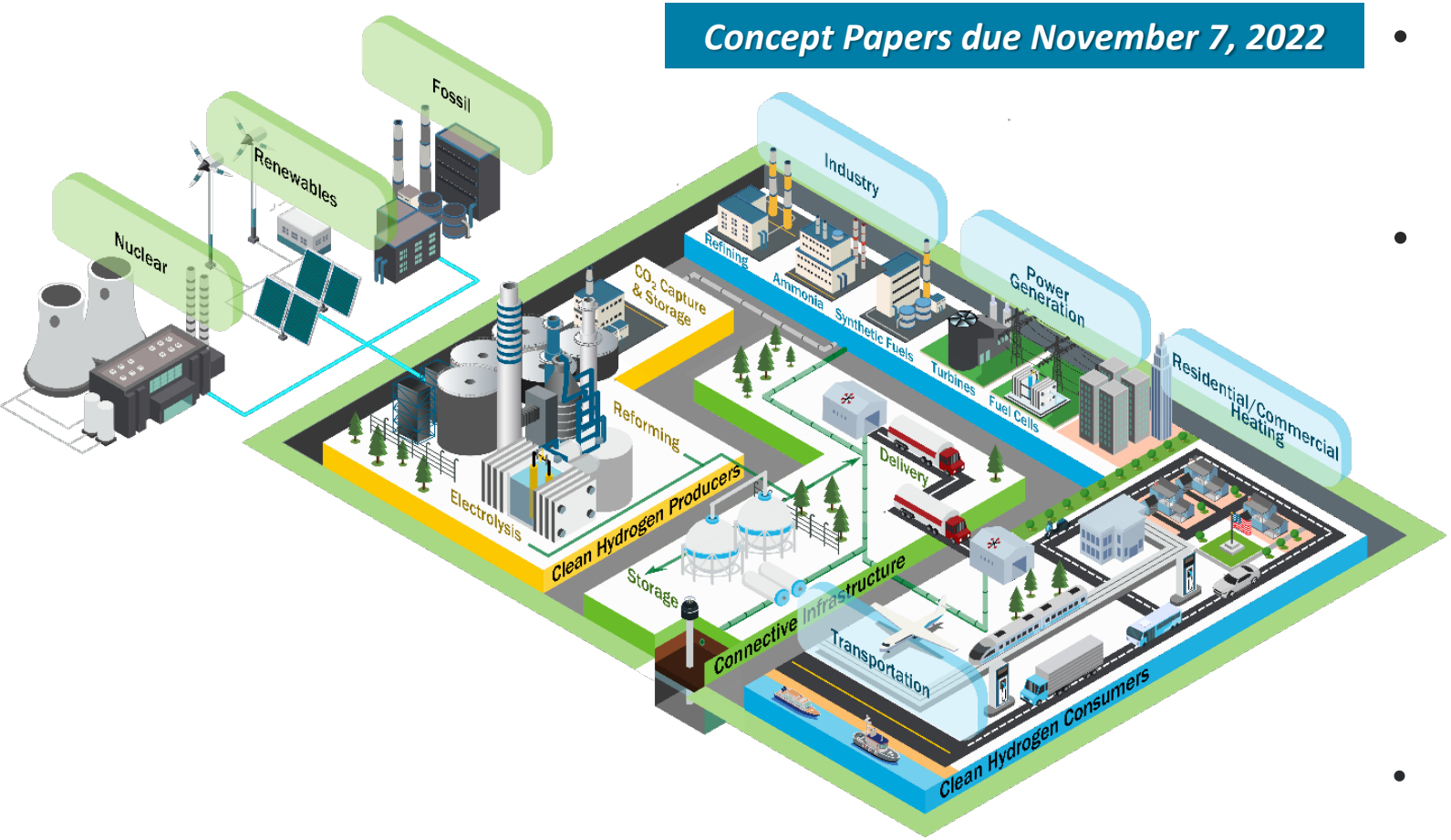
Includes quantitative, industry-driven targets to enable market competitiveness:
Examples include: \$1/kg H_2 production, \$2/kg delivery, \$8/kWh storage, \$80/kW fuel cell, etc.

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

Clean Hydrogen Hubs FOA Released! *(more to come from OCED)*

Biden-Harris Administration Announces Historic $7 Billion Funding Opportunity to Jump-Start America's Clean Hydrogen Economy | Department of Energy

Concept Papers due November 7, 2022



- DOE is aiming to select six to ten hubs for a combined total of up to $7 billion in federal funding
- Includes a Community Benefits Plan to:
  - Support meaningful community and labor engagement;
  - Invest in America's workforce;
  - Advance diversity, equity, inclusion, and accessibility; and
  - Contribute to the President's goal that 40% of the overall benefits of certain federal investments flow to disadvantaged communities
- All questions regarding this FOA should be submitted to: H2Hubs@hq.doe.gov

Funding Opportunity Announcements (FOAs) for Electrolysis & Manufacturing/Recycling Programs under development

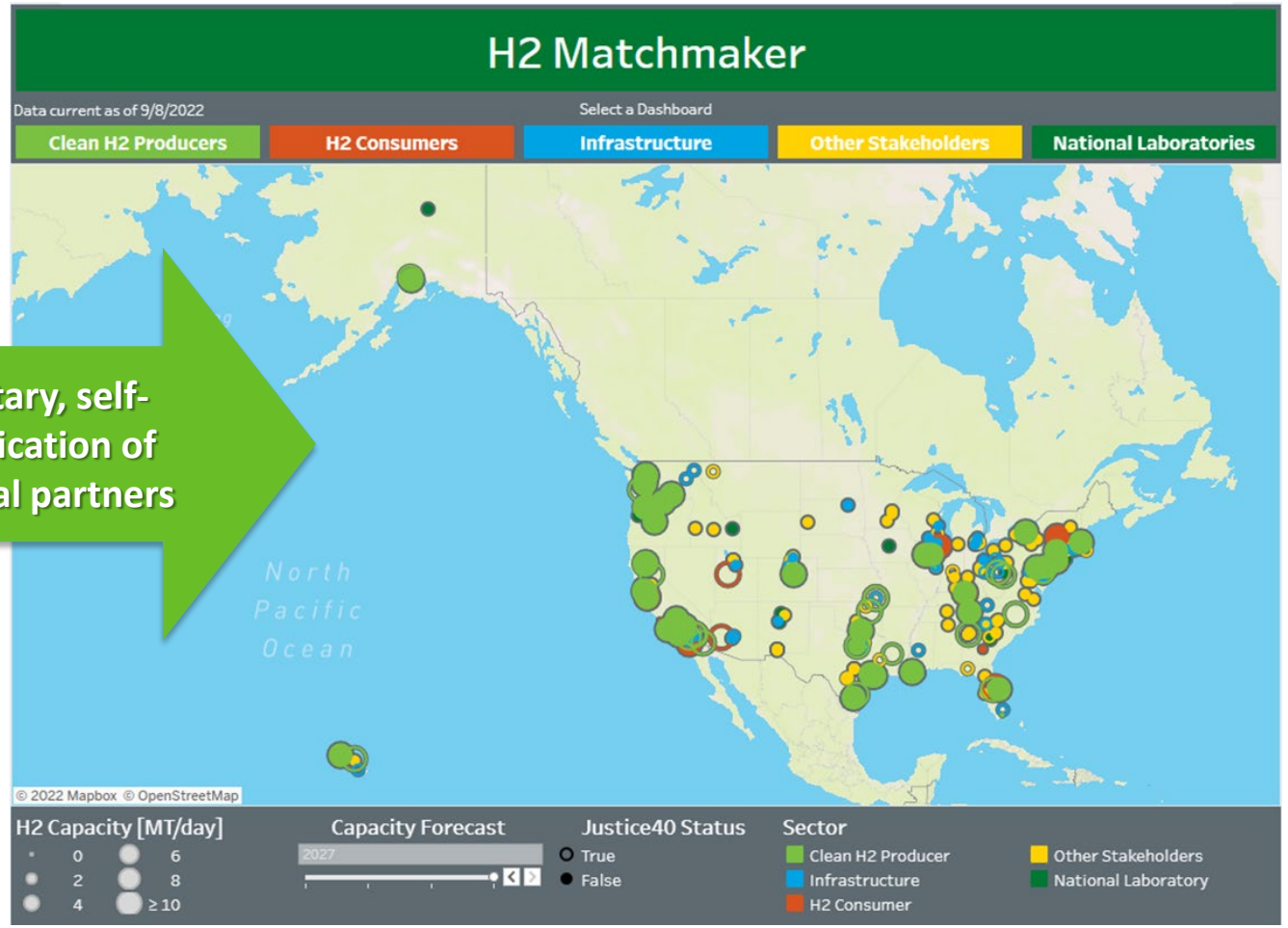
H_2 Matchmaker (https://www.energy.gov/eere/fuelcells/h2-matchmaker)

H_2 Matchmaker aims to facilitate the development of high-quality Hydrogen Hubs

414 Activities Added

- 71 H_2 Producers
- 36 H_2 Consumers
- 91 Infrastructure Providers
- 21 National Laboratory Campuses
- Only one tribal entity listed on the site

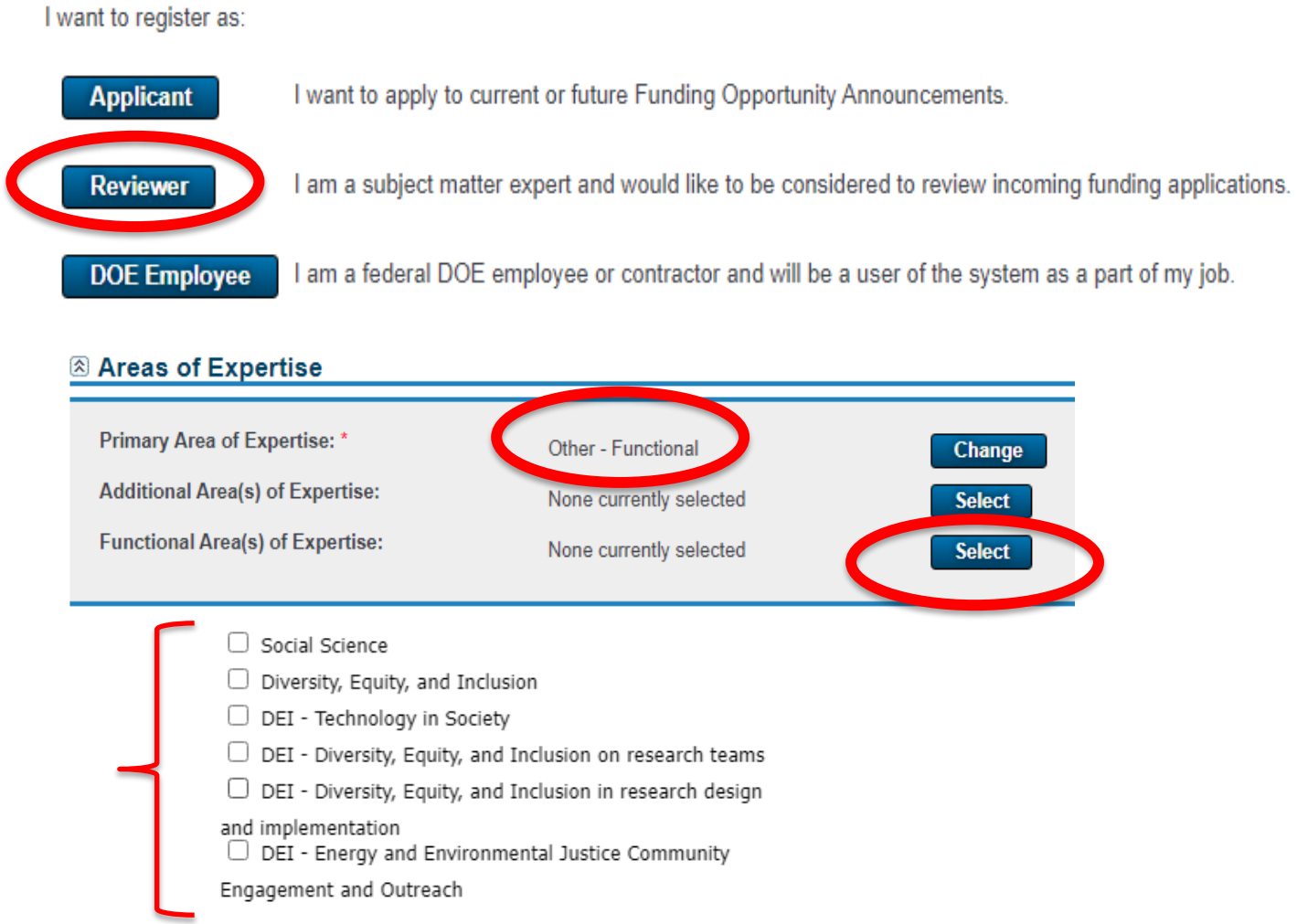
Voluntary, self-identification of potential partners



Request from DOE: Help publicize & encourage data entry

Getting Involved: Suggest or Become an EJ Reviewer

Go to the EERE Funding Opportunity Exchange website and select the "Reviewer" button to register



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 Matchmaker** for 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**

Examples of Tribal Engagement

Engagement with Tribes included:

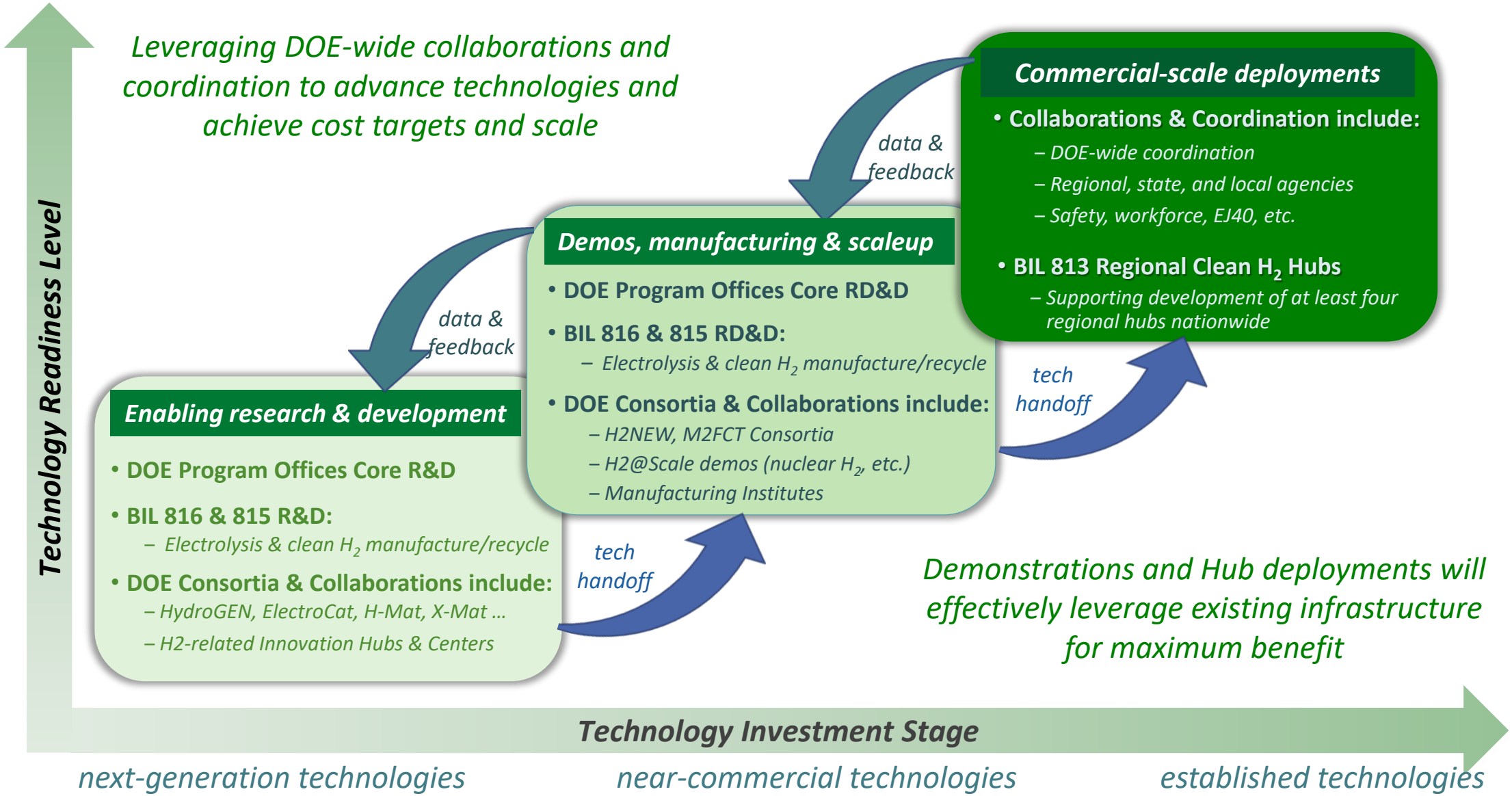
- Hydrogen Shot Summit
- Listening Sessions
- Engagement on potential BIL activities which includes direction to:

A. Support **domestic supply chains** for materials and components;
B. Identify and incorporate nonhazardous **alternative materials** for components and devices;
C. Operate in partnership with tribal energy development organizations, Indian Tribes, Tribal orgs., Native Hawaiian community-based organizations, or territories or freely associated States; or
D. Are located in **economically distressed areas** of the major natural gas-producing regions of the US

Collaboration with DOE Office of Indian Energy

See: www.energy.gov/indianenergy/office-indian-energy-policy-and-programs

All-Hand-on-Deck! Strategic Portfolio spans across RDD&D



U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Hydrogen and Fuel Cell Technologies Office (HFTO)

Dr. Eric L. Miller

Chief Scientist, U.S. Department of Energy Hydrogen and Fuel Cell Technologies Office

October 5, 2022

The Hydrogen and Fuel Cell Technologies Office (HFTO)

Mission

Research, development and demonstration (RD&D) of hydrogen and fuel cell technologies to advance:

- Clean Energy and Emissions Reduction Across Sectors
- Job Creation and a Sustainable and Equitable Energy Future

Budget Sub-Programs

Hydrogen Technologies

- Hydrogen Production
- Hydrogen Infrastructure and Storage

Fuel Cell Technologies

- Materials & Components
- Systems

Systems Development & Integration

- Transportation
- Industrial and Chemical Applications
- Grid Energy Storage and Power Generation
- Safety, Codes and Standards

Enabling

H2@Scale℠ U.S. Department of Energy

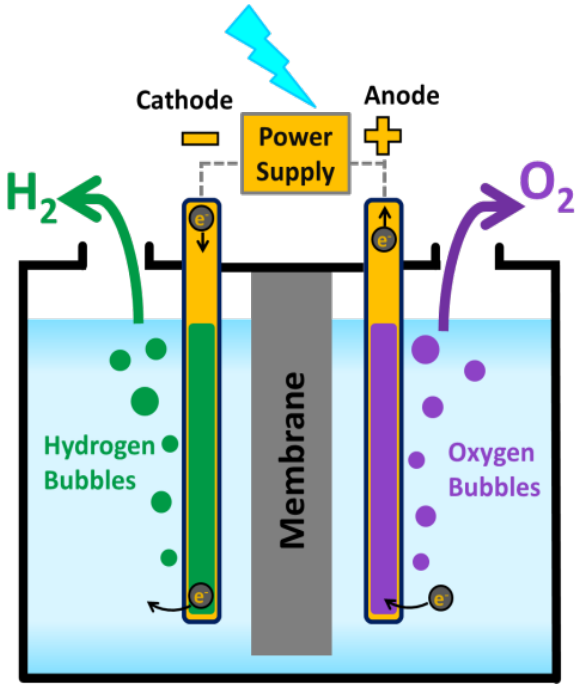
Data, Modeling, and Analysis

Coordinating RDD&D activities across the DOE Hydrogen Program

Key HFTO Technologies: Fuel Cells and Electrolyzers

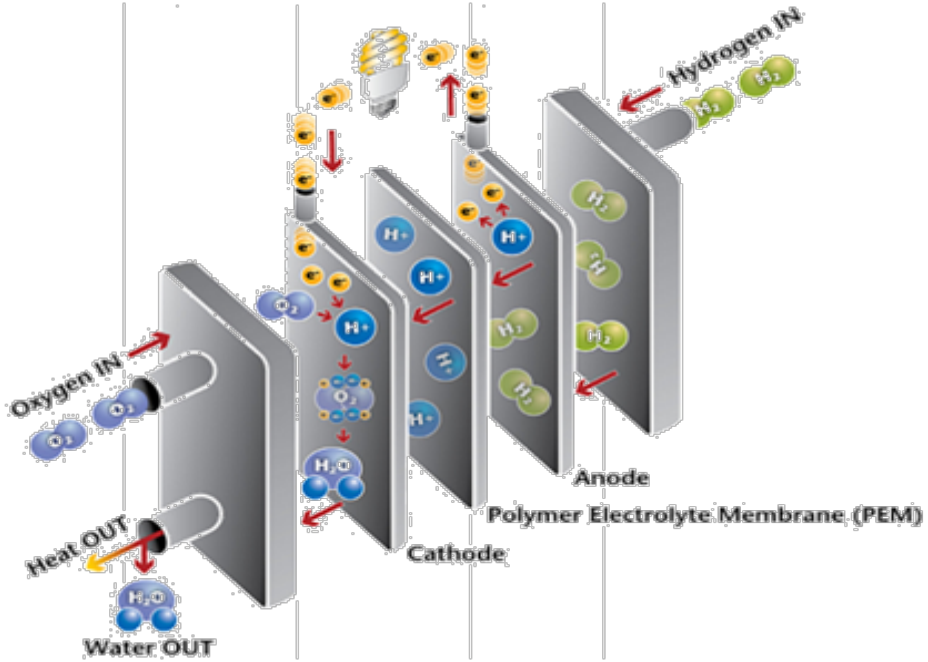
Electrolyzers: Make Hydrogen

- Electricity and Water IN
- Hydrogen and Oxygen OUT
- Makes hydrogen using electricity
- Operates like a fuel cell “in reverse”



Fuel Cells: Use Hydrogen

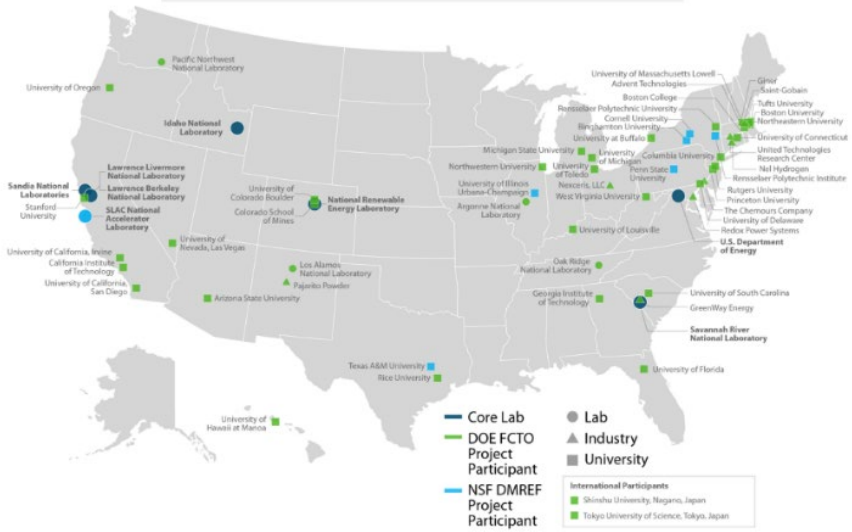
- Hydrogen and Oxygen IN
- Electricity and Water OUT
- Makes electricity using hydrogen
- No combustion involved



HydroGEN R&D: Advanced Water-Splitting Materials

HydroGEN
Advanced Water Splitting Materials

11 Labs, 10 Companies, 39 Universities, 2 Funding Agencies



Core National Lab Team

NREL Transforming ENERGY
BERKELEY LAB Bringing Science Solutions to the World
Sandia National Laboratories
INL Idaho National Laboratory
Lawrence Livermore National Laboratory

- **31 seedling projects supported**
- **46 capabilities utilized across 5 labs**
- **4 community benchmarking workshops**
- **118 Publications, Impact factor* = 2.20**
  2,783 citations, 436 authors
- **STEM Work Force Development**
- **Diverse leadership and community**

*Field-weighted citation impact (FWCI) indicates how the number of citations received by the Publication Set's publications compares with the average number of citations received by all other similar publications in Scopus.

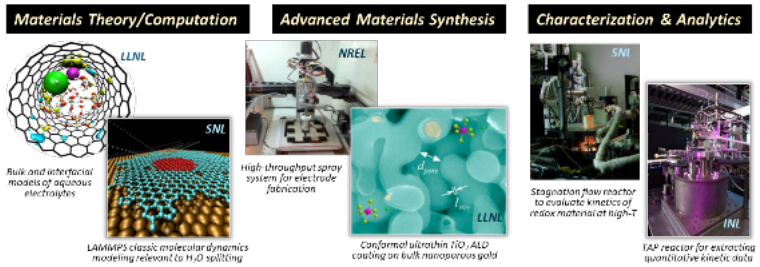
Non-Disclosure Agreement (NDA) → Information Disclosure

Intellectual Property Management Plan (IPMP) → IP Protection

Materials Transfer Agreement (MTA) → Freedom to Operate

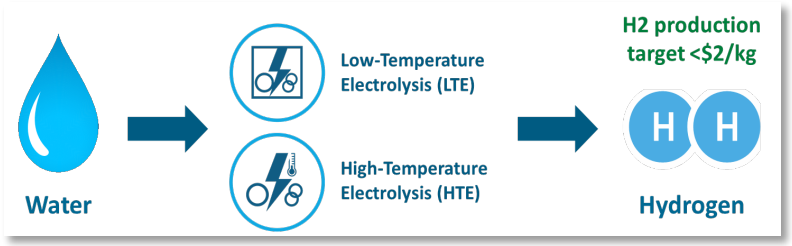
Cooperative Research and Development Agreement (CRADA) → Collaboration

https://www.h2awsm.org/working-with-hydrogen



HydroGEN is vastly collaborative, has produced many high value products, and is disseminating them to the R&D community.

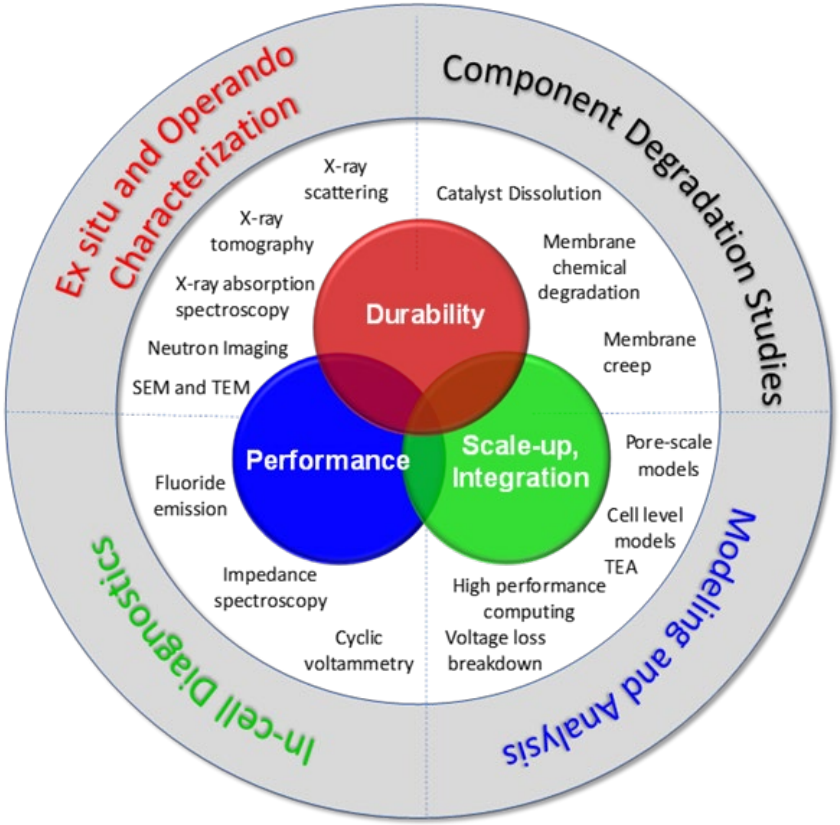
H2NEW RD&D: Accelerating Progress in Electrolyzers



Electrolyzer Stack Goals by 2025		
	LTE PEM	HTE
Capital Cost	$100/kW	$100/kW
Elect. Efficiency (LHV)	70% at 3 A/cm^2	98% at 1.5 A/cm^2
Lifetime	80,000 hr	60,000 hr

Includes focus on durability to:

- → Improve understanding of degradation mechanisms
- → Develop and validate accelerated degradation processes to evaluate durability



Combines world-class experimental, analytical, and modeling tools

Consortium Team

NREL · INL · Pacific Northwest · Argonne · Lawrence Livermore National Laboratory · NETL · Los Alamos · Oak Ridge National Laboratory · NIST · Berkeley Lab · Carnegie Mellon University · Colorado School of Mines · UC Irvine

PEM, Liquid Alkaline (new expansion), SOEC

M2FCT RD&D: Advancing Heavy-Duty Fuel Cell Technologies

"Team-of-teams" approach for rapid feedback, idea development, and information exchange,

MEA Projects

GM · Carnegie Mellon University · NIKOLA

Membrane Projects

Lubrizol · 3M · NIKOLA

Stack Projects

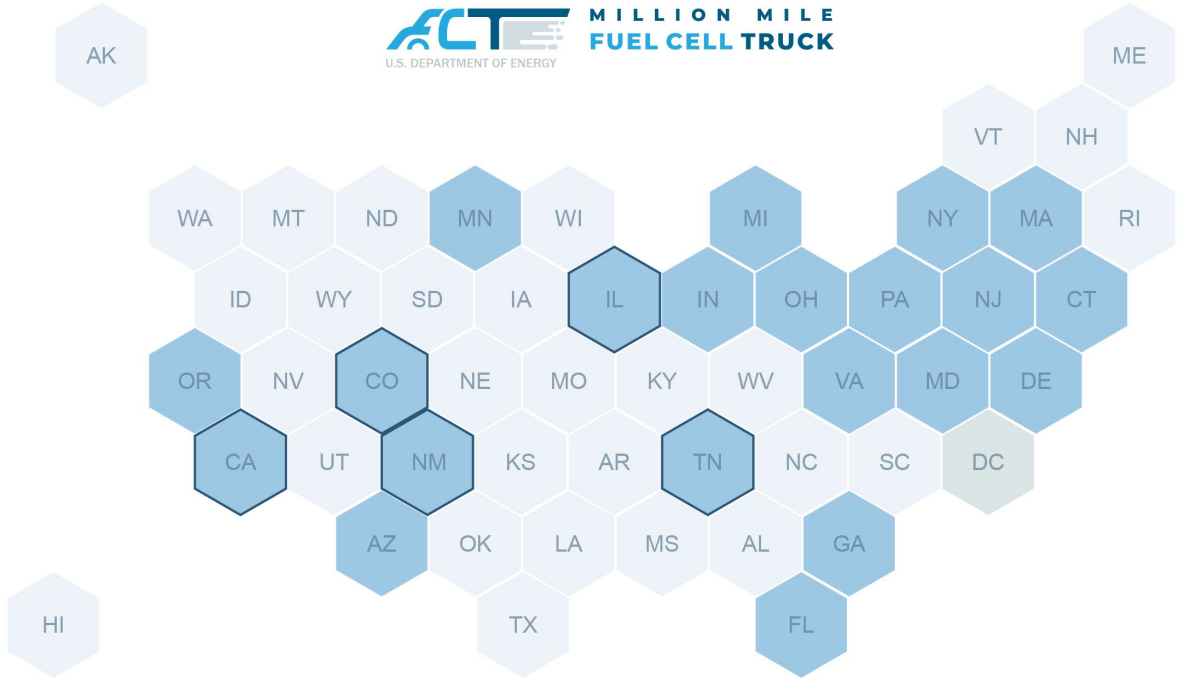
Cummins · PLUG POWER

Bipolar Plate Projects

Raytheon Technologies · NEOGRAF SOLUTIONS · TreadStone Technologies, Inc. · GM · PLUG POWER

Air Management Projects

CATERPILLAR · EATON · R&D Dynamics Corporation · MAHLE Driven by performance



LABS

Primary Labs
- LANL
- LBNL
- ANL
- NREL
- ORNL

Partners
- PNNL
- BNL
- NIST

ACADEMIA

Partners
- Cornell
- Carneige Mellon Univ.
- Colorado School of Mines
- Drexel University
- Florida International Univ.
- GeorgiaTech
- Northeastern
- UC Irvine
- UC Merced
- University at Buffalo
- University of Tennessee

INDUSTRY

Partners
- 3M Company
- Akron Polymer Products
- Ballard
- Chemours
- Cummins
- Caterpillar
- Eaton
- General Motors
- Kodak
- Lubrizol
- Mahle
- Nikola Motors
- Pajarito Powder
- Plug Power
- NeoGraf Solutions
- R&D Dynamics Corp
- Raytheon Technologies
- Strategic Analysis
- TreadStone Technologies

Main Laboratories

Los Alamos NATIONAL LABORATORY · BERKELEY LAB · Argonne NATIONAL LABORATORY · OAK RIDGE National Laboratory · NREL NATIONAL RENEWABLE ENERGY LABORATORY

Affiliate Laboratories

Pacific Northwest NATIONAL LABORATORY · NIST National Institute of Standards and Technology · BROOKHAVEN NATIONAL LABORATORY

Discretionary Funds Project Partners

Drexel UNIVERSITY · UNIVERSITY OF CALIFORNIA MERCED · BUFFALO STATE The State University of New York · FIU FLORIDA INTERNATIONAL UNIVERSITY · UCI

HFTO Examples of Accomplishments

Innovation

1,256 Patents

in hydrogen and fuel cell technologies through HFTO funding from Labs, Industry and Academia

35% from National Labs

Technology-to-Market

30 Technologies Commercialized

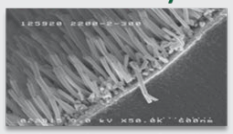
By private industry

65 With Potential to Enter Market

in the next 3-5 years

Examples of Technologies Enabled

Fuel Cell Catalysts



Catalyst and Supports for PEM Fuel Cells
3M

Hydrogen Tube Trailers

Hydrogen Tube Trailers
Hexagon Lincoln

Forklifts

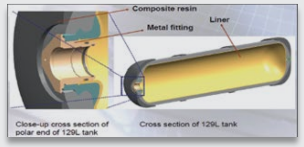
Class-1, -2, and -3 Forklifts
Plug Power (GenDrive FCs)

Electrolyzers

Electrolyzer System
Proton Series

PEM Electrolyzer System
Giner

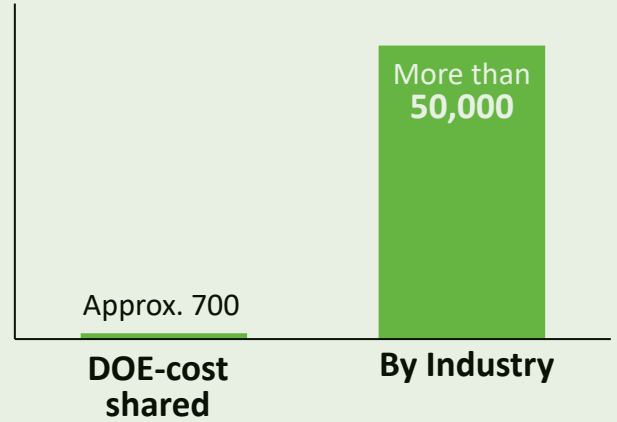
Hydrogen Tanks



Optimized 129L Tank
Quantum Technologies

Market Uptake

Hydrogen fuel cell forklifts in the U.S.



American-made small-scale hydrogen refueler

- Exported to Japan
- Uses electrolysis

International Coordination in Clean Hydrogen

Collaborating through multiple global and bilateral partnerships—key priority is creating coordinated framework to leverage activities, identify gaps, and avoid duplication to accelerate progress

CEM Global Ports Coalition with EC
Numerous Bilaterals on Hydrogen
Hydrogen Council, IRENA, and more

The International Partnership for Hydrogen and Fuel Cells in the Economy

Enabling the global adoption of hydrogen and fuel cells in the economy

H_2 Production Analysis (H2PA)
To facilitate international trade
Common analytical framework for GHG emissions footprint

Regulations, Codes, Standards, Safety and Education & Outreach Working Groups

www.iphe.net

Breakthrough Agenda in collaboration with other partnerships is mapping activities across global H_2 initiatives to identify gaps, focus areas, and prioritized workstreams

IPHE Early Career Network

Chair
Christine Watson (USA)

Co-Chair
Regional Director of Asia, Middle East, USA
Gaurav Shukla (India)

Co-Chair
Kendall Parker (USA)

Calling all hydrogen-enthusiast **STUDENTS** (undergrad & grad), **POST-DOCS**, and **EARLY CAREER PROFESSIONALS** worldwide!

Connect with peers, mentors, scientific researchers, industry professionals, and policymakers!

Join 230+ members from over 37 countries!

Join now & fill out our survey on YOUR career needs and interests:
www.iphe.net/early-career-chapter

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Sanskar Vaishnav
(Denmark)

Regional Director of Europe
Thilo Krechlak
(Germany)

Regional Director of Africa
Faan Du Preez
(South Africa)

Education & Outreach Directors
Qingwang Yuan
(USA)
Bikram Roy Chowdhury
(USA)

Communications & Social Media Director
Yangwei Liu
(USA)

Community Manager
Ander Martinez Alonso
(Belgium)

IPHE Comm. Liaison
Ted Kwon
(Korea)

Opportunities for Continued Engagement

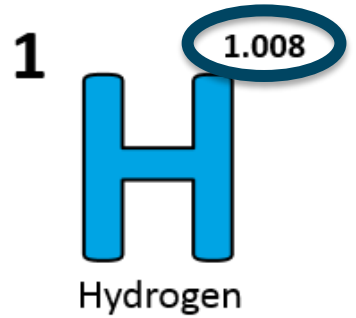
ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

Save the date!

2023 DOE Annual Merit Review and Peer Evaluation Meeting
June 5-8, 2023

Hydrogen and Fuel Cells Day
October 8

- Held on hydrogen's very own atomic weight-day



INCREASE YOUR H2IQ hydrogen.energy.gov

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https://h2tools.org/

CENTER FOR Hydrogen SAFETY
Connecting a Global Community

www.aiche.org/CHS

Sign up to receive hydrogen and fuel cell updates

www.energy.gov/eere/fuelcells/fuel-cell-technologies-office-newsletter

Learn more at: energy.gov/eere/fuelcells AND www.hydrogen.energy.gov

We would love to hear from you!

Tribal Point of Contact

Michelle Fox

Michelle.fox@ee.doe.gov

Thank you

Hydrogen and Fuel Cell Technologies Office
U.S. Department of Energy

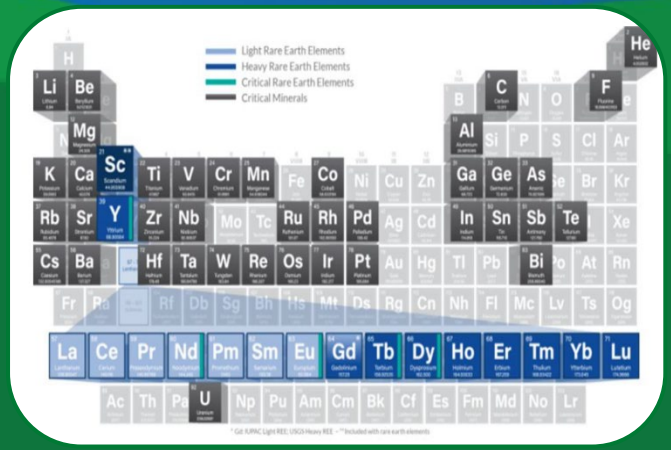
www.energy.gov/fuelcells
www.hydrogen.energy.gov

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

Fossil Energy and Carbon Management Hydrogen Program

Bob Schrecengost
Division of Hydrogen with Carbon Management

October 5, 2022



Fossil Energy and Carbon Management (FECM)

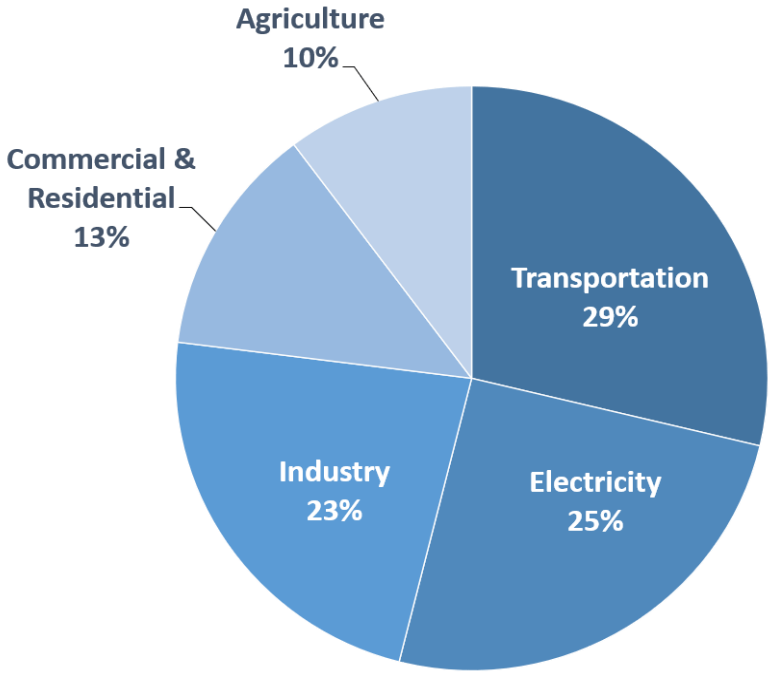
Office of Fossil Energy and Carbon Management

DOE-FE is now DOE-FECM

New name for our office reflects our **new vision**

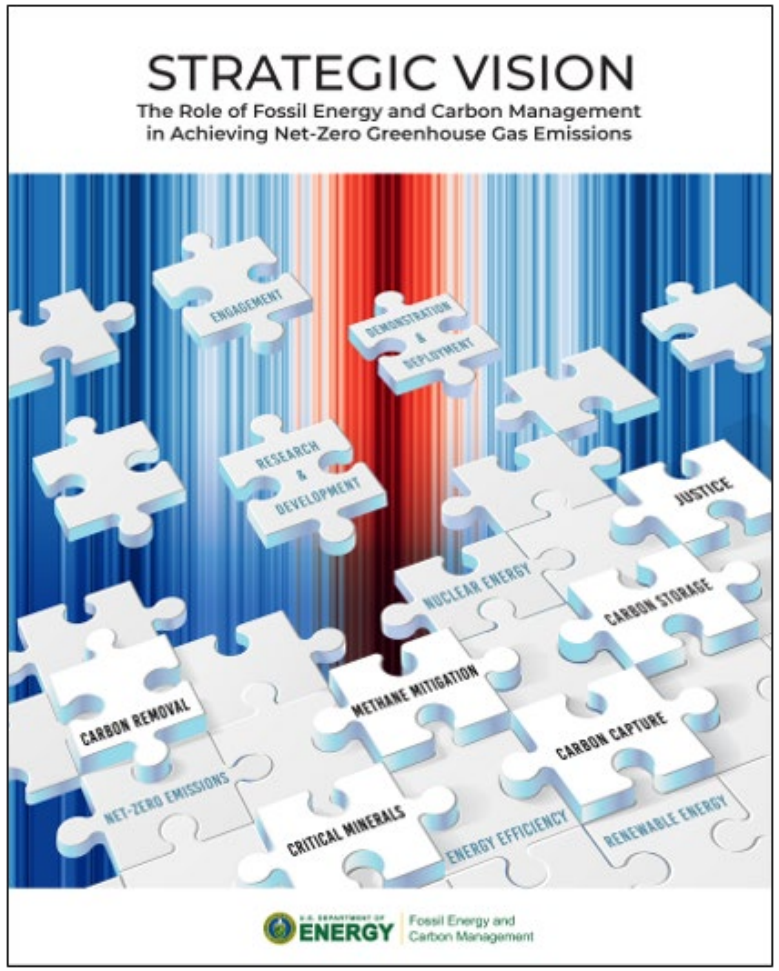
- President Biden's goals:
  - 50% emissions reduction by 2030
  - CO_2 emissions-free power sector by 2035
  - Net zero emissions economy by no later than 2050

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2019



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

A Vision for Carbon Management



A carbon management framework that will guide FECM's engagement with offices across the Department, Federal agencies, tribal and international governments, industry, non-governmental organizations, and communities

Advancing Justice, Labor, and Engagement

Priorities: *Justice, labor, and international and domestic partnerships*

Advancing Carbon Management Approaches Toward Deep Decarbonization

Priorities: *Point-source carbon capture (PSC), carbon dioxide conversion, carbon dioxide removal (CDR), and reliable carbon transport and storage*

Advancing Technologies that Lead to Sustainable Energy Resource

Priorities: *Hydrogen with carbon management, domestic critical minerals (CM) production, and methane mitigation*

Hydrogen Program Elements in FECM

- FECM's role is to focus on hydrogen production from fossil resources, waste such as plastics, and available biomass, along with CCUS, to achieve net-zero carbon hydrogen, as well as large scale power generation using turbines and large scale/geological H_2 storage.
- FECM also collaborates with EERE's Hydrogen and Fuel Cell Technologies Office.

Advanced Energy and Hydrogen Systems

- 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 Technologies

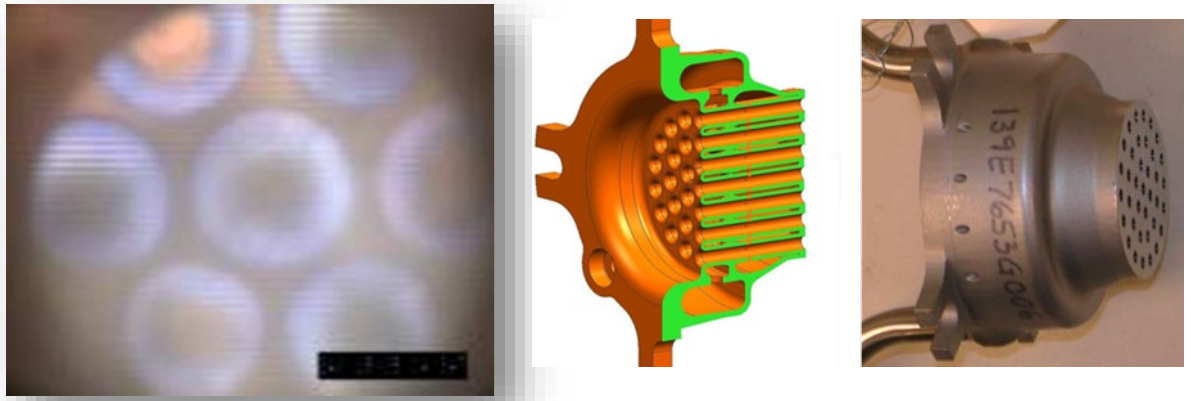
- The Natural Gas Technologies Program is comprised of 4 subprograms, including the newly-proposed Natural Gas Hydrogen Research subprogram.
- Focus areas for the new subprogram include advancing technologies for the carbon-neutral production, transportation, and storage of hydrogen sourced from natural gas.

Advanced Turbines (AT) Program Goals

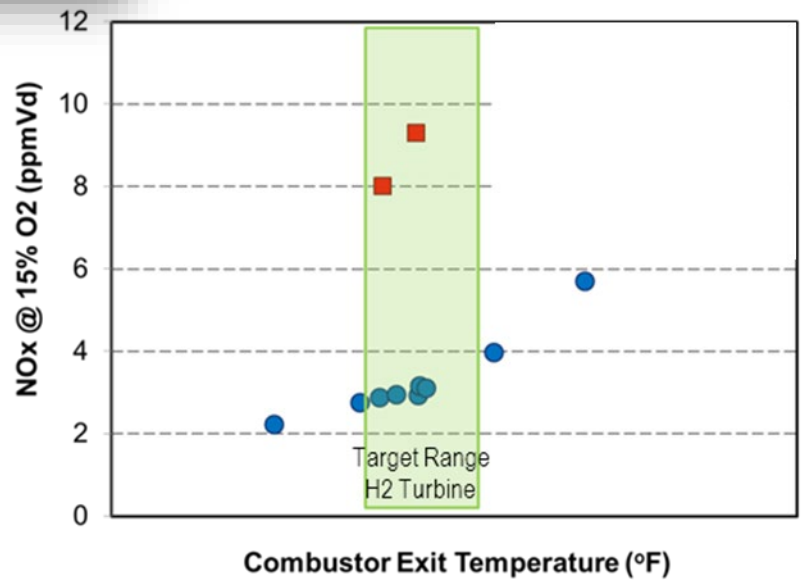
Mission - Deliver low cost, clean and carbon free electric power

Achieve 100% hydrogen firing with low NOx

- Past tests for 100+ hours full can combustor operation with > 90% H_2, 20 hrs operation with 100% H_2.
- < 3 ppm NOx @15% O_2 at target temperature with N_2 diluent.
- NOx emissions for H_2 fuels likely similar to natural gas that have been demonstrated for full scale combustor geometries.



High-Hydrogen



H2IQ Hour webinar recording on H_2 NOx emissions available soon.
https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office-webinars

Ref: Proceedings of ASME Turbo Expo 2012, June 11-15, 2012, Copenhagen, Denmark, GT2012-69913; DEVELOPMENT AND TESTING OF A LOW NOX HYDROGEN COMBUSTION SYSTEM FOR HEAVY DUTY GAS TURBINES, W. York, W. Ziminsky, E. Yilmaz *

Current Gasification System Research

Modular Technology: Helping Gasification Access New Markets

Smaller, modular gasifier

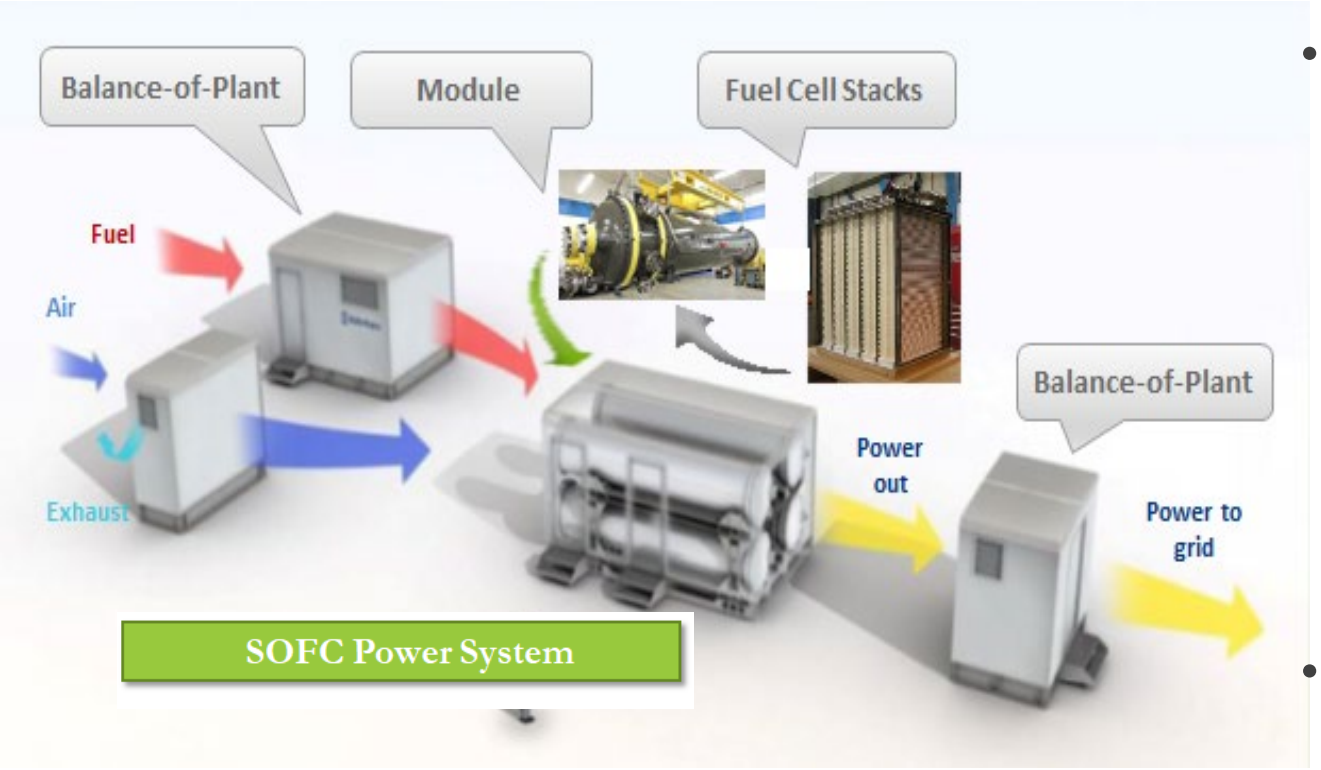
- Faster development
- Lower capital investment
- Lower financial risk

New Markets

Business Impacts:

- **CapEx/OpEx reduction:** through advanced manufacturing, plant-wide cost reduction opportunities
- **Regional opportunities:** enable local markets to quickly and cost-effectively utilize local feedstocks including legacy coal waste, wase plastic, MSW, and biomass wastes with CCS technology.

Current SOFC System Research



- Conduct R&D to address critical needs and mature technology – Synergy with reversible solid oxide fuel cell technology for hydrogen production
  - Cell materials and fabrication to improve performance and lower cost
  - Understanding cell and stack degradation mechanisms
  - Balance-of-plant components – cost reduction and reliability improvement
- Acquired fabricating and operational experience on integrated, prototype field tests – SOFCs and RSOFCs

Open FECM Hydrogen R&D FOAs

FOA 2400: Fossil Energy Based Production, Storage, Transport and Utilization .

- Advanced Air Separation for Low-Cost H2 Production via Modular Gasification (funding $5M, # of awards TBD)
- Clean Hydrogen Production and Infrastructure for Natural Gas Decarbonization (funding $21M, # of awards TBD)
    - Methane Pyrolysis/Decomposition, Thermochemical or Biological In-Situ Conversion, Cyclical Chemical Reforming
    - Hydrogen from Produced Water
- Technologies for Enabling the Safe and Efficient Transportation of Hydrogen Within the U.S. Natural Gas Pipeline System (funding $3M, # of awards TBD)
- Fundamental Research to Enable High Volume, Long-term Subsurface Hydrogen Storage (funding $3M, # of awards TBD)

Hydrogen R&D Awards

FOA 2400: Fossil Energy Based Production, Storage, Transport and Utilization .

- Solid Oxide Electrolysis Cell (SOEC) Technology Development for H_2 Production ($8M over 2 years, 8 awards)
- H_2 Combustion Systems for Gas Turbines: F-class, Industrial and Aero ($15M over 4 years, 3 awards)
- Ammonia Combustion Systems for Gas Turbines ($6M over 4 years, 2 awards)
- Demonstration of a Rotating Detonation Engine in a Gas Turbine ($7M over 4 years, 1 award)
- Initial Engineering Design of Advanced CO_2 Capture from H_2 Production ($4.5M over 1.5 years, 3 awards)
- Modularization for Clean Hydrogen Cost Reductions for Hydrogen Shot ($8.4M over 3 years, 6 awards)
- Production of Clean hydrogen from High Volume Waste Materials and Biomass, with carbon capture ($7.5M over 3 years, 5 awards)
- Sensors & Controls for co-gasification of waste plastics in production of hydrogen with CCS ($1M over 2 years, 2 awards)
- FEED Studies of Advanced CO_2 Capture from Hydrogen Production: SMR or ATR Plants ($12M over 3 years, 2 awards)

Hydrogen R&D Awards

FOA 2613: Advanced Energy Materials for Hydrogen Turbines for Stationary Power Generation

- Develop turbine components within the hot gas path using ceramic matrix composites ($4.7M over 3 years, 6 awards)

FOA 2397 University Turbines System Research

- Focus on Hydrogen Fuels Awards on hydrogen combustion systems, ammonia combustion fundamentals, and rotating detonation engines

FOA 2376 Gasification

- Enabling Gasification of Blended Coal, Biomass and Plastic Wastes to Produce Hydrogen with Potential for Net Negative Carbon Dioxide Emissions – ($2M over 2 years, 4 awards)

FOA 2300 SOFCs

- Solid Oxide Fuel Cell, Electrolyzer, and Hybrid Technology Development – ($34M over 3 years, 12 awards)

U.S. Government Hydrogen Program and Funding

Inflation Reduction Act (IRA) - Hydrogen Provisions

On August 16, 2022, President Biden signed the IRA into law. The bill raises $737 billion in revenue and authorizes $369 billion for energy security and climate change-related spending, including for hydrogen specifically. According to White House analysis, the IRA sets the U.S. on track to decrease GHG by about 40% below 2005 levels by 2030. Key hydrogen-related funding covered in the bill includes:

Hydrogen Production and Storage

- Expands IRS Section 45V to introduce a new 10-year **clean hydrogen production tax credit (PTC)** of up to $3/kg multiplied by an applicable percentage for qualified facilities producing hydrogen after December 31, 2022. *See further details on right.*
- Expands IRS Section 48 **investment tax credit** (ITC) to include "energy storage technology", which can include hydrogen energy. The ITC starts at 6% but can increase to 40% if certain requirements are satisfied. Construction of facilities must begin before January 1, 2025. Generally, taxpayers cannot claim both the ITC and PTC for the same project.
- The IRA also includes a "direct pay option" for the same amounts instead of a tax credit. The direct payment for hydrogen and carbon capture facilities will be available for only the first 5 years of production.

Hydrogen Fuel Cell Technology

- $2 billion in grants administered by DOE for domestic production of efficient hybrid, plug-in electric hybrid, plug-in electric drive, and **hydrogen fuel cell** EVs, with a 50% recipient cost share requirement and up to 3% of funding reserved for program administration
- Revised tax credit available for EVs and hydrogen fuel cell vehicles, for a maximum credit of $7,000 for qualified taxpayers.

Kg of CO_2 per kg of H_2	Credit Value ($)
4 - 2.5 kg CO_2	$0.60 / kg of H_2
2.5 - 1.5 kg CO_2	$0.75 / kg of H_2
1.5 - 0.45 kg CO_2	$1.00 / kg of H_2
0.45 - 0 kg CO_2	$3.00 / kg of H_2

The clean hydrogen production tax credit will provide up to $3 per kg of qualified clean hydrogen produced based on a scaled metric of carbon intensity beginning at the base value of $0.60 per kg of hydrogen produced (seen above).

The term 'qualified clean hydrogen' denotes hydrogen which is produced through a process that results in a lifecycle greenhouse gas emissions rate of not greater than 4 kg of CO_2e per kg of hydrogen.

Sources: Fuel Cell & Hydrogen Energy Association (link), WhiteHouse.gov (link)

U.S. Government Hydrogen Program and Funding

Bipartisan Infrastructure Law (BIL) – Hydrogen Provisions

On November 15, 2021, President Biden signed the BIL into law. The bill authorizes $1.2 trillion for a variety of infrastructure-related spending, including $8.5 billion to spur clean hydrogen supply chains, regional clean hydrogen hubs, and commercializing clean hydrogen in transportation, utility, industrial, commercial and residential sectors.

Hydrogen Hubs

- $8 billion authorized and appropriated (FY22-FY26) in grants to accelerate commercialization of, and demonstrate the production, processing, delivery, storage, and end-use of, clean hydrogen. Requires the Secretary of Energy to solicit proposals for regional clean hydrogen hubs and select four regional hubs, which will demonstrate the production, processing, delivery, storage, and end-use of clean hydrogen. Grants will be administered by the newly created DOE Office of Clean Energy Demonstrations (OCED).

Hydrogen R&D

- Establishes a DOE Clean Hydrogen Research and Development Program, which aims to advance R&D and commercialize the use of clean hydrogen in the transportation, utility industrial, commercial, and residential sectors; and (2) demonstrate a standard of clean hydrogen production in the transportation, utility, industrial, commercial, and residential sectors by 2040.
- $1 billion in grants administered through DOE Office of Energy Efficiency and Renewable Energy (EERE) for a newly established clean hydrogen electrolysis program, with the goal of reducing the cost of hydrogen to <$2/kg by 2026.
- $500 million in grants administered through DOE EERE for hydrogen manufacturing, recycling, and research projects.

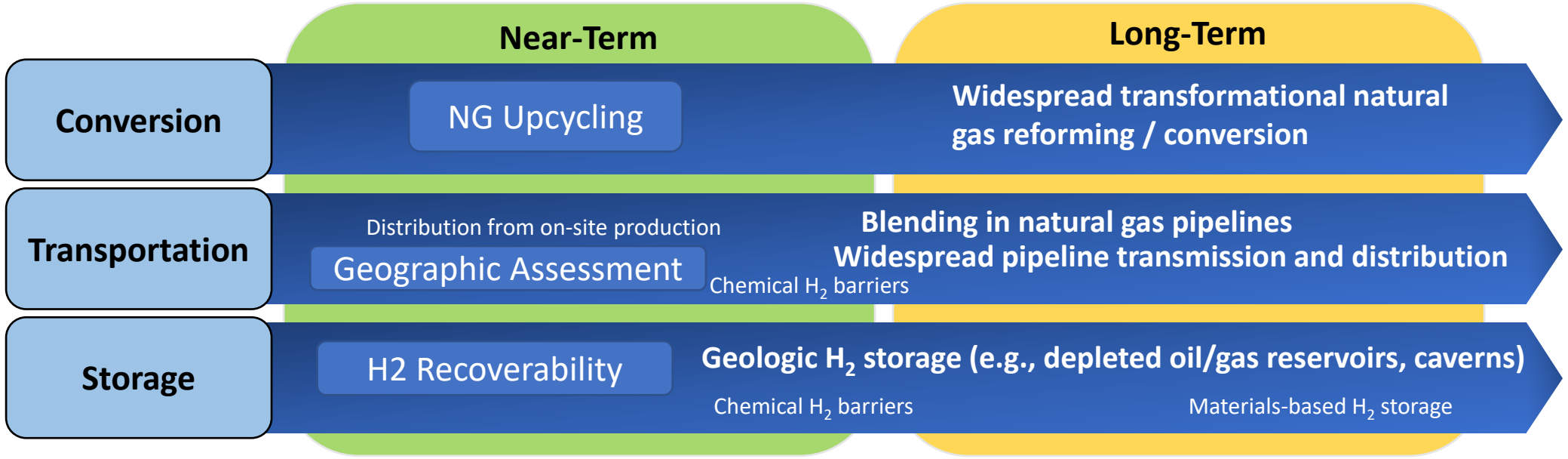
Other

- Requires the DOE to create a national strategy, roadmap, and standard for carbon intensity of clean hydrogen production.
- $2.5 billion in grants for publicly accessible electric vehicle charging infrastructure and hydrogen/propane/natural gas fueling infrastructure.
- $250 million in grants to increase energy efficiency by leveraging high-efficiency systems which use natural gas and hydrogen.

Sources: Bipartisan Policy Center (link)

Natural Gas Decarbonization and Hydrogen Technologies

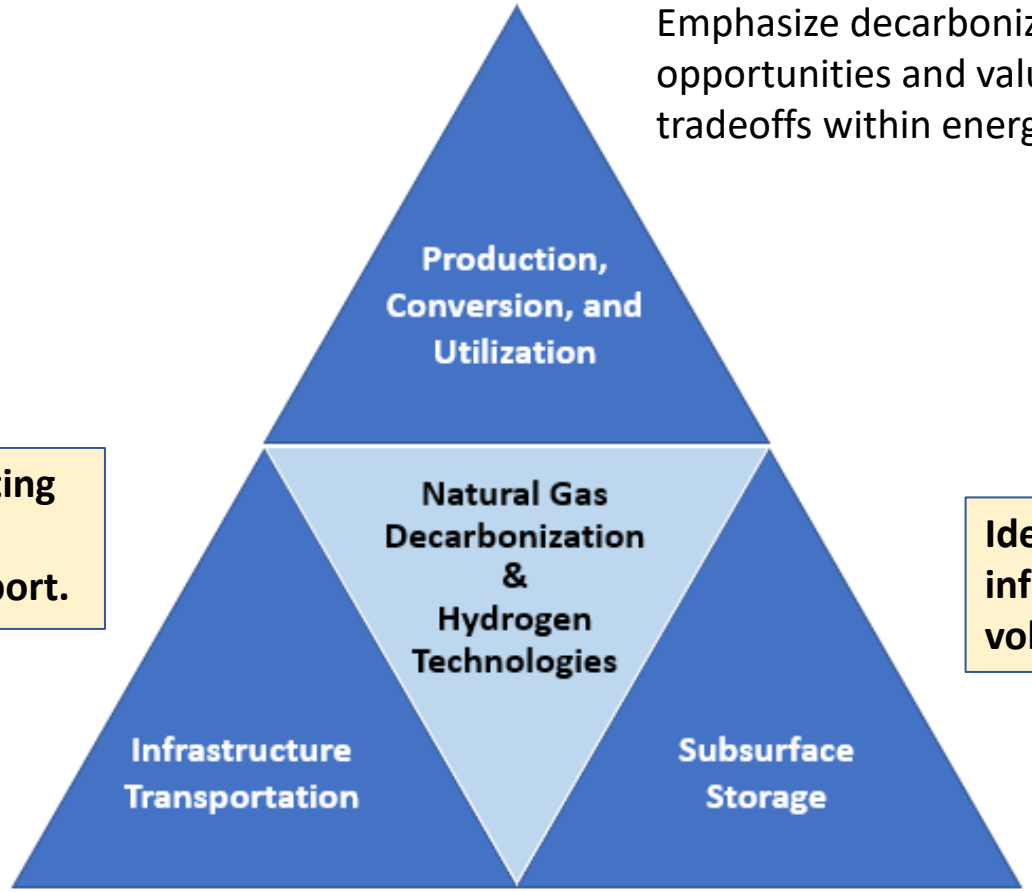
- The **Natural Gas Decarbonization and Hydrogen Technologies** (**NGDHT**) Program was formally initiated in 2022 Omnibus.
- NGDHT Program coordinates with other DOE offices to support the transition towards a clean hydrogen-enabled economy through the decarbonization of natural gas conversion, transportation, and storage.
  - Supports transformational concepts for clean hydrogen production from domestic natural gas resources, with emphasis on decarbonization opportunities and value tradeoffs within energy markets.
  - Works to ensure the suitability of existing natural gas pipelines and infrastructure for hydrogen transport, while emphasizing technology opportunities to detect and mitigate emissions.
  - Identifies underground storage infrastructure to handle high volume fractions of hydrogen, while seeking demonstration opportunities for novel bulk storage mechanisms.



Natural Gas Decarbonization and Hydrogen Technologies Program

Transformational concepts for clean H_2 production from domestic natural gas resources.

Emphasize decarbonization opportunities and value tradeoffs within energy markets.



Ensuring suitability of existing natural gas pipelines and infrastructure for H_2 transport.

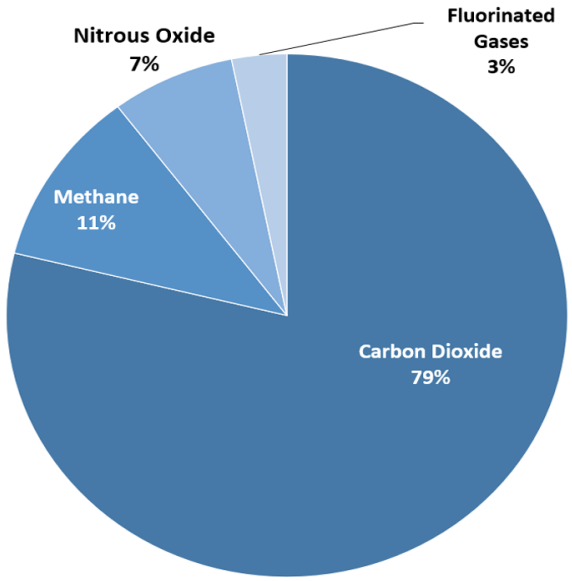
Emphasize technology opportunities to detect and mitigate emissions.

Identify underground storage infrastructure to handle high volume fractions of H_2.

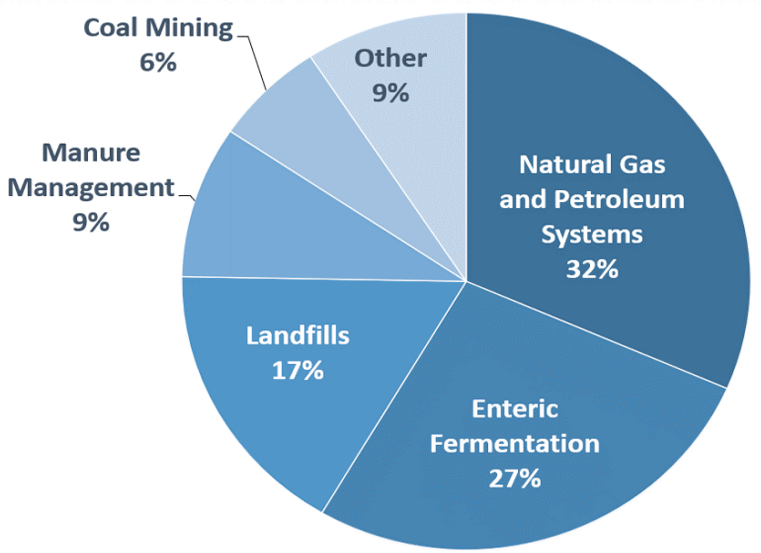
Emphasize demonstration opportunities for novel bulk storage mechanisms.

Methane Mitigation Technologies Program

U.S. Greenhouse Emissions in 2020 *



U.S. Methane Emissions in 2020, By Source *



- The research program is mitigating methane emissions across the oil and natural gas supply chain with work in areas such as:
  - Production (flaring and venting)
  - Gathering lines
  - Pipelines
  - Components (pneumatic controllers, compressors, meters, etc.)
  - Orphan wells

- The research program quantifies emissions from these same parts of the supply chain.
  - Work with EPA to inform their emission factors
  - Independent assessments to inform our own research plans

* Source: U.S. Environmental Protection Agency (EPA) https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020

Technology Pathways for Natural Gas Decarbonization and Clean Hydrogen Production

Natural Gas Feedstock

↓

Transformational Hydrogen Production

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

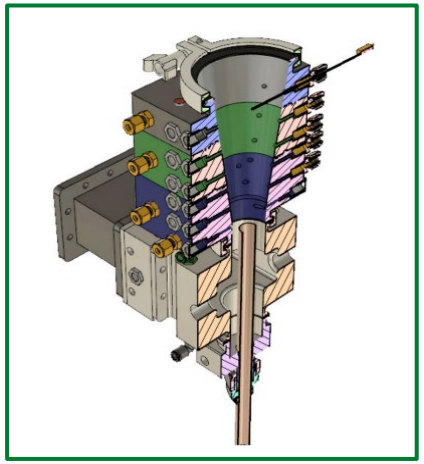
↓

Hydrogen, Solid Carbon, Liquids

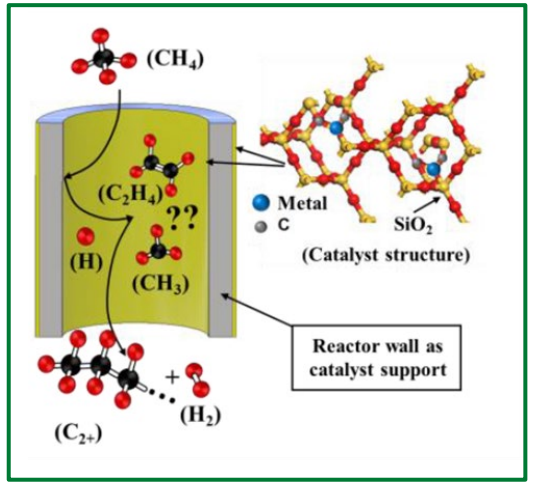
NATIONAL ENERGY TECHNOLOGY LABORATORY

NETL's support of DOE's Initiatives

- 13 total projects are underway targeting reduction of natural gas being flared with modular reactors.
- Processes include electric-powered reactors, photocatalytic conversions that can operate under normal sunlight, and self-heating reactor designs that leverage natural gas as the feedstock and fuel.
- Carbon nanotubes and nanofibers, chemicals like benzene, toluene, xylene, and methanol, and key precursors like ethylene and propylene will be created from associated gas.
- 8 of the 13 proposed systems co-produce purified hydrogen along with target chemicals.
- Partnerships across 9 universities and research organizations.



Design concept for a modular fluidized bed component as part of a microwave plasma reactor development collaboration between NETL and West Virginia University



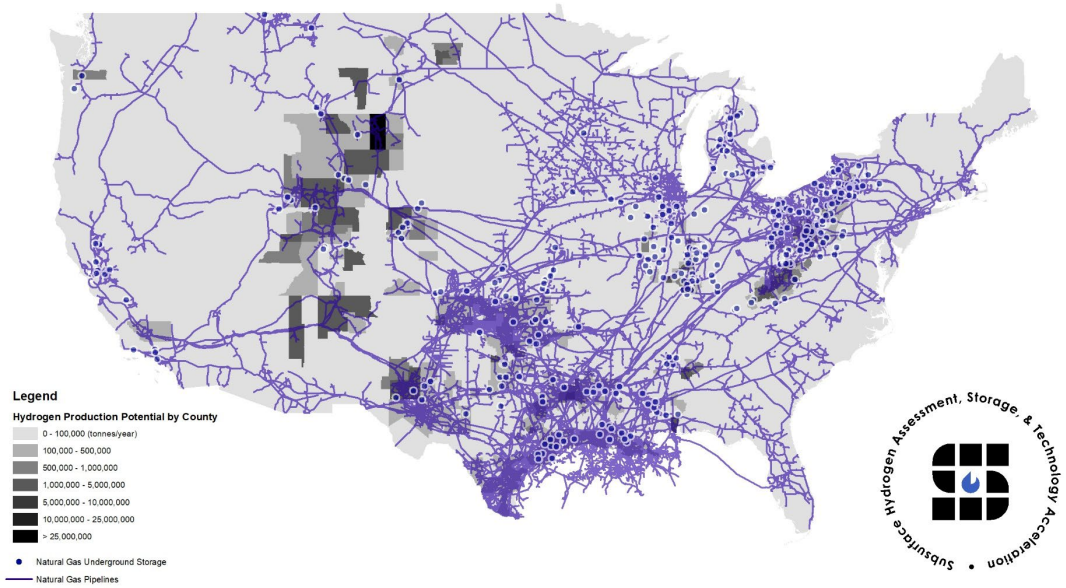
Design for isolated metal atoms in silica built into a catalytic wall reactor as part of an NETL collaboration with the University of Maryland

Hydrogen Pipeline Transportation

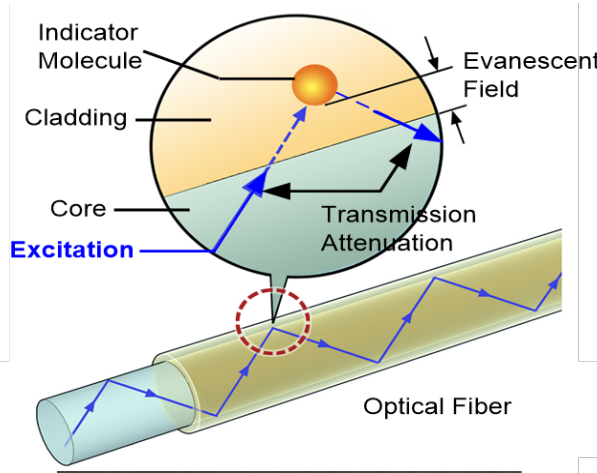
- Characterization of long-term hydrogen impact on piping and pipeline materials and gas blending.
- Life-cycle analysis of emissions from transportation infrastructure.
- Develop advanced sensors, coatings, and materials for hydrogen transportation within blended or dedicated infrastructure.

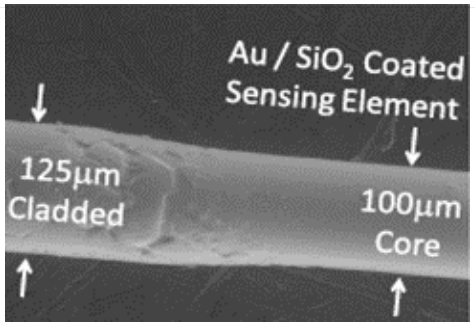
U.S. Natural Gas Pipeline Network
~3 million miles of mainline and other pipelines that link production areas, storage facilities, and consumers.

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

Natural Gas Pipeline Infrastructure and Hydrogen

Goals & Objectives

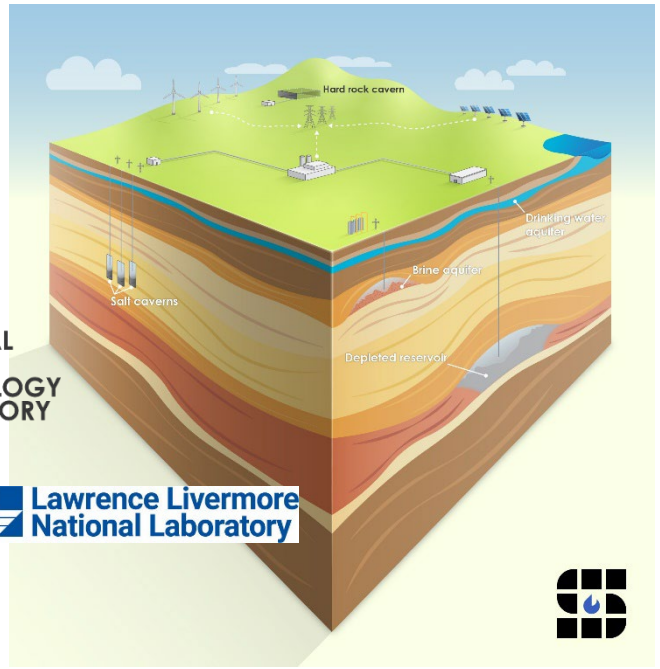
- Validate the utilization potential of existing natural gas infrastructure as a potential means to expedite increased transport of hydrogen, ammonia, and carbon dioxide.
  - Efficient and flexible transport requires pipelines capable of handling both single components and blended mixtures, as well as 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; sealing; safety; and control of hydrogen content variability.
- Investigate regional uncertainties regarding pipeline materials, methods of construction, their location of use, and other relevant characteristics.
  - 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**

Subsurface Hydrogen Storage

SHASTA
Subsurface Hydrogen Assessment, Storage, and Technology Acceleration



NATIONAL ENERGY TECHNOLOGY LABORATORY

Lawrence Livermore National Laboratory

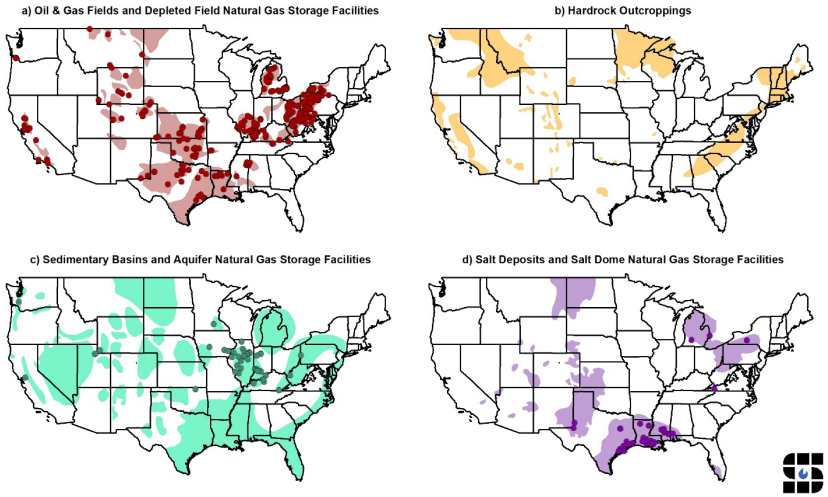
Pacific Northwest NATIONAL LABORATORY

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.



FECM Funding Opportunity Announcement (FOA)

Clean Hydrogen Production, Storage, Transport, and Utilization to Enable A Net Zero Carbon Economy (DE-FOA-0002400)

Objective

Develop technologies enabling clean hydrogen production, transport, storage, and use in the energy sector, including electricity, heat, transportation, and industrial use.

FOA Areas of Interest

Significant advances in technology, economics, and infrastructure are needed in areas of interest

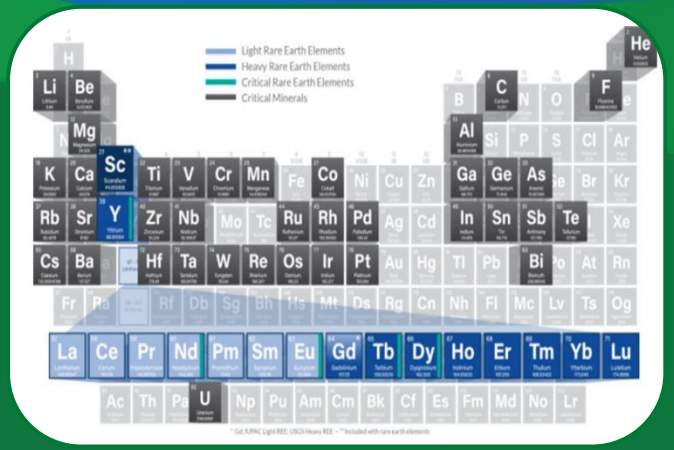
- **Issue Date: FY22**
- **Application Submittal Deadline:** TBD
  Selection Notifications: TBD
- **Awards:** TBD

- Life-Cycle Net Zero-Carbon and Negative-Carbon Emitting Technologies for Clean Hydrogen Production from Modular Gasification
- Solid Oxide Electrolysis Cell Technology (SOEC) Development
- Carbon Capture
- Advanced Turbines
- Natural Gas-Based Hydrogen Production
- Hydrogen Pipeline Infrastructure
- Subsurface Hydrogen Storage

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

Resources

- Methane Mitigation Technologies | Department of Energy
- Resource Sustainability | netl.doe.gov
- SHASTA – SHASTA (doe.gov)



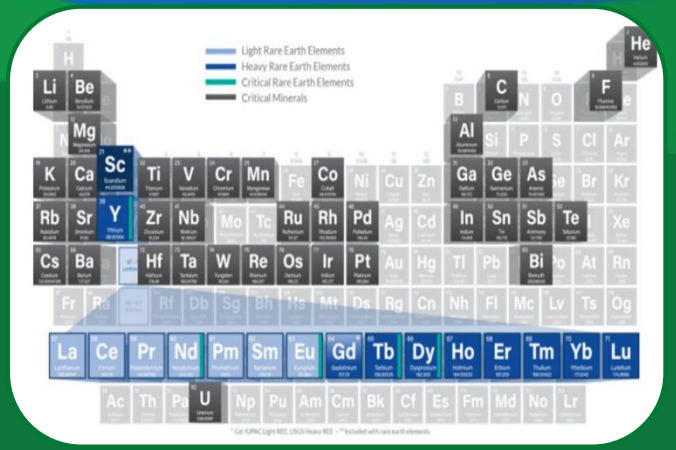
U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

Office of Carbon Management Technologies Overview

Mark Ackiewicz

DIRECTOR, OFFICE OF CARBON MANAGEMENT TECHNOLOGIES
OFFICE OF FOSSIL ENERGY AND CARBON MANAGEMENT

October 5, 2022



Bipartisan Infrastructure Law (BIL)

FECM - **$6.5 billion** in new carbon management funding over 5 years through the Infrastructure Investment and Jobs Act (Bipartisan Infrastructure Law).

Carbon Dioxide Removal - Direct Air Capture
Regional Direct Air Capture Hubs: $3.5 billion
DAC Technology Prize Competition: $115 million

Carbon Dioxide Utilization and Storage
Carbon Storage Validation and Testing: $2.5 billion
Carbon Utilization Program: $310 million

Front-End Engineering Design Studies
Carbon Capture Technology Program (Transport Infrastructure): $100 million

CCUS and CDR Facilitate Deep Decarbonization

Reduce the cost of capture/increase rates

- Power Sector
- Industry
- Carbon Dioxide Removal
- Design Studies and Demonstrations

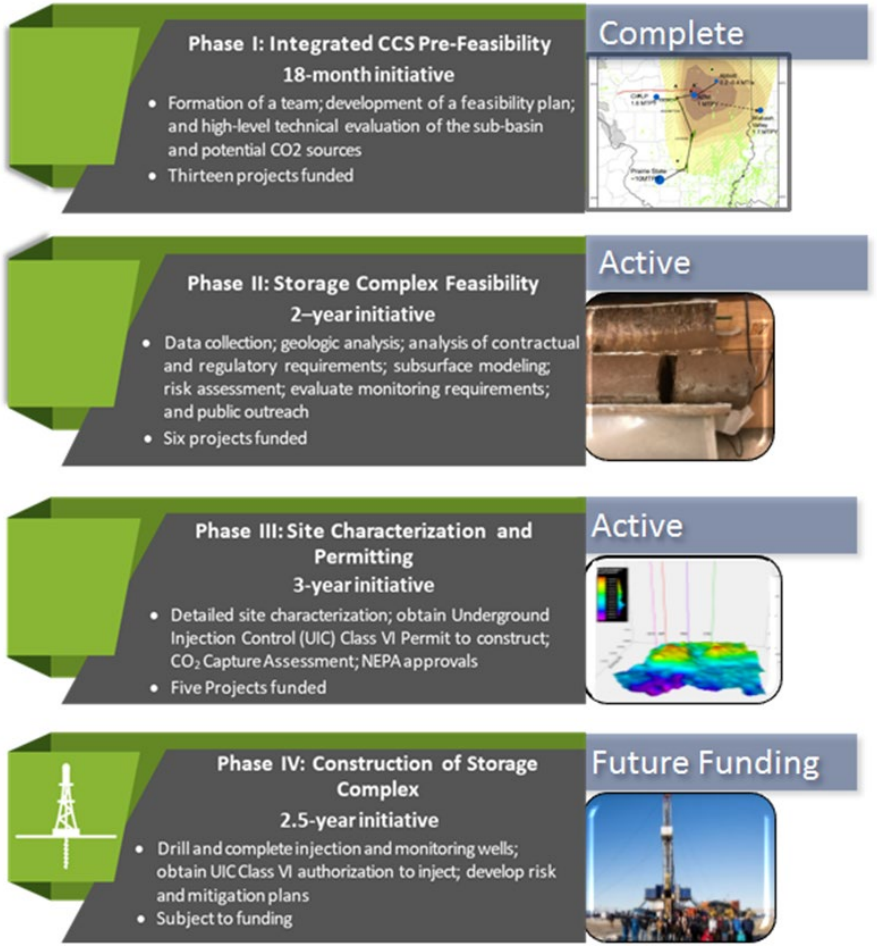
Develop low-carbon supply chains through conversion

- Aggregates
- Fuels and Chemicals
- Solid Carbon Products

Optimize geologic storage operations

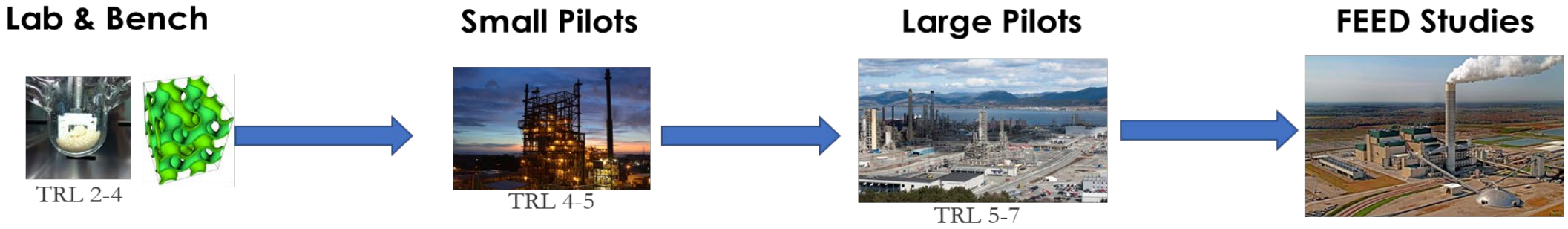
- CarbonSAFE Infrastructure, Partnerships
- Geomechanics (pressure and state of stress)
- Conversion of fossil assets
- Enabling real-time decision making through AI

CarbonSAFE - Infrastructure



Point Source Capture Program

Integrated Approach to Accelerate Technology Development



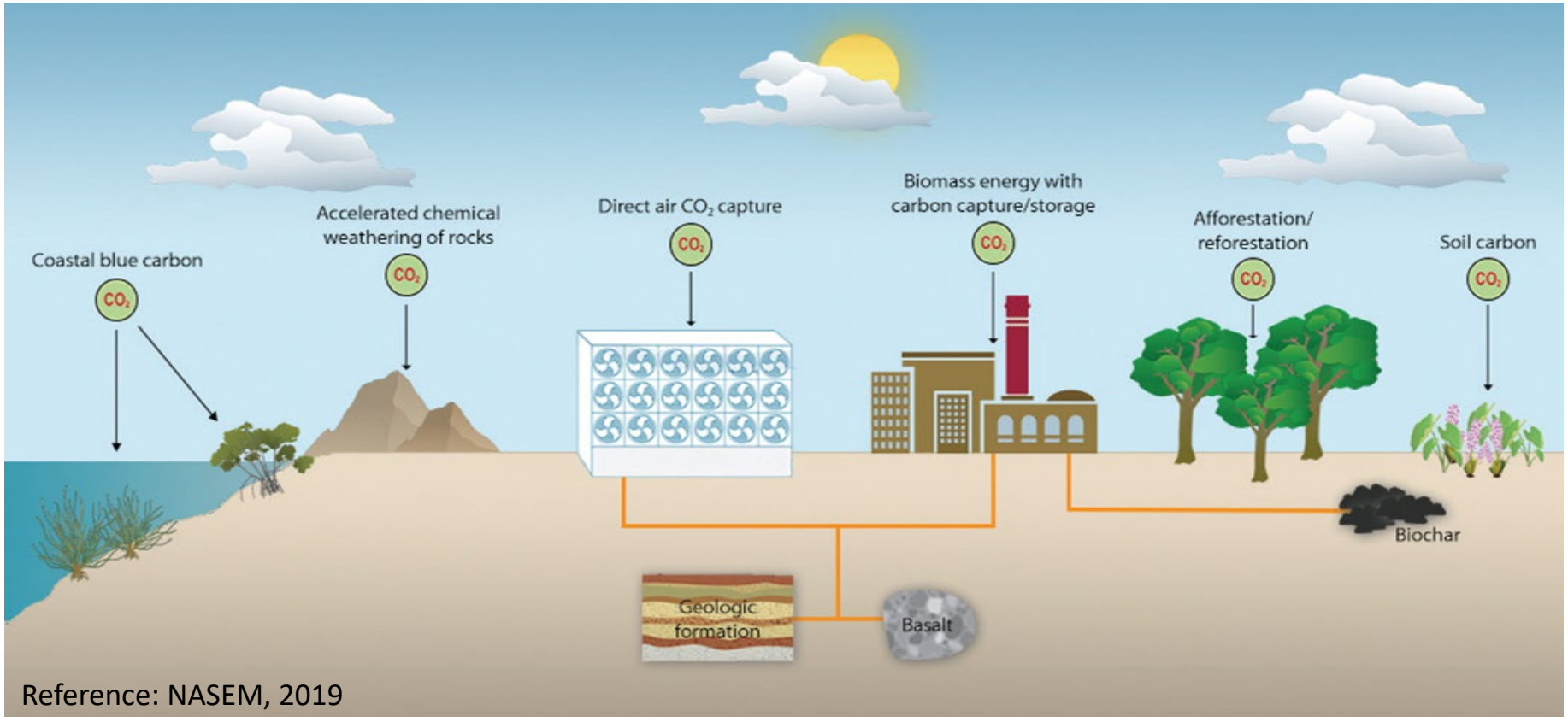
Point Source Capture Focus

- Develop capture technologies for the power and industrial sectors
- Reduce CAPEX/OPEX under a wide range of feed conditions
- Achieve high capture efficiencies (>95%)
- Maximize co-benefit pollutant removal
- Engineering-based Simulation ($CCSI^2$)
- Create low-carbon supply chains (i.e., cement, steel, hydrogen, etc.)

CDR Areas of Interest in FECM

- Biomass with Carbon Removal and Storage
- Direct Air Capture (DAC)
- Direct Ocean Capture (DOC)
- Accelerated Weathering and Mineralization

- Rigorous LCA and TEA (net-removed costs)
- Low-carbon energy, land, water resources required
- Leveraging transport and storage infrastructure
- Justice and work force considerations



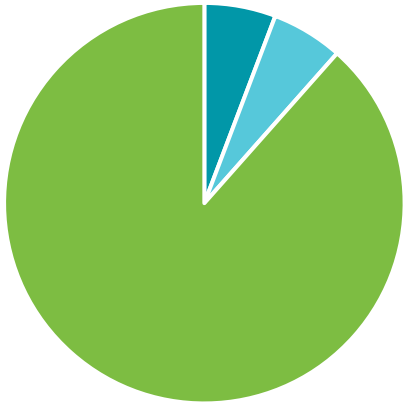
Reference: NASEM, 2019

Carbon Negative Shot: Key Performance Elements

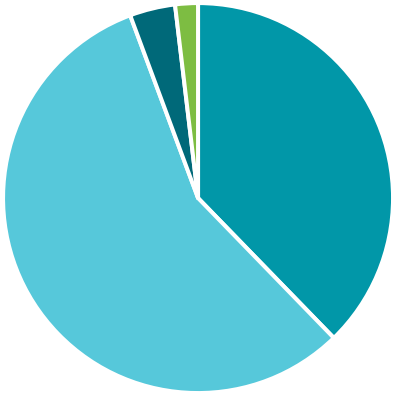
Carbon Negative Shot's key performance elements will guide a responsible industry that is responsive to the climate crisis, such that multiple true, durable removal pathways can be deployed at their most affordable cost at the scale required to address the climate crisis.

1. Less than **$100/net metric ton CO_2e** for both capture and storage
2. Robust accounting of full life cycle emissions
3. High-quality, durable storage with costs demonstrated for MRV **for at least 100 years**
4. Enables necessary **gigaton-scale** removal

Soil Carbon Sequestration



Direct Air Capture and Storage



Blue are costs associated with ambient air capture

Green are costs associated with ensuring durable storage

Ensure the first ton of removal is true, durable removal

Ensure the last ton of removal is as affordable as it can be

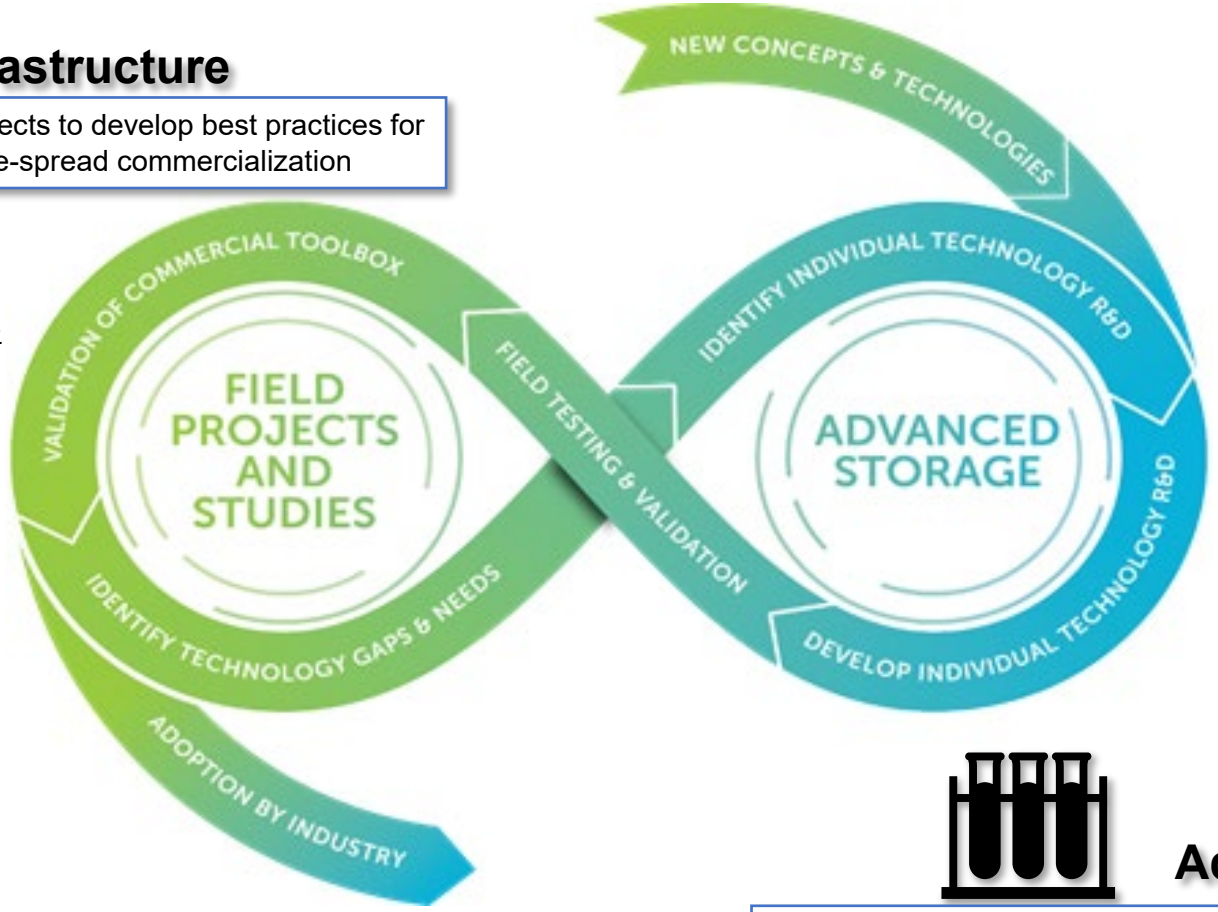
Carbon Transport and Storage RD&D: An Iterative Process towards Deployment

Storage Infrastructure

Large-scale demonstration projects to develop best practices for industry and facilitate wide-spread commercialization

Storage Infrastructure Focus

- CarbonSAFE
- Regional Initiatives
- Offshore Storage
- Brine Extraction Strategy Test **(BEST)**
- Transition of O&G infrastructure



Advanced Storage Focus

- Well Integrity and mitigation
- Monitoring, verification, and accounting
- Storage complex efficiency and security
- **SMART**: **S**cience-Informed **M**achine Learning for **A**ccelerating **R**eal **T**ime Decisions
- **NRAP:** National Risk Assessment Partnership

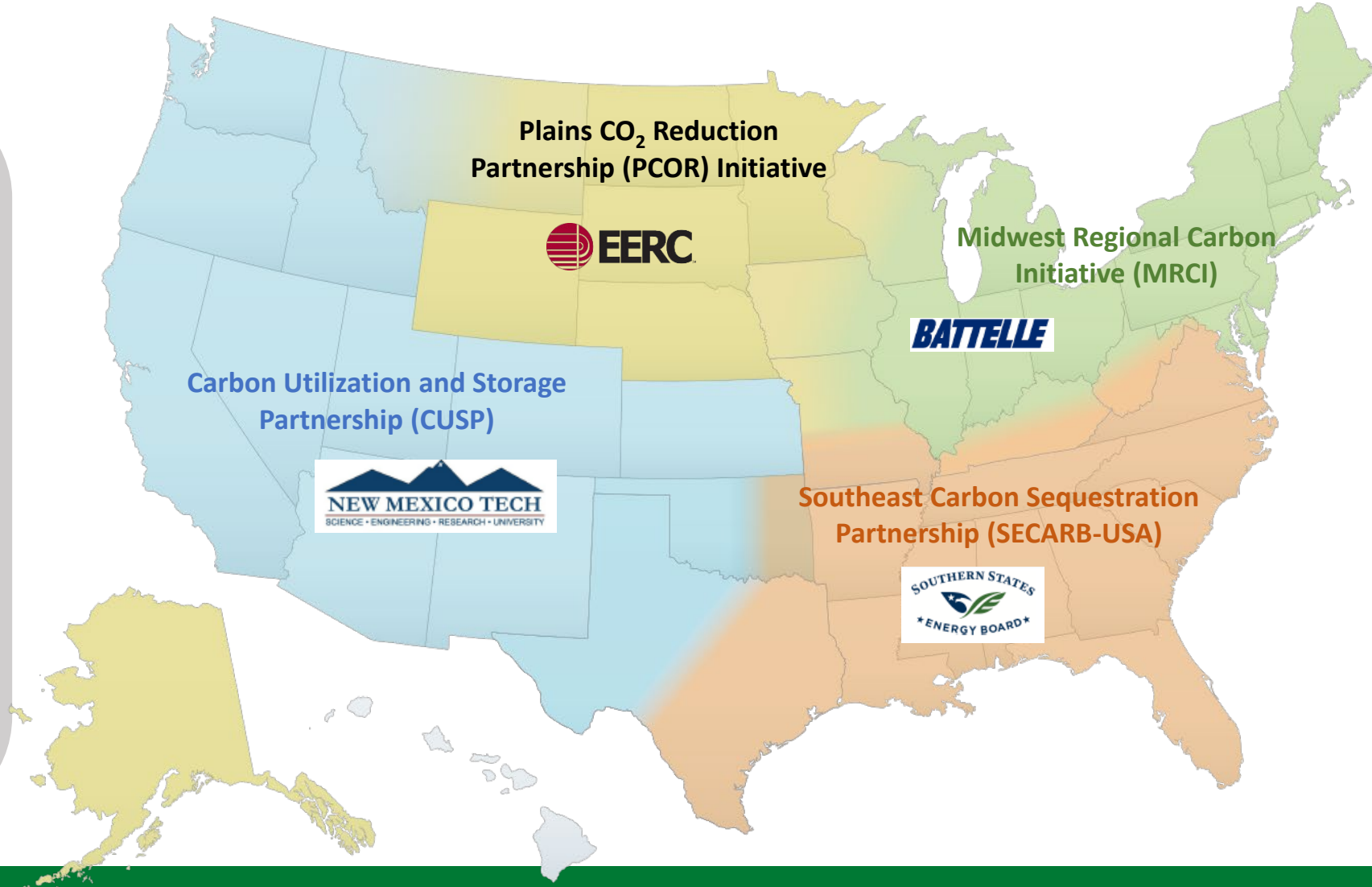
Advanced Storage

Harness early-stage storage concepts to technology demonstration

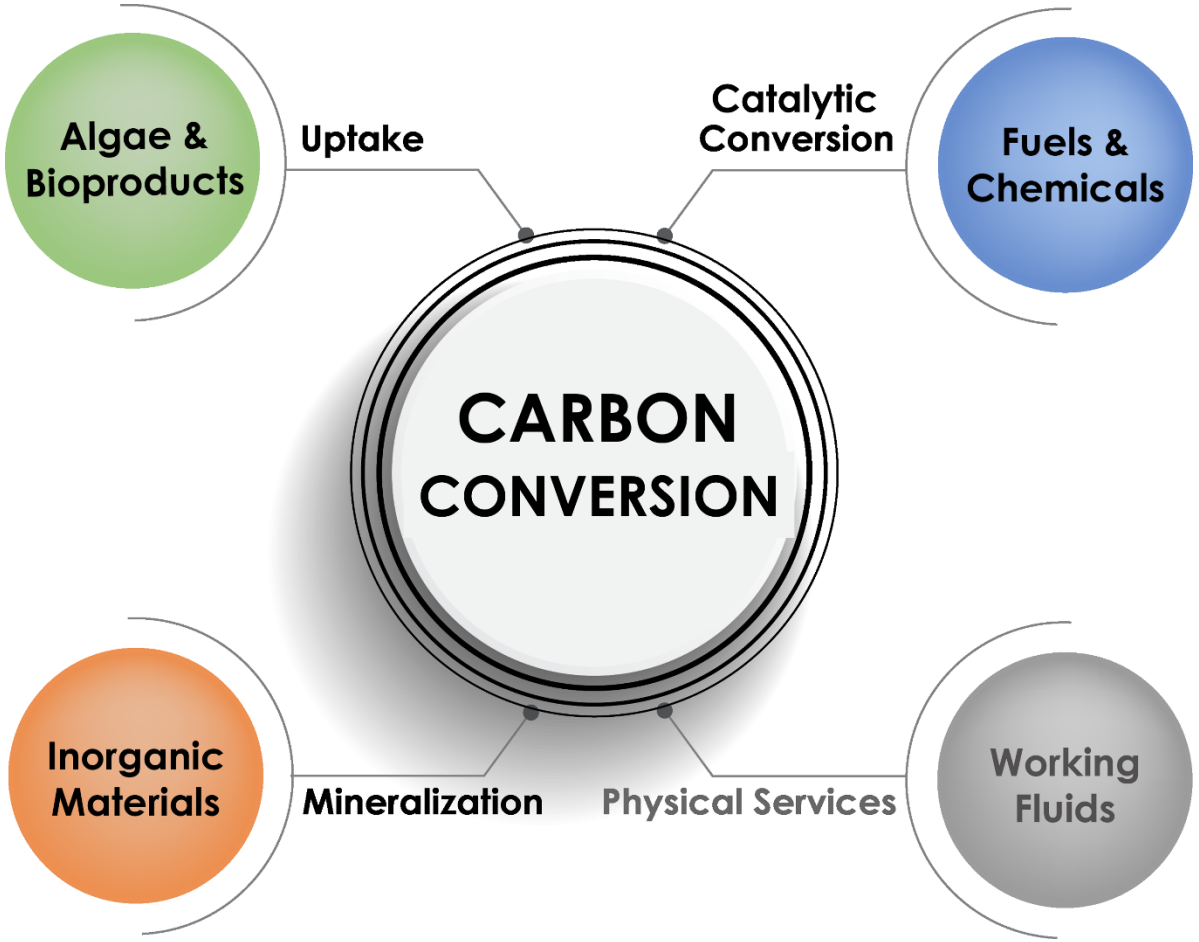
Regional Initiatives to Accelerate CCUS

Four Key Activities

- Promote regional technology transfer
- Address certain technical challenges
- Facilitate data collection, sharing, and analysis
- Evaluate existing regional infrastructure



Carbon Conversion/Utilization Program



Challenges

- Scale & Rate of CO_2 emissions relative to of CO_2 conversion
- Determining economic viability and environmental impact requires significant resources -> very place-based
  - Technical viability is relatively easy to qualify
- Sweet spot of low carbon & low-cost energy like electricity, CO2 sources, markets, and transportation between it all

Funding Opportunity Announcements (FOAs)

FOA Process Flow

I – Follow the Money

- President's Congressional Request Budget
- House Committee Mark
- Senate Committee Mark
- Annual FY Appropriation

II – Structure the Opportunity

- Generate Annual Spend Plan for all Technology Areas
- Complete Acquisition Planning Process
- Identify Portfolio of FOA's to be Initiated
- Schedule FOA Critical Path Milestones

III – Initiate the Competitive Phase

- Develop Requirements Document
- Generate Procurement Strategy
  - *Craft Evaluation Criteria, Scoring Plan, Program Policy Factors, Selection Criteria*
  - *Select Merit Review Chair & Source Selection Official*
  - *Staff Scoring Panels with Subject Matter Experts*
- Publish & Issue FOA

IV – Select, Negotiate and Award Projects

- Complete Initial Screening, Qualify Applications
- Develop Consensus Strengths and Weaknesses, Score Applications
- Prepare Senior Technical Briefing
- Select and Announce Winners
- Initiate Negotiations and Make Award

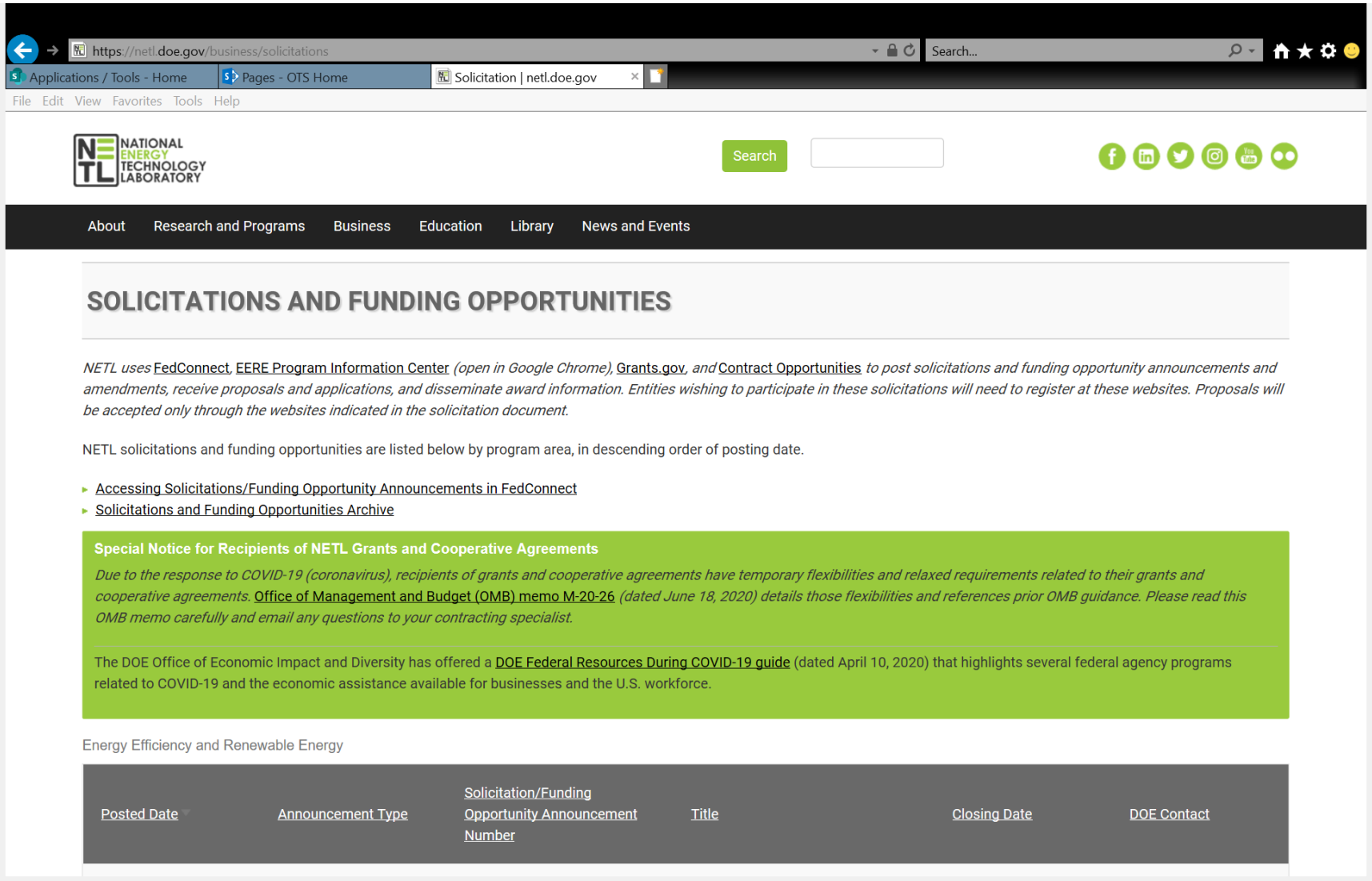
V – Advance the Technology

- Evaluate Performance and Measure Progress
  - *Technology Maturation Planning*
  - *Technology Readiness Assessments*
  - *Independent Program/Project Peer Reviews*
- Inform Future R&D Needs

Steps to Apply for Financial Assistance Award

https://netl.doe.gov/business/solicitations

- Identify opportunity of interest through **Funding Opportunity Announcement (FOA)**
- Meet registration requirements
- Prepare and submit application



Current FECM Carbon Management FOAs

- **DE-FOA-00002614 (Amendment 4): Carbon Management**
  - AOI-2F. Carbon Dioxide Removal (CDR) Research and Development (R&D): Field Validation of Abiotic Ocean-Based Carbon Removal
  - AOI-2G. CDR R&D: Integrated Carbon-Neutral Methanol Synthesis from Direct Air Capture and Carbon-Free Hydrogen Production.

- **DE-FOA-00002711: BIL Section 40305, Storage Validation and Testing. Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Phases III, III.5, and IV.**
  - AOI 1: CarbonSAFE Phase III: Site Characterization and Permitting
  - AOI 2: CarbonSAFE Phase III.5: NEPA, FEED Studies, and Storage Field Development Plan only
  - AOI 3: CarbonSAFE Phase IV: Construction

- **DE-FOA-00002730: BIL, Front-End Engineering Design (FEED) for Carbon Dioxide (CO_2) Transport**
  - Areas of interest: Current opening is for pipelines
  - Future areas of interest and openings of this FOA may consider other modes of transport

Current OCED Carbon Management FOA

- **DE-FOA-00002738: BIL, FEED Studies for Integrated Carbon Capture, Transport, and Storage Systems (OCED)**

  - AOI 1.1: FEEDs for Integrated CCS Systems at Coal Electric Generation-Only Facilities
  - AOI 1.2: FEEDs for Integrated CCS Systems at Coal CHP Facilities

  - AOI 2.1: FEEDs for Integrated CCS Systems at NGCC Electric Generation Facilities or NG SMR Facilities Producing H2 for Electricity Generation
  - AOI 2.2: FEEDs for Integrated CCS Systems at NG Simple Cycle Electricity Generation Facilities or NG CHP Facilities

  - AOI 3.1: FEEDs for Integrated CCS Systems at Ammonia Facilities Not Purposed for Electric Generation
  - AOI 3.2: FEEDs for Integrated CCS Systems at Industrial Facilities Not Purposed for Electric Generation

FOA #	Title	Open Date	Close Date	DOE Funding Available (up to)	DOE Funding per project (up to)	Cost-share requirement
DE-FOA-00002614	DE-FOA-00002614 (Amendment 4): Carbon Management	9/30/2022	11/30/2022	Phase 1: 2F: $2M; 2G: $4M Phase 2: 2F: $8M; 2G: $16M	Phase 1, AOI-2F: $200k Phase 1, AOI-2G: $400k Phase 2, AOI 2F: $4M Phase 2, AOI 2G: $8M	20% for all phases and AOIs
DE-FOA-00002711	BIL Section 40305, Storage Validation and Testing. Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Phases III, III.5, and IV.	9/22/2022	11/28/2022	$2.25 billion over 5 years	AOI 1: $15M to $110.5M AOI 2: $100k to $4.55M AOI 3: $30M to $195M	AOI 1: 20% AOI 2: 20% AOI 3: 50%
DE-FOA-00002730	BIL, Front-End Engineering Design (FEED) for Carbon Dioxide (CO_2) Transport	9/22/2022	11/28/2022	$92 million over 5 years	$750k to $3M	20%
DE-FOA-00002738	BIL, FEED Studies for Integrated Carbon Capture, Transport, and Storage Systems (OCED)	9/22/2022	12/05/2022	$189 million	AOI 1.1: $12.5M AOI 1.2: $6.5M AOI 2.1: $10.0M AOI 2.2: $6.5M AOI 3.1: $5.5M AOI 3.2: $9.0M	50% for all AOIs

Potential Resources and Opportunities for Further Engagement and Development

DOE's Carbon Matchmaker

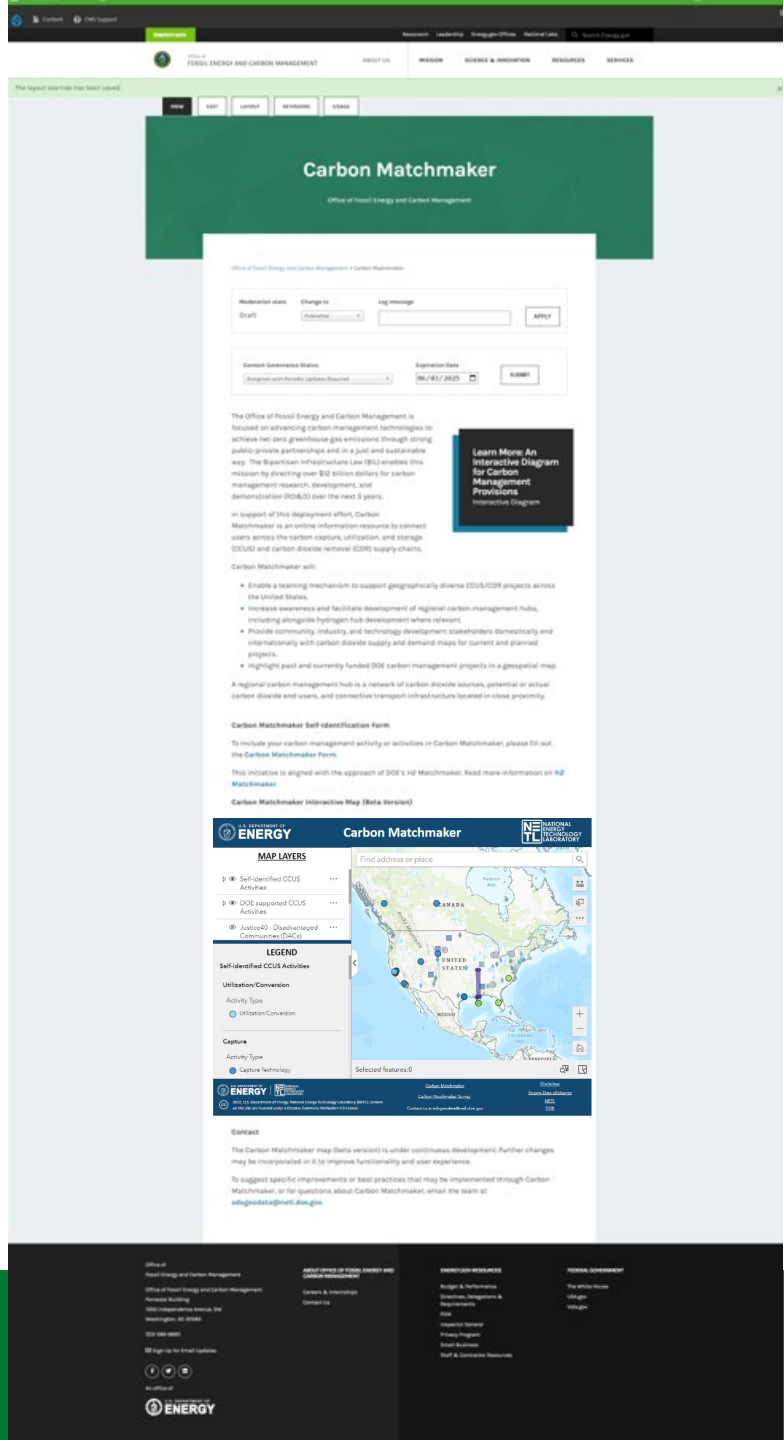
A partnering and teaming tool for DOE carbon management funding opportunities, mirroring DOE's H2 Matchmaker.

Carbon Matchmaker is an online information resource to connect users across the carbon capture, utilization, and storage (CCUS) and carbon dioxide removal (CDR) supply chains.

Carbon Matchmaker will:

- Enable a teaming mechanism to support geographically diverse CCUS/CDR projects across the United States.
- Increase awareness and facilitate development of regional carbon management hubs, including alongside hydrogen hub development where relevant.
- Provide community, industry, and technology development stakeholders domestically and internationally with carbon dioxide supply and demand maps for current and planned projects.
- Highlight past and currently funded DOE carbon management projects in a geospatial map.

https://www.energy.gov/fecm/carbon-matchmaker



DOE Annual Carbon Management Meeting

- Held annually in Pittsburgh, PA, typically in August
- 2022 event: Over 700 registrants
- DOE-funded carbon management projects present
- Includes other Federal agencies, international, etc.
- Excellent opportunities to network and build relationships
- 2022 Event Proceedings: https://netl.doe.gov/events/conference-proceedings

MICKEY LELAND ENERGY FELLOWSHIP (MLEF)

- A **10-week** summer research program for Science, Technology, Engineering, and Math (STEM) students
- Receive **mentorship** from DOE scientists and engineers
- Provide **hands-on experience** complementing course of study and connect **theory to practice**
- Increase **confidence**, enhance **communications skills**, and promote **critical thinking** and **problem solving**

MLEF PROGRAM

The 2023 program now accepting applications. Deadline is January 23, 2023

STIPEND*

- Undergraduate students: $650 per week
- Master's students : $750 per week

*Some participants may be eligible to receive a housing and travel allowance.

Contacts

Sandra Peñaherrera, Program Manager

Cristina Cordero, Program Coordinator

MLEF@hq.doe.gov; www.energy.gov/fe/mlef

Contacts

- FECM Tribal Point of Contact:

Joe Giove (joseph.giove@hq.doe.gov)

- Director, Office of Carbon Management Technologies:

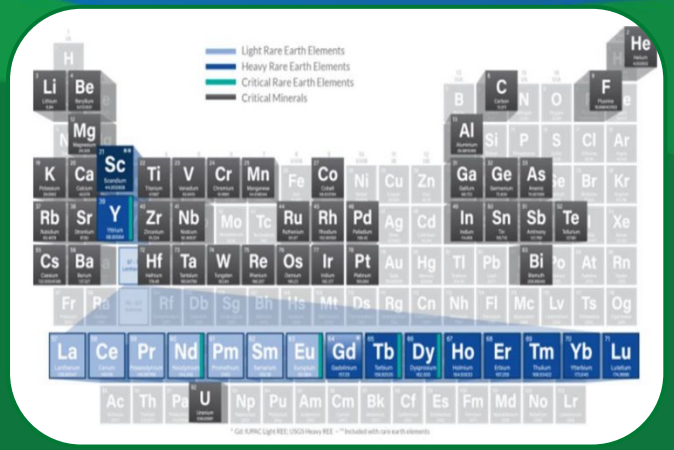
Mark Ackiewicz (mark.ackiewicz@hq.doe.gov)

- Acting Director, Division of Hydrogen with Carbon Management:

Bob Schrecengost (robert.schrecengost@hq.doe.gov)

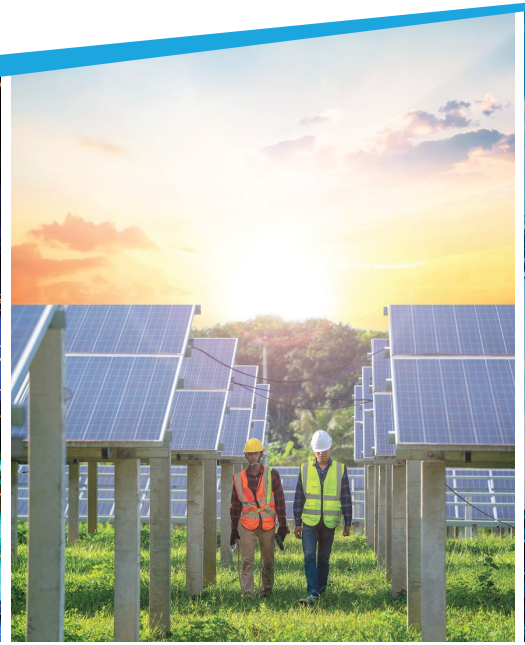
U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

Questions?



Office of Clean Energy Demonstrations






Tribal Clean Energy Summit

Todd Schrader
Director for Project Management
Office of Clean Energy Demonstrations
U.S. Department of Energy

Background

- The International Energy Agency says we need global public investments of at least $90 billion this decade for large-scale clean energy demonstration projects to achieve net zero emissions by 2050

- Two historical climate laws enacted in FY 2022—the Bipartisan Infrastructure Law and Inflation Reduction Act—appropriated more than $25 billion to the Office of Clean Energy Demonstrations (OCED) to deliver large-scale clean energy demonstration projects

- OCED will accelerate clean energy technologies from the lab to market and fill a critical innovation gap on the path to achieving our nation's climate goals while mitigating risks that allow private sector investors and developers to act

OCED Mission

"Deliver clean energy technology **demonstration projects at scale** in partnership with the **private sector** to **accelerate deployment**, **market adoption**, and the **equitable transition** to a decarbonized energy system."

OCED Mandate

CENTER OF EXCELLENCE

Serve as primary DOE office to deliver full scale clean energy demonstration projects and project management oversight excellence

CLEAN ENERGY + EQUITABLE

Help enable 100% clean electricity by 2035 and net zero emissions by 2050 through an equitable energy transition

FOLLOW ON INVESTMENT

Unlock and scale trillion-dollar clean energy follow on investment from the private sector and other sources of capital

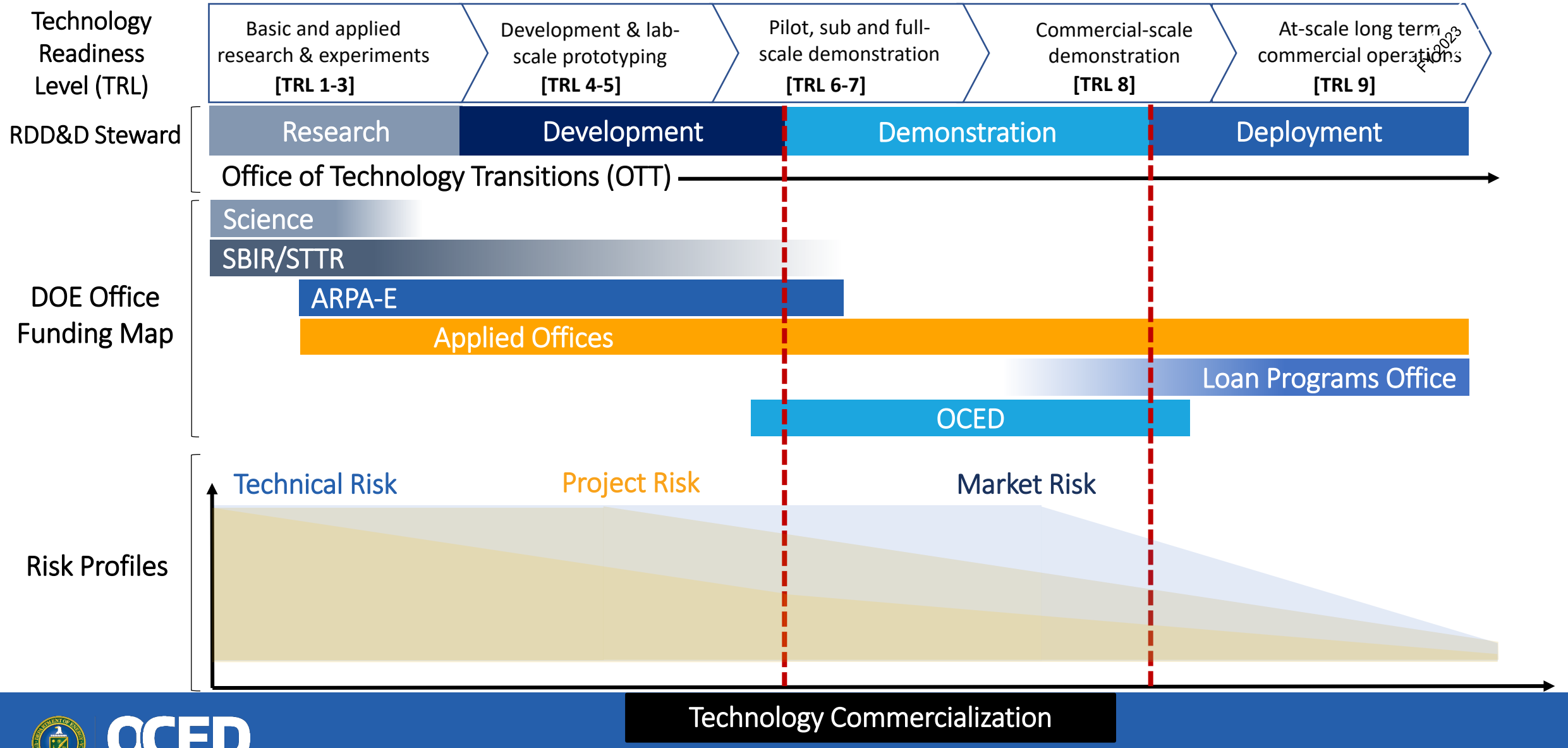
DE-RISK TECHNOLOGY

Maintain risk-based, balanced, and defensible portfolio of investments

ENGAGEMENT + OUTREACH

Leverage private sector and broader energy ecosystem to inform OCED and DOE technology commercialization efforts

OCED Role Across Research, Development, Demonstration & Deployment (RDD&D) Continuum



OCED Project Phases

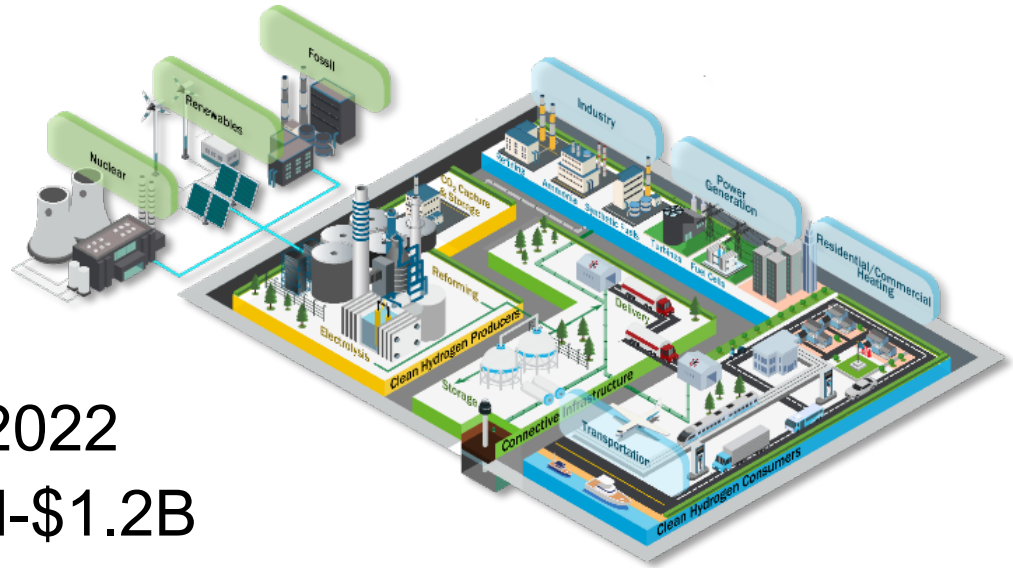
☆ Initial Application
◇ Go/No-Go Decisions

	Application	Phase 1: Detailed Plan	Phase 2: Develop, Permit, Finance	Phase 3: Install, Integrate, Construct	Phase 4: Ramp-Up & Operate
	Pre - DOE funding	**Up to $10M DOE Funding , Non-Federal Cost Share ≥ 50%, 12-18 Months**	**TBD DOE Funding, Non-Federal Cost Share ≥ 50%, 2-3 Years**	**TBD DOE Funding, Non-Federal Cost Share ≥ 50%, 2-4 Years**	**TBD DOE Funding, Non-Federal Cost Share ≥ 50%, 2-4 Years**
Engineering, Procurement, Construction, Operations	• Conceptual Design • Technical Readiness • Project Schedule • Total Project Cost Estimate	• Engineering & Design Documents • Technical Maturation Plans • Integrated Project Schedules	• Mature Engineering & Design • Technical Risk Management • Execution ready schedule & cost estimate, PM Tools • Operations Plan	• Ongoing execution reporting • Interim Go/No-Go reviews	• Ongoing performance Reporting • Technical risk updates, tracking • Final TPC accounting
Business Development & Management	• Business Strategy • Team Description • Workforce Plan • Finance Plan • Market potential analysis	• Project Management Plan • Risk Management Plan • Financial modelling • Site selection	• Finalized project structure, management, financing • Ongoing risk management • Final legal, workforce, procurement agreements • Feedstock & Offtake Plans	• Ongoing execution reporting • Ongoing risk management	• Updated financial analyses • Revised growth plans • Updated Risk Management
Permitting & Safety	• Safety history/culture description • Regulatory approval timeline overview	• Initial Hydrogen Safety Plan (HSP) & Site Safety Plan • Physical, Information, Cyber Security Plans • Environmental & Regulatory preparations	• Execution ready HSP and security plans • Permits & approvals in place for construction	• Ongoing permit, environmental, safety reporting • Permits & approvals in place for operations	• Ongoing permit, safety, and security reporting
Community Engagement & Impacts	• Initial Equity Plan addressing community engagement, Justice40, community consent or benefits agreements, job quality, workers rights, etc.	• Stakeholder engagement and Community Consent or Benefits Agreement drafts	• Finalized Equity Plan, Agreements • Community development targets identified, tracking plans	• Ongoing reporting on Equity Plan activities	• Revised community engagement plans for operations • Ongoing reporting and evaluation
Technical Data & Analysis	• Lifecycle Analysis • Techno-economic Analyses	• Project Production Model • Updated Lifecycle and Technoeconomic Analysis	• Final Lifecycle & Technoeconomic Analyses • V&V and Project Completion Testing Plans	• Periodic analyses updates • V&V data collection • Project completion testing and performance ramp V&V	• Validated performance model • Finalize lifecycle and technoeconomic analyses • Dissemination of analyses, lessons learned

Regional Clean Hydrogen Hubs

Build 6-10 regional clean H2Hubs across the country to create networks of hydrogen producers, consumers, and local connective infrastructure to accelerate use of hydrogen

- Feedstock diversity
- End use diversity
- Geographic diversity
- Employment and training



Current Status

- Issued funding announcement in September 2022
  - Planning 6-10 awards ranging from $400M-$1.2B
  - Concept papers are due by Nov 7, 2022
  - Full applications are due by April 7, 2023

Additional Opportunities for Public Comment

DOE Draft Clean Hydrogen Production Standard

- Currently open for comment
- Questions and Comments can be directed to: cleanh2standard@hq.doe.gov

Draft DOE National Clean Hydrogen Strategy and Road Map

- Currently open for comment
- Additional workshop and listening session info coming soon!

Thank You!

For more information, please visit: energy.gov/OCED

Email: OCED@hq.doe.gov

Office of Clean Energy Demonstrations

Thank you

DOE Hydrogen Program
U.S. Department of Energy

www.hydrogen.energy.gov