IES

Integrated Energy Systems

Framework for Optimization of ResourCes and Economics (FORCE) Overview

Integrated Energy Systems (IES) Tools:

Capability Overview and Training

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Technical & Economic Assessments (TEA)

Resource Potential

- Market size
- Resource availability
- Resource attributes
- Infrastructure requirements

Technology Potential

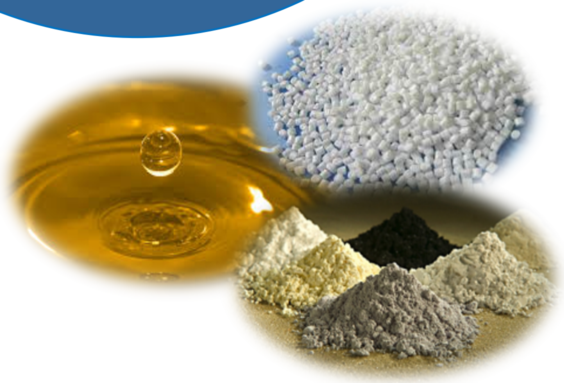
- Thermodynamics
- Performance
- Systems integration and control

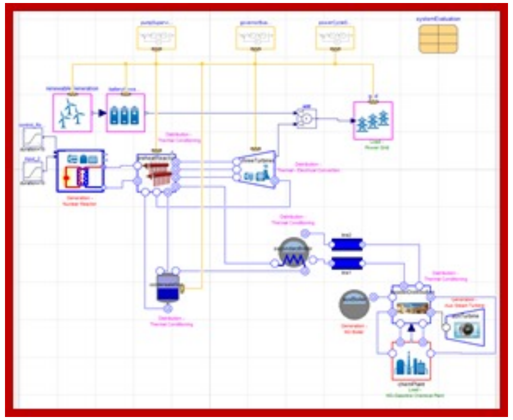
Economic Potential

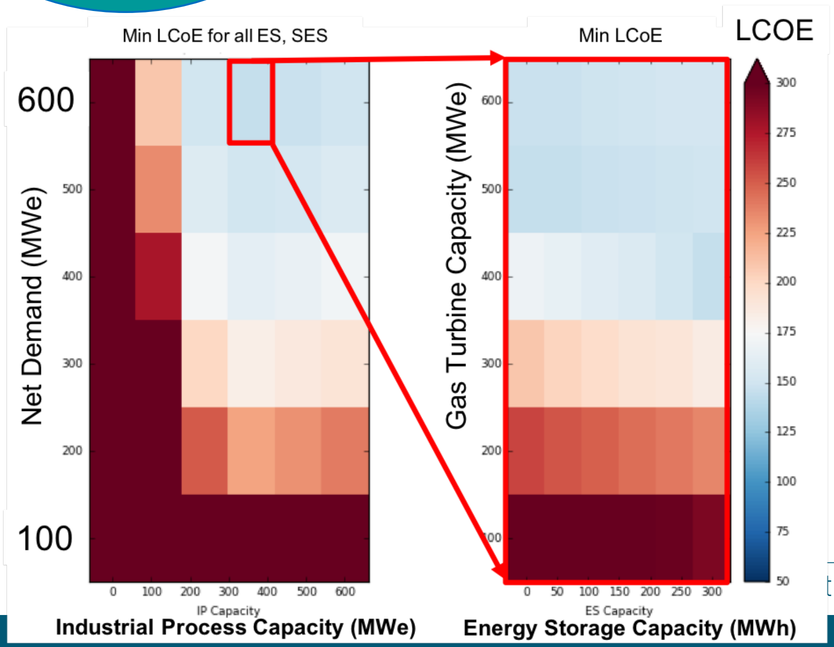
- Pro forma
- ROI / IRR
- Cash Flow

Market Potential

- Competition
- Policy, Regs







Planning energy resources

- Capacity Expansion Models (CEMs)
  - Used to model evolution of system of electricity generation assets
  - Considers change in demand, retirements and completion of construction projects to determine if additional capacity is needed in future years
    - If so, determines lowest cost capacity additions to meet projected demand (including reserves), with consideration of construction lead time
  - Some models include other parts of the economy to determine demand

- Production Cost Models (PCMs)
  - Models the current year in much greater detail
  - Predicts which existing facilities will operate when to meet demand
    - Selection based primarily on lowest short-run operating costs
    - Constrained by physical limitations of grid, dispatchability, start-up time, ramp rates, etc.
  - Outputs include electricity costs, plant revenues, reserve margins, etc.

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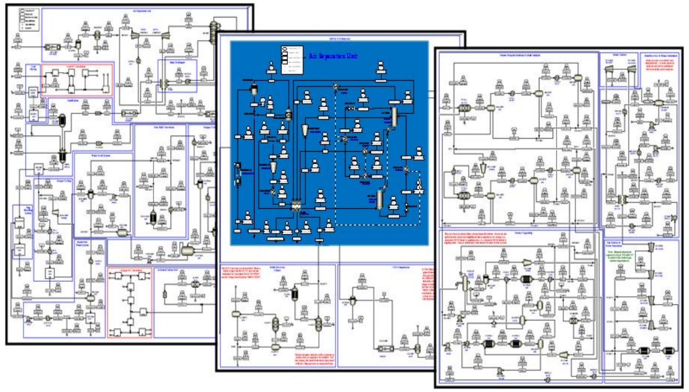
Energy system modeling, analysis, and evaluation for energy system optimization

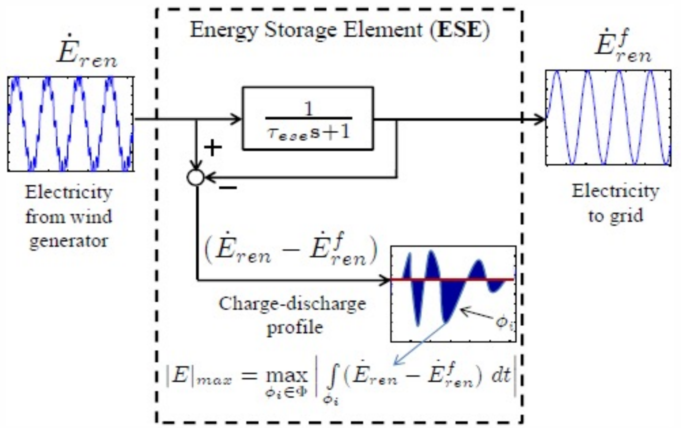
Graded approach to identify design, and evaluate hybrid system architectures

Aspen Plus® and HYSYS® Process Models



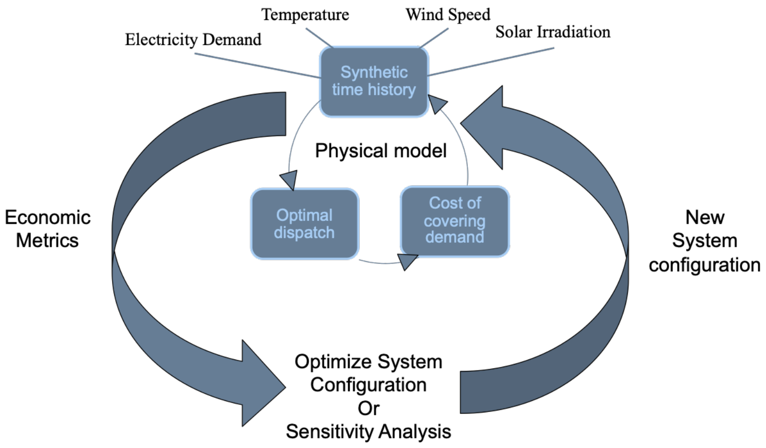
Process modeling addresses technical and economic value proposition

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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FORCE

- Framework for Optimization of ResourCes and Economics
  - Analysis of interconnected energy-related resources
    - Steam, electricity, hydrogen, water desalination, synthetic fuels, etc.
    - Coupling and control of IES
    - Carbon reduction of the existing energy grid via optimization of energy flows
  - Techno-economic analysis of integrated energy systems
    - What is the potential economic benefit of introducing technologies to a system?
    - Greenfield or existing systems
    - Dynamic analysis of interconnected subsystems
    - Unit sizing, dispatch optimization
    - Alternative market opportunities for existing generators

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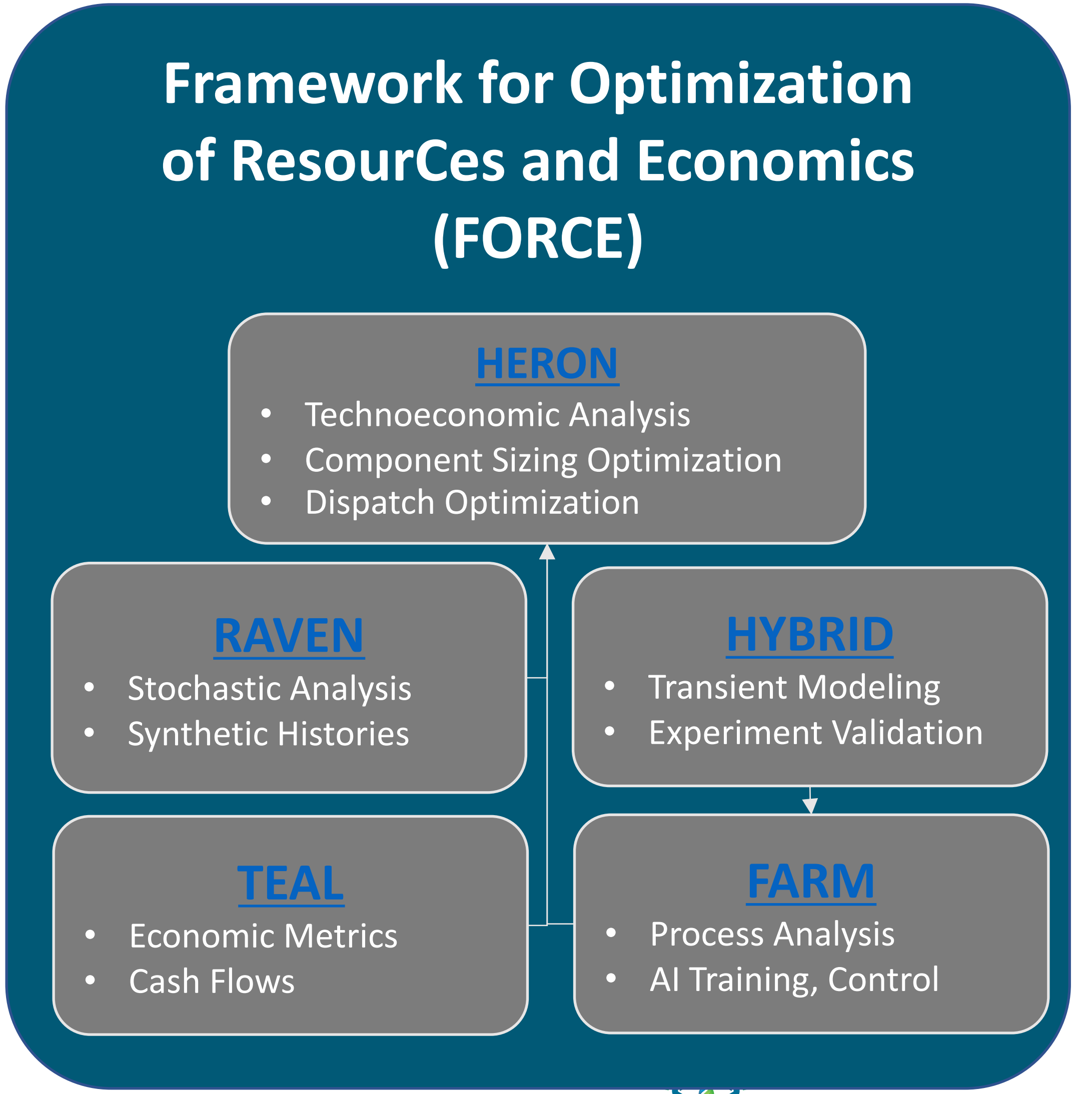
Suite of IES modeling, analysis, and optimization tools

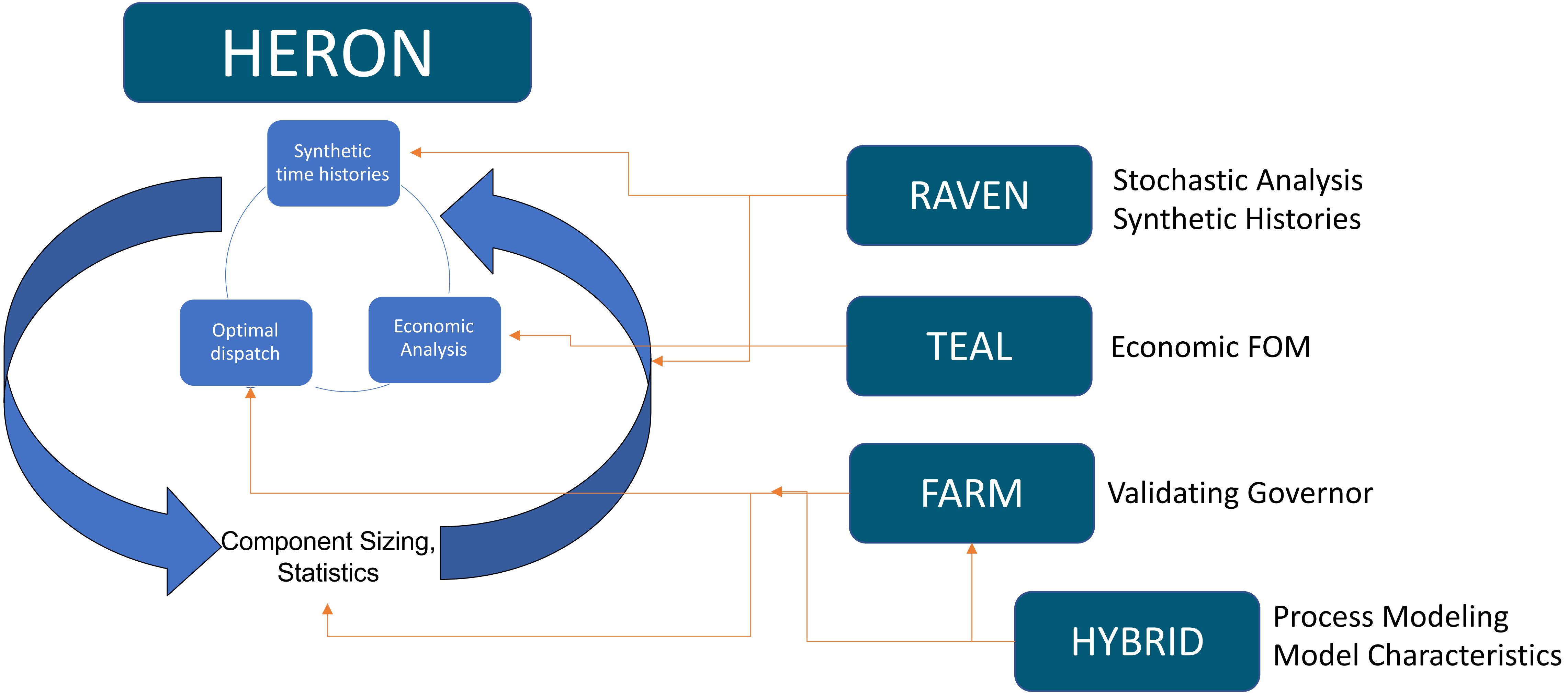
Tools for technoeconomic assessment of IES configurations with workflow automation

- **FORCE**
  - Integrate physical plant modeling with technoeconomic optimization
- **HERON**: Holistic Energy Resource Optimization Network
  - Dispatch flexible systems and optimize technoeconomic analysis
- **RAVEN**: Risk Analysis Virtual ENvironment
  - Integrate physical input uncertainties and probabilistic time series data
- **HYBRID**: High fidelity, dynamic model repository
  - Simulation of physical plant processes
- **TEAL**: Tool for Economic AnaLysis
  - Integrate economic input uncertainties and calculate financial metrics
- **FARM**: Feasible Actuator Range Modifier
  - Supervisory control

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



Process model coupling



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IES change the paradigm for energy generation and use, so we are breaking new ground in energy system planning and analysis

- Many other efforts exist to optimize energy systems, specifically for the grid
- What makes the IES approach different
  - Nuclear has different requirements that must be considered
    - Nuclear Quality Assurance (NQA 1)
    - Safety, licensing
    - Reactor operation
  - Full probabilistic approach is unique
  - Detailed system dynamics are included
  - Cross-sectoral energy system options are embraced
- Leveraging existing and ongoing efforts and toolsets to further enhance analysis and system optimization capability

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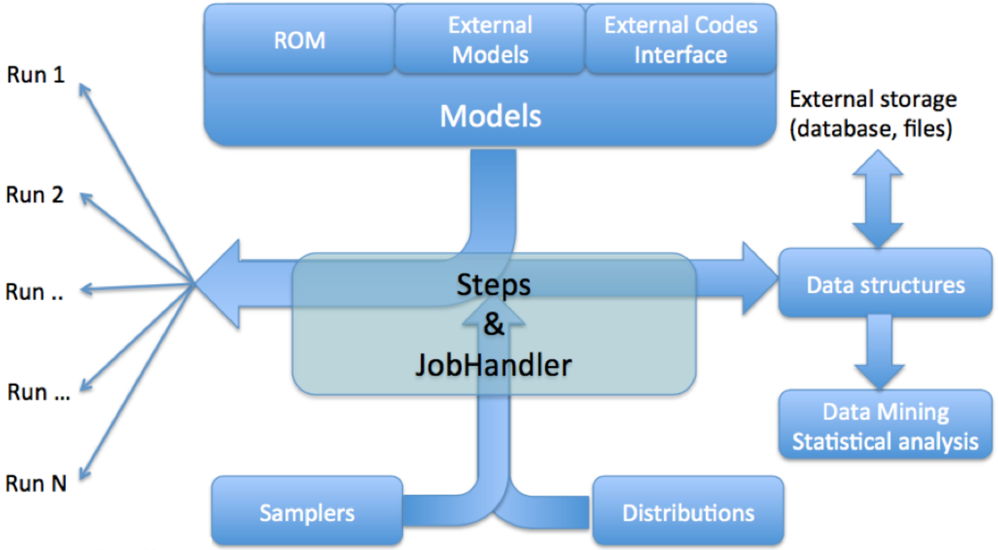
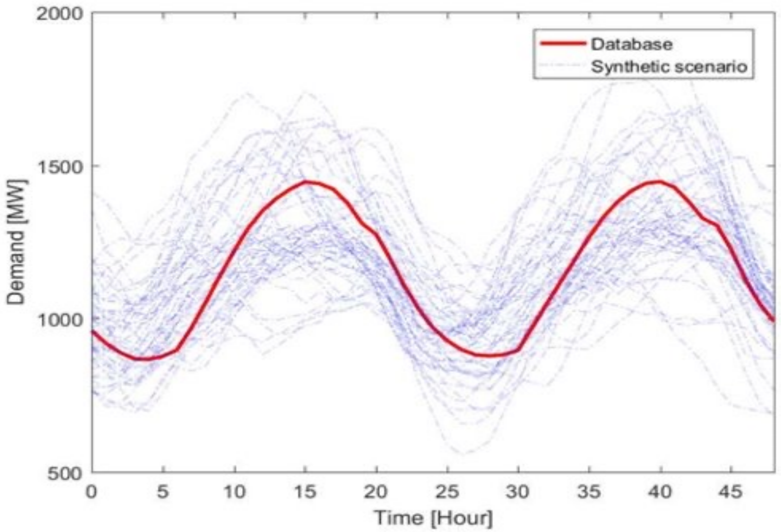
Machine learning, optimization

- Synthetic time series
  - Energy demand, load
  - Market pricing
  - Wind, solar availability
- Multilevel optimization
  - Conjugate gradient
  - Simultaneous perturbation stochastic Approximation
- Stochastic analysis
  - Metric quantification
- Machine learning and AI
  - Surrogate training
  - Validation
  - Serialization





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