

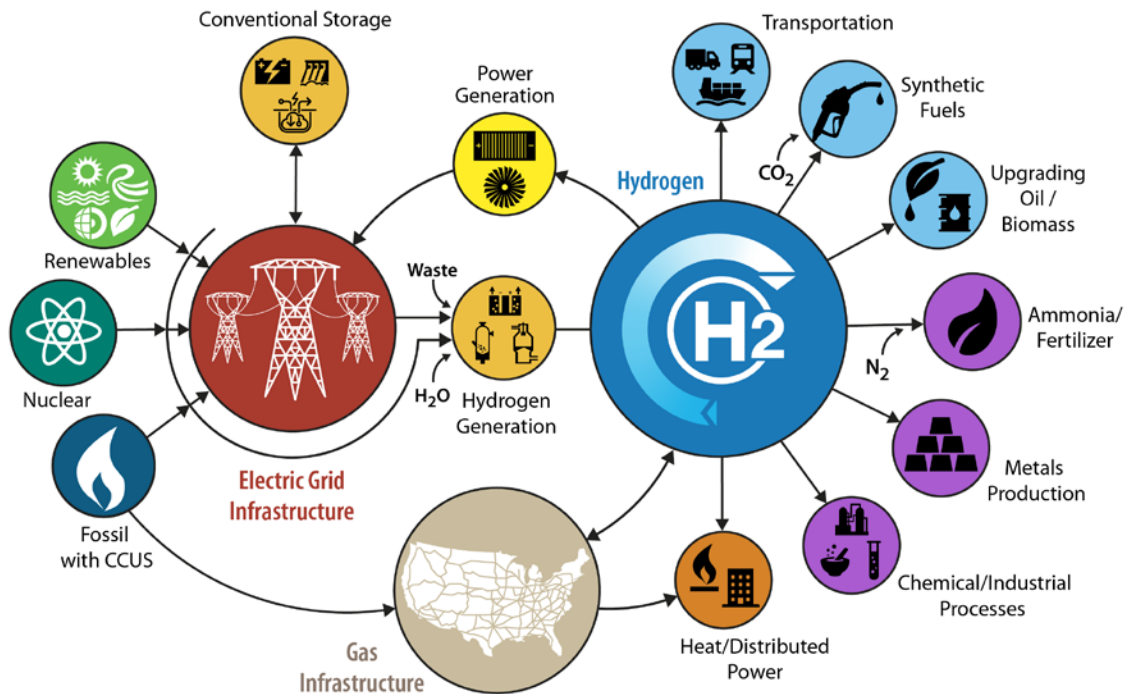


NREL: Driving Hydrogen Advancement

Martin Keller, Director
Hydrogen Americas Summit
October 11, 2022

H2@Scale Vision

Making, moving, storing, and using hydrogen, which embodies the goals of **carbon-free electricity** resources and generation, by 2035 and a net-zero energy system by 2050.

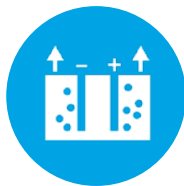


NREL's FCHT Strategy is Focused on Accelerating Progress & Impact

Energy justice and
American jobs are
considerations that
underlie all these efforts.



NREL Research Spans
MAKE/MOVE/STORE/USE



Make

R&D on Advanced
Production
Technologies



Move

Infrastructure
Research &
Large-Scale
Demonstration
and Deployment



Store

Hydrogen Storage
Materials and
Systems Research



Use

Hydrogen
Penetration into
Heavy-Duty
Transportation
Sector

Expanding Green
Hydrogen Into New
End-Use Cases



ARIES Hydrogen Expansion

NREL's Flatirons Campus grows capability to de-risk large-scale deployments (~100MW) through smaller scale validation (1-5MW) with analysis to extrapolate to larger systems

- Hydrogen infrastructure construction progresses at Flatirons Campus
- All major sub-systems now installed: Nel Hydrogen 1.25 MW PEM electrolysis system, 600 kg ground storage system, hydrogen compressor, Toyota 1 MW PEM fuel cell generator, and 3.7 MW integrated cooling system
- Engaged with HFTO on electrolyzer capability expansion

Electrochemical Characterization



Ink Composition and Optimization



Roll-to-Roll Manufacturing



Manufacturing Lab

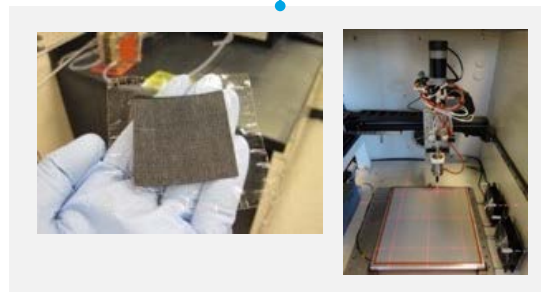


Powders

Mass Production



Ink Composition and Optimization



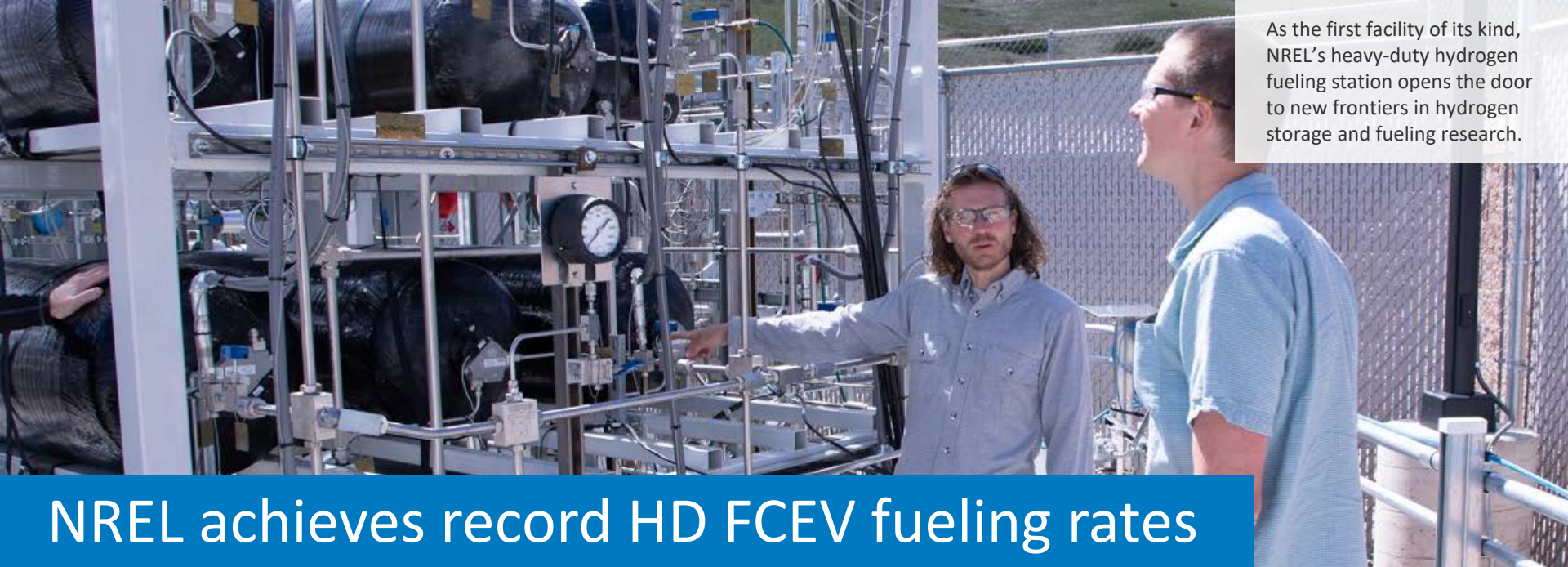
MEA integration



Performance Evaluation

Electrolysis and Fuel Cell Research

From Powders to Power



As the first facility of its kind, NREL's heavy-duty hydrogen fueling station opens the door to new frontiers in hydrogen storage and fueling research.

NREL achieves record HD FCEV fueling rates

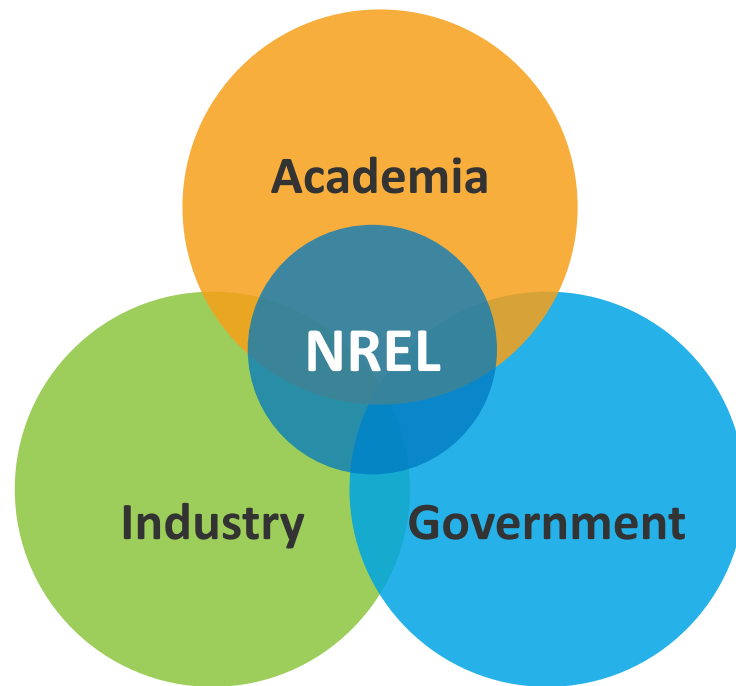
Innovating High Throughput Hydrogen Stations (IHS) Project

NREL researchers have successfully demonstrated high-flow-rate hydrogen fueling into a heavy-duty (HD) vehicle system using state-of-the-art capabilities at NREL's Energy Systems Integration Facility as part of the Advanced Research on Integrated Energy Systems environment.

- **75.9 kg fill in 5 min 43 sec** with mass flow rates of **13.2 kg/min average** and **23.6 kg/min peak** (91-97% SOC) – All 9 HDVS tanks

Partnerships Key for Larger Impact

- **Funding doubled** from FY20 to FY 21
- **35 new** strategic partnership projects in FY22
- **\$23.7M total value** (\$7.4M cash to NREL)



Recent Agreements in the News

- September 2022: Fortescue Future Industries, \$80M over 10 years
- October 2021: Electric Hydrogen, \$3.6M over 3 years

A satellite view of Earth at night, showing the illuminated continents of North and South America. The city lights are visible as bright yellow and orange spots against the dark background of the planet. The sun is visible on the left horizon, creating a bright glow and lens flare effect.

Thank You

www.nrel.gov

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De-Risking the Hydrogen-CCS Value Chain

Brian J. Anderson, Ph.D.
NETL Director

Hydrogen Americas Summit
October 11, 2022

The National Energy Technology Laboratory



Organization Snapshot

MISSION

Driving innovation and delivering solutions for an environmentally sustainable and prosperous energy future:

- Ensuring affordable, abundant and reliable energy that drives a robust economy and national security, while
- Developing technologies to manage carbon across the full life cycle, and
- Enabling environmental sustainability for all Americans.

VISION

To be the nation's premier energy technology laboratory, delivering integrated solutions to enable transformation to a sustainable energy future.

MAJOR INITIATIVES

- Decarbonization & Carbon Management
- Environmentally Sustainable Supply Chains
- Integrated Energy & Industrial Systems
- Advanced Data & Computing Solutions for Applied Energy Challenges

3 RESEARCH LABS & 2 STRATEGIC OFFICES



- One of 17 DOE national laboratories
- One of three applied research national labs
- Government owned & operated
- **1000+** R&D projects in 50 states
- **\$5.0B** total award value
- **\$1.2B** FY22 budget

IMPLEMENTS R&D PROJECTS FOR DOE'S OFFICES OF:

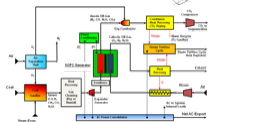
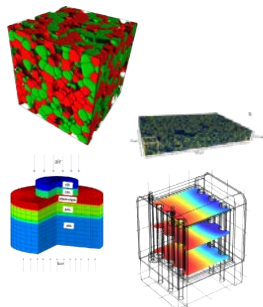
- Fossil Energy & Carbon Management
- Energy Efficiency Renewable Energy
- Electricity
- Cybersecurity, Energy Security, & Emergency Response
- Manufacturing, & Energy Supply Chains
- Grid Deployment
- Clean Energy Demonstrations

Innovation Across Hydrogen Value Chain

Technology Accelerator

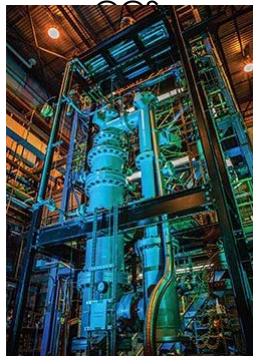
Production

Solid oxide electrolysis of water for hydrogen



Multi-scale SOEC Modeling

Advanced **natural gas reforming** and **gasification** with



50 kW Chemical Looping Reactor

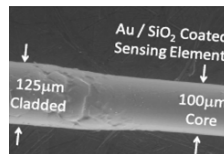
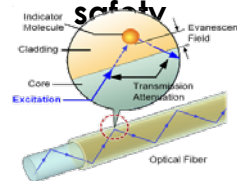
Transport & Storage

Microwave-enabled **modular ammonia** production from



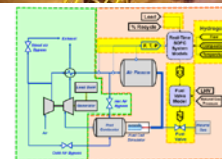
NETL's ReACT Laboratory

Sensors for real-time pipeline monitoring and **hydrogen safety**



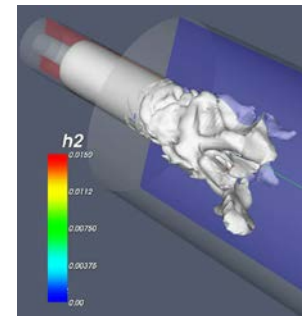
Distributed Fiber Optics Sensors for temperature, strain, gas chemistry, pH, corrosion, and acoustic vibration

Operability of SOFCs with **integrated energy systems**



Hybrid Performance Cyber-Physical Test Facility

Hydrogen and ammonia **gas turbine combustion**



LES Simulation of combustor flashback with increasing H2 content in natural gas

Strategic Systems Analysis

Scaling H₂ Technologies with Systems Analysis

- NETL has developed numerous tools to assist with managing the hydrogen value chain, from production, to transport and storage, to utilization, and for carbon emission management.
- These tools assess:
 - Techno-economic and life-cycle analysis technology
 - Economic analysis
 - Resource availability
 - System design and optimization

Many tools are publicly available

TEA/LCA Tech Assessments				
Economic Assessments				
Resource Assessments				
Design/Optimization				
Value Chain:	Production	Transport/Storage	Utilization	CO ₂ Management

Natural Gas Life-cycle Analysis



H₂ Pipeline Cost Model



CCSI²



H₂ Screen



Number of tools within
Degree of relevance to
planning H₂ Investment

Fewer



More



Less

More

Optimizing Subsurface Storage

Leveraging CO₂ Transport & Storage Capabilities for Hydrogen

CO₂ and H₂ Infrastructure Literacy

CO₂ Screen, H₂ Screen

U.S. storage capacity of formations (saline, salt and depleted wells) with economic implications
H₂ under development (2023)



Carbon Storage Atlas

A coordinated update of carbon capture and storage (CCS) potential across the United States

<https://netl.doe.gov/carbon-storage/risk-integration/publications#collapseFE0031888>



Regional H₂ Market Analysis

How to grow a hydrogen economy in a region – Appalachia (2022):

[Public Report](#)

Also assess Appalachia H₂ costs in geologic ethane storage reservoir



CO₂ & H₂ Transport

Onshore CO₂ Pipeline Transport

FECM/NETL CO₂ Transport Cost Model

Publicly Available:
<https://netl.doe.gov/energy-analysis/details?id=543>

Tool to calculate the technical performance and costs of transporting CO₂ by pipeline

H₂ Pipeline Transport

FECM/NETL Hydrogen Pipeline Cost Model (H2_P_COM)

And accompanying models
Near completion

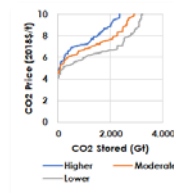
Focus of subsurface team modeling effort

CO₂ & H₂ Storage

Onshore CO₂ Storage

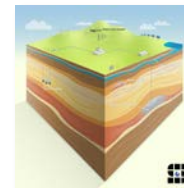
FECM/NETL CO₂ Saline Storage Cost Model

Publicly Available:
<https://netl.doe.gov/energy-analysis/details?id=2403>



H₂ Storage

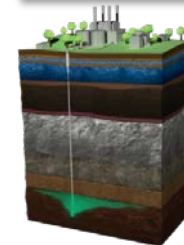
H₂ Subsurface Storage Cost Model
Under development



National Risk Assessment (NRAP)

Demonstrate CO₂ and H₂ Subsurface Risks via EDX:

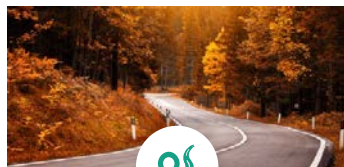
<https://edx.netl.doe.gov/nrap/>



Revitalizing America's Energy Communities



NETL's Role in the Interagency Working Group on Coal & Power Plant Communities & Economic Revitalization



Upgrade Infrastructure



Clean-Up
Environmental Damage



Community, Stakeholder
Engagement



Deliver Quality Jobs



Delivering Federal Resources to Help
Revitalize America's Energy
Communities

\$195B+

Value of Open/Planned
Opportunities

169

Open/Planned
Opportunities

12

Agencies
Represented

68

Opportunities w/
no cost share

\$135B+ in Bipartisan Infrastructure Law funding in Clearinghouse



THANK YOU!



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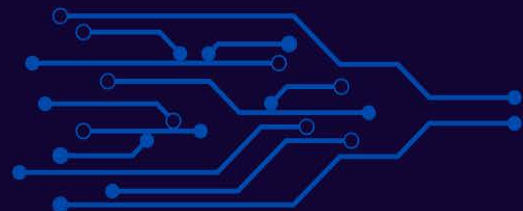
@NETL_DOE

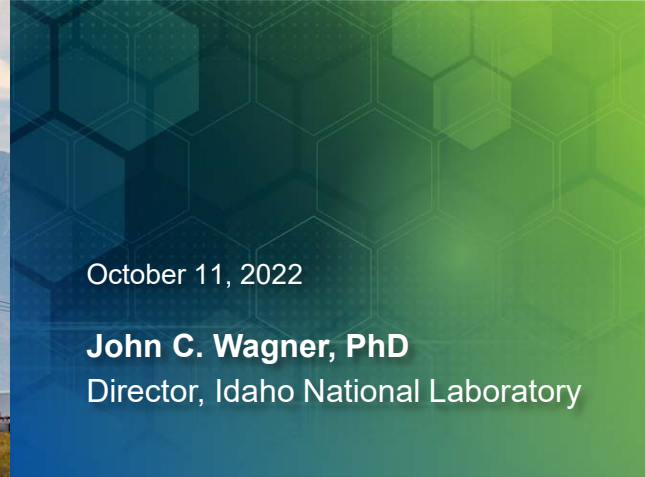
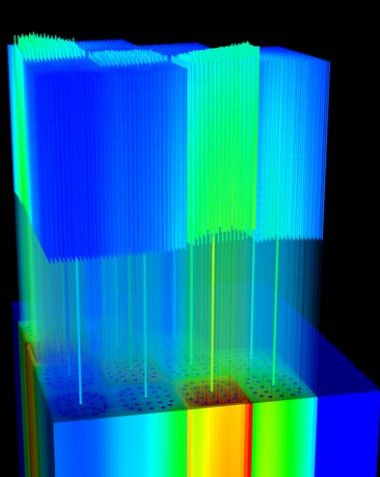
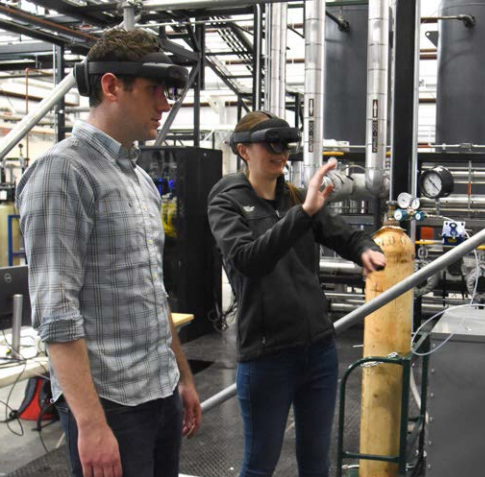


@NETL_DOE



@NationalEnergyTechnologyLaboratory





October 11, 2022

John C. Wagner, PhD
Director, Idaho National Laboratory



Hydrogen Americas Summit – U.S. Research Labs Driving Hydrogen Advancement

Battelle Energy Alliance manages INL for the
U.S. Department of Energy's Office of Nuclear Energy



Addressing the world's most pressing challenges through research, development, and demonstration



VISION

INL will change the world's energy future and secure our critical infrastructure.

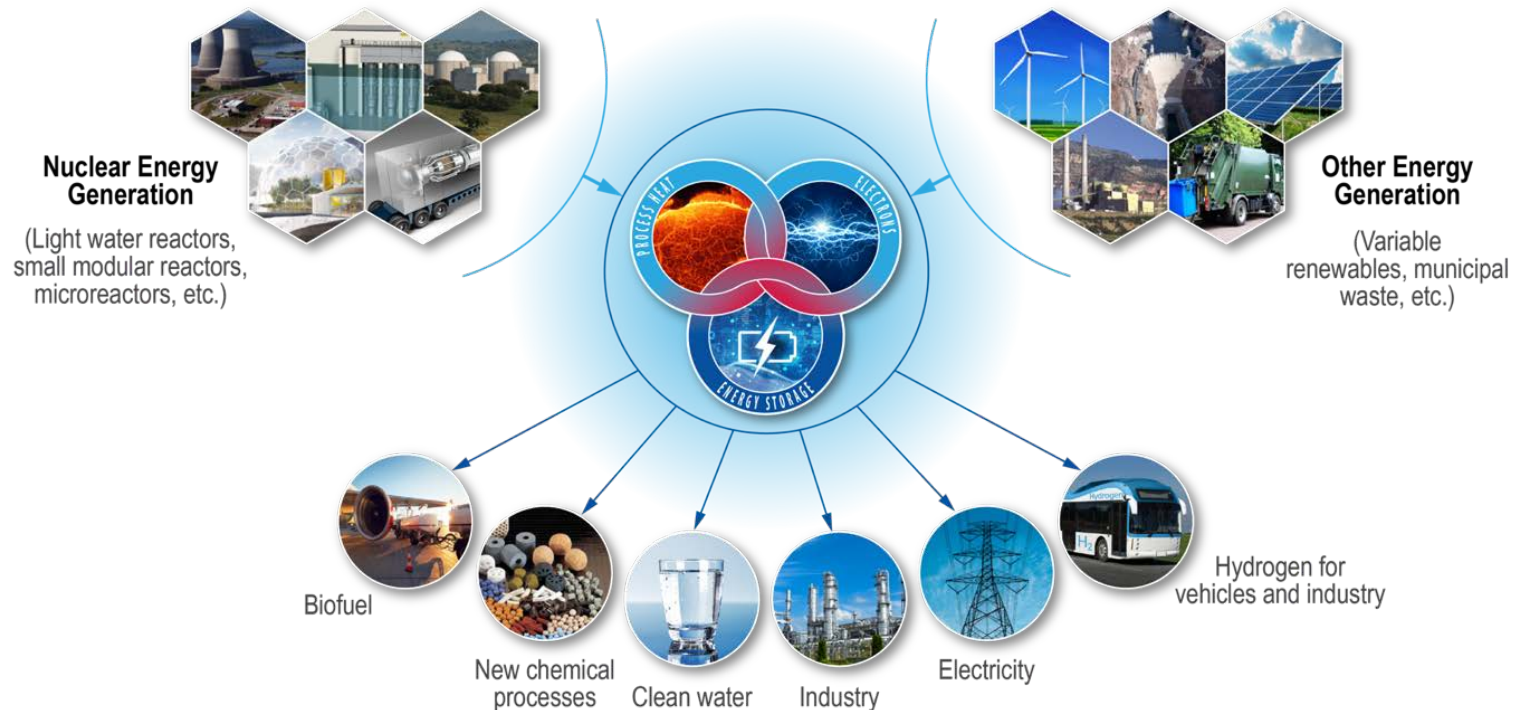
MISSION

Discover, demonstrate and secure innovative nuclear energy solutions, clean energy options and critical infrastructure.

VALUES

Excellence, Inclusivity,
Integrity, Ownership,
Teamwork, Safety.

Shifting the energy paradigm through innovative integrated energy systems research, development & deployment



Enabling commercial developers to operate, verify, and validate fully integrated high-temperature electrolysis module performance



Hydrogen creates new opportunities for the existing commercial fleet and for future advanced reactors



Constellation: Nine-Mile Point Plant

- H₂ production beginning in 2023
- NEL Hydrogen PEM module



Energy Harbor: Davis-Besse Plant

- H₂ production beginning in 2024
- 2 MW_{eDC} Cummins PEM module



Xcel Energy: Prairie Island Plant

- H₂ production beginning in 2024
- Bloom Energy HTE modules



Pinnacle Northwest Hydrogen

- Project award in discussion
- 20 MW_{eDC} PEM Electrolysis
- H₂ storage for gas turbine combustion test
- Combustion in Saguaro NCGG plant

Converting the INL fleet to hydrogen and electric vehicles is essential to achieve net-zero by 2031



86
MOTOR
COACHES

2.7

MILLION MILES DRIVEN
EACH YEAR

435,000



GALLONS OF
FUEL USED
EACH YEAR



Idaho National Laboratory

*Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy.
INL is the nation's center for nuclear energy research and development, and also performs research
in each of DOE's strategic goal areas: energy, national security, science and the environment.*

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