GMLC 1.1: Metrics Analysis
(Foundational Analysis for GMLC Establishment)

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

This project assesses the feasibility and usefulness of metrics for measuring change in the evolving electricity infrastructure. Metrics and associated methods are being developed to assess the power grid's evolution with respect to characteristics that are organized into the following six categories: **Reliability, resilience, flexibility, sustainability, affordability, and security.**

Expected Outcomes

- Validation and adoption of metrics with stakeholders and regional partners

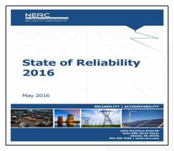
PROJECT FUNDING			
	FY16 $	FY17$	FY18 $
total	1581	1584	1584

Reliability

Lead: Joe Eto (LBNL)

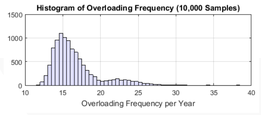
Value: new metrics for reliability value-based planning and bulk power system assessment

New metrics for distribution that capture the economic cost of interruptions to customers



New metrics for system impacts using North American Electric Reliability Corporation transmission/generation availability data

New probabilistic transmission planning metrics

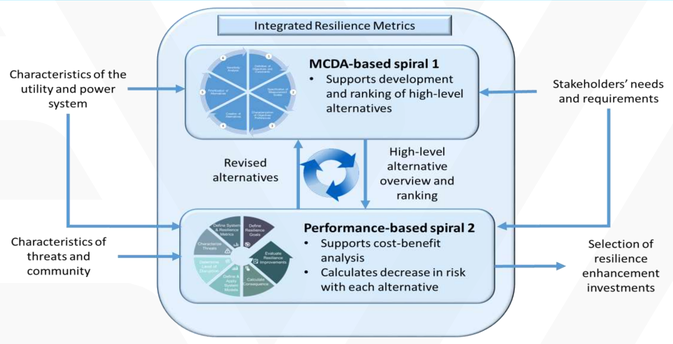


Accomplishments Year 1+2:
- APPA has incorporated ICE Calculator into eReliability Tracker
- Membership in NERC Performance Analysis Subcommittee (responsible for preparing Annual State of Reliability report)
- Demonstration prob. transmission planning metrics with ERCOT in progress

Resilience

Leads: Vanessa Vargas (SNL)
Jim Kavicky (ANL)

Value: create new metrics/process for resilience investment.



Accomplishments Year 1+2:
- Developed and documented performance-based resilience metric design for electric power infrastructure
- Document the methodologies and differences between performance-based and attribute-based approach
- Engaged stakeholders and provided decision support in New Orleans
- Designed economic metrics (performance based) to evaluate local resilience benefits
- Developed initial MCDA survey mechanism

Flexibility

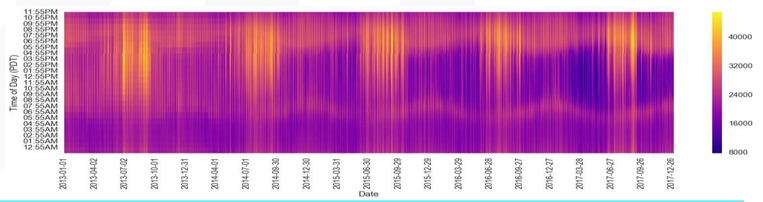
Lead: Tom Edmunds(LLNL)

Value: Develop and demonstrate usefulness of new flexibility metrics

Developed large set of candidate metrics that represent network properties of flexibility and lack of flexibility, engaging stakeholders to identify most useful metrics

Lagging indicators
- Requires statistical analysis of market and grid conditions to reveal curtailments, loss of load, or other economic impacts caused by insufficient flexibility.

Leading indicators
- Requires production cost simulations with weather and other uncertainties to design for sufficient flexibility.
- Use production cost models to examine tradeoffs between different sources of flexibility.



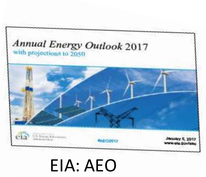
Accomplishments Year 1+2:
- Reduced 23 metrics down to 5 essentials
- Wrote software to visualize data and reveal trends with 5-years of CAISO & ERCOT data
- Presentations to CAISO & ERCOT

Sustainability

Lead: Garvin Heath (NREL)

Value: Identify needed improvements to GHG and water metrics and reporting

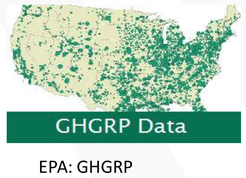
- Evaluated current federal data products' ability to track changes in electric-sector CO_2 emissions that may result from future grid modernization; identified coverage gaps for certain energy sources anticipated to grow.
- Completed survey of available water scarcity metrics.
- Engaged with EIA and other stakeholders to improve federal data products' ability to track changes in electric-sector CO_2 emissions from distributed generation (DG).



EIA: AEO

EPA: eGRID

EIA: MER



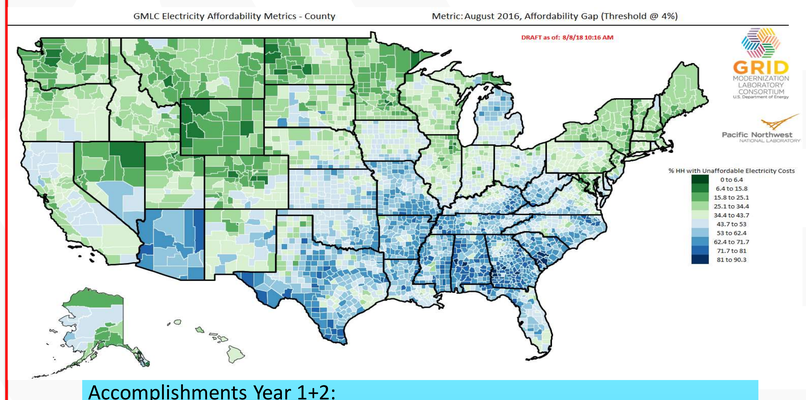
EPA: GHGRP

Accomplishments Year 1+2:
• EIA survey teams are changing forms to better capture DG penetration in manufacturing (MECS), commercial (CBECS) and utility systems (861)
• Demonstrated need for new *Relative Water Risk* metric

Affordability

Lead: Dave Anderson (PNNL)

Value: Establish new metrics based on electricity cost burden on consumers



Accomplishments Year 1+2:
- Electricity cost-burden metrics published
- Alaska use case completed
- National affordability dashboard
- Macro affordability metrics developed
- Continued engagement with data partners

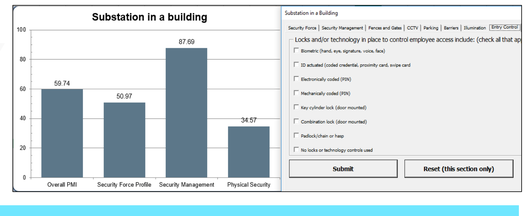
Security

Lead: Steve Folga (ANL)

Value: Spur electric industry adoption of DHS Protective Measures Indices (PMI) for physical security metrics

Physical Security Metric:
- Measures the ability of electric sector to resist to disruptive events such as man-made attacks, etc.
- Accounts for existing protective measures at electric assets and their relative importance
- PMI approach has been applied by DHS at over 600 electric facilities
- PMI approach has been modified for use by Public Safety Canada and European Commission

Defines "security" as reducing the risk to critical infrastructure by physical means or defense cyber measures to intrusions, attacks, or the effects of natural or manmade disasters (PPD 21)



Accomplishments Year 1+2:
- Developed survey methodology for Protective Measurement Index (PMI) for physical security based on DHS data
- Endorsed by DHS and utilities (ComEd, Idaho Falls)
- Completing initial version of survey tool (Excel) with dashboard capability (*shown above*)
- Continuing outreach to EEI and electric sector

U.S. DEPARTMENT OF ENERGY

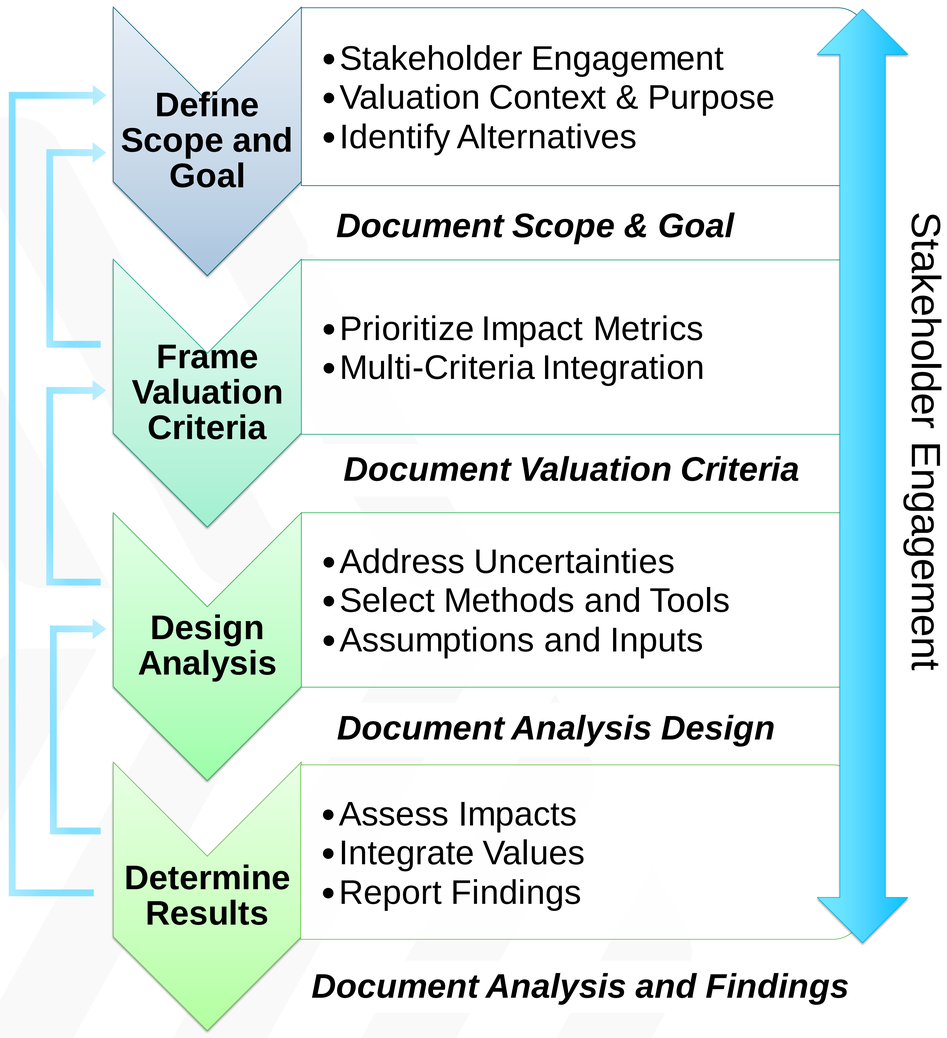
Institutional Support

Grid Services & Technologies Valuation Framework – GMLC 1.2.4

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

Develop a valuation framework that will allow electricity-sector stakeholders to **conduct, interpret, and compare valuation studies** of existing and emerging grid services and technologies with high levels of **consistency, transparency, repeatability, and extensibility**.



Expected Outcomes

Framework will be a systematic approach to conduct and interpret valuations of grid technologies and services:

- Increased transparency.
- Ability to identify value beyond monetary savings and costs.
- Guidance applicable to a broad range of applications.
- Initiate acceptance of Phase I Framework through Stakeholder Advisory Group (SAG).

A foundation for a long-term vision of improved, broadly consistent valuation principles.

Significant Milestones	Date
Initial SAG Workshop	Sept. 2016
Initial Framework 1.0	June 2017
Test Case #1: Bulk System	Aug. – Dec. 2017
SAG Workshop	Dec. 2017
Revised Framework 2.0	May 2018
Test Case #2: Distribution	Apr. – Oct. 2018
Revised Framework 2.1	Aug. 2018
External Review	Sept. – Oct. 2018
Framework Guidance 3.0	Dec. 2018

Accomplishments

Established Stakeholder Advisory Group (SAG)

- Crucial industry & regulator involvement

Developed Initial Valuation Framework

- Revised and refined Framework with input from SAG and Test Cases

Test Case #1: Use of Framework to ***Compare Studies***

- Nuclear Power Subsidies in Three States
- Valuation structure works
- Imposing the discipline of the structure on the studies could have reduced costs, improved credibility

Test Case #2: Use of Framework to ***Construct Study***

- Microgrid alternatives for distribution upgrade
- Considered multiple value criteria, including resilience
- Used SAG as “role players”
- SAG concluded process flow improved valuation quality: ***transparency, repeatability & credibility***
- Revised Framework with SAG insights

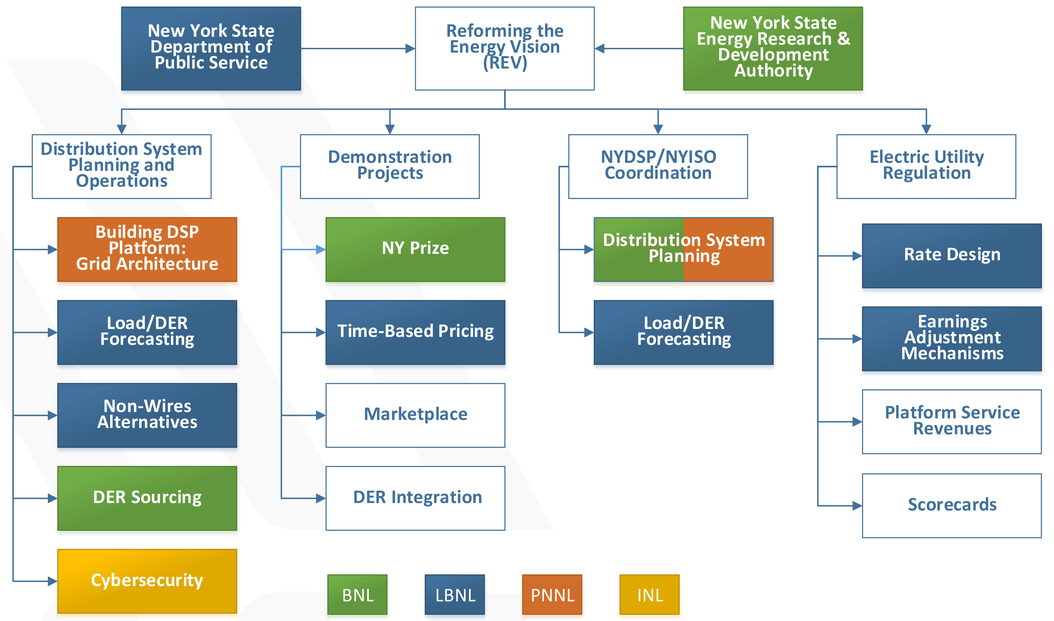
1.3.22 Technical Assistance to New York REV

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

The New York State Reforming the Energy Vision (REV), initiated in 2014, will fundamentally change the operation of the electric grid in New York State to a more distributed, consumer-focused energy delivery system.

This GMLC project is providing objective technical assistance by a team of experts from the national laboratories to New York State agencies and policy makers to enable the REV, and, as a result, gain knowledge that can be leveraged for DOE's Grid Modernization Initiative.



Expected Outcomes

- Technical guidance provided to regulators, policy makers and stakeholders to address challenges associated with establishing a Distributed System Platform envisioned by REV
- Insights on what business models work and why, as well as customer adoption of the REV model
- Lessons learned from REV on deploying DER at the distribution level that can be applied to grid modernization efforts in other states

Significant Milestones	Date
Identify high priority TA tasks by NYS Agencies	7/15/16
Annual progress report and lessons learned from REV	12/31/16
Midterm progress report and lessons learned from REV	5/1/17
Final annual progress report	10/1/17
Summary report with insights and lessons learned from REV	10/1/17

Progress to Date

- Supported NYDPS staff on development of new business model elements: earning adjustment mechanisms, scorecards metrics, and platform service revenues.
- Supported utilities and NYDPS staff on designing and implementing innovative pricing pilots and demonstration projects
- Supported NYDPS staff, utilities, and other stakeholders on grid architecture issues associated with REV
- Provided a set of cybersecurity standards for non-traditional utility market participants
- Supported NYSERDA for NY Prize competition intended to support the planning and development of community microgrids

Distribution System Decision Support Tool Development and Application

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

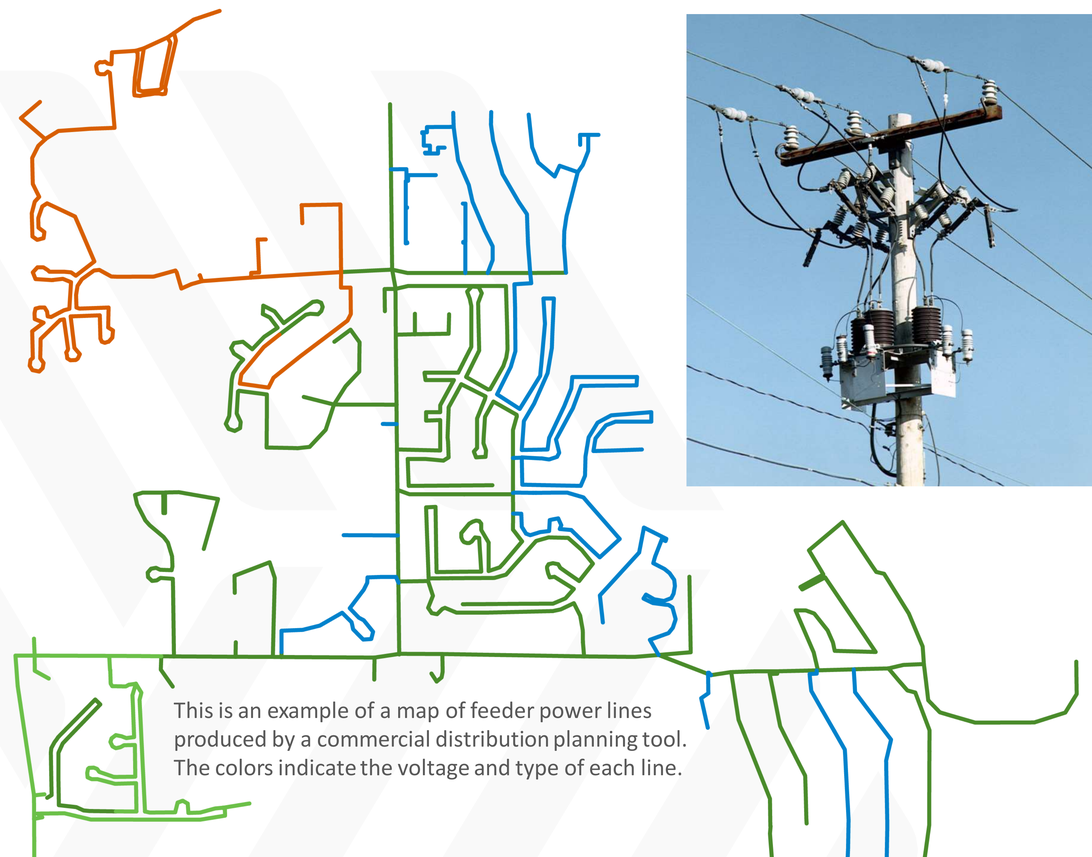
Project Description

Identify strategies and provide technical assistance to state regulators and utilities on advanced electric distribution planning methods and tools. These efforts focus on incorporating emerging grid modernization technologies and the significant deployment of distributed energy resources.

Expected Outcomes

- State utility regulators gain the understanding they need to oversee modernization of the grid and approve utility cost recovery for prudent grid modernization investments.
- Gaps between existing and emerging distribution planning practice are identified, and utilities and regulators have recommended strategies and tools to advance planning processes.

Significant Milestones	Date
Publish a report on the status of emerging distribution planning practices by states for addressing high levels of DER penetration in distribution systems	Dec 2017
Conducted three workshops for state utility regulators on distribution system planning and emerging issues. (33 states represented)	May 2018
Publish a technical report that identifies remaining gaps, development requirements, and lessons learned on distribution system planning tools.	Sept 2018



This is an example of a map of feeder power lines produced by a commercial distribution planning tool. The colors indicate the voltage and type of each line.

Progress to Date

- Technical assistance to states assessing and deploying grid modernization and support for planning organizations.
- Summary report on commercial distribution system analysis tools, including maturity and gaps, for addressing high levels of DERs.
- Detailed summary of state activities in distribution system planning with DERs and grid modernization - from a regulatory perspective.
- Developed, facilitated and presented at Regional PUC workshops targeted at state utility regulators on distribution system planning and emerging issues.

Links provided in presentation, to be posted at 2018 GMI Peer Review.

1.4.29 Future Electric Utility Regulation

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

- Provide technical assistance and analysis for public utility commissions and a series of reports with multiple perspectives on evolving utility regulation and ratemaking, utility business models and electricity markets:
  - Adapting to new technologies and services
  - Assessing potential financial impacts on utilities and customers
  - Engaging consumers
  - Addressing utility incentives to achieve grid modernization goals

Expected Outcomes

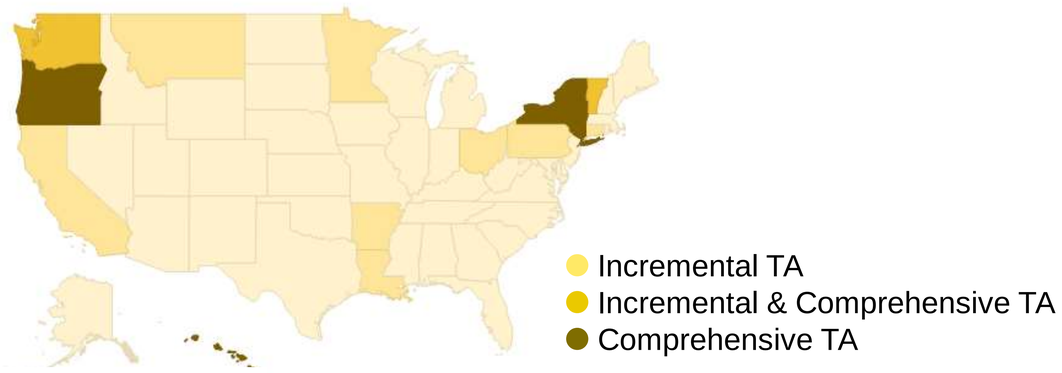
- States will have improved capability to consider alternative regulatory and ratemaking approaches to enable grid modernization investments.
- Approaches will better tie utility earnings to consumer value, economic efficiency, and other policy goals.
- Ultimately, states will provide utilities with regulatory guidance and incentives to efficiently deploy capital to achieve grid modernization goals.

Significant Milestones	Date
Upgrade financial modeling tools and assess financial impacts of new technologies and services on utilities and customers	10/1/16, 10/1/17
Complete 6 reports for Future Electric Utility Regulation series by electric industry thought-leaders	4/1/17, 5/15/17, 11/1/17, 8/1/18, 1/1/19, 1/1/19
Publish technical report on performance-based regulation (PBR) with case studies and results of productivity and incentive power research	5/15/17
Provide technical assistance on financial impacts for 3-4 states each year	10/1/17, 1/1/19
Provide technical assistance on PBR, distribution services markets, energy services pricing to 2-4 states each year	10/1/17, 1/1/19

FUTURE ELECTRIC
Utility Regulation

Progress to Date

- Technical assistance to states:



- Financial modeling tools and analysis
  - Upgraded FINancial impacts of Distributed Energy Resources model and assessed combined financial effects of aggressive 10-year ramp-up of energy efficiency and distributed solar on utility costs and returns and customer rates and bills
  - Upgraded Integrated Energy System Model and evaluated impact of several time-based rate designs on energy consumption patterns (with and without enabling control technology) and associated distribution grid impacts
- Future Electric Utility Regulation series (see feur.lbl.gov)
  - *The Future of Centrally-Organized Wholesale Electricity Markets* (March 2017)
  - *Regulatory Incentives and Disincentives for Utilities Investments in Grid Modernization* (May 2017)
  - *Value-Added Electricity Services: New Roles for Utilities and Third Parties* (October 2017)
  - *The Future of Transportation Electrification: Utility, Industry, and Consumer Perspectives* (August 2018)

Market and Reliability Opportunities for Wind and Bulk Power System

Partners: NREL, ANL, EPRI

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

WETO 3.1.0.408

Project Description

Wholesale electricity markets exist to schedule and dispatch generating units, given demand and the transmission network configuration, at minimum cost to the system. The goal of this project is to assess **reliability** and **revenue sufficiency** impacts under a wide range of market design options and revenue sources. Key research questions include:

- How do reliability needs evolve with different system fleets?
- As the system evolves, how well does the system meet needs?
- What are the options to meet those needs?

Expected Outcomes

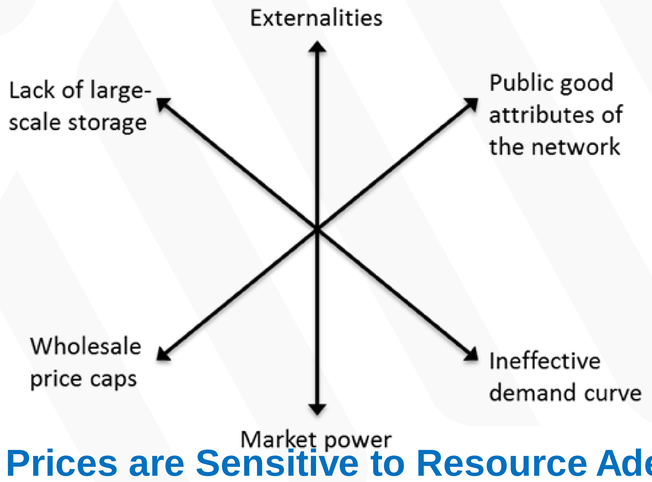
- Improved modeling and insights into the functioning of electricity markets
- Increased expertise of strategic decision making for investments and operations
- Quantitative impact of various electricity market designs for ensuring system reliability and economic efficiency in an evolving power system

Significant Milestones	Date
Modeling analysis of operating reserves requirements and strategic generator bidding behavior in RTS-GMLC using a production cost model	March 2017
Analysis of historic capacity market data	February 2018
Technical report on the challenges of marginal cost pricing in wholesale electricity markets with high wind and solar penetration levels	December 2017
Develop ERCOT-like production cost model database with various wind buildout futures	September 2017
Develop a game theoretical model for capacity expansion	June 2018
Journal article draft on the impact of reliability level on energy prices with various wind penetration levels	June 2018
Journal article draft on impact of variable renewable energy (VRE) policies on wind investments, energy prices and power market outcomes	September 2018
Modeling analysis of operating reserve price and eligibility assumptions in ERCOT-like system with various wind penetration levels	September 2018

U.S. DEPARTMENT OF ENERGY

Progress to Date

Electricity Markets are Complex – Identifying and informing on six attributes preventing perfectly competitive markets

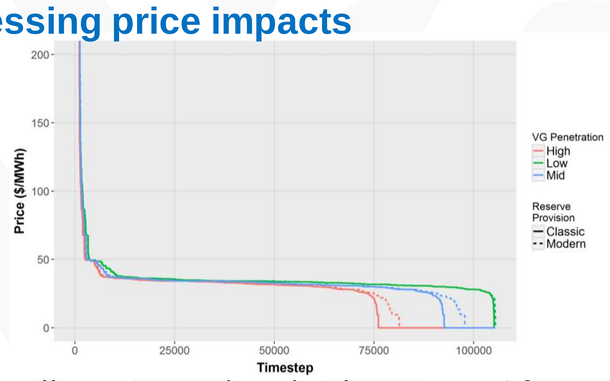


Marginal-cost pricing alone cannot guarantee cost recovery outside of perfect competition, and current electricity market structures have at least six attributes that preclude them from functioning as perfectly competitive markets.

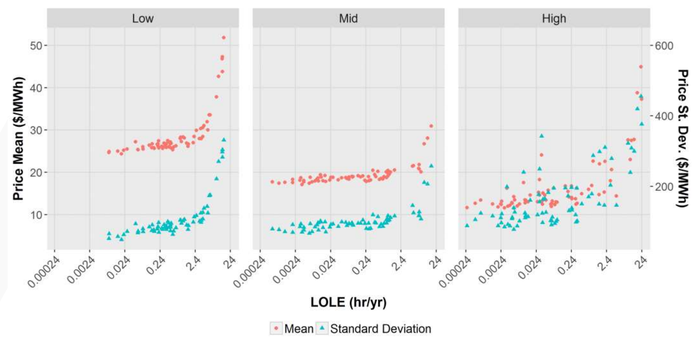
More wind and other VRE can further exacerbate revenue sufficiency and resource adequacy.

Milligan, Michael, Bethany A. Frew, Kara Clark, and Aaron P. Bloom. 2017. "Marginal Cost Pricing in a World Without Perfect Competition: Implications for Electricity Markets with High Shares of Low Marginal Cost Resources." NREL/TP-6A20-69076. National Renewable Energy Lab. (NREL), Golden, CO (United States).

Prices are Sensitive to Resource Adequacy – Designing methods and assessing price impacts



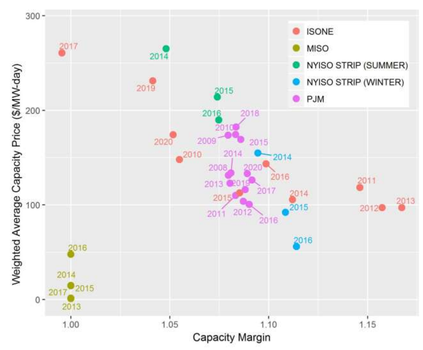
Allowing wind and solar to **provide reserves** ("Modern") can increase energy prices relative to alternative "Classic" case



Mean and standard deviation of energy **prices decrease** with increasing system resource adequacy, driven primarily by decreasing scarcity pricing events

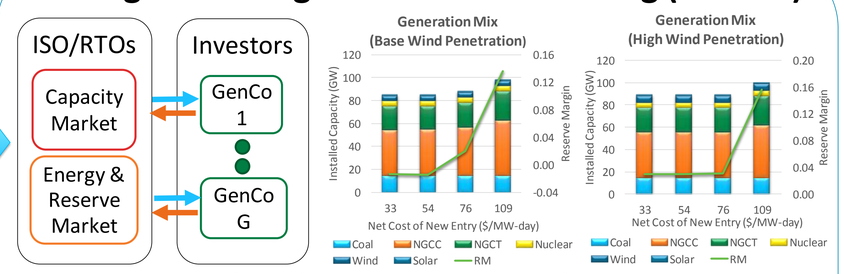
Capacity Market Rules and Investor Behavior Matters – Developing game theoretical model for capacity expansion

Capacity Market Design



No convergence on treatment of VRE in capacity market design

Strategic Multi-Agent Resource Planning (SMARP)

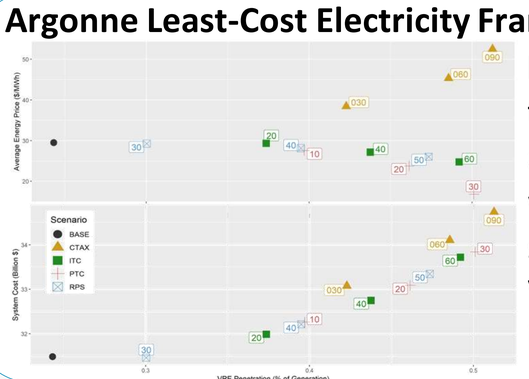


Proper market design is key to achieving long-term resource adequacy in a competitive market environment with high VRE penetration levels

VRE Incentive Schemes

Direct and indirect policies to support VRE can result in different market outcomes

Argonne Least-Cost Electricity Framework (ALEAF)



Energy price trends are not always aligned with changes in system costs as VRE penetrations increase