U.S. DEPARTMENT OF ENERGY

DOE Hydrogen Program Panel Discussion

EERE - Sunita Satyapal, FE- John Litynski, NE- Alison Hahn, SC- Linda Horton, ARPA-E- Scott Litzelman

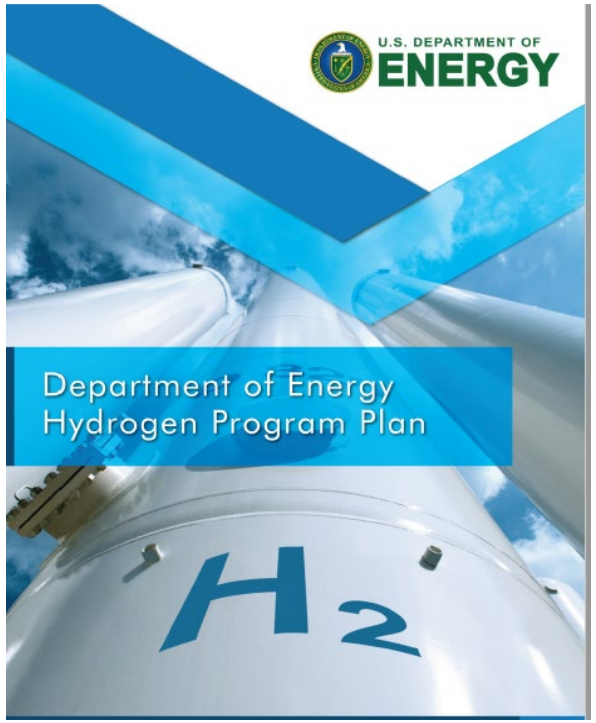
Hydrogen Annual Merit Review

June 7, 2021

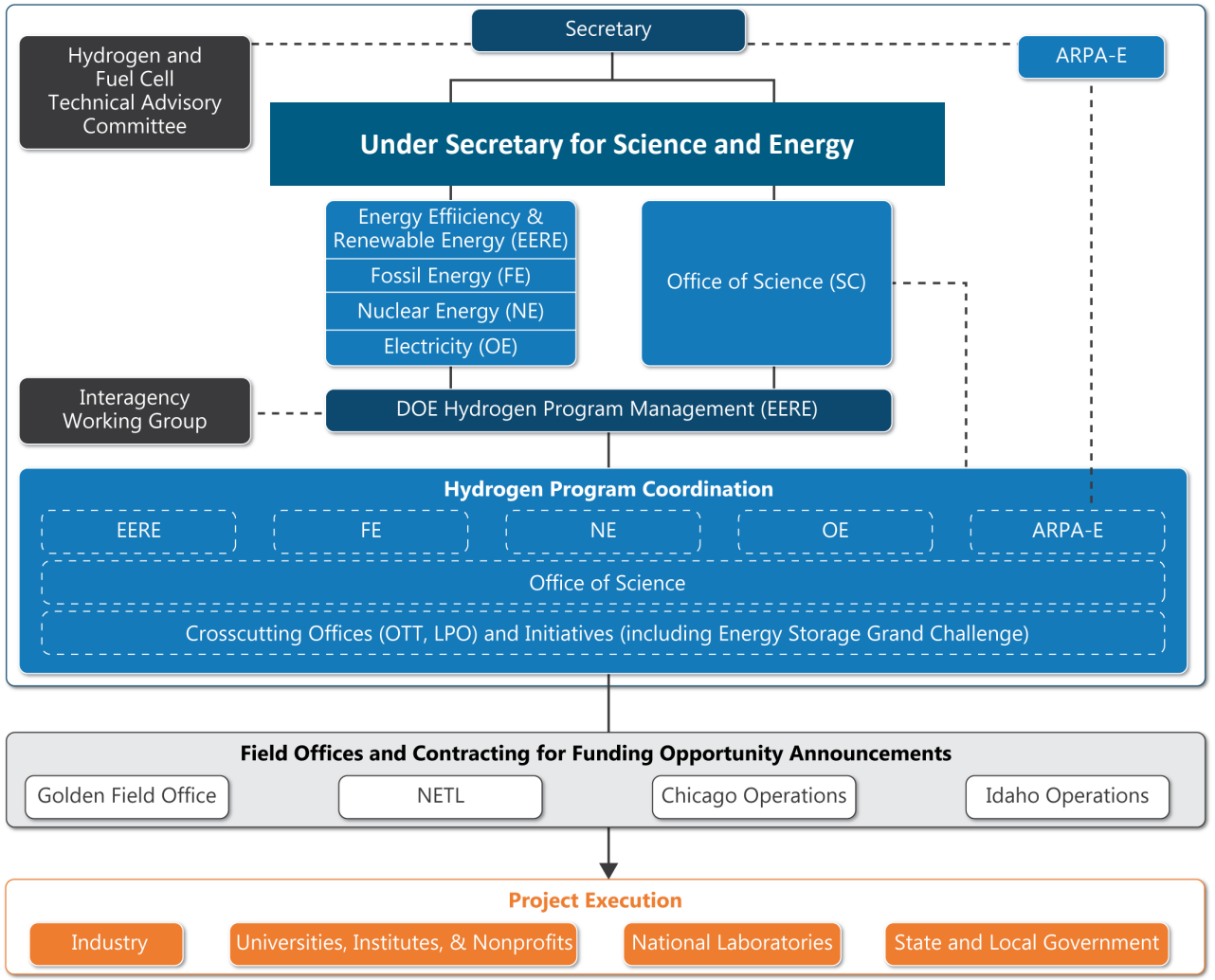
The DOE Hydrogen Program: An Integrated Approach for Collaboration on Hydrogen Across DOE Offices

The Energy Policy Act (2005) Title VIII and Energy Policy Act of 2020 provide key authorization

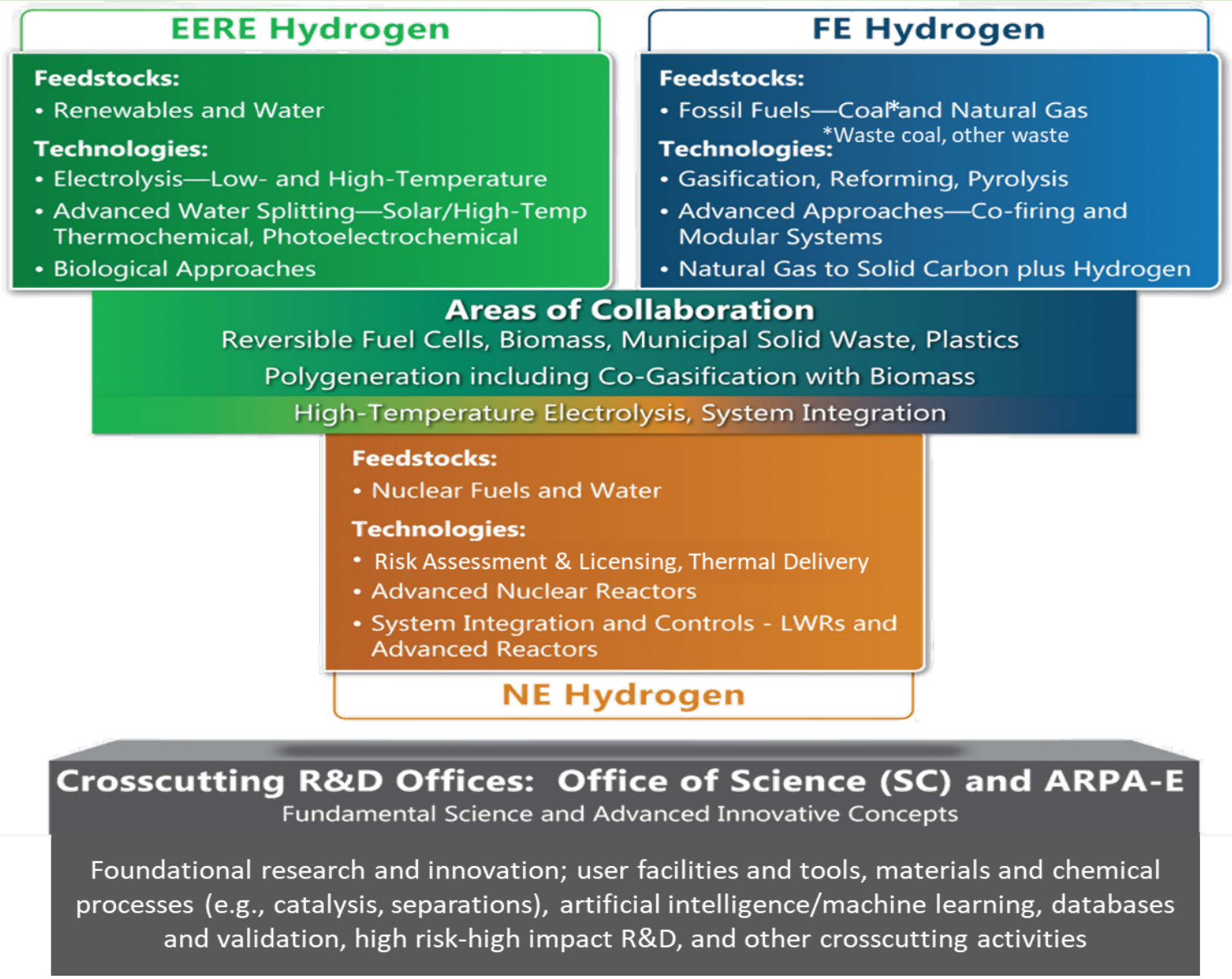
Hydrogen Program Plan



www.hydrogen.energy.gov



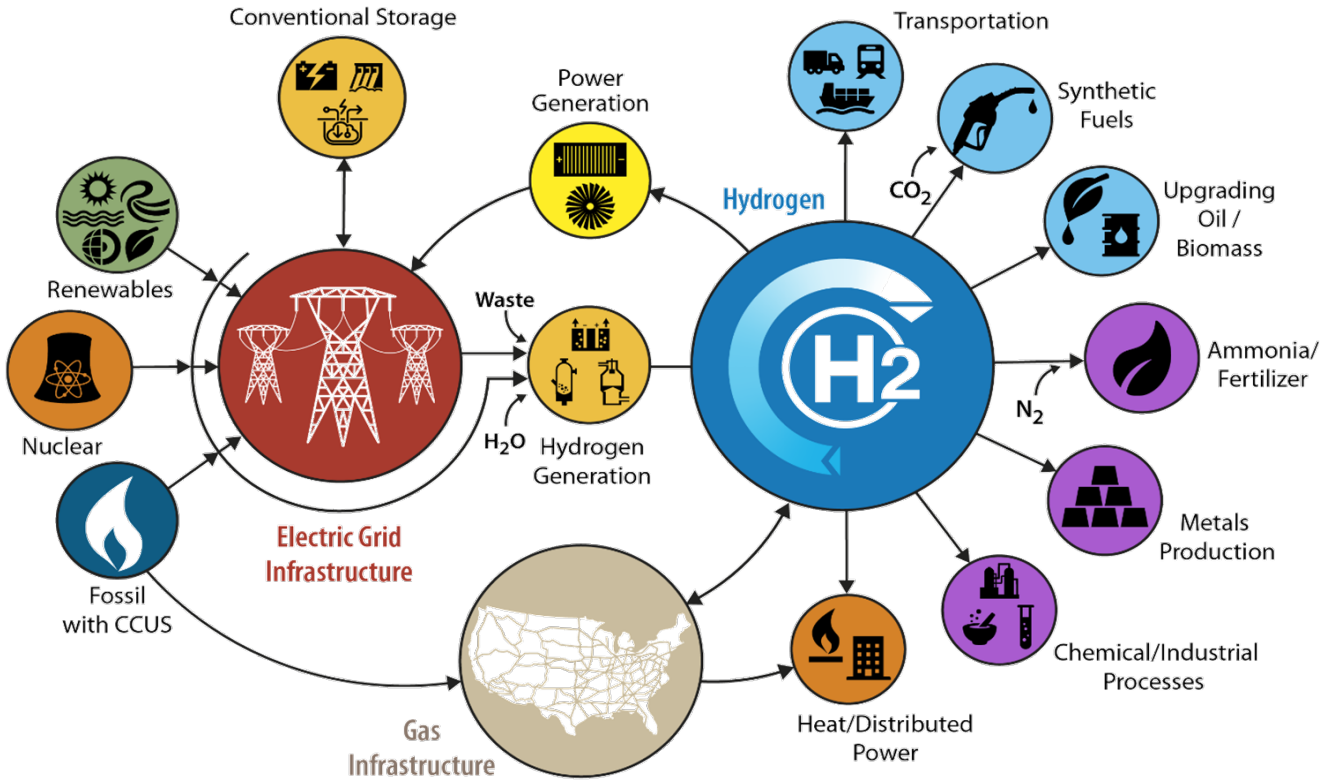
DOE Hydrogen Program – Collaboration



EERE: Office of Energy Efficiency and Renewable Energy
FE: Office of Fossil Energy
NE: Office of Nuclear Energy

Hydrogen at Scale - A Guiding Framework

DOE's H2@Scale initiative provides an overarching vision for how hydrogen can enable energy pathways across applications and sectors in an increasingly interconnected energy system.



Global potential estimated by H_2 Council: $2.5 trillion, 30 million jobs, 6 GT CO_2 reduction.

Priorities

1. **Low cost, zero carbon hydrogen generation: $1 - $2/kg**
2. **Low cost, efficient, safe hydrogen delivery and storage**
3. **End use applications to achieve scale and sustainability, enable emissions reduction and address EJ40 priorities**

Enablers: Workforce development, safety, codes, standards

Hydrogen Activities in Fossil Energy (FE)

John Litynski, Deputy Director Advanced Fossil Technology Systems

Fossil Energy - Hydrogen R&D Investments and Areas

Key Focus Areas:

- Low-cost, net-zero hydrogen production and utilization technologies, including Turbines, Gasification, Solid Oxide Fuel Cells, and Pre-Combustion R&D

Future RD&D:

- Carbon-Neutral Hydrogen Production Using Gasification and Reforming Technologies
- Hydrogen Use for Electricity Generation, Fuels, and Manufacturing
- Large Scale Hydrogen Transport Infrastructure
- Large Scale On-site and Geological Hydrogen Storage

Recent Accomplishments:

- Developed hydrogen combustion fundamentals and analysis tools to enable low NOx hydrogen combustor designs and zero carbon power generation. Developing combustors and materials.
- Hydrogen production with 99% CO_2 capture can be achieved with small incremental costs
- Worlds largest clean hydrogen facility (Port Arthur SMR/CCS) operating for 7 years – commercial demo
- Pre-FEED studies completed for clean hydrogen production facility – Shifting to waste coal, biomass, and plastics
- Developed several pre-combustion (CO_2/H_2) separation technologies at small pilot scale

FE Funding and Key Hydrogen Activities

CCS Demonstration Project

Air Products Hydrogen Production w/ CCUS

- **On going operations since April 2013**
- **Over 7 million tons CO_2 injected**

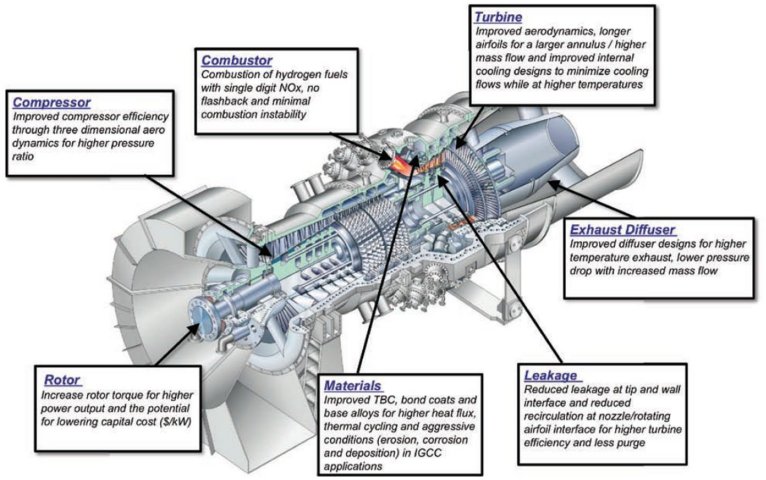
FY2021 Hydrogen Related R&D Investments

- **Advanced Energy Systems:**
  - Solid Oxide Fuel Cells - materials, components, systems, reversible SOFC at utility scale;
  - Turbines - 100% H_2 firing, retrofit systems;
  - Gasification and reforming technologies
- **Carbon Capture Utilization & Storage:** Capture - Pre-combustion capture (gasification and industry)
- **Crosscutting R&D:**
  - Energy Storage - large scale materials-based and H_2 storage, grid-scale energy storage;
  - Simulation Based Engineering /Integrated Energy Systems - Modeling and optimization tools for FE and FE-based and IES systems
- **21st Century Power Systems:** FEED studies for gasification-based carbon-negative power and hydrogen co-production

FY 2021 Funding Opportunities

Fossil Energy based Production, Storage, Transport & Utilization of H2 - $27.5M

- Topics include development of solid-oxide electrolysis; engineering design of advanced CO_2 capture from H_2 production; and H_2 combustion systems for gas turbines (includes coordination with HFTO)



University Turbines Systems Research — Focus on H_2 Fuels: $6.4M

- Topics include H_2 combustion fundamentals and applications for gas turbines; & H_2-air rotating detonation engines

Hydrogen Activities in Nuclear Energy (NE)

Alison Hahn, Reactor Optimization and Modernization Team Lead

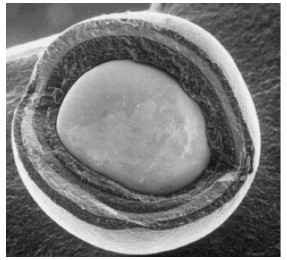
NE Mission Focus Leads to Global Competitiveness in Nuclear Technology

Existing Fleet

Advanced Reactor Pipeline

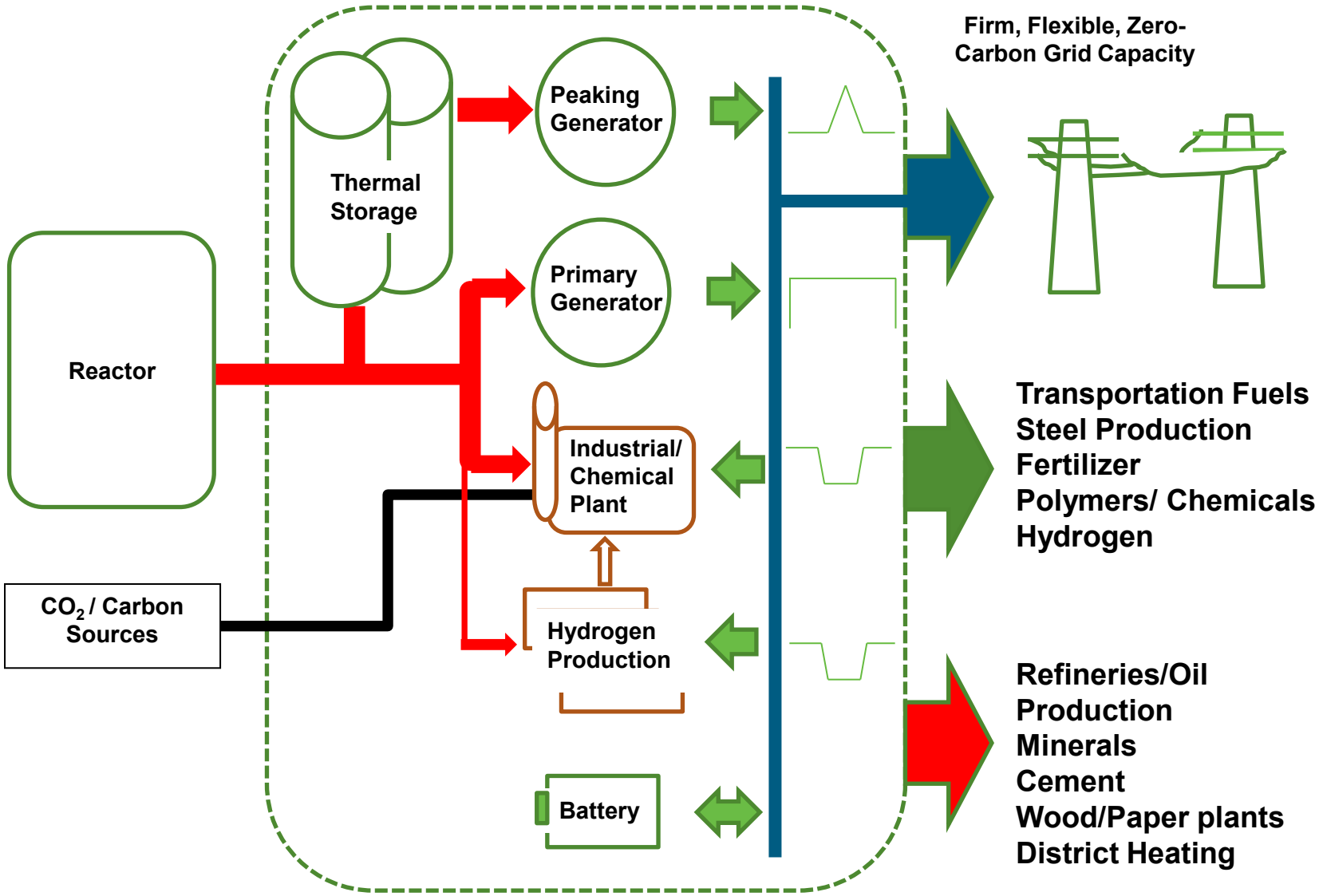
Fuel Cycle Infrastructure

Global Competitiveness



52% of emissions free electrical power in US.

Nuclear Integrated Energy Systems Strategy



Recently Funded Nuclear Powered Hydrogen Demonstrations

Hydrogen Demos

Four demos at three nuclear plants

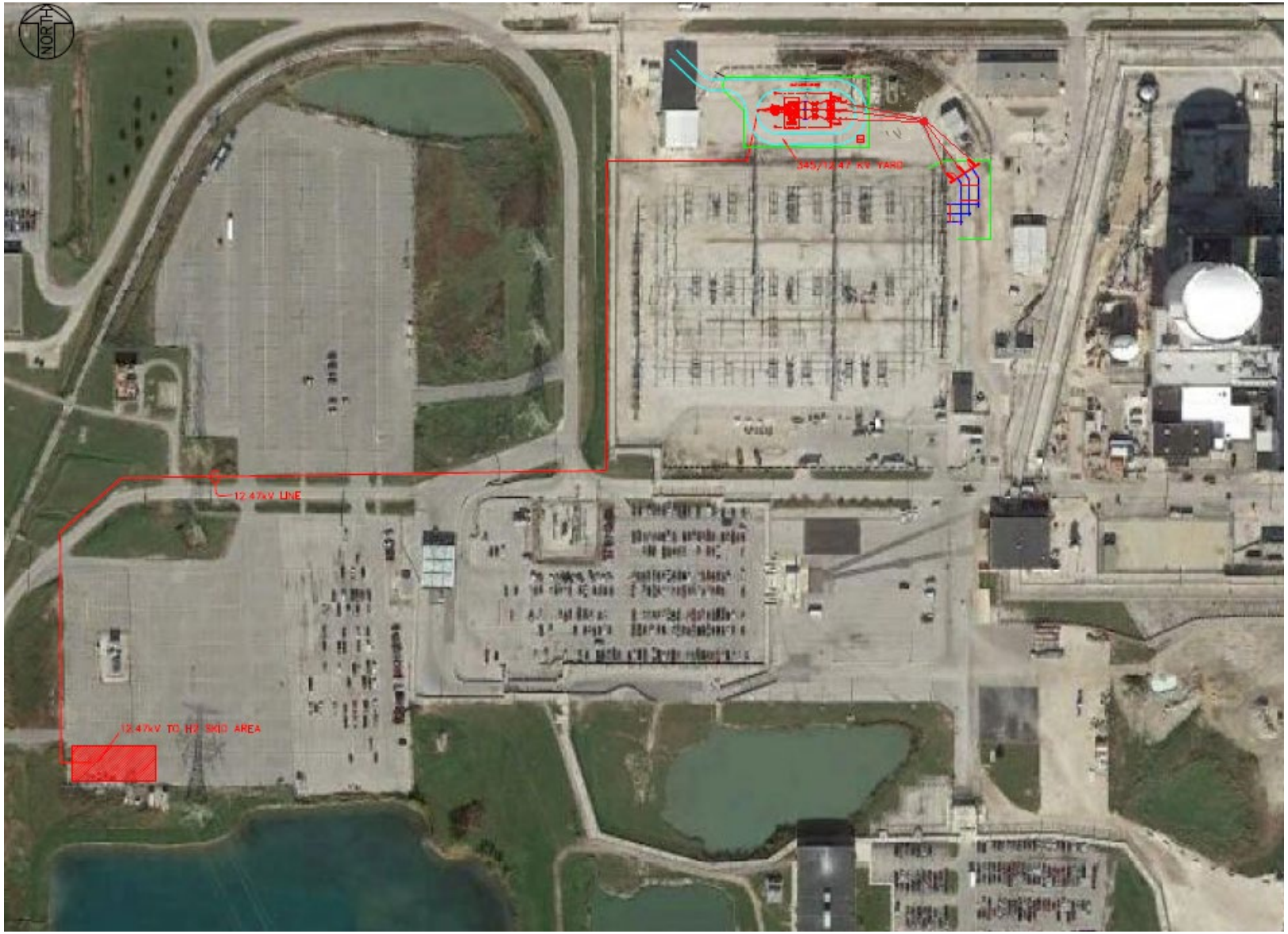
Electrolysis Technology

Low-temp PEM: ~60% efficient

High-temp steam: ~80% efficient

	kW	kg/day H_2
Exelon LT	1,000	430
Energy Harbor LT	2,000	860
FC Energy HT	250	180
Xcel HT	150	110

***estimated**

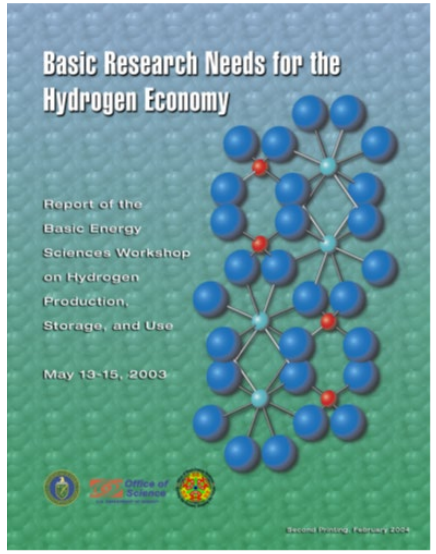


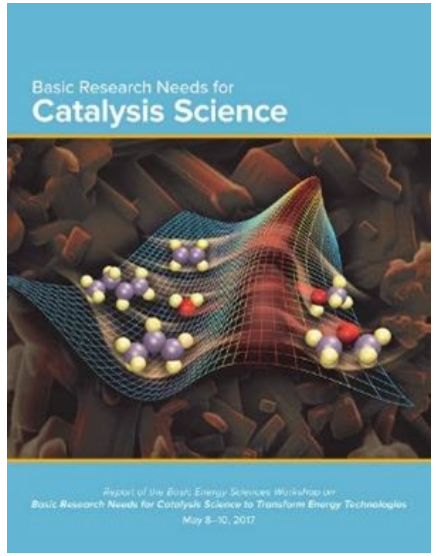
Hydrogen Research in Basic Energy Sciences (SC)

Linda Horton, Associate Director of Science for Basic Energy Sciences

Hydrogen and Fuel Cell Underpinning Science in SC-BES

- Fundamental chemical and materials sciences research to advance understanding and transformative approaches for hydrogen generation and use
- Research topics include
  - **Discover, design, and synthesize advanced materials** including catalysts for chemical conversions, membranes for separation, purification and ion transport, photoelectrodes for solar hydrogen production, and novel materials for hydrogen storage.
  - **Understand chemical mechanisms, leading to their design and control,** for efficient and selective chemical processes such as reactions, separations, ion/molecular transport, molecular update/release.
  - **Advance experimental and computational tools, including AI/ML,** to accelerate discovery and increase understanding of fundamental chemical, materials, and biological processes.
- Annual solicitations applicable for basic research in these areas include the “open” annual SC FOA. FOAs focused on special topics (e.g., Energy Frontier Research Centers, etc.) can also be relevant to hydrogen research.
- At the core of SC-BES strategic planning are reports from “Basic Research Needs” workshops and roundtables (e.g., 2003 Hydrogen Economy; 2017 Catalysis Science; 2019 Liquid Solar Fuels). For 2021, SC-BES is planning a hydrogen-focused roundtable to explore new science opportunities to advance hydrogen technologies.





Roundtable on Foundational Science for Carbon-Neutral Hydrogen Technologies

Organized by SC-BES (lead), EERE-HFTO, FE, and NE

Goal: Identify the key underpinning science needs and priority research opportunities that will accelerate RDD&D of net-zero hydrogen technologies in the US

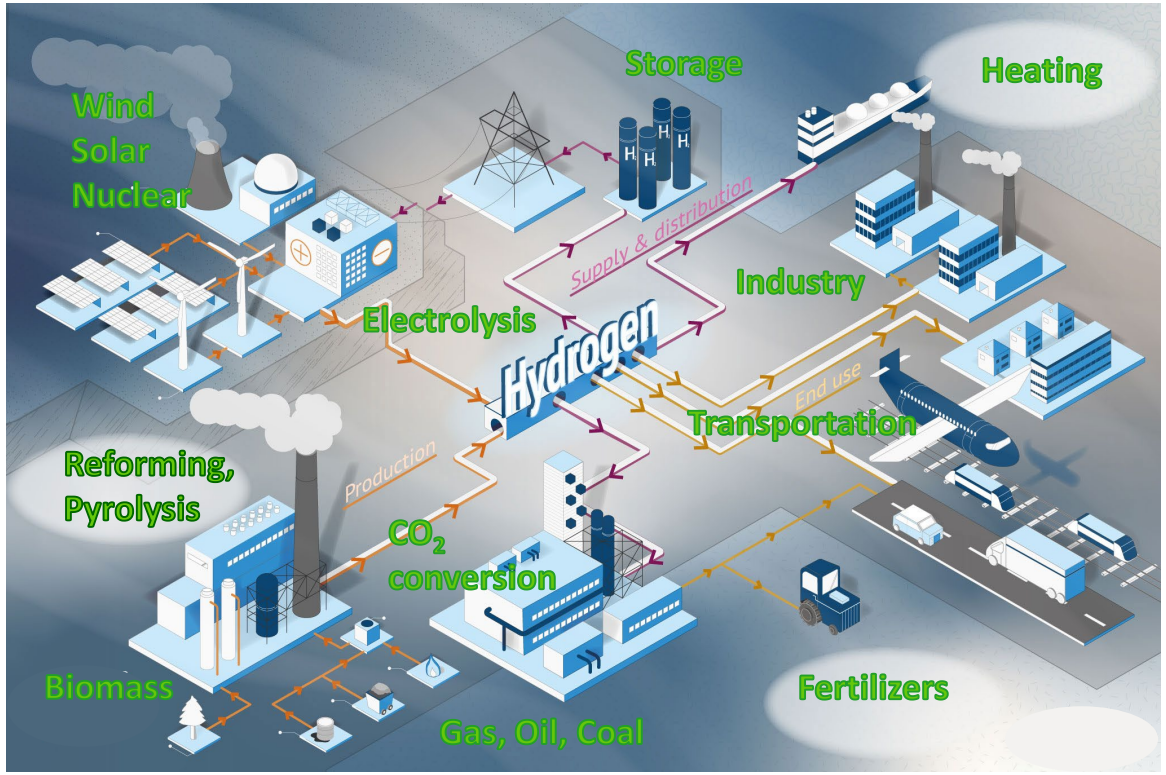
Roundtable Scope:

- Production, delivery, storage, and use of H_2 in carbon-neutral cycles
  - Water splitting and thermal (gasification/pyrolysis) processing of feedstocks as resources for H_2 production
  - H_2 used as a fuel (energy carrier) and chemical (reactant)
- Focus on crosscutting basic science concepts and approaches to impact multiple technology areas
- Preparation of a resource document on the status of hydrogen technologies for use by the roundtable and community

Participants: A diverse group representing labs, universities, industry, and other stakeholders

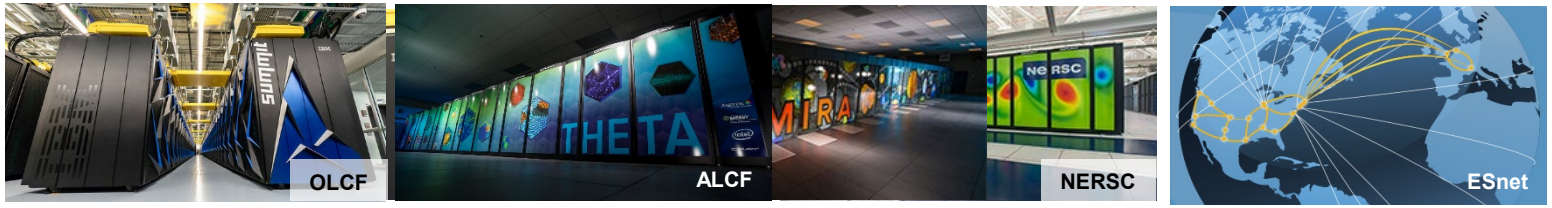
Target date: Early August

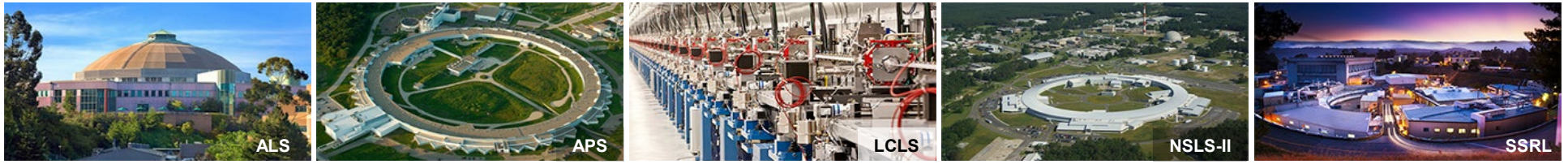
Output: A public report describing Priority Research Opportunities that identify fundamental science needed to enable technologies to overcome barriers as outlined by DOE Technology Offices



SC User Facilities Have Important Roles in Hydrogen Research

- Advanced Scientific Computing Research leadership class computers cross many disciplines to accelerate transformative progress
- Biological and Environmental Research user facilities bring bioanalytical instrumentation, genomic sequencing, and systems biology tools for innovative approaches for biological hydrogen generation
- Basic Energy Sciences light, neutron, and nanoscience facilities provide advanced synthesis and characterization to enable next-generation energy technologies

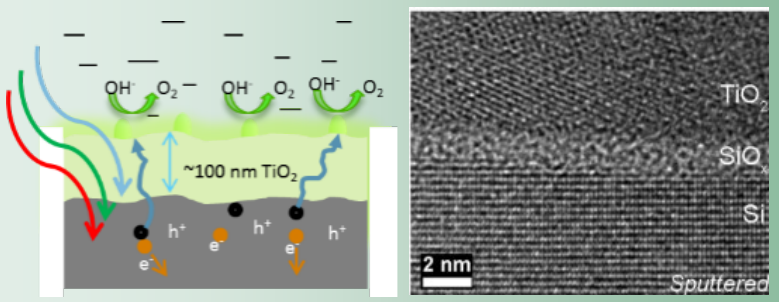




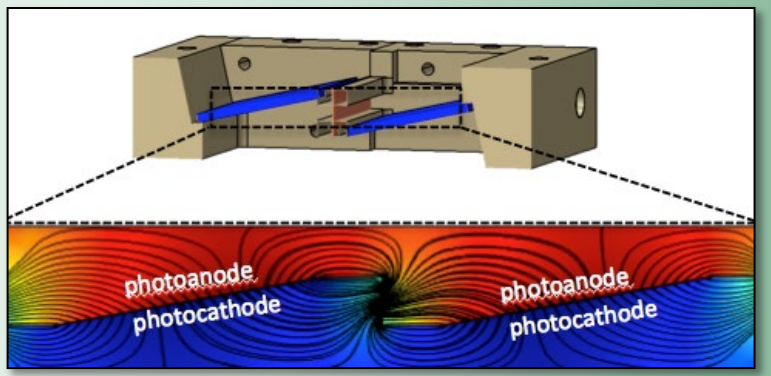
Strong collaboration between SC-BES User facilities and hydrogen-related consortia have resulted in joint publications in high-impact, peer reviewed journals.

Photoelectrochemical Generation of H_2 and Benchmarking of Performance

Materials discovery and mechanistic study on semiconductor/electrolyte interfaces



Protective layers formed by atomic layer deposition enabled stable photoelectrodes

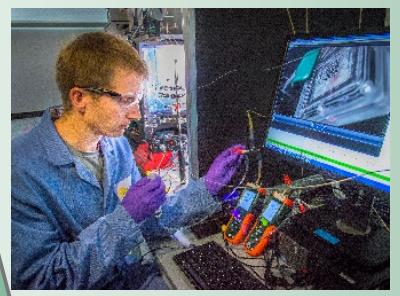


Multi-physics, multi-scale modeling & simulation

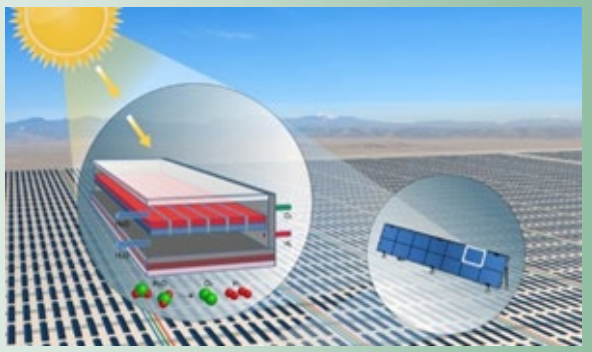
Science, 2014, 344, 1005; Energy and Environ. Sci., 2015, 8, 2409-2416; Angew. Chemie Int. Ed., 2016, 55, 12974

Modeling, Integration, and Assembly R&D

Prototyping of 19% efficient solar fuel generators



Experimental demonstration of solar fuel generators

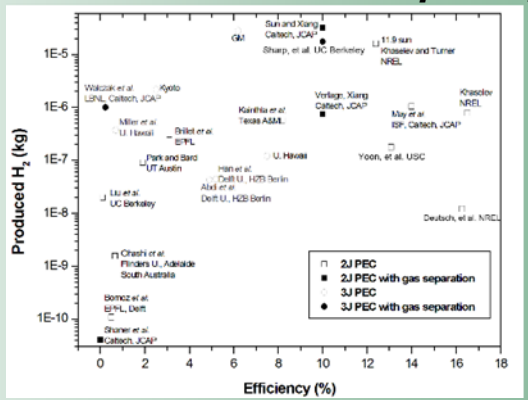


Life-cycle net energy assessment & analysis

Energy and Environ. Sci, 2015, 8, 3166-3172; *Adv. Energy Mat.* 2017, 7, 1602791; *Energy and Environ. Sci*, 2016, 9, 803-819

Development & Commercialization

Establishing Benchmarking and Best Practices for PEC water-splitting



Benchmarking device performances in real-world conditions

Coordinate with National Lab Nodes experts to establish Best Practices for materials characterization and benchmarking.

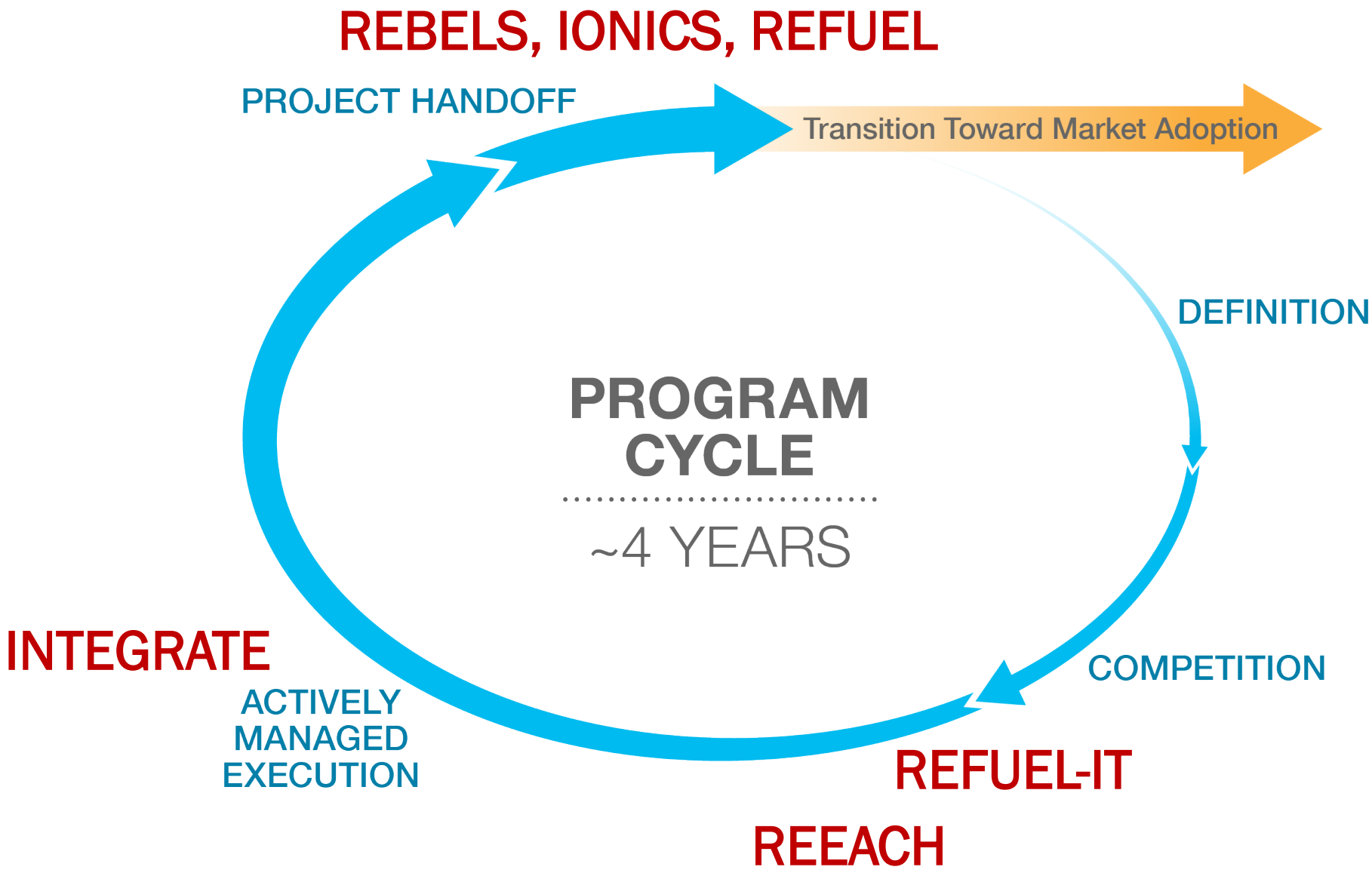
EERE - HydroGEN

ARPA-E Hydrogen and Fuel Cells Activities

Scott Litzelman, Ph.D., Program Director, Advanced Research Projects Agency - Energy

For more details see presentation by Grigorii Soloveichik on Wednesday at 10 am (ARPAE001)

How ARPA-E starts and manages programs



Interest in stationary hydrogen storage

US Department of Energy
Advanced Research Projects Agency-Energy

Request for Information (RFI)
DE-FOA-0002468
on
Stationary Hydrogen Storage Technology Development

Stationary Hydrogen Storage

In this video, ARPA-E Program Director Dr. Zak Fang discusses stationary hydrogen storage in connection with ARPA-E's OPEN 2021 funding opportunity.

https://arpa-e.energy.gov/open-2021/webinars

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- Organizational support

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Thank you!

More info on the DOE Hydrogen Program:

www.hydrogen.energy.gov