U.S. DEPARTMENT OF ENERGY

Fossil Energy and Carbon Management

Fossil Energy and Carbon Management: Clean Hydrogen Perspectives

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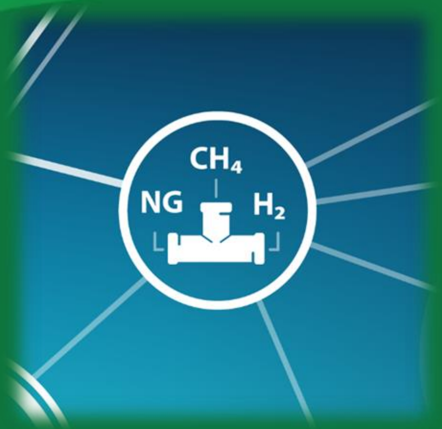
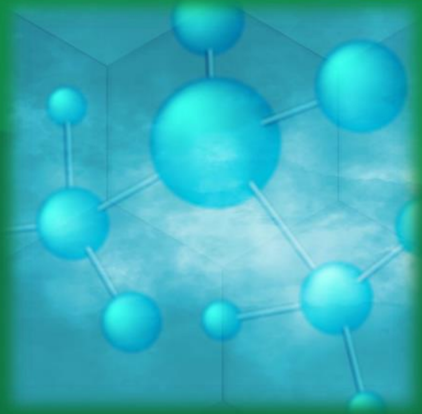




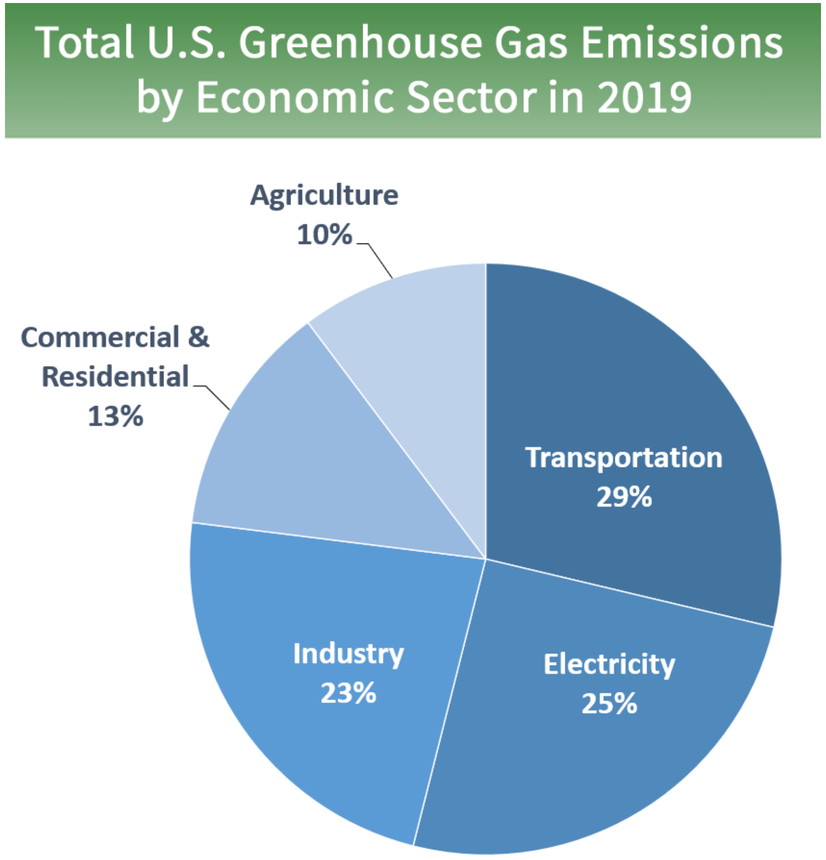
Fossil Energy and Carbon Management (FECM)

Office of Fossil Energy and Carbon Management

DOE-FE is now DOE-FECM

New name for our office reflects our **new vision** to achieve decarbonization and carbon management

- Administration Goals:
  - 50% emissions reduction by 2030
  - CO_2 emissions-free power sector by 2035
  - Net zero emissions economy by no later than 2050



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

FECM Mission: Deep Decarbonization and Environmental Justice

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

Priority Technology Areas

1. Point source carbon capture
2. Carbon dioxide (CO_2) removal
3. CO_2 conversion into products
4. Reliable CO_2 storage
5. Hydrogen production (non-electrolytic)

Office of Carbon Management
(FECM-20)

6. Critical mineral production from industrial and mining waste
7. Methane mitigation

Office of Resource Sustainability
(FECM-30)

Supporting Legacy Communities (Justice)

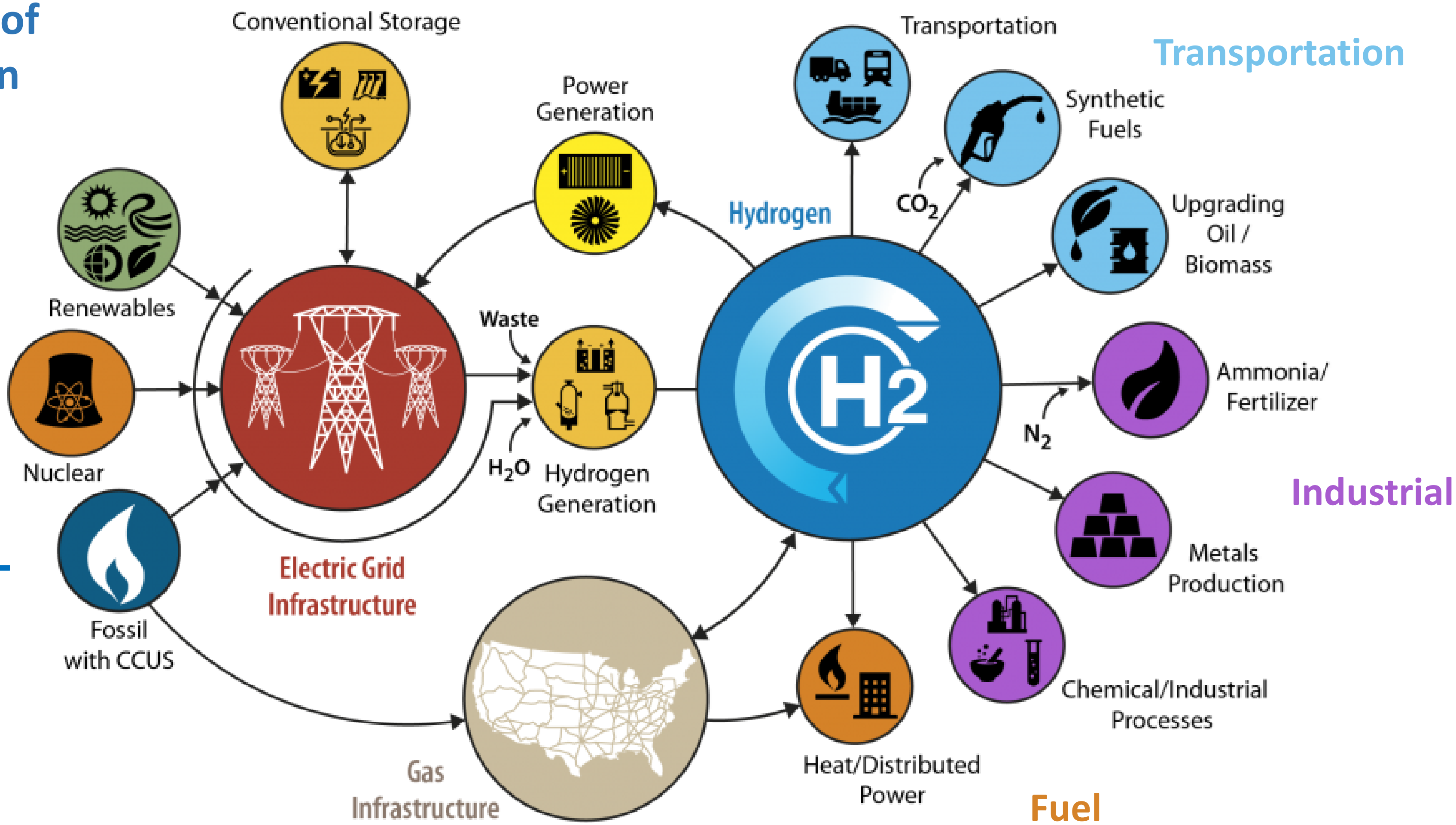
- Good-paying jobs
- Job growth acceleration
- Healthy economic transitions
- Improve community conditions

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

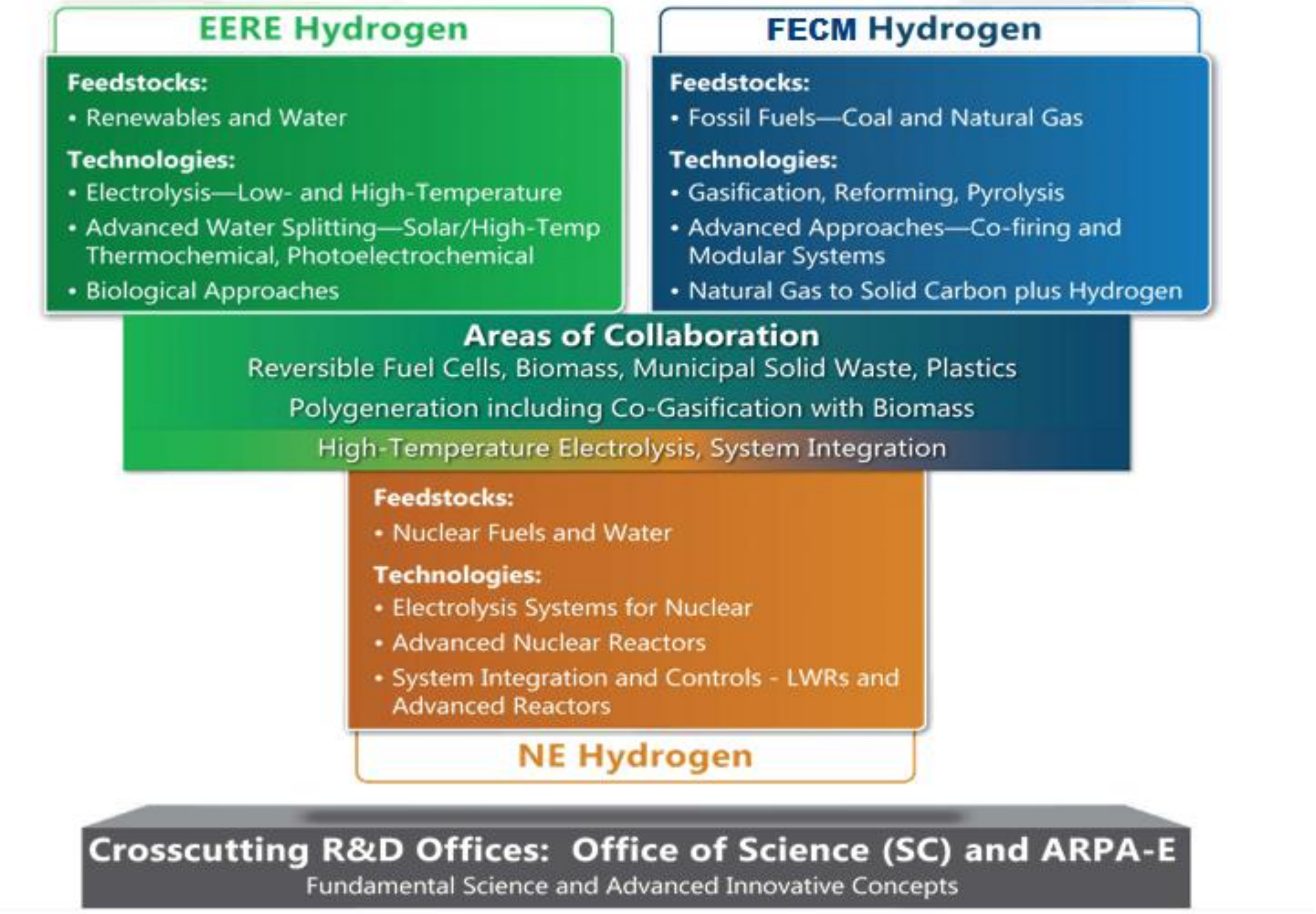
Hydrogen Supply Chain

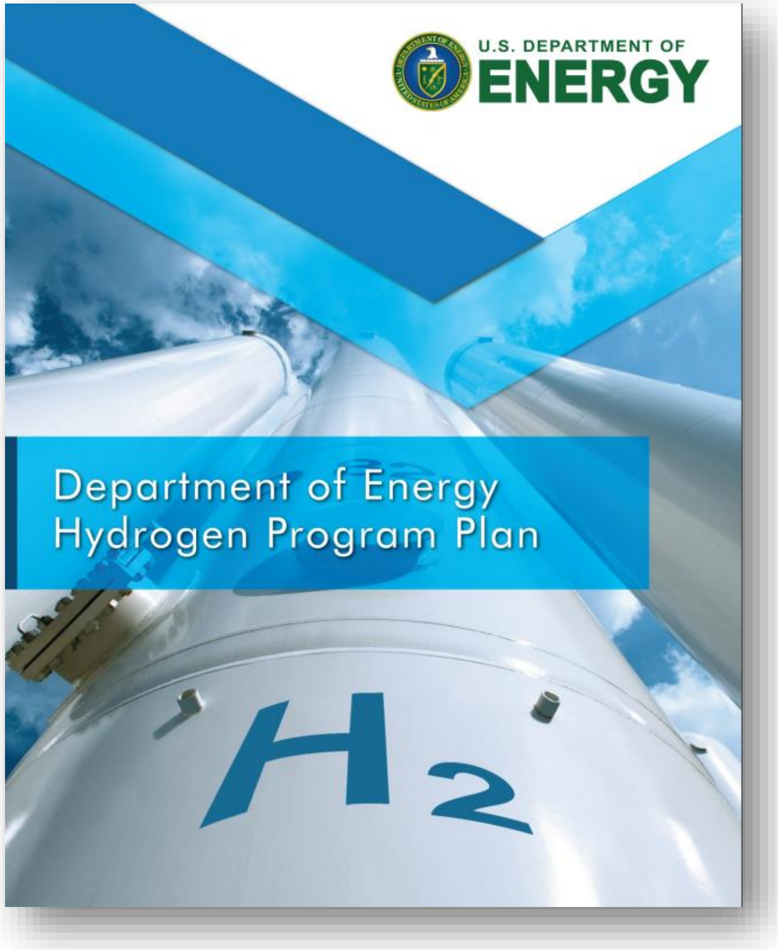
The How, Why, and Where of the Hydrogen Supply Chain

- Abundant natural gas
  *2,867 TCF
- Low cost
  *$2 to $3 per MMBTU
- Abundant CO_2 storage
  *3,000 GT of CO_2



Driving Towards Net-Zero Together





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

Why Hydrogen?

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

Department of Energy
Hydrogen Program Plan 2020

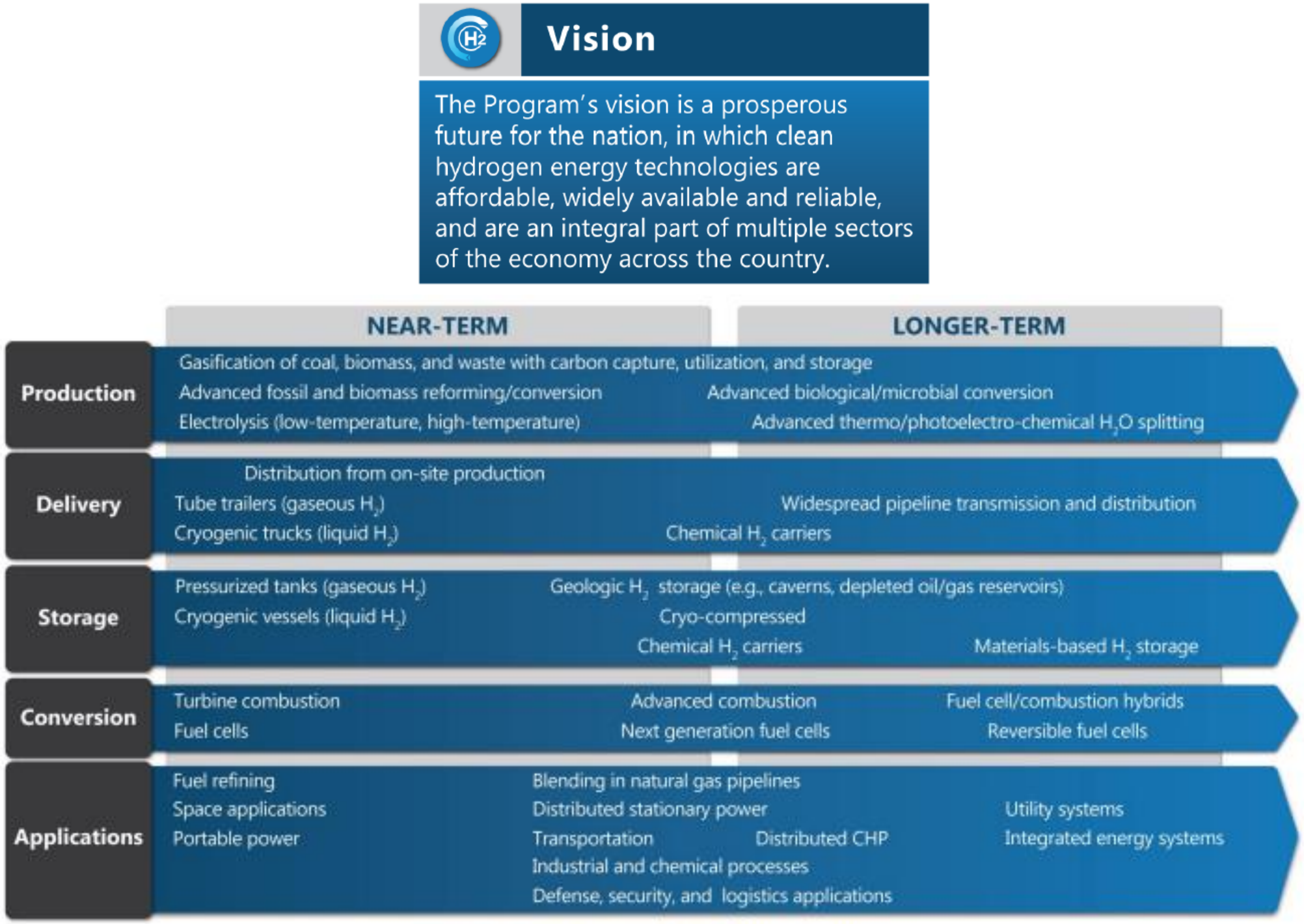
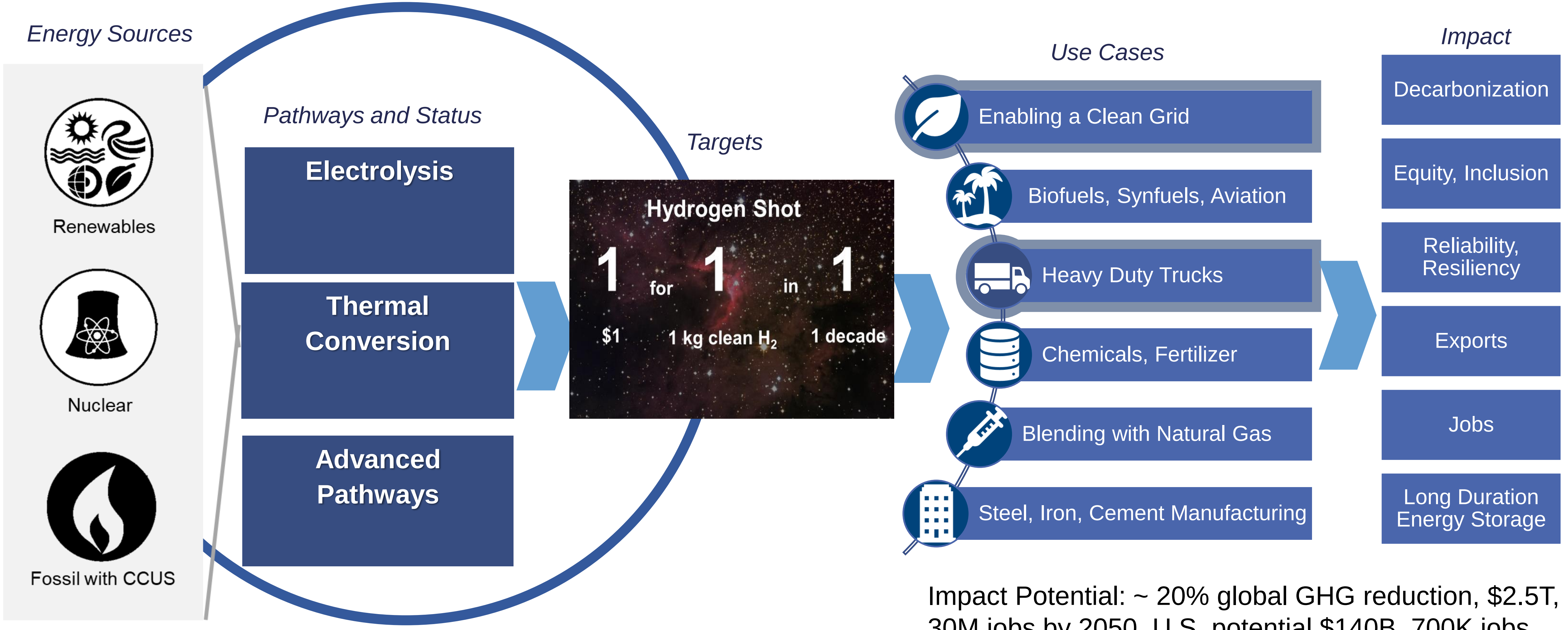


Figure 2. Key hydrogen technology options

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

Hydrogen Production Pathways and Targets for Impact



Impact Potential: ~ 20% global GHG reduction, $2.5T, 30M jobs by 2050. U.S. potential $140B, 700K jobs.

FECM’s Clean Hydrogen Strategy

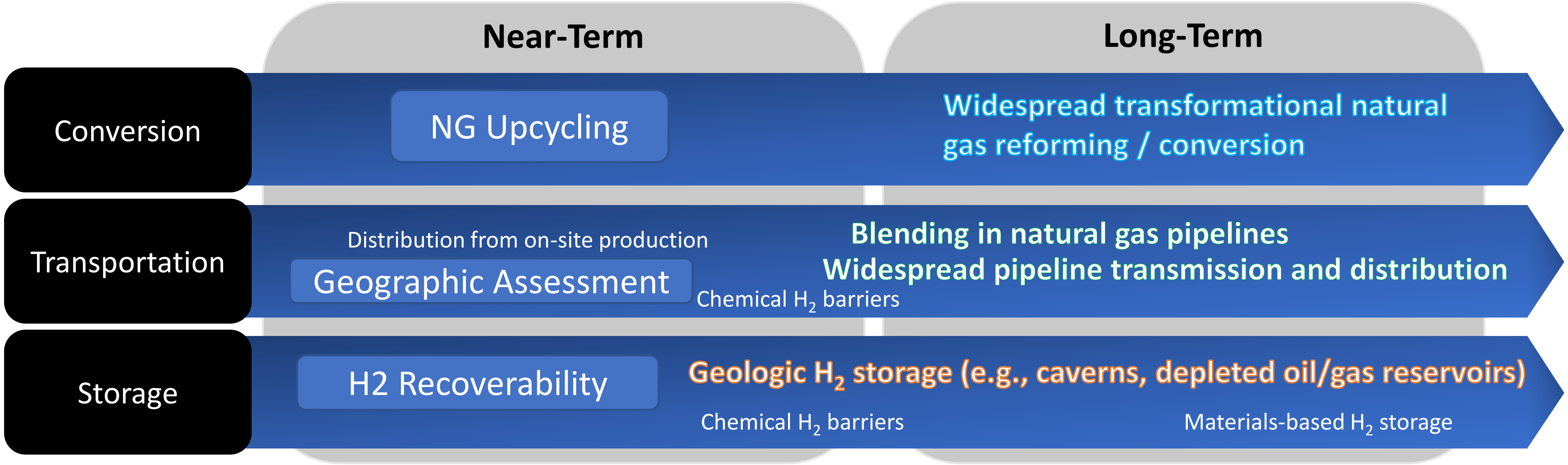
Near-Term
- Conduct technoanalysis on all fossil-based hydrogen production pathways
- Regional analyses
- Hydrogen safety studies

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

Long-Term
- Deployment of advanced hydrogen production methods
- Special projects for U.S. hydrogen economy

Program Mission and Challenges

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



Natural Gas Decarbonization & Hydrogen Technologies Research Program

Hydrogen Production from Natural Gas

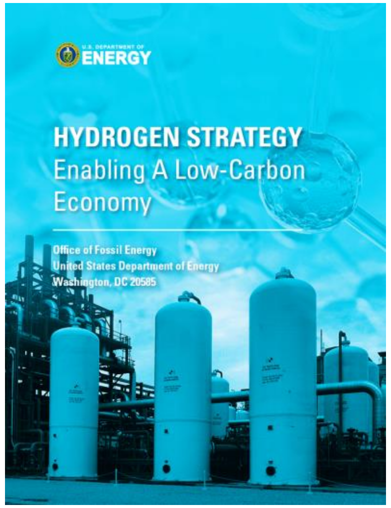
- Natural gas is the **“bridge fuel”** to enable a hydrogen economy and transformational methods will maintain its relevance as a feedstock even as green hydrogen become cost-competitive.
- Improved methods of **decarbonization** drive disruption of existing hydrogen production.
- Widespread industrial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

Hydrogen Transportation in Existing Infrastructure

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

Hydrogen Storage within the Subsurface

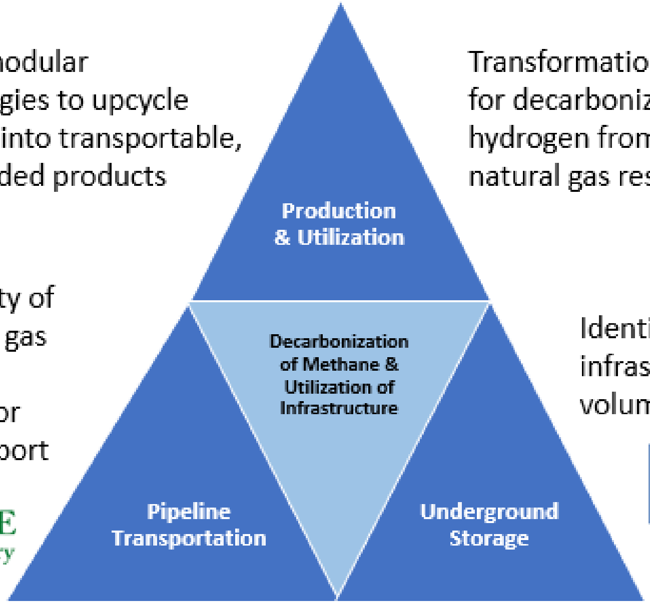
- Existing storage mechanisms at refineries or **end-use locations** are commercial technologies, but safety considerations remain key, particularly at **larger volumes**.
- Subsurface storage can utilize depleted oil and natural gas reservoirs, as well as salt domes, but long-term storage permanence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



NATIONAL ENERGY TECHNOLOGY LABORATORY

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

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



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

Identify underground storage infrastructure to handle high-volume fractions of hydrogen

Oak Ridge National Laboratory

Lawrence Livermore National Laboratory

Pacific Northwest National Laboratory

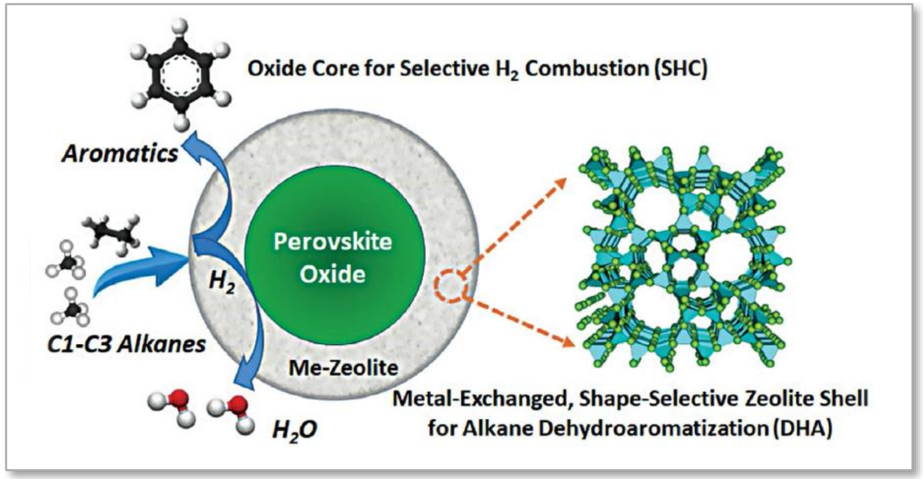
Transformative Natural Gas to Hydrogen Production

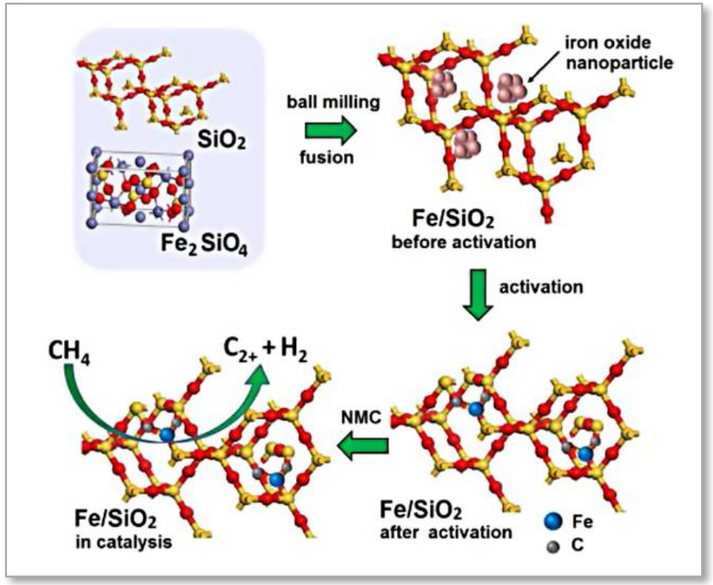
Natural Gas Feedstock

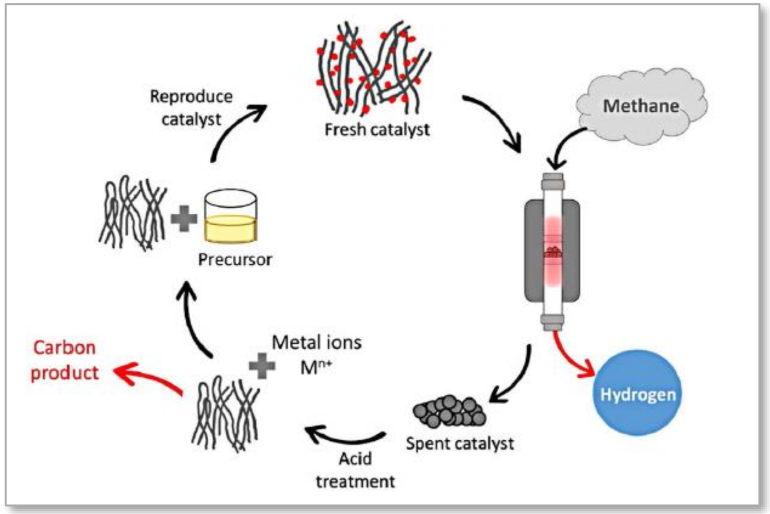
Transformational Hydrogen Production

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

Hydrogen, Solid Carbon, Liquids







Natural Gas Pipeline Infrastructure and Hydrogen

Goals:

- Validate the utilization potential of existing natural gas infrastructure as a potential means to expedite increased transport of hydrogen, ammonia, and carbon dioxide.
  - Efficient and flexible transport requires pipelines capable of handling both single components and blended mixtures, as well as intermittent and alternating gas chemistries.
- Determine material compatibility of natural gas pipeline materials with hydrogen, carbon dioxide, and ammonia for current pipeline routes to guide decisions on introducing non-traditional gases in these pipes.
- Address design challenges of hydrogen transport and compression, including:
  - Materials and coatings
  - Light gas compression
  - Sealing
  - Safety
  - 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**

Hydrogen Storage R&D Needs

Either at production or end-use locations

Goals

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

Current Status

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

Objectives

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

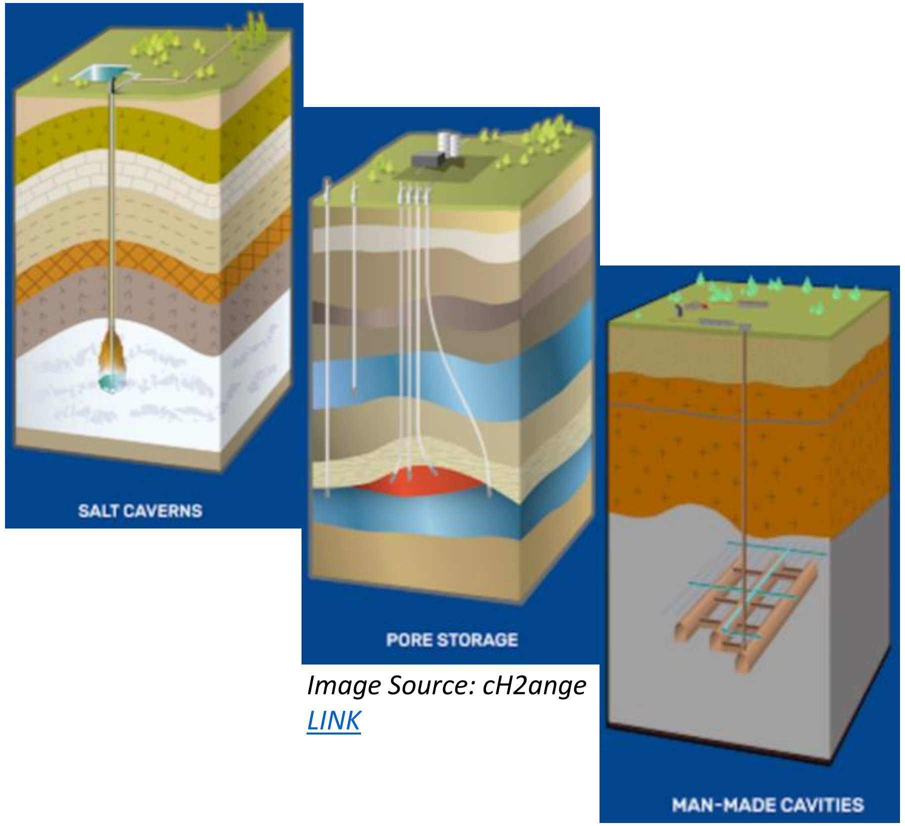
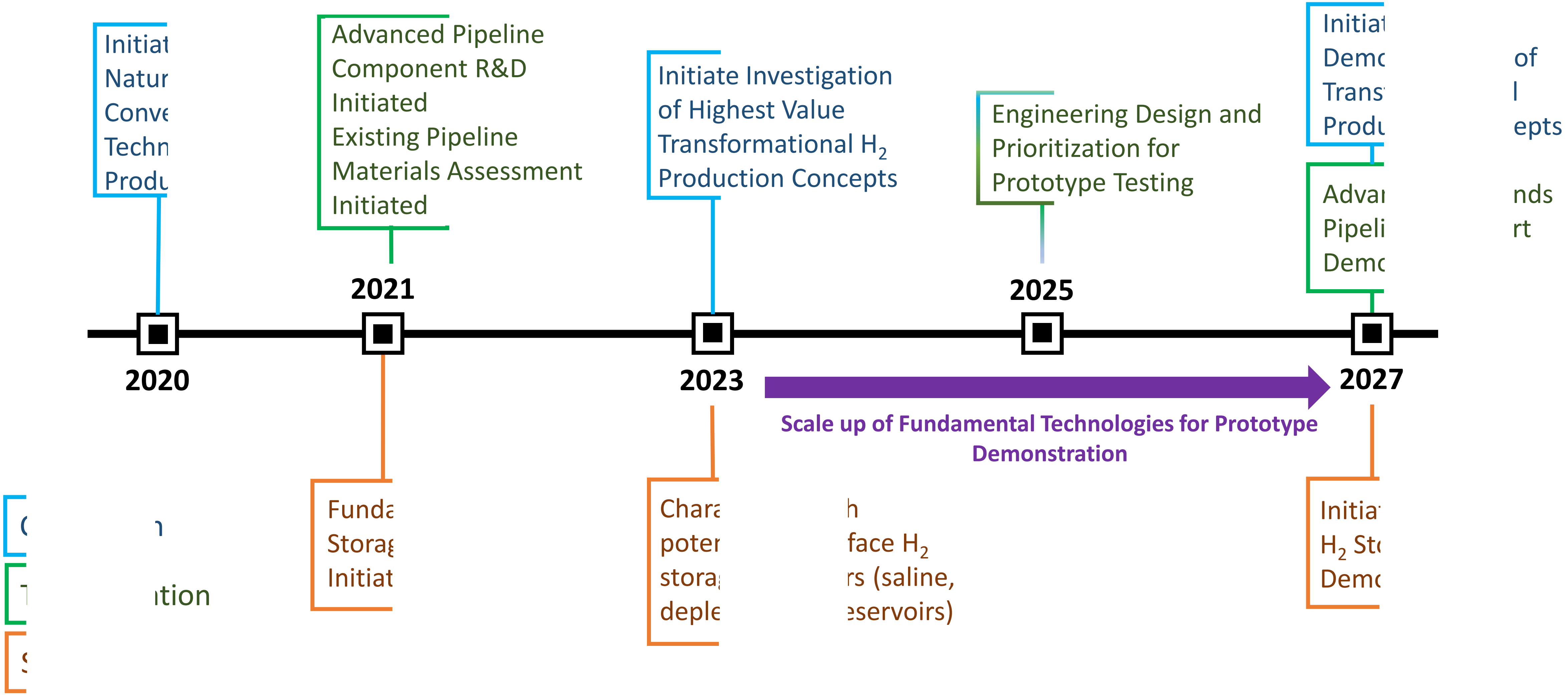


Image Source: cH2ange
LINK

SHASTA Subsurface Hydrogen Assessment, Storage, and Technology Acceleration — National Energy Technology Laboratory, Pacific Northwest National Laboratory, Lawrence Livermore National Laboratory

Conversion, Transportation, and Storage Timeline

Hydrogen Production, Transportation, and Storage



Questions?

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