



# Ducks on Water: Lessons Learned from New England's System Operational Analysis and Renewable Energy Integration Studies

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<http://liines.net>

Invited Presentation  
IEA-ETSAP Workshop  
Helsinki, Finland  
November 24, 2025

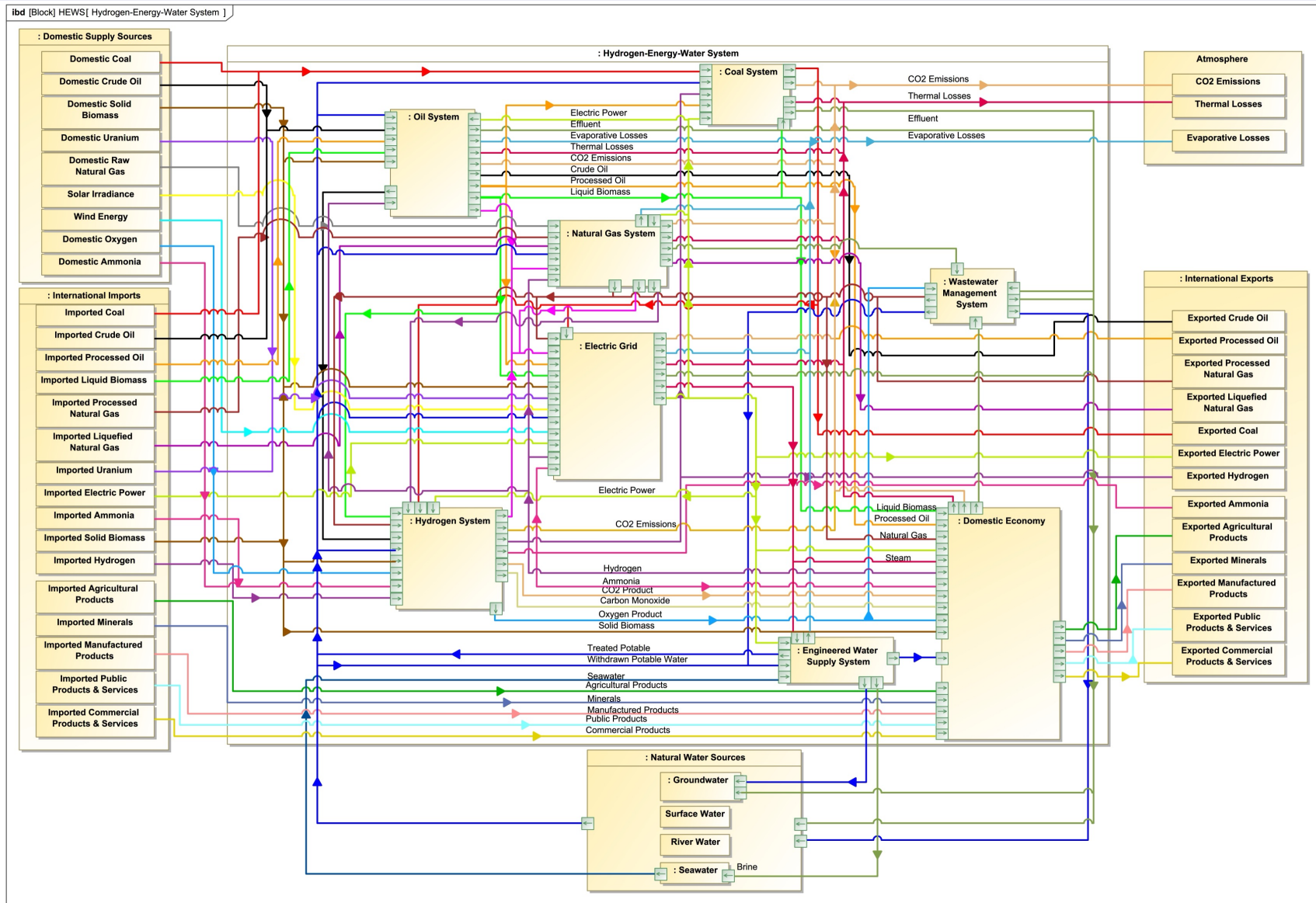


# Presentation Abstract

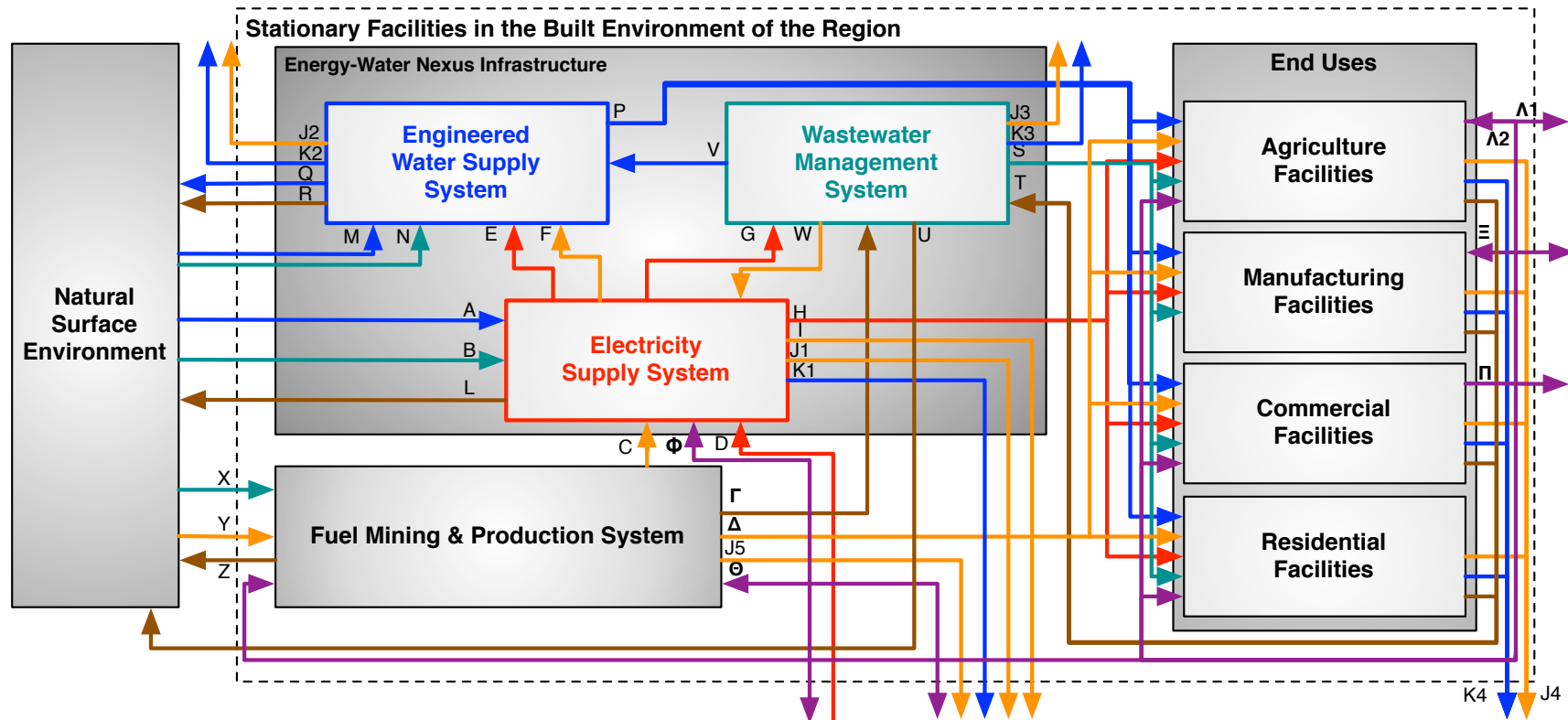
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The introduction of variable energy resources (VERs), like solar and wind, necessitates fundamental changes in the power grid's dynamic operation. This evolution is caused by several drivers including decarbonization, growing electricity demand, the deregulation of electricity markets, active end-user participation, and digital innovations in energy technologies. Furthermore, VER forecasts are uncertain and their profiles are intermittent; thus requiring greater quantities of operating reserves. In such a case, fast-ramping natural gas and hydro-electric power plants take on a prominent grid balancing role. At even higher levels of solar PV and wind generation, grid flexibility saturates and VER curtailment becomes the only remaining option for reliable grid balancing. To avoid this undesirable future, demand-side resources become a necessary path for energy system development. These resources are not just energy artifacts, but also exist within other engineering systems. Consequently, their integration gives rise to new multi-disciplinary challenges such as the energy-water nexus. This presentation seeks to share lessons learned from two system operational analysis and renewable energy integration studies conducted in cooperation with ISO New England. In the first, VER resources are increased in the coming decade to reveal a future of grid saturation and VER curtailment. The follow-on New England Energy-Water Nexus Study shows that coordinated energy-water resources can create a triple bottom-line synergy worth \$70M/yr. The presentation concludes that a decarbonization agenda must evolve from power grid studies with electricity as a single energy carrier to multi-energy engineering systems studies that specifically coordinate multiple energy carriers through many layers of coordinated planning and operations management decisions.

# Hydrogen-Energy-Water Reference Architecture



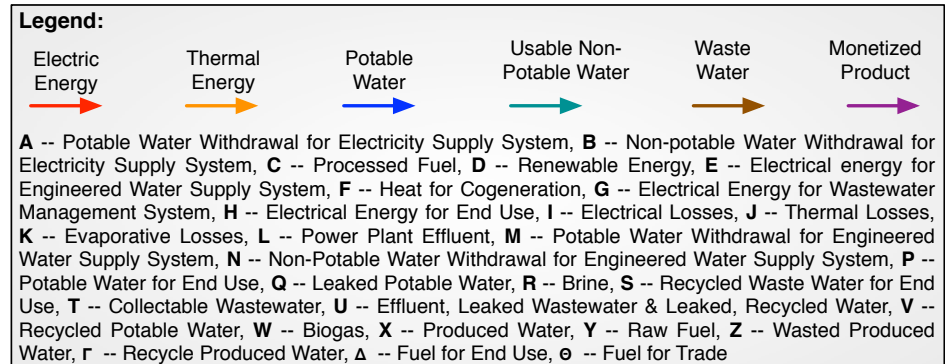
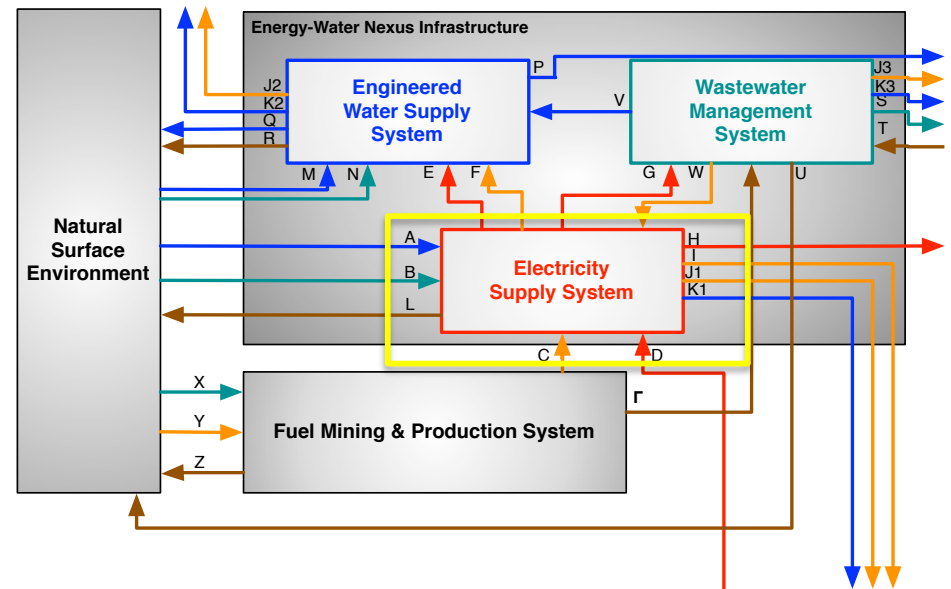
# Why Integrated Infrastructure Systems Engineering? A Motivational Abu Dhabi Example



“In the early 2010’s, the UAE was embarking on a new macro-economic industrial and energy policy. After oil prices fell from \$147 to \$33/barrel during the Great Recession of 2008, the UAE sought to diversify its petrol economy towards energy-intensive industries such as steel, aluminum, tourism, and transportation. ... [Farid] knew that the UAE needed to tie its economic aspirations to integrated infrastructure systems planning and redouble its commitment to the aqueous environment.

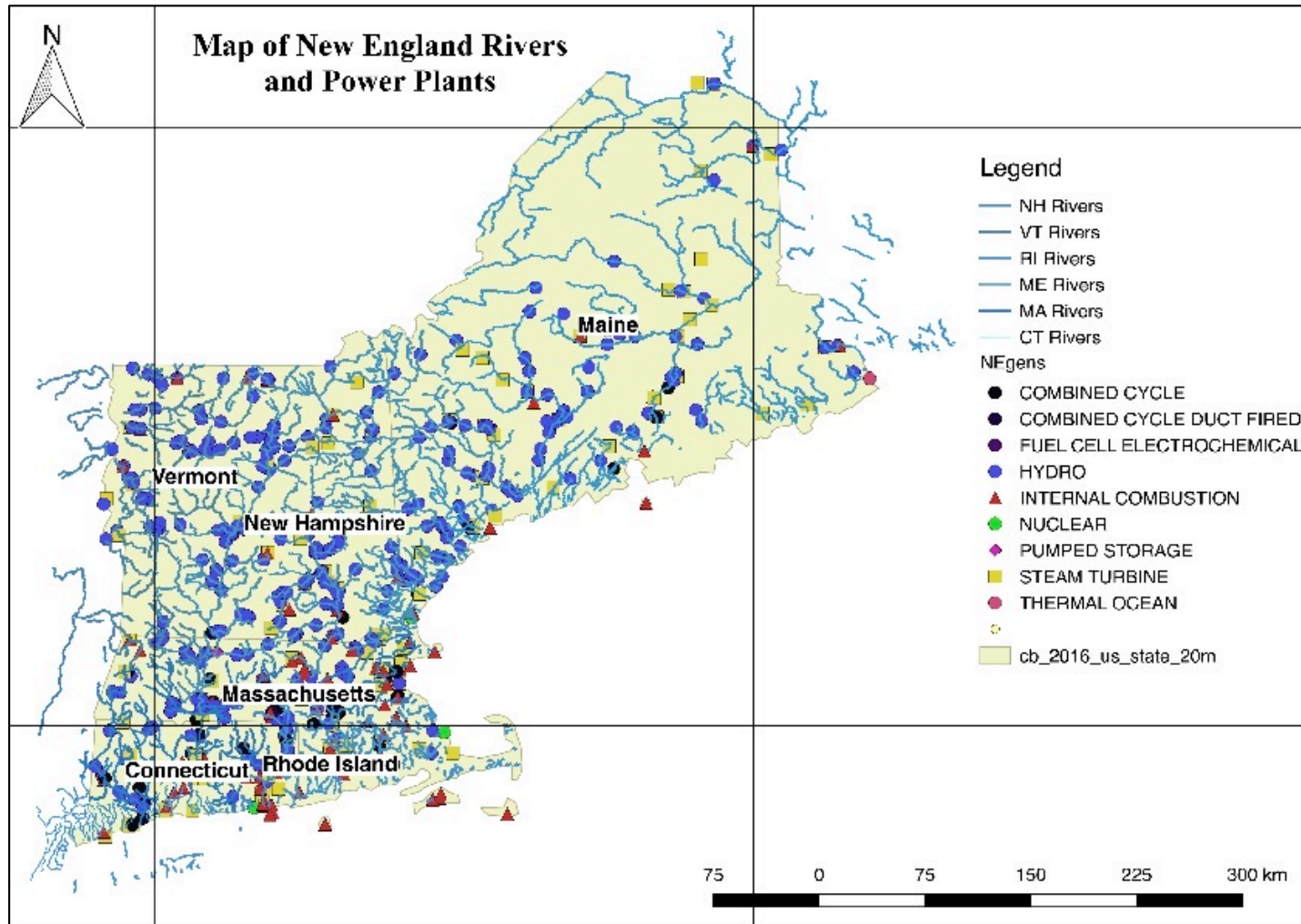
# System-Level View of the Energy-Water Nexus

- Important to capture all the physical flows between the three physical infrastructures & the natural surface environment
- In the ISO-NE model, each water utility fits inside a “bubble” → full hydraulic modeling does not provide additional insight.
- Sufficient to capture all interfaces w/ electric supply system and impose aggregate energy constraints



*EPECS will be enhanced to provide values for these flows.*

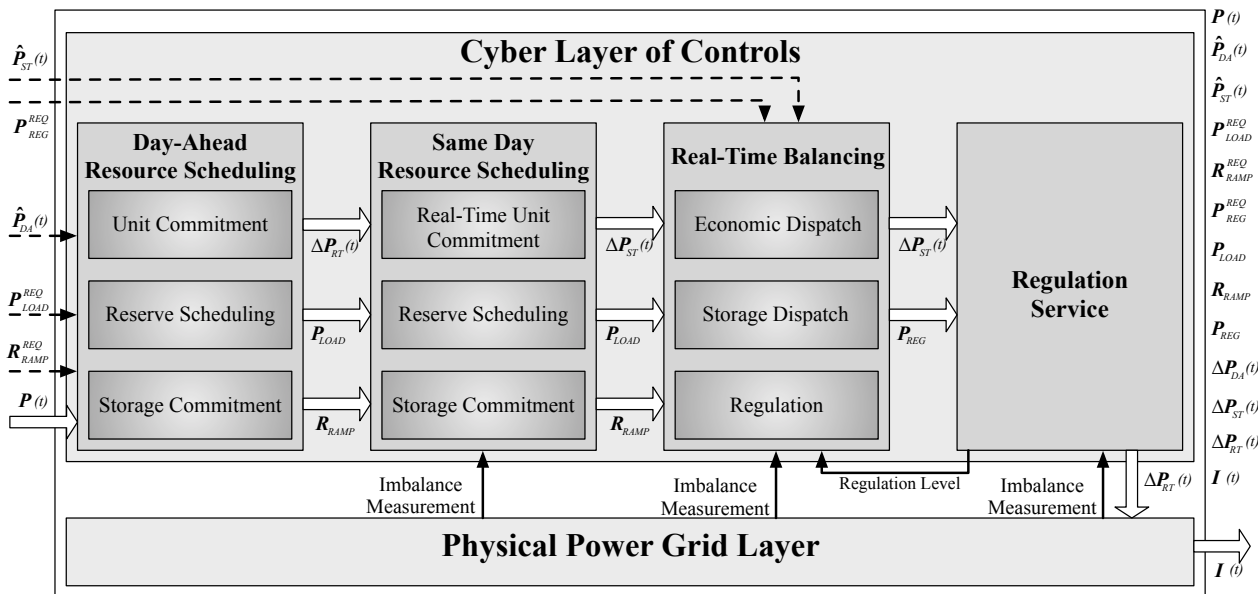
# New England Power Plants and Rivers



Most power plants are located near a water source. This indicates the strong coupling between the water supply and energy supply systems.



# Electric Power Enterprise Control System Simulation (EPECS)



**ENGINEERING  
SYSTEMS  
ANALYTICS**

Engineering Systems Analytics LLC has licensed the EPECS Software to ISO New England as the default tool for their stakeholder-driven planning processes.

# Flexible Water-Energy Resources Scenarios

	2040-RPS+NG	2040 High VRE	2040 High VRE Plus	2040 Conventional	2040-5 High NG	2040-6 High VRE Geo
Hydro Run-of-River & Pond	1854MW (6.21%)	1788MW (5.99%)	1646MW (7.10%)	1782MW (5.97%)	1798MW (5.99%)	1784MW (5.97%)
Pumped Storage	1758MW (6.15%)	1758MW (6.15%)	1758MW (6.15%)	1758MW (6.15%)	1758MW (6.15%)	1758MW (6.15%)
Water Load	565MW (1.89%)	565MW (1.89%)	565MW (2.44%)	565MW (1.89%)	565MW (1.89%)	565MW (1.89%)
System Peak Load	28594 MW	28594 MW	22103MW	28594MW	28594 MW	28594 MW

- Flexible water resources have load shedding (rather than shifting) capability
- Run-of-river & pond-hydro is curtailable at \$4.5/MWh (as in ISO-NE study)
- Demand side resources are incentivized at \$50/MWh (as in ISO-NE study)
- Flexible water resources are assumed to contribute to operating reserves.
- 709.7GWh of pumped storage is treated as dispatchable throughout the study.

**We extended the energy mix to 2040 and used the EPECS to measure the effects of dispatchable vs non-dispatchable water-energy resources.**

# Balanced Sustainability Scorecard

**Table 15:** The range of **improvements** caused by coordinated flexible operation of the energy-water nexus.

<b>Balancing Performance</b>	
Average Load Following Reserves	1.24–12.66%
Average Ramping Reserves	5.28–18.35%
Percent Time Curtailed	2.67–10.90%
Percent Time Exhausted Regulation Reserves	0%
Std. Dev. of Imbalances	3.874–6.484%
<b>Environmental Performance</b>	
Total Water Withdrawals	0.65–25.58%
Total Water Consumption	1.03–5.30%
Total CO <sub>2</sub> Emissions	2.10–3.46%
<b>Economic Performance</b>	
Total Day-Ahead Energy Market Production Cost	29.30–68.09M\$
Total Real-Time Energy Market Production Cost	19.58–70.83M\$



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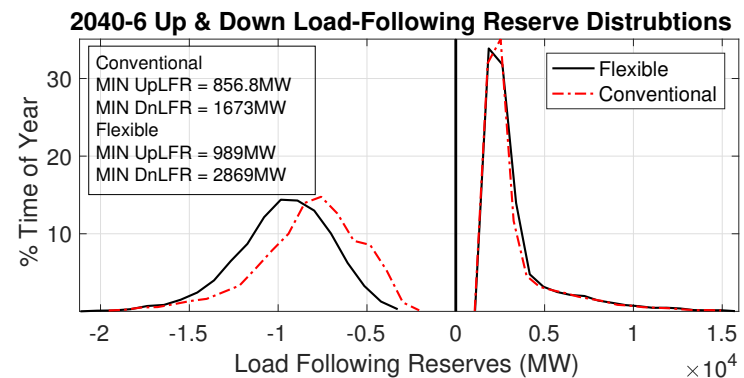
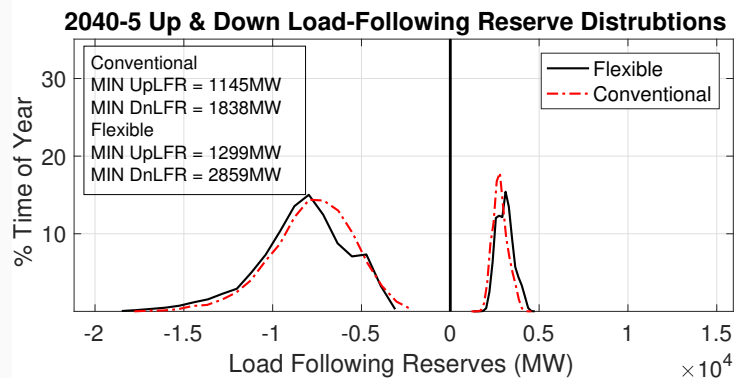
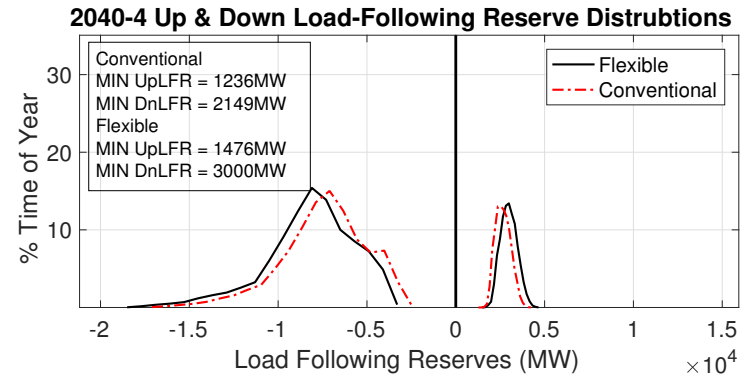
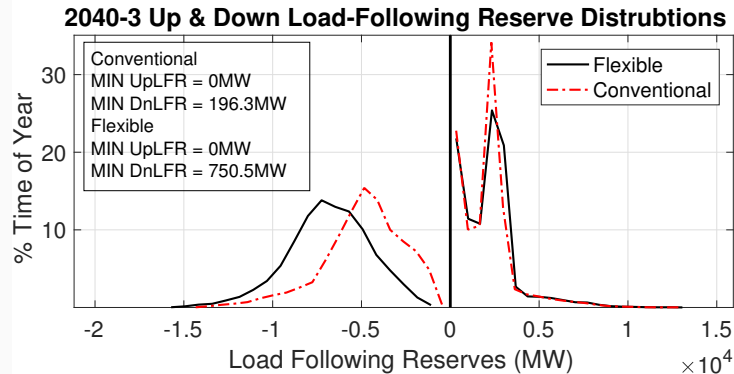
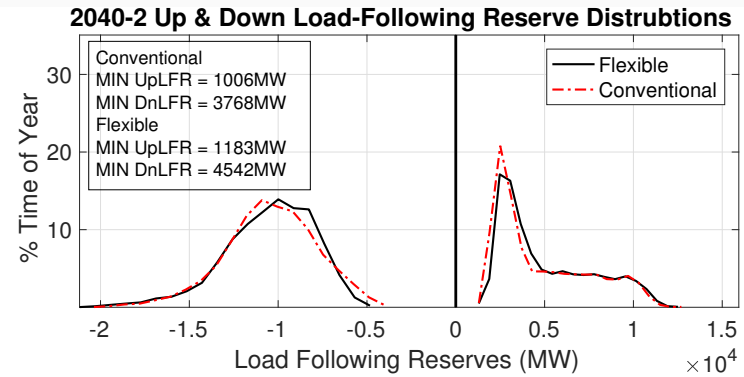
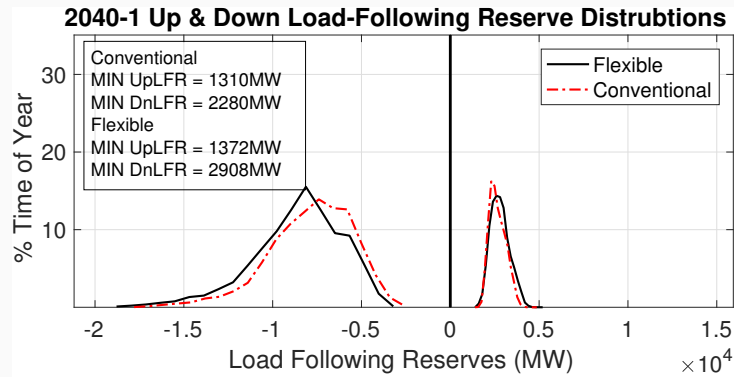


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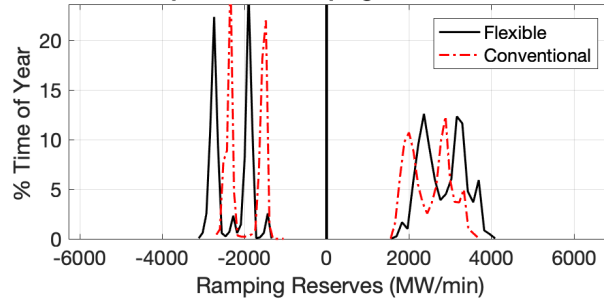


# Load Following Reserves: Flexible vs Conventional 2040



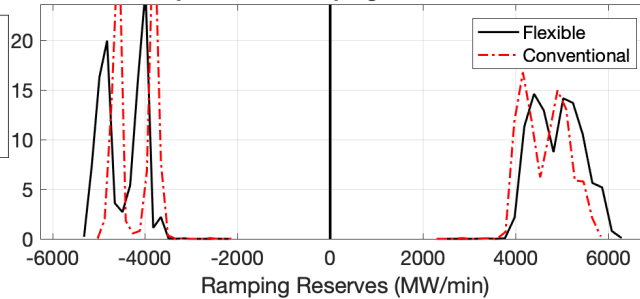
# Ramping Reserves: Flexible vs Conventional 2040

2040-1 Up & Down Ramping Reserve Distributions



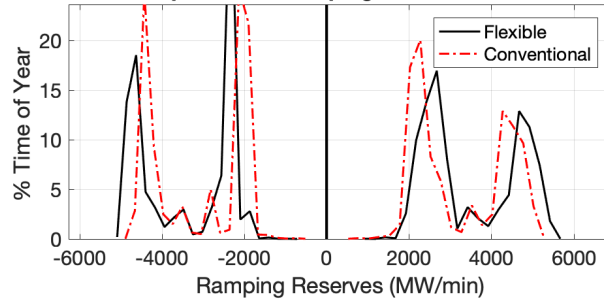
Conventional  
 MIN +RampR = 1583MW/min  
 MIN -RampR = 1013MW/min  
 Flexible  
 MIN +RampR = 1524MW/min  
 MIN -RampR = 1307MW/min

2040-2 Up & Down Ramping Reserve Distributions



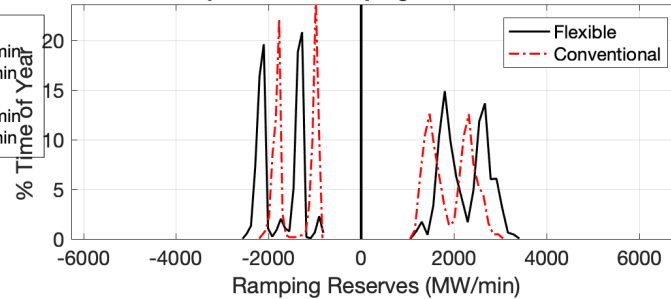
Conventional  
 MIN +RampR = 2203MW/min  
 MIN -RampR = 2067MW/min  
 Flexible  
 MIN +RampR = 2273MW/min  
 MIN -RampR = 2089MW/min

2040-3 Up & Down Ramping Reserve Distributions



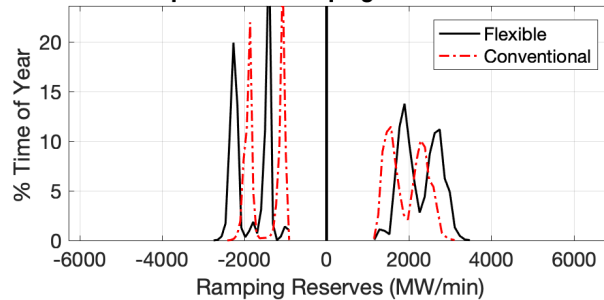
Conventional  
 MIN +RampR = 457.1MW/min  
 MIN -RampR = 431.2MW/min  
 Flexible  
 MIN +RampR = 867.6MW/min  
 MIN -RampR = 630.9MW/min

2040-4 Up & Down Ramping Reserve Distributions



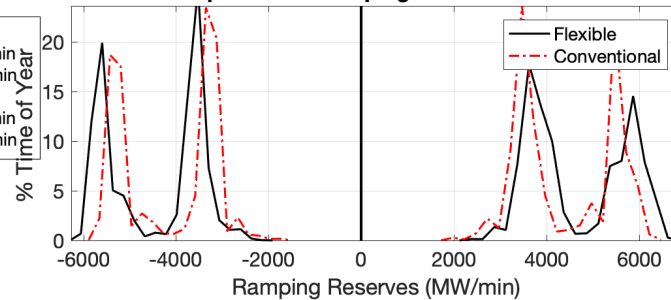
Conventional  
 MIN +RampR = 1099MW/min  
 MIN -RampR = 803.3MW/min  
 Flexible  
 MIN +RampR = 1095MW/min  
 MIN -RampR = 788.2MW/min

2040-5 Up & Down Ramping Reserve Distributions



Conventional  
 MIN +RampR = 1147MW/min  
 MIN -RampR = 882.3MW/min  
 Flexible  
 MIN +RampR = 1141MW/min  
 MIN -RampR = 875.6MW/min

2040-6 Up & Down Ramping Reserve Distributions



Conventional  
 MIN +RampR = 1700MW/min  
 MIN -RampR = 1594MW/min  
 Flexible  
 MIN +RampR = 2005MW/min  
 MIN -RampR = 1888MW/min

# Water Withdrawals: Conventional vs Flexible 2040

