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Analysis using HERON with Industrial Partners

August 2021

Paul W Talbot, Dylan James McDowell, Binghui Li, Aaron S Epiney, Shannon M Bragg-Sitton, Richard D Boardman, James Richards

Changing the World's Energy Future

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LWRS LIGHT WATER REACTOR SUSTAINABILITY

HERON

Analysis using HERON with Industrial Partners

An Overview

August 2021

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Outline

- Software Introduction
  - FORCE
  - HERON
- Case Studies
  - 2017: Nuclear-Renewable IES
  - 2018: Water Desalination (APS)
  - 2019: Hydrogen in Midwest (Exelon)
  - 2020: Hydrogen in Illinois (EPRI)
- Ongoing Efforts

Energy Grid Modeling at INL

- FORCE (Framework for Optimizing ResourCe Economics)
  - Umbrella term for integrated energy system (IES) model tools at INL
  - Techno-economic analysis tools
  - Grid level (HERON)
  - Interconnections, operation (HYBRID)

- HERON (Holistic Energy Resource Optimization Network)
  - Stochastic technoeconomic analysis
  - Grid-level capacity optimization
  - Expected potential profitability of configurations based on scenario sampling
  - Dispatch optimization

What can you do with HERON?

- Capacity Optimization
  - If hydrogen production and storage is introduced to a system, how large should it be to maximize profit, flexibility, and resilience?
- Stochastic Technoeconomic Analysis
  - What kind of return can be expected by introducing a new configuration and with what certainty?

What can you do with HERON?

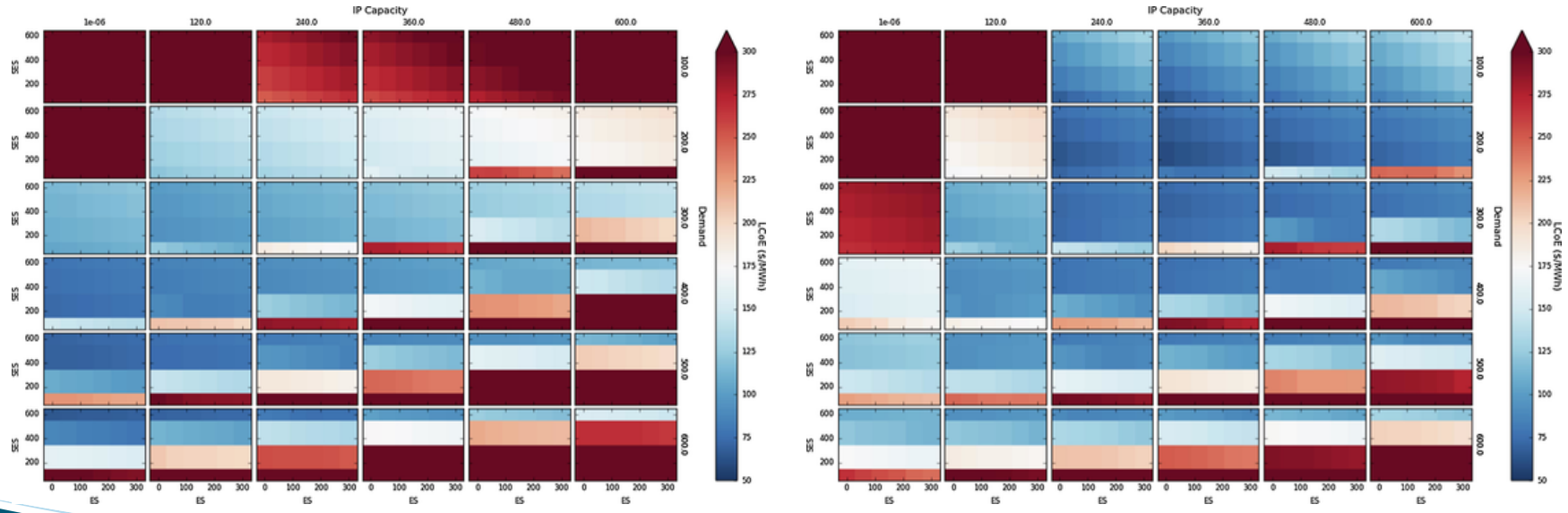
- Dispatch Optimization
  - How should flexible technologies and storage be dispatched to optimize performance and profit?
- Inputs
  - Economics: CAPEX, OPEX, discount rates, inflation
  - Stochastic histories: load and pricing data
  - Physics: Plant behavior, ramp rates
- Outputs
  - Optimal expected NPV, confidence

Case Studies

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

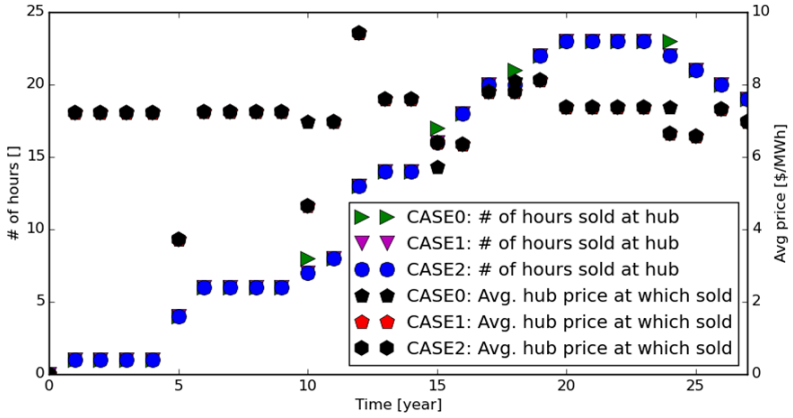
2017 Integrated Energy System

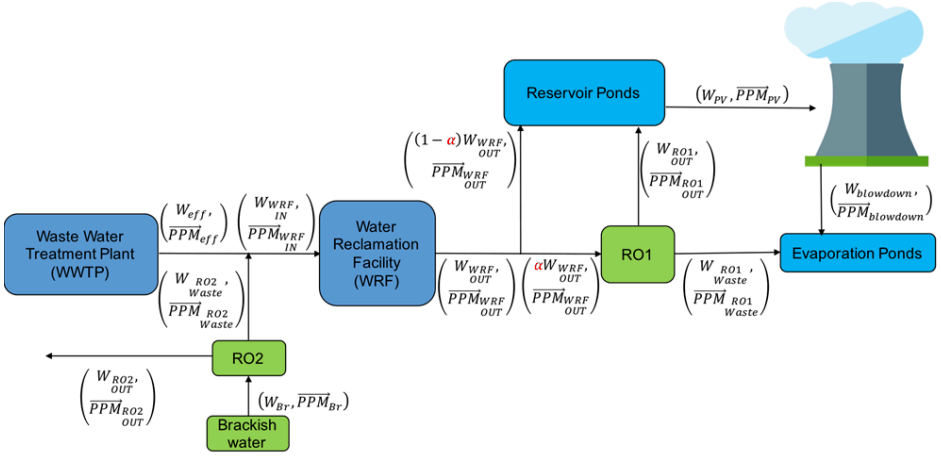
- Can coupling a secondary industrial process (IP) increase economic viability?
  - Increasing solar and wind installation
  - Parametrize IP, wind, electrical storage, and projected demand
  - Conclusion: viable cases exist for secondary industrial processes
    - High commodity prices, high wind energy penetration, and low demand



2018 Desalination IES (APS)

- Can water desalination be an economic IES for Palo Verde?
  - Increasing wind and solar installation in Arizona and California
  - Projected price volatility at Palo Verde hub
  - Various desalination configurations
  - Conclusion: Desalination improves water acquisition, not chiefly helpful to offset variable energy production





2019 Midwest IES (Exelon)

- Can hydrogen production be a viable IES in the Midwest?
  - High temperature steam electrolysis (HTSE), hydrogen storage
  - Parametric sweep over possible configurations and sizes
    - Conclusions:
      - Profitable IES configurations exist
      - Hydrogen market, discount rate drivers

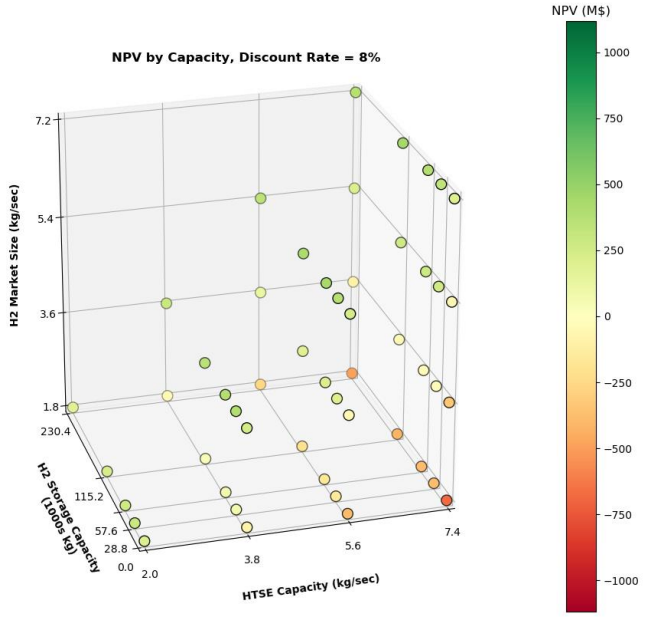
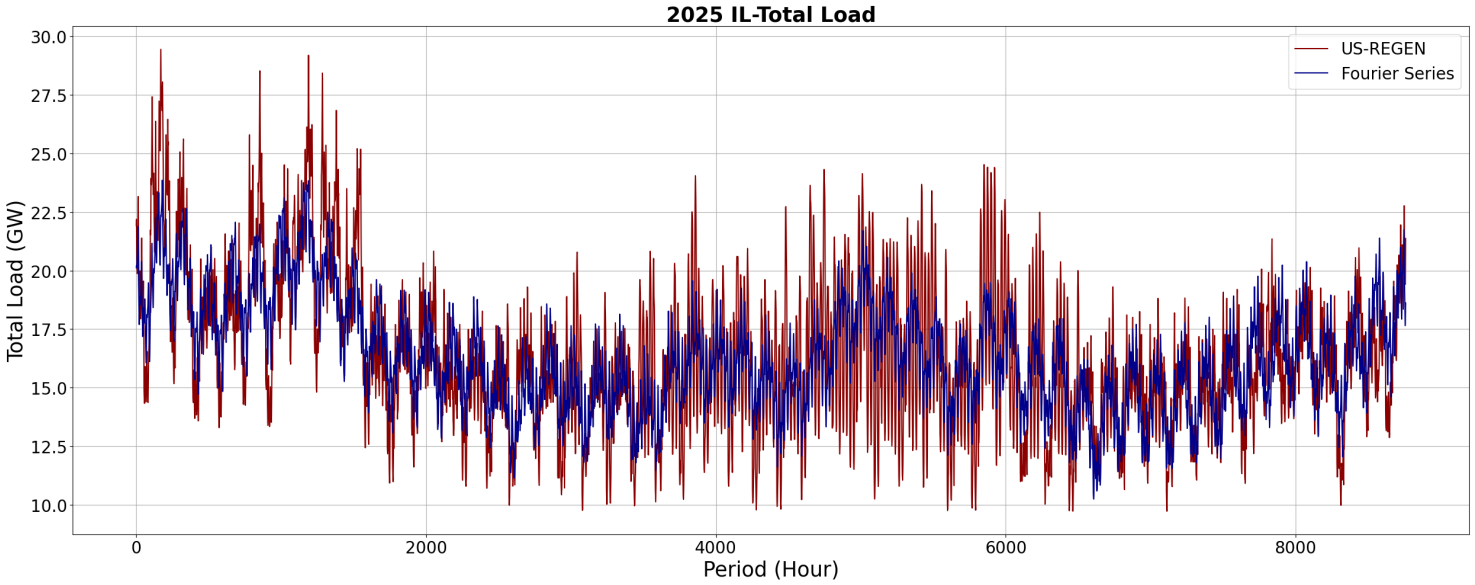


Table 21. Maximum ΔNPV for each combination of hydrogen market prices and discount rates over a seventeen-year span.

Hydrogen Market Price	*Discount Rate [%]*	*HTSE size [kg/s]*	*Hydrogen Market Size [kg/s]*	*Storage Size [kg]*	*ΔNPV (2019$)*	*Deviation (2019$)*
Low	12	2.0	1.8	28800	9.83E+07	1.72E+06
Low	10	2.0	1.8	28800	1.41E+08	1.72E+06
Low	8	3.8	3.6	28800	2.13E+08	1.12E+06
Med	12	3.8	3.6	28800	2.09E+08	1.86E+06
Med	10	5.6	5.4	57600	3.07E+08	3.83E+06
Med	8	7.4	7.2	115200	4.39E+08	1.97E+06
High	12	7.4	7.2	115200	7.42E+08	1.17E+06
High	10	7.4	7.2	115200	9.45E+08	1.76E+06
High	8	7.4	7.2	115200	1.19E+09	2.04E+06

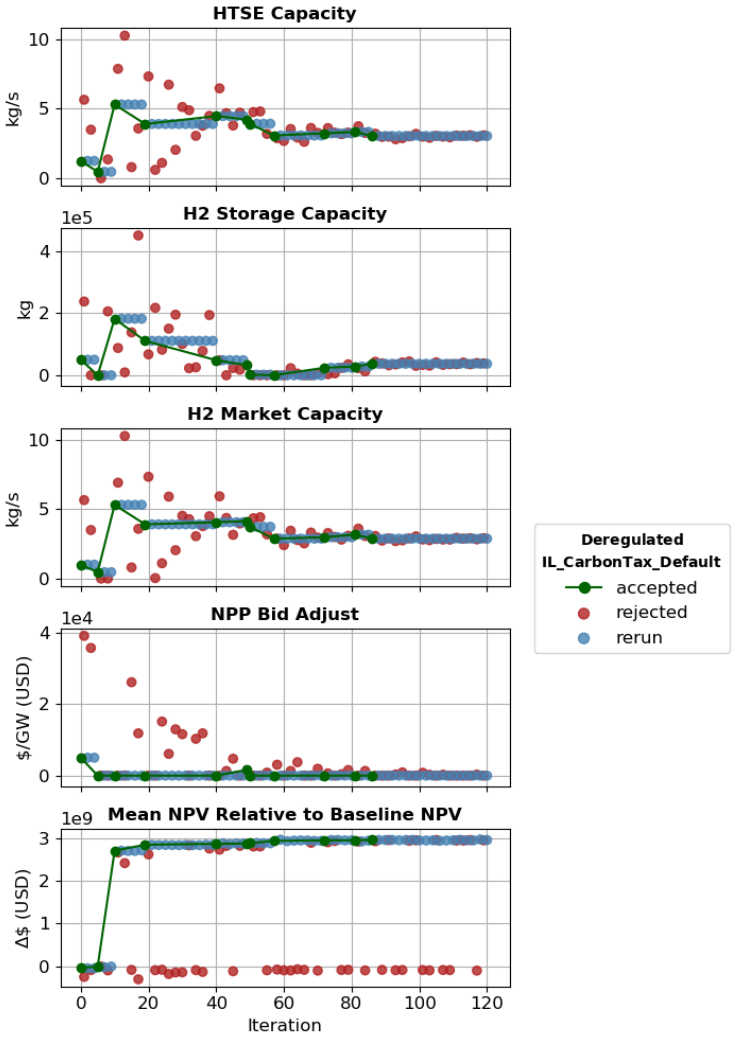
2020 Regulated, Deregulated Markets (EPRI)

- How does IES profitability compare in different markets?
  - Various scenario projections (carbon tax and renewable penetration strategies)
  - Optimize size of IES components in given markets
  - Study focus on Illinois (increasing wind generation and existing nuclear)



2020 Regulated, Deregulated Markets (EPRI)

- How does IES profitability compare in different markets?
  - Conclusions:
    - Optimal IES exists for various markets, scenarios
    - More IES opportunities in deregulated markets with less favorable nuclear conditions, more volatility



Ongoing Work

- Improved thermal energy storage handling
  - AI-control, perfect foresight, or buy-sell breakpoints
- Graphical user interface
- Tighter integration with process models
- Many ongoing research agreement partnerships
  - Throughout academia, industry
  - Utilities owning existing nuclear plants
  - New technology vendors for advanced nuclear

References and Cases

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