Hybrid Participation Model Study

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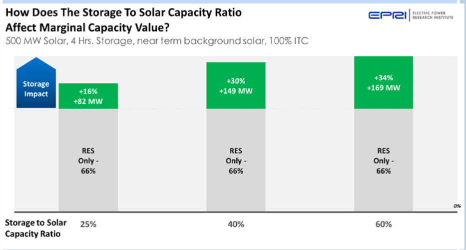
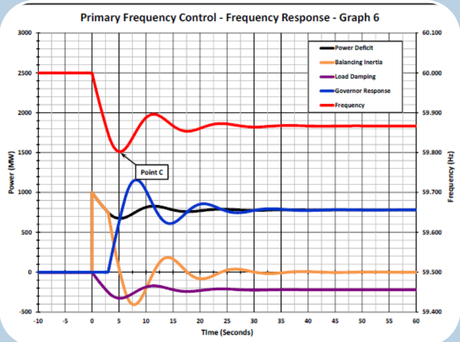
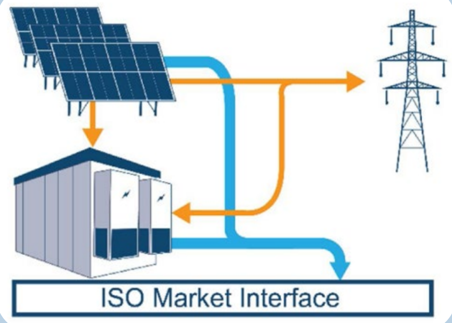
EPRI Benefits Study - Overview







Production Cost Modeling Simulation

- Assess Costs and reliability for energy and operating reserve

Capacity value assessment

- Approximation using critical time period assumptions from simulations

Voltage control, frequency control, black start

- Qualitative discussion on capabilities

Recommendations

- Participation Model Enhancements to consider

EPRI Participation Model Assessment - Overview

- **Purpose**: To quantify the incremental change to energy market costs and/or reliability by moving from IESO foundational models to the proposed enduring models
  - Standalone storage, co-located hybrid, integrated hybrid
- **Process**: The study will use an advanced production cost model to simulate overall IESO energy + Operating Reserve (OR) operation costs using the Power System Optimizer (PSO) software and a zonal representation of the IESO system
- **Results**: Simulated difference in overall energy market production costs between foundational models and enhanced models across a full simulation year
  - Reliability and price/profit comparisons will be conducted as well
  - Focus on metric comparison across cases and not on single simulation numbers
- **Outcome**: Study results will be compared to enhanced participation model implementation cost estimates to develop a criteria for when to implement enhanced models

EPRI Production Cost Model - Data Sources

- 2021 Annual Planning Outlook
- 2022 Annual Acquisition Report
- IESO Resource Tally
- Historical market data published on the IESO’s webpage
- Enelytix Eastern Interconnection Dataset

Aim for realistic future scenario with available data

Modeling Caveats

- Production cost models are inherently limited in their ability to perfectly capture practical conditions
  - Human behaviors which cannot be easily captured (e.g., bidding strategies)
  - Limit to the number of constraints while remaining computationally tractable (multiple annual runs vs. daily Day-Ahead SCUC)
- Future conditions (solar, wind, load, etc.) cannot be perfectly anticipated
  - Potential changes to generation portfolio, operation strategy, network configuration, etc. happening before target year (late 2020s)
- Unable to model the contractual impacts of different resources to the overall settlement of the IESO markets

EPRI Production Cost Model - Key Assumptions (Inputs)

- Annual demand forecast, supply mix, re-contracting of existing resources, Pickering Nuclear Generating Station retirement, key interface transfer limits - all consistent with 2021 Annual Planning Outlook system assumptions
- Generic offer data for different fuel types
  - Heat rate, ramp rate, minimum generation, etc.
- 2000 MW effective capacity of new hybrid + standalone storage resources
- Hybrids modelled with foundational models and proposed enhanced models
  - Co-located and integrated
- Standalone storage modelled with interim storage model and enduring storage design
- Bid-offer curves for standalone storage and hybrids as developed by EPRI and Lawrence Berkeley National Laboratory (LBNL)
  - Participation models that do not include state-of-charge management require emulated bids from market participants

Study Scenario 1 - High Hybrid Intake

Hybrid New Builds Modelling:

- 750 MW effective capacity East zone new build solar hybrids (500 MW storage, 750 MW solar)
- 500 MW effective capacity East zone new build wind hybrids (435 MW storage, 500 MW wind)
- 750 MW of Southwest + West zone new build storage paired with existing wind

Scenario	Participation Model Used	Co-located:Integrated Ratio
1A	Foundational Hybrid Models	50:50
1B	Foundational Hybrid Models	100:0 (all co-located)
1C	Foundational Hybrid Models	0:100 (all integrated)
1D	Enhanced Hybrid Models	50:50
1E	Enhanced Hybrid Models	100:0 (all co-located)
1F	Enhanced Hybrid Models	0:100 (all integrated)

Assumptions regarding the location, size and connection arrangement of hybrid and storage facilities are for study purposes only, without prior knowledge of where and how these facilities will be located. They are not intended as a guide or endorsement.

Study Scenario 2 - Medium Hybrid + Medium Standalone Storage Intake

Hybrid + Standalone Storage New Builds Modelling:

- 375 MW effective capacity East zone new build solar hybrids (250 MW storage, 375 MW solar)
- 250 MW effective capacity East zone new build wind hybrids (220 MW storage, 250 MW wind)
- 375 MW of Southwest + West zone new build storage paired with existing wind
- 650 MW of East zone new build standalone storage
- 350 MW of Southwest + West zone new build standalone storage

Scenario	Participation Model Used	Co-located:Integrated Ratio
2A	Foundational Hybrid Models + Interim Storage Model	50:50
2B	Foundational Hybrid Models + Interim Storage Model	100:0 (all co-located)
2C	Foundational Hybrid Models + Interim Storage Model	0:100 (all integrated)
2D	Enhanced Hybrid Models + Enduring Storage Model	50:50
2E	Enhanced Hybrid Models + Enduring Storage Model	100:0 (all co-located)
2F	Enhanced Hybrid Models + Enduring Storage Model	0:100 (all integrated)

Assumptions regarding the location, size and connection arrangement of hybrid and storage facilities are for study purposes only, without prior knowledge of where and how these facilities will be located. They are not intended as a guide or endorsement.

Study Scenario 3 - Standalone Storage Intake Only (No Hybrid Case)

Standalone Storage New Builds Modelling:

- 1300 MW of East zone new build standalone storage
- 350 MW of Southwest zone new build standalone storage
- 350 MW of West zone new build standalone storage

Scenario	Participation Model Used
3A	Interim Storage Model
3B	Enduring Storage Model

Assumptions regarding the location, size and connection arrangement of hybrid and storage facilities are for study purposes only, without prior knowledge of where and how these facilities will be located. They are not intended as a guide or endorsement.

Sensitivity Studies

- Evaluate additional scenarios that may provide useful insights
- Options prioritized with IESO project team
- Learn from existing runs what sensitivities are most valuable

Scenario	Sensitivity
4A	Greater/less than four hour batteries
4B	Storage/renewable ratios
4C	Real-time adjustment
4D	Operating Reserve Scenarios

Siting Hybrid Resources

Hybrid energy storage systems in N. American ISO Interconnection Queues in 2021

- Some RTOs/ISOs have reported whether the energy storage systems are standalone or hybridized with solar, wind, or other technologies.
- Hybrid projects in the interconnection queue total over 133 GW in North America.*
- Almost all hybrid resources include wind or solar on below

	Indication of Hybrid?	No. of Projects	Capacity at Point of Interconnection (Net MW)
CAISO	Yes	267	76,011
ERCOT	Yes	89	12,112
ISO-NE	Yes	91	2,352
MISO	Yes	77	14,263
NYISO	Yes	10	2,349
PJM	Yes	333	21,853
SPP	Yes	21	4,493
Total Identified Hybrid Systems		867	133,430

*Most data from end of 2021

Interconnection Queue Source

Why go Hybrid?

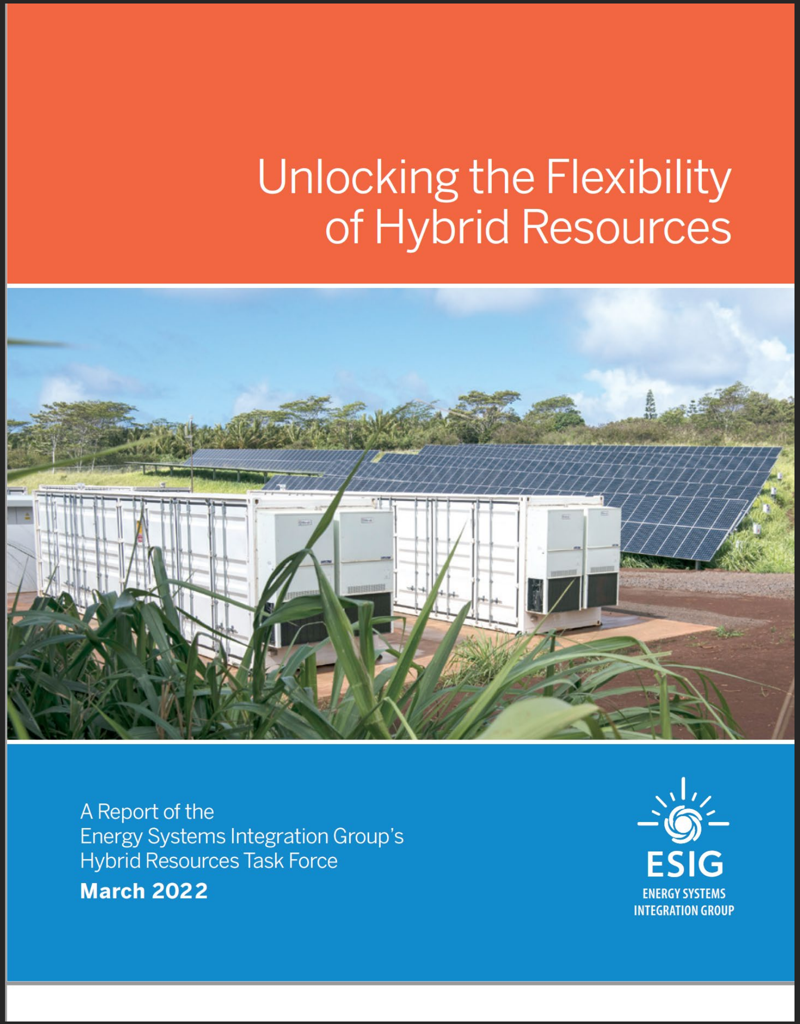


TABLE 1
Key Drivers for Resource Hybridization

Rank	Key Driver	Description
1	Tax incentives (investment tax credit)	If storage resources are charged predominantly from on-site renewable resources, they are eligible to receive the U.S. federal investment tax credit.
2	Avoided transmission and distribution upgrades	A shared point of interconnection for multiple resource types can minimize the need for interconnection upgrades while maximizing available energy and grid services that can be provided at the point of interconnection.
3	Avoided curtailment	The curtailment of wind or solar resources can be reduced through combination with battery storage or on-site load flexibility. Wind or solar energy generated during periods of surplus renewable energy can be used to charge batteries, and energy provision shifted to periods of system need.
4	Reduced development costs	Shared costs for engineering, land, interconnection, and equipment for multiple resources can reduce overall costs.
5	Reduced financing costs	Combining multiple resources can reduce long-term risk and thus lower the cost of debt financing.
6	Captured DC clipping losses	Clipping losses—which occur when solar plants are designed with a high inverter loading ratio to increase production but lead to some curtailment—can be captured if battery storage is DC-coupled to the solar resource.
7	Market design rules that limit the participation of solar or wind alone	Stand-alone wind and solar resources may not qualify for certain market products, but could with the addition of storage.
8	Simplified procurement for utility off-takers	A single power purchase agreement of bundled energy, storage, and grid services may simplify the procurement process for utility buyers.
9	Hybrids' flexibility	The addition of battery storage to generation resources serves as a hedge against future market conditions and volatility, as alternative control schemes and storage can change operations based on system conditions.
10	Land constraints	Combining multiple resources at a single location can reduce the land needed for renewable projects.

This ranking of key drivers for resource hybridization was generated by the members of the Energy Systems Integration Group's Hybrid Resources Task Force.

Source: Energy Systems Integration Group.

Several drivers for hybridizing

Energy Systems Integration Group, Unlocking the Flexibility of Hybrid Resources, March 2022. Available: https://www.esig.energy/wp-content/uploads/2022/03/ESIG-Hybrid-Resources-report-2022.pdf.

Criteria for Hybrid Resource Siting

Timing

Revenue Potential

Transmission Availability and Utilization

Reliability Support

Longevity

A good site is one that can be built quick, earn maximum revenue, can be delivered to where it is needed, support reliability, and will last

Criteria for Resource Siting

- Can the battery be added to the site quickly?
- Is there interconnection capacity that can support it?
- How often is the connection capacity free? Existing resources with low capacity factors allow for more capacity usability.
- How long does the existing contract last for?
- Will the life of the existing facility last past existing contracts?

Strategic assessments can point to valuable locations

Reliability Support

- Smoothing out local generation can reduce regulation burden
- Accommodating scheduling error from forecast error of local generation can ensure balance and reduce imbalance penalties
- Increase resource adequacy using existing sites
- Avoid transmission overload and improve stability
- Provide operating reserve and other ancillary services

Hybrid facilities have opportunity to simultaneously improve reliability and reduce costs

Revenue Potential Assessment

- Single schedule, LMP-based pricing, can provide greater value to specific locations across the network
- Battery siting in existing locations with volatile LMP can earn additional arbitrage revenue
- Capacity Value dependent on location (trans. and dist. Sited)
- Siting at locations that have existing renewable curtailment can lead to curtailment reduction and free charging
- Siting at locations with high locational volatility infers congestion mitigation and potential reliability benefit

With knowledge on locational price volatility, preferable siting can be estimated

Locational Value Assessments

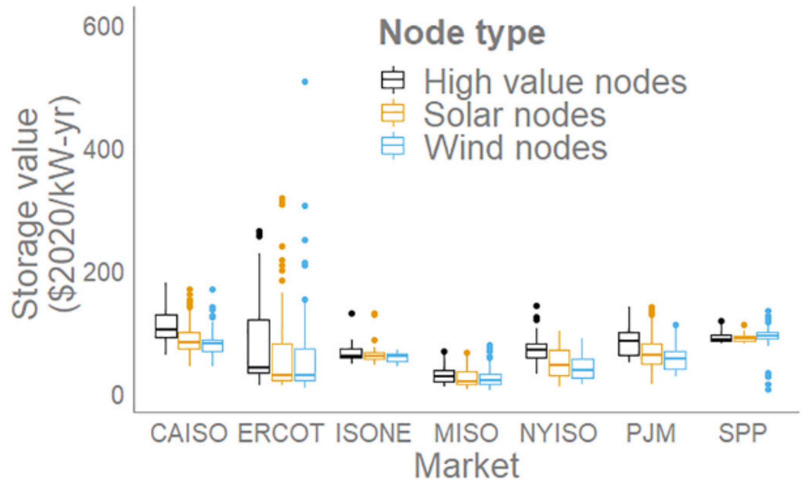
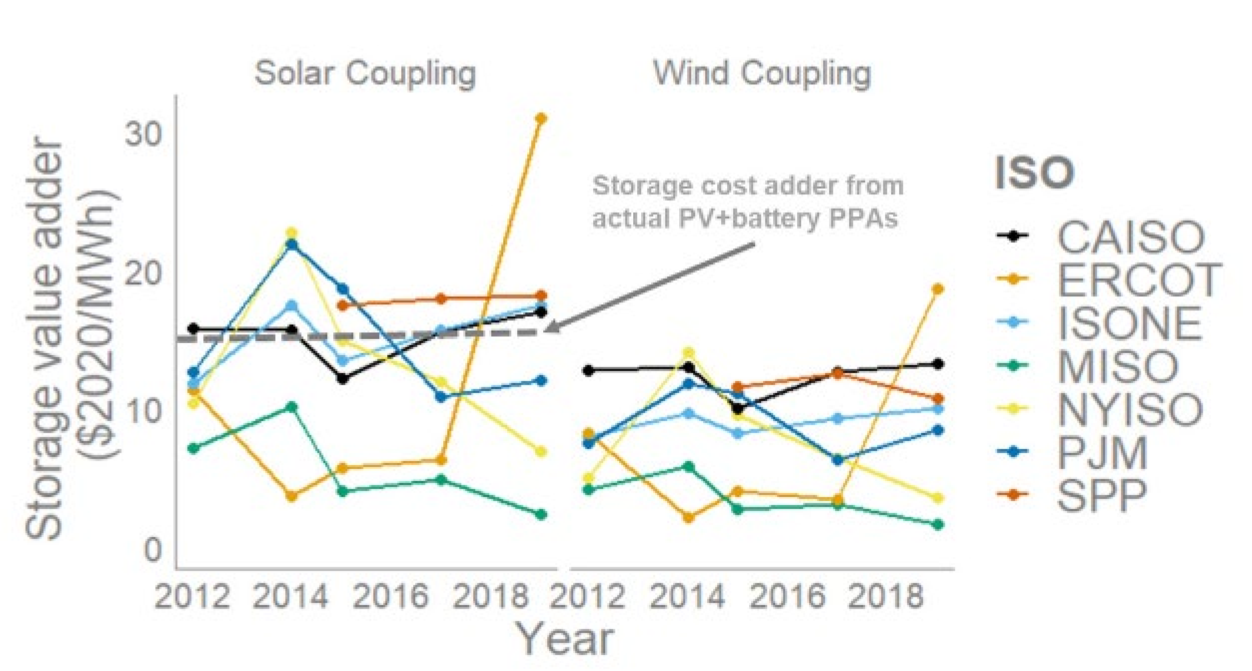


Fig. 4. Annual standalone storage value across different node types and by market for all years between 2012 and 2019. Deviation of storage value across node types produces the largest coupling penalties.



Assessments for hybrid and independent siting of battery in U.S. RTO Markets – Approach can be used for valuable sites within Ontario.

Gorman, W. 2021. "Are Coupled Renewable-Battery Power Plants More Valuable Than Independently Sited Installations?" *Energy Economics*. Vol. 107, March 2022.

Price volatility is a key driver of adding battery to existing facilities

Capacity Value of Hybrid Resources

- Interconnection limit, local generation availability, storage duration, and anticipated portfolio all affect capacity value
- Inverter loading ratio with dc coupling (e.g., solar hybrids) can have capacity value improvements
- Transmission (and distribution) availability to load centers will improve capacity value

TABLE 4

Two Options for Hybrid Resource ELCC Calculations

OPTION A	OPTION B
Individual Resource Accreditation	**Aggregate Resource Accreditation**
Is a sum of ELCC individual hybrid resources, capped at the point of interconnection	Evaluates the hybrid plant ELCC at the aggregate plant level as a unique resource
Advantages	
• Is simple to implement and understand • Does not require unique modeling for all hybrid configurations	• Evaluates the specific characteristics of the hybrid plant • Considers charging constraints • Considers benefits of higher inverter loading ratios and DC coupling
Disadvantages	
• Does not account for portfolio effects at the plant level • Does not consider charging constraints • Does not consider benefits of higher inverter load ratios and DC coupling	• Requires individual analysis of each hybrid resource on the system • Is computationally burdensome and analytically time-consuming

Note: ELCC = effective load-carrying capability.

Source: Energy Systems Integration Group.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Interconnection Queue References

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