U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

For technical support during the meeting contact H2-MACH@ee.doe.gov

Manufacturing Automation and Recycling for Clean Hydrogen Technologies Experts Meeting

May 24-26, 2022

U.S. DEPARTMENT OF ENERGY

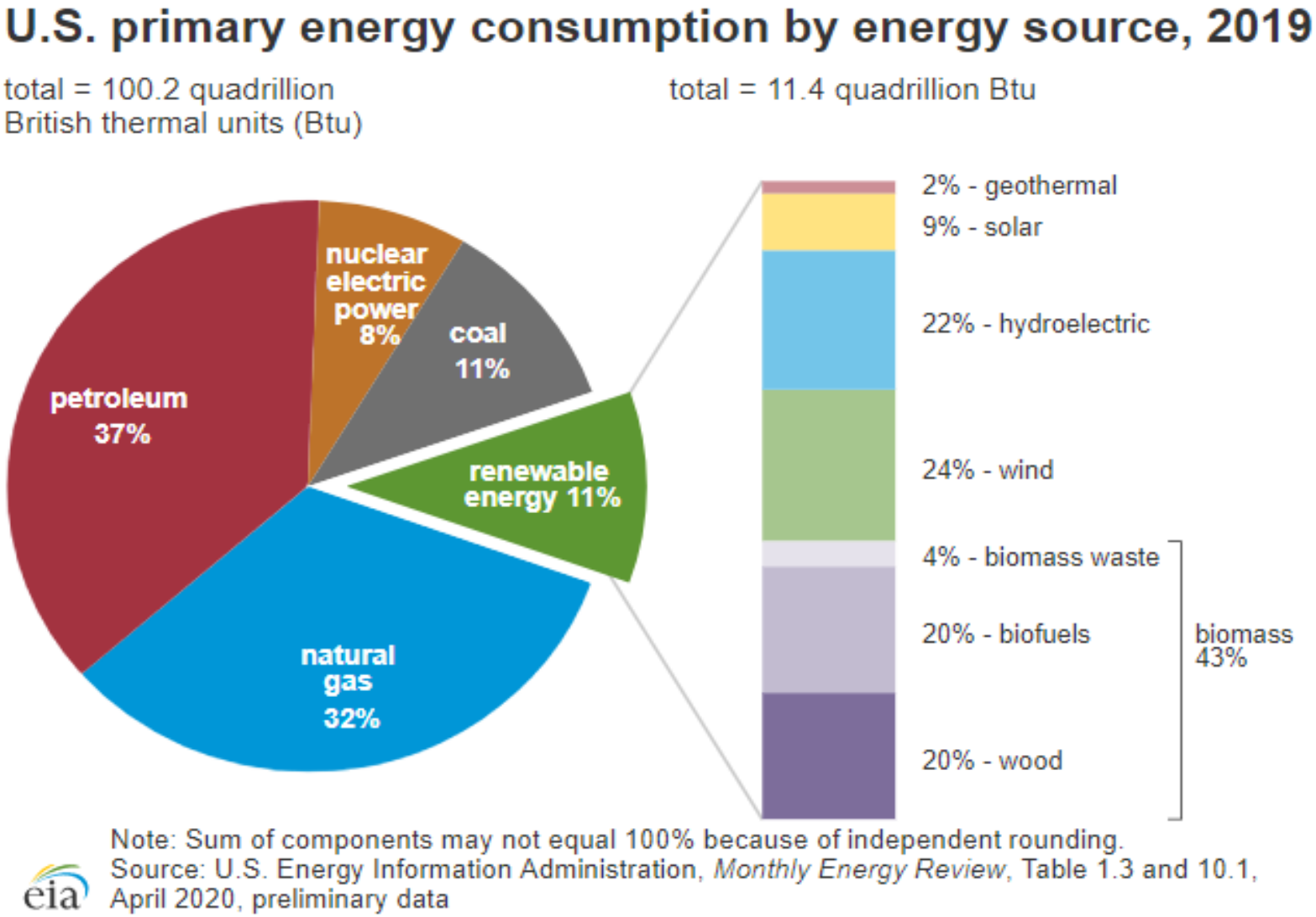
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Hydrogen and Fuel Cell Technologies Office Introduction

Dr. Dimitrios Papageorgopoulos, Program Manager, Fuel Cell Technologies
Hydrogen and Fuel Cell Technologies Office
U.S. Department of Energy

Manufacturing Automation and Recycling of Clean Hydrogen Technologies, May 2022

U.S. Energy Landscape and Key Goals



Administration Goals include:

- Net zero emissions economy by 2050 and 50 - 52% reduction by 2030
- 100% carbon-pollution-free electric sector by 2035

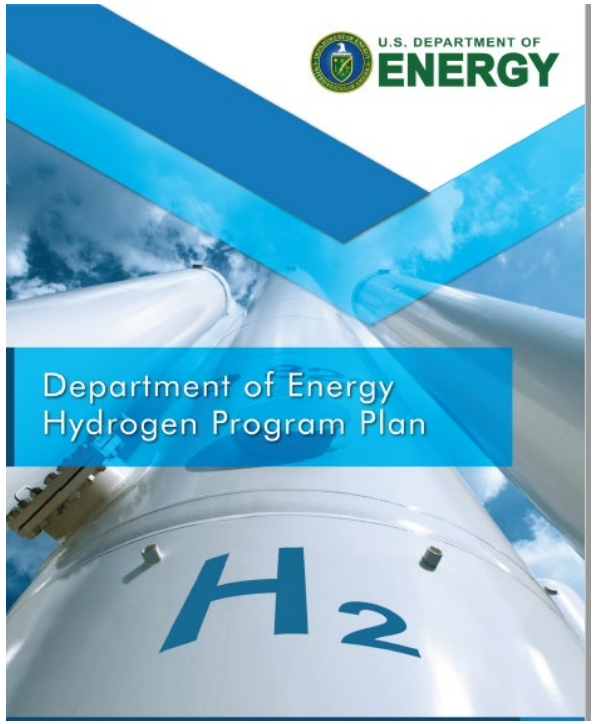
Priorities: Ensure benefits to all Americans, focus on jobs, EJ40: 40% of benefits in disadvantaged communities

EJ: Environmental Justice

The U.S. DOE Hydrogen Program

The Energy Policy Act (2005) Title VIII and Energy Policy Act of 2020 provide key authorization, coordinated across DOE Offices

Hydrogen is one part of a broad portfolio of activities to decarbonize



DOE Hydrogen Program is coordinated across offices and includes:

- **The entire value chain from production through end use**
- **All resources (renewables, nuclear, and fossil+CCS)**
- **Research, development, demonstration, deployment (RDD&D)**

www.hydrogen.energy.gov

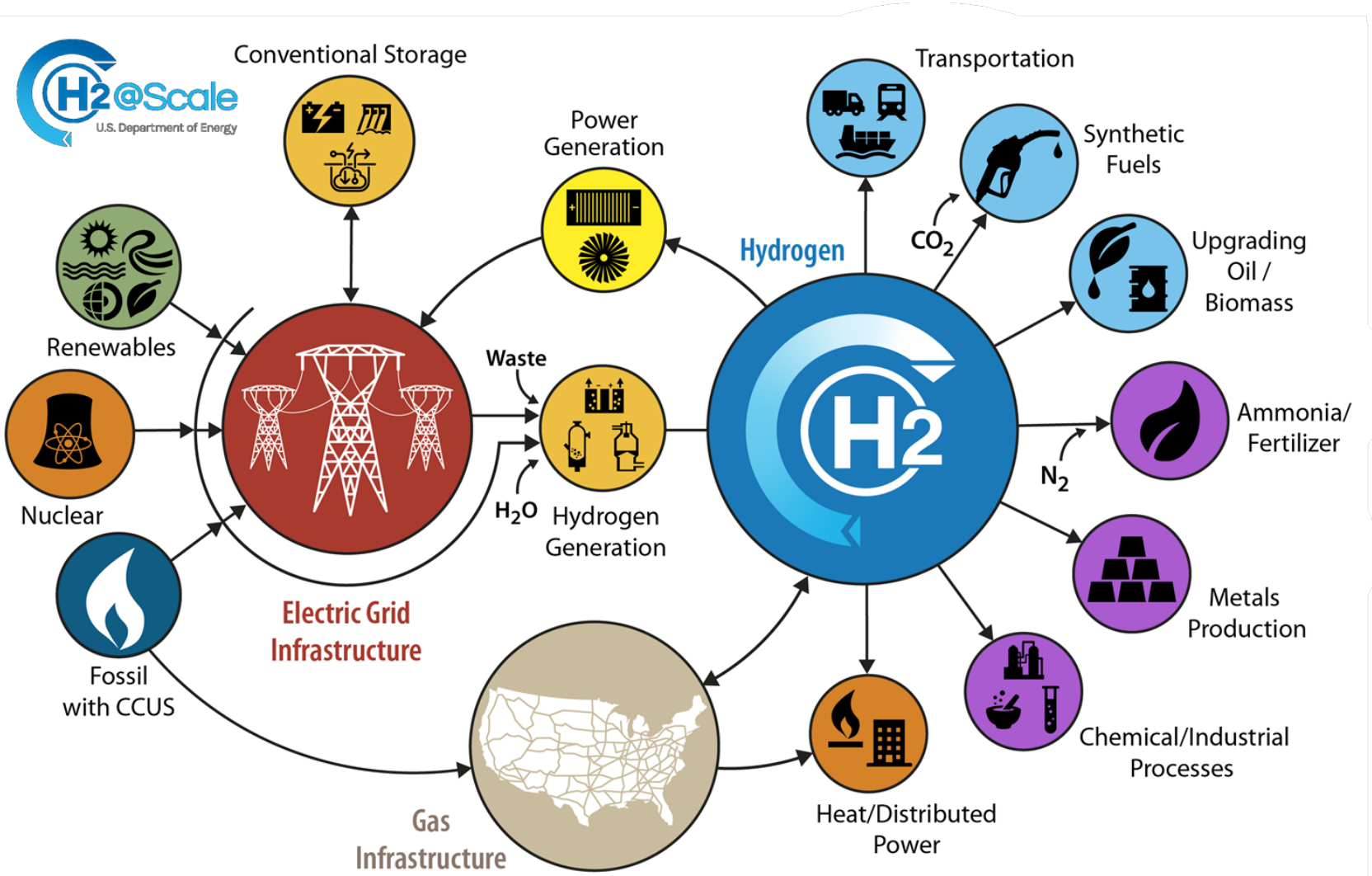
Priorities

1. **Low cost, clean hydrogen**
2. **Low cost, efficient, safe hydrogen delivery and storage**
3. **Enabling end use applications at scale for impact**

Includes workforce development, safety, codes, standards, and EJ priorities

More than 400 projects, >200 companies & universities, 15 national labs. ~$100M to $400M per year across DOE

H2@Scale: Enabler for Deep Decarbonization across Sectors and Jobs



Key Opportunities

- **Industry and Chemicals**
  Steel, ammonia, cement, syn fuels (e.g., aviation), exports
- **Transportation**
  Trucks, marine, buses, etc.
- **Power and Energy Storage**
  Long duration storage, NG blending, turbines, fuel cells

U.S. Snapshot

- 10 MMT of H_2/yr produced today with scenarios for 2-5X growth.
- +10 MMT H_2 would ~ double today's solar or wind deployment
- Potential for 700K jobs, $140B by 2030

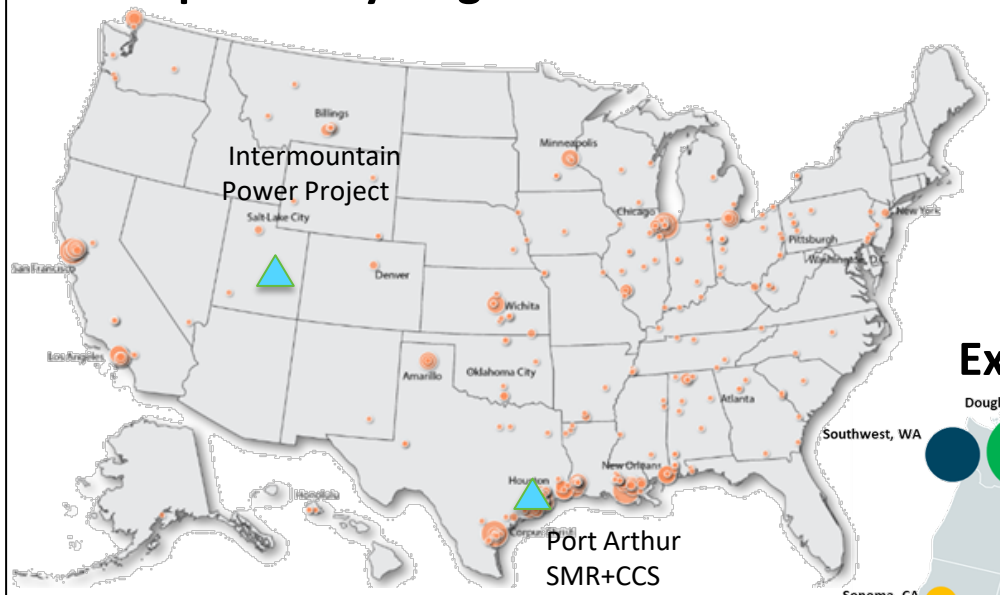
Snapshot of Hydrogen and Fuel Cells in the U.S.

Deployment Examples

>550MW	Backup Power
>50,000	Forklifts
>172 MW	PEM* Electrolyzers
~70	Fuel Cell Buses
~50	H_2 Retail Stations
>13,000	Fuel Cell Cars

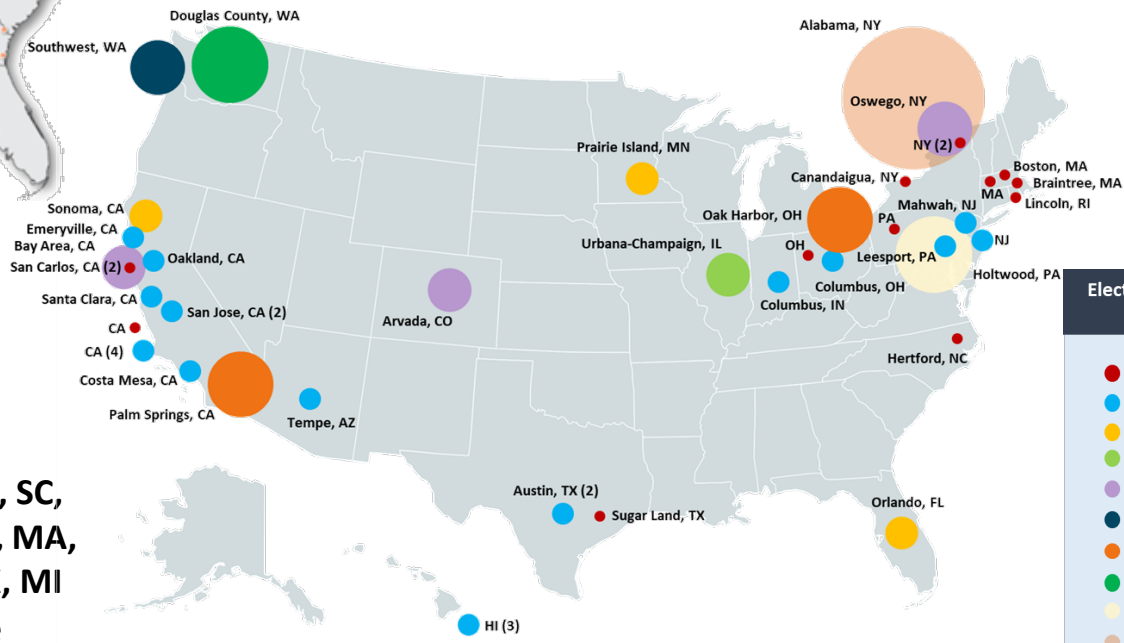
* PEM: Polymer electrolyte membrane

Examples of Hydrogen Production Locations



- 10 million metric tons (MMT) H_2/yr
- Over 1,600 miles of H_2 pipelines
- World's largest H_2 storage cavern

Examples of PEM Electrolyzer Installations



Current and under construction installations over 120 kW as of Jun. 2021
** Source: Arjona, et al, DOE HFTO Program Record, June 2021*

Examples of Hydrogen Station Plans

California
200 Stations Planned
California Fuel Cell Partnership Goal

Northeast
12 – 20 Stations Planned

AZ, HI, OH, SC, NJ, NY, CT, MA, CO, UT, TX, MI
And more

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

Bipartisan Infrastructure Law - Hydrogen Highlights

- **Includes $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

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

- **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**

Sec. 40314, EPACT Sec. 815 and Related BIL Provisions

"Clean H_2 Electrolysis Program": BIL Includes RDD&D across multiple electrolysis technologies, compression, storage, drying, integrated systems, etc. - directly supports Hydrogen Shot

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

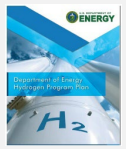
"Clean Hydrogen Manufacturing and Recycling"

Focus on manufacturing and end of life/recycling RD&D

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

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: Includes working with EPA to develop an initial clean hydrogen production standard per Sec. 822 $\leq$ 2 kg CO_2e/kg H_2

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

Section 815a: Clean Hydrogen Manufacturing Initiative

Research, development and demonstration projects to advance new clean H_2 delivery, storage and use equipment **manufacturing technologies and techniques**.

The Secretary, to the maximum extent practicable, shall give priority to clean hydrogen equipment manufacturing projects that—

A. Increase efficiency and cost-effectiveness in—

i. the **manufacturing process**; and

ii. the use of resources, **including existing energy infrastructure**;

B. Support **domestic supply chains** for materials and components;

C. Identify and incorporate nonhazardous **alternative materials** for components and devices;

D. Operate in partnership with tribal energy development organizations, **Indian Tribes, Tribal orgs., Native Hawaiian community**-based organizations, **or territories or freely associated States**; or

E. Are located in **economically distressed areas** of the major natural gas-producing regions of the US

Section 815b: Clean H_2 Tech Recycling RD&D Program

Multiyear grants will be awarded for RD&D projects **to create innovative and practical approaches to increase the reuse and recycling** of clean H_2 tech.

Including by:

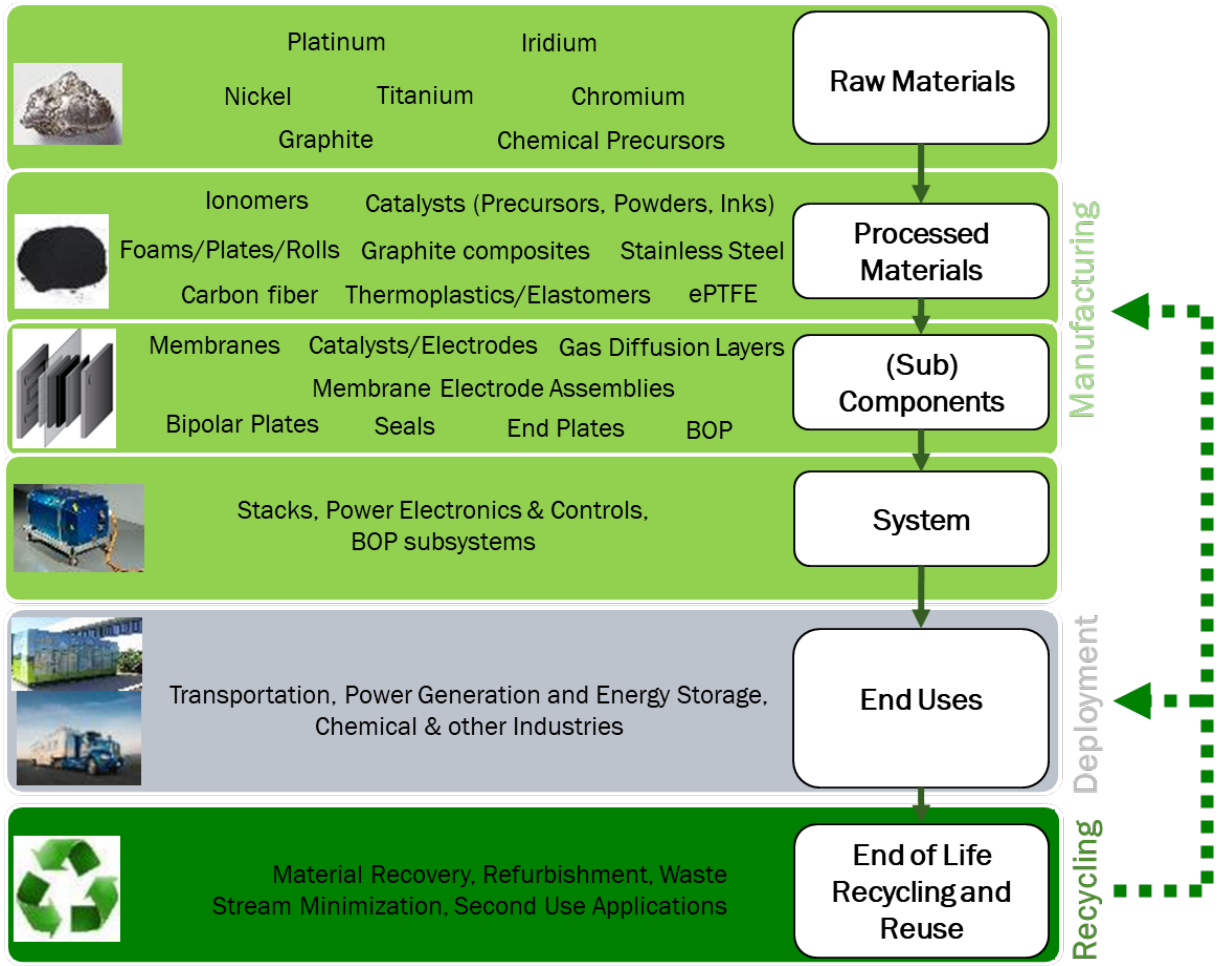
A. Increasing the efficiency and **cost-effectiveness of the recovery of raw materials** from clean hydrogen technology components and systems, including enabling technologies such as electrolyzers and fuel cells;
B. **Minimizing environmental impacts** from the recovery and disposal processes
C. addressing any barriers to the research, development, demonstration, and commercialization **of technologies and processes for the disassembly and recycling of devices** used for clean hydrogen production, processing, delivery, storage, and use
D. Developing **alternative materials, designs, manufacturing processes,** and other aspects of clean H_2 tech.
E. Developing alternative **disassembly and resource recovery** processes that enable efficient, cost-effective, and environmentally responsible disassembly of, and resource recovery from, clean hydrogen technologies; and
F. Developing strategies to increase consumer acceptance of, and participation in, **the recycling of fuel cells**.

Independent review of project progress no later than 3 years after H.R. 3684 is enacted, and at least every 4 years after that.

Addressing Supply Chain Challenges

*Growth required across domestic clean H_2 supply chains**

Example: PEM fuel cell & electrolyzer supply chain



Key Manufacturing & Recycling Program opportunities:

- Reducing cost and increasing commercialization of clean H_2 technologies
- Development of domestic material supplies – including recycling and alternative non-hazardous materials
- Development of manufacturing capacity to meet projected H_2 demand
- Leadership on energy and environmental justice issues for a new industry

*www.energy.gov/eere/fuelcells/water-electrolyzers-and-fuel-cells-supply-chain-deep-dive-assessment

Goals for This Meeting:

- Identify RD&D gaps in automation/scaling of manufacturing and recycling for polymer electrolyte membrane (PEM) and solid oxide cells/stacks/systems, and hydrogen storage tanks
  - Determine what scalable manufacturing and recycling technologies/processes are ready for larger demonstrations at pilot scale to de-risk industry adoption
  - Identify what additional R&D could lead to pilot demonstrations in 2-4 years

- Create opportunities for experts in differing areas to overlap in expert presentations, panel discussions, and moderated breakout sessions to address needs

Meeting Agenda* – Day 1

11:00 AM	HFTO Welcome and Introduction	Dimitrios Papageorgopoulos, *DOE Hydrogen & Fuel Cell Technologies Office*
11:15 AM	Manufacturing Expert Presentations	Brian James, **Strategic Analysis, Inc.** Kathy Ayers, **Nel Hydrogen, US** Todd Striker, **Cummins, Inc.** Dan Hawtof, **Corning Inc.** Michael Skocik, **Advanced Robotics for Manufacturing Institute**
1:30 PM	- Break -	
2:00 PM	Cell Manufacturing and Assembly Automation Expert Panel:	Steve Rock, **Advent Technologies, Inc.** Natalya Bailey, **Bloom Energy** Scott Swartz, **Nexceris, LLC** Gary Robb, **EERE**
3:00 PM	Breakout Sessions	
Cell Manufacturing Automation Needs	Inspection/Component Tracking	Materials/Components Flow and Supply Chain Analysis
4:00 PM	- Wrap-up and Adjourn -	

**All times in Eastern Standard Time*

Thank you

Dr. Dimitrios Papageorgopoulos
Program Manager, Fuel Cell Technologies,
Hydrogen and Fuel Cell Technologies Office
Dimitrios.Papageorgopoulos@ee.doe.gov
U.S. Department of Energy

DOE Annual Merit Review and Peer Evaluation Meeting
June 6-8, 2022

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