IES
Integrated Energy Systems

Modeling & Simulation and Experimental Systems Development under the DOE Office of Nuclear Energy Integrated Energy Systems Program

Conference on Generation IV and Small Reactors (G4SR)
Non-Electric Applications of Nuclear Heat
Toronto, Canada
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Overview

- **Motivation**
- How to make predictions for IES: **Modeling Tools**
- Nuclear Cogeneration & Integrated Systems—**Examples in Action**
- **IES Experimental program**

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Energy market trends and global climate reality

Climate change

28% by 2040

Projected increase in world energy use by U.S. Energy Information Administration.*

2.7 degrees by 2040

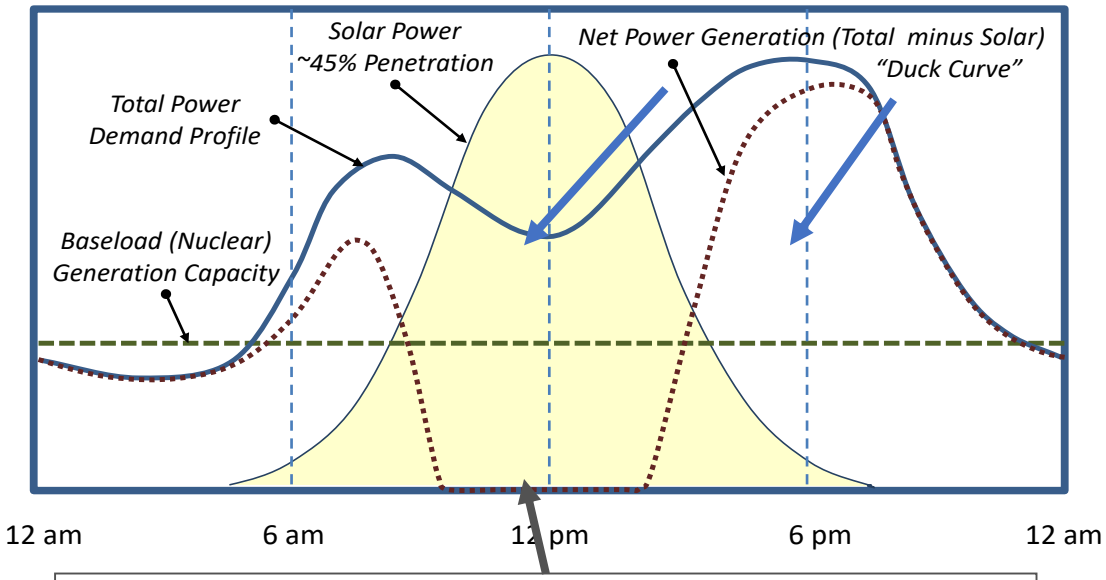
Projected increase in atmospheric temperatures if global greenhouse gas emission continue at current rate by Intergovernmental Panel on Climate Change

U.S. CO_2 emissions in 2018 (LLNL, 2018)

33% Electricity -> **only 1/3!**
36% Transportation
19% Industry
11% Residential/Commercial

Cross-sectoral solutions are needed to ensure decarbonization across all energy use sectors.

Impact of VREs on electric grid



Thermal power plants will be curtailed unless the energy can be used for non-electricity production

- Peak generation ≠ peak demand
- Requires additional components and approaches to maintain stable, reliable grid

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IES Guiding Questions

- 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 technology can leverage though IES production coupling?
- What are optimal coupling strategies between IES technologies and nuclear power plants? Safety?
- What is the governing control scheme for IES?

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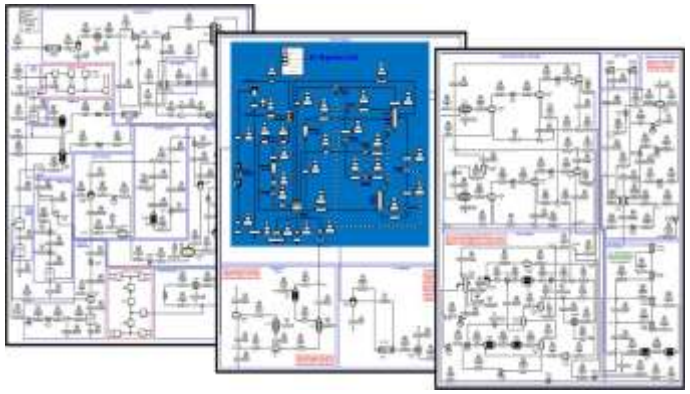
FORCE: Framework for Optimization of ResourCes and Economics

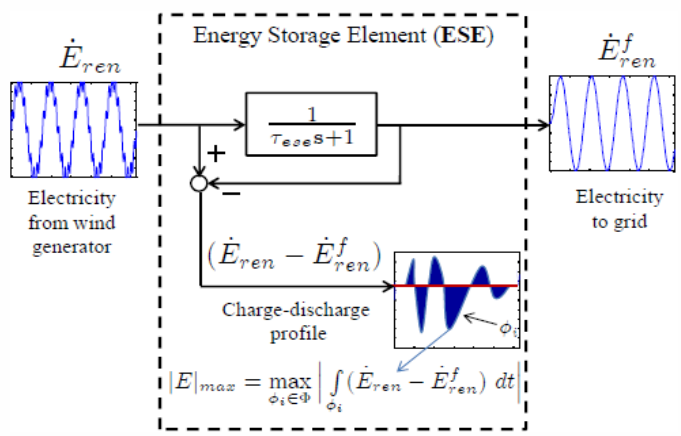
Graded approach to identify design, and evaluate hybrid system architectures

Aspen Plus® and HYSYS® Process Models



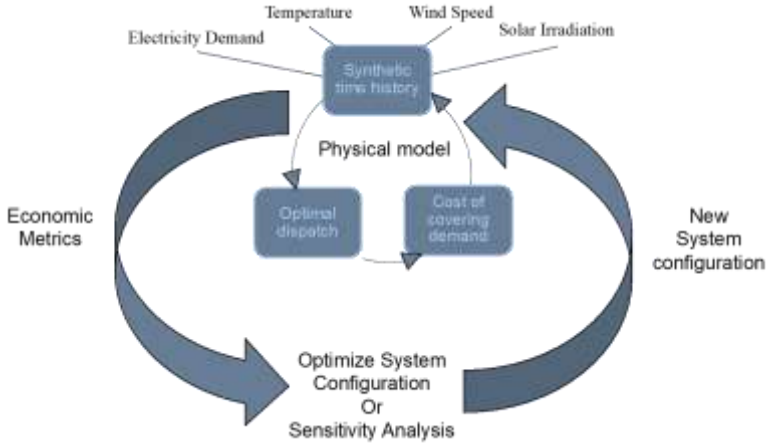
Process modeling addresses technical and economic value proposition

Modelica®, Aspen Dynamics®



Dynamic modeling addresses technical and control feasibility

HERON (INL System Optimization)



System modeling addresses whole-system coordination

Consideration of Resource—Technology—Economic—Market Potential

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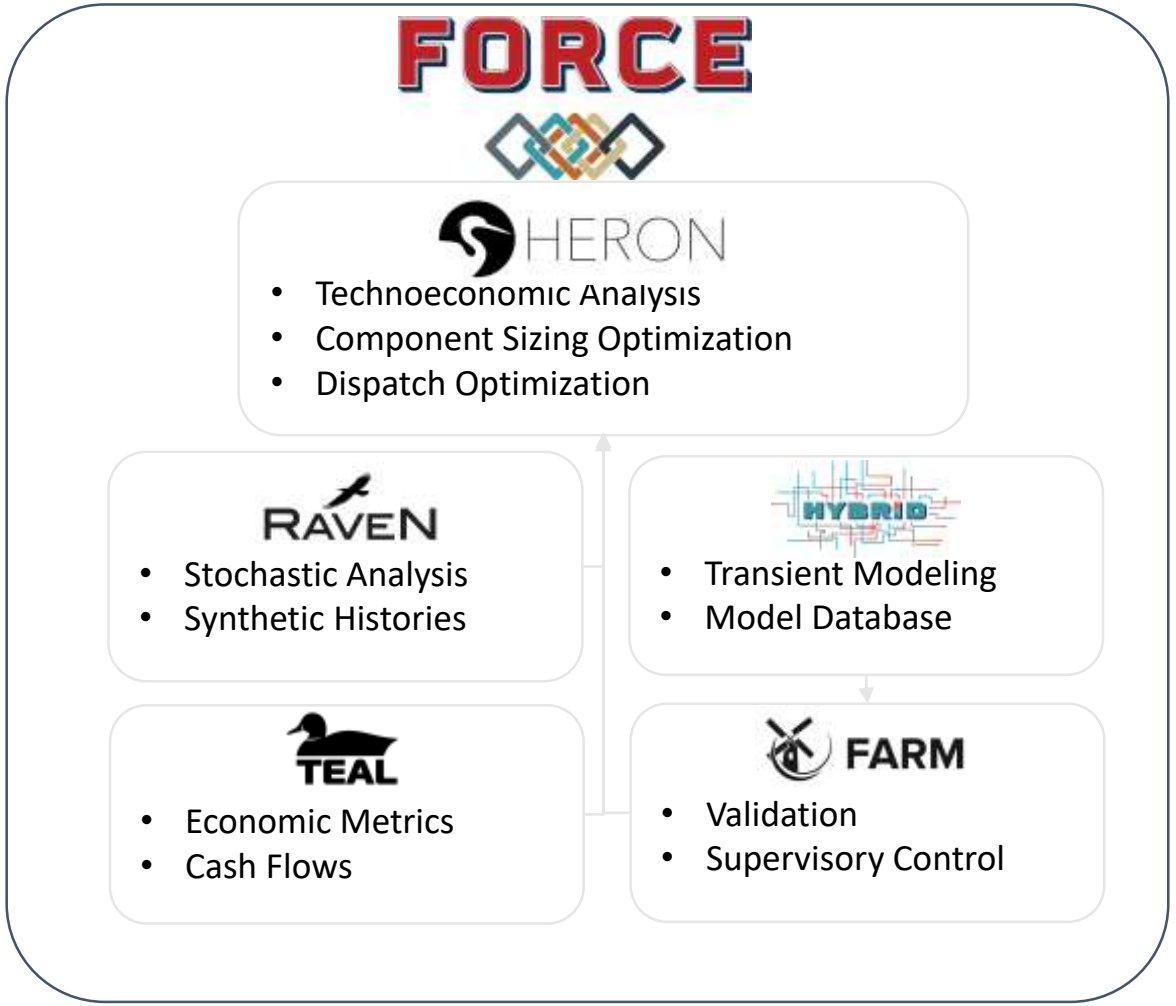
IES Analysis Tool Suite

- INL tools enable IES modeling analysis
  - Physical process, integration modeling and safety analysis.
  - Long-term technoeconomic analysis
  - Capacity, dispatch optimization
  - Stochastic analysis, multiple commodities
  - Energy storage, varied markets
  - Real-time optimization and control

See https://ies.inl.gov/SitePages/System_Simulation.aspx for more information and to access opensource tools.



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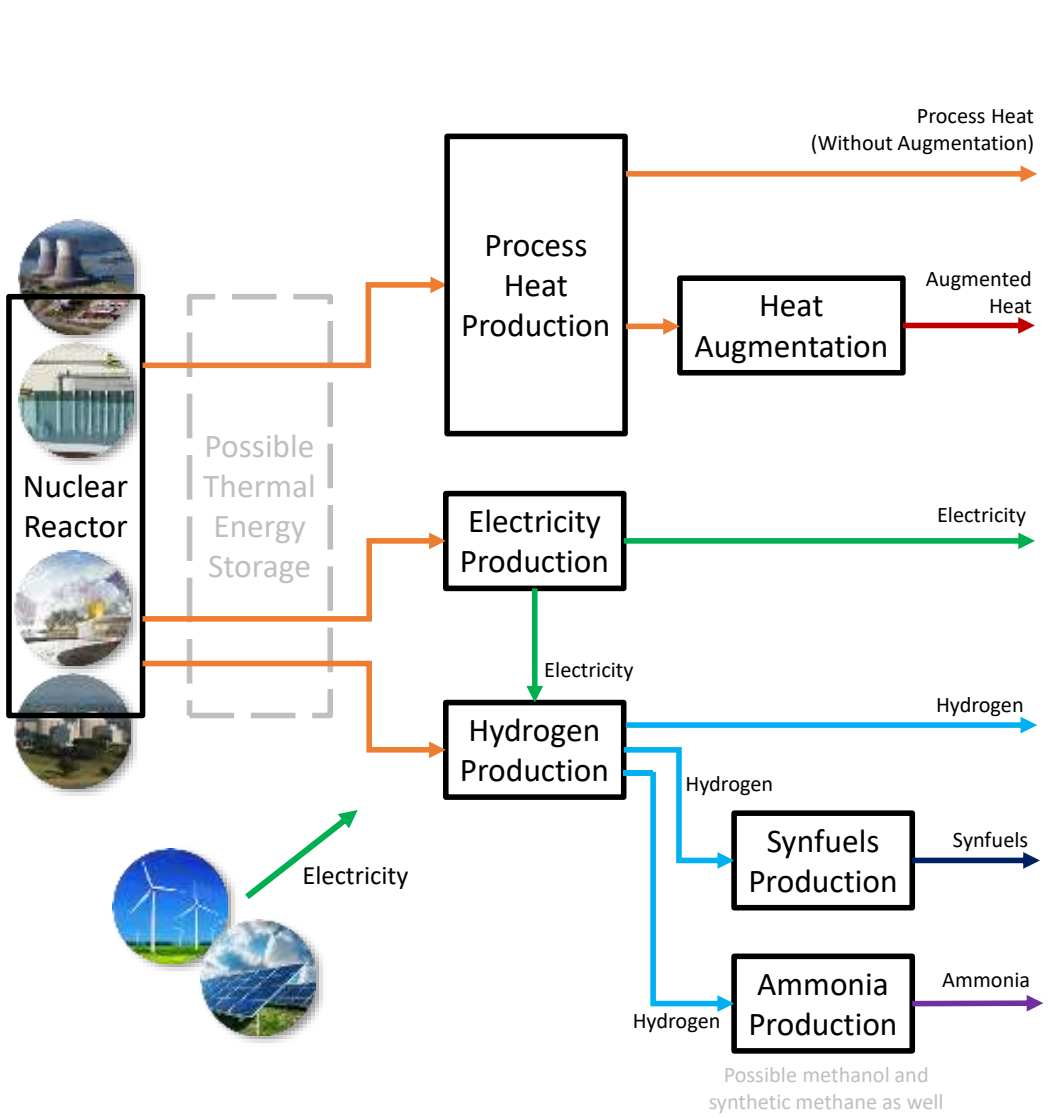
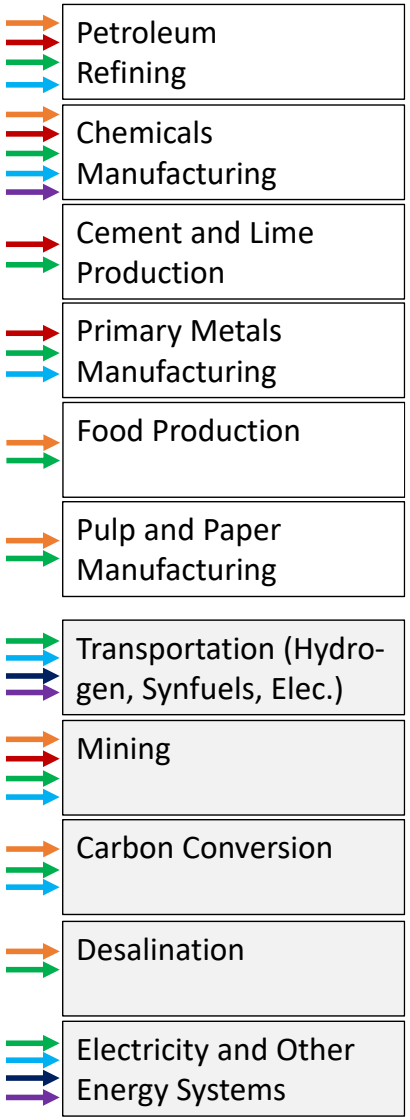
Potential nuclear-driven IES opportunities





IES involve

- Thermal, electrical, and process intermediates integration
- More complex systems than co-generation, poly-generation, or combined heat and power
- May exploit the economics of grid-coordinated energy systems
- May provide grid services through demand response (import or export)

Reactor sizes and temperatures align with the needs of each application

Source: INL, *National Reactor Innovation Center (NRIC) Integrated Energy Systems Demonstration Pre-Conceptual Designs*, INL EXT-21-61413, Rev. 1, April 2021

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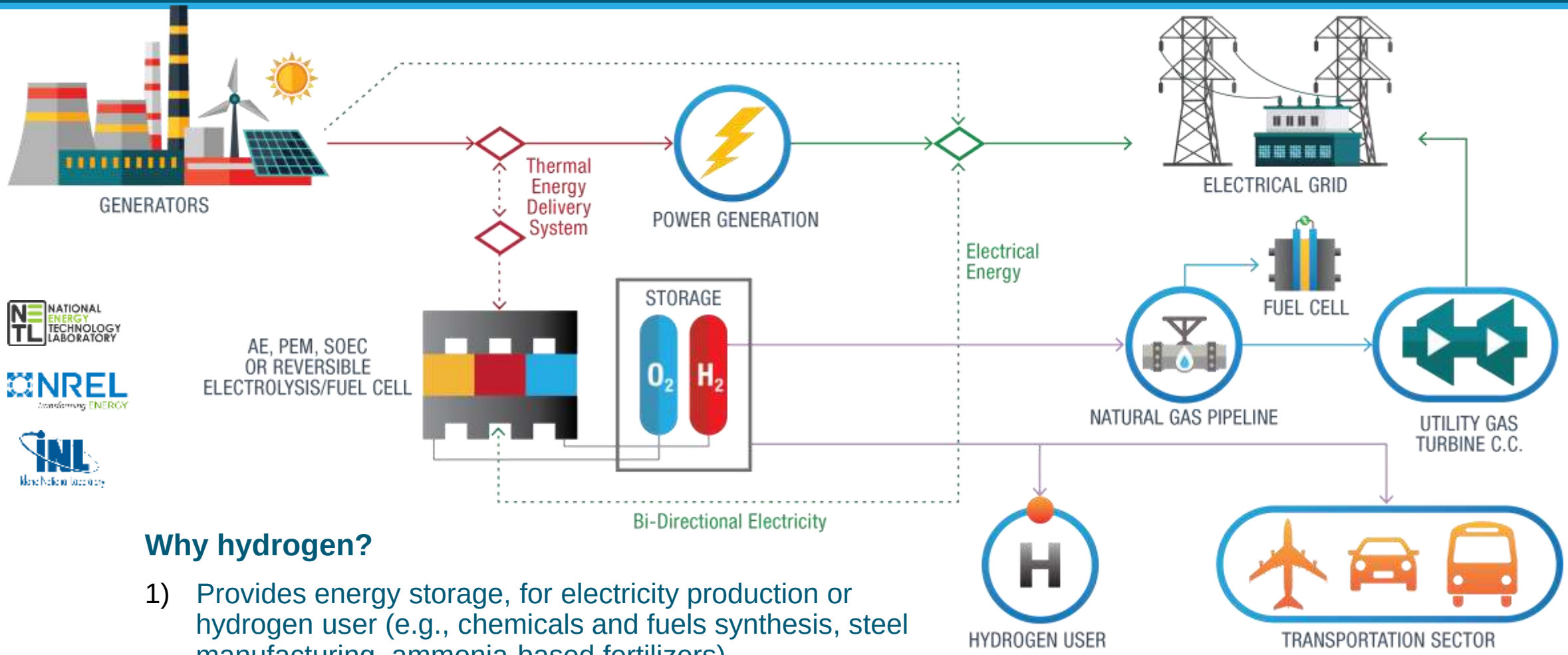
Priority Application: Hydrogen Production via Electrolysis



Why hydrogen?

1) Provides energy storage, for electricity production or hydrogen user (e.g., chemicals and fuels synthesis, steel manufacturing, ammonia-based fertilizers)

2) Provides second source of revenue to the generator

3) Provides opportunity for grid services, including reserves and grid regulation

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Nuclear-H_2 demonstration projects

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

- H_2 production using direct electrical power offtake
- Develop monitoring and controls procedures for scaleup to large commercial-scale H_2 plants
- Evaluate power offtake dynamics on NPP power transmission stations to avoid NPP flexible operations
- Produce H_2 for captive use by NPPs and clean hydrogen markets

Projects

- Constellation: Nine-Mile Point NPP (~1 MWe LTE/PEM)
- Energy Harbor: Davis-Besse NPP (~1-2MWe LTE/PEM)
- Xcel Energy: Prairie Island or Monticello NPP (~150 kWe HTSE)
- APS/Pinnacle West Hydrogen: Palo Verde Generating Station (~15-20 MWe LTE/PEM)

Nine Mile Point NPP LTE/PEM

Davis-Besse NPP LTE-PEM

Thermal & Electrical Integration at an Xcel Energy NPP HTSE/SOEC

Prairie Island ***Monticello***

Palo Verde Generating Station, H_2 Production for Combustion and Synthetic Fuels

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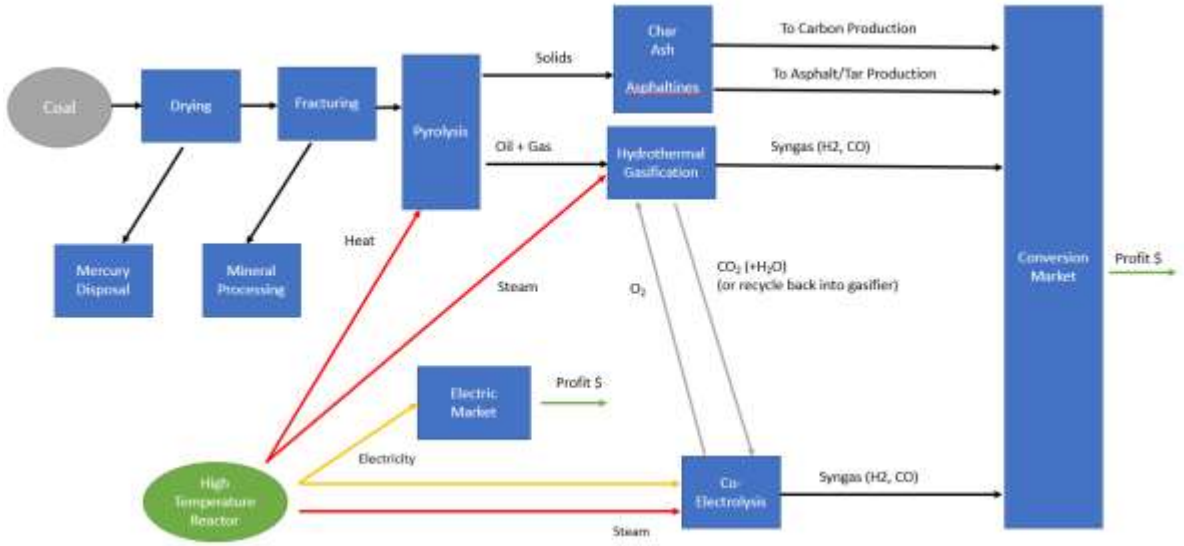
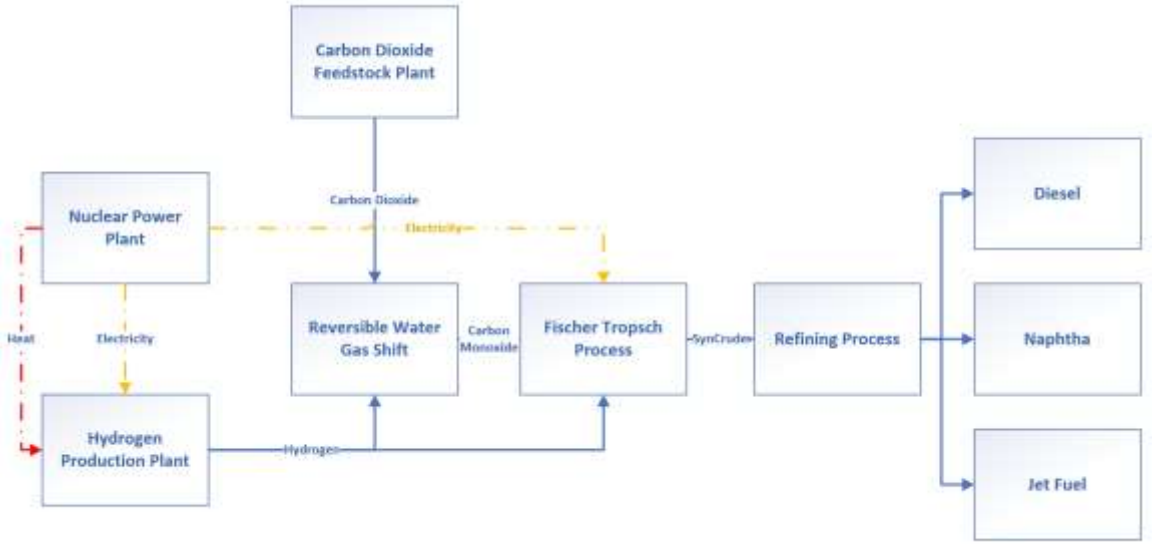
Ongoing Case Studies



Nuclear–Carbon Conversion



Nuclear Synthetic Fuels Production

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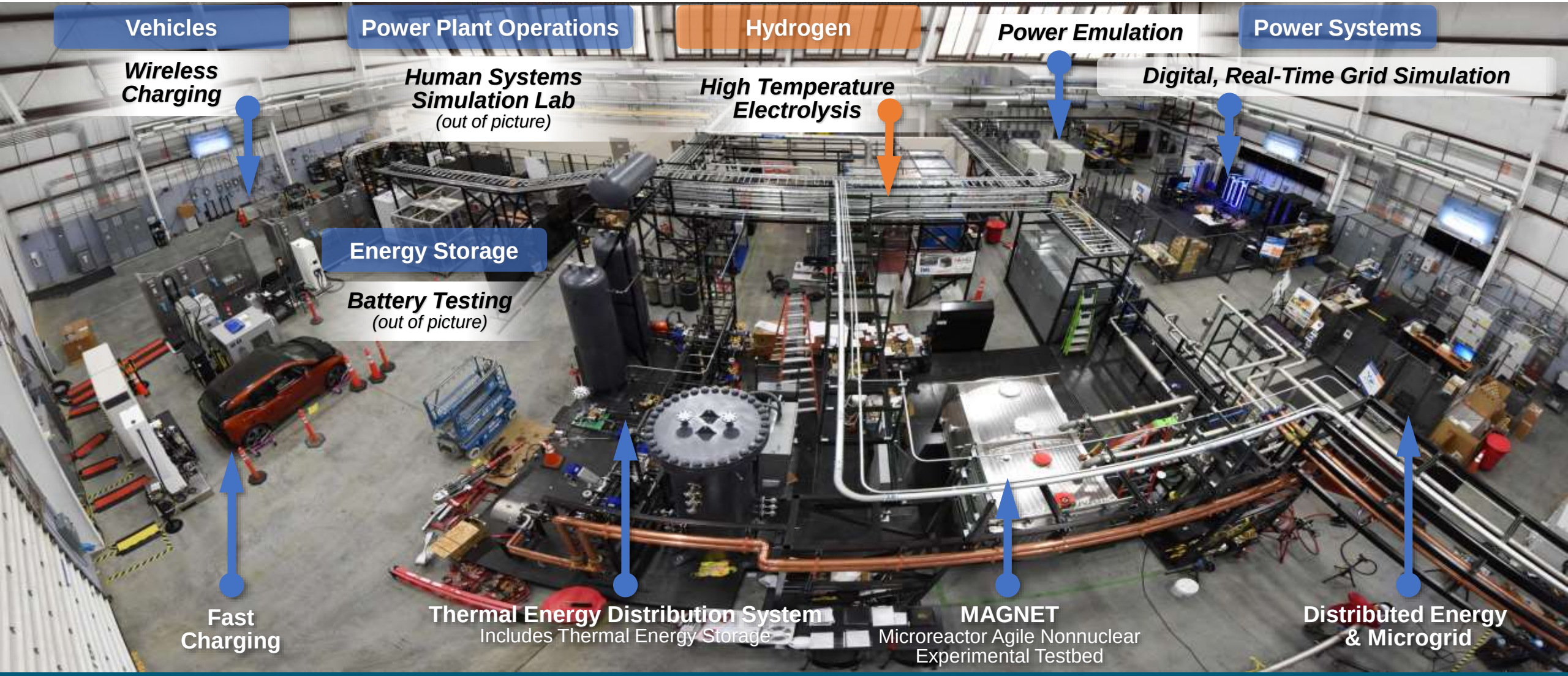
Integrating systems for a net-zero future
We also do experiments



Dynamic Energy Transport and Integration Laboratory (DETAIL)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