2022 AMR Plenary Session

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U.S. Department of Energy

June 6, 2022
Introduction – Energy, Market, and Policy Context
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

Note: Sum of components may not equal 100% because of independent rounding
Source: Data collected from U.S. Energy Information Administration, April 2022, Monthly Energy Review, preliminary data
U.S. Energy Related CO₂ Emissions by Sector End-Use

Need to address all sectors with a portfolio approach

Hydrogen can provide benefits particularly in hard to decarbonize sectors: industry, heavy duty transport and to enable energy storage

Note: Sum of sectors may not equal 100% due to independent rounding
Source: M. Koleva, DOE HFTO, NREL, adapted from EIA, 2020, U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

Total: ~5.9 GT (CO₂)
Snapshot of Hydrogen and Fuel Cells in the U.S.

- 10 million metric tons produced annually
- More than 1,600 miles of H₂ pipeline
- World’s largest H₂ storage cavern

**Use of Hydrogen in the U.S. Today**

- 35% Ammonia & Methanol
- 8% Other Metals (2%)
- 55% Refining

**Examples of Hydrogen Production Locations**

**Examples of Deployments**

- >500MW Backup Power
- >50,000 Forklifts
- >620 MW PEM* Electrolyzers
- >80 Fuel Cell Buses
- ~50 H₂ Retail Stations
- >13,000 Fuel Cell Cars

*Proton exchange membrane

- 0 – 50
- 50 – 100
- 100 – 200
- 200 – 400
- 400 – 800

Hydrogen Production Units
Gaseous Metric Tons/Day
Offsite PEM Electrolyzer Locations and Capacity – 2021 Snapshot

Operational and Under Construction: 172 MW Capacity

PEM: Proton Exchange Membrane
Current and under construction installations over 120 kW as of June 2021
Source: Arjona, et al, DOE HFTO Program Record 20009, June 2021
hydrogen.energy.gov/program_records.html
PEM Electrolyzer Locations and Capacity – 2022 Snapshot

Operational and Under Construction: > 620 MW Capacity

PEM: Proton Exchange Membrane
Current and under construction installations over 120 kW as of May 2022

Source: Arjona, V., DOE HFTO Program Record 22001, June 2022
Cumulative Installed Capacities of Wind, Solar, and Electrolyzers in the U.S.

Similar to solar and wind, electrolyzer deployments are scaling up rapidly.

Electrolyzer deployment in the U.S. is scaling up exponentially.

Global electrolyzer market estimates vary.
Scenarios show over 60 GW by 2030.

Penetration of Renewables Drives the Need for Energy Storage

For the first time in history, in May 2022, renewable power in California exceeded demand.
Developing Our Strategy, Sharpening Our Goals
“Water the roots, not the leaves, to grow the trees.”
The U.S. DOE Hydrogen Program Spans Multiple DOE Offices

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 H₂ value chain from production through end-use
- H₂ production from all resources (renewables, nuclear, and fossil + CCS)

H₂@Scale provides a vision to guide how hydrogen can enable clean-energy pathways across applications and sectors in an increasingly interconnected energy system

DOE Hydrogen Program Plan (2020)

www.hydrogen.energy.gov
## Comprehensive DOE Strategy Across the Hydrogen Value Chain

<table>
<thead>
<tr>
<th>Production</th>
<th>NEAR-TERM</th>
<th>LONGER-TERM</th>
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<tbody>
<tr>
<td>Electrolysis (low-temperature, high-temperature)</td>
<td>Advanced thermo/photoelectro-chemical $\text{H}_2\text{O}$ splitting</td>
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<tr>
<td>Advanced fossil and biomass reforming/conversion/pyrolysis</td>
<td>Advanced biological/microbial conversion</td>
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<td>Gasification of biomass, legacy coal waste, and other wastes with carbon capture, utilization, and storage</td>
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<td>Distribution from on-site production</td>
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<tr>
<td>Tube trailers (gaseous $\text{H}_2$)</td>
<td>Widespread pipeline transmission and distribution</td>
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<tr>
<td>Cryogenic trucks (liquid $\text{H}_2$)</td>
<td>Chemical $\text{H}_2$ carriers</td>
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<tr>
<td>Storage</td>
<td>Pressurized tanks (gaseous $\text{H}_2$)</td>
<td>Geologic $\text{H}_2$ storage (e.g., caverns, depleted oil/gas reservoirs)</td>
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<tr>
<td>Cryogenic vessels (liquid $\text{H}_2$)</td>
<td>Cryo-compressed</td>
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<td></td>
<td>Chemical $\text{H}_2$ carriers</td>
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<td>Materials-based $\text{H}_2$ storage</td>
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<tr>
<td>Conversion</td>
<td>Turbine combustion</td>
<td>Advanced combustion</td>
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<tr>
<td>Fuel cells</td>
<td>Next generation fuel cells</td>
<td>Fuel cell/combustion hybrids</td>
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<tr>
<td>Applications</td>
<td>Fuel refining</td>
<td>Blending in natural gas pipelines</td>
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<tr>
<td>Space applications</td>
<td>Distributed stationary power</td>
<td>Utility systems</td>
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<tr>
<td>Portable power</td>
<td>Transportation</td>
<td>Distributed CHP</td>
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<td></td>
<td>Industrial and chemical processes</td>
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<td>Defense, security, and logistics applications</td>
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Coordinated Strategy Across RDD&D

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

Portfolio includes:
1) Single project recipients & subrecipients
2) Consortia—leveraging national labs
3) Direct projects at/with labs
4) Small business innovation projects

Consortia:

Examples

- HydroGEN
- ElectroCat
- H-Mat
- H2NEW
- MILLION MILE FUEL CELL TRUCK
Program Priorities and Key Initiatives to Address Them

**Program Priorities**

1. Low-Cost Clean Hydrogen Production
2. Safe, Low-Cost Delivery and Storage Infrastructure
3. Low Cost, Durable, and Efficient Fuel Cells & Low-NO\textsubscript{x} Turbines
4. Enable End Use Applications at Scale

**Key Initiatives to Address Priorities**

- **H2NEW, HydroGEN, ElectroCAT, Hydrogen Shot Incubator Prize, H2 Demos**
- **H-Mat, HyBlend, HyMARC, SHASTA, C-Fiber Tanks, Liquefaction, Sensors**
- **M2FCT, ElectroCAT, Low-NOx Turbine RD&D**
- **H2@Scale demos, Hydrogen Hubs, H2 Matchmaker**

**DOE Targets include:**

- **Clean Hydrogen**
  - $1/kg production
  - $2/kg delivery
  - $9/kWh storage

- **Electrolyzers**
  - $150/kW
  - 73% efficiency
  - 80Khr durability

- **Fuel Cells for Heavy Duty Trucks**
  - $80/kW
  - 25Khr durability

- **Enable EJ40 Priorities**

Examples from multiple offices across DOE.
DOE Hydrogen Program: Budgets & Plans
### DOE Hydrogen Program Fiscal Year (FY) Funding across Offices

**FY21 Appropriations:** $318.9 M  
**FY22 Appropriations:** $330.3 M*  
**FY23 Request:** $406 M  
**OTT** $100 M

<table>
<thead>
<tr>
<th>Appropriations ($ millions)</th>
<th>FY21</th>
<th>FY22</th>
<th>FY23</th>
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<tbody>
<tr>
<td><strong>EERE</strong></td>
<td>$155.9 M</td>
<td>$162.0 M</td>
<td>$217.5 M</td>
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<td><strong>SC</strong></td>
<td>$88.7 M</td>
<td>$125.3 M</td>
<td>$50 M</td>
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<td><strong>FECM</strong></td>
<td>$23 M</td>
<td>$20 M</td>
<td>$12 M</td>
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<td><strong>NE</strong></td>
<td>$17 M</td>
<td>$23 M</td>
<td>$116 M</td>
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<td><strong>ARPA-E</strong></td>
<td>$34.34 M</td>
<td>$23 M</td>
<td>$12 M</td>
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<td><strong>OTT</strong></td>
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*Final to be updated EOY; pending SC, ARPA-E, and other final allocations by end of year. ARPA-E funding is determined annually based on programs. Annual funding only, excludes BIL funding and new offices (e.g., OCED) developed through office and stakeholder priorities. FY funding 2023 is TBD.

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 Subprograms

<table>
<thead>
<tr>
<th>Hydrogen Technologies</th>
<th>Fuel Cell Technologies</th>
<th>Systems Development &amp; Integration</th>
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<tbody>
<tr>
<td>Hydrogen Production</td>
<td>Materials &amp; Components</td>
<td>Transportation</td>
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<tr>
<td>Hydrogen Infrastructure and Storage</td>
<td>Systems</td>
<td>Industrial and Chemical Applications</td>
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<td>Grid Energy Storage and Power Generation</td>
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<td>Safety, Codes and Standards</td>
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Data, Modeling, and Analysis
Hydrogen and Fuel Cell Technologies Office Budget

### FY21 Appropriations
- Total: $150 M
  - Data, Modeling and Analysis: $51 M
  - Fuel Cell Technologies: $25 M
  - Hydrogen Delivery & Storage: $41 M
  - Hydrogen Production: $30 M

### FY22 Appropriations
- Total: $157.5 M
  - Data, Modeling and Analysis: $64 M
  - Fuel Cell Technologies: $30 M
  - Hydrogen Delivery & Storage: $46 M
  - Hydrogen Production: $15 M

### FY23 Request
- Total: $186 M
  - Data, Modeling and Analysis: $87 M
  - Fuel Cell Technologies: $25 M
  - Hydrogen Delivery & Storage: $56 M
  - Hydrogen Production: $15 M

### Activities
- Guide and strengthen portfolio through rigorous analysis
- Validate first-of-a-kind systems across applications, de-risk technologies. Includes safety, codes, standards, workforce development
- Continue heavy-duty fuel cell R&D, including supply chain
- Increase bulk storage, liquid, and delivery focus (e.g., carriers)
- Supplement production RD&D with BIL funding (including $1B)
The Bipartisan Infrastructure Law (BIL)
a.k.a
Infrastructure Investment and Jobs Act (IIJA)
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

• Aligns with Hydrogen Shot priorities by directing work to reduce the cost of clean hydrogen to $2 per kg by 2026

• Requires developing a National Hydrogen Strategy and Roadmap
“Clean H₂ Electrolysis Program”: BIL Includes research, development, demonstration and deployment (RDD&D) across multiple electrolysis technologies, compression, storage, drying, integrated systems, etc. Directly supports Hydrogen Shot

“Clean Hydrogen Manufacturing and Recycling”
Raw Materials → Processed Materials → Subcomponents → End Product
Focus on manufacturing and end of life/recycling RD&D

Regional Clean H₂ Hubs: At least 4 Hubs, geographic diversity, includes renewables, fossil + CCS, nuclear, for clean hydrogen production, multiple end use applications.

National Hydrogen Strategy and Roadmap: Includes working with EPA to develop an initial clean hydrogen production standard per Sec. 822: $2 \text{ kg CO}_2 \text{e per kg H}_2$

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

Sec. 40314 (EPACT Sec 815): Clean Hydrogen Manufacturing & Recycling $0.5 \text{ Billion over 5 years}$

Sec. 40314 (EPACT Sec 813): Regional Clean Hydrogen Hubs; $8 \text{ Billion over 5 years}$

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

Broad Stakeholder Engagement included:

- **Interagency**: ~10 agencies
- **Webinars**: >1,700 participants
- **Industry**: >85 through industry coalitions
- **15 National Labs**
- **Tribal, Labor Union, EJ communities**
- **Environmental organizations**

**DOE**: HFTO (lead) EERE, FECM, NE, SC, OTT, LPO, OE, OP, OCED, ED, IE, ELEP, and more (DOE Science and Energy Tech Team, “SETT”)
Guiding Principles include

- Enable Deep Decarbonization
- Catalyze innovation & investment
- Spur domestic manufacturing
- Grow sustainable jobs
- Foster diversity, equity & inclusion
- Advance environmental justice
- Enable affordability and versatility
- Approach holistically

Vision:
Affordable clean hydrogen for a net-zero carbon future and a sustainable, resilient, and equitable economy

Benefits:
Emissions reduction; quality job growth; energy security and resilience; positive community impact

Strategy

1. Target strategic, high-impact end uses
   Achieve 5 MMT/year of clean hydrogen by 2030

2. Reduce the cost of clean hydrogen
   Enable $2/kg by electrolysis by 2026 and $1/kg H₂ by 2031

3. Focus on regional networks
   Deploy 4 or more clean hydrogen hubs and ramp up scale

Enablers:
- Workforce development
- Safety, codes and standards
- Policies and incentives
- Stimulating private sector investment
- Energy and environmental justice

Work with other agencies to accelerate market lift off
Target Strategic, High-Impact Uses of Hydrogen
U.S. Energy Related CO₂ Emissions by Sector End-Use

Total: ~5.9 GT (CO₂-eq)

Hydrogen can provide benefits particularly in hard to decarbonize sectors: industry, heavy duty transport and to enable energy storage

VCLRW - Ventilation, Cooking, Lighting, Refrigeration & Washing
BOM - Balance of Manufacturing

Other industrial: aluminum, cement and lime, construction, agriculture, plastics, wood, electrical equipment, transportation equipment, computing and electronics equipment, paper products, glass, etc.

Note: Sum of sectors may not equal 100% due to independent rounding
Some applications can start to be competitive at a higher threshold cost and can jumpstart the market.

Threshold cost for each application includes cost of production, delivery, storage, compression/processing/dispensing, as required, to the point of use for each application.
Clean Hydrogen Demand and Costs for Market Penetration

Scenario Analyses for H₂ Demand**

- ~ 10-15% of trucks using fuel cells
- ~ 100% SAFs in 2050
- ~ 10% of U.S. steel making
- All domestic ammonia demand
- Energy storage in a clean grid
- Roughly half of domestic methanol
- H₂/NG blends for high-temp heat and power in industry
- Additional applications, include stationary power, synfuels, and export potential

Costs include production, delivery, dispensing to the point of use (e.g., high-pressure fueling for vehicle applications)
The Opportunity for Clean Hydrogen

Clean Hydrogen Use Scenarios

- Catalyze clean $H_2$ use in existing industries (ammonia, refineries), initiate use for sustainable aviation fuels (SAFs), steel, potential exports
- Scale up use for heavy-duty transport, industry, and energy storage
- Market expansion across sectors for strategic, high-impact uses
Range of Potential 2050 U.S. Clean Hydrogen Demand

- Recognizes range of uncertainties
- Includes conservative and ambitious scenarios
- Core range: ~18–36 MMT H₂
- Maximum range: ~36–56 MMT H₂

Potential Opportunities for:
- ~5 MMT/yr by 2030
- ~20 MMT/yr by 2040
- ~50 MMT/yr by 2050

Refs: 1. NREL MDHD analysis using TEMPO model; 2. Analysis of biofuel pathways from NREL; 3. Synfuels analysis based off H₂@Scale; 4. Steel and ammonia demand estimates based off DOE Industrial Decarbonization Roadmap and H₂@Scale. Methanol demands based off IRENA and IEA estimates; 5. Preliminary Analysis, NREL 100% Clean Grid Study; 6. DOE Solar Futures Study; 7. Princeton Net Zero America Study
Stakeholder Reported Barriers to Hydrogen Market Adoption

- 4,900+ total registrants,
- 3,200+ participants at Plenary
- 34 countries

Cost to end user: 22%
Need for sufficient infrastructure: 19%
Public awareness/understanding: 17%
Need for technology advancements: 11%
Lack of incentives for companies: 8%
Competing technologies: 6%
Safety concerns: 6%
Lack of suitable end uses: 5%
Lack of gov. support for R&D: 5%

Source: Hydrogen shot summit, Sept 2021

https://www.energy.gov/eere/fuelcells/hydrogen-shot-summit
Focus on Cost-Reduction
### Key Goals: Reduce the cost of fuel cells and hydrogen production, delivery, storage, and meet performance and durability requirements—guided by application-specific targets

<table>
<thead>
<tr>
<th>FUEL CELL R&amp;D</th>
<th>HYDROGEN TECHNOLOGIES R&amp;D</th>
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</table>
| **Fuel Cell System** *(heavy duty vehicle)* | **Production Cost** *(electrolytic hydrogen)* | **Delivery & Dispensing Cost** | **Onboard Storage Cost**
| $323/kW† | $7/kg† | $11/kg† | $21/kWh |
| $227/kW | $5/kg† | $9.5/kg | |
| $185/kW | $4.50/kg * | $8/kg* | $16/kWh |
| | $3.50/kg * | | |

- $80/kW
- **$1/kg**
- **$2/kg**
- $9/kWh

### Notes:
- *Based on 275 kW heavy-duty fuel cell system cost analysis (2021), adjusted to reflect cost of system that meets 25,000 hours durability.
- †For range: Delivery and dispensing at today’s (2020) stations with capacity 450 kg/day.
- ††For range: Delivery and dispensing at today’s (2020) stations with capacity 450-1,000 kg/day at high volume manufacturing.
- **See Hydrogen Technologies Plenary presentation for more information about pending Program Record.**

### Onboard Storage Cost

- **Low-Volume (Current) Estimate**
- **High-Volume Projection**
- **2030 Target**

### All costs based on $2016

Note: Graph is not at scale. For illustrative purposes only.
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
Strategy includes Hydrogen Shot

Baseline 2020 cost: PEM $1,500/kW, $50/MWh, 90% capacity factor

Electrolysis
Cost: $5/kg H₂*
(at low volume)

Thermal Conversion (e.g., NG)
Cost: $1.50/kg
but high emissions

Advanced Pathways >$10/kg
H₂/TBD

Hydrogen Shot
1 for 1 in 1
$1 1 kg clean H₂ 1 decade

Use Cases
- Enabling a Clean Grid
- Biofuels, Synfuels, Aviation
- Heavy Duty Trucks
- Chemicals, Fertilizer
- Blending with Natural Gas
- Steel, Iron, Cement Manufacturing

Impact
- Decarbonization
- Equity, Inclusion
- Reliability, Resiliency
- Exports
- Jobs
- Long Duration Energy Storage

* Baseline 2020 cost: PEM $1,500/kW, $50/MWh, 90% capacity factor
How to reduce cost? Examples across multiple pathways

**H₂ from Electrolysis**

- 2020*: ~$5/kg
- 2026: $2/kg
- 2031: $1/kg

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

**Thermal Conversion**

- Example: Natural Gas Conversion + CCUS

- 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.
Scenario to Reduce PEM Electrolyzer Cost

- Increase manufacturing volume (multi-GW)
- Reduce capital cost <$300/kW by 2025, ~150/kW by 2030
- Maintain performance and durability while addressing stack and balance-of-plant (BOP) costs

Need Demonstrations & Deployments, together with Research & Development
Hydrogen Shot Incubator Prize

Hydrogen Shot Incubator Prize complements conventional FOAs by providing vouchers for entrepreneurs to use national lab experts for proof of concept. The voucher recipients are encouraged to pitch to investors or apply for future FOAs.

FOAs, Consortia, Demos, H2 Hubs, Loan Guarantees

Feedback requested on industry needs includes:
- **System Demonstration and Deployment (TRL 7-9)**: Pilot and commercial demonstrations of complete systems coupled with infrastructure and use applications.
- **Advanced Manufacturing (TRL 6-7)**: High-throughput manufacturing and assembly processes.
- **Advanced Systems (TRL 5-7)**: Higher performance systems, with optimized balance of plant components.
- **Advanced Components (TRL 4-5)**: Higher performance, durable components, such as MEAs, up through stacks.
- **Advanced Materials (TRL 1-3)**: Improved electrocatalyst, catalyst supports, electrolytes, membranes, etc.

AI and machine learning tools explored with AI Office to de-risk demos and validate integrated systems. Ramp up scale through demos and H2 Hubs.
Hydrogen Shot Incubator Prize

1. Propose!
   Accelerate development of new solutions for clean hydrogen production.
   - Up to 10 Winners
   - $10,000 cash
   - $50,000 in vouchers

2. Prove!
   Design a plan for concept demonstration and technoeconomic and emissions analyses with the help of national laboratory experts.
   - Up to 5 Winners
   - $100,000 cash
   - $300,000 in vouchers

3. Pitch Day!
   Present proof-of-concept along with experimental and analytical findings to potential investors and commercial partners.

Incentivize development of innovative off-roadmap technologies with the potential to produce clean hydrogen at $1/kg in one decade

Learn More: www.herox.com/HydrogenShotPrize
Focus on Regional Networks
Build Regional Networks through “Clean Hydrogen Hubs”

Examples of Stakeholder and RFI Input
RFI findings: Regional clusters and geographic factors

**Pacific Northwest**
- Port communities
- Tribal communities
- Extensive renewables
- 8 jobs per $1M invested in $H_2$

**California**
- Diverse populations
- Extensive infrastructure
- Emissions regulations
- 40,000+ jobs

**Southwest**
- Tribal and Hispanic communities
- Underutilized solar
- Nuclear power
- Up to 2B tonnes/yr emission reduction potential

**Central U.S.**
- Ample wind
- Geological storage
- Railway transport
- Nuclear resources
- >630,000 tonnes/yr CO$_2$ reduction

**Great Lakes**
- Major national corridors
- Nuclear power
- 60,000+ jobs

**New England**
- Offshore wind
- Fishing communities
- Backup power and winter heating
- ~120K tons CO$_2$/year reduction

**Appalachia**
- Retiring fossil plants
- Mining, refining transferable skills
- Carbon capture and sequestration
- 70,000 tons/yr H$_2$ production

**Great Lakes**
- Ample wind
- Geological storage
- Railway transport
- Nuclear resources
- >630,000 tonnes/yr CO$_2$ reduction

**Alaska and Hawaii**
- Extensive renewables – geothermal, solar, ocean
- Backup power
- Isolated communities
- 86,000 tonnes/yr emission reduction

**Gulf Coast**
- Existing infrastructure
- Multiple opportunity zones
- Renewable resources
- 1,000s of jobs
- Chemical industry

**Southwest**
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**California**
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Resource Analysis Helps Identify Clean-Hydrogen Opportunities

Deployments are likely to vary regionally depending on availability of resources and CCS

- **On-shore wind**
- **Solar – Utility Scale**
- **Solid Biomass**
- **Nuclear**
- **Natural Gas**
- **CCS**

*Clean methane reforming facilities for most of the data points.*
Priority deployments for hydrogen in industry include sectors where other decarbonization pathways are challenging, such as high-temperature heat generation, steelmaking, and ammonia production.

National Distribution of Industrial Sites, CO₂ Output, and CO₂ Sink Demand

Mapping industrial sites to CO₂ sources and demands can help identify industrial clusters for potential decarbonization hubs.

Adapted from Carbon Capture and Utilization in the Industrial Sector | Environmental Science & Technology (acs.org)
Example of Matching Supply and Demand: H₂ Potential and Ammonia Production Plants

Resource mapping helps identify regions with substantial resources of clean energy and hydrogen demand, to inform early deployments. Examples show hydrogen, ammonia, wind, and nuclear.

Adapted from national lab, H2@Scale, and US Industry Hydrogen Roadmap
Ongoing Work and Accomplishments to Address Key Priorities
Program Enabled 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
Hydrogen Tube Trailers
Forklifts
Electrolyzers
Hydrogen Tanks

Examples:
- Fuel Cell Catalysts
- Hydrogen Tube Trailers
- Forklifts
- Electrolyzers
- Hydrogen Tanks

Market Uptake

Hydrogen fuel cell forklifts in the U.S.

More than 50,000

Approx. 700

DOE-cost shared
By Industry

American-made small-scale hydrogen refueler

- Exported to Japan
- Uses electrolysis
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)

Let’s talk about your project. Call or email for a no-cost pre-application consultation: (202) 287-5900 or LPO@hq.doe.gov
**H2NEW Consortium to Accelerate Progress in Electrolyzers**

**Includes focus on durability to:**

→ Improve understanding of degradation mechanisms

→ Develop and validate accelerated degradation processes to evaluate durability

**Electrolyzer Stack Goals by 2025**

<table>
<thead>
<tr>
<th></th>
<th>LTE PEM</th>
<th>HTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>$100/kW</td>
<td>$100/kW</td>
</tr>
<tr>
<td>Elect. Efficiency (LHV)</td>
<td>70% at 3 A/cm²</td>
<td>98% at 1.5 A/cm²</td>
</tr>
<tr>
<td>Lifetime</td>
<td>80,000 hr</td>
<td>60,000 hr</td>
</tr>
</tbody>
</table>

**Combines world-class experimental, analytical, and modeling tools**

**Consortium Team**

- NREL
- INL
- Pacific Northwest
- Lawrence Livermore
- Oak Ridge
- National Laboratory
- National Institute of Standards and Technology
- UC Irvine
- Carnegie Mellon University
- MINES
Million Mile Fuel Cell Truck Consortium (M2FCT)

### MISSION
Advance efficiency and durability, and lower cost, of PEMFCs for heavy-duty vehicle applications

### APPROACH
Pursue a “team-of-teams” approach with teams in analysis, durability, integration, and materials development

### OBJECTIVE
Achieve MEA target: 2.5 kW/gdm, power (1.07 A/cm² current density) at 0.7 V after 25,000 hour-equivalent AST

---

**MEAs**
- gm
- Nikola

**Membranes**
- T
- GDL
- 3M

**Stacks**
- NIKOLA

**Bipolar Plates**
- Raytheon Technologies
- TreadStone Technologies, Inc.
- NeoGraf

**Air Management**
- CATERPILLAR
- EATON
- MAHLE

**Main Laboratories**
- Los Alamos National Laboratory
- Oak Ridge National Laboratory
- Argonne National Laboratory

**Affiliate Laboratories**
- Pacific Northwest National Laboratory
- Brookhaven National Laboratory

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U.S. DEPARTMENT OF ENERGY
OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY
HYDROGEN AND FUEL CELL TECHNOLOGIES OFFICE
Investigated key U.S. opportunities to enable the growth of electrolytic hydrogen and fuel cell markets

Example: PEM fuel cell & electrolyzer supply chain

Platinum, Iridium, Nickel, Titanium, Chromium, Graphite, Chemical Precursors

Raw Materials

Ionomers, Catalysts (Precursors, Powders, Inks), Foams/Plates/Rolls, Graphite composites, Stainless Steel, Carbon fiber, Thermoplastics/Elastomers, ePTFE

Processed Materials

Membranes, Catalysts/Electrodes, Gas Diffusion Layers, Membrane Electrode Assemblies

Components

Bipolar Plates, Seals, End Plates, BOP

System

Stacks, Power Electronics & Controls, BOP subsystems

End Uses

Transportation, Power Generation and Energy Storage, Chemical & other Industries

Material Recovery, Refurbishment, Waste Stream Minimization, Second Use Applications

End of Life Recycling and Reuse

Strategy leverages DOE National Laboratories, partnering with industry and academia

DOE National Laboratories across energy, science, and security:
- Support RD&D
- Offer User Facilities and science resources
- Help to de-risk technology adoption, accelerating progress
2021 H2@Scale CRADA Call Results

Topic 1: H2@ARIES – Integrated Hydrogen Energy System Testing/Validation

ARIES with: Integrated Megawatt Scale Hydrogen System

• NREL, SoCalGas, University of California Irvine: Validation of interconnection and interoperability of grid-forming inverters sourced by H₂ technologies in view of 100% renewable microgrids (TA062)

• NREL, GKN Powder Metallurgy, SoCalGas: High Efficacy Validation Of HYdridE MEga Tanks at the ARIES Lab (HEVHY METAL) (TA063)

• NREL, EPRI: Hydrogen Production, Grid Integration, and Scaling for the Future (TA064)

• NREL, GE Renewable Energy, Nel Hydrogen: Optimal Wind Turbine Design for H₂ Production (TA061)

Advanced Research on Integrated Energy Systems (ARIES)
Additional Projects Supporting ARIES

**Topic 2: Applied Risk Assessment and Modeling for H2@Scale Applications**

- **PNNL, SNL, Seattle City Light, Port of Seattle**: Large-Scale Hydrogen Storage – Risk Assessment Seattle City Light and Port of Seattle
- **SNL, Wabtec**: Risk Assessments of Design and Refueling for Hydrogen Locomotive and Tender (SCS033)


HyBlend and H-Mat Consortia—Opportunities Available

To assess and enhance compatibility of key materials with hydrogen, and to accelerate the use of hydrogen in multiple applications (including in natural gas blending)

National lab consortium to assess and improve performance and reliability of materials in hydrogen, reduce costs, and inform codes and standards

Pipeline materials compatibility R&D, technoeconomic analysis, and life-cycle analysis to assess the feasibility of hydrogen blending in the U.S. natural gas pipeline infrastructure

Materials R&D aims to lower cost of components in H₂ infrastructure and enhance life by 50%

Online data portal shares information with R&D community worldwide, and international MOUs enable coordination

Testing pipeline materials in H₂ blends for risk analysis tool data and to inform codes and standards

Cost and emissions life-cycle analyses of blending and RNG to inform RDD&D

Over 30 partners
First-of-a-kind Hydrogen Business Case Prize—Links Students with Experts

**Concept**
Development of user-friendly computational tools that characterize regional value propositions for hydrogen in multiple applications, including co-locating supply and demand.

**Goals**
- Educational opportunities through mentoring sessions and potential internships
- Inform stakeholders about investment opportunities

**Winners**
- **1st place:** Super Hydrogen Family – USC, U of S. Florida, U of Central Florida (see #SA185)
- **2nd place:** Bend Hydrogen – Oregon State (see #SA182)
- **3rd place:** Pure Hydrogen – UC Berkeley (see #SA183)
- **4th place:** H24SCR – U of Oklahoma

Coordinated by, Masha Koleva
Hydrogen Business Case Prize Mentors

Thank you, mentors!

Jamie Randolph
Andrew Martinez
Yuri Freedman
Kaz Nagasawa
Kun Zhang
Misho Penev
Freddie Briggs
Beth Carter
Kareem Afzal
Growing Connections, Strengthening Networks
The redwoods are the tallest trees on earth—growing tall and enduring long dry spells—on harsh terrain and despite shallow roots.

They are able to do this through the collective strength of their roots which are an interwoven system, where each tree supports—and is supported by—the trees around it.
Developed and Launched H2 Matchmaker to facilitate H2 Hub Partnerships

Available at: www.energy.gov/eere/fuelcells/h2-matchmaker

This link will open the H2 Matchmaker self-identification form.
Promoting Safety includes Center for Hydrogen Safety (CHS) Activities

Over 80 members from industry, government, and academia—and growing!

New Hydrogen Safety Credential!
Composed of 7 fundamental hydrogen safety e-courses, including:
- Properties & Hazards
- Safety Planning
- System Operation
- Inspection & Maintenance

www.aiche.org/CHS
Enabler: Developed Federal Regulatory Map & Identified Gaps

Gaps Identified

- FERC for pipeline transmission, electricity production, and heating
- FHWA for bridges and tunnels
- FRA, USCG, and FAA for rail, maritime, and aviation use

Interagency Working Group on Hydrogen and Fuel Cell Technologies

<table>
<thead>
<tr>
<th>Partners</th>
<th>Examples of Collaborations &amp; Focus Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOE, DOT</td>
<td>Pipelines, buses, rail, marine, air, infrastructure</td>
</tr>
<tr>
<td>DOE, DOD across services</td>
<td>H2Rescue Truck for disaster relief, vehicles and infrastructure, Unmanned Underwater Vehicles (UUVs), microgrids and resiliency, and more</td>
</tr>
<tr>
<td>DOE, USPS</td>
<td>FC lift trucks and hydrogen infrastructure</td>
</tr>
<tr>
<td>DOE, NASA NSF</td>
<td>Cryogenic hydrogen systems, fuel cells, electrolyzers, storage (NASA), DOE consortia (NSF)</td>
</tr>
<tr>
<td>DOE, DOC, NIST</td>
<td>Metering, diagnostics, supply chain</td>
</tr>
<tr>
<td>DOE, EPA</td>
<td>Clean hydrogen standard, emissions analysis</td>
</tr>
</tbody>
</table>

IWG members share RDD&D information on their programs and collaborate through joint projects and gap analysis.
H2 Twin Cities Initiative Launched at COP26

Connecting Communities Around the World to Deploy Clean Hydrogen Solutions

Phase 1: November 10 – December 29, 2021
Applicants self-identify and self-pair on the H2 Twin Cities website

Phase 2: January 3 – March 18, 2022
A single, joint application is prepared
Open submission
Deadline extended to July 25

Selections
WG will evaluate proposals

Pairing Types

Sibling Cities
Ideas
People

Mentor - Mentee
Business Cases
Codes, Stand.

Share and learn more: www.energy.gov/eere/twincities
Diversity, Equity, and Inclusion
Environmental Justice
Workforce Development
Primary Elements of DOE Justice40


Disadvantaged communities

Current Thoughts:
• Census Tract Level
• 36 Indicators

VULNERABILITY
FOSSIL DEPENDENCE
ENERGY BURDEN
ENVIRONMENTAL HAZARDS

Can also identify non-geographic DACs – groups that share a common characteristic

Distribution of census tracts identified as geographic DACs

Emphasis is on Benefits in Underserved & Disadvantaged Communities

Example: DOE project with CTE for UPS Fuel Cell Delivery Vans

Trucks will be demonstrated in disadvantaged community in Ontario, CA

Key Accomplishments:
- 10 trucks built with validation testing complete; 5 more in assembly
- Operations have begun in disadvantaged community out of UPS Service center in CA

Goal: Demonstrate 15 fuel cell trucks (up to 125-mile range)

Project impact per year: Savings of
- 285 metric tons of CO2e
- 280,000 grams of criteria pollutants
- 56,000 gallons of diesel
Examples of Tribal Engagement

Engagement with Tribes included:

- Hydrogen Shot Summit
- Listening Sessions
- Engagement on potential BIL activities, such as Sec. 815 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

Example: HBCU/MSI Funding Opportunity and Topic Overview

HFTO partnered with FECM and added topics to educate and train the next generation of engineers and scientists at HBCUs/MSIs, and increase investments in traditionally underrepresented and disadvantaged communities in the U.S.

<table>
<thead>
<tr>
<th>Topic Area</th>
<th>Expected # of Awards</th>
<th>DOE Funds per Award ($K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Storage Materials Development</td>
<td>Up to 6</td>
<td>up to $300</td>
</tr>
<tr>
<td>PGM-free Catalysts and Electrodes for Fuel Cells and Electrolyzers</td>
<td>Up to 6</td>
<td>up to $300</td>
</tr>
<tr>
<td>Hydrogen Materials Compatibility – RD&amp;D</td>
<td>Up to 6</td>
<td>up to $300</td>
</tr>
<tr>
<td>Hydrogen Materials Compatibility – Gap Analysis</td>
<td>Up to 1</td>
<td>up to $250k</td>
</tr>
<tr>
<td>Total</td>
<td>Up to 7</td>
<td>up to $2M total</td>
</tr>
</tbody>
</table>

Goals: Build the talent pipeline and expand knowledge in hydrogen with a focus on materials R&D

- Uses established HFTO consortia and provides partnership opportunities
- Offers students the opportunity to travel to national laboratories
- Provides opportunity for creative partnership models with industry and pipeline


HBCU: Historically Black Colleges and Universities.
MSI: Minority Serving Institutions
LANL and Pajarito Powder Establish Collaboration with Minority Serving Institutions (MSIs)

Project Goals include:

• Develop a mutually beneficial relationship between LANL, Industry Partners, and MSIs through HFTO support
• Provide opportunities for MSI scholars to perform cutting-edge fuel cell research at LANL
• Encourage MSI scholars to pursue advanced degrees and enter the Hydrogen and Fuel Cell Workforce

Pajarito Powder and LANL host Industry day
Discuss research opportunities and host facility tour
Building an alliance for MSI industry internships

Students with BS, MS, or PhD Degrees

LANL
Industry
Example: Workforce Development

Industry-led project on Hydrogen Education for a Decarbonized Global Economy (H2EDGE)

Key Accomplishments:
• **Professional short courses** in development include:
  - Basic H₂ science, end uses, storage, delivery, safety, electrolyzer technology trends.
• **Oregon State University**: New sustainable engineering course on H₂ economy basics, challenges, barriers. Student projects with industry sponsors.
• **University of Delaware**: Developing laboratory course on PEM fabrication, gas separation, electrochemical compression.

See: EPRI project (SCS028)

Goals:
• Develop and deliver professional training courses and university curriculum content
• Collaborate with industry and university partners to develop certifications, credentials, qualifications, and standards for training

Next Steps:
• Conduct gaps assessments of professional training activities and university curriculum requirements
• Begin delivering professional training through short courses
• Develop new courses at a third partner university
• Advance the university engagement network by adding Affiliate Universities
The U.S. Department of Energy (DOE) is looking for talented, bright, early career professionals to partner with DOE Hydrogen Program Managers working to achieve the Hydrogen Energy Earthshot goal of $1 per 1 kilogram in 1 decade (“1 1 1”).

Are you graduating soon or just starting your career in hydrogen?

Do you want to help make clean hydrogen affordable for all?

The Hydrogen Shot Fellowship might be the opportunity you’re looking for!

Apply today at: www.zintellect.com Keyword: Hydrogen Shot
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](http://www.iphe.net/early-career-chapter)
Examples of International Collaborations

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

- **H₂ 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 H₂ initiatives to identify gaps, focus areas, and prioritized workstreams
Building Momentum
Strategic RDD&D Portfolio

Leveraging DOE-wide collaborations and coordination to advance technologies and achieve cost targets and scale

Enabling research & development
- DOE Program Offices Core R&D
- BIL 816 & 815 R&D:
  - Electrolysis & clean H₂ manufacture/recycle
- DOE Consortia & Collaborations include:
  - HydroGEN, ElectroCat, H-Mat, X-Mat ...
  - H₂-related Innovation Hubs & Centers

Technology Investment Stage
- next-generation technologies
- near-commercial technologies
- established technologies

Commercial-scale deployments
- Collaborations & Coordination include:
  - DOE-wide coordination
  - Regional, state, and local agencies
  - Safety, workforce, EJ40, etc.
- BIL 813 Regional Clean H₂ Hubs
  - Supporting development of at least four regional hubs nationwide

Demos, manufacturing & scaleup
- DOE Program Offices Core RD&D
- BIL 816 & 815 RD&D:
  - Electrolysis & clean H₂ manufacture/recycle
- DOE Consortia & Collaborations include:
  - H2NEW, M2FCT Consortia
  - H₂@Scale demos (nuclear H₂, etc.)
  - Manufacturing Institutes

Leveraging DOE-wide collaborations and coordination to advance technologies and achieve cost targets and scale

Data & feedback
Tech handoff
Tech handoff
DOE-wide coordination
Regional, state, and local agencies
Safety, workforce, EJ40, etc.
Year in Review Highlights

- June 2021: RFI Issued for H₂ Demonstration Opportunities

- Sept 2021: $52.5M to fund 31 Projects for H₂ Tech including EERE and FECM
  
- Dec 2021: Launched H₂ Twin Cities at COP26
  
- March 2022: Launched H₂ Matchmaker

- June 2022: Two BIL RFIs Announced
  
- HBCU & MSI Talent Pipeline
  
- Science Roundtable Report
  
- Issue H₂ Hub NOI

- Launch H₂ Shot Incubator Prize

- $8M National Lab H₂@Scale Projects

- >8 workshops, webinars, stakeholder feedback (5,000 pgs.)

- President Signs BIL

- $20M for Clean H₂ From Nuclear (EERE and NE)

- ARPA-E ReFuel-IT NH₃ project demo

- SuperTruck3 Awards

- DAIMLER

U.S. DEPARTMENT OF ENERGY

OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY

HYDROGEN AND FUEL CELL TECHNOLOGIES OFFICE
Actions to Catalyze, Accelerate and Enable Scale

**Clean Hydrogen Production**
- 2022-2025: Catalyze RD&D in electrolysis, thermal conversion, & new pathways to meet Hydrogen Shot
- 2026-2029: Apply replicable, scalable production from renewables, nuclear, & fossil waste with CCS
- 2030-2035: Scale up electrolyzer manufacturing and recycling/reuse capacity

**Delivery and Storage Infrastructure**
- 2022-2025: Identify and prioritize barriers to infrastructure roll out
- 2026-2029: Initiate supporting infrastructure for regional hubs
- 2030-2035: Develop sustainable regional clean hydrogen networks

**End Uses and Market Adoption**
- 2022-2025: Engage regulators to lay groundwork for strategic adoption across sectors
- 2026-2029: Initiate transition for hard to decarbonize industries
- 2030-2035: Deploy at least four regional clean hydrogen hubs

**Enablers**
- 2022-2025: Engage stakeholders; address safety codes and standards; develop critical supply chains
- 2026-2029: Use and expand workforce, talent pools, and apprenticeship programs
- 2030-2035: Ensure 40% of benefits accrue to disadvantaged communities in hub regions
- 2030-2035: Demonstrate business cases and attract private capital

Achieve 5 MMT production capacity and $1/kg target
Deliver hydrogen at scale
Scale up hydrogen hubs and prepare export opportunities
Achieve Justice 40, create good-paying jobs, and ensure public health & safety

Target table will be provided to meet BIL deliverable on targets for 2, 7, 15 years
Regional Clean Hydrogen Hubs Notice of Intent (NOI) Released Today!

NOI (DE-FOA-0002768) available at https://oced-exchange.energy.gov/

DOE Office of Clean Energy Demonstrations (OCED) anticipates issuing a Funding Opportunity Announcement in collaboration with the Hydrogen and Fuel Cell Technologies Office (HFTO) and the DOE Hydrogen Program.
**DOE Issues H2 Hub NOI—June 6, 2022**

**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
- Final cost 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
- Updated financial analyses
- Revised growth plans
- Final TPC accounting

**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, Justice-40, 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 Techno-economic Analysis
- Final Lifecycle & Techno-economic Analyses
- V&V and Project Completion Testing Plans
- Periodic analyses updates
- V&V data collection
- Propet completion testing and performance ramp V&V
- Validated performance model
- Finalize lifecycle and techno-economic analyses
- Dissemination of analyses, lessons learned

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H2Hub project phases, including examples of likely activities and deliverables in each phase, subject to change prior to the FOA release.

---

Issued by OCED in collaboration with HFTO and DOE Hydrogen Program, all relevant offices

NOI (DE-FOA-0002768) available at [https://oced-exchange.energy.gov/](https://oced-exchange.energy.gov/)
Highlights and Milestones Summary

**FY2021**
- Awarded first-of-their-kind demo projects, including: Large Scale Fuel Cell Powered Data Center, Renewable H₂ Production on Refueling Barge, Two H₂ for Steel projects
- Launched Hydrogen Shot
- Launched H₂NEW, Million Mile Fuel Cell Truck consortium and HydroGEN 2.0
- Launched H₂EDGE Workforce Development Project
- Developed H₂ energy storage financial assessment tool
- Launched HyBlend Project and 5 CRADA projects on HD fueling
- Released SuperTruck III FOA

**FY2022**
- BIL signed into law
- Issued Request for Information for BIL sections 813, 815, and 816
- Held multiple workshops and webinar including on BIL H₂ Provisions and RFIs
- Released Hub NOI in collaboration with OCED
- Selected over $51M in new projects
- Selected (3) SuperTruck III Projects Focused on M/HD H₂ Fuel Cell Trucks
- Launched Hydrogen Shot Incubator Prize
- Issue FY22 FOAs
- Complete DOE National Clean Hydrogen Strategy and Clean Hydrogen Standard guidance

**FY2023**
- Issue BIL FOAs for Sec. 813 and 815-Electrolysis and Manufacturing & Recycling
- Issue Annual FOAs
- Select at least four H₂ Hubs (OCED in collaboration with HFTO and DOE Hydrogen Program)
- Select Hydrogen Shot Incubator Propose! Phase Winners
- Complete milestones for current RD&D projects
- Complete coordinated, prioritized action plan with other agencies
- Complete coordinated workstreams and international architecture for global hydrogen partnerships

U.S. DEPARTMENT OF ENERGY
OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY
HYDROGEN AND FUEL CELL TECHNOLOGIES OFFICE
Acknowledging HFTO’s Collaboration Network

Collaboration and coordination to accelerate progress and advance environmental justice

Cross-Office work with Multiple DOE Offices

**EERE** (Solar, Wind, Vehicle Tech., Advanced Manufacturing, Bioenergy, Building Tech., Water Power);
**ARPA-E**; **Fossil Energy & Carbon Management**; **Nuclear Energy**; **Office of Science**, and more

DOE Crosscutting Initiatives


Interagency Collaboration & Coordination

Including **DOD**, **DOT**, **DHS**, **EPA**, **NASA**, **NSF**, **NIST** among others

International Collaboration

**IEA**, **IPHE**, **CEM**, **HEM**, **MI**, **IRENA**, **CH-JU**, **Bilaterals**, and many more

Other External Partners

**Regional and National Associations and States**
**FCHEA, NASEO and many more**

**Labor groups, Tribes, and EJ Communities**

**Public-private partnerships**
**21 CTP, USDRIVE, etc.**
Hydrogen and Fuel Cell Technologies

Will be hiring several Feds

Open to U.S. Citizens

Will be Hiring

Hydrogen Production including Clean H₂ Electrolysis
Ned Stetson (Acting)

Hydrogen Infrastructure & Storage Technologies including Clean H₂ Manufacturing & Recycling
Ned Stetson

Fuel Cell Technologies including Clean H₂ Manufacturing & Recycling
Dimitrios Papageorgopoulos

Technology Acceleration including H₂ Hubs in Collaboration with OCED:
Jesse Adams

*Also supports H₂ Technologies

Senior Advisor
Eric Miller

Director
Sunita Satyapal

Operations Includes Katie Randolph, Shawna McQueen, Vanessa Arjona

System Analysis
Neha Rustagi *

DOE Clean Energy Corps Applicant Portal: [www.energy.gov/applicant-portal](http://www.energy.gov/applicant-portal)
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

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
HFTO is Hiring!

If you are interested in applying to be part of our team, please submit resumes to the DOE Applicant Portal and email hftoinquiries@ee.doe.gov to let us know you have submitted your resume. Include “Clean Energy Corps Applicant” in the subject line of the email.
“It is the long history of humankind (and animal kind, too) that those who learned to collaborate and improvise most effectively have prevailed.”

– Charles Darwin
Thank you

Dr. Sunita Satyapal
Director, Hydrogen and Fuel Cell Technologies Office
Coordinator, DOE Hydrogen Program
Sunita.Satyapal@ee.doe.gov
U.S. Department of Energy

www.energy.gov/fuelcells
www.hydrogen.energy.gov
Additional Information

www.energy.gov/fuelcells
www.hydrogen.energy.gov
HFTO Project Partners: Labs, Universities, and Industry

3M Company
Air Products and Chemicals
Ames Laboratory
Argonne National Laboratory
Army Corps Engineers
Brookhaven National Laboratory
Carnegie Mellon University
Caterpillar Inc.
Center for Transportation and the Environment
Clemson University
Collaborative Composite Solutions Corporation
Colorado School of Mines
Cummins Inc.
C-Zero, LLC
DOT National Highway Traffic Safety Administration
Drexel University
Electric Power Research Institute Inc
Electricore Inc.
Exelon Corporation
Frontier Energy, Inc.
FuelCell Energy, Inc.
Gas Technology Institute
General Motors LLC
Georgia Institute of Technology
Giner ELX, Inc.
Greenway Energy, LLC
Hornblower Energy
Hy-Performance Materials Testing, LLC
Idaho National Laboratory
Ivys, Inc.
Lawrence Berkeley National Laboratory
Livermore National Laboratory
Lix Power, Inc.
Los Alamos National Laboratory
Lubrizol
Massachusetts Institute of Technology
Missouri University of Science & Technology
Montana State University
NASA WSTF
National Energy Technology Laboratory
National Institute of Standards and Technology
National Renewable Energy Laboratory
NEL Hydrogen, Inc.
Neogaf Solutions LLC
Nexceris, LLC
Nikola Motor Company
North Carolina State University
Northbound
Northwestern University
Oak Ridge Institute
Oak Ridge Institute for Science & Education
Oak Ridge National Laboratory
ORAU
Oregon State University
Pacific Northwest National Laboratory
Pennsylvania State University
Plug Power Inc.
Proton Energy Systems, Inc.
Raytheon Technologies Research Center
Redox Power Systems, LLC
Rensselaer Polytechnic Institute
Saint-Gobain Ceramics and Plastics, Inc.
Sandia National Laboratories
Savannah River National Laboratory
Shell
Skyre, Inc.
SLAC National Accelerator Laboratory
Southern Company Services
Strategic Analysis, Inc.
The Chemours Company FC, LLC
The University of Alabama
The University of Tennessee, Space Institute
The University of Toledo
Treadstone Technologies, Inc.
U.S. Naval Research Laboratory
United Technologies Research Center
University of California, Irvine
University of California, San Diego
University of Colorado
University of Colorado, Boulder
University of Connecticut
University of Delaware
University of Florida
University of Hawaii
University of Illinois at Urbana-Champaign
University of Kansas Center for Research, Inc.
University of Kentucky
University of Michigan
University of North Texas
University of Oregon
University of South Carolina
University of Southern California
University of Tennessee-Knoxville
University of Virginia
Vanderbilt University
Washington State University
West Virginia University
Collaborative H₂ Projects between HFTO and other EERE Offices

**Advanced Manufacturing (AMO)**
- Manufacturing electrolyzer stacks
  *NexTech Materials, Ltd, $4.2M*
- Electrolyzer cell and stack assembly
  *Cummins, Inc, $7.2M*
- Low-cost PEM electrolysis at scale
  *Proton Energy Systems, $5.5M*
- Integrated MEAs & scale-up
  *Giner ELX, Inc., $5.8M*
- Advanced manufacturing for PEM electrolyzer components
  *3M, $6.1M*

**Bioenergy Technologies (BETO)**
- Upgrading bio & renewable natural gas
  *Production Summit Utilities, $5M*

**Solar Energy Technologies (SETO)**
- Clean H₂ to jet fuel using CSP
  *Dimensional Energy, $3.4M*
- Solar thermo-electrochemical process
  *for H₂ Arizona State University, $0.5M*

**Wind Energy Technologies (WETO)**
- FlexPower: PV-wind-storage hybrid energy systems including H₂
  *NREL, INL, SNL, NETL $5.5M*
- Wind to H₂ modeling and optimization
  *NREL, $0.15M*

**Offshore Wind to H₂ (SBIR)**
- Offshore wind and PEM electrolysis
  *Giner Inc., $1.1M*
- Offshore wind and AEM electrolysis
  *Alchemr, Inc., $1.1M*
- Optimizing wind technology for H₂ production
  *NREL, GE, Nel, $0.5M*