De-Carbonization / DER Report for NYSRC Executive Committee Meeting 1/12/2024

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The January 2024 edition of the De-Carbonization / Distributed Energy Resources (DER) Report includes the following items:

- NERC White Paper: Grid Forming Functional Specifications for BPS-Connected Battery Energy Storage Systems
- NERC Releases Findings and Critical Recommendations from Inverter-Based Resource Level 2 Alert
- NERC Lesson Learned: 540 MW Wind Turbine Loss due to Unexpected Insufficient Ride-through
- EPRI ESCA: Key Drivers and Challenges of the Energy Transition
- Snapshot of the NYISO Interconnection Queue: Storage / Solar / Wind / Co-located

NERC White Paper: Grid Forming Functional Specifications for BPS-Connected Battery Energy Storage Systems

One of the most significant obstacles of deploying Grid Forming Inverter Based Resources (GFM IBRs) on the Bulk Power System (BPS) is establishing clear interconnection requirements for the expected performance, testing, and validation of the technology. This White Paper addresses how Transmission Owners (TO), Transmission Planners (TP), and Planning Coordinators (PC) can establish these requirements and test interconnecting resources to ensure they meet the GFM specifications. The recommended set of GFM tests are provided in this paper, designed to verify the unique characteristics of GFM. The paper also addresses GFM model quality and accuracy as a prerequisite to any studies being conducted.

There are 2 chapters and 2 major appendices in this report:

1. Functional specifications for GFM Bess: Blackstart and additional considerations
2. Verifying GFM Functionality: Functional tests and success criteria under charging and discharging scenarios
3. Appendix A: Industry Experience with GFM integration
4. Appendix B: Example of GFM Functional Test with a Different OEM (all models passed)

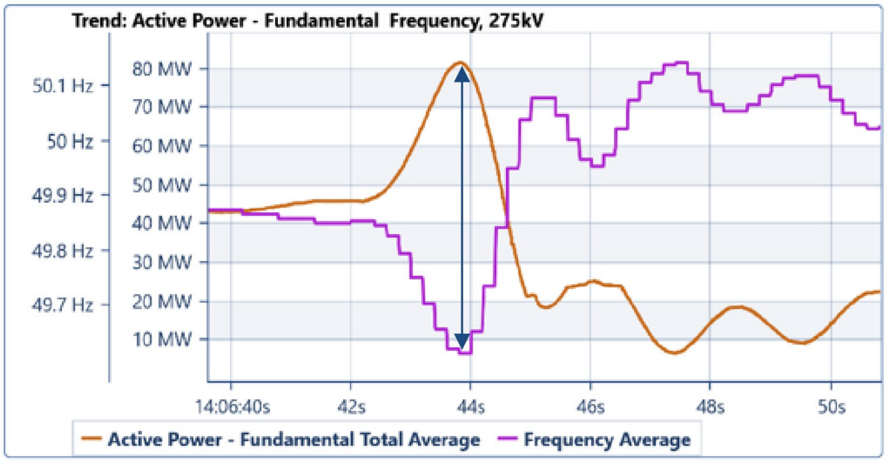
Existing Grid Following (GFL) IBR technology can provide a number of essential reliability services to the BPS. Demonstration projects have illustrated these capabilities for many years, and modern IBR facilities can provide regulation services, primary and fast frequency response, dynamic voltage support, etc. GFM controls do not preclude a resource from providing any of these critical features to the BPS. Rather, GFM controls enable additional features from BESS beyond what can be provided from GFL today. Examples include operating in low system-strength conditions, improving overall system stability, helping stabilize the system following large generator loss events (supporting arresting frequency changes), and potentially enabling blackstart capability.

Widespread adoption has been relatively slow due to limited pilot projects (particularly of large numbers of GFM resources in one area) and difficulties establishing GFM performance specifications and testing procedures. Furthermore, detailed studies of GFM technology require EMT modeling, which is challenging for large areas due to lack of expertise and computational limitations today.

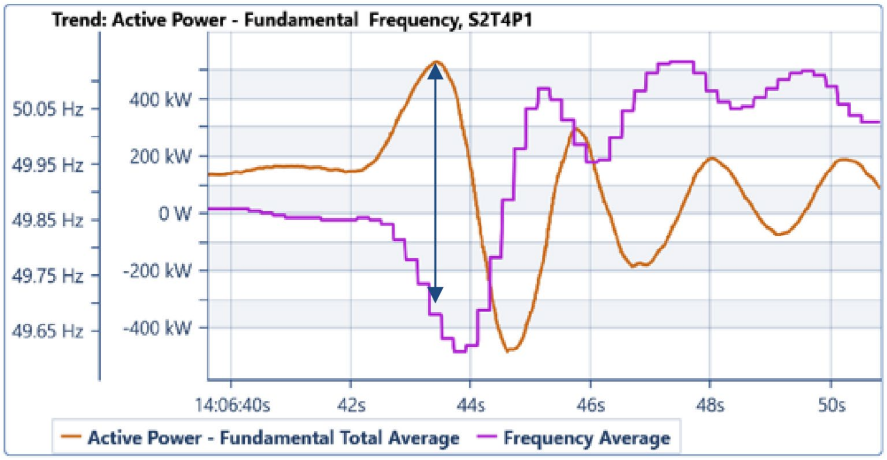
Independent System Operators/Regional Transmission Operators/utilities should work with stakeholders to carry out studies of the implementation of GFM technology in low grid-strength areas and act quickly to implement pilot projects (similar to how the provision of ancillary services from GFL IBRs has been tested in the past). Experiences from GFM BESS project installations around the world, particularly Great Britain and Australia are in Appendix A of the report.

As an example, Appendix A describes the Hornsdale Power Reserve BESS project (150MW/193.5MWh) in Australia, which was upgraded from GFL to GFM control with capabilities to provide inertia service to enhance grid stability. This section shows the results of GFM vs GFL response for inverters. In this case, two test inverters were upgraded with the actual GFM firmware while the remaining 292 inverters ran on Grid Following controls. This verified the different GFM and GFL control responses for the same disturbance. The two figures below show the GFL and GFM active power responses to the change in frequency. The GFM control contributes maximum power earlier than the GFL control, which is important to support the frequency nadir and avoid underfrequency load shedding. This test also shows that GFM controllers have faster response to over-frequency conditions.

GFL IBR Response to Frequency Event:



GFM IBR Response to Frequency Event:



Enabling GFM in BPS-connected BESS allows for system-wide enhancement of stability margins as these resources are interconnected. Therefore, system stability enhancements can be achieved at much lower cost when compared with transmission assets. GFM controls can be implemented on any type of IBR including new solar photovoltaic and wind plants, with some limitations. However, GFM controls in BESS are particularly low-hanging fruit for assuring BPS reliability since they already have the needed energy buffer on the DC side. This makes the enhancement purely software-based (minimizing much more costly hardware-based improvements and/or the moderate level of curtailment that may be needed for other IBR technologies).

Some areas like the Hawaiian Islands already need GFM BESS to maintain grid stability and prevent large-scale outages. Other areas of the USA are reaching relatively high penetrations of IBRs and will face similar challenges. Industry is faced with a unique window of opportunity to procure, test, and gain experience with GFM IBRs now, before significant adverse reliability issues arise in the future due to the lack of sufficient GFM resources.

AEMO, the Australia Energy Market Operator, published Voluntary Specification for Grid-forming Inverters in May 2023. This document provides guidance to stakeholders while the regulatory environment around GFM technology develops. It specifies "core" GFM capabilities, which require only a small energy buffer and can be delivered through control changes, and "additional" GFM technical capabilities that require a large energy buffer through hardware or operational practices change as well as over current capability. Core requirements include:

- Nearly instantaneous (< 5 ms) reactive response to an external voltage magnitude step, to oppose the change in grid voltage.
- Nearly instantaneous active power response to a voltage phase angle step, by injecting or absorbing power to oppose the change in phase angle.
- Inertial response from GFM inverters should be inherent (no calculation of frequency), providing a near instantaneous active power response to a grid disturbance (e.g., load or generation trip). If the inertia is configurable, it needs to be tuned based on network conditions and requirements (high inertia constant may increase risk of power oscillations, particularly in strong systems).
- The response when the inverter is at a limit, and in transition to and from a limit condition, must be smooth and stable.
- The behavior at a limit should not be detrimental to stability and to harmonic performance (for example, clipping of current waveforms).
- Surviving loss of the last synchronous machine (SM): provided that the resultant state of the system is within the operating envelope of the GFM inverter, GFM should operate stably in a grid without any other GFM inverters or SMs; remain stable for a transition from a grid with SMs to one without (and back); provide frequency and reactive support which should be unaffected by these transitions.
- Operate stably under a very low short-circuit ratio, as defined by the system operator; provide system strength support to nearby GFL inverters during and after disturbances.
- Provide positive damping for oscillations: following a disturbance, GFM inverter output should be adequately damped. Add damping to the system for the oscillatory phenomena listed in the document.
- Additional capabilities include higher current capability above the continuous rating, larger headroom, and energy buffer and power quality improvements

Presently, it is recommended that all new BESS connecting to the BPS should have the capability for GFM Operation, or future capability to be upgraded with GFM controls (if necessary). TOs should establish this requirement in their interconnection requirements or power purchase agreements (PPA). Developers and GOs can also ensure that these requirements are in contractual language with the equipment manufacturers. Newly interconnecting BESS enable GFM capability or have the capability for GFM controls. Additionally, GFM controls should be enabled only after being studied by the responsible entity, as with any new resource or change.

Related links:

- PV Magazine: Hornsdale Big Battery Begins providing the Inertia Grid Services at Scale in World First
- NREL: Power HIL validation of MW-scale grid-forming inverter stabilization of Maui transmission system
- World Energy: Upgrade at Tesla Battery Project Demonstrates Feasibility of 'Once-In-A-Century Energy Transformation' for Australia
- AGL: Broken Hill Battery Energy Storage System

NERC Releases Findings and Critical Recommendations from Inverter-Based Resource Level 2 Alert

On November 30th, NERC Announced the release of this Report entitled I*nverter-Based Resource Performance Issues Report: Findings from the Level 2 Alert*. The report is based on information provided by Owners of all bulk power system-connected IBR facilities as a result of a request initiated at the start of the Level 2 Alert in March, 2023. The report provides key findings and critical recommendations based on the analysis NERC conducted with this data, and provides details of the extent of potential risks posed to the bulk power system.

Some of the report's key findings include:

- Many Generator Owners indicated that they did not have the requested facility data readily available.
- About 5,200 MW of Bulk Electric System IBRs have voltage and frequency protection settings within the NERC PRC-024 "no trip zone."
- About one-fourth of reported facilities use phase lock loop loss of synchronism protection with a trip threshold that results in increased likelihood of inadvertent tripping during normally cleared grid faults.
- About one-quarter of the reported facilities use a fault ride-through mode that does not adequately support bulk power system reliability.
- About one-third of the reported facilities use a "triangle-shaped" facility reactive power capability curve, indicating a significant amount of underused reactive power capability.

The report also includes crucial recommendations that should be addressed in a timely manner:

- The NERC Inverter-Based Resource Performance Subcommittee of the Reliability and Security Technical Committee will develop a standard authorization request (SAR) for enhancements to FAC-001 to support the uniform IBR performance requirements established by Transmission Owners. Based on this and other NERC reports, the subcommittee should also consider proposing commissioning requirements for Generator Owners of IBRs; the SAR might mention that the standard could be applied at commercial operation to ensure adequate risk mitigation steps occurred during the commissioning process.
- NERC will develop two Reliability Standard Projects: Project 2020-02 – Modifications to PRC-024, and Project 2023-02 – Performance of IBRs, to produce performance and post-disturbance analytical expectations that will address the systemic IBR performance issues and support a more reliable IBR fleet. Both projects are considered high priority given the recent FERC Order No. 901. This report reiterates the criticality of implementing these standards in a timely manner to ensure adequate ride-through performance of IBRs as well as proactive risk mitigation by Generator Owners.
- NERC will issue a Level 2 alert in early 2024 to gather modeling and study information from Generator Owners and Transmission Providers. This alert will share recommended practices regarding modeling and study enhancements as well as gather data to assess the extent of condition of possible modeling and study risks. Both the upcoming Level 2 alert on modeling and study practices and this alert on IBR performance issues will inform the contents of a Level 3 alert, providing essential actions for high-risk IBR Issues that will be issued in the first half of 2024.

NERC's efforts in this area are a component of its 2023 work plan priorities, which strive to keep NERC at the forefront of the transformation by focusing on four key areas: Energy, Security, Agility and Sustainability. To learn more about NERC's work surrounding IBRs, visit the Inverter-Based Resource Activities Quick Reference Guide.

These recommendations all align with the intended goals and activities set forth in FERC Order No. 901 regarding enhancements to NERC Reliability Standards for IBRs.

NERC Lesson Learned: 540 MW Wind Turbine Loss due to Unexpected Insufficient Ride-through Performance

During this Event, there was a loss of 540 MW of wind generation that occurred coincident with a transmission line fault. After the entity's investigation of the failure to ride through the normally cleared system fault, it was determined that there were numerous instances of incorrect protection settings as well as a failure to maintain critical facility infrastructure. This investigation was completed through coordination between both the GO and the original equipment manufacturer's Engineering department. Additional details include:

- The largest percentage of Wind Turbine Generator (WTG) tripping (201 turbines, 264 MW) was due to an incorrectly set logic parameter in the low voltage ride-through control scheme. This parameter is responsible for enabling or disabling a WTG's low voltage ride-through curve. With this parameter and function unintentionally disabled, WTGs cannot utilize their low voltage ride-through curves. Instead, they use extremely sensitive low-voltage trip thresholds and time delays during grid disturbances. This unintentionally enabled low-voltage protection setting caused a facility to trip off-line for a point of interconnection (POI) voltage that, during the grid disturbance, was well within the "No Trip Zone" specified in NERC PRC-024.
- Numerous other WTGs (39 turbines, 55 MW) also tripped due to the failure of the WTG controller's UPS system. The UPS failed to keep the WTG controllers from restarting and tripping the WTGs off-line. Low battery levels within the UPS and unintentional operations of the UPS system caused the WTGs to fail to remain on-line during the grid disturbance. Both the low UPS battery and unintentional operation of the UPS systems are due to a failure by the GO to sufficiently maintain this critical facility infrastructure.
- 100 WTGs (221 MW) also tripped off-line due to a converter trip signal in the control system. The GO and the WTG manufacturer have not been able to determine the cause of this tripping. These same turbines tripped for a similar fault in 2020 and the cause was not determined at that time either. This lack of ability to determine the cause of the tripping is resulting in the continual failure of a significant number of wind turbines being able to ride through normally cleared faults on the transmission system.

The GO has implemented a number of corrective actions to ensure that the facility's ride through performance addresses the "No Trip Zone" in the future.

The facility dynamic models are also undergoing updates to be submitted to the facility's TOP. Additional details on these corrective actions are as follows:

- The GO and original equipment manufacturer coordinated to determine the parameter at fault and to specify the appropriate parameter value. The correct parameter value is currently being updated at WTGs across the affected facilities to enable the expected low-voltage ride through capability.
- The GO is currently performing upgrades on all WTG UPS systems to ensure that battery levels are monitored and maintained sufficiently and that the UPS systems will operate as expected.

The following are lessons learned for this report:

- Sufficient documentation and maintenance of essential controls and systems is necessary for reliable operation. Investigations of as-left settings should be performed, and any discrepancies between as-left settings and those documented should be investigated, studied, and corrected.
- UPS systems are critical to the ride-through performance of WTGs. Routine maintenance and adequate monitoring are necessary to ensure UPS systems are operational.
- It is critical that GOs analyze and determine the cause(s) of poor ride through performance when they occur even when the amount of MW loss is below reportable thresholds as the causes of small losses are often the same as larger losses. Failure to determine the cause of these events and take appropriate corrective action continues to subject the BPS to higher reliability risk.

EPRI ESCA: Key Drivers and Challenges of the Energy Transition

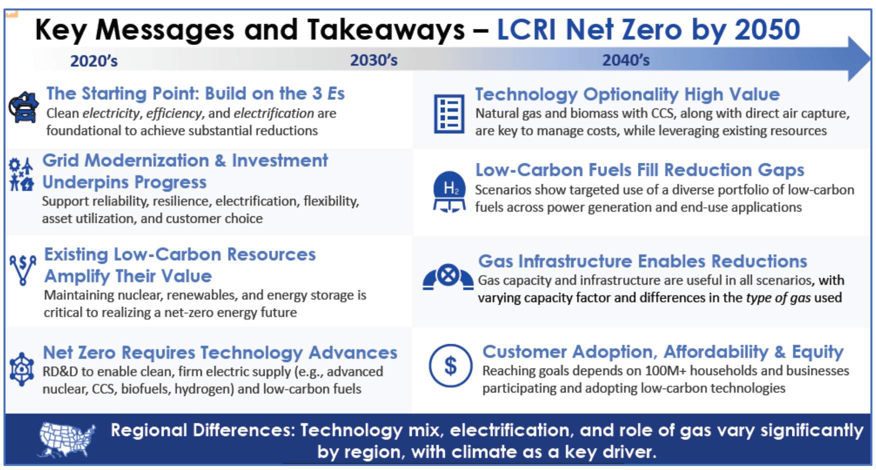
This publicly available presentation (EPRI Download Page) is provided by EPRI's ESCA (Energy Systems and Climate Analysis) group and looks to identify and address the core challenges that are facing energy companies on the path to decarbonization. It identifies the drivers of decarbonization in the United States along with the EPRI initiatives and programs looking to address these challenges. The presentation is divided into 4 sections:

- Today and Tomorrow's Targets
- Pathways to Decarbonization
- Decarbonization Drivers
- Challenges and EPRI Research

The USA's National Determined Contribution (NDC) to the Paris agreement is a 50% reduction in Greenhouse Gas (GHG) emissions by 2030, based on the base year 2005, with a broader goal of net-zero GHG emissions economy-wide by 2050. The current administration has a target for a nationwide carbon pollution-free Electric sector by the year 2035, while federal operations aim for 100% carbon-free electricity by 2030, half of which will be procured on an hourly basis. In order to achieve 50% reduction by 2030, the USA would have to decrease emissions at a rate that is 4 times greater than the progress shown from 2005 to 2021.

For the Electric Sector, the target of zero implies the following:

- Net carbon emissions equal zero. Any emissions produced from operations are balanced by an equivalent amount of carbon removal or offsets
- No sources of electric power user fossil fuels
- All sources of electric power are generated from renewable resources such as wind, solar and hydro

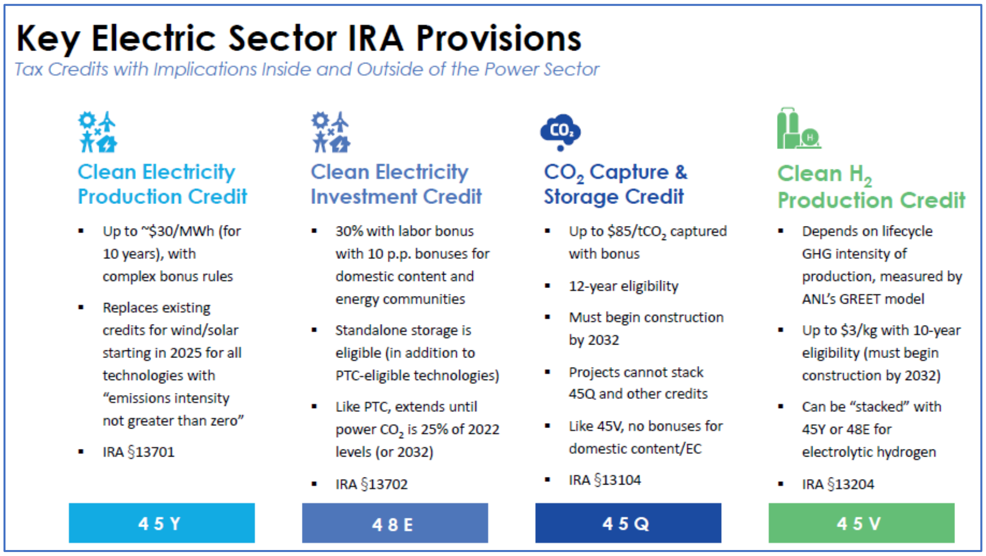


Key Findings include:

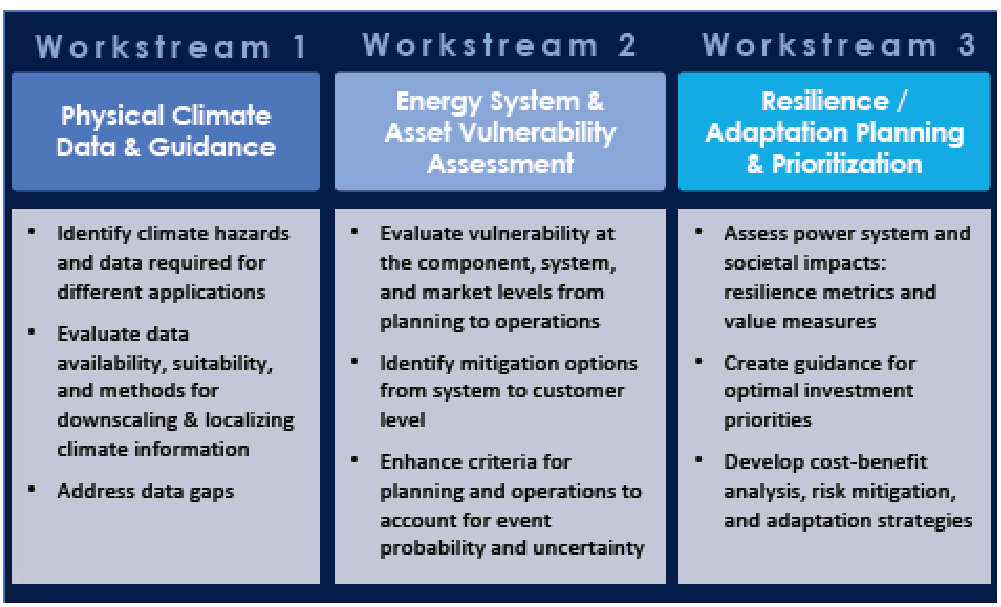
- Decarbonization in the U.S. is driven by company targets, state and federal policy, and stakeholder advocacy.
- In present and future emissions targets, it is important to be clear about the definition (and implications) of a target.
- Developing a decarbonization pathway for the electric sector, and economy-wide energy use, will involve analyzing the interaction between technology, economics, and policy. More optionality will enable affordability.
- A robust supply chain is needed to maintain the existing system while expanding clean energy technology.
- There is technical and economic potential for alternative energy carriers to enable economy-wide decarbonization
- Net-zero pathways that meet reliability and resiliency requirements will benefit from the improvement of operational capabilities to control dynamic, decentralized resources, and the streamlining of regulatory and planning processes.
- A decarbonized future is an electrified future. Stakeholder networks (utilities, regulators, market operators) can coordinate to reduce electrification barriers, and grid planning and operation can adapt to new electrified loads.
- Many of these new electrified loads have the potential to be flexible. New tools can align the various flexible demand resources and services with various types of grid situations, objectives and needs.

- Load forecasts can be improved to incorporate synchronized renewable/load profiles, weather to load dynamics, and probabilistic forecasting, DER characteristic, end-use technology adoption and historical or future weather.
- Climate resilience can be improved by addressing gaps in existing climate-related data and developing metrics for the power system. Climate trends and projection methods can be utilized in asset design, and new methods can prioritize climate risk mitigation investments.
- Energy transition challenges influence and interact with one another, and the decisions that are made today impact the options available to address challenges in the future.

Tax Credits from the Inflation Reduction Act (IRA) have an impact on 4 key areas in the Electric Sector:



EPRI's Climate Resilience and Adaptation Initiative (READi) looks to provide a Common Framework addressing the entirety of the power system, planning through operations. This will be a consistent and informed approach to climate risk assessment and strategic resilience planning that can be replicated. It will be a collaborative effort that will drive stakeholder alignment on adaptation strategies for efficient and effective investment. Climate READi's workstream areas of focus are shown below:



Deliverables will include common framework guidebooks covering:

- Climate data assessment
- Vulnerability assessment
- Risk mitigation investment
- Recovery planning
- Hardening technologies
- Adaptation strategies
- Research priorities

The presentation provides a summary of Energy Transition Challenges by category:

- Supply Chain: How to maintain the existing system while expanding clean energy technology deployment? How to maintain a robust supply chain for equipment in a safe, reliable, and environmentally responsible manner?
- Advanced Technology: What is the technical and economic potential for alternative energy carriers to enable decarbonization? What advances can be made for production, transport, storage, and utilization of low carbon fuels?
- Reliability: How will net-zero pathways meet reliability and resiliency requirements over time? Can operational capabilities be expanded to better control dynamic, decentralized resources? How can regulatory and planning processes be streamlined to support the requirements of future energy systems?
- Electrification: How will stakeholder networks (utilities, regulators, technology vendors, market operators) coordinate to reduce barriers to electrification? How can grid capacity planning and operation improve to integrate electric transportation networks through smart charging, fast charging, and storage utilization?
- Demand-side Participation: What are the economic, and emissions impacts of including the benefits of flexible demand in capacity expansion, resource adequacy, transmission, and distribution planning? What will drive customer adoption of flexible end-uses, and which market signals will customers respond to?
- Load Forecasting: How can our forecasts incorporate synchronized renewable / load profiles, weather to load dynamics, and probabilistic forecasting? How can we update our data to include DER characteristics end-use technology adoption and historical or future weather?
- Climate Resilience: What are the gaps in existing climate-related data and what variables and metrics can be effectively applied to the power system? How can we effectively apply climate trends and projections when designing new assets? What are the methods to prioritize climate risk mitigation investments

EPRI's Low Carbon Resources Initiative (LCRI) looks to identify the path for achieving net zero emissions across the economy by 2050, by way of accelerating a safe, affordable, and reliable energy transition through advancements in a variety of clean energy technologies and options. The LCRI evaluates pathways for deploying low-carbon technologies, fuels, and energy carriers in support of decarbonization across the energy economy. The LCRI is focused on a vision of the future global energy system that is decarbonized, consumer-focused, sustainable, and resilient.

Key EPRI reports on Decarbonization Pathways:

- 2021: Powering Decarbonization: Net-zero electric sector scenarios considering how a target is defined, the timing of the target, the costs of the transformation, and interactions with the end-use sectors
- 2022: LCRI Net Zero by 2050: Alternative technology strategies to achieve economy-wide net-zero emissions
- 2023: 50x30: Pathways to a 50% economy-wide reduction in GHGs by 2030,

EPRI Energy Systems and Climate Analysis Group (ESCA) Links for further information:

- ESCA Landing page: http://ESCA.EPRI.com
- ESCA webpage for Publications, Research and Newsletters:

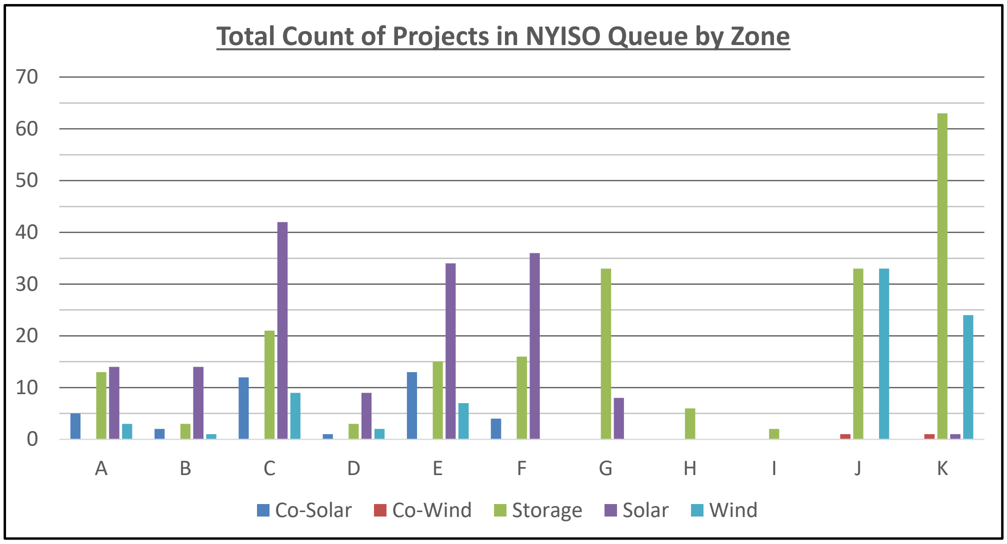
Interconnection Queue: Monthly Snapshot – Storage / Solar / Wind / CSRs (Co-located Storage)

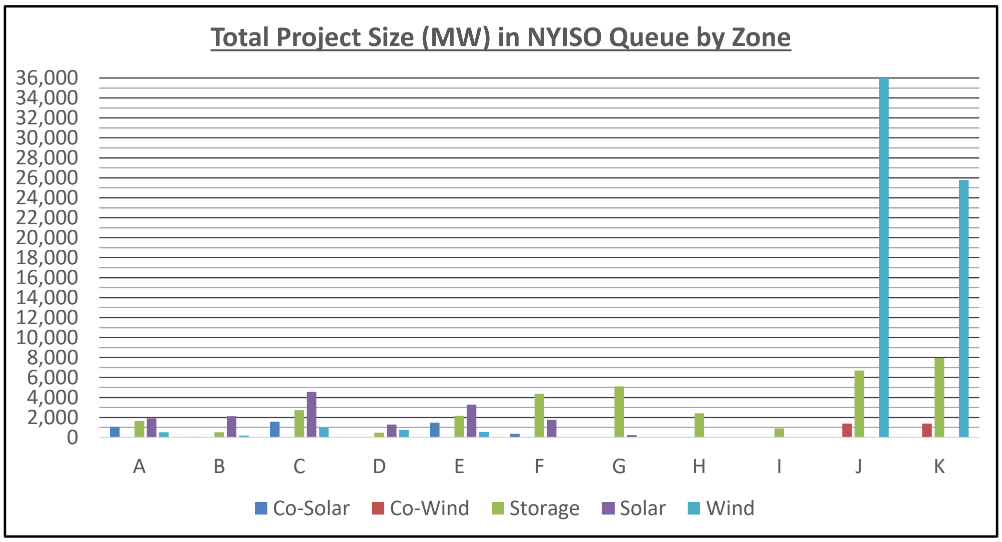
The intent is to track the growth of Energy Storage, Wind, Solar and Co-Located Storage (Solar and Wind) projects in the NYISO Interconnection Queue, looking to identify trends and patterns by zone and in total for the state. The information was obtained from the NYISO Interconnection Website, based on information published on December 20th, and representing the Interconnection Queue as of November 30th. Note that 19 projects were added, and 8 were withdrawn during the month of November.

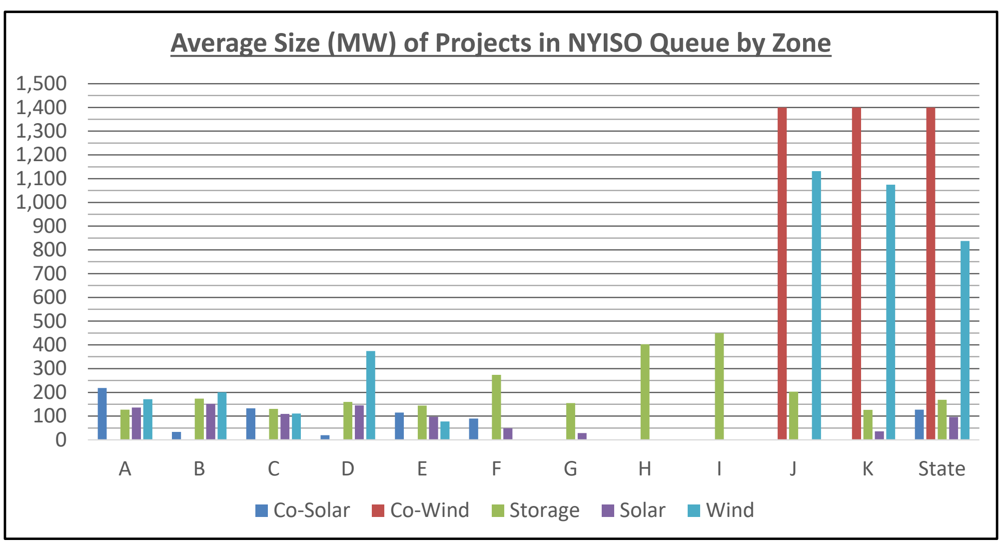
Total Count of Projects in NYISO Queue by Zone					
Zone	Co-Solar	Co-Wind	Storage	Solar	Wind
A	5		13	14	3
B	2		3	14	1
C	12		21	42	9
D	1		3	9	2
E	13		15	34	7
F	4		16	36	
G			33	8	
H			6		
I			2		
J		1	33		33
K		1	63	1	24
State	38	2	209	158	79

Total Project Size (MW) in NYISO Queue by Zone					
Zone	Co-Solar	Co-Wind	Storage	Solar	Wind
A	1,092		1,651	1,908	514
B	67		520	2,125	200
C	1,591		2,741	4,572	1,001
D	20		480	1,302	747
E	1,492		2,164	3,286	541
F	360		4,377	1,761	
G			5,108	230	
H			2,416		
I			900		
J		1,400	6,705		37,351
K		1,400	7,965	36	25,786
State	4,828	2,800	35,227	15,219	66,139

Average Size (MW) of Projects in NYISO Queue by Zone					
Zone	Co-Solar	Co-Wind	Storage	Solar	Wind
A	218		127	136	171
B	34		173	152	200
C	133		131	109	111
D	20		160	145	374
E	115		144	97	77
F	90		274	49	
G			155	29	
H			403		
I			450		
J		1,400	203		1,132
K		1,400	126	36	1,074
State	127	1,400	169	96	837


Total Count of Projects in NYISO Queue by Zone
70
60
50
40
30
20
10
0
A
B
C
D
E
F
G
H
I
J
K
Co-Solar
Co-Wind
Storage
Solar
Wind


Total Project Size (MW) in NYISO Queue by Zone
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
A
B
C
D
E
F
G
H
I
J
K
Co-Solar
Co-Wind
Storage
Solar
Wind


Average Size (MW) of Projects in NYISO Queue by Zone
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
A
B
C
D
E
F
G
H
I
J
K
State
Co-Solar
Co-Wind
Storage
Solar
Wind