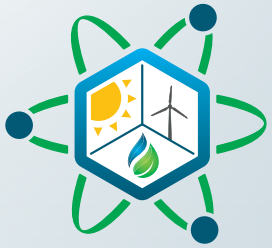


IES

Integrated Energy Systems

HERON

HERON: Overview

A Broad Look at the Holistic Energy Resource Optimization Network Software

FORCE Workshop

March 2022, Virtual

INL/MIS-22-66317

Outline

- Motivation
- What is HERON?
- Why HERON?
- Example Studies
- Current Efforts Overview
- Q&A

IES
Integrated Energy Systems

Acknowledgements

HERON development: cross-lab, university-included, industry-informed

INL Idaho National Laboratory

Argonne NATIONAL LABORATORY

OAK RIDGE National Laboratory

PURDUE UNIVERSITY

COLORADO SCHOOL OF MINES

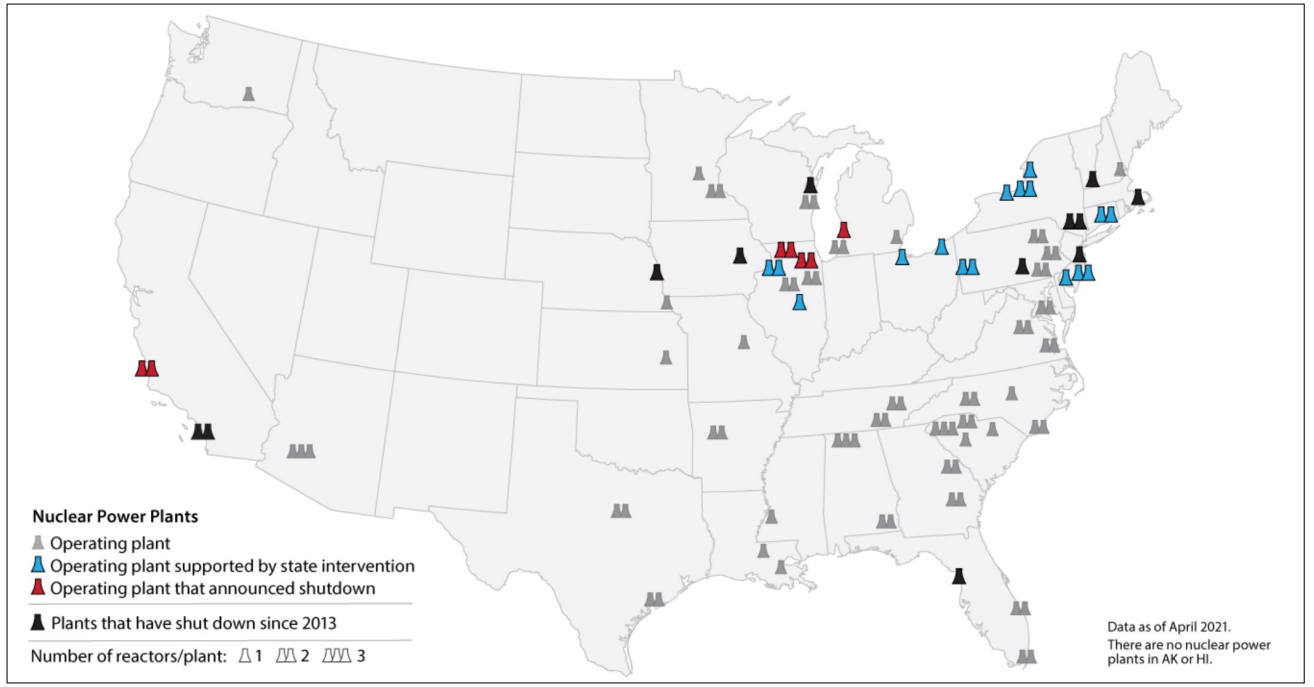
THE GEORGE WASHINGTON UNIVERSITY WASHINGTON, DC

UNIVERSITY OF MICHIGAN

IES Integrated Energy Systems

Motivations

- Changing Energy Landscape: Nuclear Power Plants (NPP)
  - 12 NPP retired from Feb 2013 through April 2021
    - Main reasons cited: cost of repairs, operating losses, low electricity prices
  - 7 NPP plan retirement from April 2021 through August 2025
    - Main reasons cited: operating losses, ending power purchase agreements



IES
Integrated Energy Systems

Congressional Research Service, "U.S. Nuclear Plant Shutdowns, State Interventions, and Policy Concerns", CRS Reports, June 10, 2021, https://crsreports.congress.gov/product/pdf/R/R46820

Motivation

- Changing Energy Landscape
  - Increased solar, wind deployment
    - Variable renewable energy sources (VREs)
    - Introduces significant uncertainty
    - Creates complications for baseload power
  - Cheap natural gas
    - Cleaner than coal
    - Acts as a “peaker” coupled with VRE
    - Still a carbon emitter

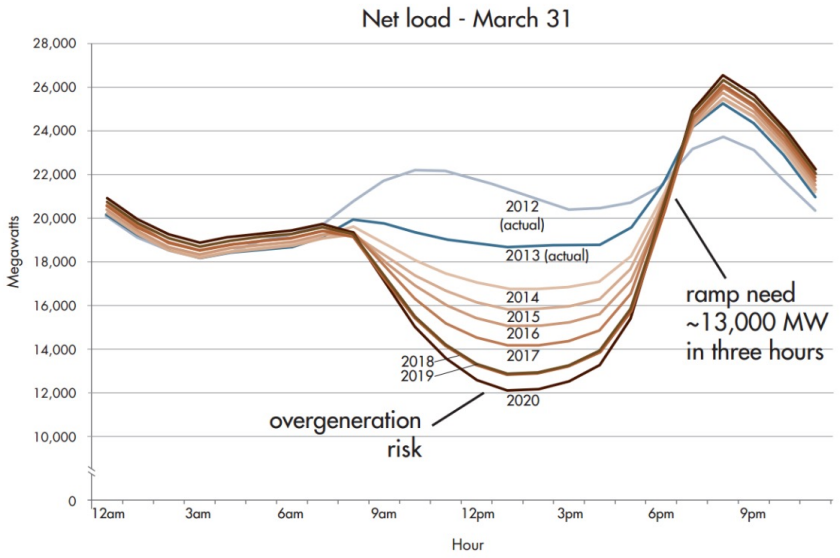


Figure 1. The CAISO duck chart

Source: CAISO 2013

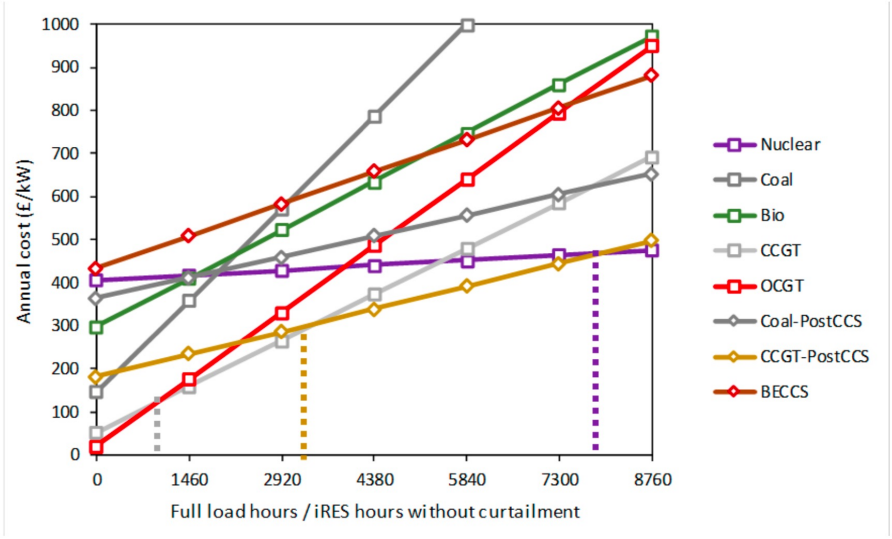
- Impact
  - Baseload nuclear needs to be more flexible to be competitive

IES Integrated Energy Systems

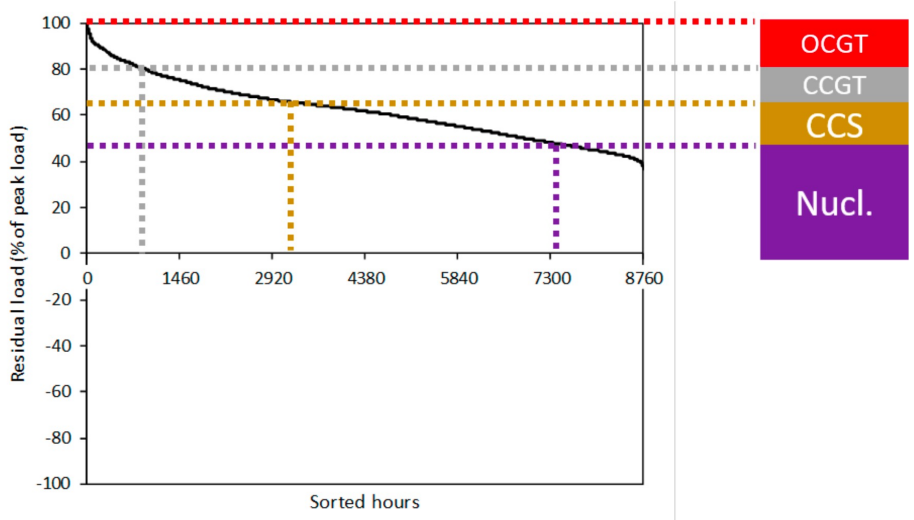
Denholm et al, “Overgeneration from Solar Energy in California: A Field Guide to the Duck Chart”, NREL report, 2015

Motivations

(a)



(b)



- Traditional Screening Curve
  - Based on baseload operation
  - Cost = Fixed + Marginal
    - Fixed: Capex, fixed Ops and Maintentance (O&M)
    - Marginal: Fuel, variable O&M
- Assumes Dispatchability
  - Baseload: 7000+ hours over demand
  - Peaker: 1000 hours or less over demand
  - VREs leave peaks, lower minimum demand
    - Requires less baseload, more peakers
  - Also assumes single-commodity market

IES
Integrated Energy Systems

Motivations

- Changing Energy Landscape
  - Main characteristics:
    - Increase in inflexible intermittent energy sources (VREs)
    - Larger gap between daily max, min electricity prices
    - Less baseload, more flexibility required
    - Battery storage is prohibitively expensive
  - How can Nuclear respond?
    - Flexible operation
      - Curtail production during low-demand hours
      - Minimal savings: most of nuclear cost is fixed, so not operating means losses
    - Integrated Energy Systems
      - Switch production during low-demand hours
      - Viability depends on regional markets for secondary commodities
      - Also depends on uncertainty of VREs

IES
Integrated Energy Systems

Motivations

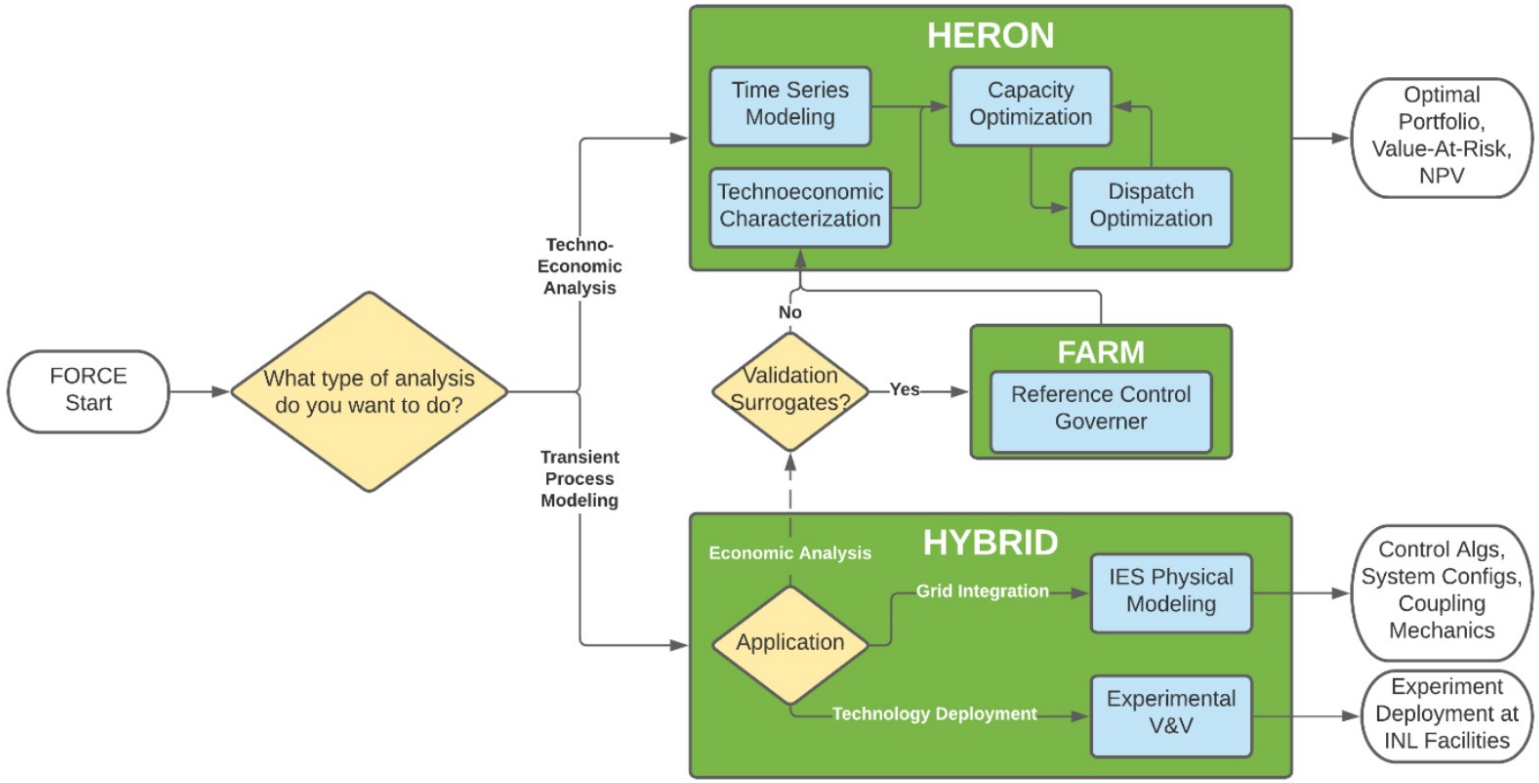
- Gaps in Capacity Expansion Modeling Software (CEM)
  - Beyond screening curve
    - Improve representation of volatility, storage, power ramping
  - Improve nuclear representation
    - Assume licensing extensions, advanced nuclear options
    - Introduce flexibility through thermally-coupled IES
      - Requires arbitrary commodity markets
  - Multiple Market System
    - Multiple time resolutions
    - Multiple commodities
    - Time-contiguous decision making
  - Capture Uncertainty
    - VRE availability uncertainty in contiguous time
    - Market pricing, demand uncertainty

IES
Integrated Energy Systems

FORCE

Capabilities

- Portfolio optimization
- Dispatch optimization
- Process model simulation
- Control simulation
- Economic analysis
- Supervisory control
- Stochastic analysis
- Workflow automation
- Validation and verification
- Digital twinning



IES
Integrated Energy Systems

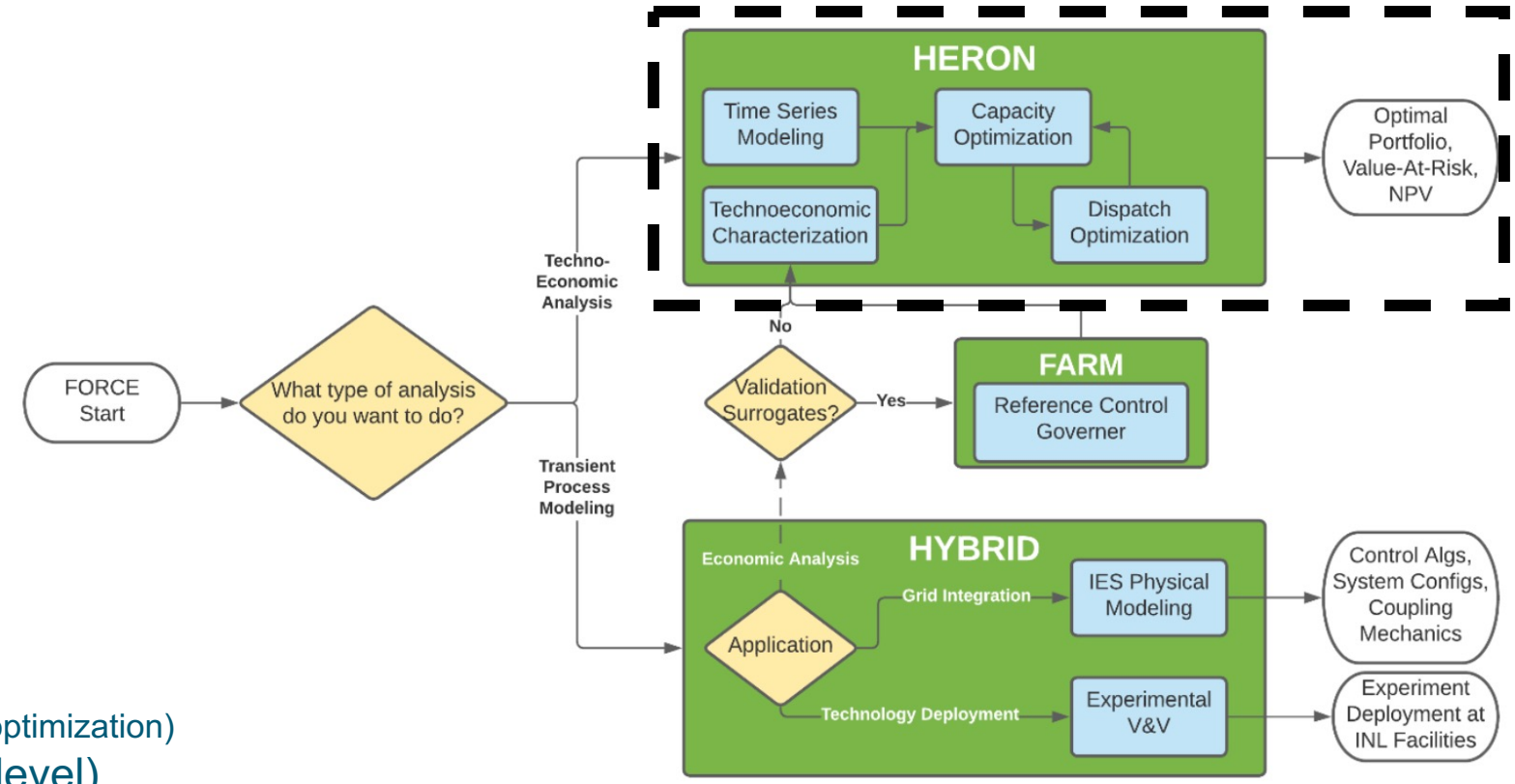
FORCE

HERON

- Portfolio optimization
- Dispatch optimization
- Stochastic analysis
- Workflow automation
- Economic analysis
  - Multiyear, Multi-history
  - Expected Value, Value at Risk

HYBRID

- Process model simulation
  - Steady state
  - Transient
- Control simulation
- Economic analysis
  - (Component-level daily/weekly optimization)
- Supervisory control (system-level)
- Validation and verification
- Digital twinning



IES
Integrated Energy Systems

What is HERON?

… and what isn't it?

What is HERON?

- Software for stochastic macro technoeconomic analysis of mixed-energy systems
- Command-line software tool
- Optimizes portfolio mixes to maximize statistical benefit
  - Expected NPV
  - Value at Risk
- Free, open source, openly available (https://github.com/idaholab/HERON)

IES
Integrated Energy Systems

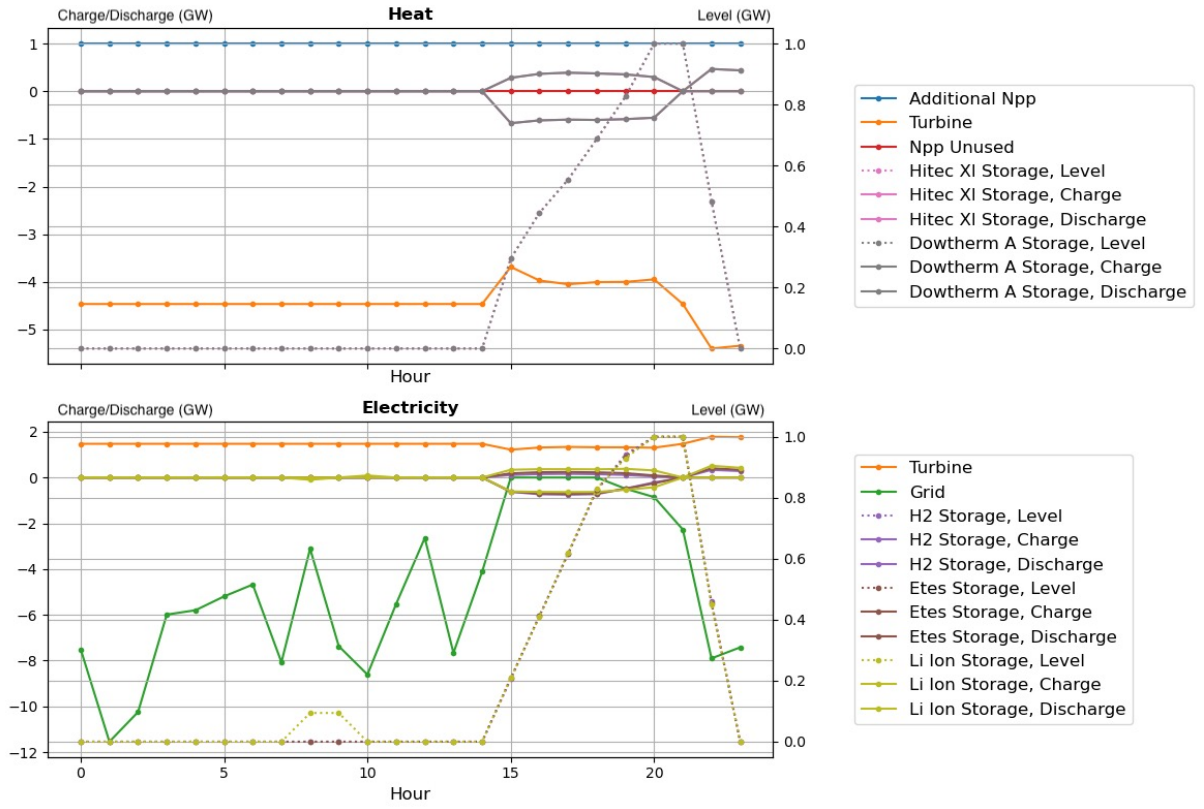
What is HERON?

- Features:
  - Mixed-Energy
    - electricity, hydrogen, water, heat, arbitrary commodities
  - Flexible Economics
    - arbitrary economic drivers
    - Capital costs
    - Fixed Operations, Maintenance costs
    - Variable Operations, Maintenance costs
    - Fuel consumption costs
    - Market sales for commodities
    - Policy-driven incentives

IES
Integrated Energy Systems

What is HERON?

- Features (ct'd):
  - Stochasticity
    - uncertain wind, solar, demand, prices
    - portfolio across <u>many</u> scenarios
      - optimize expected profit or Value at Risk
  - Contiguous Time
    - No time "slices"
      - Time "windows" capture connected time
    - Include inertial terms
      - Production ramp limitations
      - Commodity storage level tracking
      - Step-by-step volatility



IES
Integrated Energy Systems

What is HERON not?

- Not Capacity Expansion
  - HERON solves for optimal portfolios, not evolution (yet)
  - Evolution requires coupling with CEM
- Not Market Constructor
  - Market information is an input to HERON
  - However, market ROMs includable through RAVEN
- Not Regional Database
  - HERON process user inputs, no pre-defined models
    - May be able to use some existing data from published analysis
    - Current work: import model data from HYBRID
- No Graphical User Input
  - … yet!

IES
Integrated Energy Systems

Why HERON?

How did we get here?

Why HERON?

- Limitations in existing portfolio optimizers
  - Statistical analysis is afterthought or not present
  - Limited representation of Wind, Solar, Nuclear
  - Rarely include multiple markets, commodities
  - Often not openly available, easily extensible
  - Many designed on mostly-baseload pre-VRE expectations

- Integration with FORCE tools
  - Open-source models from HYBRID
  - Validation through FARM
  - Stochastic engine through RAVEN
  - Economic analysis through TEAL
  - Part of open-source solutions for Lab, University, Industry collaboration

IES
Integrated Energy Systems

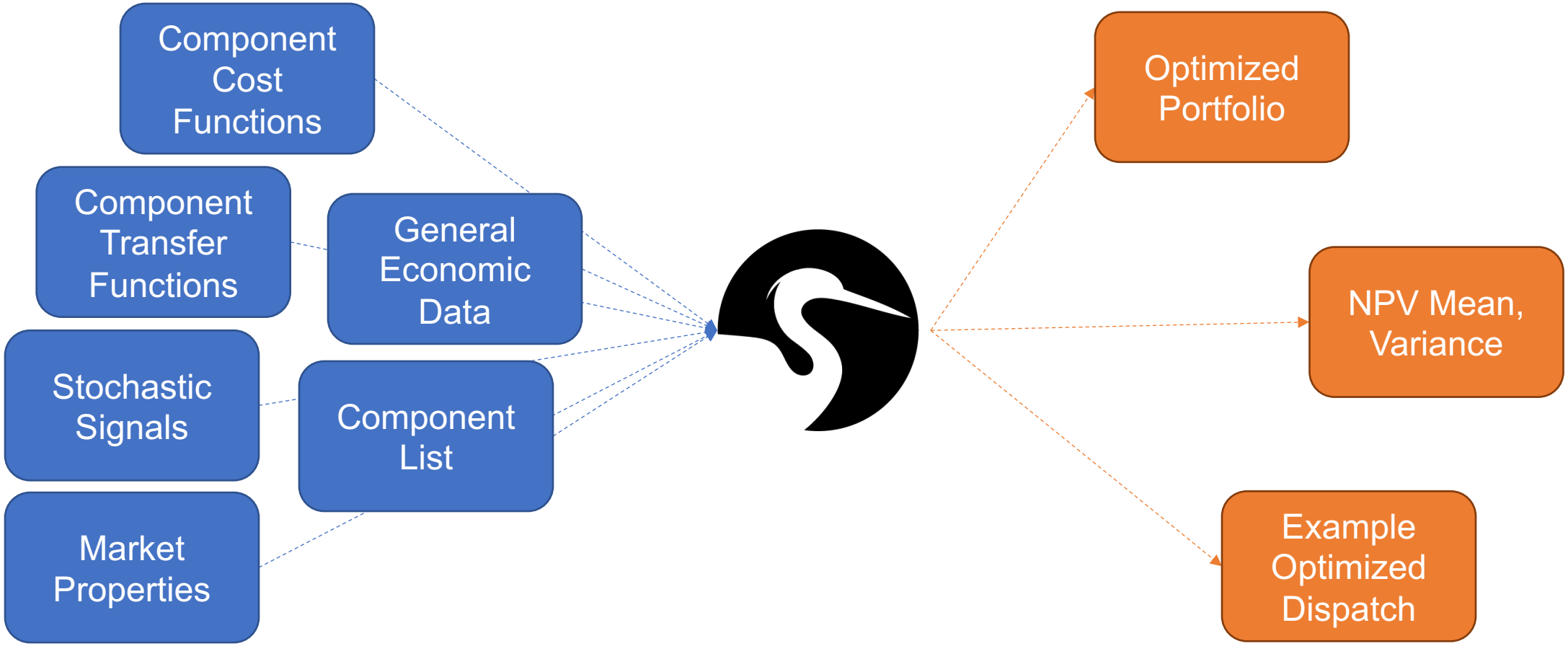
Why HERON?

- Why stochastic sampling?
  - Why not just analyze historical or forecast data?
- “Golden Year Problem”
  - Common practice: solve optimal portfolio for single history
  - Fails to capture range of possible outcomes
  - Driving economics is in outlier scenarios
    - High demand/low VRE
    - Low demand/high VRE
    - Sudden ramping demand
    - Stressed storage usage
  - Historic or Forecasted single scenarios can’t reliably capture outliers

Inputs and Outputs

How does this stuff work anyway?

HERON I/O



IES
Integrated Energy Systems

Example Studies

TEA is as TEA does

Example Studies

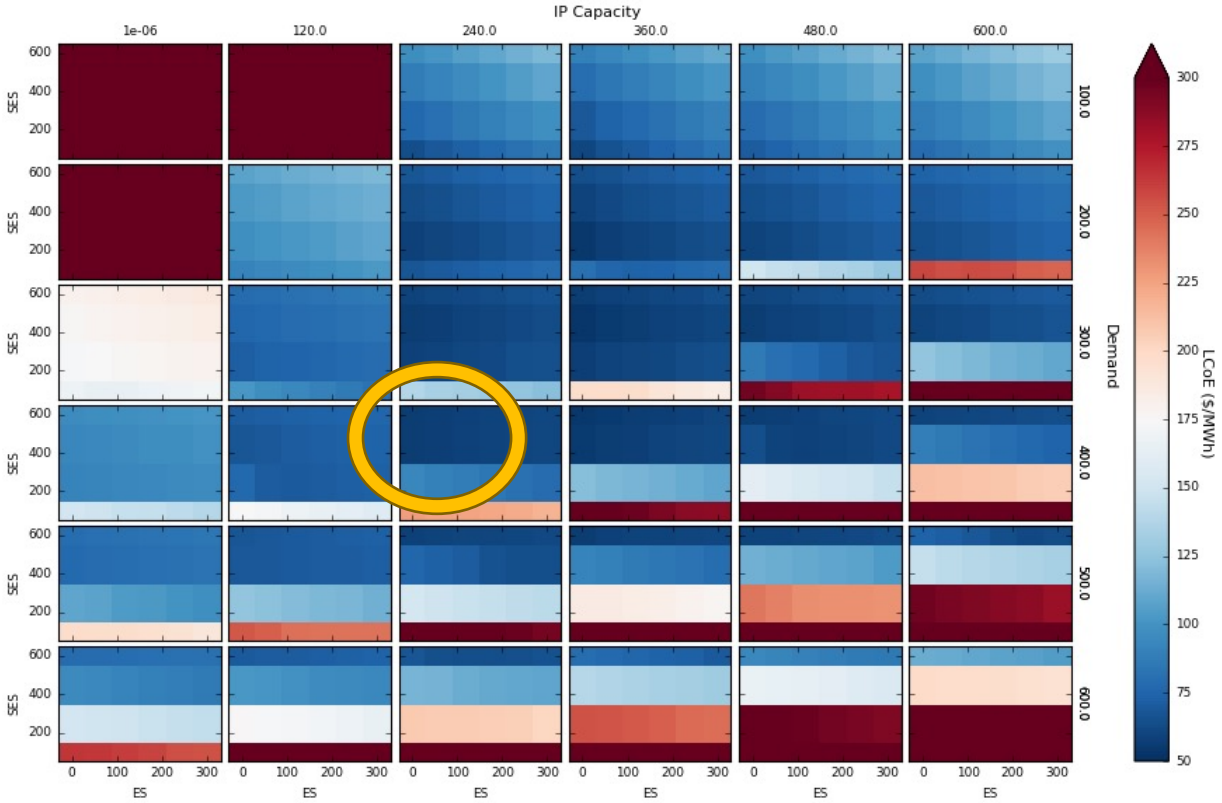
- A sampling of what has been done, and can be done

- 2017: Nuclear-Hydrogen
- 2018: Nuclear-Water Desalination (APS)
- 2019: Nuclear-Hydrogen in Midwest (Exelon)
- 2020: Nuclear-Hydrogen in Regulated, Deregulated Markets (EPRI)
- 2021: Nuclear-Thermal Energy Storage in NYISO (EPRI)

IES
Integrated Energy Systems

2017: Nuclear-Industrial Coupling

- What are potentially profitable configurations of nuclear-industrial coupling given stochastic wind?
  - Nuclear, Natural Gas (SES), Battery (ES), Hydrogen Generator (IP)



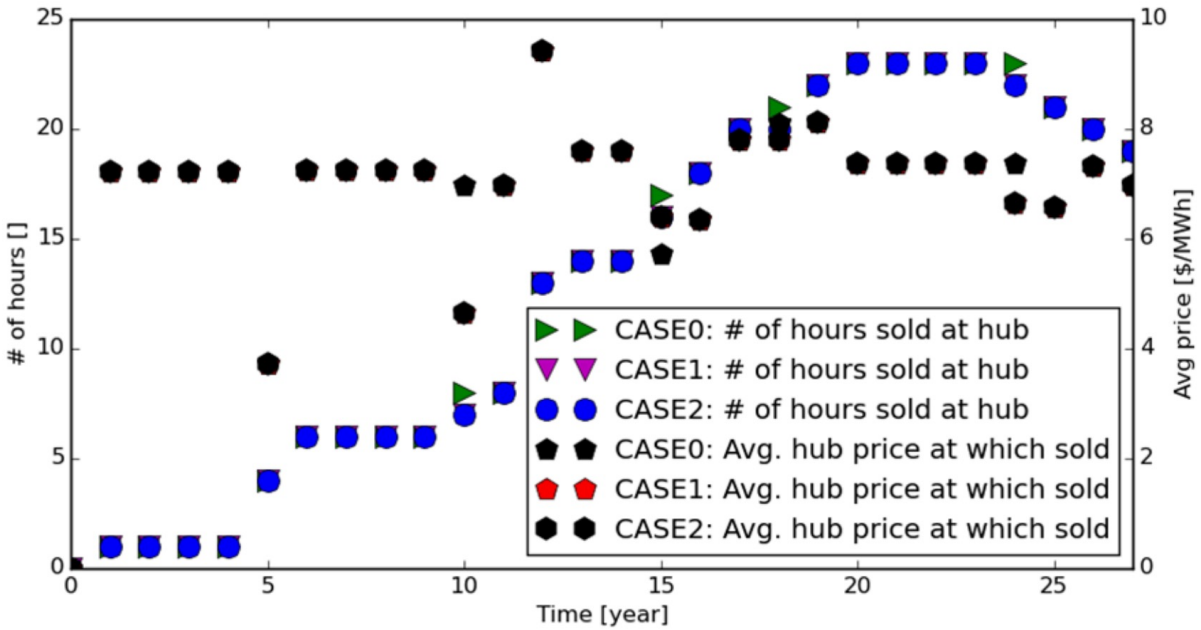
- Results
  - Expected Profitability factors
    - Outlier scenarios
    - Wind penetration
    - Capacity of IES
    - Secondary market pricing

https://www.osti.gov/biblio/1593858-economic-analysis-nuclear-hybrid-energy-system-stochastic-environment-including-wind-turbines-electricity-grid

IES Integrated Energy Systems

2018: Water Desalination in Arizona

- Can water desalination be a profitable IES for the Palo Verde nuclear plant?
  - Partnership with Arizona Public Service (APS)
  - Multiple desalination coupling opportunities
  - Public, Private reports



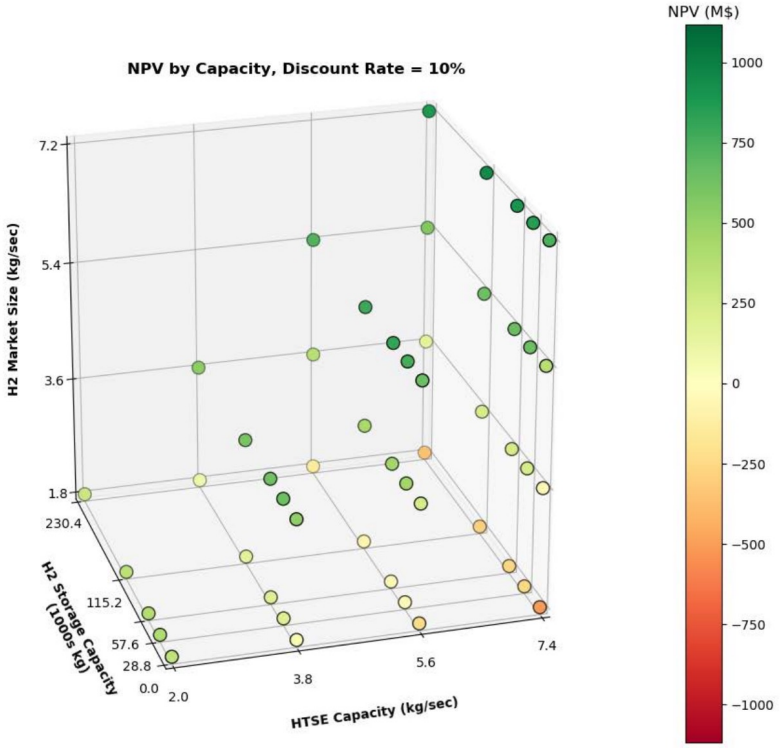
- Results
  - Projected demand growth outpaces VREs
  - Few IES-enabled hours
  - Limited desal IES options
  - Desalination is profitable
    - Flexibility through IES is not

https://www.osti.gov/biblio/1634115-economic-assessment-nuclear-hybrid-energy-systems-nuclear-renewable-water-integration-arizona

IES
Integrated Energy Systems

2019: Hydrogen in Midwest

- How does introducing hydrogen IES for a Midwest reactor impact its economic viability?
  - NREL, Exelon, ANL



- Results
  - Ideally HTSE slightly larger than demand
  - Build small H_2 storage
  - High H_2 price leads to larger HTSE
  - Overbuilding is very expensive
  - All simulations led to profitable IES
    - if sized optimally

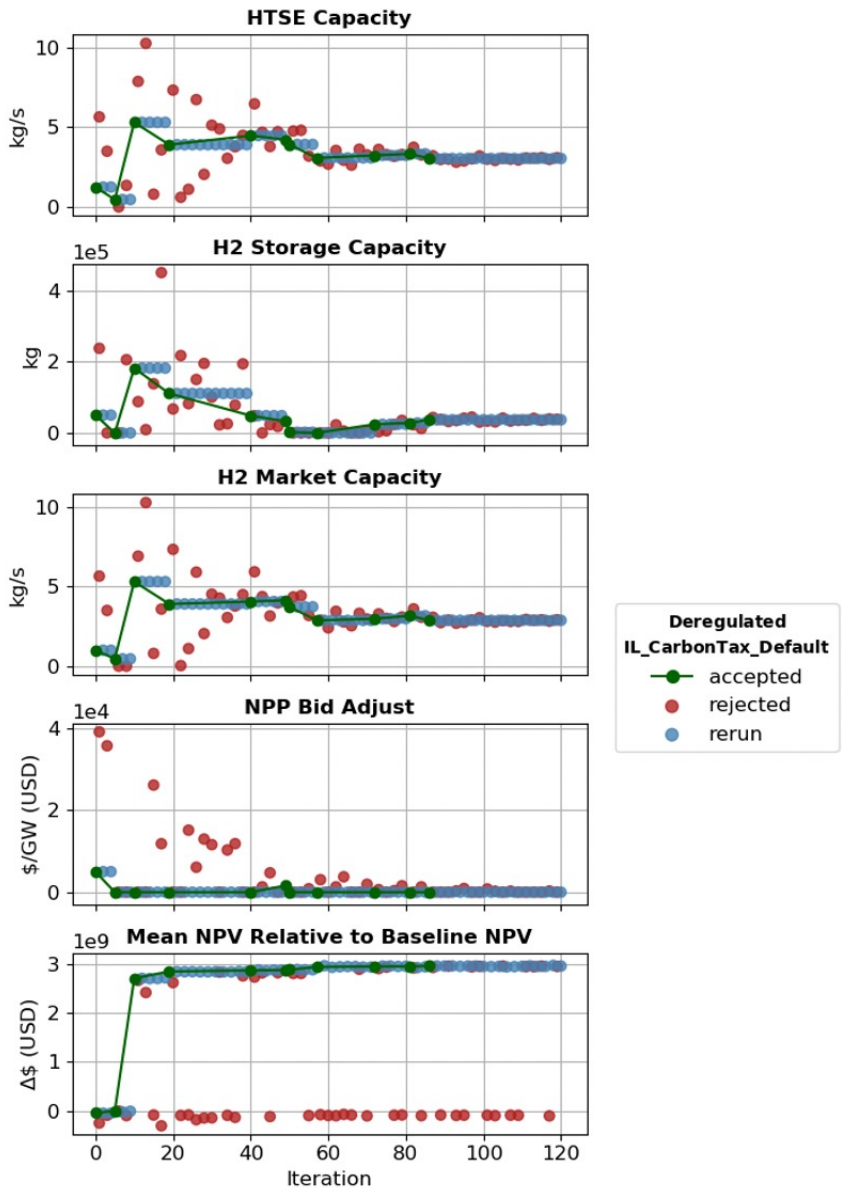
https://www.osti.gov/biblio/1569271-evaluation-hydrogen-production-feasibility-light-water-reactor-midwest

IES Integrated Energy Systems

2020: Hydrogen in Regulated, Deregulated Markets

- How does the impact of introducing hydrogen IES change in regulated versus deregulated markets?
  - Projected futures with EPRI and US-REGEN in Ohio
  - Stochastic Net Demand

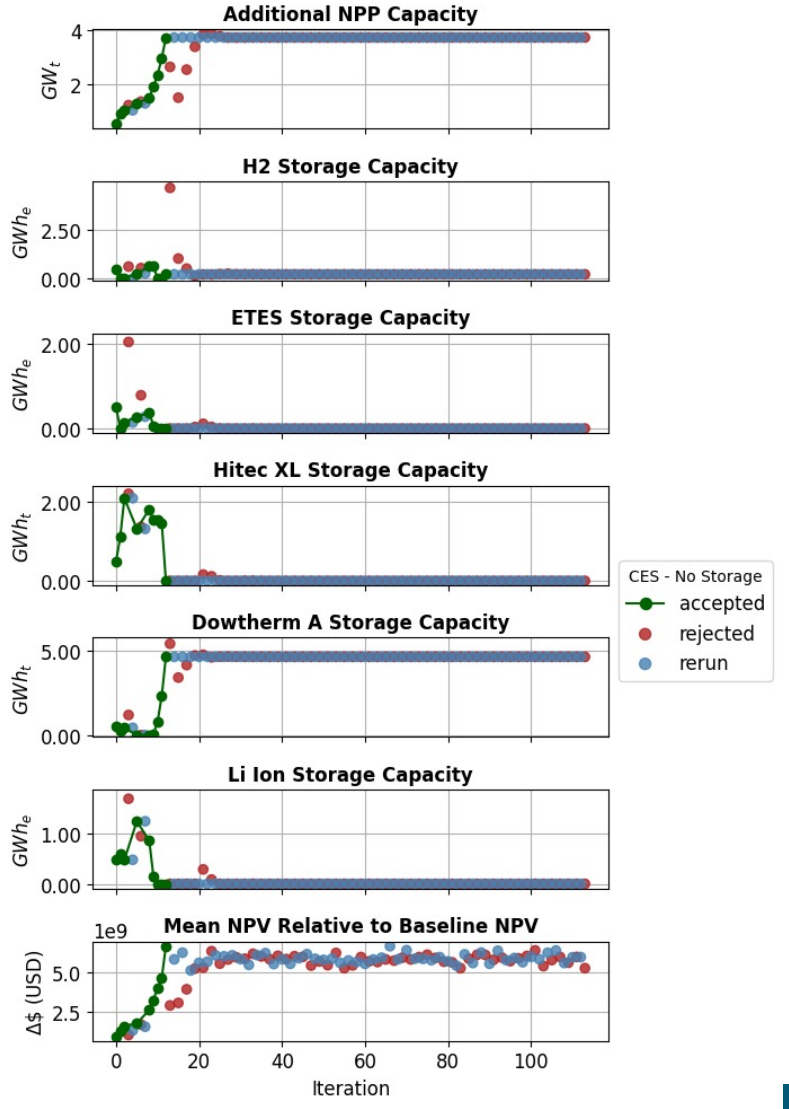
- Results
  - Deregulated markets have higher prices
    - Potential for IES flexibility
    - Volatility + High Prices ideal for IES
  - Carbon Tax pushes toward Nuclear IES
    - Renewable Portfolio Standard less motivating



https://www.osti.gov/biblio/1755894-evaluation-hybrid-fpog-applications-regulated-deregulated-markets-using-heron

2021: Thermal Energy Storage in NYISO

- What benefits can TES offer NYISO in projected scenarios?
  - Projected futures with EPRI and US-REGEN
  - TES Technologies from INL Research
  - No auxiliary commodity markets
  - Stochastic wind, solar, demand
- Results
  - TES best for volatile, high prices
  - Amount of TES matters more than which tech
  - TES capital costs drive inclusion
  - Building TES is binary decision
    - If profitable, build fixed amount
    - Not a sliding scale for construction



Ongoing Efforts

Coming soon to a terminal near you

Usability Improvements

- Interactive Synthetic History Training (Jupyter) *September 2022*
- Value-at-Risk Economic Metric for Optimization *Complete*
- Automated Levelized Cost workflow *September 2022*
- Loading Components from HYBRID *June 2022*
  - And sending dispatch points to HYBRID
- Real-Time Optimization Demonstration *September 2022*

Stay connected: https://github.com/idaholab/HERON

IES
Integrated Energy Systems

2022 TEA Studies

- IES direct studies
  - Thermal Energy Storage — *Konor Frick, konor.frick@inl.gov*
  - Carbon Conversion — *Elizabeth Worsham, elizabeth.worsham@inl.gov*
  - SynFuels Applications — *Konor Frick, konor.frick@inl.gov*
  - FARM Demonstration — *Roberto Ponciroli, rponciroli@anl.gov*

- Externally driven studies
  - APS and Hydrogen — *Andrew Foss, andrew.foss@inl.gov*
  - Exelon-GMI Tri-Lab — *Jason Hansen, jason.hansen@inl.gov*

IES
Integrated Energy Systems

Questions?

- Q&A
  - as time permits

- Upcoming training sessions:
  - HERON: More In-Depth Discussion, Demonstration
  - HYBRID: Process modeling (transient, steady-state, ROM)

IES
Integrated Energy Systems