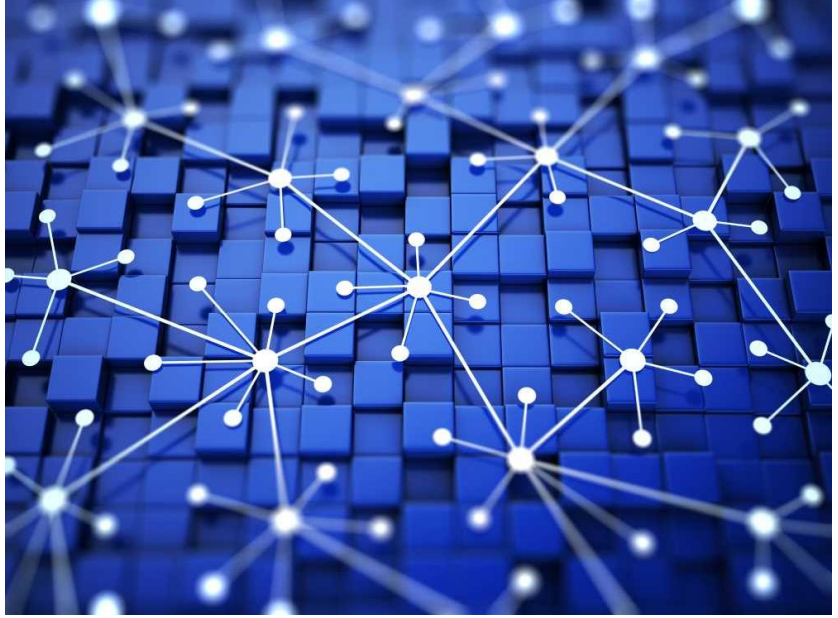




Advanced Technology Working Group Spring Technical Conference

May 2, 2024

Welcome

Jason Pause, Department of Public Service

King Look, Con Edison

CONFERENCE AGENDA

Today's ATWG Spring Technical Conference will cover the topics below.

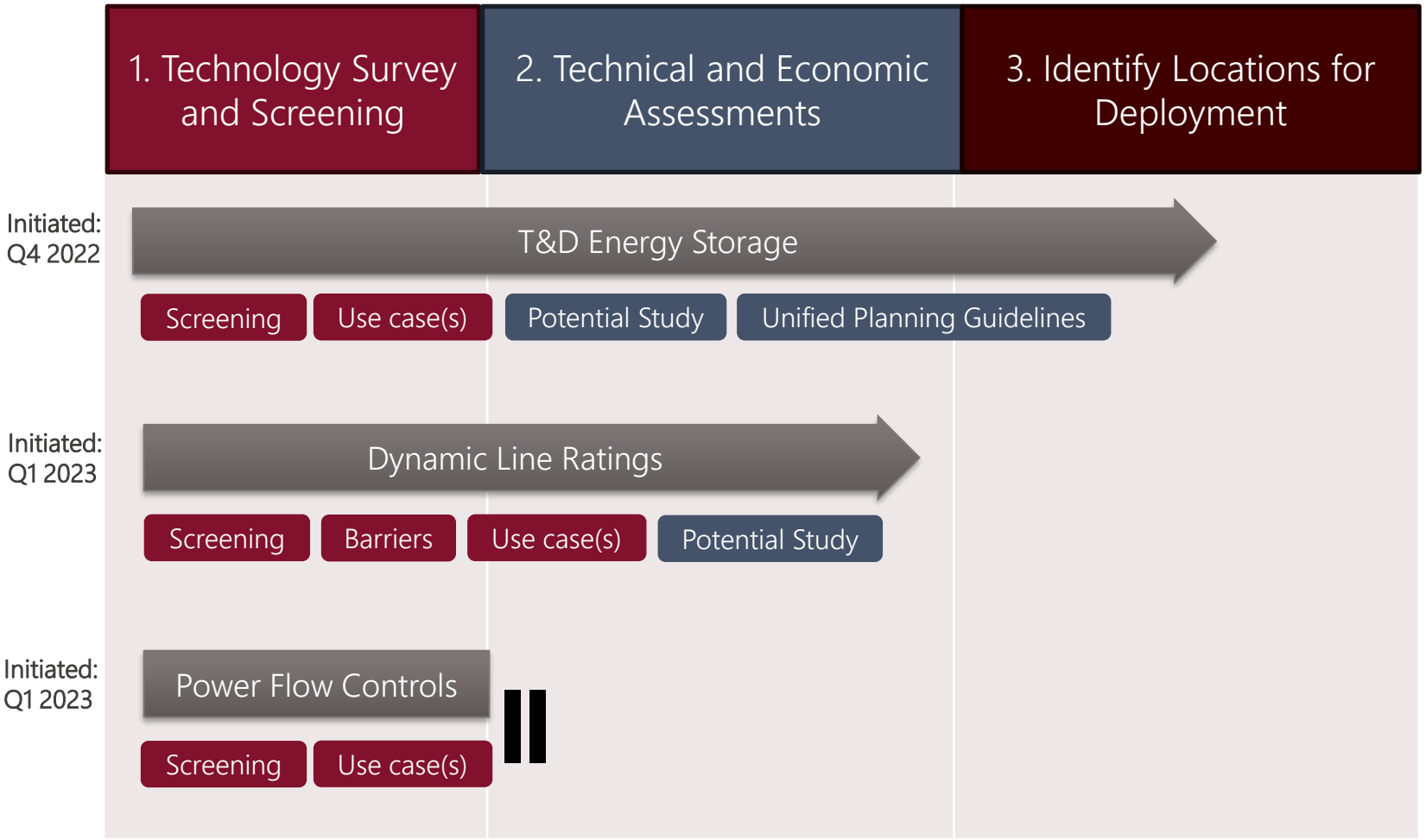
Topic	Lead	Time
1. Welcome	Department of Public Service	10 minutes
2. Task Force Summaries	Energy Storage Task Force, Dynamic Line Ratings Task Force, Power Flow Control Task Force	30 minutes
3. New York R&D Opportunities for Electric T&D	NYSERDA, NYPA, Brookhaven National Laboratory	45 minutes
4. Advanced Technology Concept Papers	Concentric Energy Advisors	20 minutes
5. Wrap-up and next steps	Con Edison	10 minutes

Task Force Summaries

King Look, Con Edison

ATWG TASK FORCE TECHNOLOGY EVALUATION PROGRESS

The ATWG is proceeding with a standardized assessment process across technology areas.



Milestones: Technology Scouting and Assessment

- Technology screening
- Barriers assessment (as needed)
- Development of use case or use cases
- Initiation of technical potential study
- Development of unified planning guidelines for transmission owners

ATWG
Energy Storage Task Force

Chris Schramm, Avangrid

OVERVIEW

This Task Force is focused on developing planning guidelines for T&D Energy Storage that support the CGPP.

TASK FORCE LEADS

- Current: Chris Schramm (Avangrid)
- Upcoming: Jessica Barcco (Consolidated Edison) & Michael Grinshpun (National Grid)

MISSION

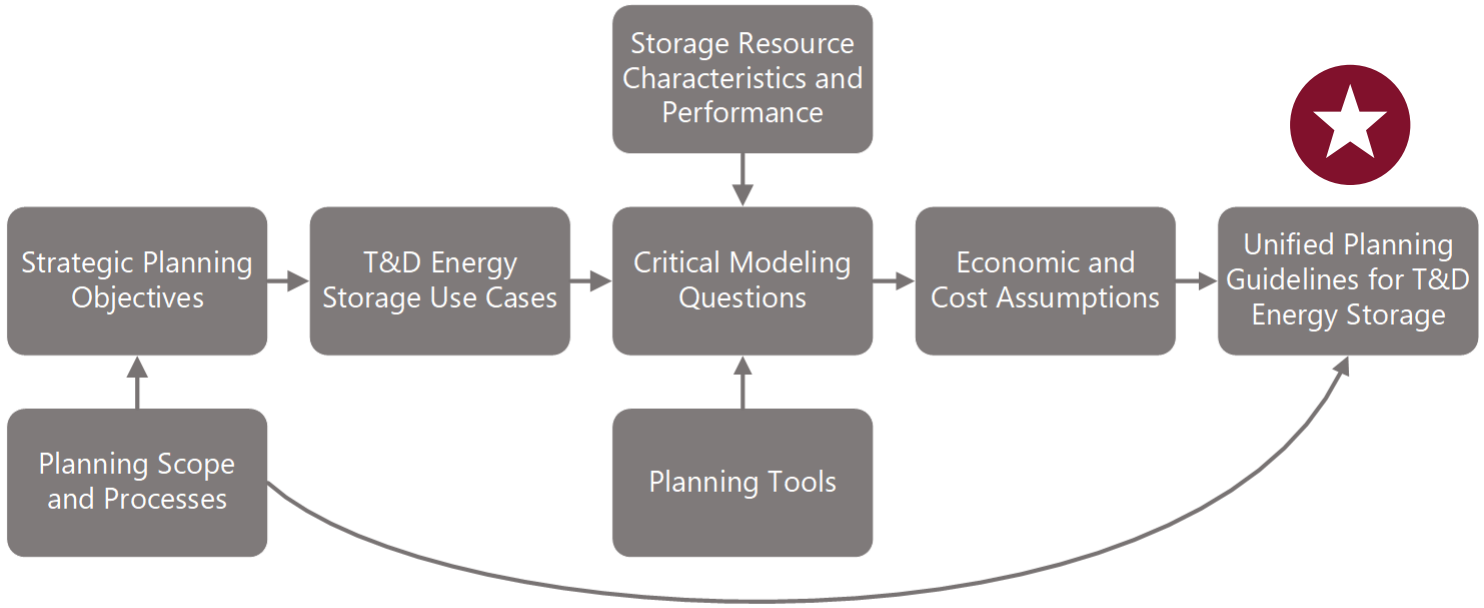
- Apply Energy Storage to Support New York's T&D system.
- Facilitate better planning support for the CGPP including identification of possible use cases
- Ensure consistent analysis of energy storage solutions across the Joint Utilities of New York

2024 ACTIVITIES AND GOALS

- Complete Unified Planning Guidelines (UPG) for T&D Energy Storage.
- Incorporate insights from the T&D Energy Storage Potential Study.

UNIFIED PLANNING GUIDELINES FOR T&D ENERGY STORAGE

The UPG will support a modeling and analysis approach for T&D energy storage for use in the CGPP.



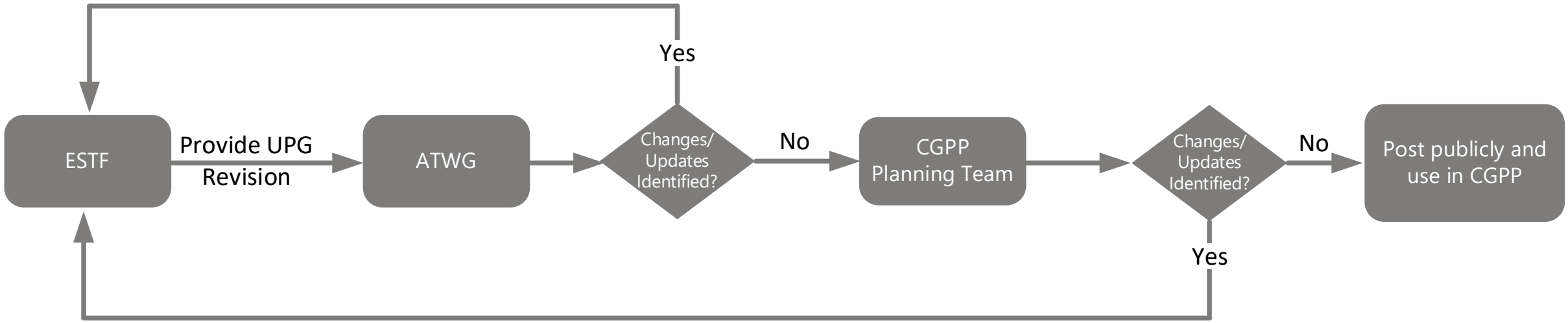
CONTENTS

NEXT STEPS FOR THE UNIFIED PLANNING GUIDELINE

The UPG will require review and input from the actual planners working on the CGPP

OBJECTIVES

- Provide planning guideline draft to ATWG for review *(May)*
- Present planning guideline draft to CGPP utility planners for review and recommendations *(June)*
- Adjust guideline as needed to incorporate recommended planning changes
- Provide initial modeling recommendations for incorporation into network model development *(CGPP Stage 2)*



ONGOING EFFORTS: ENERGY STORAGE POTENTIAL STUDY

The ESTF is working with DNV to determine the potential for energy storage to support New York's T&D systems.

Scope of Work

Task 1: Characterize the landscape for energy storage as part of the T&D system and identify energy storage use cases that could be used to help meet the State's clean energy goals.

Task 2: Develop a formalized economic framework for assessing the economics of the various use cases in each utility's service territory.

Task 3: Apply the framework and help assess the potential for T&D energy storage in each utility's T&D system.

Task 4: Prepare a Final Report that includes findings and recommendations, project results and lessons learned, and analyses of environmental and economic benefits.

Use Cases

- T&D infrastructure investment deferral
- Distribution system resiliency/reliability
- DER hosting capacity improvements
- Residential electrification & load growth
- EV Charging Infrastructure
- Transmission-level renewables hosting
- Transmission system congestion relief
- Mobile & temporary energy storage

Timeline

- The Study is entering Phase 2, with an initial completion date set for June/July 2024.

QUESTIONS

ATWG Dynamic Line Ratings (DLR) Task Force

Ruby Chan & Pete Harpolis, Central Hudson

MISSION AND GOALS

This Task Force is exploring Dynamic Line Ratings (DLR) technology to integrate more renewable generation.

DLR Task Force Leads

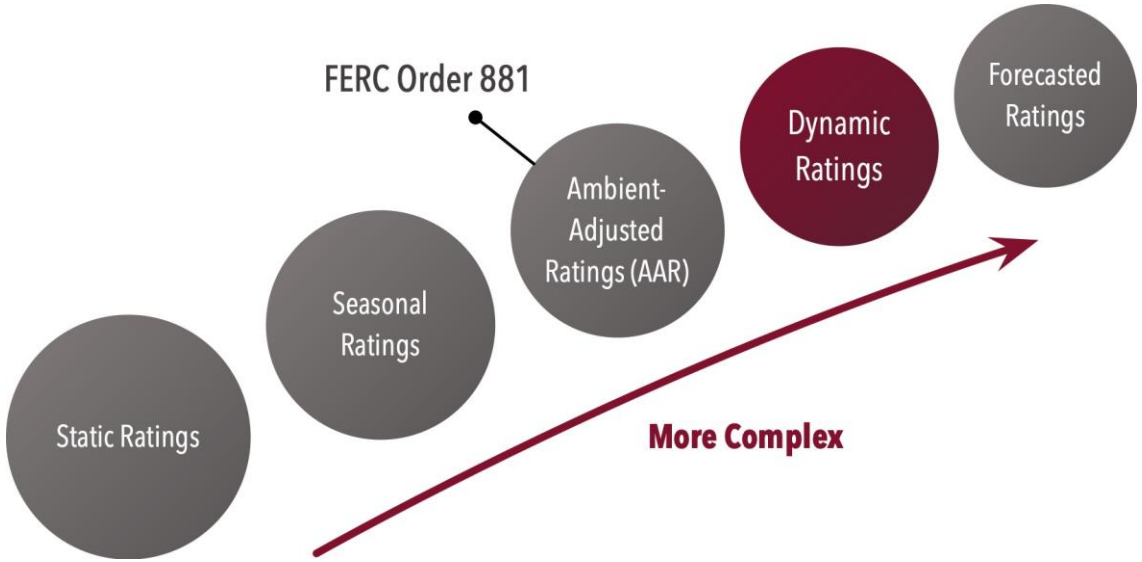
Ruby Chan and Pete Harpolis, Central Hudson Gas & Electric

Mission

- Identify and reduce barriers to deploying DLR
- Unbottle renewable generation to meet NY Statewide CLCPA Policy Goals

2024 Goals

- Assess technical potential of DLR to increase capacity of transmission in New York
- Develop DLR Guide for planners



Source: Advanced Technology Working Group, *Research and Development Plan for Advanced Transmission and Distribution Technologies*, Revised March 18, 2024.

BARRIERS ASSESSMENT AND USE CASE DEVELOPMENT

Following technology screening, the task force began a barriers assessment and development of a DLR use case.

Barriers Assessment: 2023 Q2-Q3

Process

- Evaluated barriers to identify key constraints or development issues for DLR
- Assessed ability to proceed with technical and economic assessments

Outcome: Recommendations for Technology Scouting and Assessment

- Sponsor a DLR Potential Study
- Develop a DLR Guide for Planners

Use Case Development: 2023 Q4 – 2024 Q1

Process

- Developed a use case that considers grid needs, functional characteristics, interconnection, benefits, and responsibilities of relevant parties
- Considered multiple options and confirmed a primary use case for transmission systems

Outcome: Use Case: DLR for transmission systems

"Calculate and communicate an accurate line rating for one or more sections of an existing transmission line based on real-time measurements of local or physical conditions."

ONGOING EFFORTS: DLR POTENTIAL STUDY

The DLR Task Force issued an RFP for study of DLR potential in New York.

RFP Design

- The RFP was released through the NYSERDA mini-bid framework to a shortlist of contractors.
- The RFP will leverage ongoing demonstration projects with NY Utilities.
- The RFP will leverage the Use Case developed by the DLR Task Force.

Timeline

- Issue RFP: Q2 2024
- Select contractor: Q3 2024
- Study completion: Q1 2025
- Memorialize results : Q2 2025

DLR Potential Study: Scope of Work for Contractor

Task 1: Assess the scope of DLR use cases implementation in the US and abroad;

Task 2: Develop an economic framework that utilities can use to evaluate DLR use cases;

Task 3: Assess potential for DLR on all types of transmission lines in operation across utility service territories; and

Task 4: Develop a final report summarizing the results from the first three tasks and evaluating the statewide potential for DLR used as part of the transmission system.

UPCOMING WORK: DLR GUIDE FOR PLANNERS

A DLR planning guide will support consistent evaluation of DLR solutions for addressing grid needs.

Objectives

- Facilitate planning support for the CGPP.
- Clarify the planning study questions involving DLR technologies.
- Create consistency of review between DLR and traditional solutions.
- Develop standardized economic analysis of DLR solutions (use cases).

CGPP Context

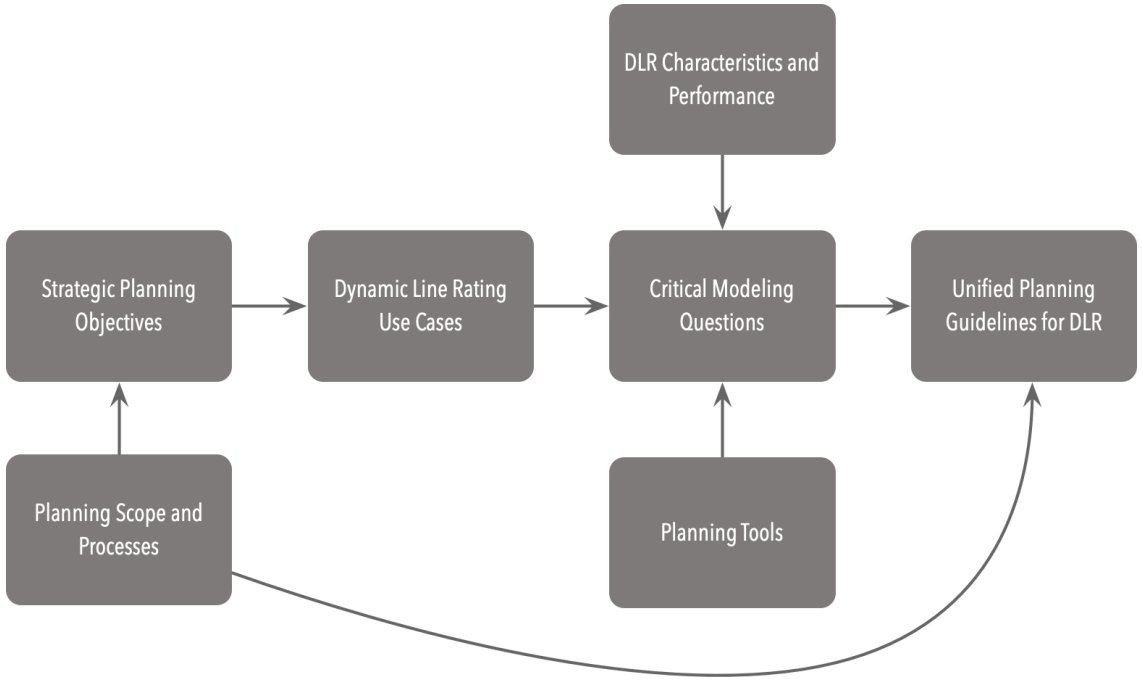
- Characterize grid needs that planners will encounter as part of the CGPP.

Methodology

- Represent DLR solutions in a transmission planning model
- Examine the suitability of DLR solutions for addressing grid needs
- Apply basic economic and cost assumptions to analyzing DLR in a transmission analysis

Timeline

- The DLR Guide for Planners will be developed in parallel with the DLR Potential Study.



QUESTIONS

New York R&D Opportunities for Electric T&D

NYSERDA

NYPA

Brookhaven National Lab

NYSERDA

NYSERDA ELECTRIC POWER T&D (EPTD) R&D PROGRAM

To date: Awarded over 230 Projects, approximately 50 active

Energy Storage

Batteries, Flywheel, Thermal, Compressed Air Energy Storage (CAES), Geo-Mechanical (Pumped Hydro), Hydrogen

Transmission / Sub-Transmission

Phasor Measurement Units/ Situational Awareness / State Estimation), Volt-Var Optimization, Optical Sensors, Flexible Alternating Current Transmission Systems (PFC), DLR (Temperature, Tension, Weather, Lidar), Power Electronics, Off-Shore Wind analysis, Stability/ Inertia Measurement

Distribution Automation

Integrated System Models (ISM), Advanced Distribution Management Systems (ADMS) Applications (Fault Location Isolation & System Restoration (FLISR) / Conservation Voltage Optimization (CVO) / Switch Order Management (SOM) / Distributed Energy Resources Management System(DERMS), Forecasting (Weather / Load - Electrification)

DER Integration

Grounding, Ground Fault Over-Voltage (GFOV), Unintentional Islanding, Hosting Capacity, Reclose Blocking, Direct Transfer Trip Alternative, Smart Inverters

NYSERDA EPTD R&D PROGRAM

Support for the Advanced Technology Working Group (ATWG)

Future Grid Solicitation

(Program Opportunity Notice (PON) 4393) - Open / Targeted ($3-5 million/challenge) Demonstrations / Product Developments / Studies – Round 4 awards

- **Power flow control devices**
- **Energy storage for Transmission and Distribution services**
- **Tools for improving operator situational awareness**
- Transformer monitoring
- **Advanced conductors**
- Compact tower design
- **Distribution Energy Resource Management Systems (DERMS)**
- **Offshore wind analysis**

NYSERDA EPTD R&D PROJECTS

Project	Description	Sched Comp
Dynamic Line Rating	Avangrid plans to demonstrate a dynamic line rating system. This project intends to validate a non-contact, advanced transmission line monitoring system on transmission lines along Avangrid's four 230 kV lines in the Hornell area to increase resiliency and reliability, reduce grid congestion, and provide real-time data that could aid in more renewable energy resources into the New York State electrical grid. Working with Wind Sim and Line Vision	2025
Dynamic Line Rating	The Electric Power Research Institute and its partner Con Edison will demonstrate three (3) dynamic line rating systems. This project intends to validate three (3) different types of advanced transmission line monitoring systems on Con Edison's transmission lines to increase resiliency and reliability, reduce grid congestion, and provide real-time data that could aid in more renewable energy resources into the New York State electrical grid. Working with Ampacimon, Prisma Photonics	2026

NYSERDA EPTD R&D PROJECTS

Project	Description	Sched Comp
NY Energy Storage Potential	DNV will develop a comprehensive and systematic analysis framework to assess those T&D energy storage use cases that have been implemented or are undergoing feasibility studies for implementation both domestically and internationally, The objective of this study is to identify electric T&D energy storage use cases that could be employed to help meet the State's clean energy goals; develop a formalized economic framework that each utility can apply in a consistent manner and tailor to its service territory for assessing the economics of the various use cases over the analysis timeframe; assist each of the six (6) joint utilities when applying the framework to assess the potential for T&D energy storage in each of their service territory; and develop a final report summarizing the results.	2024
Con Edison Energy Storage	EPRI, along with its partners Con Ed and the NYPA AGILe laboratory plan to develop a comprehensive and systematic analysis framework to identify, select, prioritize, and evaluate points of interconnection for deploying energy storage across Con Ed's sixty-three (63) area stations for transmission and sub-transmission services. The analysis will optimize operations for load relief, congestion at the stations to support changes associated with future offshore wind integration, and existing electric generation fleet retirements. This study will identify the primary grid services across the area stations and prioritize these points of interconnection based on hosting capacity availability, topology in the network, physical space constraints in an urban environment, availability of primary feeders for ease of integration.	2025

NYSERDA EPTD R&D PROJECTS

Project	Description	Sched Comp
DERMS	Electric Power Research Institute and its partners Smarter Grid Solutions, and General Electric plan to demonstrate a Distributed Energy Resources Management System (DERMS) logic controls in Central Hudson Gas & Electric's territory that has existing Distributed Energy Resources (DER) in the New York Independent System Operator interconnection queue. With the potential for DER participation in wholesale markets, concerns have emerged that the NYISO dispatch instructions to DER's may result in violations of grid constraints compromising grid safety and reliability.	2024
DERMS	Electric Power Research Institute, and its partners Avangrid, Nexamp, and Siemens plan to demonstrate DERMS logic controls in Avangrid's transmission and distribution systems. The goal of this project is to evaluate the value stacking capabilities for DERs to provide both wholesale and distribution services. The mix of different services will be evaluated during the project based on regulatory requirements and technical constraints. Different use cases will be evaluated along with the communication framework between different entities, namely DER owners and aggregators, the distribution utility, and the NYISO.	2026

NYSERDA EPTD R&D PROJECTS

Project	Description	Sched Comp
Reactive Technologies - Stability	The objective of this project is to demonstrate Reactive Technologies inertia/stability measurements and monitoring system. The technology uses a method to measure electrical system inertia/stability which is visualized alongside other performance metrics of the electric grid such as frequency. To measure grid inertia/stability, the platform receives grid data into its system where the intelligence and algorithms lie. A grid-connected modulator is used to pulse the nominal frequency of the grid through small instantaneous power injections. These continuous modulations are detected by the Contractor's reactance extensible measurement unit (XMU) devices which measure the power system with high accuracy and very low latency.	2026
VEIR - Superconductor	Powering Overhead Lines with Evaporatively-cooled Superconductors (POLES) project will develop a field trial of VEIR's overhead superconducting transmission's cryogenic system (Cryogenic System) with three primary objectives: Confirm the ability to run over spans between poles greater than 100 feet and therefore the ability to cover more terrain conditions, Field test a third-party contractor installing and replacing parts for the Cryogenic System according to VEIR guidelines to assess and improve upon these installation and repair guidelines and practices, and Gauge the technical and economic feasibility of deployment in New York, obtain feedback from New York-based utilities and develop a commercialization plan for broader deployment in New York.	2026

NYSERDA EPTD R&D PROJECTS

Project	Description	Sched Comp
Switched Source - PFC	The objective of this project is to demonstrate the Phase-EQ product to reach its full potential, decarbonizing the grid, increasing reliability, and decreasing overall costs for all customers, especially disadvantaged customers, throughout New York. Every large (investor-owned) utility requires a lengthy demonstration and technical due diligence before accepting a new technology and deploying it at scale. This proposal is meant to address these very technical, up-front simulation and design tasks to get National Grid comfortable with the technology, and then deploy the Phase-EQ technology on their distribution system in order for them to build momentum and prepare to deploy the technology at scale.	2026
Utilidata - DERMS	This project will demonstrate distributed artificial intelligence (AI) at the grid edge at a rural New York municipal utility, Lake Placid Municipal Electric (LPME). Utilidata Smart Grid Chips (SGCs) will be deployed within a targeted portion of LPME's territory and will illustrate the platform's ability to provide real-time visibility for the grid as well as demonstrate Distributed Energy Resource Management System (DERMS) functionality. Specifically, the project will provide better grid and customer data (such as power flow metrics and billing information) to help LPME improve basic operations, planning, power quality, and reliability.	2026

NYSERDA ENERGY STORAGE R&D PROGRAM

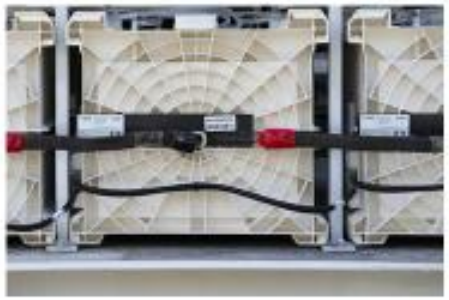
Long duration energy storage (LDES) 8+ to 100+ hour solution development and commercialization for NY

2

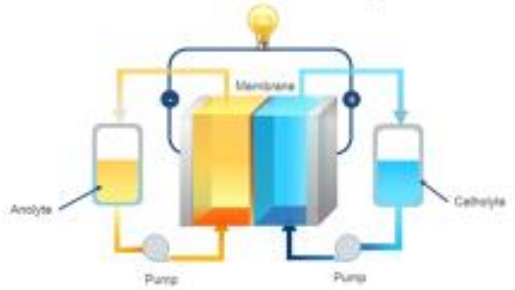
Long Duration Energy Storage Solutions

Compressed Air Energy Storage

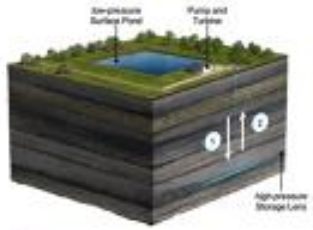
Alternative Energy Storage



Electrochemical storage



Geomechanical Storage



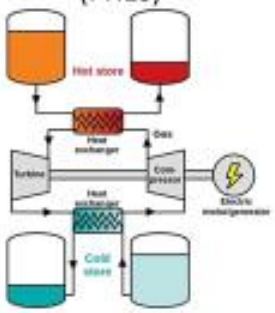
Modular, long-duration storage

Structural cost position

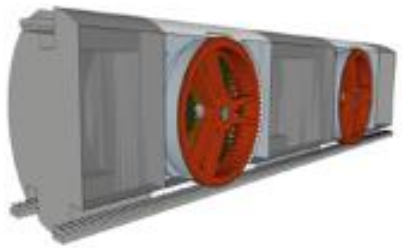
Broad geological footprint

Mature execution supply chain

Pumped heat energy storage (PHES)



Mechanical/Gravity Energy Storage



RDA

NYSERDA ENERGY STORAGE R&D PROJECTS

Project	Description	Sched Comp
Constellation – LDES	Constellation, Nine Mile Point Nuclear Station will demonstrate long-duration energy storage co-located with a baseload nuclear resource by installing a 2MW-10MW hydrogen fuel cell using 100% clean hydrogen for peak power generation and storage unit at Exelon's Constellations Nine Mile Point (NMP) nuclear site in New York. The project will be an add-on to NMP's DOE funded 1.25 MW electrolyzer project and participate in NYISO's competitive power markets including energy and capacity.	2025
Power to Hydrogen - LDES	Power to Hydrogen is developing a reversible fuel cell technology that can cost effectively and efficiently produce and store high-pressure hydrogen, then convert that hydrogen back into electricity. The technology is based on an innovative hybrid Anion Exchange Membrane / liquid alkaline cell and stack design that enables systems to operate both as an electrolyzer converting water and electricity to H2 and oxygen, and as a fuel cell to generate energy from hydrogen and oxygen.	2025

NYSERDA ENERGY STORAGE PROJECTS

Project	Description	Sched Comp
212 Solar – Energy Storage	Objective of this project to perform one field demonstration of a six hr zinc hybrid cathode energy storage system with differing use cases in a densely populated or urban environment that co-optimize Value of DER (VDER) revenue streams. The project will also demonstrate VDER use cases using battery technology with vastly greater thermal stability than the incumbent chemistry and prove that zinc hybrid technology is economically competitive with lithium-ion on a Net Round Trip Efficiency basis.	2025
Zinc 8 – Energy Storage	The primary objective is to install and operate a 100 kW, 1500 kWhr zinc air battery system from Zinc 8 at a multi family residential facility in Queens, New York. The energy storage system will be paired with the facility's existing Combined Heat and Power (CHP) and photovoltaic systems and will be charged from the grid, the CHP system or the PV system.	2025

FUTURE EFFORTS

Planned 2024 Activities to support ATWG

Continue work with other groups

Interconnection Technical, Market Development, CGPP, ESTF, DLRTF, PFCTF, Organizations: National Labs (ex; BNL), Universities, Research, (ex: EPRI), NYISO and Utilities; Investor Owned, Authorities, Municipals, Cooperatives

NYSERDA Funding

PON 5354 Rounds 2 – EV to Grid

PON 4393 Round 5 – Con Ed challenge

PON 5737 (DOE Funding) – Provides technical assistance and funding to eligible applicants for implementation projects related to outage prevention and enhanced resilience of the electric grid. For municipalities

PON 5779 – Long Duration Energy Storage

New PON to focus on technical areas selected

Support NYPA's AGILe work

NYSERDA RESEARCH INFORMATION

Interconnection Technical Working Group (ITWG)

https://www3.dps.ny.gov/W/PSCWeb.nsf/All/DEF2BF0A236B946F85257F71006AC98E

Electric Power Transmission & Distribution (EPTD) Reports

https://www.nyserda.ny.gov/About/Publications/Research-and-Development-Technical-Reports/Electric-Power-Transmission-and-Distribution-Reports

EPTD Projects

https://www.nyserda.ny.gov/Researchers-and-Policymakers/Research-Project

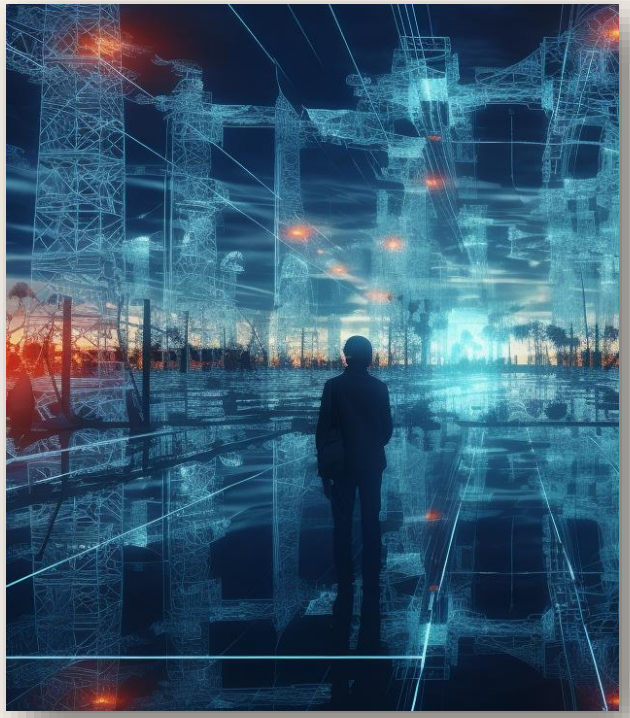
EPTD Smart Grid Program

https://www.nyserda.ny.gov/All-Programs/Programs/Smart-Grid-Program

NYPA AGILe Lab

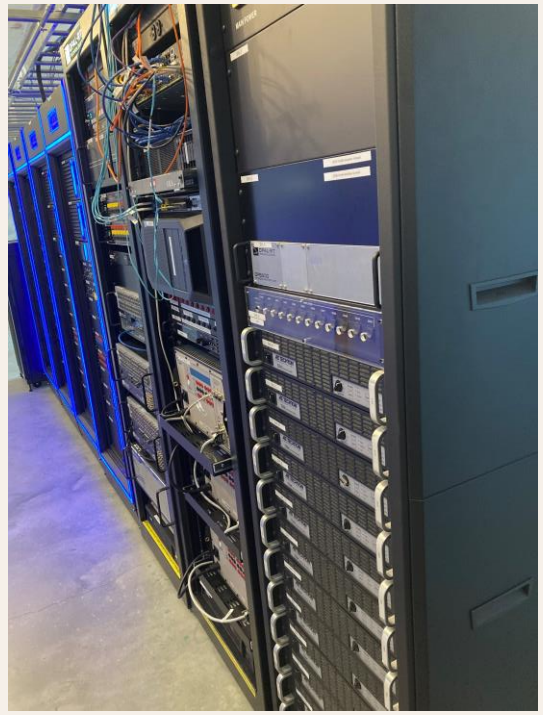
Advanced Grid Innovation Lab for Energy (AGILe)

- Enabling an Affordable, Reliable, Low-Carbon Future



Grid of the Future

- Need a platform to evaluate the grid of the future
- Need a facility to prototype solutions
- Need a platform to safely and realistically test and demonstrate solutions



AGILe

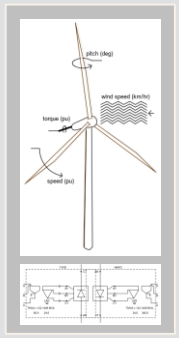
A state-of-the-art power systems laboratory to enable an affordable, reliable, low-carbon future power grid by providing a close-to-real testing environment that facilitates identifying and solving grid related challenges

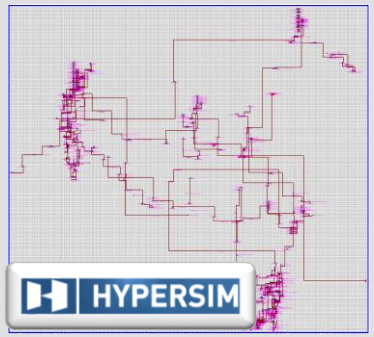
AGILe Components and Capabilities At-A-Glance

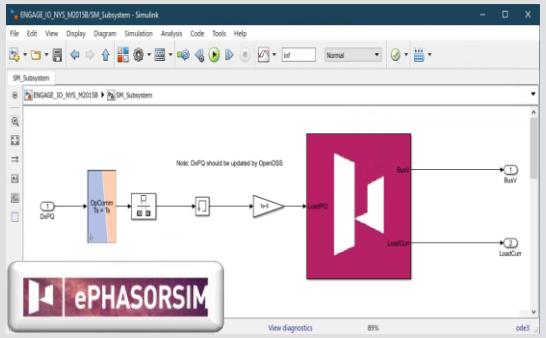
Capabilities Outcomes

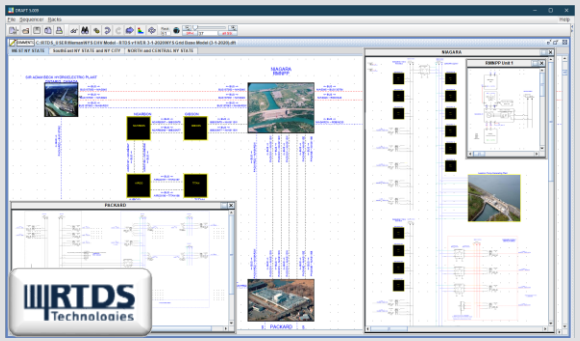
- Grid Modeling and Simulation
- Real-time hardware & software in the loop simulation
- Communication Network Emulation
- Economic Analysis
- Application Development
- Hardware Testing

NYS Grid Models & Data









Apps

OpenDSS	PSCAD	PSSE	EMTP	MatLab	DSATools
CYME	RSCAD	HYPERSIM	ePhasorSim	EXATA	GE-MAPS

Servers Simulators

RTDS | OPAL-RT | TSAT Server | Communications Emulator | MAPS Server | Work Stations

Hardware Devices

Relays | Intelligent Electronic Devices | Amplifier | GPS Clock | Substation Mockup

Technology Scouting and Assessments

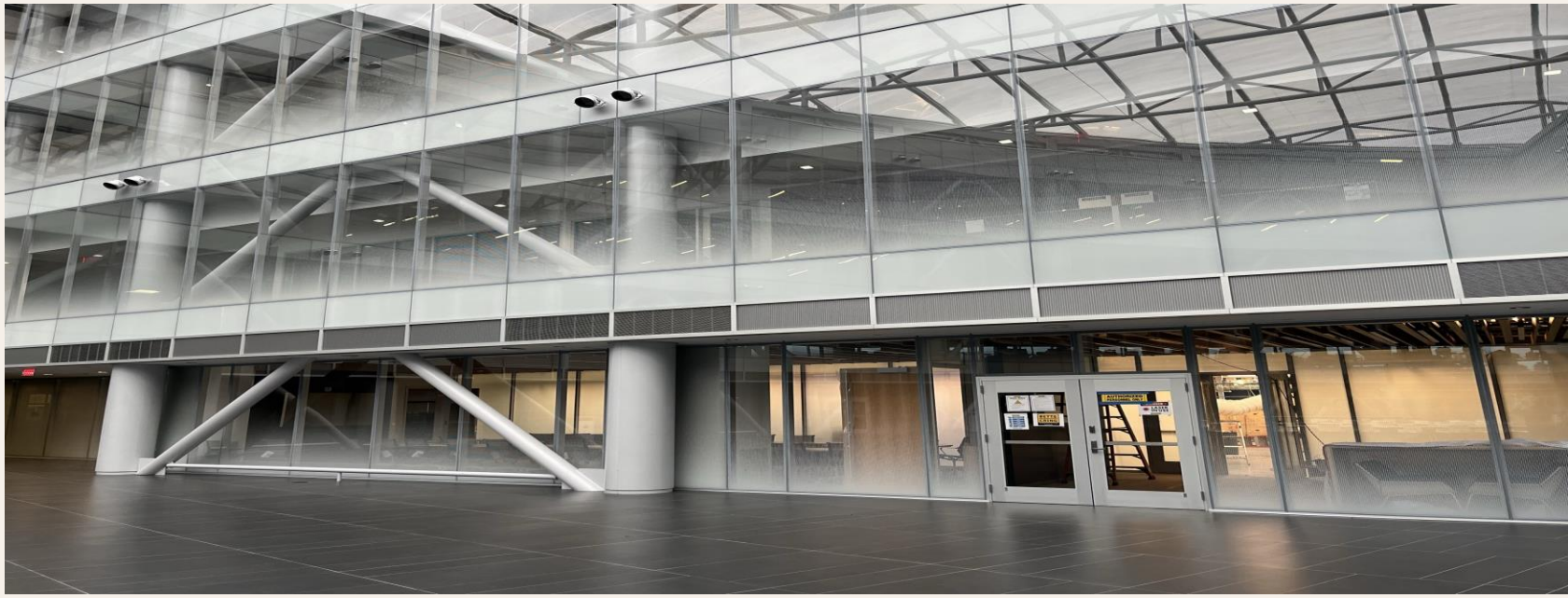
- Characterize attributes and functionality
- Identify supported grid services
- Determine maturity
- Identify constraints or development issues

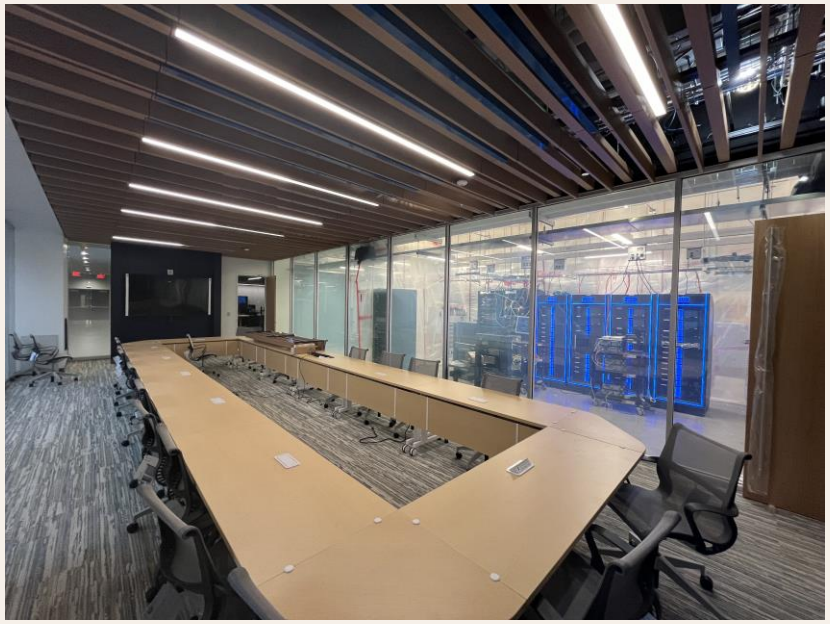
- Select most promising solutions
- Assess performance with simulation or lab demonstration
- Compare benefits and costs against traditional solutions

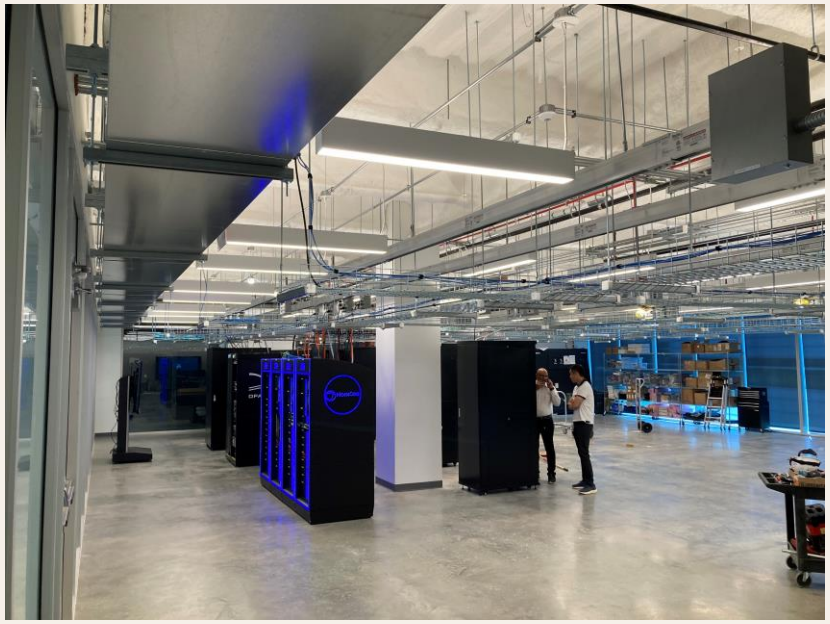
- Coordinate analysis with the CGPP
- Identify best opportunities for cost savings with advanced technologies

Update - Lab Construction

- 10,000 sq.ft. testing facility
- Grand opening scheduled on May 29th
- A one-stop shop for all NY grid stakeholders for accelerated research, development, and deployment opportunities





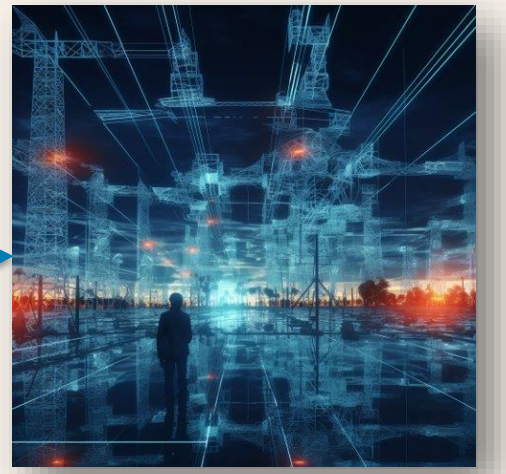


Update – Comprehensive Digital Twin of The NY State Grid

Descriptive

Informative

Predictive



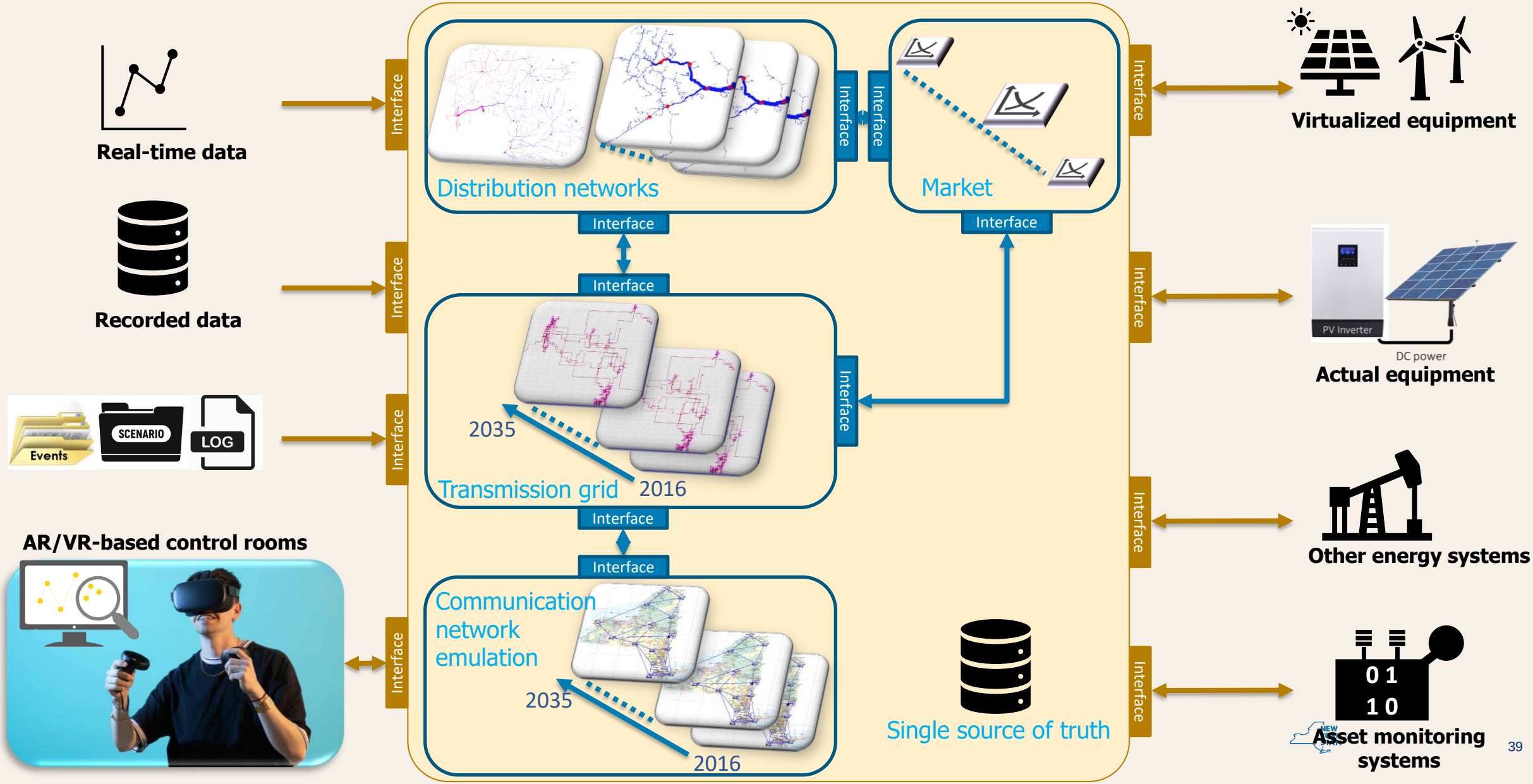
Comprehensive
Transformative

Digital Twin: A **virtual representation** of an object or system that **spans its lifecycle**, is **updated from real-time data**, and uses **simulation, machine learning and reasoning** to help **decision-making**.

Use Cases

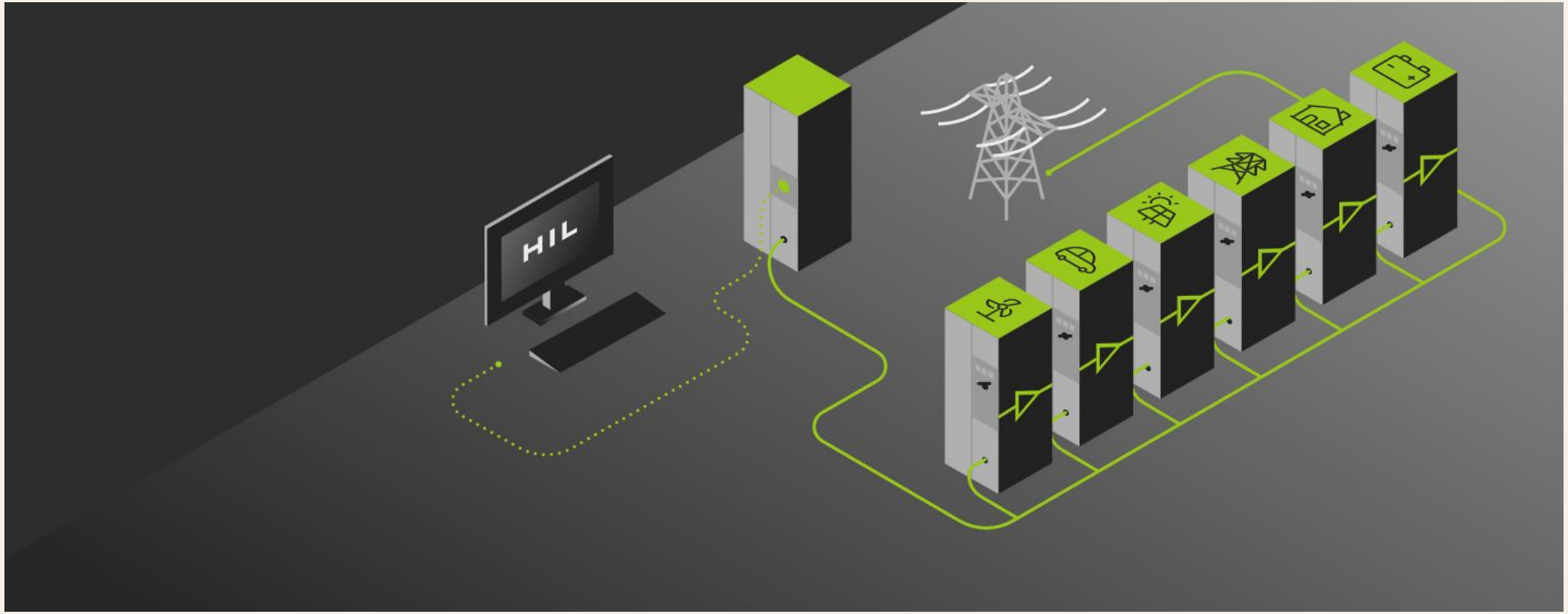
- Realistic testing of technologies
- Control room advisory by complementing expert judgement of grid operators
- Predictive operations
- Education and training
- Root-cause analysis
- Long-term decision support
- Asset management
- Field operation support
- Collaborative decision-making among stakeholders

Update – Comprehensive Digital Twin of The NY State Grid



Update – Power Hardware In The Loop (PHIL) Test Setup

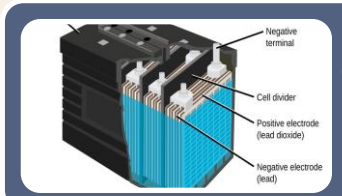
- Sized for 300 – 600 kW PHIL interface
- Supports 4-quadrant bi-directional power
- Applies realistic grid level voltage/current steady state values and transients on the DUT (Device Under Test). DUT reacts as if it is energized by the real grid.



Example Projects

Economic Assessment of DLR Operation (*NYSERDA*)

- Potential decrease in transmission congestion
- Investigate the increased revenue from transmission



Distributed & Adaptive Parameter Tuning for Hybrid PV Plants (*DOE*)

- Economic operation of hybrid PV plants
- Grid-level transient stability enhancement

Modular Power Flow Control Technology (*NYSERDA*)

- Unlock the untapped capacity of the network by MPFC
- Economic assessment of the MPFC technology

Impact of Modular Power Flow Control on Line Protection (*NYPA*)

- Identify and resolve potential relay settings
- Verify device operation and performance in conjunction with relaying equipment

BTM DER-Provided Grid Services (*DOE*)

- End-to-end aggregation and control architecture for DERs, to maximize grid services and value using BTM DERs

Example Projects

Tracking Real-time Anomalies in Power Systems (*DOE*)

- Evaluate and test intrusion detection and mitigation schemes

Real-Time Interconnection Studies and Control of New York Offshore Wind (*NYSERDA*)

- Reveal unknown dynamic impacts resulted from the grid interactions with the offshore wind farms. Develop mitigation strategies.

Universal Interoperability for grid-Forming Inverters (*DOE*)

- Enable power systems to operate with any mix of machines and inverter-based resources at any scale in an affordable, secure, reliable, sustainable, and resilient manner.
-

Instrument Transformer Monitoring using Synchrophasors (*NYPA*)

- Prevent mis-operation of protection relays
- Prevent unplanned outages, damage to substation equipment
- Minimize risk to personnel safety

Automated Generator Model Validation

- Online validation of generator model parameters for NERC compliance with no need to take the units out of service

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Interdisciplinary Science Capabilities for a Greener Future Grid at Brookhaven National Laboratory

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2024 ATWG Spring Meeting

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Grid Modeling: Current Capabilities

Grid modeling and simulation

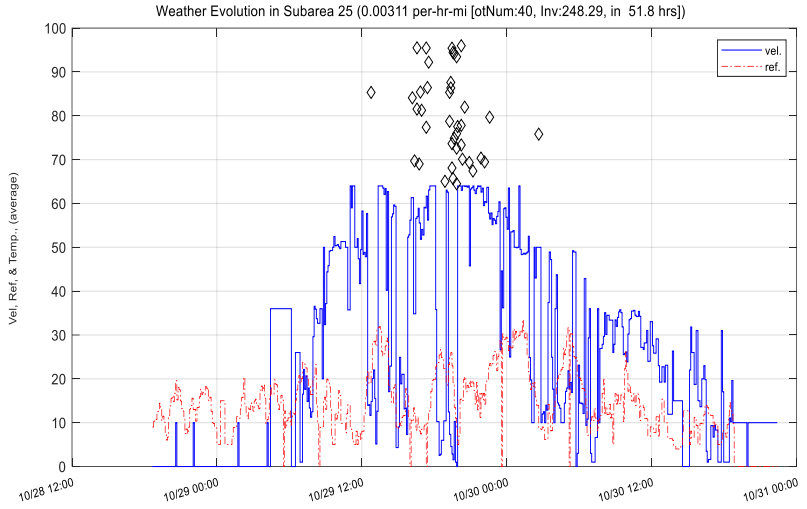
- Steady-state and dynamic impacts of renewables
- Machine-learning and physics-based transient simulator

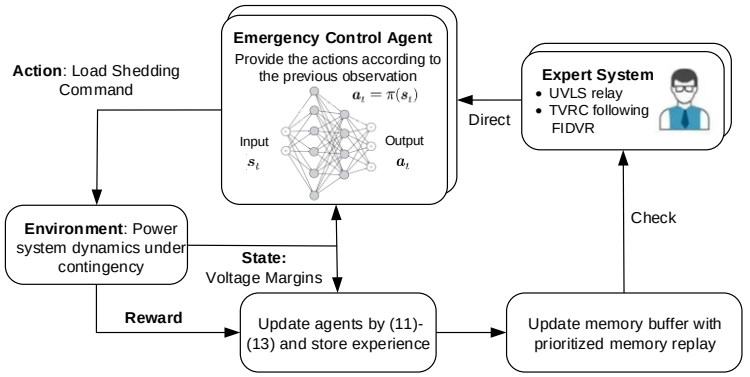
Data analytics and machine learning applications

- Model-based anomaly detection for cybersecurity
- Damage forecasting under severe weather conditions
- Data-driven stability assessment, trajectory prediction, and control

Probabilistic risk assessment

- Uncertainty modeling, quantification, and propagation
- Stochastic optimization for energy storage sizing and siting
- Probabilistic damage modeling for forecasting





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Y. Zhang, K. Tomsovic, S.M. Djouadi, M. Yue. *IET Energy Sys. Integ,* **2020,** *2(3).* 226-234.

M. Cui, J. Wang, M. Yue, *IEEE Trans. Smart Grid,* **2019,** *10(5),* 5724-5734.

Probabilistic Planning: ESS Sizing and Siting

Scenario development considering renewable and demand uncertainties

- Spatial and temporal correlation of renewable generation
- Impacts of both long-term climate change and short-term extreme weather events

Sizing and siting of energy storage systems of different technologies by formulating and solving mixed integer programming problems considering a variety of constraints including dynamics constraints

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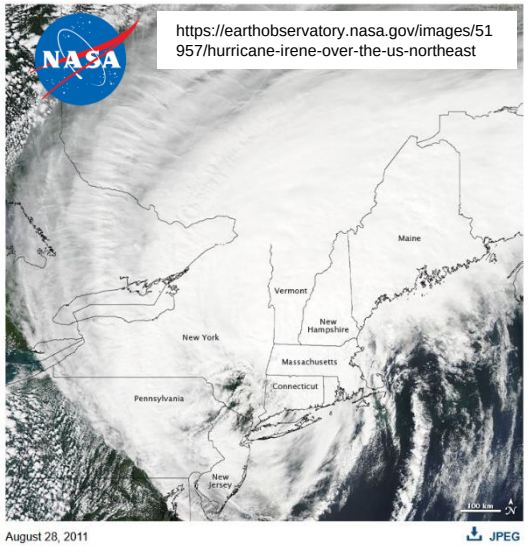
[1] T. Zhao, N. Raghunathan, A. Yogarathnam, M Yue, and P. B. Luh, “A Scalable Planning Framework of Energy Storage Systems under Frequency Dynamics Constraints,” in *International Journal of Electrical Power and Energy Systems*, Vol. 145, February 2023.
[2] B. Huang, T. Zhao, M. Yue, and J. Wang, “Two-Stage Adaptive Storage Expansion Strategy for Microgrids Using Deep Reinforcement Learning,” accepted by *IEEE Transactions on Smart Grid*, to appear.
[3] M. Yue and X. Wang, “Grid Inertial Response-Based Probabilistic Determination of Energy Storage System Capacity under High Solar Penetration,” in *IEEE Transactions on Sustainable Energy*, Vol. 6, No. 3, July 2015.

BNL LDRD: Granular Grid-Outage Nowcasting Towards Numerical Weather Prediction Forecasting



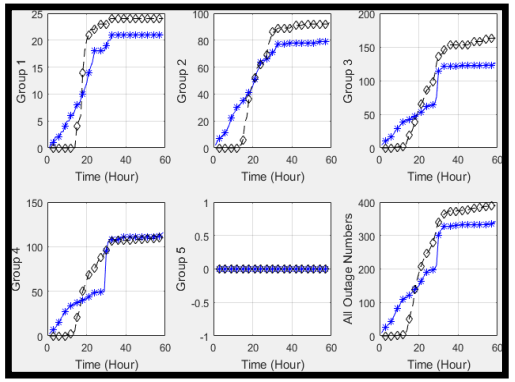
Total outages >400, most are overhead (OH) cable related

Failure rate model calculated for five areas of utility service territory

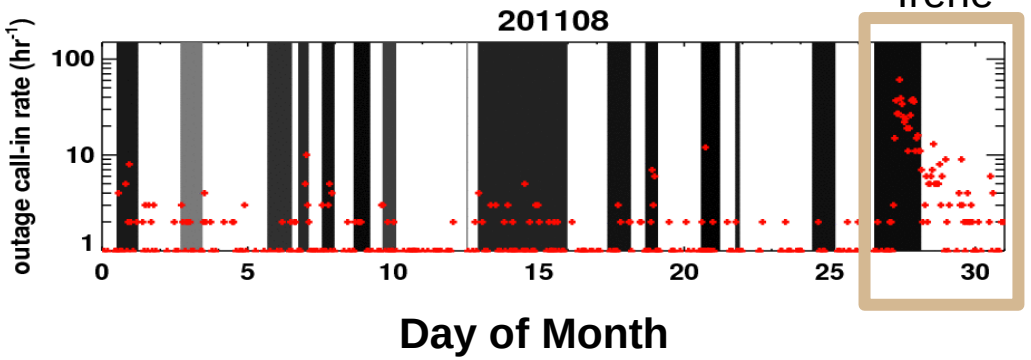
- Inputs: Hourly weather condition data and utility's component inventory.
- Output: Hourly evolution of OH outages in different areas.

Bayesian update considering both failure rate model and known outages

OH Outages (1 h interval): **actual**, **calculated**



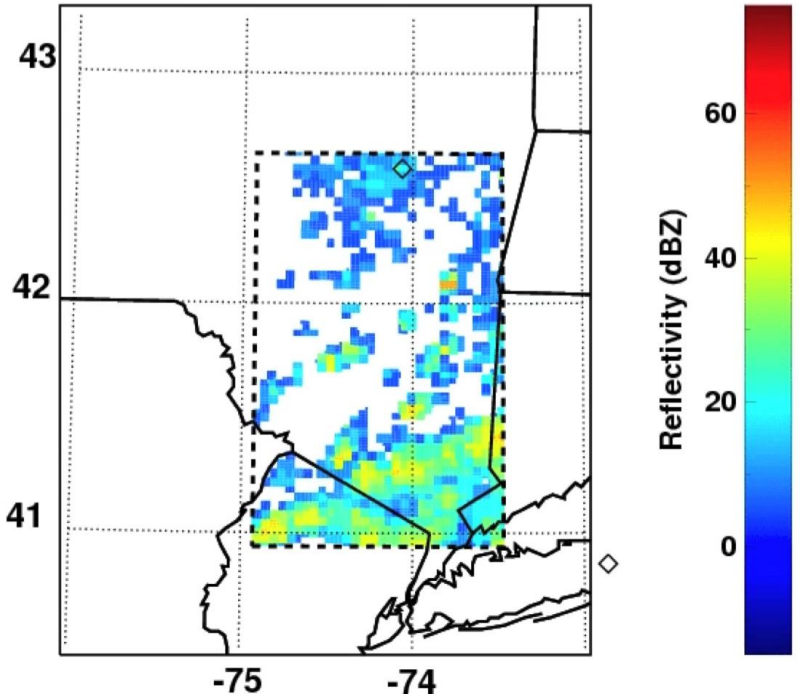
Storm-Related Utility Outages : Aug2011



Shaded areas = storm activity by radar reflectivity

\+ = general outage call in rate (hours^{-1})

Storm-Related Weather: Aug2011



Reflectivity: reflects precipitation and wind

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T. Zhao, E. Satoshi, M. Yue, M. Jensen, A. Marschilok, B. Nugent, B, Cerruti, C. Spanos, "Machine Learning-based Dynamic Granular Electric Outage Forecasting," *IEEE Resilience Week Conference Publication*, **2023,** DOI: 10.1109/RWS58133.2023.10284644.

Grid Modeling and Simulation

- Integrated transmission and distribution (T&D) modeling
  - Hybrid phasor and electromagnetic transient (EMT) simulation
  - Modeling adequacy of inverter-based resources (IBRs)
- Capturing renewables accurately
  - “Intermittency-induced outages” (IIOs) to account for fast ramping events of renewable generation
  - “Common mode IIOs” (CMOs) to account for concurrent fast-ramping events
- Tractable model with details to capture interactions among multi-scale dynamics

- Load modeling:
  - Optimal parameterization of WECC composite load model (CLM) using real-world measurement data
- HVDC meshed network modeling for onshore/offshore wind farms

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[1] A. Yogarathnam, N. R. Chaudhuri, and M. Yue, “Need for Enhanced Contingency-Dependent DER Aggregation Scheme for Transient Analysis in Modern Power Grid: A Case Study,” submitted to IEEE PES GM 2024.
[2] M. Yue, A. Yogarathnam, S. W. Kang, C. Jin, and M. Papic, “Enhanced Probabilistic Contingency Analysis Considering Fast Ramping Events of Renewable Generation,” *International Journal of Electrical Power and Energy Systems*, Volume 153, 2023.
[3] A. Yogarathnam, L. Karunaratne, N. R. Chaudhuri, and M. Yue, “Modeling Adequacy of Droop-Controlled Grid-Forming Converters for Transient Studies: Singular Perturbation Analysis,” 2023 IEEE PES Innovative Smart Grid Technologies Conference (ISGT2023).
[4] F. Zhu, T. Zhao, A. Yogarathnam, and M. Yue, “Multivariate Time-series Diffusion Model-based Generation of Transient Trajectories for Power System Applications,” IEEE T&D Conference 2024.

Cybersecurity for Power Grids

- Cybersecurity of the cloud for implementation of virtual power plants (VPPs)
- Deep learning of malware structural threat information in industry control systems (ICS) for malware detection and information sharing
- Detection, mitigation, and impact assessment of cyberattack-induced anomalies in essential demand and renewable forecasting data
- ML-based online data purification scheme against both white-box and black-box adversarial disturbances for grid stability assessment
- Trustworthy ML/AI applications to power grid control
  - A framework to integrate safety constraints into reinforcement learning (RL)-based control design using control barrier functions

[1] T. Zhao, M. Yue, and J. Wang, "Robust Power System Stability Assessment Against Adversarial Machine Learning-Based Cyberattacks via Online Purification," in IEEE Transactions on Power Systems, vol. 38, no. 6, pp. 5613-5622, Nov. 2023, doi: 10.1109/TPWRS.2022.3233735.

[2] T. Zhao, B. Beckman, M. Yue, and R. Foster, “ESE: A Tool for Enhanced STIX Elevation,” Resilience Week, September 2022.

[3] M. Yue, T. Hong, and J. Wang, “Data Analytics Based Anomaly Detection in Time Series Data for Online Cybersecure Load Forecasting,” in *IEEE Transactions on Smart Grid*, Vo. 1, No. 1, January 2019.

[4] Zhao, J. Wang, and M. Yue, "A Barrier-Certificated Reinforcement Learning Approach for Enhancing Power System Transient Stability," in *IEEE Transactions on Power Systems*, vol. 38, no. 6, pp. 5356-5366, Nov. 2023, doi: 10.1109/TPWRS.2022.3233770.

Dynamic Assessment and Control design

- Deep reinforcement learning-based emergency control
  - A fully distributed, graph-attention multi-agent framework for emergency control – under voltage load shedding
- Coordinated nonlinear control design for grid-forming and grid-following converters
- Wind energy system control
  - Data-driven wake steering control of wind turbines
  - Coordination and control of hybrid renewable-ESS energy systems for frequency and voltage support
- Online data-driven AI/ML for stability assessment, trajectory prediction, and control design
  - Predict the post-contingency state trajectories enabling online control for stability enhancement
  - ML and physics-informed grid simulator for fast full transient assessment

[1] L. Karunaratne, N. R. Chaudhuri, A. Yogarathnam, and M. Yue, “Nonlinear Backstepping Control of Grid-Forming Converters in Presence of Grid-Following Converters and Synchronous Generators,” in *IEEE Transactions on Power Systems*, vol. 39, no. 1, pp. 1948-1964, Jan. 2024..

[2] T. Zhao, M. Yue, and J. Wang, "Deep-Learning-Based Koopman Modeling for Online Control Synthesis of Nonlinear Power System Transient Dynamics," in *IEEE Transactions on Industrial Informatics*, vol. 19, no. 10, pp. 10444-10453, Oct. 2023

[3] T. Zhao, M. Yue, and J. Wang, “Structure-informed Graph Learning of Networked Dependencies for Online Prediction of Power System Transient Dynamics,” in *IEEE Transactions on Power Systems*, Vol. 37, No. 6, November 2022.

[4] T. Zhao, M. Yue, and J. Wang, "Deep-Learning-Based Koopman Modeling for Online Control Synthesis of Nonlinear Power System Transient Dynamics," in *IEEE Transactions on Industrial Informatics*, vol. 19, no. 10, pp. 10444-10453, Oct. 2023, doi: 10.1109/TII.2023.3240939.

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Expertise and Facilities Powering BNL's Grid Modeling:

Northeast Solar Energy Research Center (NSERC)

- A 907kW solar test facility on BNL Campus
- Array connected to BNL electrical grid
- Instrumented for environmental and electrical data acquisition
- Smart grid technology and equipment testbed

Long Island Solar Farm (LISF)

- 32 MWac solar photovoltaic plant
- Built through a collaboration of BP Solar, the Long Island Power Authority (LIPA), and the Department of Energy
- Although the LISF is a privately owned facility, BNL installed instrumentation throughout the solar array and collects high-resolution data that can be used for research purposes

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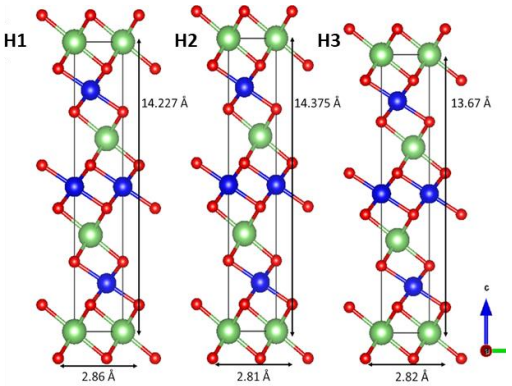
Characterizing Battery Lifetime and Mechanism *Operando*

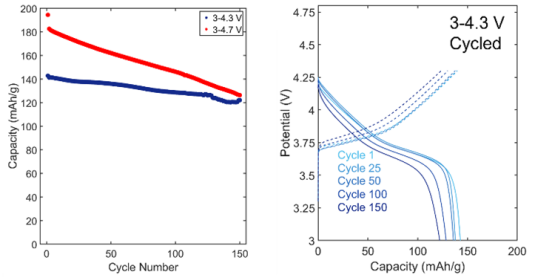
Battery degradation mechanisms were elucidated using *operando* synchrotron based X-ray characterization, scanning probe methods, and microcalorimetry



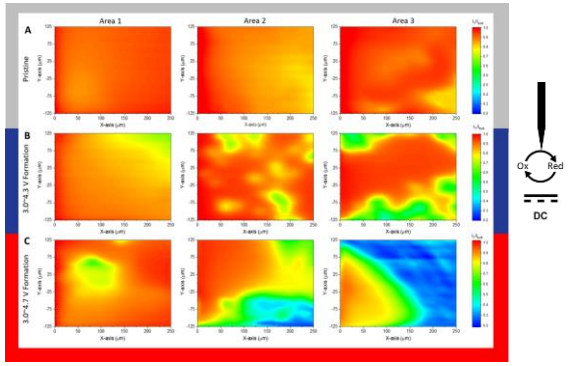
Lithium nickel manganese cobalt oxide (NMC), $LiNi_xMn_yCo_zO_2$

National Synchrotron Light Source II (NSLS-II) at BNL

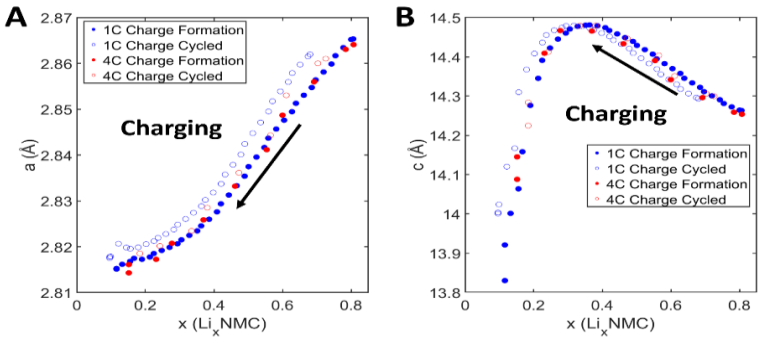
electrochemistry

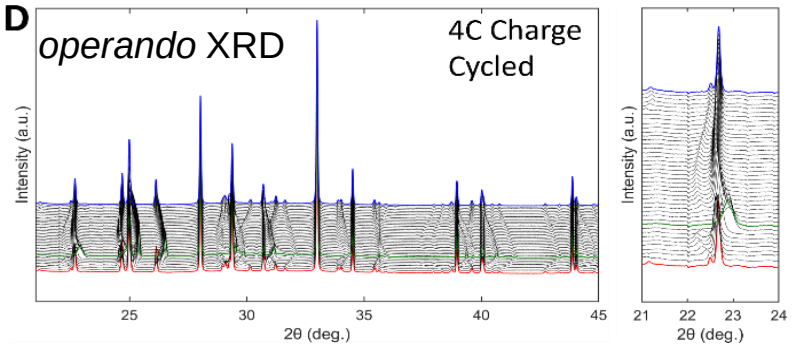


scanning probe analysis



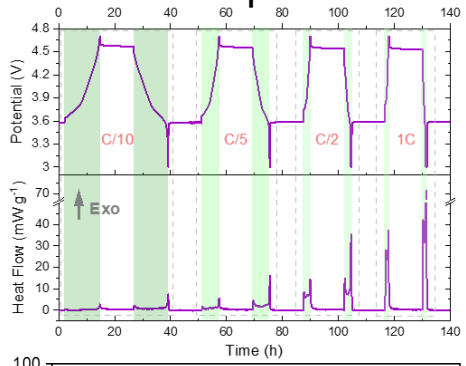
tracking structural change during fast charge

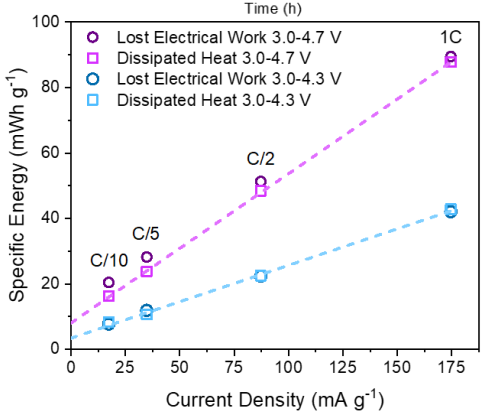




quantifying heat vs work

$\Delta E = q + w$





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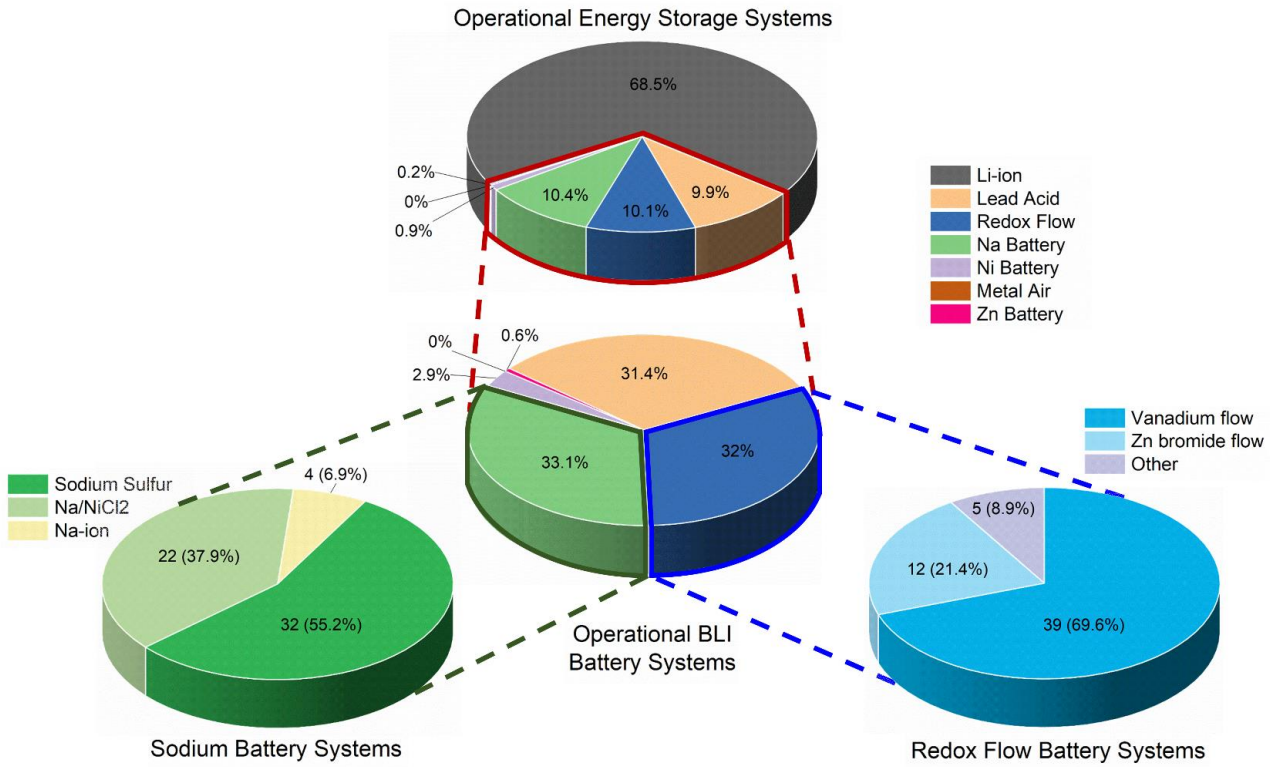
C.D. Quilty, G.P. Wheeler, L. Wang, A.H. McCarthy, S. Yan, K.R. Tallman, M.R. Dunkin, X. Tong, S. Ehrlich, L. Ma, K.J. Takeuchi, E.S. Takeuchi, D.C. Bock, A.C. Marschilok, *ACS Appl. Mater. Interfac.* **2021,** *13(43),* 50920–50935.

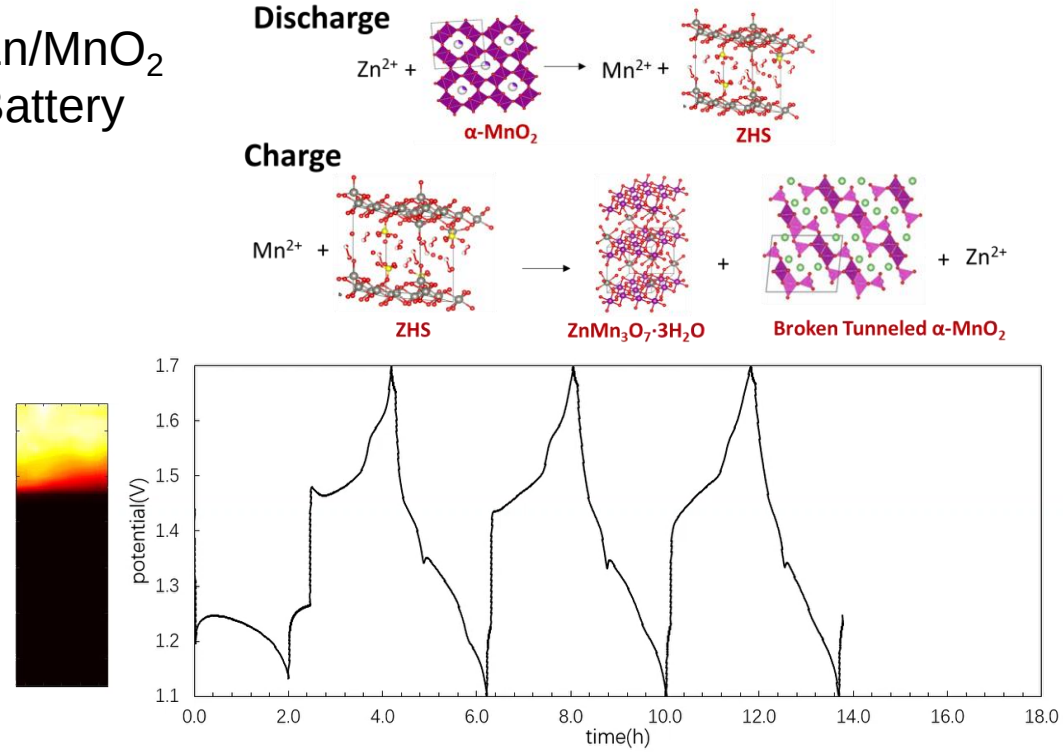
C.D. Quilty, P.J. West, G.P. Wheeler, L.M. Housel, C.J. Kern, K.R. Tallman, L. Ma, S. Ehrlich, C. Jaye, D.A. Fischer, K.J. Takeuchi, D.C. Bock, A.C. Marschilok, E.S. Takeuchi, *J. Electrochem. Soc.,* **2022,** *169,* 020545.

Safe, Low Cost, Environmentally Friendly Batteries

Due to lifetime, safety, and raw material sourcing concerns, alternative technologies to lithium ion batteries are desired for large scale (grid level) energy storage
Investigating new materials and chemistries for next-gen safe, sustainable batteries



Zn/MnO_2 Battery



"Beyond Li-Ion Batteries for Grid-Scale Energy Storage," G.P. Wheeler, L. Wang, A.C. Marschilok, in *Elements in Grid Energy Storage,* **2022.** Ed. B. Chalamala, V. Sprenkle, I. Gyuk, R. Masiello, R. Byrne, V. Gupta.

D. Wu, L.M. Housel, S-J. Kim, N. Sadique, C.D. Quilty, L. Wu, R. Tappero, S.L. Nicholas, S. Ehrlich, Y. Zhu, A.C. Marschilok, E.S. Takeuchi, D.C. Bock, K.J. Takeuchi, *Ener. Environ. Sci.,* **2020,** *13,* 4322-4333.

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QUESTIONS

Advanced Technology Concept Papers

Concentric Energy Advisors

SCOUTING NEW GRID TECHNOLOGIES

The call for Concept Papers seeks new ideas for grid technologies to support the goals of the CLCPA.

STRATEGIC OBJECTIVES

- Improve deliverability of renewable energy by reducing T&D constraints
- Optimize use of existing transmission lines and rights-of-way
- Increase infrastructure load factor

BENEFICIAL OUTCOMES

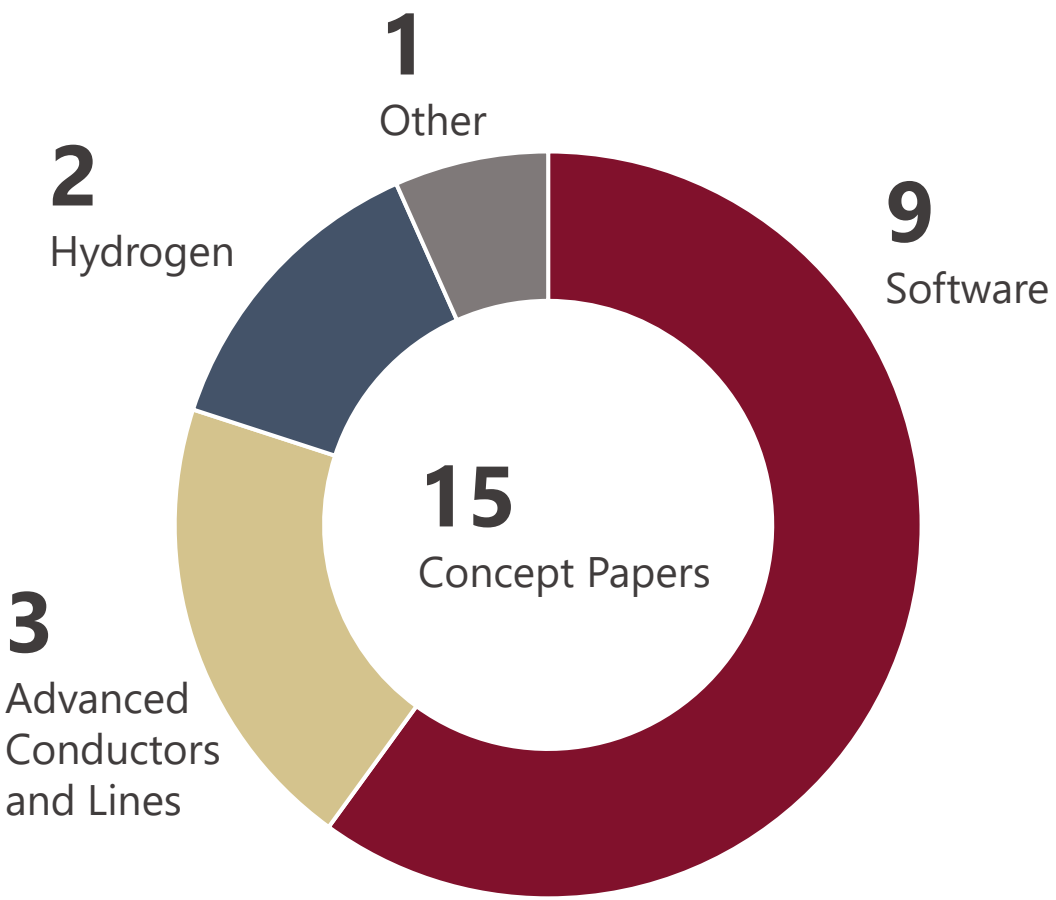
- Enhance grid reliability, security, and efficiency
- Facilitate integration of clean energy resources
- Reduce costs for consumers
- Advanced technology and innovation in New York

SOLUTION SPACE

- System planning
- System operations
- Infrastructure
- Asset management
- Energy systems integration

CONCEPT PAPERS

We received fifteen Concept Papers covering a range of grid technologies.



SOFTWARE

- DER management and grid flexibility (4)
- Grid monitoring and management (4)
- DERs or DER integration (1)

ADVANCED CONDUCTORS AND LINES

- Compact line design (1)
- Composite conductors (1)
- Superconductors (1)

HYDROGEN

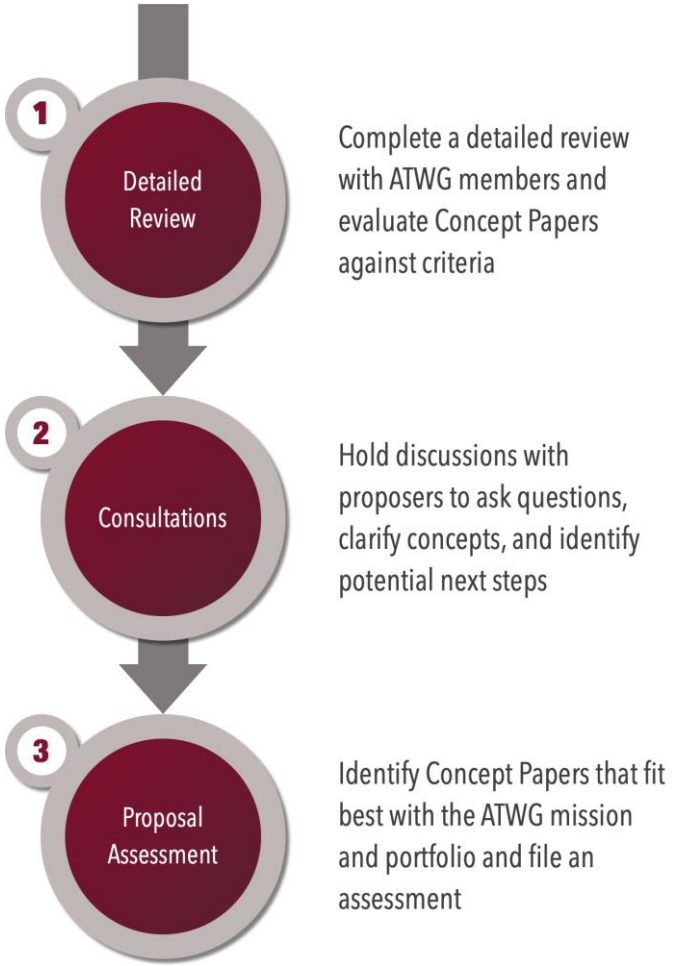
- Fuel cell electricity generation (1)
- Production, storage, and electricity generation (1)

OTHER

- Electricity infrastructure cooling (1)

NEXT STEPS

The ATWG will file an initial assessment of concept paper submissions within 60 days of this conference.



REVIEW CRITERIA

- Alignment with the stated scope.
- Technical feasibility of the proposed technology.
- Commercial maturity and the technology's ability to be deployed in New York.
- Demonstrated record of deployment with performance data.
- Availability and transparency of cost information.

ASSESSMENT

- Within 60 days of this conference, the ATWG will file its initial assessment of the proposals (Concept Papers) consistent with PSC Guidance.

QUESTIONS

Wrap-up and Next Steps

Jason Pause, Department of Public Service

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