

# ***Gateway for Accelerated Innovation in Nuclear***

**December 14, 2022**

**Chris Lohse, GAIN Innovation and Technology Manager**

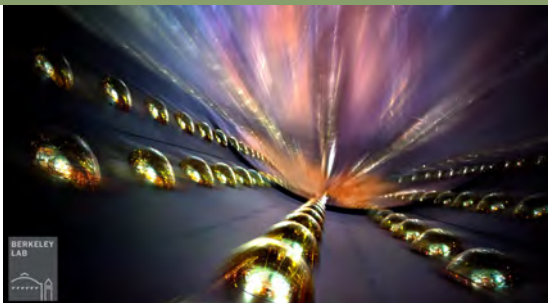
**CIBO**



## ***Mission and Vision***

### **Vision (2030)**

The U.S. nuclear industry is equipped to lead the world in deployment of innovative nuclear technologies to supply urgently needed abundant clean energy, both domestically and globally.



### **World Nuclear Energy Day**

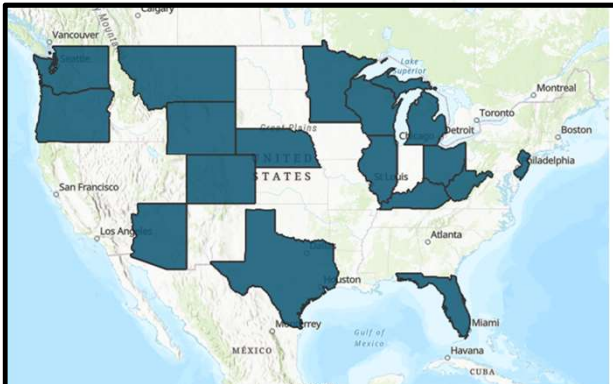


### **Mission**

Provide the nuclear energy industry with access to cutting-edge R&D, along with the technical, regulatory, and financial support necessary to move innovative nuclear energy technologies toward *commercialization* in an accelerated and cost-effective fashion.



# 2022 Activities



- ### State Level Outreach
- Policymakers, NGOs, Utilities, Regulators, Industrials, Commissioners
  - Introduce Advanced Nuclear through direct conversation or testimony
  - Help connect states to financial or technical resources across DOE complex
  - Looking at state level regs



## Advanced Nuclear Industry Milestones

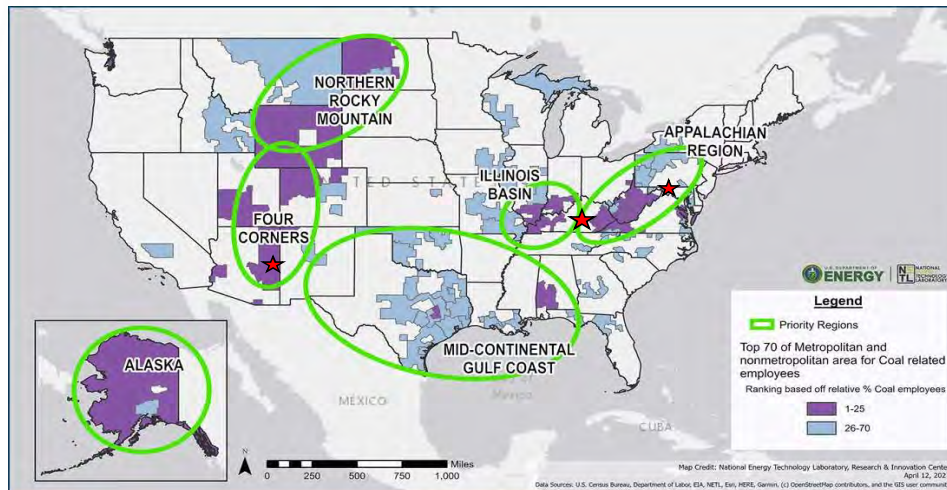
 <p><b>Purdue University and Duk...</b></p> <p>DATE 4/27/2022</p>	 <p><b>VA Legislature Passes Bill ...</b></p> <p>DATE 4/11/2022</p>	 <p><b>Indiana Passes SMR Bill</b></p> <p>DATE 3/18/2022</p>	 <p><b>NuScale Power and KGHM ...</b></p> <p>DATE 2/14/2022</p>	 <p><b>West Virginia Repeals New...</b></p> <p>DATE 2/8/2022</p>	 <p><b>Oklo Partners with Argonn...</b></p> <p>DATE 2/8/2022</p>	 <p><b>USNC Partners with Coppe...</b></p> <p>DATE 2/2/2022</p>
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# COAL TO NUCLEAR ENERGY COMMUNITY TRANSITIONS



## Case Study Pilot (in partnership with DOE-FECM)

GAIN is in the process of scoping several case studies of specific coal sites/plants to understand the parameters that will have the most influence on moving forward with transitioning a coal site to nuclear. Scope several this year – complete 1 or 2 in the calendar year and initiate others in the future.



## Coal to Nuclear Research Group

Each group is leading important projects associated with potential repurposing coal sites with nuclear technology. Use group discussions to align our individual efforts to make the most of this opportunity for the broader industry. In addition, get constructive feedback on GAIN case study pilot project.

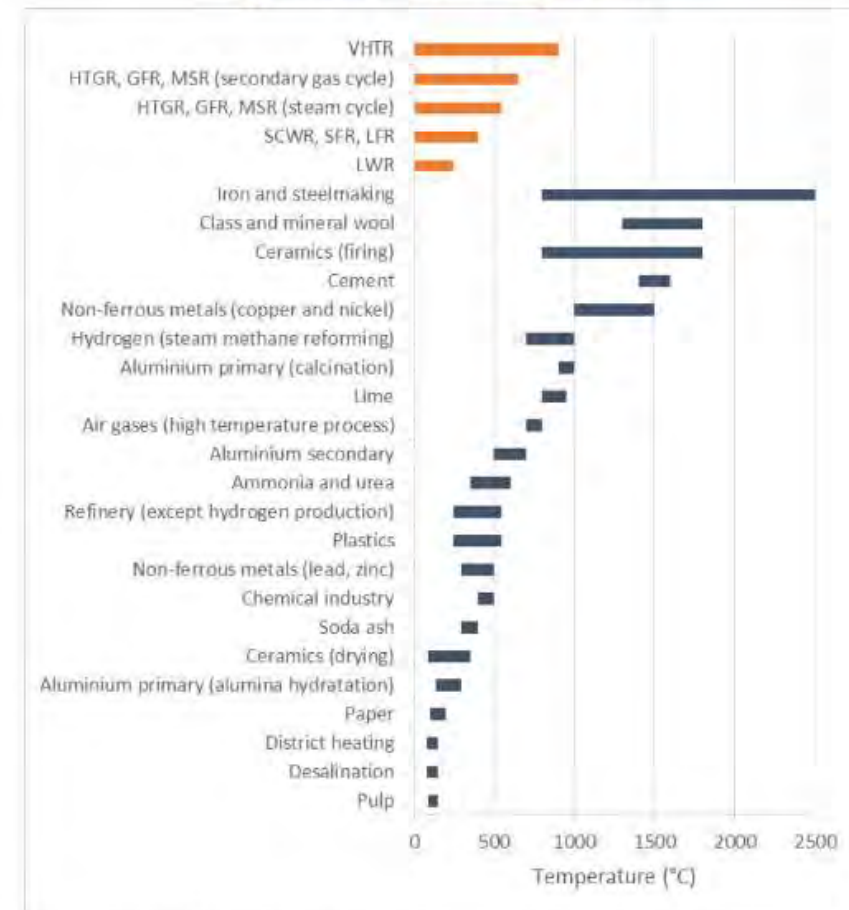


## Industrial Outreach

- GAIN has a subcontractor doing some research for determining interest in end users of nuclear
- Goals are:
  - Where does nuclear fit?
  - What makes nuclear attractive to end users?
  - What are the hurdles to adoption in these other markets?
  - What is the timeline for your deployment?



Figure 4.5: Process temperature ranges by industrial application and reactor capabilities



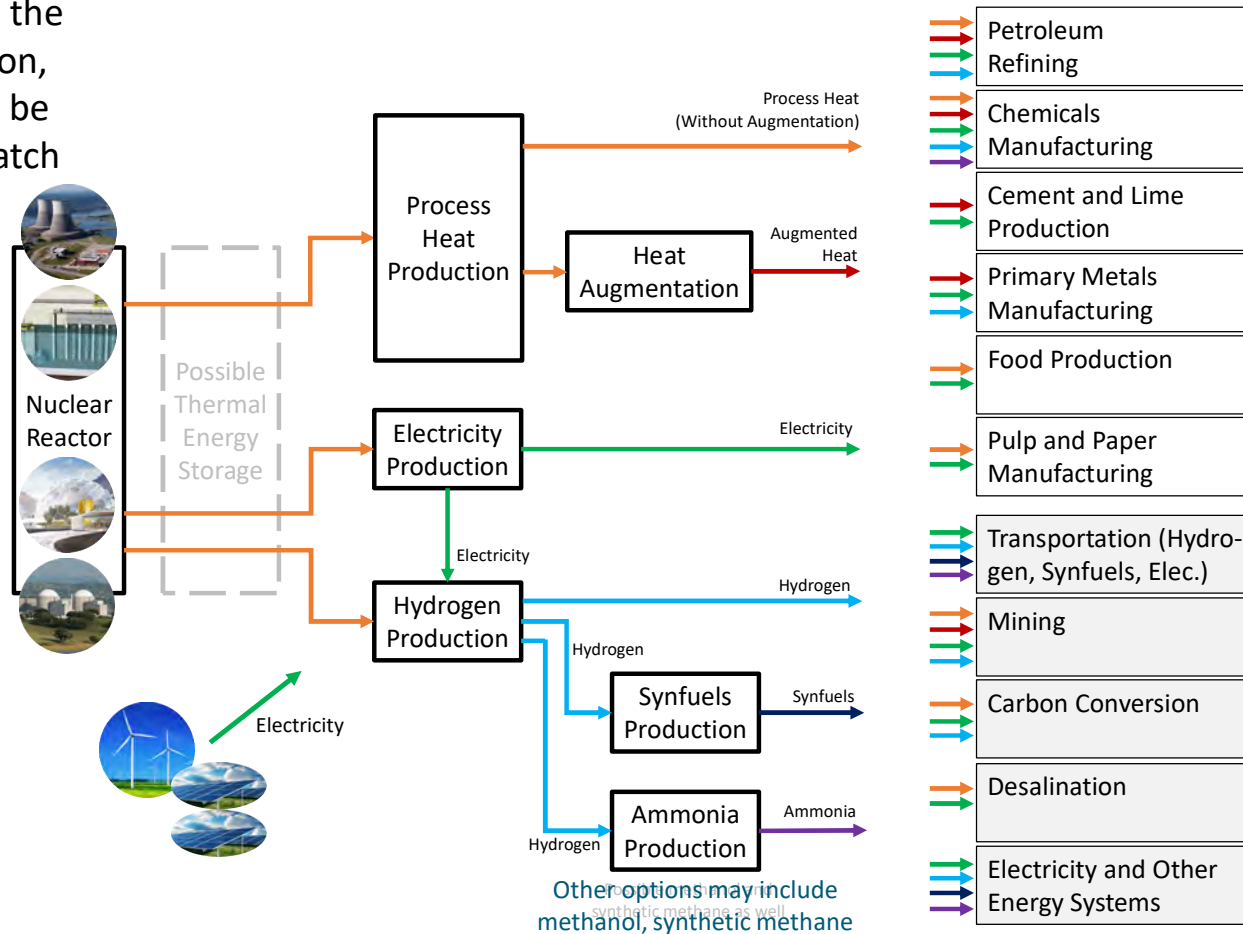
Source: Bredimas (2014) and Bredimas (2011a).

# Future clean energy systems – transforming the energy paradigm



# Summary of potential nuclear-driven IES opportunities

Reactor sizes align with the needs of each application, heat augmentation can be applied if needed to match process temperature demands.

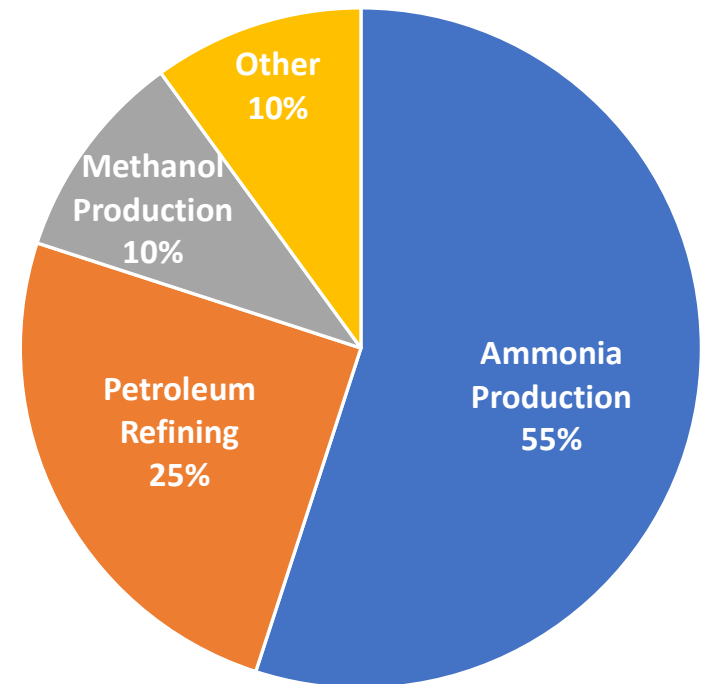


# Why the focus on hydrogen?

## Hydrogen applications in industry

- Agriculture/chemical industry: ammonia, ammonia-based fertilizers
- Petroleum refining: hydrocracking to produce gasoline, diesel
- Methanol production
- Other:
  - Food (e.g., hydrogenated oils)
  - Metalworking
  - Welding
  - Flat glass production
  - Electronics manufacturing
  - Medical applications

Fraction of Global Hydrogen Use by Industry



Data source: Hydrogen Europe  
[hydrogeneurope.eu/hydrogen-applications](https://hydrogeneurope.eu/hydrogen-applications)



## **GAIN Vouchers**

- GAIN Vouchers started in 2016
- Since Inception
  - 74 vouchers awarded - 47 completed - 44 different companies
  - \$26.4M awarded to date
- GAIN Vouchers are open to support multiple areas for advanced nuclear technology developers.

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The U.S. Department of Energy's Office of Nuclear Energy established the GAIN initiative to provide the nuclear community with access to the technical, regulatory, and financial support necessary to move innovative technologies toward commercialization.

The NE Voucher Program is one way to provide industry with access to the unique research capabilities and expertise at DOE's national labs.

**NE Vouchers  
By the Numbers**

**7**

Years nuclear energy vouchers  
have been awarded through GAIN



**44**

Different companies  
awarded vouchers to date



**74**

Total NE Vouchers  
awarded since  
inception



**47**

Total NE  
Vouchers completed



**4**

NE Voucher funding cycles  
now offered each year



**\$26.4M**

Amount of voucher funding  
awarded through GAIN since FY16



**\$500K**

Typical maximum size of  
an NE Voucher



**12 Months**

Maximum length of project

## ***GAIN Voucher Details***

- Vouchers competitively award access to facilities and staff in the DOE national laboratory complex – NOT a financial award
- Voucher value is ~\$50K to \$500K
- Voucher recipient is responsible for 20% cost share
- One-year Period of Performance
- Standard CRADA
- Available to businesses that are majority (>51%) U.S. owned
- Limit to one application per cycle
- Four cycles per year – Next deadline is October 31<sup>st</sup>

## ***GAIN Vouchers – How to Apply***

- Go to the GAIN Website: <https://gain.inl.gov>



HOME ABOUT **FUNDING OPPORTUNITIES** RESOURCES REGULATORY WORKSHOPS AND WEBINARS

How to do Business Through GAIN

NE Advance Class Patent Waiver

Request For Information - Input to DOE-NE programmatic R&D planning (DE-SOL-0008246)

**NE Vouchers**

Industry FOA: DE-FOA-0001817

Advanced Reactor Demonstration FOA: DE-FOA-0002271

## **Helpful Links**

How to do business through GAIN

 [How to do Business through GAIN](#)

Proposal Submission System

 [Submit a Proposal](#)

Nuclear Energy Voucher Documents

 [NE Voucher Process Flowchart](#)

 [NE Voucher Request 5.1.2020](#)

 [Voucher RFA Summary of Changes 5.01.2020](#)

 [Ten Tips for Writing a Successful NE Voucher Request](#)

 [NE Voucher FAQ's 5.1.2020](#)

 [GAIN Small Business Voucher CRADA 11.1.18](#)

 [DOE Standard CRADA 11.1.18](#)



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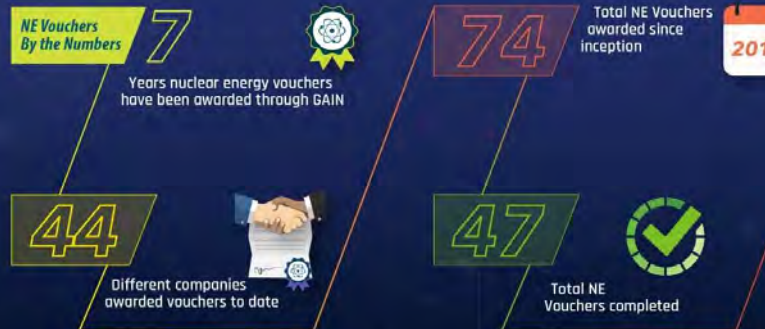
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GAIN Vouchers in Action



The U.S. Department of Energy's Office of Nuclear Energy established the GAIN initiative to provide the nuclear community with access to the technical, regulatory, and financial support necessary to move innovative technologies toward commercialization.

The NE Voucher Program is one way to provide industry with access to the unique research capabilities and expertise at DOE's national labs.



## AVAILABLE NOW: Completed Voucher Sum

Year ↓	Recipient	Proposal
2019	Analysis & Measurement Services Corp.	Testing of I&C Sensors and Cables for Small Modular Reactors
2018	Exelon Corporation	Plasma Separation Process Feasibility Study for the Commercial Enrichment of Gadolinium-157
2018	Vega Wave Systems	Radiation Testing for Nuclear Inspection Systems
2018	Oklo Inc.	Accelerate Development of Industry-Relevant Features in Modern Simulation Tools
2017	Micro Nuclear LLC	Development of the Microscale Nuclear Battery
2017	Kairos Power	Nuclear Energy Advanced Modeling and Simulation Program Thermal-Fluids Test Stand

## GAIN Voucher

<https://gain.inl.gov/SitePages/Nuclear%20Energy%20Vouchers.aspx>

Kairos Power  
partnered with

Argonne National Laboratory and Idaho National Laboratory

RFA-17-14580, Nuclear Energy Advanced Modeling and Simulation Program Thermal-Fluids Test Stand

YEAR AWARDED: 2017

TOTAL PROJECT VALUE: \$500K (\$400K DOE funds awarded, \$100K awardee cost share)

STATUS: Completed

PRINCIPAL LAB INVESTIGATORS: Elia Merzari (emerzari@anl.gov); Rich Martineau (INL retired)

**DESCRIPTION:** Argonne National Laboratory (ANL), Idaho National Laboratory (INL), and Kairos Power, LLC partnered to implement a multiscale thermal-fluids hierarchy analysis methodology for Kairos' fluoride high-temperature reactor (FHR). The project demonstrated Kairos Power's design optimization process for the heat exchanger, a vital component of the reactor's design. ANL performed high-fidelity simulations of Kairos' heat exchanger design at different spatial scales. Simulations using Nek5000, an open-source computational fluid dynamic code developed under the Nuclear Energy Advanced Modeling and Simulation program analyzed the heat and fluid flow in twisted tube heat exchangers. Software design improvements were implemented in the System Analysis Module (SAM) with the ultimate goal of providing a reliable thermal-fluid system simulator for FHRs. INL implemented additional efforts to improve the software compatibility between SAM and RELAP-7 and to bring SAM in line with the Multiphysics Object-Oriented Simulation Environment (MOOSE) Software Quality Assurance Plan. A prototype-coupled simulation was performed for a simplified tank loop. Based on the MOOSE multi-app framework, this prototype-coupled code will constitute the basis of future work in this area.

**BENEFIT:** Plant-scale physics (SAM) informed by the lower-length scale (Nek5000) can significantly improve solution accuracy and reduce uncertainty when using the software in a predictive sense where little to no empirical data is available.

**IMPACT:** This collaborative process between INL, ANL, and Kairos resulted in multiscale, multiphysics advances for FHR concepts and other advanced reactor concepts. Forming a team that worked cooperatively using the same simulation tools resulted in a shared ownership of the tools.

**LESSONS LEARNED:** Improved cooperation among DOE laboratories enhanced industry partners' confidence in relying on DOE for developing advanced modeling and simulation tools.

**NEXT STEPS:** Incorporating the Griffin application environment's use into reactor physics and radiation transport should be straightforward, as both INL and ANL are developing Griffin. Including Griffin will allow the state-of-the-art calculations to be performed on most advanced reactors incorporating single-phase coolants. Finally, the BISON nuclear fuel performance code can be coupled to the system to evaluate long-term fuel phenomena, such as irradiation damage and creep.



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# ***GAIN Mission-Driven Goals***

***GAIN: small enough to be nimble, big enough to be relevant***



- 1. Provide private entities access to financial support opportunities and national laboratory capabilities (facilities, expertise, and tools)**
- 2. Identify gaps, gather needs, and develop viable paths forward to inform DOE research programs.**
- 3. Enable the completion of key portions of a modernized risk-informed regulatory framework.**
- 4. Engage with non-nuclear audience to introduce nuclear energy to help investigate potential applications using national lab capabilities (expertise and tools) and federal funding opportunities.**
- 5. Contribute tailored, factual information to key stakeholders to motivate the integration of nuclear energy into state, regional and local plans.**



# INL research and development in integrated energy systems will enable a clean hydrogen future



**CLEAN HYDROGEN  
POWERED BY NUCLEAR**

$H_2$

*Hydrogen  $H_2$*

**THE POTENTIAL**

Hydrogen is an **economic commodity** and an element for moving energy into fuels and chemicals in the industrial, agricultural, and transportation sectors.

**THE PROBLEM**

About **95%** of the hydrogen produced in the U.S. comes from **natural gas**, resulting in emissions.

- INL is the U.S. lead nuclear laboratory **AND**
- The lead laboratory for high temperature steam electrolysis (i.e., breaking water—steam—into its constituent parts)

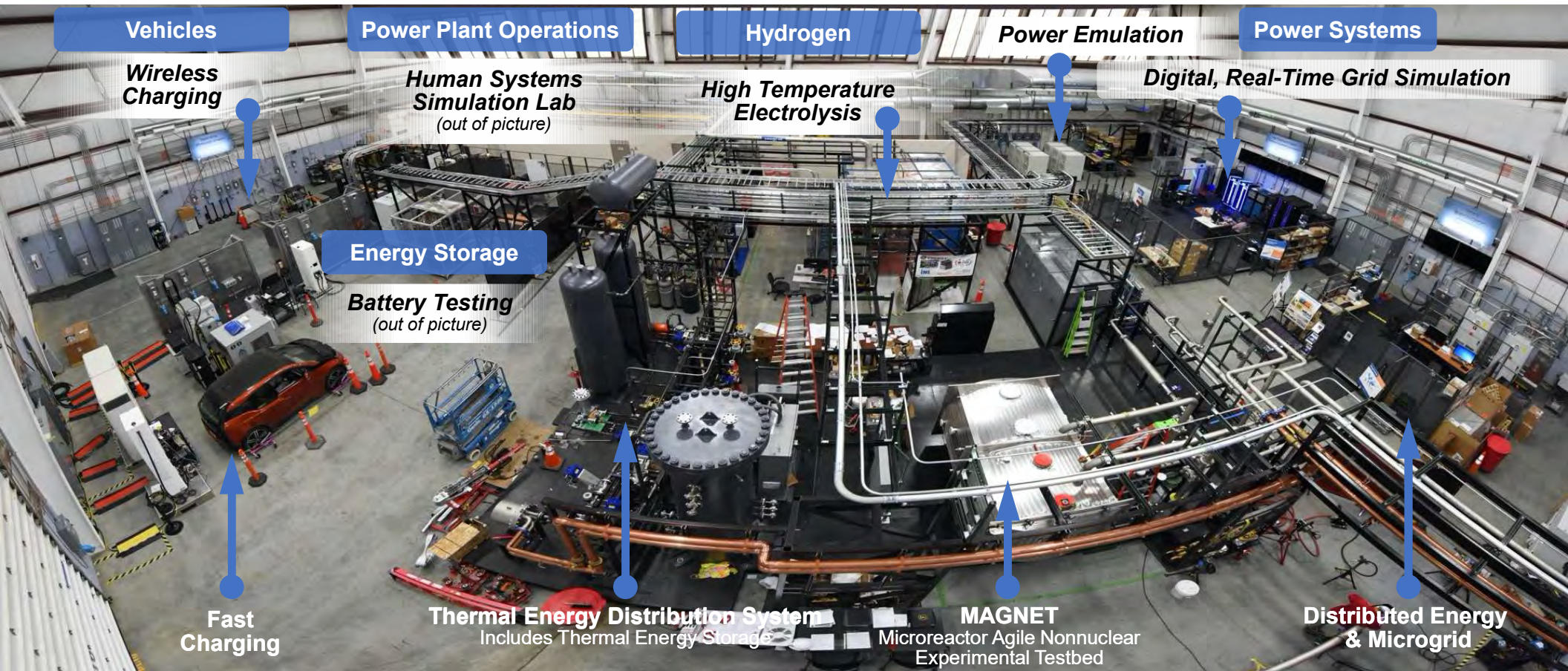


# Guiding questions in evaluating integrated energy systems

- What are **economically and technically viable** options for integrated energy system (IES) coupling to nuclear power plants in specific grid energy systems?
- What is the **statistically ideal** mix for Nuclear-IES within various markets?
- What are **driving economic factors** that existing and future nuclear technologies can leverage through IES production coupling?
- What are the **optimal coupling strategies** between IES technologies and nuclear plants?



# Dynamic Energy Transport and Integration Laboratory (DETAIL) for electrically heated testing of integrated systems





# Nuclear-H<sub>2</sub> demonstration projects

Multiple projects have been selected for demonstration of hydrogen production at U.S. nuclear power plants (NPP)

- H<sub>2</sub> production using direct electrical power offtake
- Develop monitoring and controls procedures for scaleup to large commercial-scale H<sub>2</sub> plants
- Evaluate power offtake dynamics on NPP power transmission stations to avoid NPP flexible operations
- Produce H<sub>2</sub> for captive use by NPPs and clean hydrogen markets

## Projects

- Constellation: Nine-Mile Point NPP (~1 MWe LTE/PEM)
- Energy Harbor: Davis-Besse NPP (~1-2 MWe LTE/PEM)
- Xcel Energy: Prairie Island NPP (~150 kWe HTSE)
- FuelCell Energy: Demonstration at INL (250 kWe)

**Nine Mile Point NPP  
LTE/PEM**



**Davis-Besse NPP  
LTE-PEM**



**Thermal & Electrical  
Integration at Prairie  
Island NPP  
HTSE/SOEC**

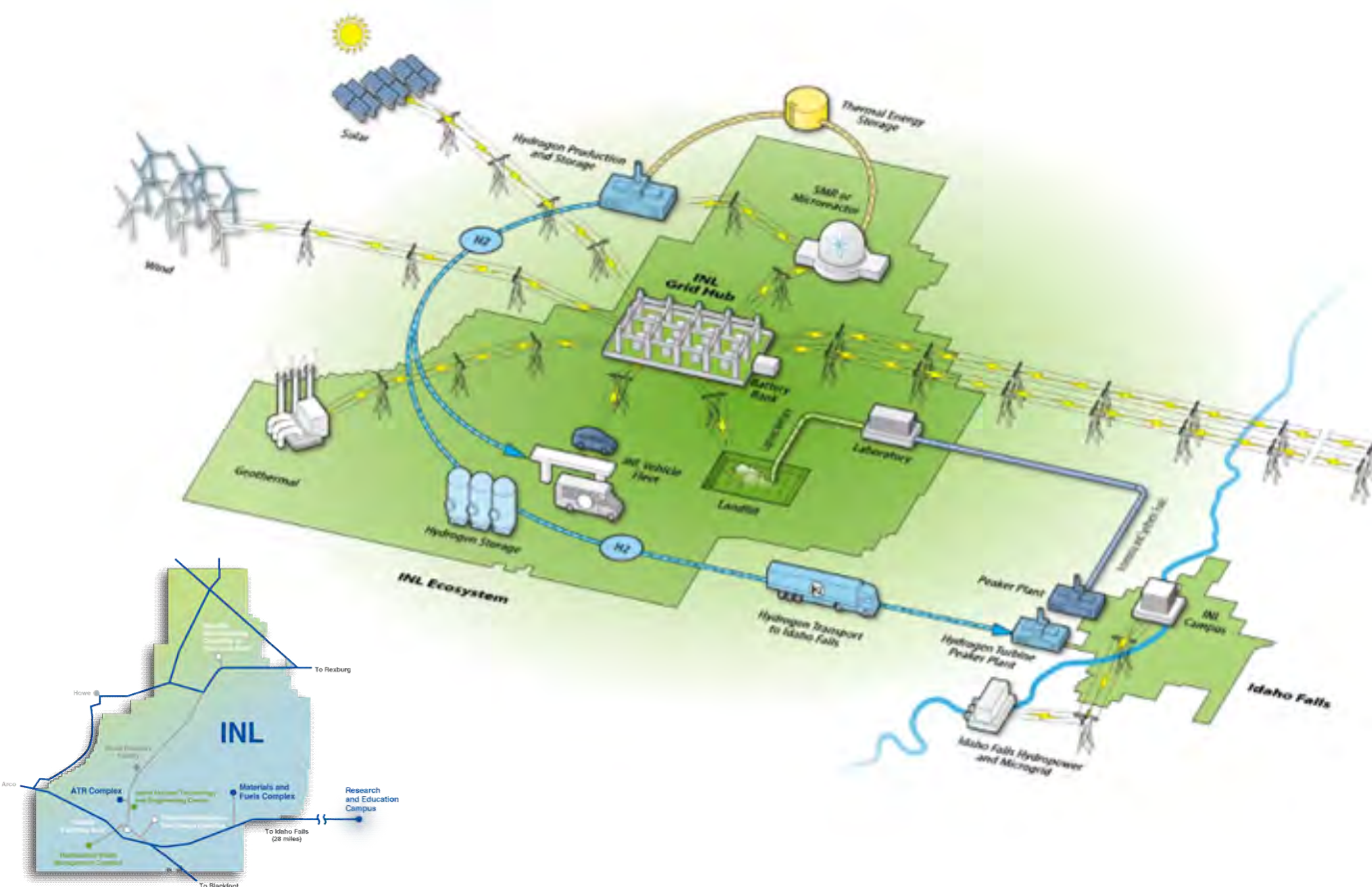


**FuelCell Energy at  
INL, SOEC at  
increasing scale**



~2024

# INL's commitment to net-zero will be a leading demonstration ushering in a secure, resilient net-zero energy future



- INL has committed to becoming a net-zero campus by 2031
- Attributes of a small city or county
- 890 sq mi
- >5400 employees
- >50 MWe purchased in FY2020
- >300 DOE-owned buildings
- Existing microgrid
- 3 fire stations, 1 museum, medical facilities, ...
- >40 miles primary roads

