Institutional Support: Portfolio Overview

Charles Goldman, Staff Scientist

Lawrence Berkeley National Laboratory

Grid Modernization Initiative Peer Review
,September 4-7, 2018

Institutional Support

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

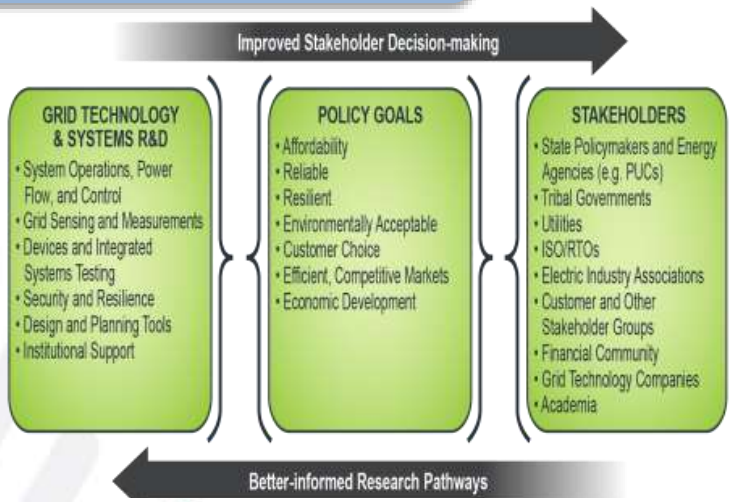
Supporting and managing institutional change in a period of rapid (and potentially disruptive) technological innovation

Expected Outcomes

- Address high priority grid modernization challenges and needs identified by electric power industry stakeholders, with particular emphasis on state policymakers and regional planning organizations

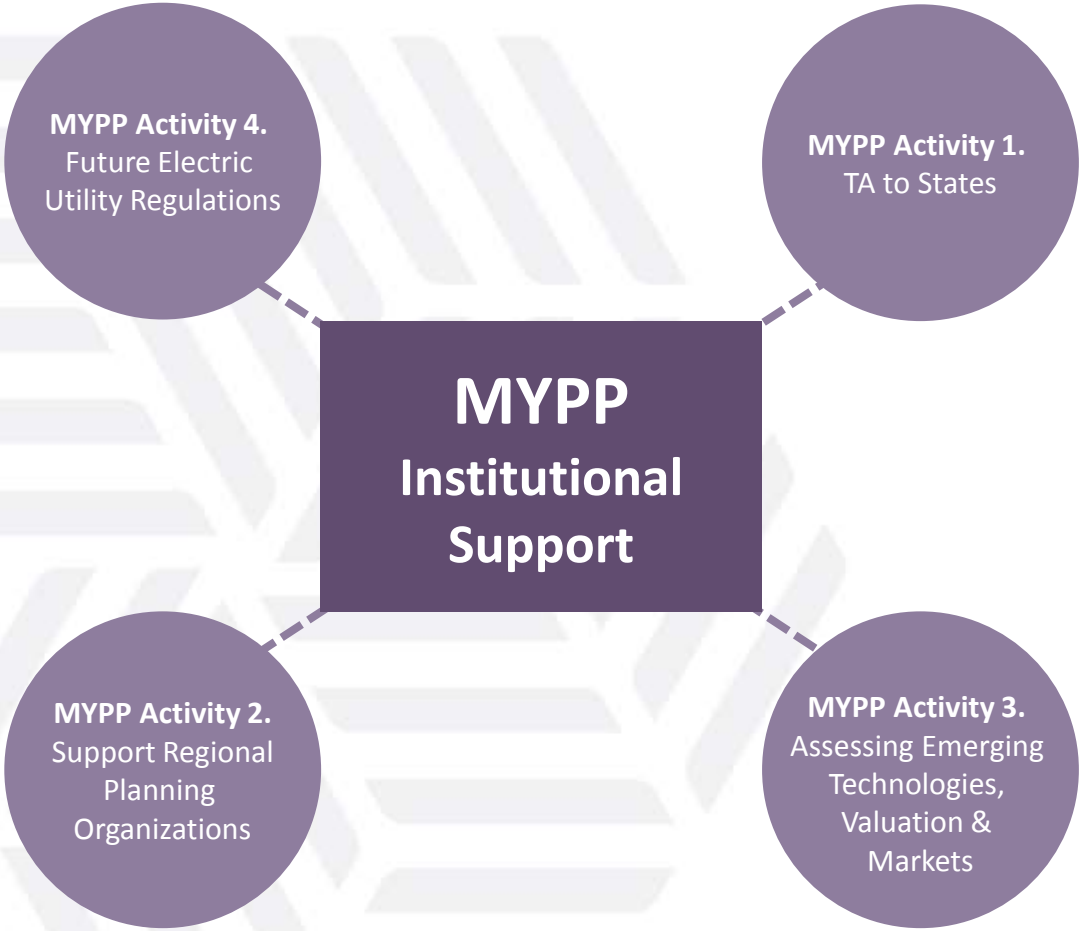
Federal Role

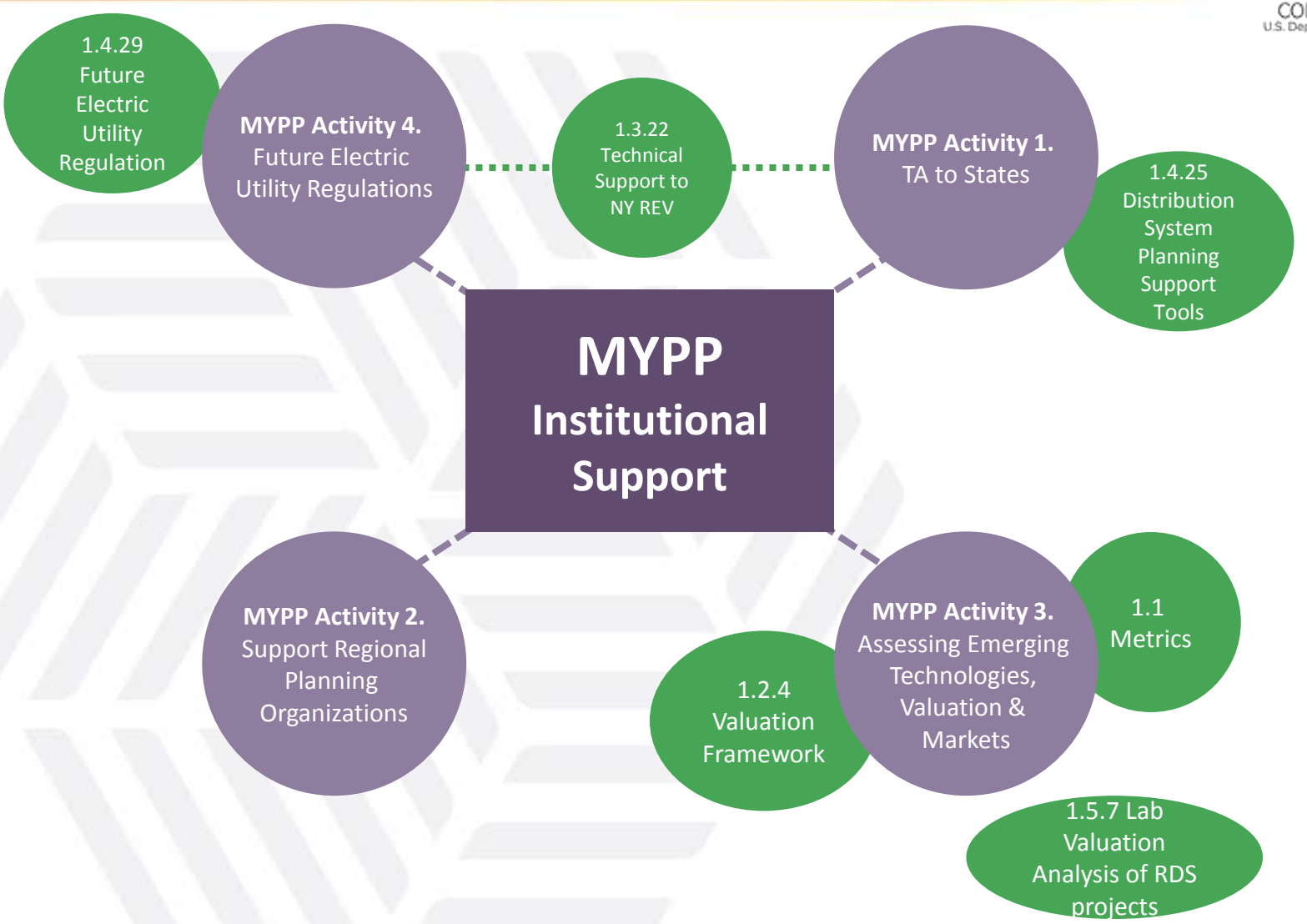
- Convene key grid stakeholders as an honest-broker for collaborative dialogues on grid modernization
- Create an over-arching suite of grid-related "institutional" analysis, workshops, and dialogues to highlight challenges and explore options for transforming the grid, focusing on key policy questions related to new technologies, regulatory practices, and market designs



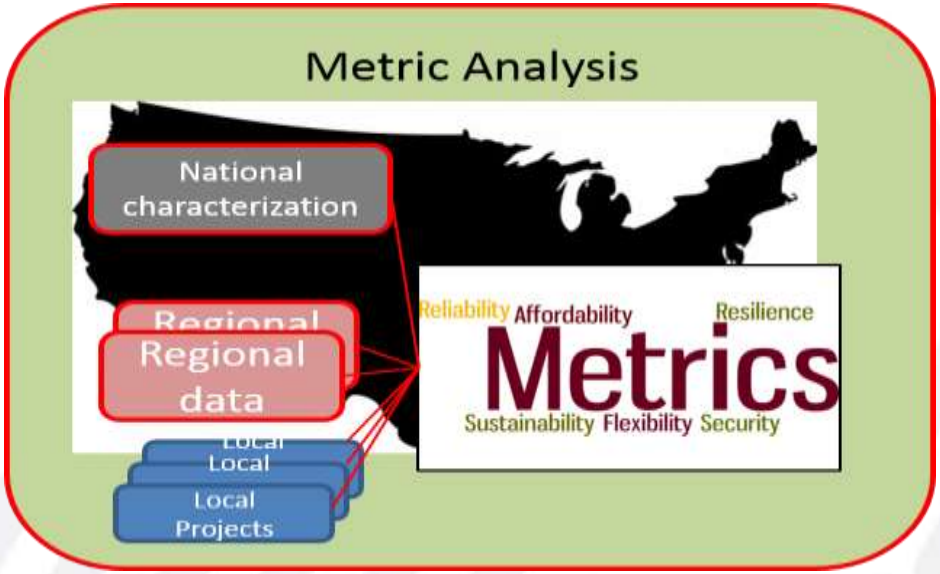
MYPP Activities & Achievements

MYPP Activities	Technical Achievements by 2020
1. Provide Technical Assistance to States and Tribal Governments	• Technical assistance to **ALL states** to inform their electricity policy decision making, accelerating policy innovation in **at least 7 states** • Technical analysis results to at least 15 states that allows them to **enhance utility distribution system planning,** including guidance on how to consider Non-Wires Alternatives, DER, and advanced grid components and systems
2. Support Regional Planning and Reliability Organizations	• Regional planning & reliability organizations develop institutional frameworks, standards, and protocols for integrating new grid-related technologies • Coordinated regional long-term planning process that uses standardized, publicly available databases of transmission and regional resource data and planning assumptions
3. Develop Methods, Tools, and Resources for Assessing Grid Modernization	• Develop a valuation framework that will allow stakeholders to **conduct, interpret**, and **compare** valuation studies of existing and emerging grid technologies and services with high levels of **consistency**, **transparency, repeatability**, and **extensibility** • New and enhanced Grid Modernization **performance and impact metrics** and data collection methods, which are used by states to track Grid Modernization progress • Analysis tools and methods that facilitate states' integration of emerging grid technologies into decision-making, planning, and technology deployment. .
4. Conduct Research on Future Electric Utility Regulation	• 3-5 states have **adopted fundamental changes a**nd 8-10 states have **adopted incremental changes** to their **regulatory structure** that better aligns utility interests with grid modernization goals


MYPP Activity 4.
Future Electric Utility Regulations
MYPP Activity 1.
TA to States
MYPP
Institutional
Support
MYPP Activity 2.
Support Regional Planning Organizations
MYPP Activity 3.
Assessing Emerging Technologies, Valuation & Markets


1.4.29 Future Electric Utility Regulation
MYPP Activity 4. Future Electric Utility Regulations
1.3.22 Technical Support to NY REV
MYPP Activity 1. TA to States
1.4.25 Distribution System Planning Support Tools
MYPP Institutional Support
MYPP Activity 2. Support Regional Planning Organizations
1.2.4 Valuation Framework
MYPP Activity 3. Assessing Emerging Technologies, Valuation & Markets
1.1 Metrics
1.5.7 Lab Valuation Analysis of RDS projects

1.1: Metrics Analysis



PoP: FY16/17/18

Budget: $4.7M

Labs: PNNL, LBNL ANL, LLNL, NREL, SNL, BNL

Partners: NERC, APPA, ERCOT, NOLA, CAISO,EIA, EPA,PG&E, SCE, ComEd

- Work directly with *strategic* stakeholders to confirm the usefulness of *new and enhanced existing* metrics that will guide grid modernization efforts to maintain and improve: reliability, resilience, flexibility, sustainability, affordability, and security
- Definition, validation and adoption of metrics by leading industry stakeholders and regional partners

1.2.4: Grid Services and Technologies Valuation Framework

PoP: FY16/17/18

Budget: $3.M

Labs: ORNL, PNNL, NREL, ANL, LBNL,SNL, LANL

Partners: NARUC

- Develop a valuation framework that will allow stakeholders to **conduct, interpret,** and **compare** valuation studies of existing/emerging grid technologies and services with high levels of **consistency, transparency, repeatability, and extensibility**
- Valuation is crucial factor in investment and policy decisions

1.4.25: Distribution System Decision Support Tool Development and Application

PoP: FY16/17/18

Budget: $2.M

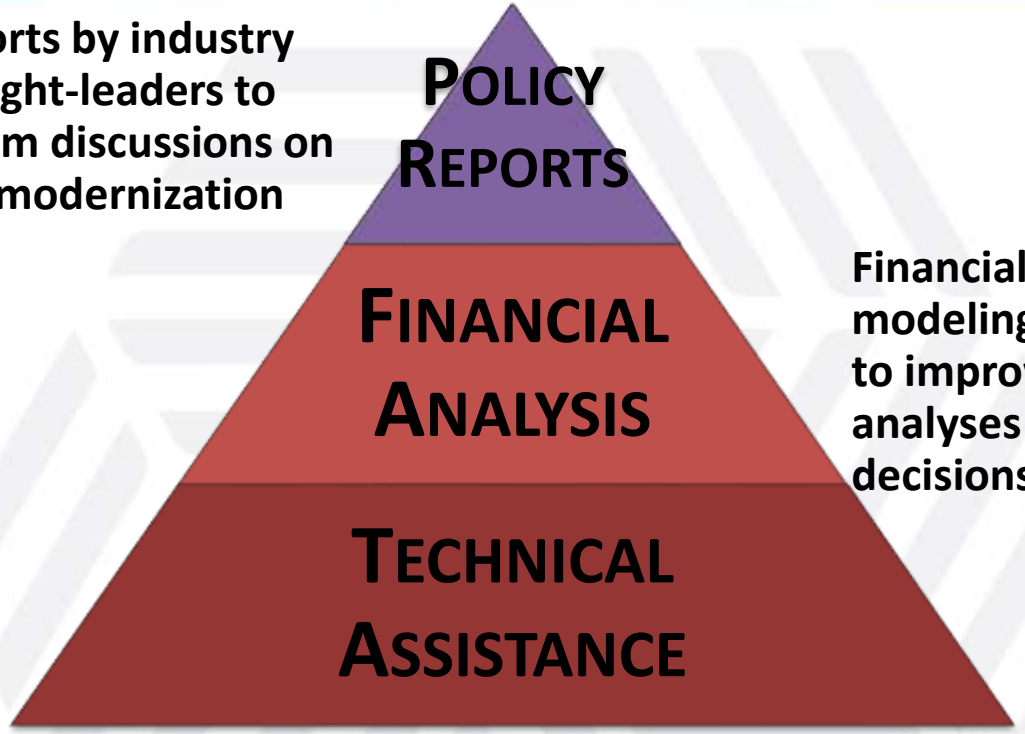
Labs: NREL, LBNL,PNNL

Partners: NARUC, NASEO, and regional partners (NECPUC, OMS, WIEB)

- Identify strategies and provide technical assistance (TA) to state PUCs and utilities that focus on advanced electric distribution planning methods and tools, with a focus on incorporating emerging grid modernization technologies and significant deployment of DER
- Develop and conduct educational training program targeted at state PUCs, energy offices

1.4.29: Future Electric Utility Regulation

Reports by industry thought-leaders to inform discussions on grid modernization



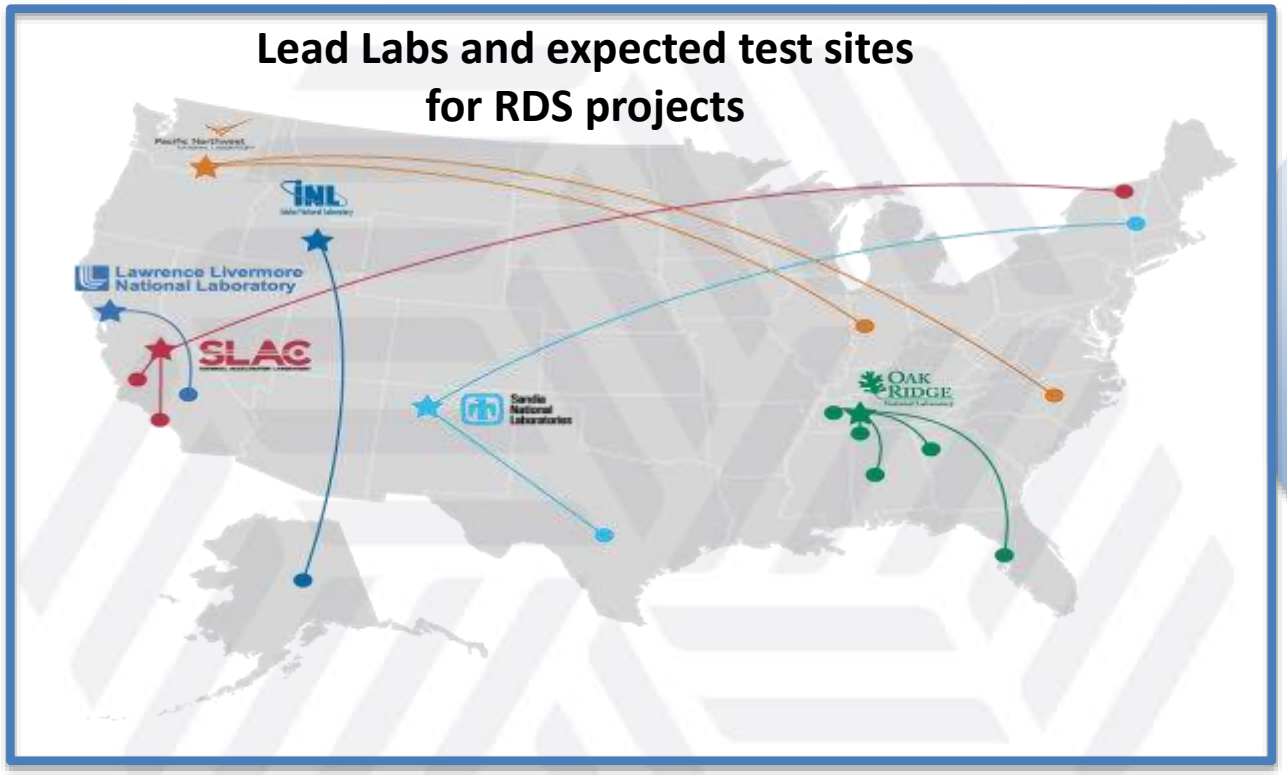
Financial modeling tools to improve analyses and decisions

PoP: FY16/17/18
Budget: $3.M
Labs: LBNL,NREL,NETL, SNL,PNNL
Partners: NARUC

Direct TA to state PUCs

- Provide technical assistance, tools, and analysis on evolving trends in utility regulation, ratemaking and utility business models
- States will have improved capability to consider alternative regulatory approaches to enable grid modernization investments that will better tie utility earnings to consumer value, economic efficiency and other policy goals

1.5.7: Laboratory Value Analysis of Resilient Distribution System (RDS) Projects



PoP: FY18/19/20

Budget: $1.5M

Labs: PNNL, ANL, LBNL, NREL, SNL

Partners: RDS Teams

- Develop methodology for estimating value of resilient distribution systems and perform value analysis for 5 RDS projects
- First authoritative valuation study of resilience field demonstrations with diverse use case scenarios that include different technologies, threat scenarios, value streams and regions with different market structures

Connections and Collaborations
Foundational and Program Projects

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

MYPP Area	Foundational Projects	Program Specific Projects
1. TA to States	1.4.25 Distribution System Planning Support Tools 1.3.22 TA to NY REV	DOE OE TPTA TA to PUCS Solar Energy Innovation Network (SEIN) Solar Technical Assistance Team (STAT)
2. Support Regional Planning and Reliability Organizations		DOE OE TPTA – Regional Planning
3. Develop Methods, Tools, and Resources for Assessing Grid Modernization	1.1 Metrics Analysis 1.2.4 Valuation Framework 1.5.7 Lab Value Analysis of RDS projects	Next Generation Distribution System Platform (DSPx) (DOE OE) Valuation Guidance for Pumped Storage Hydro (EERE Water Power Technologies Office) Energy Storage Applications and Value Streams (OE Energy Storage Program)
4. Future Electric Utility Regulation	1.4.29 Future Electric Utility Regulation	

Accomplishments and Emerging Opportunities

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

Accomplishments

- **Metrics (1.1)**
  - Reference document (v2.0) on approach and focus in each metric area (v2.0)
  - Stakeholder adoption (EIA – small DG; APPA – ICE Calculator and eReliability Tracker)
  - Impressive engagement process (~15 Working Partners)
- **Valuation Framework (1.2.4)**
  - Long-term Vision of a standard for valuation
  - Conducted test cases of initial valuation framework
  - Revised valuation guidance document out for external review
- **Distribution System Planning Support Tools 1.4.25**
  - Conducted 3 regional training workshops on emerging issues in dist. system planning attended by 33 states (>100 PUC staff)
  - Reports on state activities on distribution system planning & tools

Path Forward

- **1.1**
  - Adapt Reference document for broader audiences
  - Institutionalize proposed metrics with Working Partners
- **1.2.4**
  - Finalize and disseminate Valuation Framework Guidelines document
  - Phase II activities: Revision, Expansion, & Industry adoption
  - Phase III: Standards development
- **1.4.25**
  - Complete report on distribution system planning tools: current capabilities, gaps
  - Continue support for MN PUC and MA on interconnection rules, standards
  - Extend and expand training to state PUCs and energy offices

Accomplishments and Emerging Opportunities (cont.)

Accomplishments

- Future Electric Utility Regulation (1.4.29)
  - Provided TA to 10 states on incremental and 5 states on comprehensive regulatory/utility business model changes
  - Enhanced FINDER model to include financial impacts of EE and distributed PV on utility shareholders and participants and non-participants
  - Completed four reports in Future of Electric Utility Regulation series industry; 750 webinar attendees
- Laboratory Value Analysis of RDS Projects (1.5.7)
  - Developed uniform approach to value estimation across RDS projects
  - Worked with 5 RDS teams to enhance use cases and specify data requirements to assess benefits

Path Forward

- **1.4.29**
  - Complete state TA in 5 states (HI, LA, NY, VT, WA)
  - Conclude modeling activities linked to state TA: Impacts of EVs on utility shareholders and ratepayers; and Impacts of TOU/CPP and export rates on customer home and battery storage use
  - Finalize Future Electric Utility Regulation Reports: Resilience Investments for Electricity Systems and Ways Utilities can Provide 100% RE to Corporate Customers and Cities
- **1.5.7**
  - Continue to work with RDS teams & explore opportunities for early simulation of use cases)
  - Conduct value estimation for 5 RDS projects based on field data (yr 3)
  - Report that synthesizes outcomes, lessons learned and presents cross-cutting analysis and results (yr 3)

Summary

- Institutional Support significantly impacts pace of Grid Modernization Investments
- Many key elements of the Multi-Year Program Plan included in GMLC-funded projects (and other DOE funded activities)
- Foundational Projects
  - Metrics Analysis
  - Valuation Framework
  - Distribution System Decision Support Tools: Development & Application
  - Future Electric Utility Regulation
  - Laboratory Valuation Analysis of Resilient Distribution System Projects
- TA to many state PUCs through Foundational Projects
- DOE has leveraged Institutional Support team expertise (e.g., Staff Report on Electricity Markets and Reliability, Puerto Rico TA, Beyond LCOE)

Additional Slides

Foundational Projects

1.1 Metrics: Foundational Analysis for GMLC

- Work directly with *strategic* stakeholders to confirm the usefulness of *new and enhanced existing* metrics that will guide grid modernization efforts to maintain and improve: reliability, resilience, flexibility, sustainability, affordability, and security
- Definition, Validation and Adoption of metrics by leading industry stakeholders and regional partners

1.2.4 Grid Services and Technologies Valuation Framework Development

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

1.4.25 Distribution System Planning Support Tools

- Identify strategies and provide technical assistance (TA) to state PUCs and utilities on advanced electric distribution planning methods and tools, with a focus on incorporating deployment of DER
- Develop & conduct training course(s) for State PUCs on emerging issues in distribution system planning

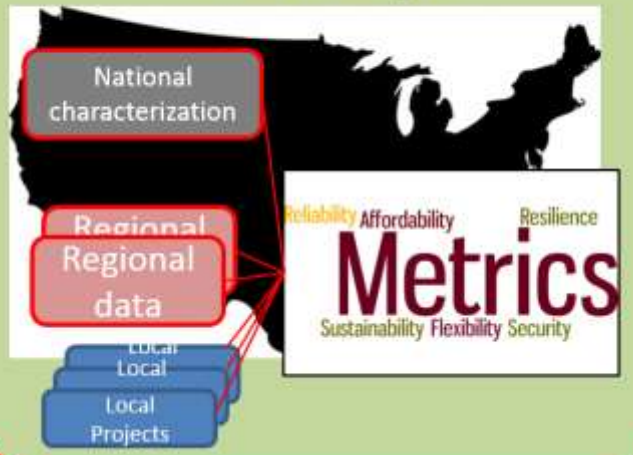
1.4.29 Future of Electric Utility Regulation

- Provide TA, tools, and analysis on trends in utility regulation and business models
- States will have improved capability to consider alternative regulatory approaches to enable grid modernization investments that will better tie utility earnings to consumer value, economic efficiency and other policy goals

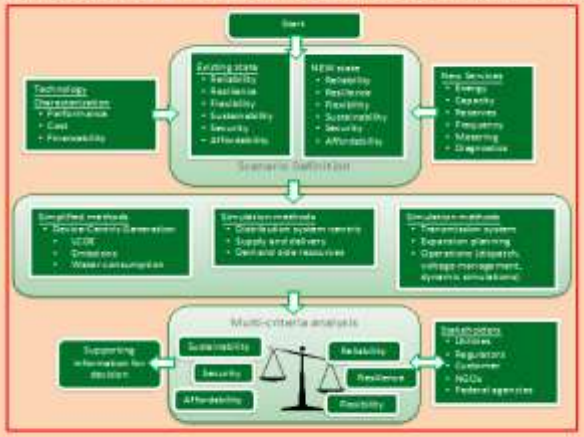
Institutional Support Projects

GRID MODERNIZATION LABORATORY CONSORTIUM

Metric Analysis



Valuation Framework Development

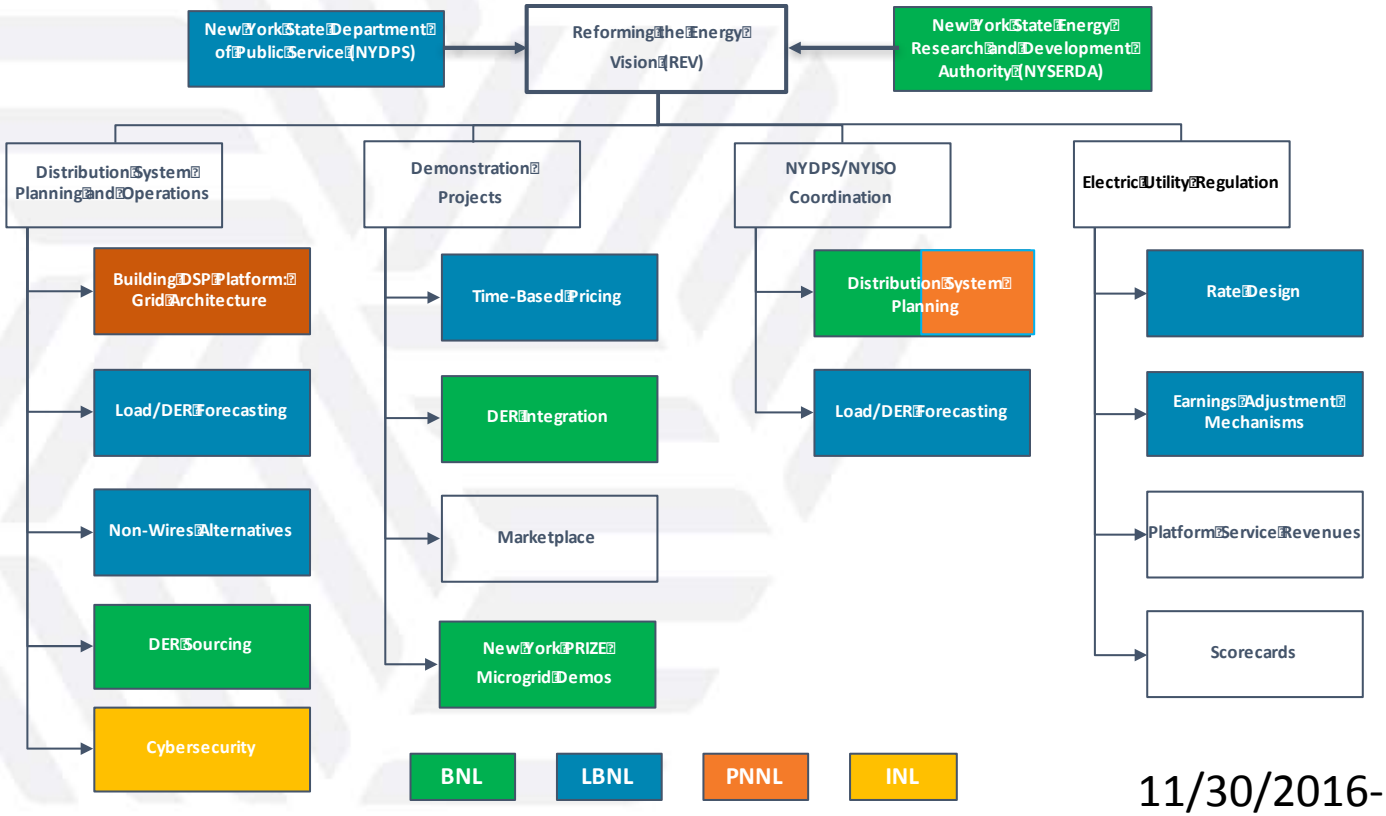


Distribution System Decision Planning

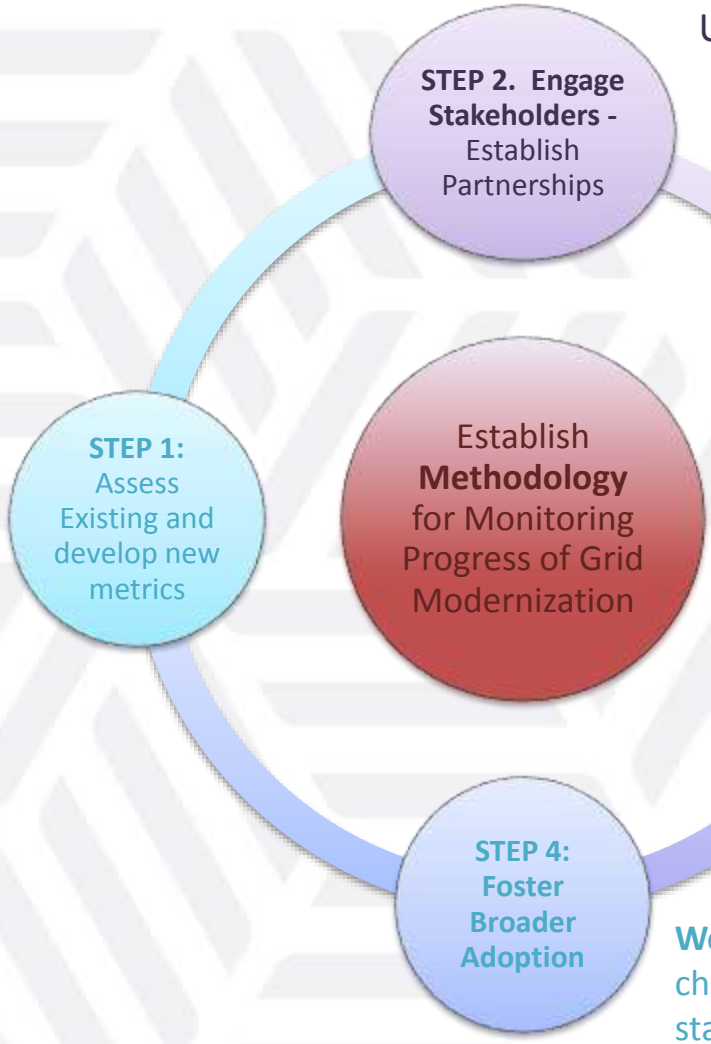
FUTURE ELECTRIC
Utility Regulation

Regional Demonstration Project: 1.3.22 -Technical Support to NY REV Initiative

- Providing technical support to NY State energy agencies (NYDPS and NYSERDA) to enable the REV vision
- Focus on creating Distributed System Platform (DSP), utility regulation and changes to utility business model, and DER demonstration projects.
- Leverage knowledge gained to support DOE's broader GMI; summarize lessons learned for other states



1.1: Metrics Analysis



Utilities and ISO/RTOs
Federal and State regulators,
Municipal authorities,
Industry associations

Work closely with existing channels (EPA, EIA, IEEE standards, best practice

Collaborate with GMLC Portfolio researchers

Utilities and key stakeholders will test metrics for self-assessment

GMLC Regional Partners will apply metrics

Work closely with existing channels (EPA, EIA, IEEE standards, EPRI, best practice

GRID MODERNIZATION INITIATIVE PEER REVIEW
GMLC 1.1 – Metrics Analysis

MICHAEL KINTNER-MEYER

September 4–7, 2018

Sheraton Pentagon City Hotel – Arlington, VA

GMLC1.1: Metrics Analysis
High Level Summary

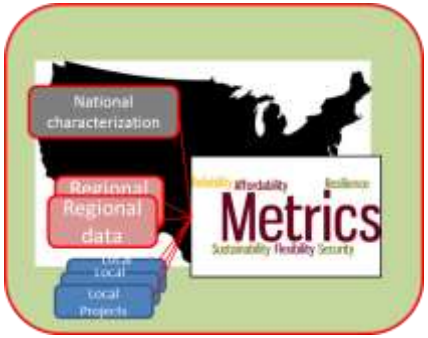
Project Objectives

Work directly with *strategic* stakeholders to confirm the usefulness of *new and enhanced existing* metrics that will guide grid modernization efforts to maintain and improve:

- **Reliability,**
- **Resilience,**
- **Flexibility,**
- **Sustainability,**
- **Affordability, and**
- **Security.**

Expected Outcomes

✓ Definition, Validation, and Adoption of metrics and analysis approaches by leading industry stakeholders and regional partners



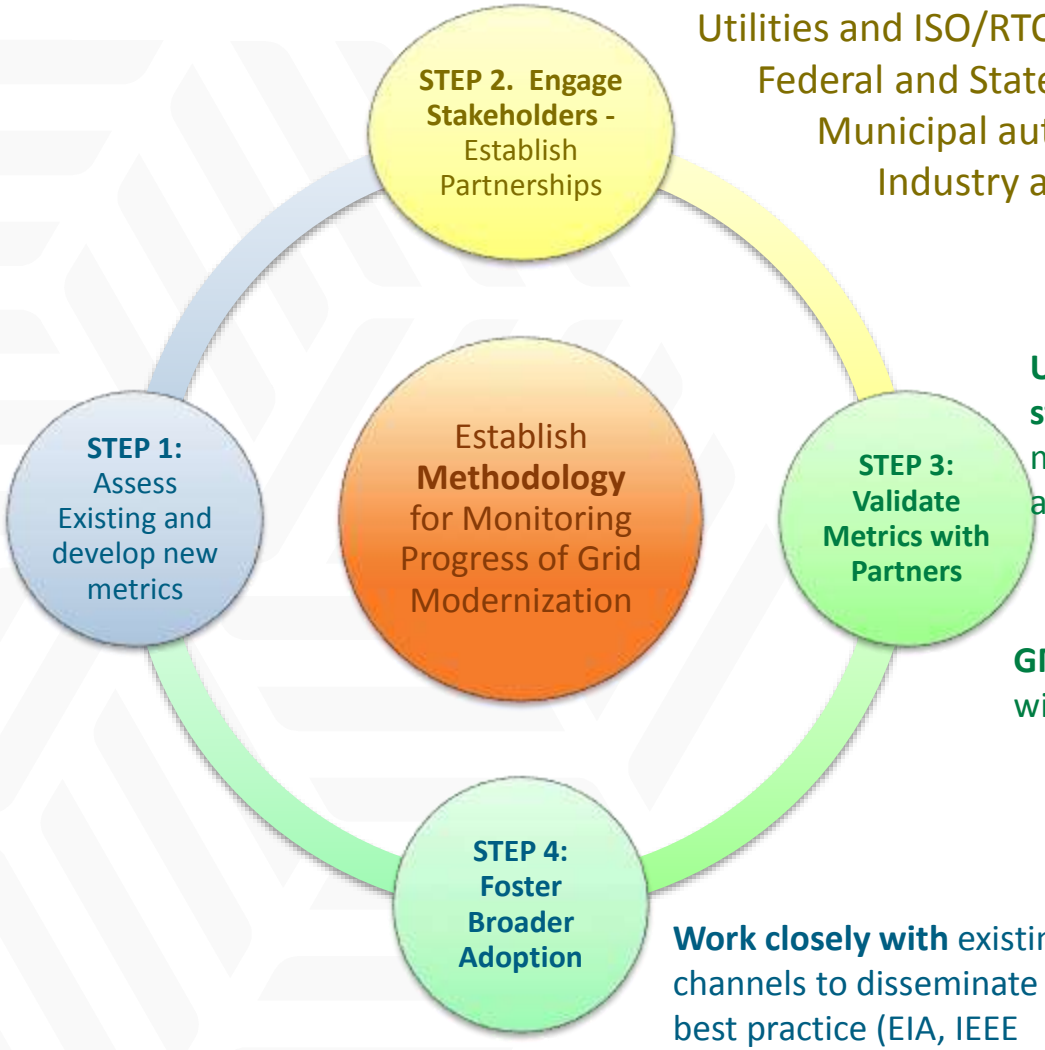
Value Proposition

✓ Ensuring that all stakeholders understand how grid modernization investments will affect and benefit them

✓ Audiences: grid modernization technology developers and investors; utility and ISO technology adopters or sponsors; federal, state, and municipal regulatory or oversight authorities; **and electricity consumers** (i.e., the ratepayers**)**

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

GMLC1.1: Metrics Analysis
Approach



Utilities and ISO/RTOs
Federal and State regulators,
Municipal authorities,
Industry associations

Work closely with existing channels (EPA, EIA, IEEE standards, EPRI, EPA)

Collaborate with GMLC Portfolio researchers

Utilities and key stakeholders will test metrics for self-assessment

GMLC Regional Partners will apply metrics

Work closely with existing channels to disseminate best practice (EIA, IEEE standards, EPRI EPA)

GMLC1.1: Metrics Analysis
Approach

- **Formation of a strong lab team with senior staff**
  - **Joe Eto,** LBNL, Reliability lead, and +1

  - **Vanessa Vargas**, SNL and James **Kavicky**, ANL: Resilience leads

  - **Tom Edmunds**, LLNL: flexibility lead

  - **Garvin Heath**, NREL: Sustainability lead

  - **Dave Anderson**, PNNL: Affordability lead

  - **Steve Folga**, ANL: Security Lead

  - **Monisha Shah, Gian Porro**, NREL, stakeholder leads [e]

GMLC1.1: Metrics Analysis
Accomplishments to Date

- **Working partnerships**:
  - Reliability: NERC, APPA, ERCOT
  - Resilience: NOLA, 100 Resilient Cities
  - Flexibility: ERCOT, CAISO
  - Sustainability: EIA, EPA, ERCOT, PG&E, MN-PUC
  - Affordability: SCE, WA State UTC
  - Security: EEI, ComEd , Idaho Falls Power, SCE
- ► **Uptake of proposed metrics**
  - **EIA: submitted modifications to Form 861 and CBECS to reflect small DG generators** (May, 2018)
  - **APPA: ICE Calculator integrated into eReliability Tracker** (Dec., 2017)
  - **NOLA: building microgrid based on SNL's consequence-based approach and testing ANL's approach** (Nov., 2017)
- **Publications and information dissemination**
  - **Living document: Metrics Analysis: Reference Document, v2.1, May 2017**
  - *(Sustainability) Journal paper: CO_2 emission estimates from U.S. electricity: Potential for underestimation as grid modernizes* (submitted to Energy & Environmental Science, 8/14/18)
  - *(Resilience) Journal paper*: Development of Grid Resilience Metrics (submitted to IEEE Transaction on Industrial Informatics on Resilience in Energy Industries, 4/30/2018)
  - 3 technical reports:
    - Flexibility[1]
    - Affordability[2]
    - Resilience
- **Technical Workshops:** EPRI, CEC, SCE, FERC, IEEE-PES, WI-PUC, Smart Grid Northwest

[1] Edmunds, Thomas, Omar Alzaabi, and Andrew Mills, Flexibility Metrics to Support Grid Planning and Operations, *LLNL-CONF-738350, Siebel Energy Institute Future Markets Workshop*, Washington, DC, July 26, 2017.
[2] Anderson, David. 2018. *Electricity Affordability Metrics for the US*, National webinar of the Clean Energy States Alliance. June 14, 2018. PNNL-SA-135678.

GMLC1.1: Metrics Analysis
Accomplishments to Date

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

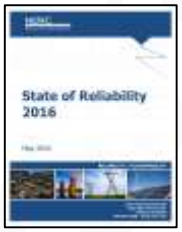
Reliability

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

AMERICAN PUBLIC POWER ASSOCIATION — eReliabilityTracker



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

New probabilistic transmission planning metrics

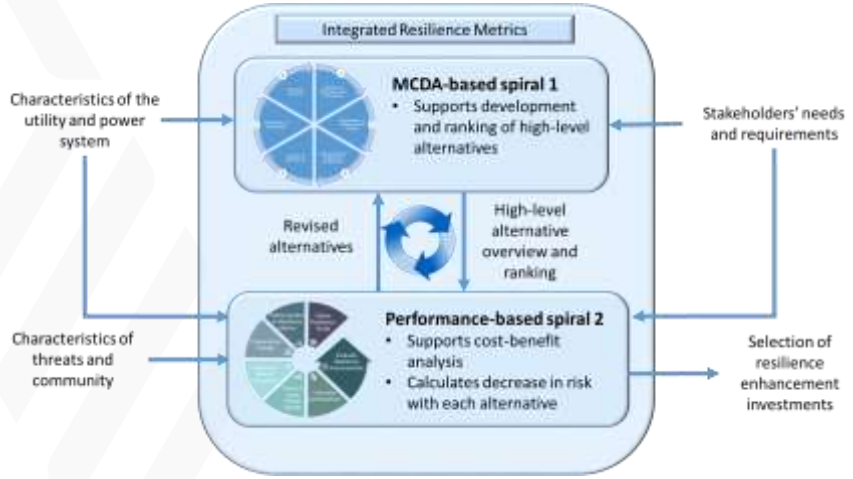
Accomplishments Year 1+2:

- APPA has incorporated ICE Calculator into eReliability Tracker (Dec., 2917)
- Membership in NERC Performance Analysis Subcommittee (responsible for preparing Annual State of Reliability report), (Jan., 2018)
- 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 (2017)
- Document the methodologies and differences between performance-based and attribute-based approach (April, 2018)
- Engaged stakeholders and provided decision support in New Orleans (Nov., 2017)
- Designed economic metrics (performance based) to evaluate local resilience benefits
- Developed initial MCDA survey mechanism (March, 2018)

GMLC1.1: Metrics Analysis
Accomplishments to Date

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Flexibility

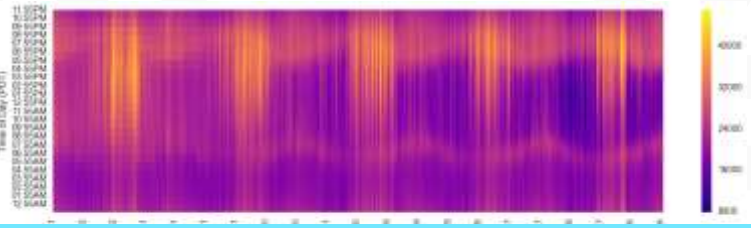
Lead: Tom Edmunds(LLNL)

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 (Feb. 2018)
- Wrote software to visualize data and reveal trends with 5-years of CAISO & ERCOT data (Jul. 2018)
- Presentations to CAISO & ERCOT (Nov., 2017, Apr., 2018)

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) (May, 2018)
- Demonstrated need for new *Relative Water Risk* metric (Jan, 2018)

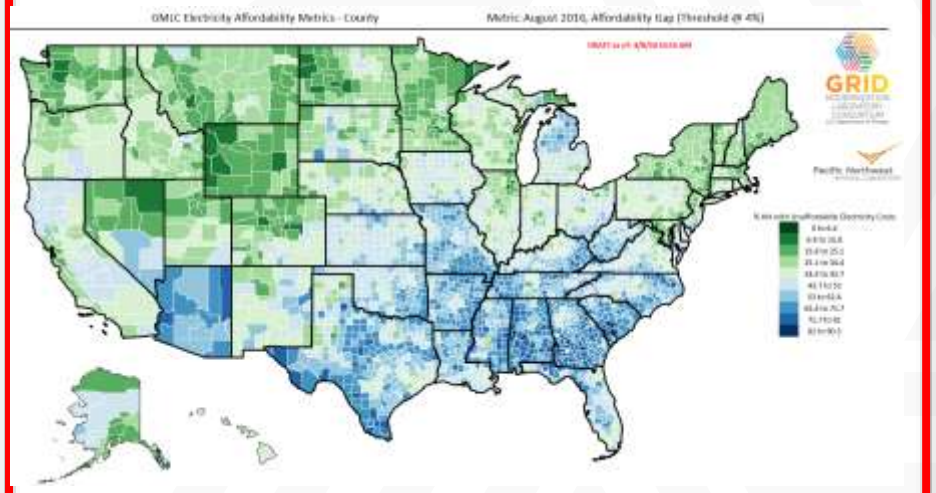
GMLC1.1: Metrics Analysis
Accomplishments to Date

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

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 (May, 2017)
- Alaska use case completed (May, 2018)
- National affordability dashboard (Jun., 2018)
- Macro affordability metrics developed (Apr., 2018)
- Continued engagement with data partners

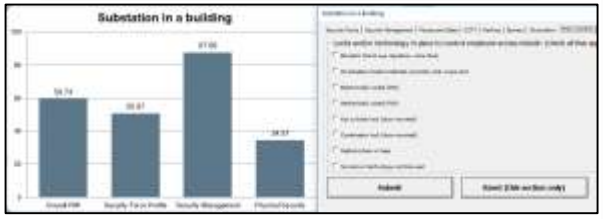
Security

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 (Nov. 2016)
- Endorsed by DHS and utilities (ComEd, Idaho) (Feb., 2017)
- Completing initial version of survey tool (Excel) with dashboard capability (*June, 2018)*
- Continuing outreach to EEI and electric sector

GMLC1.1: Metrics Analysis
Institutionalization Pathways

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Reliability

Pathway: utility adoption
- Metrics: ICE calculator adopted in eReliability Tracker

Resilience

Pathway: city/utility adoption
- Metrics: adoption by NOLA to built Microgrids
- broad information dissemination through “100 Resilient Cities”

Flexibility

Pathway: adoption by RTOs
- Retrospective metrics: through publishing in IEEE
- Prospective metrics: by working with ISOs

Sustainability

Pathway: Data Collection Agency
- Metrics: GHG Emissions of DERs
- Adoption into EIA End use (MECS and CBECS) and Utility Surveys (EIA 861)

Affordability

Pathway: State Energy Offices
- Dashboard offered by Energy offices

Security

Pathway: Utility Adoption
- Metrics: Physical Security Attributes
- PMI Dashboard offered by EEI to Member Utilities

GMLC1.1: Metrics Analysis

Next Steps and Future Plans

- Remainder of year 3 activities (expected end March 30, 2019)
  - Completing existing tools in all metrics areas
  - Transition of the Reference Document to more accessible document for targeted audience:
    - Into several documents with extended EXECUTIVE SUMMARY
    - Individual Metric subject discussions
    - Appendices with work products
  - Institutionalizing proposed metrics with
    - EIA: commercial buildings survey (CBECS): DG enhancements
    - CEC
    - EEI
    - IEEE
- Discussion with DOE on potential new/continued Metrics project with potential objectives
  - Enhance existing activities
  - Applying comprehensive set of metrics with partners to measure grid modernization progress

GMLC1.1: Metrics Analysis
Mapping Metrics to Decisions and Stakeholders

- Motivation
  - Improve understanding of the metrics being used to inform decision-making in the electric sector (e.g., capacity investment, retirement, operations, policy, regulatory RD&D)
  - Complements to-date stakeholder approach
  - Use to inform Year 3 work plans and longer-term DOE metrics and valuation activities
- Approach
  - Elicit directly from representative stakeholders: metrics of most interest in their decision-making (leverage GMLC1.2.4: valuation framework development)
  - Mine from publicly-available proceedings and identify set of metric used
- Initial Findings (*to be updated by August 27*)
  - Several decision frameworks (e.g., NY REV) document a diverse set of benefit and cost metrics to inform a variety of decisions — *may not always be applied in practice*
  - *More variation in breadth occurs in case- or proceeding-specific examples examined to date*
  - ***Reliability and affordability metrics are commonly in use; sustainability (environmental, economic) appear less frequently; resilience still uncommon***
  - Continuing to extend literature review to cover a broader range of situations – e.g., performance regulation, transmission capacity investment, allocation of stranded costs associated with asset retirement

GRID MODERNIZATION INITIATIVE PEER REVIEW:

1.2.4 Grid Services and Technologies Valuation Framework

PATRICK O'CONNOR, ORNL

September 4–7, 2018

Sheraton Pentagon City Hotel – Arlington, VA

Grid Services and 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**.

Value Proposition

- **Valuation is crucial factor in investment and policy decisions…**
- **But lack of underlying framework**
  - Prevents comparison or consolidation
  - Leads to conflict over correct method
  - Slows approval of investment
- **Decision makers** need information they can reliably interpret and compare

Project Objectives

Produce a framework: a systematic approach to conducting and interpreting valuation, resulting in:

- Increased transparency in methods and assumptions used to evaluate grid technologies and services.
- The ability of stakeholders to identify value beyond monetary savings and costs.
- Useful and used guidance for the broad range of valuation applications.
- The foundation of reaching a long-term vision of improved, broadly consistent valuation practices.

Contribution to GMI MYPP Goals

Incorporate new technologies, including DER, into modern grid planning, operations, & optimization

GMMYPP Goals:

Grid Services & Technologies Valuation Framework
Project Team

Project Participants and Roles

Laboratories

ORNL – Project manager; framework development
PNNL – Review state of valuation
ANL – Taxonomy and glossary
NREL – Test cases
LBNL – Review and taxonomy support
SNL – Framework development support
LANL – Framework development support

Industry

National Association of Regulatory Utility Commissions (NARUC) – partner supporting Stakeholder Advisory Group (SAG) engagement

PROJECT FUNDING			
Lab	FY16 $	FY17$	FY18 $
ORNL	375k	325k	415k
PNNL	200k	175k	205k
NREL	95k	200k	170k
ANL	155k	100k	60k
LBNL	105k	100k	60k
SNL	40k	50k	60k
LANL	30k	55k	30k
TOTAL	**$1M**	**$1M**	**$1M**

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Sectors

- ✓ Regulators/Legislators
- ✓ Utilities
- ✓ Customer/Environmental Groups
- ✓ Technical Experts
- ✓ Regional Coordinators
- ✓ Suppliers

Name	Organization
Denis Bergeron	Maine Public Utilities Commission
Ed Finley; Alt. Kim Jones	North Carolina Utilities Commission
Matthew Shuerger	Minnesota Public Utility Commission
Nick Wagner	Iowa Public Utility Commission
Ray Palmer	Federal Energy Regulatory Commission
Jeff Morris	Washington State Legislature
Tom Sloan	Kansas State Legislature
Gary Brinkworth	Tennessee Valley Authority
Lilian Bruce	Electric Power Board, Chattanooga
Sekou Sidime	Commonwealth Edison
Enrique Mejorada	Pacific Gas & Electric
David Kolata	Citizens Utility Board
Ron Lehr	Western Clean Energy Advocates

Name	Organization
Michael Bailey	Western Electricity Coordinating Council
David Whiteley	Eastern Interconnection Planning Collaborative
J. T. Smith	Midcontinent ISO
Betsy Beck	American Wind Energy Association
Rohan Ma	Solar City
Elia Gilfenbaum	Tesla
Jonathan Lesser	Continental Economics
Bernard Neenan	Independent Consultant
Ben Hobbs	Johns Hopkins University
Michael Moore	Cornell University
Erin Erben	EPRI

Grid Services & Technologies Valuation Framework
Roadmap to the Vision

Phase I: Baseline Framework Development	*Phase II: Revision, Expansion, Industry Adoption*	*Phase III: Standards Development*
Goal: **Transparency** and **repeatability** with **credibility to industry** • Focus on the *process* of valuation. • Industry-reviewed draft framework. • Test cases to apply the framework.	Goal: **Comparability** and **extensibility** with **usage by industry** • More formal structure. • Expand coverage to include other infrastructures. • Application of framework by DOE and contractors. • Industry use of framework for selected valuation studies.	Goal: **Industry hand-off** for development of **"Generally Accepted Valuation Principles (GAVP)"** • "Champion Organization" for long-term ownership. • Stakeholder-driven process to transform guidelines into GAVP. • Ability for professional certification, third-party audit. • Likely to take 5+ years, even with Valuation Framework as the foundation.

2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026

Grid Services & Technologies Valuation Framework

Approach

Approach:

1. Engage Stakeholder Advisory Group (SAG)
2. Review Past Valuation Studies
3. Identify Best Practices and Guidance
4. Formulate Framework
5. Apply to Test Cases & Incorporate Advisor Input
6. Iterate and Refine

Key Issues:

- Valuation-based decisions are now more complex
  - New technologies (e.g., renewable energy, storage)
  - New grid structures (e.g., microgrid)
  - Complex value metrics (e.g., resilience)
  - Multi-criteria values (some not easily monetized)
- Implicit assumptions and choices of evaluation methods are not transparent
- Uneven quality, inconsistent studies

Distinctive Characteristics:

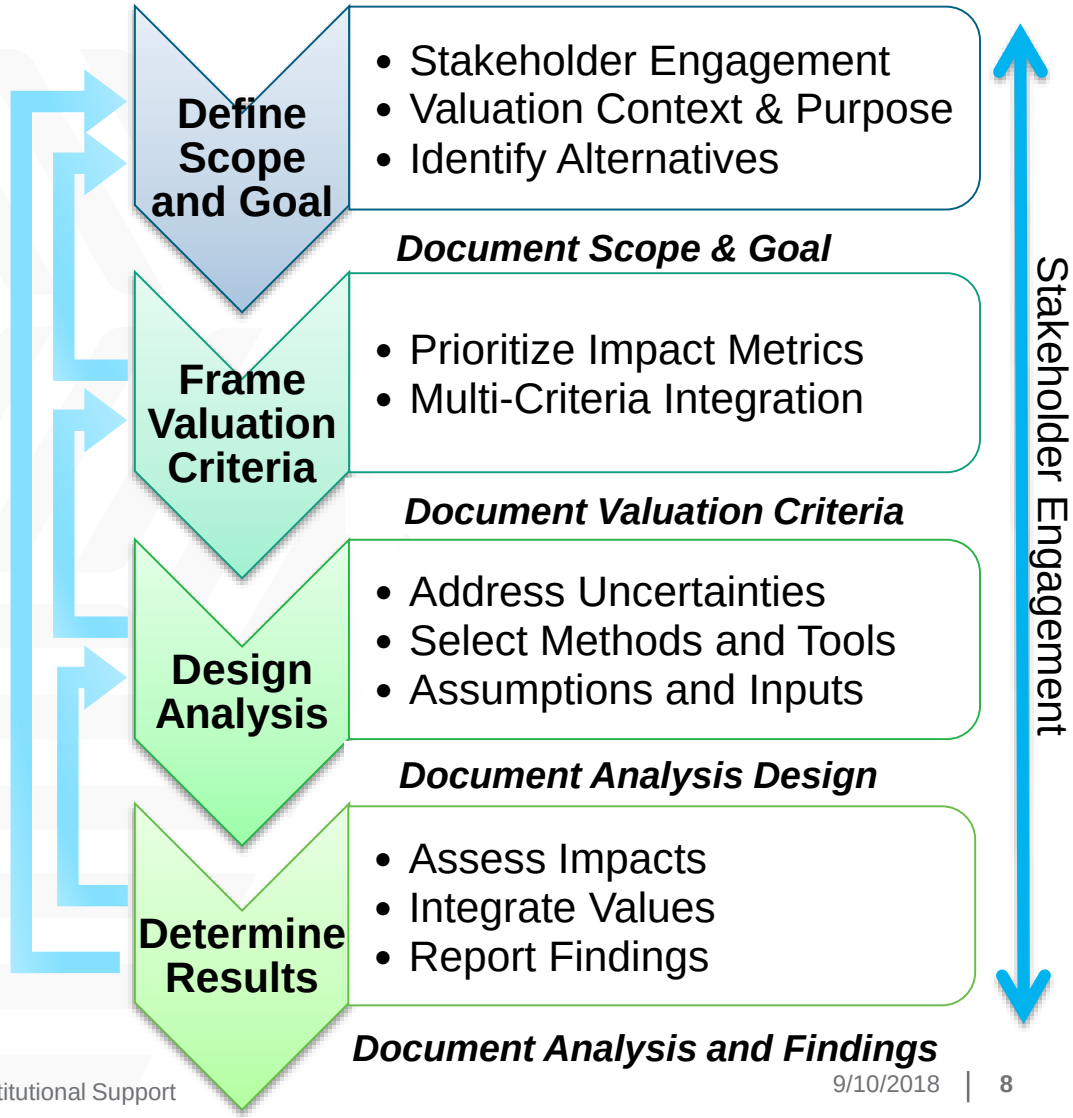
- The Framework is a process, not another model.
- Deliberate identification of decision basis, stakeholder viewpoints, metrics needed, multi-criteria approach, uncertainties, choice of methods & tools.
- Ensures early alignment of valuation methods with study goals and scope.

Accomplishments

- Established Stakeholder Advisory Group (SAG) [Sept. 2016]
  - Crucial industry & regulator involvement
- Developed Initial Valuation Framework [June 2017]
  - Long-term Vision of a Standard for Valuation – set goals and scope
  - Assessed current practices and state-of-the-art – need & gap analysis
  - Initial Structure & Guidance (Version 1.0)
  - Review by SAG [Dec. 2017]
- Test Cases
  - #1: Tabletop exercise on nuclear power subsidies – review past studies through the valuation "lens" [Aug. – Dec. 2017]
  - #2: Pilot application to microgrids using SAG volunteers [Apr. – Oct. 2018]
- Revised Guidance – Version 2.0 [July 2018]
- External Review (invited ~30 industry experts + SAG) [Aug. 2018]

Grid Services & Technologies Valuation Framework
Activities of Past Year: Refined Framework

- Expanded step descriptions.
- Enhanced guidance for stakeholder engagement.
- Specified information flows among phases and steps.
- Added documentation requirements for each phase.



Activities of Past Year: Test Cases

Test Case 1: Use of framework to ***compare similar*** **studies**

Recent state studies on support for “at-risk” nuclear power projects were systematically analyzed using “version 0” of the valuation framework

Key Findings and Framework Improvements:

- *Finding*: use of a formal process for valuation may potentially have saved resources and improved consistency of study outputs
- *Framework Improvement*: Ensure Valuation objective is followed and metrics directly address the decision basis.
- *Framework Improvement:* Made explicit the information flows between steps.
- *Framework Improvement:* Adjusted order and potential for iterations between process steps.

Activities of Past Year: Test Cases

Test Case 2: Use of framework to ***construct*** **a complex study**

Subset of SAG as stakeholders worked intensively with project team

Alternatives for fictional Anytown, FL:

- Upgrade of substation (BAU)
- Various microgrid configurations

Key Framework improvements:

- Guidelines to better identify alternatives, metrics, and methods.
- Directions on use of iteration.
- Added non grid-related metrics, e.g. jobs, economic development.
- Focused on analysis methods, beyond engineering models.
- Created documentation of decisions as they were made during study.
- Added final step to track results.

Grid Services & Technologies Valuation Framework
Activities of Past Year: Stakeholder Advisory Group

SAG includes policymakers, regulators, utilities, grid operators, generation developers, and advocacy groups.

SAG: Workshops / Reviewed Outputs / Participated in Test Case #2

12/17 & 11/18 Throughout 2018 April – October/2018

Key Feedback from SAG

- Valuation Framework is a valuable tool
- This valuation process is especially useful for decisions with significant public accountability.
- Process metrics and methods must go beyond engineering-centric models to include economics, environment, stakeholder acceptance.
- Provided guidance for dealing with uncertainties and risk.
- Stakeholder engagement is crucial for acceptance of decisions.
- The SAG was supportive of this project's accomplishments.
  - *Structured process and inherent transparency* improves usefulness and objectivity.
  - Especially useful with *complex metrics*, *advanced technologies* and *new grid architectures.*

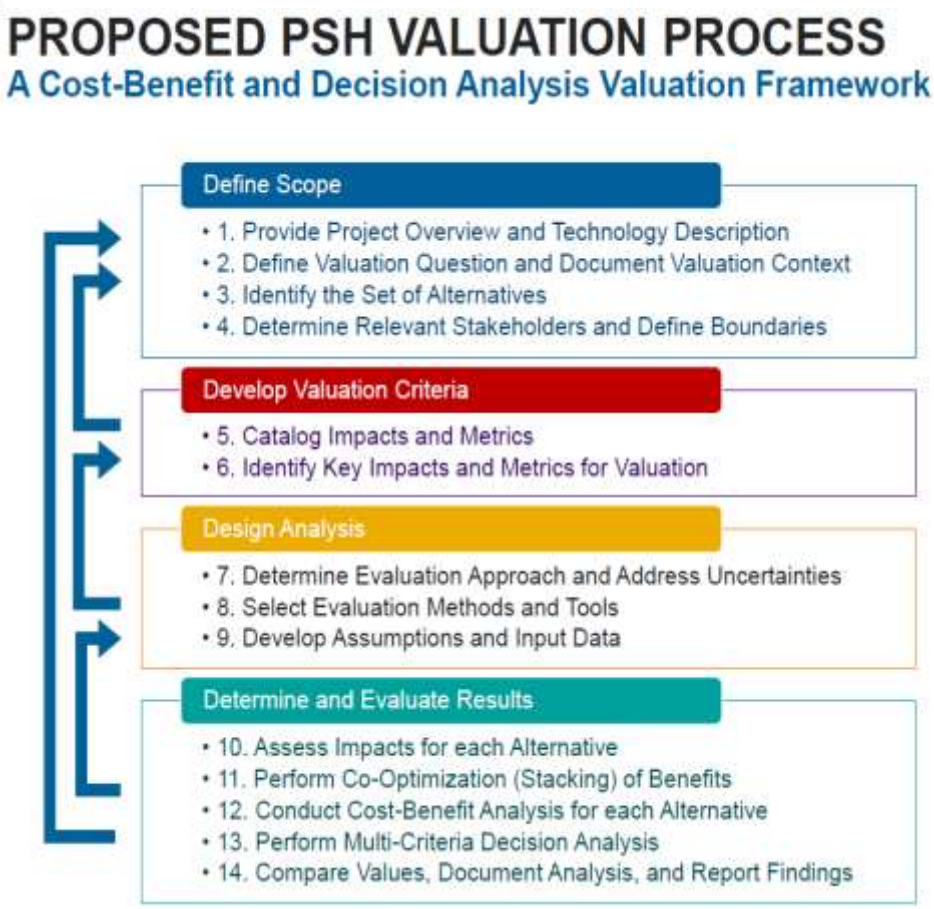
Activities of Past Year: Outreach to DOE Projects

Valuation Framework Applied in Other DOE Projects

- EERE Water Power Technologies Office (WPTO): Assessing the Value of Pumped-Storage Hydropower (PSH)
- Across DOE offices: Beyond LCOE
- GMLC/Laboratory Value Analysis Team (LVAT): Value 5 distribution system demonstrations

Other Projects Used as Resources for Valuation Framework

- GMLC Metrics Analysis (GMLC 1.1)

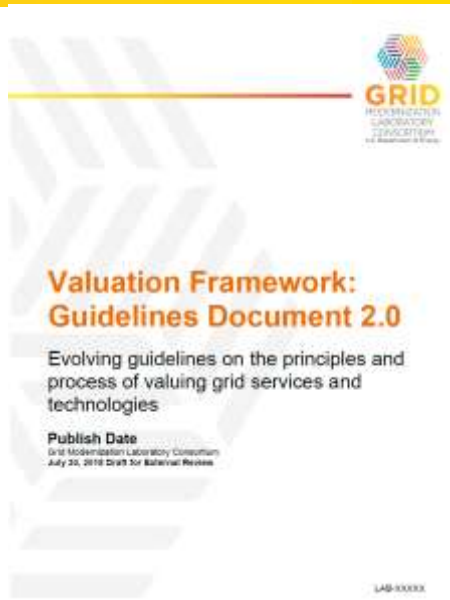


Basis for Future Valuation Standard/GAVP

- Valuations become more complicated as grid technologies and grid configurations become more complex.
- Reliance on “traditional” methods and models have not kept pace
  - Flawed by implicit assumptions (metrics, models) used in earlier, simpler grid studies.
  - Tradeoffs not addressed adequately.
- Other disciplines have met similar challenges by standardizing the required elements in a process:
  - ISO 9000
  - Building Commissioning
  - Medical Procedure Checklists
  - Aviation Checklists
- Guidance Document describes a framework of steps to make sure that requirements are specified and choices are made deliberately.
  - Generally assumed this is already done, but very often it is not.
  - The Framework’s *structured process and inherent transparency* will improve objectivity of valuation studies and usefulness of results to decision makers.

Grid Services & Technologies Valuation Framework
Next Steps for Phase 2

- *Practical applications – work with ongoing valuation efforts to apply the Framework*.
  SAG participants recommended having the project team provide assistance and facilitation to appropriate policy-making or valuation studies. [2019 – 2020]
- *Disseminate the Valuation Guidance* [2019 – 2020]
  Effectively communicate the "process" methodology
- *Continue outreach and "cross-pollination" with other DOE projects.* [2019 – 2020]
  Application of the framework, and continued improvement through feedback from users
- *Standardize principles developed in the Valuation Framework.* [2020 – 2021]
  The Framework will identify essential activities that must be included in a valuation study to ensure transparency, accuracy, unbiased results, and results responsive to the needs of decision makers.



Roadmap to the Vision

Phase II: Revision, Expansion, Industry Adoption

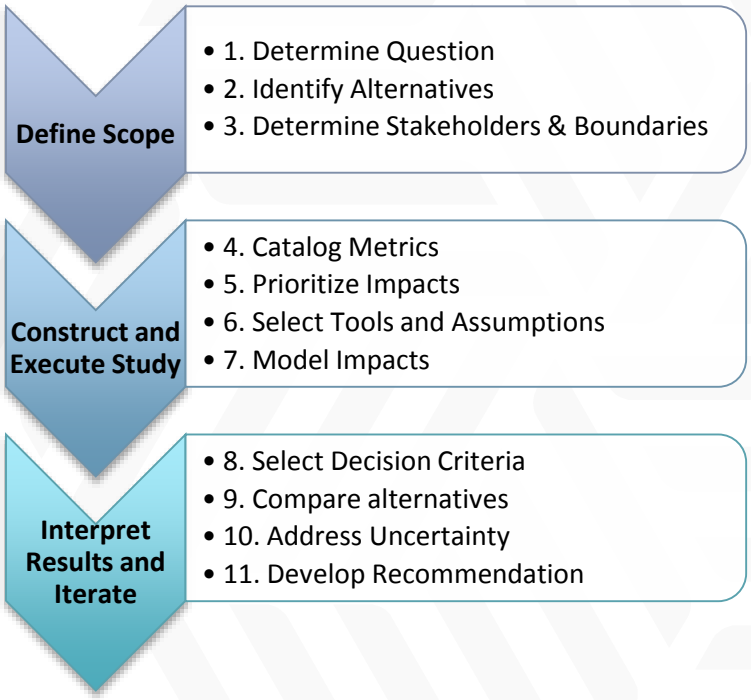
Goal: **Comparability** and **extensibility** with **usage by industry**

BACKUP SLIDES

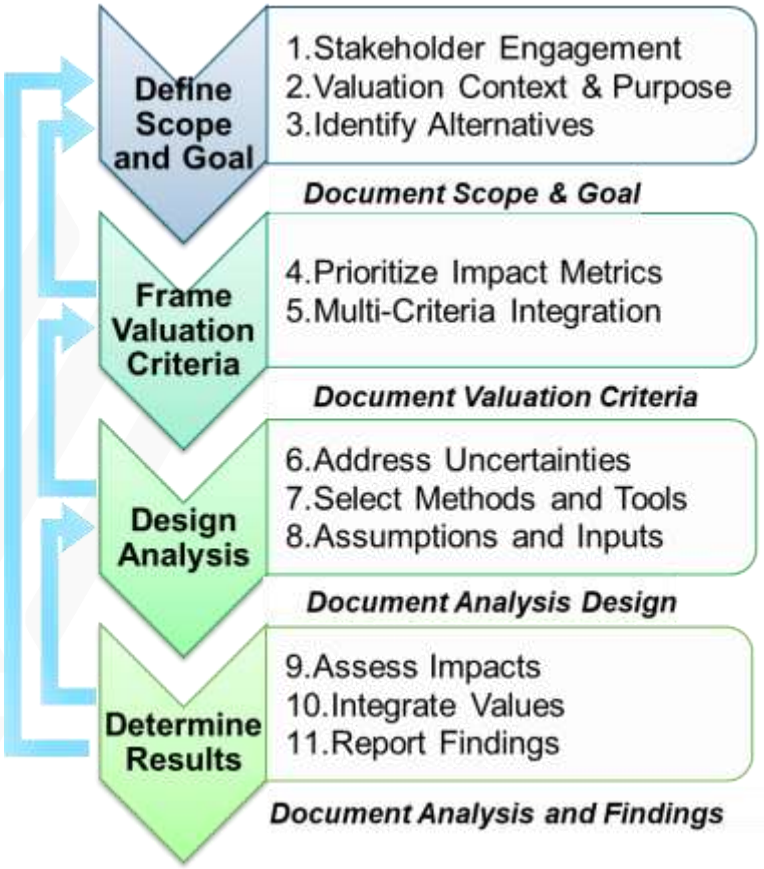
Evolution of the Framework from Benefit-Cost process to broader Electricity-Sector Valuation approach

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Version 1



Version 2



Valuation Framework Development

Objectives

- Develop a Grid Services and Technology Taxonomy
- Describe Valuation formally, as an explicit *Process,*
- Develop Standard, Stakeholder-Vetted Guidelines for the process.

Phases

A. Define the scope of the valuation including purpose, alternatives, and stakeholder engagement
B. Frame the valuation criteria through identification of key metrics and integration
C. Design the analysis including methodology selection, input data, and treatment of uncertainty
D. Determine and document the results

Phases	Steps
Decide to do a Valuation	Identify need; Define Basic Purpose and Objective
	➢ Result: Decision Documentation
A: Define Scope & Goal	1. Plan and Initiate Stakeholder Engagement
	2. Document the Valuation Context and Purpose
	3. Identify the Range of Alternatives
	➢ Result: Scope & Goal Documentation
B: Frame Valuation Criteria	4. Identify Key Impact Metrics for Valuation
	5. Determine Multi-Criteria Integration Approach
	➢ Result: Valuation Criteria Documentation
C: Design Analysis	6. Determine Approach to Address Uncertainties
	7. Select Assessment Methods and Tools
	8. Develop Assumptions and Input Data
	➢ Result: Analysis Design Documentation
D: Determine & Present Results	9. Impacts for Each Alternative
	10. Calculate Integrated Values for Each Alternative
	11. Compare Values, Document Analysis & Report Findings
	➢ Result: Results Documentation

A. Define Scope and Goal

1. Expanded stakeholder engagement guidance
   - Accounting for stakeholder perspectives and priorities
   - Soliciting inputs and feedback from stakeholders to ensure buy-in
   - Identifying primary basis for making decision/choosing alternative – formulate in terms of metrics/impacts to be considered
   - Guidance for factoring stakeholder input into other activities
2. Additional guidance on framing purpose, scope and context of the valuation
   - Formulate the specific decision
   - Define scope – energy sub-sector, technologies, policies, etc.
   - Identify resource and schedule constraints
3. Define alternatives
   - Must be specific about choices
   - Include “business as usual” case

B. Frame Valuation Criteria

4. Identify relevant impacts and metrics
   - What is basis for decision (from #1)?
   - Prioritize metrics – essential/important/desirable
   - Characterize complex/compound metrics in terms of basic metrics; Specify methods to obtain complex metrics from the basic ones
   - **Expand metrics beyond power system attributes** – e.g., economics
5. Formulate approach to integrate multiple criteria
   - How to visualize/process complex valuations with disparate, sometimes competing metrics and their tradeoffs
   - Expanded guidance on options – monetize, other common units, list separately, suggested graphic presentations
   - Tradeoffs and prioritization among metrics/impacts
   - Will help frame and inform constructive debate among stakeholders about choice

C. Design the Analysis

6. How to address uncertainty – categorize and manage it
   - Uncertainty in data, model accuracy, events/condition of power grid
   - Uncertainty can drive various types of Risk
   - Different strategies for different metrics: Sensitivity analysis; Scenario analysis; Probabilistic analysis
   - Illustrative scenarios and sensitivity studies may be efficient to address complex, multi-variate valuation decisions (e.g., resilience)
7. Select Methods and Tools
   - Characterize tools' capabilities in same terms as the information requirements of the valuation question (steps #1, 2, 3, 4, 5)
   - Use methodologies for deriving and calculating metrics (steps #4, 5, 6)
   - SAG members cautioned against analysts' over-reliance on models with which they are comfortable ("when you're a hammer…")
   - **Reduce emphasis on engineering models** – choice is not likely to be between models, but rather between methods and between levels of calculation detail/resolution

C. Design the Analysis (continued)

8. Assumptions & Input Data
   - The choice of assumptions about the state of the region and the power system and its customers will have substantial impacts on the quantitative results of the modeled alternatives.
   - Are data available? Confidence in data accuracy?
   - **Consistency required among input data from different sources**
   - Often **implicit assumptions** are made that can bias results: the framework offers a **deliberate process** to help identify such assumptions and document them

D. Determine and Present Results

9. Assess impacts for each alternative
   - Informed by steps #4, 6, 7, 8
10. Calculate integrated values for each alternative
    - Informed by Steps #1,5
11. Compare values, document analysis and findings

    This step documents the findings, including the opportunity to publish a "matrix" of metrics, if appropriate, rather than trying to combine all metrics into a single valuation number/index/metric. Step 1 (Stakeholder Engagement) and Step 5 (Multi-Criteria Integration Approach) inform the format and content of the presentation of valuation findings. Steps 8 (Assumptions & Input Data), 9 (Calculate Impacts); and 10 (Calculate Integrated Values) determine the numeric values.

Grid Services & Technologies Valuation Framework

Test Case #1 (Tabletop)

Focus: State Support for Existing At-Risk Nuclear Generators

- Explore recent studies on the implications of premature retirement of existing at-risk nuclear plants or the impacts of specific support programs (e.g., zero emissions credits [ZEC])
- From a specific state perspective (PUC or legislature)
- NY, IL, OH

New York

- PSC approved creation of ZECs to provide additional revenue stream to at-risk (upstate) nuclear plants as part of Clean Energy Standard (CES) Order
- CES cost study conducted by PSC/NYSERDA staff based on State Benefit-Cost Analysis requirements includes impact of ZEC program

Illinois

- Legislation passed as part of a broader Jobs Bill related to electricity generation that creates Zero Emissions Credits (ZECs) to provide additional to qualifying nuclear plants
- Comprehensive analysis conducted by state agencies to estimate impacts of pre-mature nuclear plant retirement

Ohio

- Senate Bill 128 introduced to Zero Emission Nuclear Resource Program (ZEN) to provide additional revenue stream to at-risk nuclear plants Followed PUC filing and decision on Energy Security Plan (ESP) to promote electricity rate stability via a virtual PPA that was later prevented by FERC
- Fiscal analysis conducted by Ohio Legislative Service Commission (LCS) and stakeholder-specific analysis (e.g., Ohio Consumer's Counsel)

Brattle published separate but similar analyses for IL, NY, and OH estimating the contribution of at-risk nuclear plants to each state's economy, including the potential impact of plant closures on power prices and cost to consumers

Grid Services & Technologies Valuation Framework

First Test Case – Tabletop Exercise

(*August – December 2017)*

*Purpose: Test the Framework's usefulness for interpreting, **comparing**, and contrasting studies; and identify opportunities for improvement*

*Approach: Compare Framework Guidelines to approaches used in existing assessments of potential state **support for existing nuclear generators that are economically at-risk***

Best practices identified during the review

- A must-follow, clear question and directive to perform the analysis
- Identification of boundaries for analysis – geographic, time scales
- Well-documented Cost-Benefit Analysis methodology with intent to apply consistently across investment/policy decisions
- Robust documentation of methods and results for each process step
- Recognition that future is uncertain: implications on method selection and confidence in results

Key improvement opportunities that were identified

- This exploration of prior work was helpful in informing the structure of the valuation approach
- Need to connect how the valuation study will explicitly inform a specific decision
- Consider establishing an integrated method from which all impacts can be derived consistently
- Often the final benefits or costs may be highly uncertain. It is important to identify and document what factors and assumptions drive this uncertainty.
- Allocation of costs, benefits, and risks can be an important consideration, including the resulting synthesis of these allocation outcomes
- Robust documentation that includes the decision context and key analyses can inform future valuations for similar questions considered in other jurisdictions

Grid Services & Technologies Valuation Framework

Test Case #2 (Interactive Exercise)

Focus: Project Opportunity – Microgrid

Source: https://www.delta-ee.com/research-consulting/micro-grids.html

Question:

Identify the value of a microgrid that postpones the need for a substation upgrade and / or provides additional resilience and compare to a baseline option (substation upgrade).

Alternatives:

- Build microgrid
- Upgrade substation and distribution feeders
- Add generators to defer substation upgrading
- Add distributed storage / gen without coordination

Stakeholders Represented:

- Utility
- Directly impacted customers
- Other customers
- Local government
- Community representatives

Potential Metrics:

- Cost to owner
- Cost to utility
- Value streams on bulk power system
- Economic value to Anytown, FL
- Value streams to owner (under tariff options)
- Reliability (short outages)
- Resilience for bulk power system
- Impact on emissions
- Equity / cost distribution
- Cost minimization
- Innovation impacts

Grid Services & Technologies Valuation Framework
Second Test Case – Interactive Exercise with Volunteers from SAG (*April – October 2018)*

*Purpose: Test drive the framework to systematically and transparently **consider a more complex valuation of a grid technology** or service – **microgrid vs. conventional system** expansion; consider **value of improved resilience** in addition to power production economics*

*Approach**: Used a sub-set of the SAG; performed a detailed consideration of each step in the framework through roleplay, discussions of experience, and review and recommendations*

Key improvement opportunities identified:

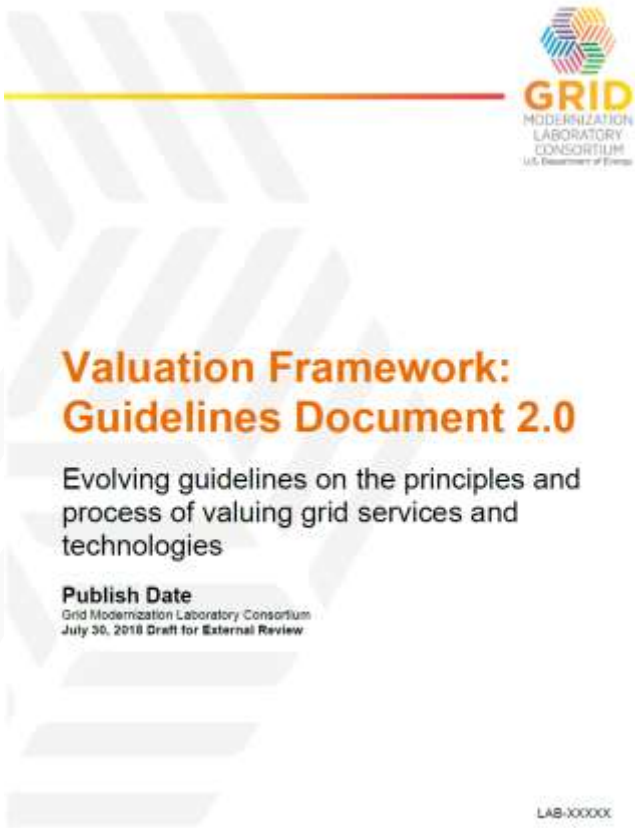
- Develop guidance to help identify alternatives, and include tools that help remind stakeholders of the basis for consideration
- Improve the method for identifying key metrics by increasing stakeholder input and considering non-power system metrics (e.g., regional economics)
- Provide option for methods to calculate metrics, together with estimated costs/effort and expected accuracy of each method
- Guidance document, as presented, was too focused on engineering models and technical calculations – basis of decision is often economics or “soft” metrics
- Provide visualization options for multiple metrics
- Include the framework’s activities explicitly tracking impacts resulting from each alternative on key metrics
- Improve directions regarding iterations back to previous steps (when, how, etc.)
- Develop methods for reminding stakeholders of decisions made during previous steps

Grid Services & Technologies Valuation Framework
Some Takeaways from Test Cases, SAG Coordination

- Expand list of metrics – don't limit to electrical system
- Over-reliance on engineering models. Choice of financial calculation methods also important.
- *Methods* more important than *models.*
- Decision makers may need analysis methods for broad/regional impacts (not just grid engineering-focused) to make their choice.
- Consultants very often are pre-disposed to use their own or familiar models and methods. *Much concern about making sure methodology used for valuation actually addresses the information needs of decision makers and important stakeholders.*
- *SAG participants very positive about the value of Valuation Framework.*
  - Making sure valuation analysis results (type, scope, format) match decision makers' needs
  - Being deliberate in choosing – **and documenting** – methods, assumptions, input data, valuation criteria. Required for both quality and transparency of valuation
  - Applying the framework *process* more valuable than developing large catalogs of tools and resources

External Review of Guidance

- Project team and SAG Identified approximately 50 potential external reviewers across the energy sector
- Version 2.0 of the Valuation Framework Guidelines Document has incorporated additional work by project team, extensive internal review, and some feedback from Test Cases
- External Reviewers invited to comment
  - Is the document sufficiently specific to identify the audience(s) for which it written? If not, who (do you think) is the audience?
  - Does the document help advance the overarching goals of improving the transparency, consistency, and repeatability of the valuation process? If not, how can it be improved?
  - The document describes in general terms an overarching process. As a next step, where in the document or process do you think more concrete guidance is needed, and would advance the discipline of valuation?
  - Any other comments regarding usefulness, strengths & weaknesses, next steps?



GRID MODERNIZATION INITIATIVE PEER REVIEW

GMLC 1.4.25 - Distribution System Decision Support Tool Development and Application

MICHAEL R. INGRAM, NREL

September 4-7, 2018

Sheraton Pentagon City – Arlington, VA

Distribution System Decision Support Tool Development and Application

High-Level Project Summary

Project Description

Identify strategies and provide technical assistance to state regulators and utilities that focus on advanced electric distribution planning methods and tools, with a focus on incorporating emerging grid modernization technologies and the significant deployment of DER

Value Proposition

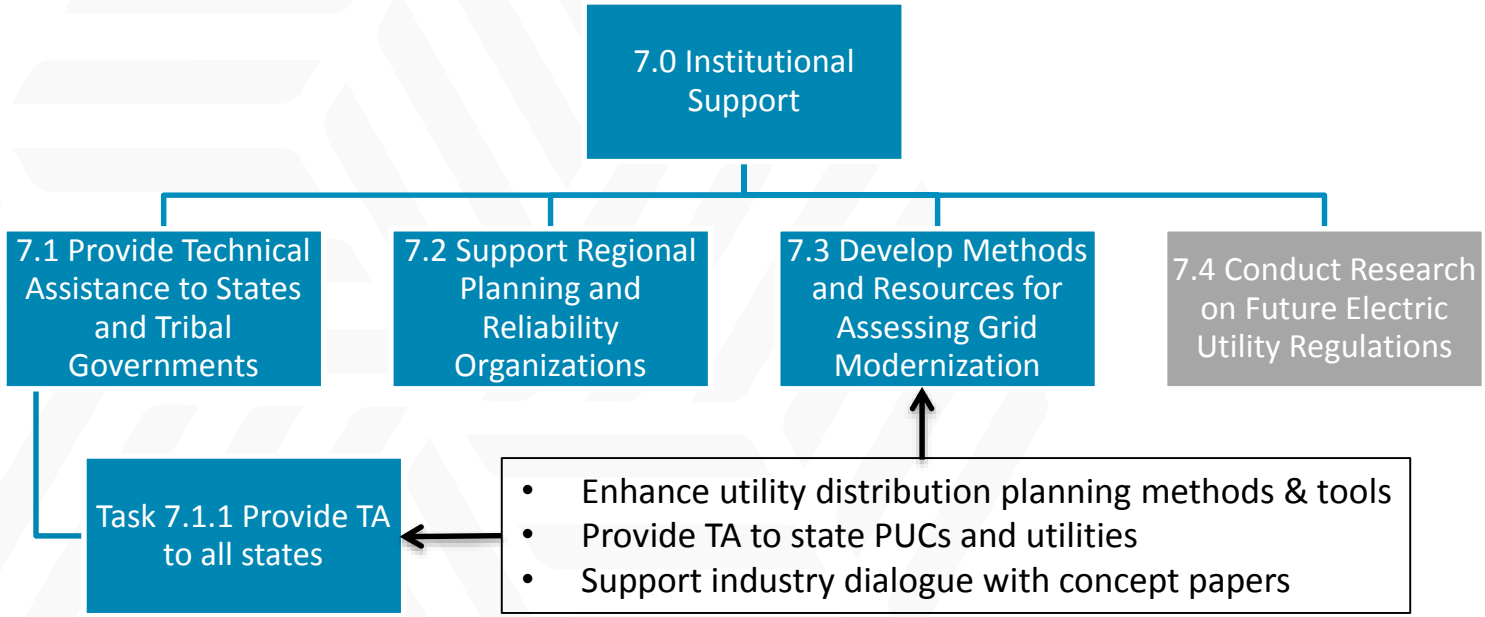
- ✓ Electric distribution systems are aging and in need of expensive upgrades
- ✓ Large amounts of DERs are being integrated to distribution systems in U.S.
- ✓ PUCs and decision makers have asked for assistance in understanding the distribution systems, planning and prioritizing upgrades

Project Objectives

- ✓ Provide technical assistance to state regulators in partnership with NARUC
- ✓ Identify gaps in existing and emerging planning practices & approaches
- ✓ Compile information on existing planning tools, identify gaps and necessary functions
- ✓ Provide technical assistance to electric utility industry and associated stakeholders

Distribution System Decision Support Tool Development and Application

Relationship to Grid Modernization MYPP



Distribution System Decision Support Tool Development and Application

Project Team

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Participants and Roles

Michael Ingram – NREL (Electric Utility)

Lisa Schwartz – LBNL (Regulatory)

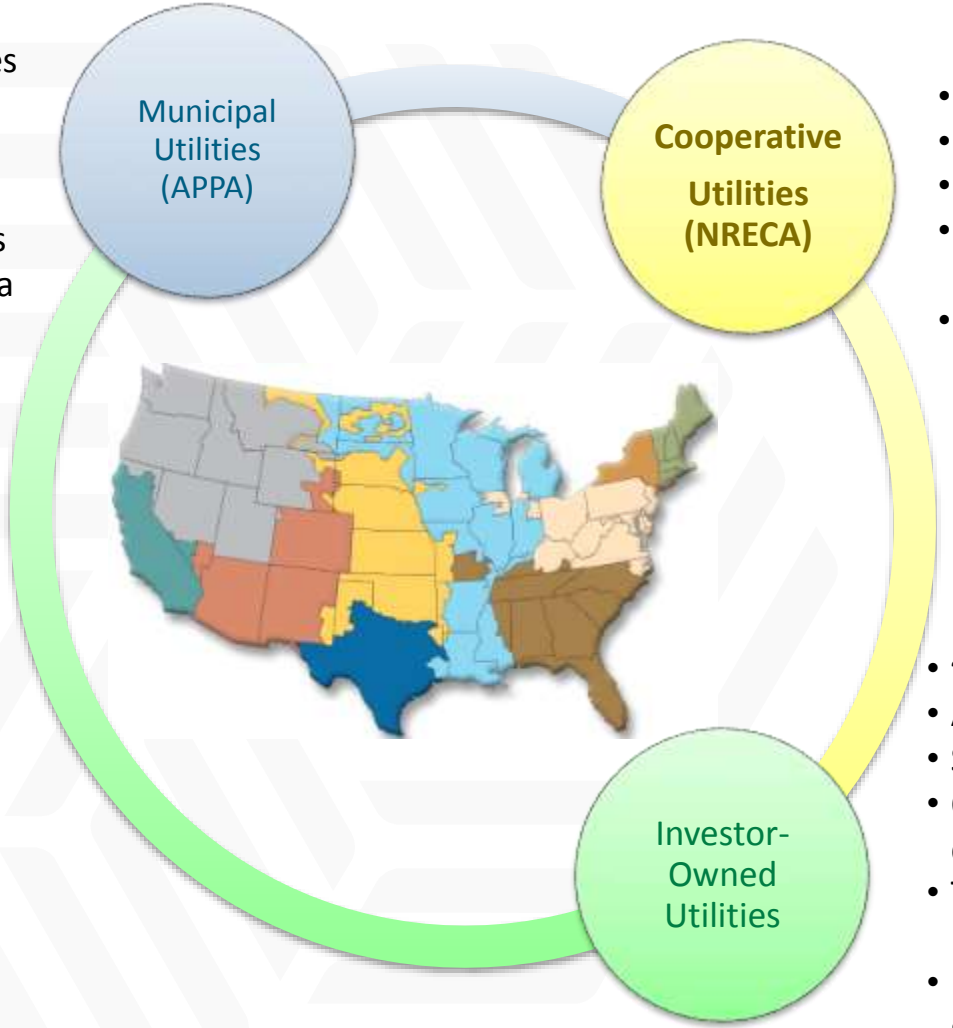
Juliet Homer – PNNL (Tools & Regulatory)

PROJECT FUNDING			
Lab	FY16 $	FY17 $	FY18 $
NREL	$350k	$350k	$350k
LBNL	$250k	$250k	$250k
PNNL	$234k	$233k	$233k

Distribution System Decision Support Tool Development and Application

Market Context

- ~2000 municipal Utilities
- Average 2200 meters
- Serve 10% of market
- Own & maintain 7% of U.S. distribution feeders
- ~1300 municipals have a single substation!
- Most municipal utilities are very small and distribution planning is less complex



- ~900 cooperative utilities
- Average 13,000 meters
- Serve 13% of market
- Own & maintain 42% of U.S. distribution Feeders
- Many cooperatives leverage external partners for planning

- ~170 investor-owned utilities (IOU)
- Average 400,000 meters
- Serve 72% of market
- Own & maintain 50% of U.S. distribution feeders
- Typically have large Electric Distribution Planning departments
- Regulated utilities, under new scrutiny in distribution planning

Data from DOE, EIA, NRECA, APPA, EEI

Distribution System Decision Support Tool Development and Application

Approach

- ✓ Support Regulatory Agencies – Deliver in-person training courses for state PUCs on emerging distribution planning practices, methods and tools, with support and guidance from NARUC and a state PUC advisory group. Develop detailed summary of state activities in distribution system planning with DERs and grid modernization (from a regulatory perspective). *2017 & 2018*
- ✓ Engage with APPA and NRECA; Identify the highest priority TA on distribution system tools and needs that this team can provide. Share information with other GMLC teams. *2017 & 2018*
- ✓ Provide detailed assessment of existing distribution planning tools, capabilities, gaps and recommendations for filling those gaps. *2017 & 2018*
- ✓ Interview top distribution system analysis tool vendors (CYME, Synergi and Milsoft) to assess capabilities of current tools, planned developments and gaps. *2018*

Distribution System Decision Support Tool Development and Application

Accomplishments to Date

- ✓ Developed, facilitated and presented at Regional PUC workshops (NE, MW, West) targeted at state utility regulators on distribution system planning and emerging issues.
- ✓ Detailed summary of state activities in distribution system planning with DERs and grid modernization - from a regulatory perspective.
- ✓ Summary report on commercial distribution system analysis (DSA) tools, including maturity and gaps, for addressing high levels of DERs.
- ✓ Technical assistance to many states assessing and deploying grid modernization and support for planning organizations. (*including CA, CO, HI, MA, MN, NY, OR*)

Distribution System Decision Support Tool Development and Application

Accomplishments to Date

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

3 Regional Trainings, 33 States

- New England – CT, ME, MA, NH, RI, VT
- Midwest (MISO footprint) – AR, IL, IN, IA, KY, MI, MN, MO, MT, ND, OH, SD, TX, WI
- West – AK, AZ, CA, CO, HI, ID, MT, NM, NV, OR, UT, WA, WY
- 101 sessions on utility distribution systems and distribution planning, in-depth technical sessions, and moderated discussion
- Public utility commission advisory group identified distribution planning needs to help guide training program
- Co-hosted by National Association of Regulatory Utility Commissioners, National Association of State Energy Officials and regional partners

NATIONAL ASSOCIATION OF REGULATORY UTILITY COMMISSIONERS
DEDICATED TO PUBLIC SERVICE

NASEO
National Association of State Energy Officials

Distribution System Decision Support Tool Development and Application

Accomplishments to Date

New England (9/2017)

- 63% rated training excellent, 30% good (7% average)

Midwest (1/2018)

- 71% rated training excellent, 26% good

West (5/2018)

- 89% rated training excellent, 11% good

100% of respondents would recommend the training to colleagues (all regions)

Some of the things participants liked best:

- *The depth of the presentations and expertise of the trainers*
- *Quality of presenter[s] and team approach to coverage of topics*
- *Quality of content and applicability*
- *[L]earning directly from the active researchers on topics that are cutting-edge, as well as the basic background*
- *[E]xplained concepts in terms that all could understand*
- *Came away with some solid actions & questions to take home*

Distribution System Decision Support Tool Development and Application

Accomplishments to Date

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

State Engagement in Electric Distribution Planning, PNNL, LBNL, and NREL. December 2017

	States with advanced practices					Other state approaches										
	California	Hawaii	Massachusetts	Minnesota	New York	D.C.	Florida	Illinois	Indiana	Maryland	Michigan	Ohio	Oregon	Pennsylvania	Rhode Island	Washington
Statutory requirement for long-term distribution plans or grid modernization plans[a]	✓			✓					✓							
Commission requirement for long-term distribution plans or grid modernization plans[a]		✓	✓		✓					✓	✓					
No planning requirements yet, but proceeding underway or planned						✓							✓		✓	✓
Voluntary filing of grid modernization plans								✓				✓		✓		
Non-wires alternatives analysis and procurement requirements	✓				✓										✓	
Hosting capacity analysis requirements	✓	✓		✓	✓											
Locational net benefits analysis required	✓				✓											
Smart grid plans required													✓			
Required reporting on poor-performing circuits and improvement plans							✓	✓				✓		✓	✓	
Storm hardening requirements							✓			✓						
Investigation into DER markets		✓														

(a) For one or more utilities.

Distribution System Decision Support Tool Development and Application

Accomplishments to Date

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Results from Distribution System Tools Report:

Focus on Analysis Types & Applications

- Power Flow Analysis
- Power Quality Analysis
- Fault Analysis
- Dynamic Analysis

Maturity Levels ranking:

0 – None of the DSA tools offer this function
1 – Only a small number of DSA tools offer it
2 – More than 50% of DSA tools offer it
3 – Most or all tools offer the function

This report has provided significant input into the DSPx project

Distribution System Analysis Types and Applications	Maturity Level
Power Flow Analysis	
Peak Capacity Planning Study	3
Voltage Drop Study	3
Ampacity Study	3
Contingency and Restoration Study	3
Reliability Study	3
Load Profile Study	3
Stochastic Power Flow Study	2
Volt/var Study	2
Real-Time Performance	2
Power Quality Analysis	
Voltage Sag and Swell Study	3
Harmonics Study	2
Fault Analysis	
Arc Flash Hazard Analysis	3
Protection Coordination Study	3
Fault Location Identification	1
Dynamic Analysis	
Long-Term Dynamics	1
Electromechanical Dynamics	2
Electromagnetic Dynamics	3

Information from report presented at IEEE conferences in 2017 & 2018

Distribution System Decision Support Tool Development and Application

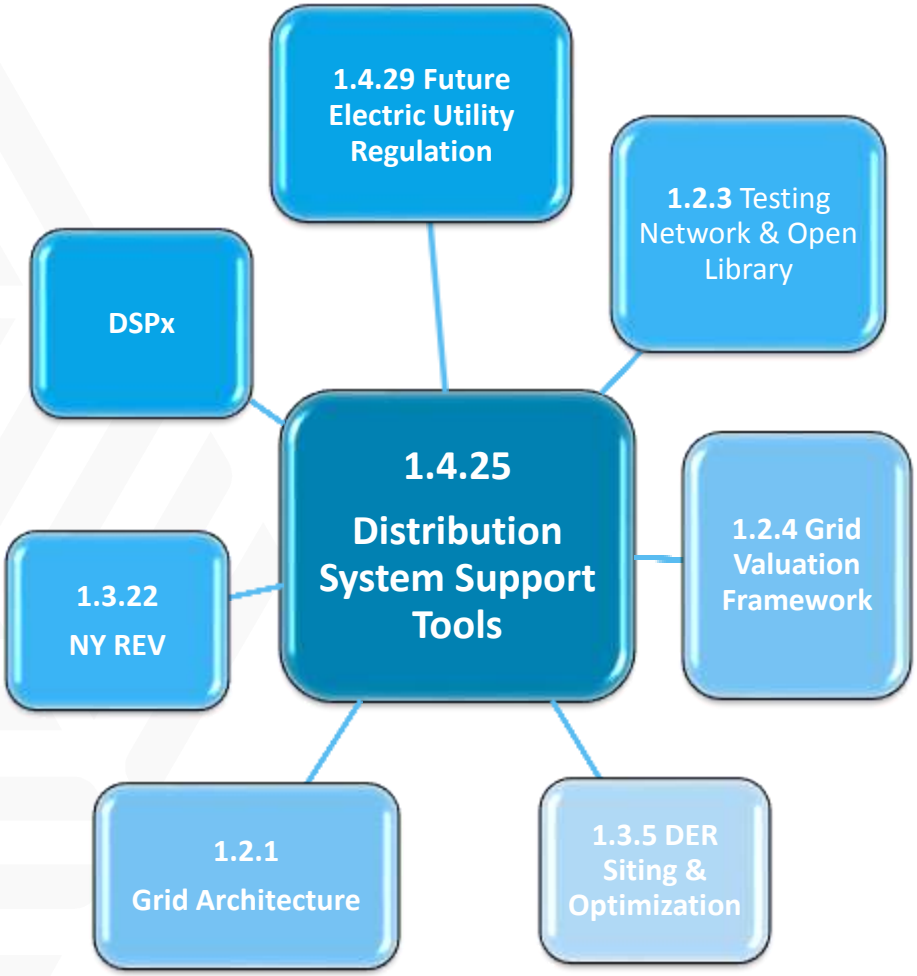
Accomplishments to Date

- ✓ Support of Massachusetts Technical Standards Review Group (ongoing)
- ✓ Technical assistance for the Minnesota PUC in their Interconnection Rule Making
  - ✓ Presently working to incorporate new national standards IEEE 1547-2018, UL 1741SA.
- ✓ Midwest Governor's Association Support
- ✓ California PUC training on DER, distribution planning

Distribution System Decision Support Tool Development and Application

Project Integration and Collaboration

- ✓ **1.4.29: Future Electricity Utility Regulation** – Contribute design and implementation options. Electric utility regulation is a key aspect of this project as this team works to educate regulators on existing and emerging planning methods and tools. Providing TA to MN PUC for interconnection policy.
- ✓ **1.3.5 DER Siting and Optimization Tool for CA** – NY and CA regulators are coordinating on tool development and demonstration
- ✓ **1.2.1: Grid Architecture** – Apply evolving grid architecture with distribution planning tools and methods.
- ✓ **1.2.3 Testing Network & Open Library** – Coordinating tools report with Open Library.
- ✓ **1.3.22: Technical Support to the NYS REV Initiative** – Partner with NY utilities and BNL team to understand advanced approached in distribution system upgrades, planning, non-wires alternatives. Evaluation of alternative distribution planning methods used by Con Edison in the Brooklyn-Queens Demand Management project.
- ✓ **1.1: Foundational Analysis for GMLC Establishment** –Validate and demonstrate grid performance metrics
- ✓ **Next Generation Distribution System Platform (DSPx)** – Developing a cooperative report focused on distribution interconnection standards and codes, distribution planning tools. Coordinate with DSPx and provide inputs as requested (e.g., the distribution planning tools report).



Distribution System Decision Support Tool Development and Application

Next Steps and Future Plans

- ✓ Deliver technical report that identifies distribution system planning tools for DERs and grid modernization – current capabilities, data needs and gaps [09/2018].
- ✓ Developing a report focused on distribution interconnection standards and codes, *and impact on* distribution planning tools. To be published in collaboration with DSPx [12/2018]
- ✓ *Ongoing* support for MN PUC and Mass TSRG with respect to interconnection rules, distribution planning methods, and national standards adoption

- ✓ Extend and expand training (*pending funding*)
  - ✓ Offer to PUCs and state energy offices in Mid-Atlantic and South [01/2019 and TBD]
- ✓ Integrate grid modernization decision framework and implementation roadmap developed by DOE's Next Generation Distribution System Platform (DSPx) initiative to inform transition pathways from legacy systems to modernized infrastructure [TBD]

Thank You For Listening !!!

Distribution System Decision Support Tool Development and Application

Western States Workshop Agenda (Backup Slide)

May 1, 2018 – Pre-training activities

1:00 – 4:00 pm	WIEB Strategy Advisory Committee meeting: Dissemination of Western U.S. Interconnection Findings to States
4:00 – 5:00 pm	Considerations for a Modern Distribution Grid – Joe Paladino, U.S. Department of Energy

May 2, 2018 – Training begins

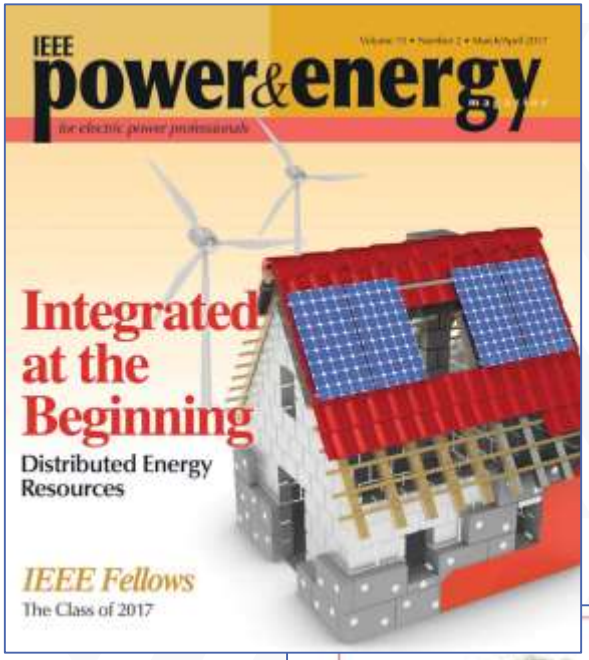
8:00 – 8:15 am	Welcome and opening remarks – Maury Galbraith (WIEB), Kerry Worthington (NARUC), Fred Hoover (NASEO), Lisa Schwartz (Berkeley Lab)
8:15 – 9:45 am	Distribution systems 101 – Kevin Schneider (PNNL) and Emma Stewart (LLNL)
9:45 – 10:00 am	Break
10:00 – 10:45 am	Distribution system controls and automation – Barry Mather (NREL) and Kevin Schneider (PNNL)
10:45 am – 12:15 pm	Utility distribution planning 101 – Mike Coddington (NREL) and Kevin Schneider (PNNL)
12:15 – 1:15 pm	Lunch
1:15 – 2:45 pm	Distributed energy resources – Mike Coddington (NREL), Emma Stewart (LLNL), Jeremy Twitchell (PNNL)
3:00 – 3:45 pm	Reliability metrics and reliability value-based planning – Joe Eto (LBNL)
3:45 – 4:30 pm	Impacts of distributed energy resources on transmission systems: The distribution/transmission interface – Barry Mather (NREL)

May 3, 2018

8:00 – 8:45 am	Forecasting load on the distribution and transmission system with distributed energy resources – Andrew Mills (LBNL)
8:45 – 9:30 am	PUC distribution planning practices – Lisa Schwartz (LBNL)
9:30 – 9:45 am	Break
9:45 – 10:45 am	Emerging distribution planning analyses: Multiple scenario forecasts, hosting capacity analysis, locational net benefits analysis – Debra Lew (GE Energy Consulting)
10:45 – 11:30 am	Walk-through of long-term utility distribution plans: *Part 1 - Traditional plans* - Lavelle Freeman (GE Energy Consulting)
11:30 am – 12:30 pm	Lunch
12:30 – 1:30 pm	Moderated discussion: *How are states beginning to engage in distribution system planning?* Moderator: Lisa Schwartz (LBNL) • Value of state engagement – Chair Jeff Ackermann (CO PUC) • Barriers to state engagement – Maury Galbraith (WIEB) • Less time-intensive approaches vs. full-scale DSP – Jeremy Twitchell (PNNL) • Oversight roles – Dallas Harris (NV PUC) • Integrating DSP with other forms of planning – Dave Parsons (HI PUC) • Stakeholder engagement – Kathi Scanlan (WA UTC)
1:30 – 2:30 pm	Walk-through of long-term utility distribution plans: *Part 2 - Grid modernization plans and plans for high levels of distributed energy resources* - Debra Lew (GE Energy Consulting)
2:30 – 3:00 pm	Moderated discussion: *What questions can states ask utilities to better inform state engagement in distribution system planning?* Moderator: Lisa Schwartz (LBNL)

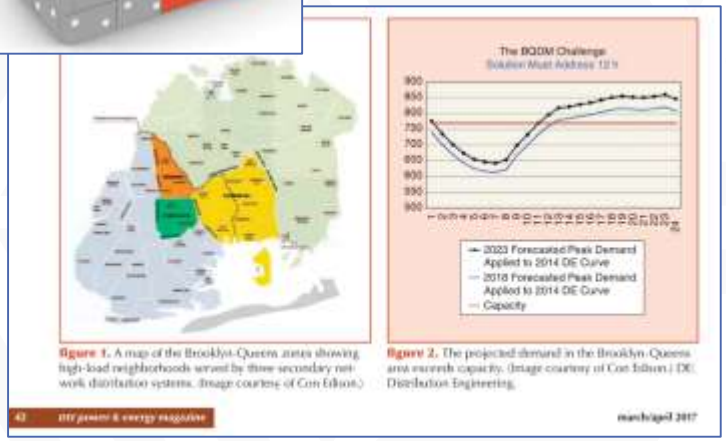
Distribution System Decision Support Tool Development and Application

NY REV (Backup Slide)



NREL-led IEEE Report on Alternatives to Traditional Distribution System Planning with Con Edison:

- Long-term Forecast showed Brooklyn Queens networks would see overloads on peak days
- Traditional approach was to build out distribution circuits, add substation transformers & switchgear, and new transmission upgrades (all underground)
- Cost estimate to serve all of this new load >$1Billion
- NY DPU via NY REV seeks alternatives from Con Edison rather than traditional investments



Many solutions were employed, including Energy Efficiency measures, Fuel Cells, Solar PV systems, Volt-VAR Optimization, Demand Response, Gas-Fired Distributed Generation, Battery Energy Storage Systems (BESS), and more…..

GRID MODERNIZATION INITIATIVE PEER REVIEW
1.4.29 – Future Electric Utility Regulation

PETER CAPPERS (BERKELEY LAB)

September 4–7, 2018

Sheraton Pentagon City Hotel – Arlington, VA

Future Electric Utility Regulation
High-Level Project Summary

Project Description

Provide technical assistance and analysis for public utility commissions (PUCs) 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 utility shareholders and customers
- Engaging consumers
- Addressing utility incentives to achieve grid modernization goals

Value Proposition

- ✓ Modernizing grids requires utilities to make large investments in the face of rapid change and increasing risk and uncertainty.
- ✓ This project helps PUCs and utilities explore regulatory changes to deploy needed capital.

Project Objectives

- ✓ Improve capability of states to consider alternative regulatory and ratemaking approaches that enable grid modernization investments.
- ✓ Better tie utility earnings to consumer value, economic efficiency, and other policy goals.
- ✓ More efficiently deploy capital to achieve grid modernization goals.

Relationship to Grid Modernization MYPP

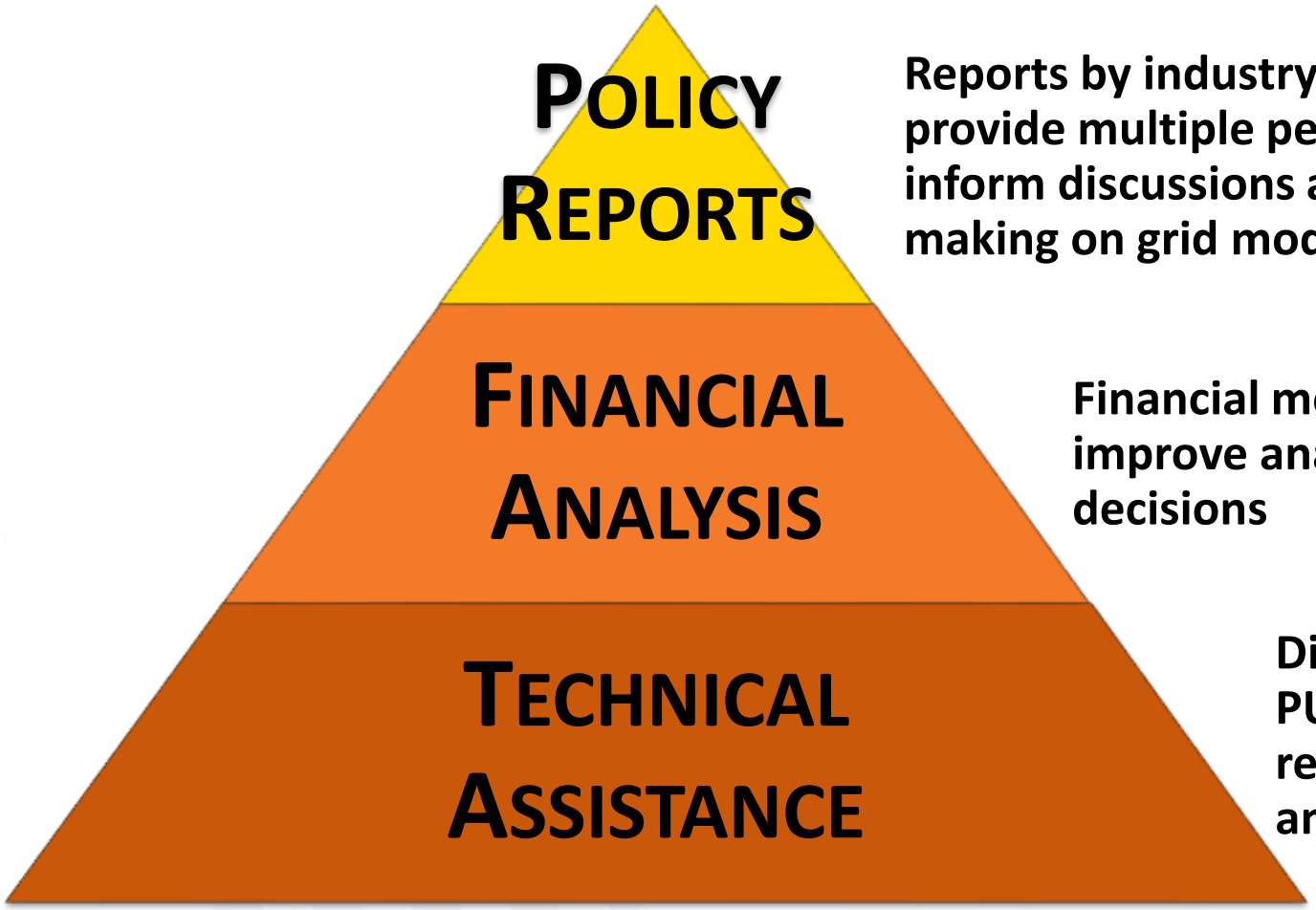
Future Electric Utility Regulation
Project Team

Project Participants and Roles

- LBNL – Project manager; modeling and state technical assistance (TA); Future Electric Utility Regulation report series; performance-based regulation technical report
- NREL – Plus one; modeling and state TA
- NETL – Modeling and state TA
- SNL – State TA
- PNNL – State TA
- National Association of Regulatory Utility Commissioners – Outreach

PROJECT FUNDING			
Lab	**FY16 $**	**FY17 $**	**FY18 $**
LBNL	$810	$803	$803
NREL	$71	$125	$125
NETL	$75	$0	$0
SNL	$34	$41	$42
PNNL	$10	$30	$30
TOTAL	**$1M**	**$1M**	**$1M**

Future Electric Utility Regulation
Approach



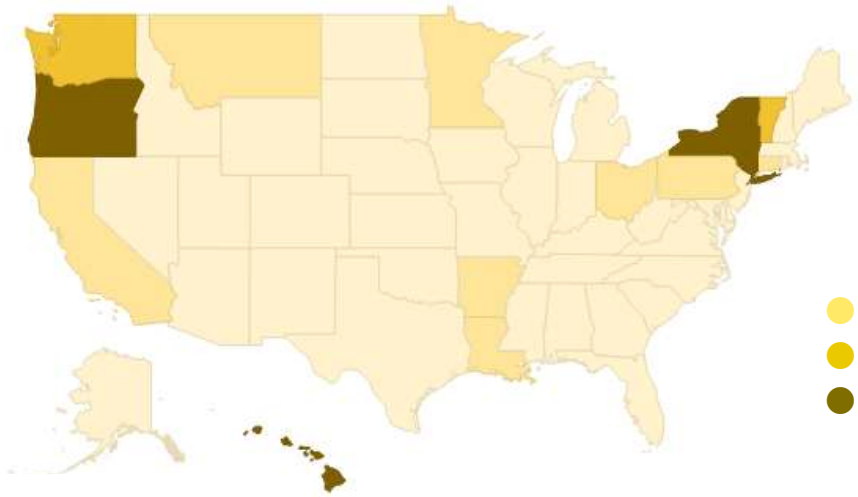
Reports by industry thought-leaders provide multiple perspectives to inform discussions and decision-making on grid modernization

Financial modeling tools to improve analyses and decisions

Direct TA to state PUCs to provide requested expertise and resources

Future Electric Utility Regulation
Accomplishments to Date

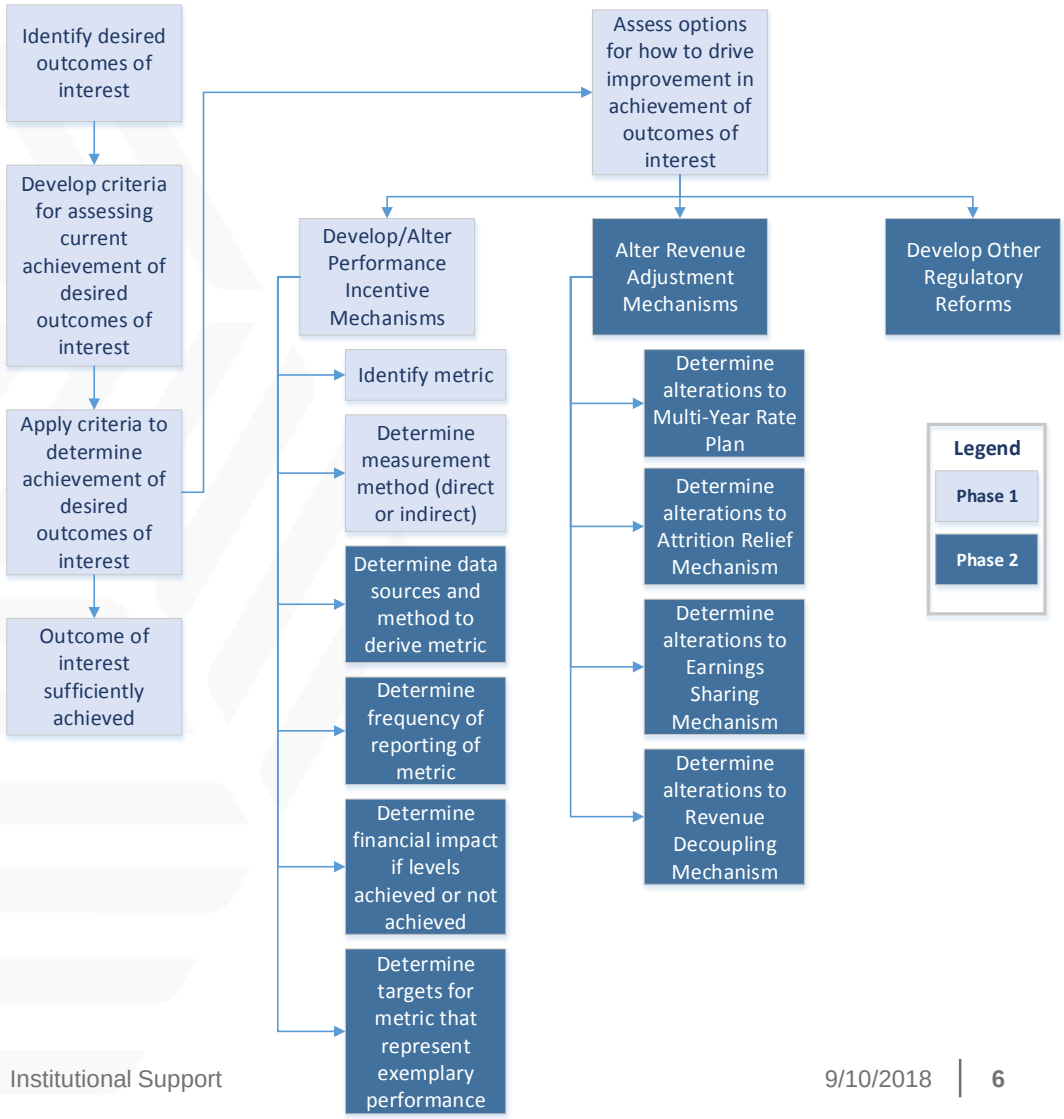
- Two types of TA
  - **Incremental changes**: Initiatives that consider modest (i.e., narrow) changes to specific elements of cost of service (COS) regulation
  - **Comprehensive changes**: Initiatives that examine fundamental, alternative approaches to COS



- Topics covered to date include
  - Cost recovery approaches for grid modernization investments
  - Customers economics of DER
  - Metrics and performance incentive mechanisms
  - Utility financial impacts of DER
  - Revenue recovery mechanisms
  - Performance-based regulation
  - Utility investor valuation framework and shareholder incentives

Future Electric Utility Regulation
Accomplishments to Date

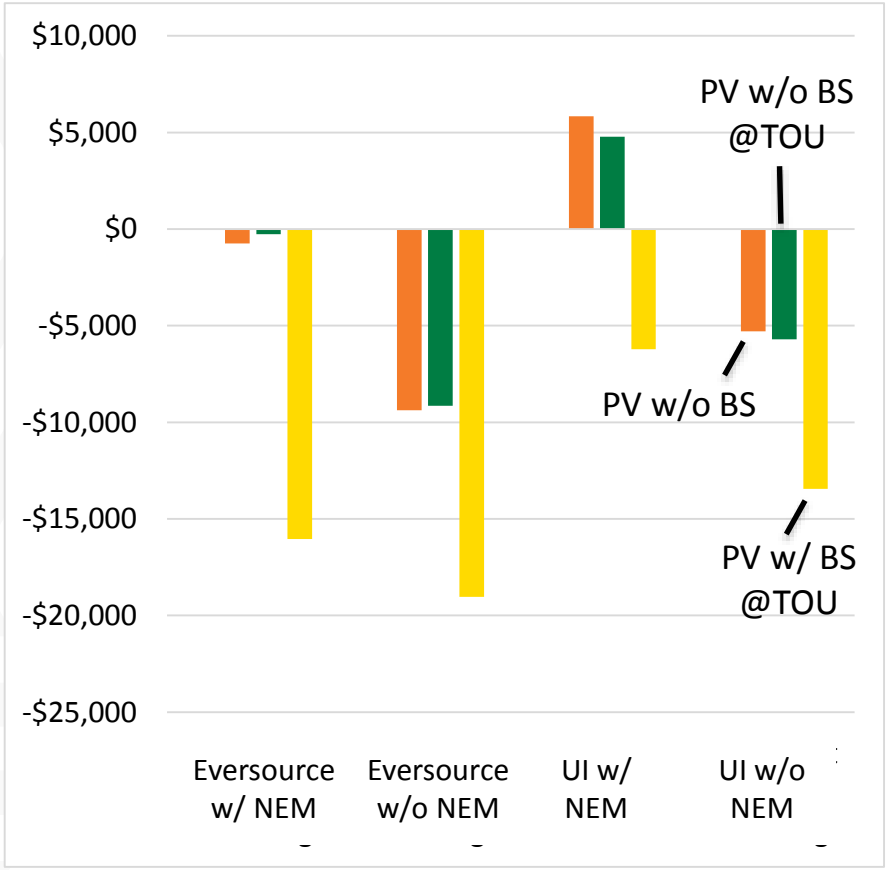
- Regulatory proceeding in Hawaii to investigate economic and policy issues associated with transition to PBR
- LBNL supporting Commission and staff since December 2017
  - Reviewed and commented on Opening Order, Convening Order, and Staff Report on "*Goals and Outcomes for PBR in Hawaii*"
  - Developed a process for segmenting issues of interest into two phases that Commission adopted (see graphic)
  - Supported stakeholder workshops
- Full Commission sent letter of appreciation to DOE for the value of TA delivered so far



Future Electric Utility Regulation
Accomplishments to Date

- NREL conducted modeling of the economics of solar PV plus battery storage (BS) systems in Connecticut (December 2017)
  - Used existing NREL REopt model
  - Informed design of PV & BS incentive program
  - Assessed opportunities for customer use of storage as back-up power
- NREL improved Integrated Energy Systems Model for assessing DER impacts and load response under various rates (August 2018)
  - Added capability to assess export rates
  - Improved treatment of storage and appliance response to export rates
  - States can use model to examine how rates can drive consumer behavior to minimize grid impacts and investments, and evaluate customer economics

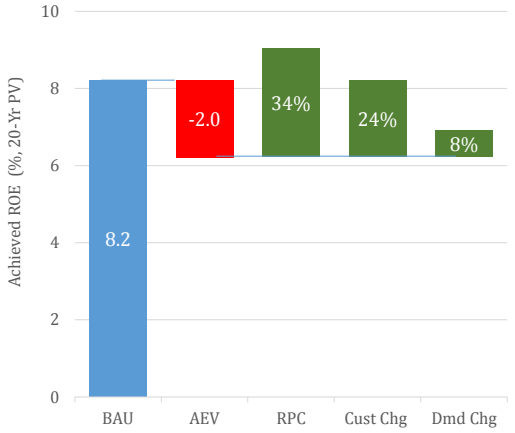
Net Present Value of PV and Storage Investment



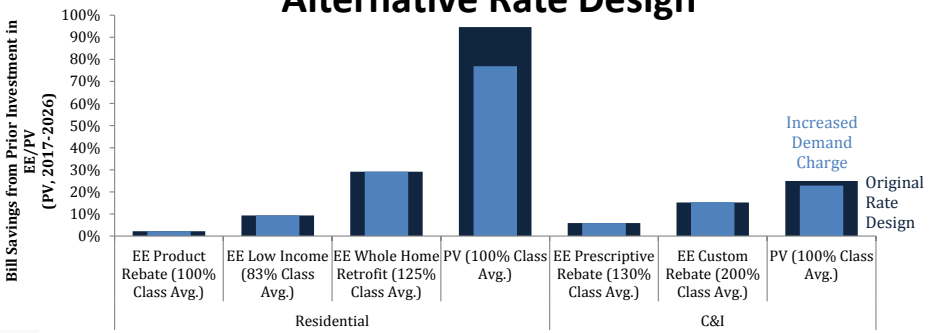
Future Electric Utility Regulation
Accomplishments to Date

- LBNL analyzed utility and customer (participant and non-participant) financial impacts from combined effects of aggressive 10-yr ramp-up of energy efficiency and distributed solar PV for a northeast utility (April 2017)
  - Hourly impacts ➔ shifts in timing of system peak
  - Impacts on utility costs, revenues, earnings, return on equity and customer rates
  - Impact of mitigation approaches — e.g., alternative revenue collection mechanisms such as demand charges and increased fixed customer charges
  - Presented to a number of national/regional regulatory and policymaking organizations
  - Published in a peer-reviewed journal
- Framework and results used to support subsequent technical assistance activities in Michigan and Minnesota

Utility ROE Impacts under Alternative Revenue Collection Mechanisms



Participant Bill Impacts (Savings) under Alternative Rate Design



Future Electric Utility Regulation
Accomplishments to Date

FUTURE ELECTRIC
Utility Regulation

- Innovative series of reports taps industry thought leaders to grapple with complex electricity issues
- Unique multiple-perspective approach highlights different views on the future of utility regulation and business models and achieving a reliable, affordable, and flexible power system to inform ongoing discussion and debate
- 4 of 6 reports completed so far
- Commissioners and their Staff, Utilities, and other stakeholders have all indicated the importance these reports have played in their development of positions on these topics

Future of Electric Utility Regulation

Next Steps and Future Plans

- Next Steps
  - Complete **state TA** to support decision making in HI, LA, NY, VT, and WA
  - Conclude **modeling** activities
  - Finalize the last two installments of the **Future Electric Utility Regulation report** series
- Future Plans
  - Continue providing state TA through DOE-funded efforts
  - Apply expanded analytical models in new DOE-funded research projects
  - Possibly continue with the FEUR report series

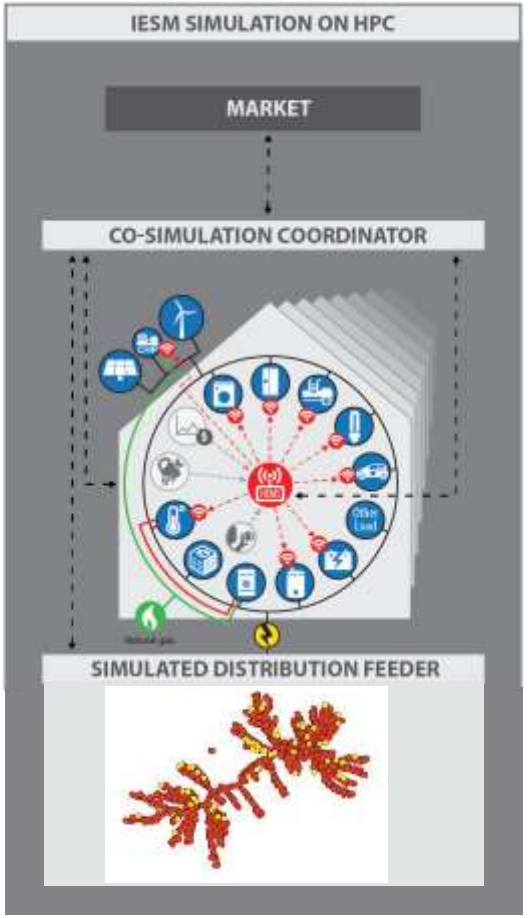
BACKUP SLIDES

Technical Assistance Opportunities to Date

- Cost recovery mechanisms for demand response (MN)
- Cost recovery approaches for grid resiliency and security investments (PA)
- Customer economics of DER (CT, Puerto Rico, WA)
- Distribution system services and market design (HI)
- DR potential and cost effectiveness (OR)
- Metrics and performance incentive mechanism design and implementation experience (HI, LA, NY, VT)
- Microgrid development (Pittsburg)
- Revenue recovery mechanism design and implementation experience (OH, MT)
- Utility financial impacts of DER aggregations (AK)
- Utility investor valuation framework and shareholder incentives (CA)
- Regulatory approaches for improving resilience (New Orleans, LA)

Integrated Energy System Model (IESM) Overview

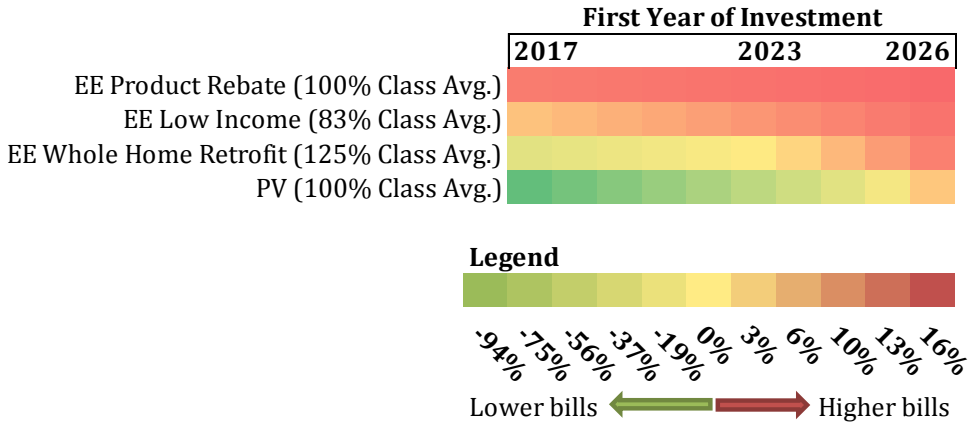
- IESM simulates performance of *technologies* within multiple *buildings* under various retail *market* structures
- Co-simulation coordinator integrates feeder & building simulations, home energy management systems (HEMS) & markets
  - Python-based (plan to adopt HELICS)
- HEMS schedules operation of appliances in response to consumer preferences, price, weather, and distributed generation forecasts
  - Multi-objective, stochastic optimization based on model predictive control (MPC)
  - HEMS controls thermostat, EVSE and water heater
  - Runs on HPC to parallellize hundreds of HEMS



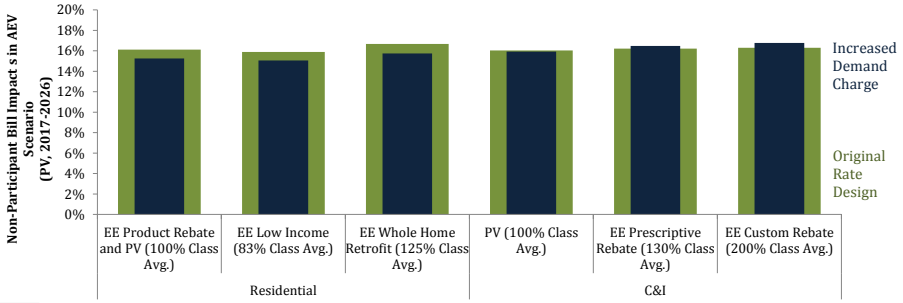
Participant/Non-Participant Impacts from EE & PV for Northeast Utility

- For participants, PV systems are so large no matter when they are installed, they provide net bill savings but not so for EE – size of energy savings can not keep pace with rising retail rates
- For non-participants, because rates are designed for the class-average customer and all customer sub-populations are scaled up or down from class-average, the impact of greater reliance on demand charges have very minor effects on size of non-participating customer bill impacts

Magnitude and Timing of Participant Bill Impacts

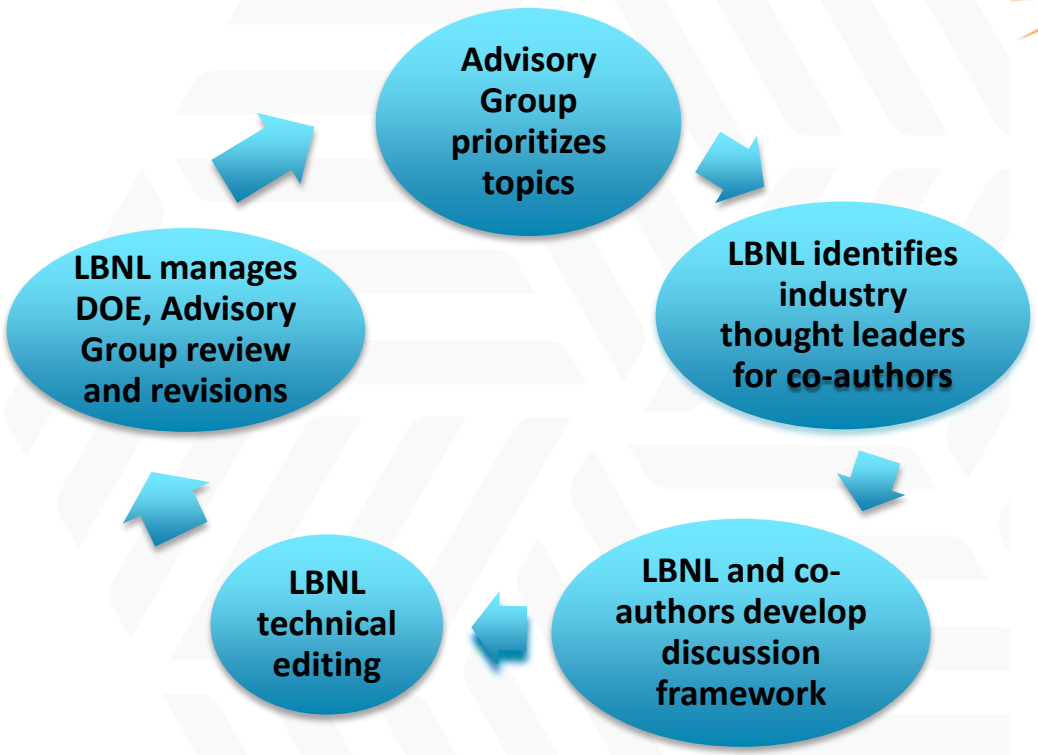


Non-Participant Bill Impacts under Alternative Rate Design



Satchwell, Andrew, Peter Cappers, and Charles A Goldman. ***Financial Impacts of a Combined Energy Efficiency and Net-Metered PV Portfolio on a Prototypical Northeast Utility***. 2017. https://emp.lbl.gov/publications/financial-impacts-combined-energy

FEUR Report Series: Process and Advisory Group Members



FUTURE ELECTRIC Utility Regulation

The Future Electric Utility Regulation Advisory Group is composed of recognized experts including state regulators, utilities, stakeholders, and academia. The Advisory Group provides input to the topics and key issues the series covers and their prioritization, and reviews draft reports.

- **Chair Jeffrey Ackermann,** Colorado Public Utilities Commission
- **Janice Beecher**, Institute of Public Utilities, Michigan State University
- **Ashley Brown**, Harvard Electricity Policy Group
- **Steven Caldwell,** National Grid
- **Paula Carmody**, Maryland Office of People's Counsel
- **Ralph Cavanagh**, Natural Resources Defense Council
- **Steve Corneli**, consultant
- **Tim Duff**, Duke Energy
- **Peter Fox-Penner**, Boston University Questrom School of Business
- **Scott Hempling,** attorney
- **Val Jensen,** Commonwealth Edison
- **Commissioner Travis Kavulla,** Montana Public Service Commission
- **Steve Kihm,** Seventhwave
- **Chair Nancy Lange**, Minnesota PUC
- **Lori Lybolt**, Consolidated Edison
- **Jeff Lyng**, Xcel Energy
- **Sergej Mahnovski**, Edison International
- **Kris Mayes**, Arizona State University College of Law/Utility of the Future Center
- **Jay Morrison**, National Rural Electric Cooperative Association
- **Delia Patterson**, American Public Power Association
- **Commissioner Carla Peterman**, California PUC
- **Sonny Popowsky**, Former consumer advocate of Pennsylvania
- **Commissioner Jennifer Potter,** Hawaii PUC
- **Karl Rábago**, Pace Energy & Climate Center, Pace University School of Law
- **Rich Sedano**, Regulatory Assistance Project

FEUR Report Series: Publications to Date

- Jones, Philip B, Jonathan Levy, Jenifer Bosco, John Howat, and John W Van Alst. ***The Future of Transportation Electrification: Utility, Industry and Consumer Perspectives***. Ed. Schwartz, Lisa C. Vol. FEUR Report No. 10. 2018. https://emp.lbl.gov/publications/future-transportation-electrification
- Blansfield, Jonathan, Lisa Wood, Ryan Katofsky, Benjamin Stafford, Danny Waggoner, and National Association of State Utility Consumer Advocate. ***Value-Added Electricity Services: New Roles for Utilities and Third-Party Providers***. Ed. Schwartz, Lisa C. Vol. FEUR Report No. 9. 2017. https://emp.lbl.gov/publications/value-added-electricity-services-new
- Kihm, Steve, Janice Beecher, and Ronald Lehr. ***Regulatory Incentives and Disincentives for Utility Investments in Grid Modernization***. Ed. Schwartz, Lisa C. Vol. FEUR Report No. 8. 2017. https://emp.lbl.gov/publications/regulatory-incentives-and
- Glazer, Craig, Jay Morrison, Paul Breakman, Allison Clements, and National Association of State Utility Consumer Advocate. ***The Future of Centrally-Organized Wholesale Electricity Markets***. Ed. Schwartz, Lisa C. Vol. FEUR Report No. 7. 2017. https://emp.lbl.gov/publications/future-centrally-organized-wholesale

GRID MODERNIZATION INITIATIVE PEER REVIEW

GMLC 1.5.7 – Laboratory Value Analysis of Resilient Distribution System (RDS) Projects

MICHAEL KINTNER-MEYER

September 4–7, 2018

Sheraton Pentagon City Hotel – Arlington, VA

GMLC1.5.7: LVAT
High-Level Project Summary

Project Description

- Develop methodology for estimating value of resilient distribution system and perform value analysis of 5 RDS projects
- Engage with state policymakers/regulators and key stakeholders to communicate lessons learned

Value Proposition

✓ This work will be the first authoritative valuation study of resilience field demonstrations under diverse use-case scenarios that include different:
- ✓ technologies
- ✓ threat scenarios
- ✓ potential value streams
- ✓ regions with different market structures

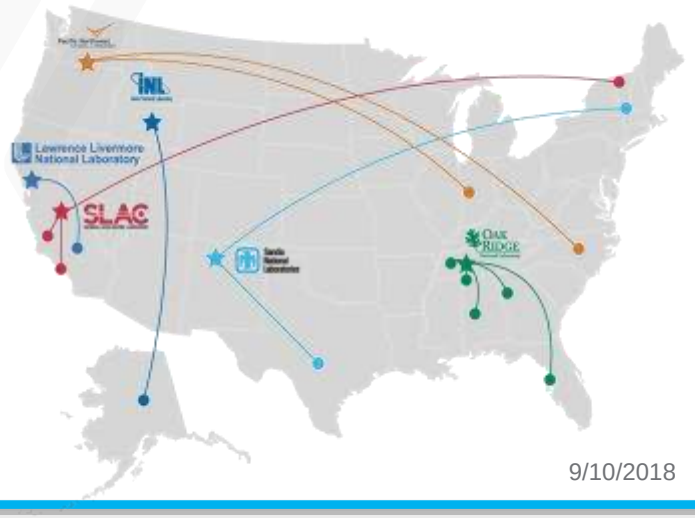
Project Objectives

✓ Assess and quantify potential value streams for 5 RDS projects

✓ Discuss outcomes of value analysis from a national perspective

✓ Share lessons learned with policymakers/regulators and key stakeholders

Lead Labs and expected test sites for RDS project



GMLC1.5.7: LVAT
Project Team

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Participants and Roles

PNNL- **Michael Kintner-Meyer,** PI, POC: ORNL
ANL - **Jim Kavicky,** Plus 1, POC: LLNL

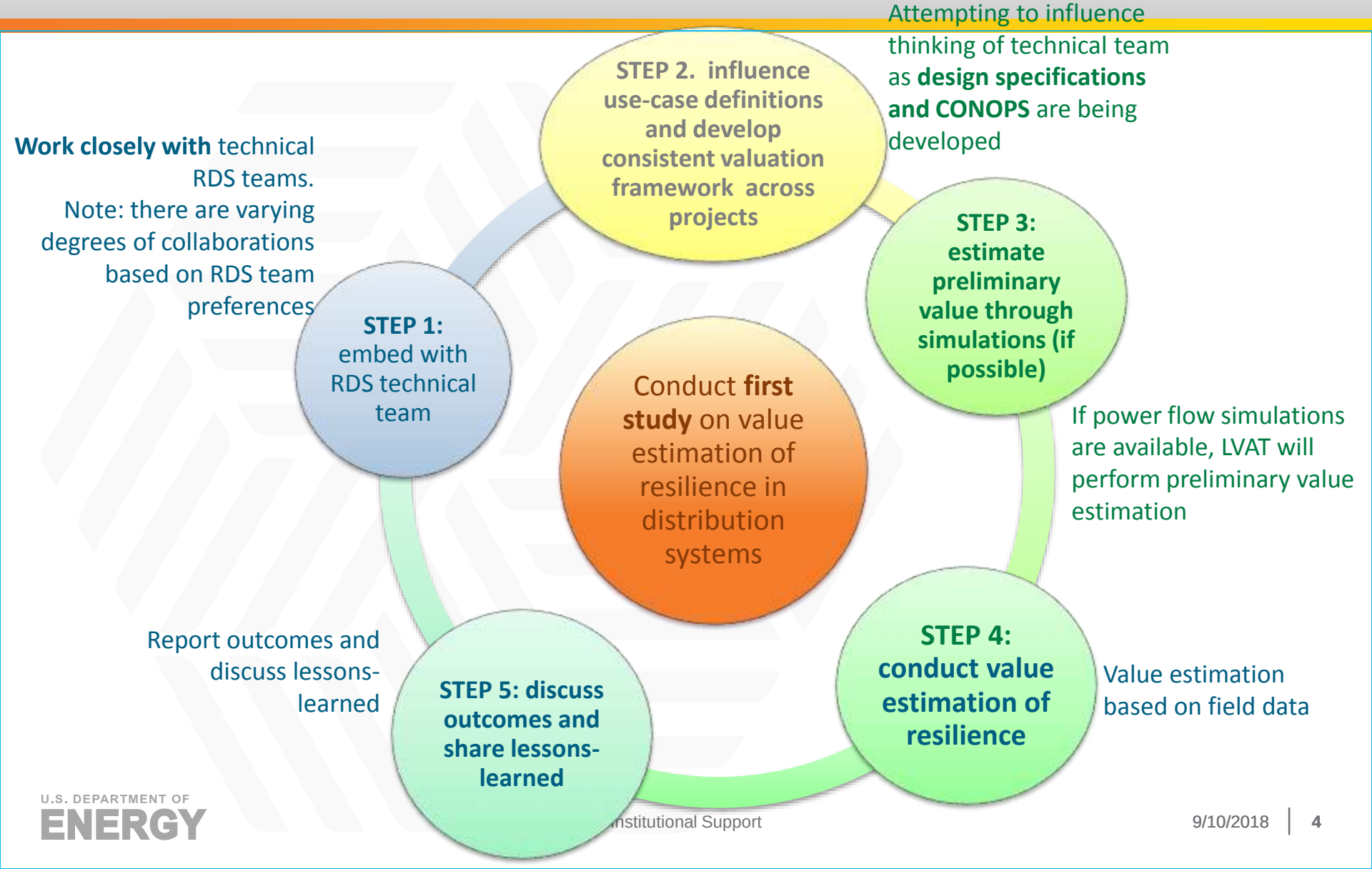
LBNL - **Chuck Goldman**, POC: SNL
- **Peter Larson,** POC: INL
NREL - **Mark Ruth**, POC: PNNL
SNL - **Vanessa Vargas**, Methodology
PNNL- **Patrick Balducci,** POC: SLAC

Laboratory	FY18 (year 1)	FY19 (year 2)	FY20 (year 3)	total
ANL	150	100	125	375
LBNL	100	50	75	225
NREL	80	50	70	200
PNNL	200	100	200	500
SNL	80	80	40	200
total	610	380	510	1500

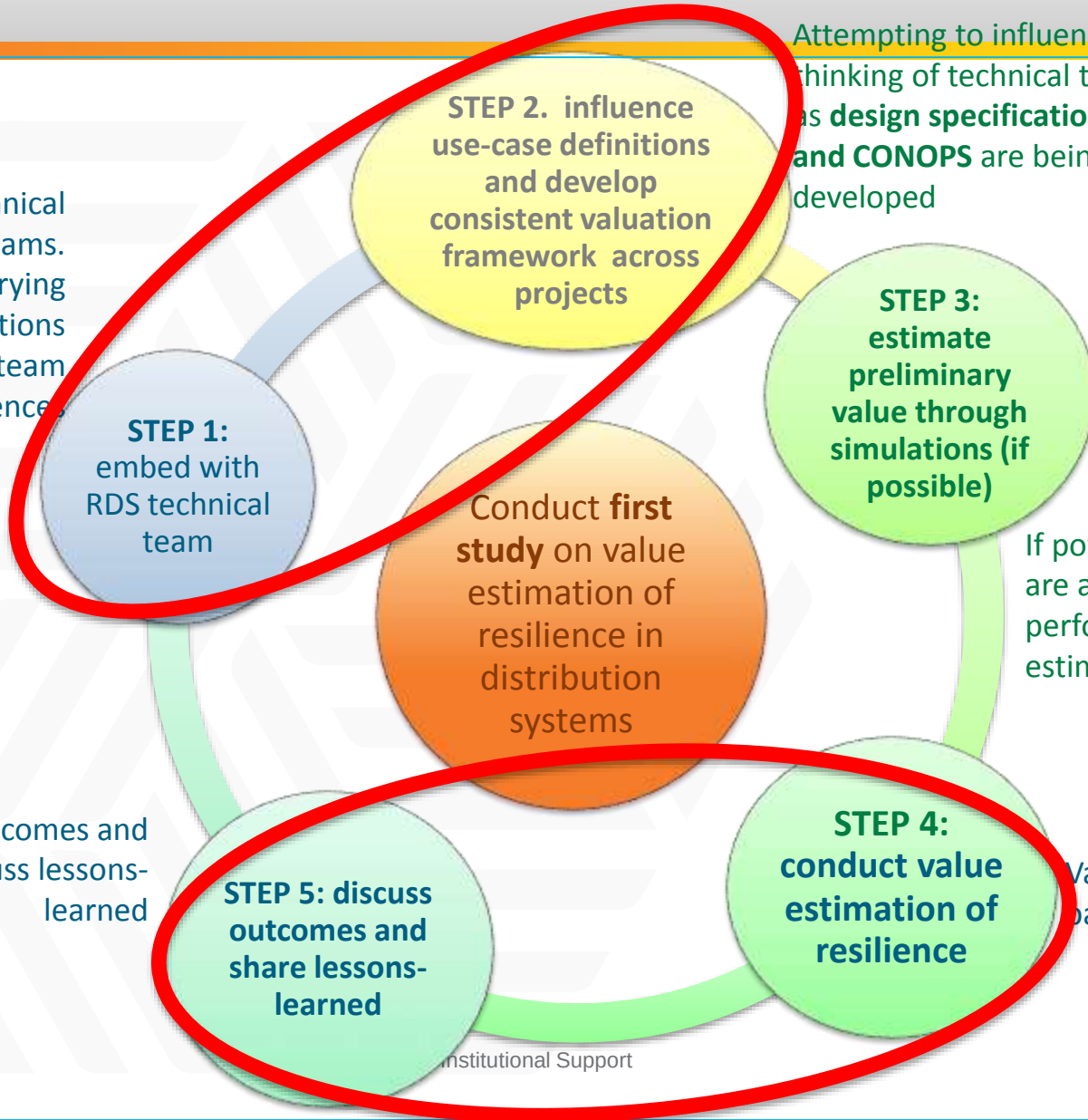
5+ RDS teams

(Resilient Distribution System)

GMLC1.5.7: LVAT
Approach



GMLC1.5.7: LVAT
Approach



Attempting to influence thinking of technical team as **design specifications and CONOPS** are being developed

Work closely with technical RDS teams.
Note: there are varying degrees of collaborations based on RDS team preferences

If power flow simulations are available, LVAT will perform preliminary value estimation

Value estimation based on field data

Report outcomes and discuss lessons-learned

GMLC1.5.7: LVAT
Accomplishments to Date

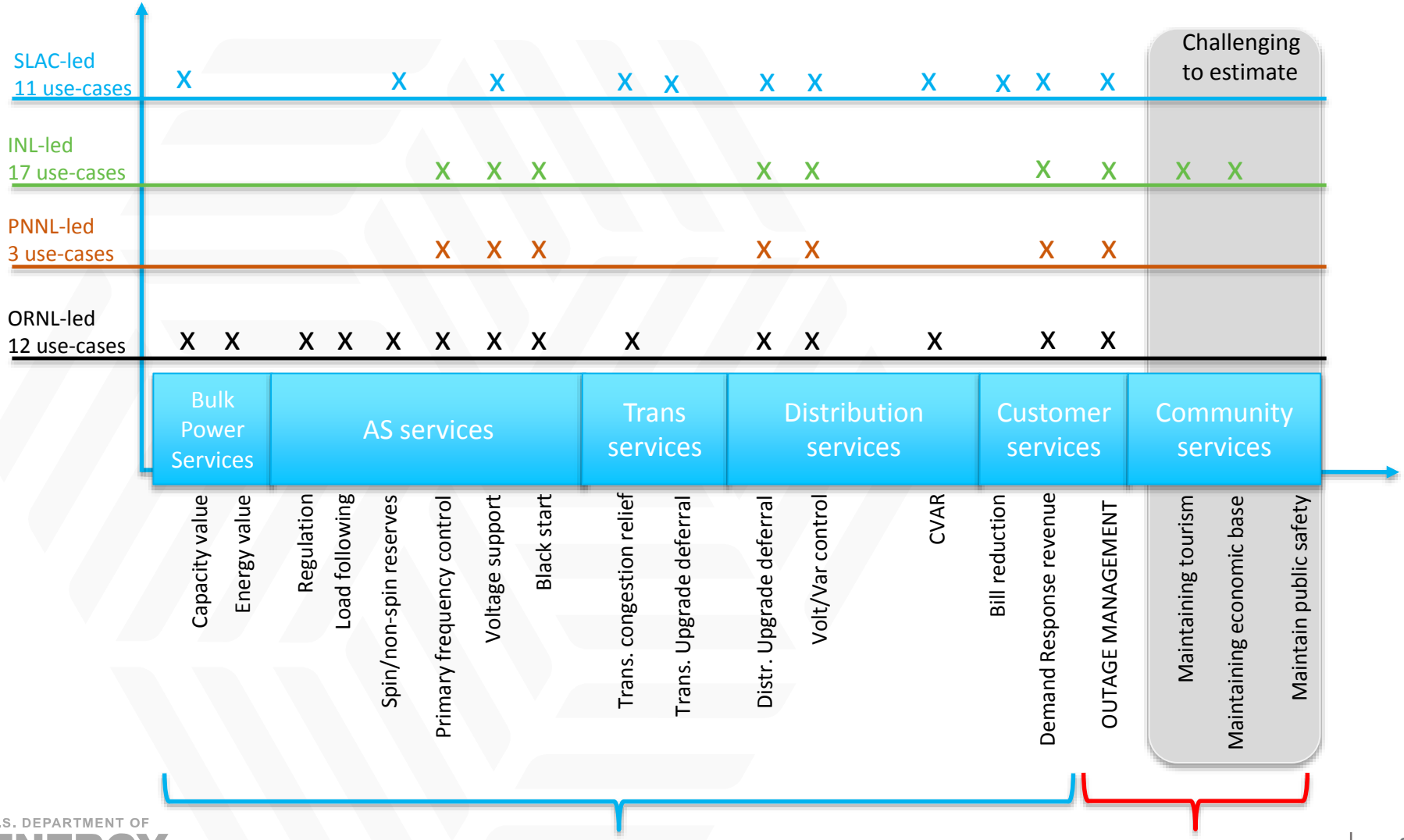
- Embedded to various degrees in technical RDS teams
  - More: PNNL, ORNL, INL
- Explained to RDS team what LVAT's role is and discussed rules of engagement
- Worked with RDS to sharpen and enhance use cases and how benefits will be assessed
  - Developed a survey for RDS team to elicit key information necessary to perform value estimation of resilience
- Approach for value estimation established

Approach to Value Estimation

- Basis of value – Avoided costs, avoided losses, revenues, and societal impacts (e.g., value of emissions reductions, customers/community economic losses)
- Technology costs
  - should include all software, land, overhead, engineering, integration, and various insurance, tax, and debt-related costs if calculating revenue requirements
  - If technology is not commercially available, we may adopt a learning curve for cost decline
- Estimate technology benefits - it is estimated on the margin comparing the with and without technology cases
- Value estimation includes all projected costs and revenue for the system, customer, and societal costs over the lifecycle of an asset or assets
  - Resilience:
    - Estimate value of outage mitigation to utility and customers *(e.g., avoided outages up to few days)*
    - Estimate value to community/society *(e.g., avoided outages of several weeks)*
  - Value streams for other services:
    - Estimate value streams for bulk power, ancillary services, transmission and distribution services, and customer benefits
- Present value (PV) of resilience and other benefits minus PV costs = Net Benefits

GMLC1.5.7: LVAT

Methodology: Potential Values to be considered

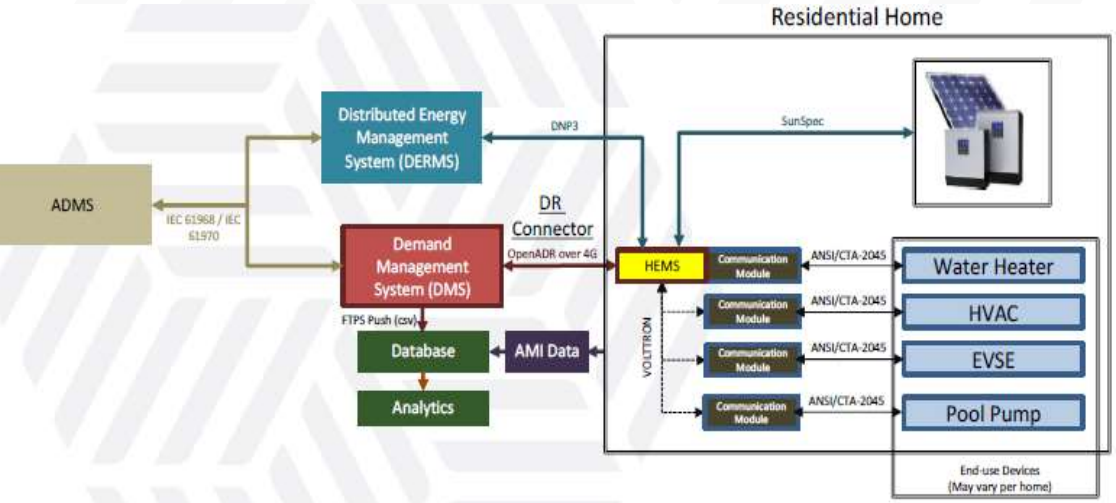


GMLC1.5.7: LVAT

Example: ORNL-led: Integration of Responsive Residential Loads into Distribution Management Systems

ORNL-Led RDS Project

- Objective:
  - Validate low-cost, open-source, interoperable home energy management system (HEMS) in residential homes to provide grid-services
- Innovation:
  - Low-cost hardware and software for connecting and controlling end-use devices in homes (DMS/DERMS)
- Test sites:
  - Chattanooga, TN (TVA)

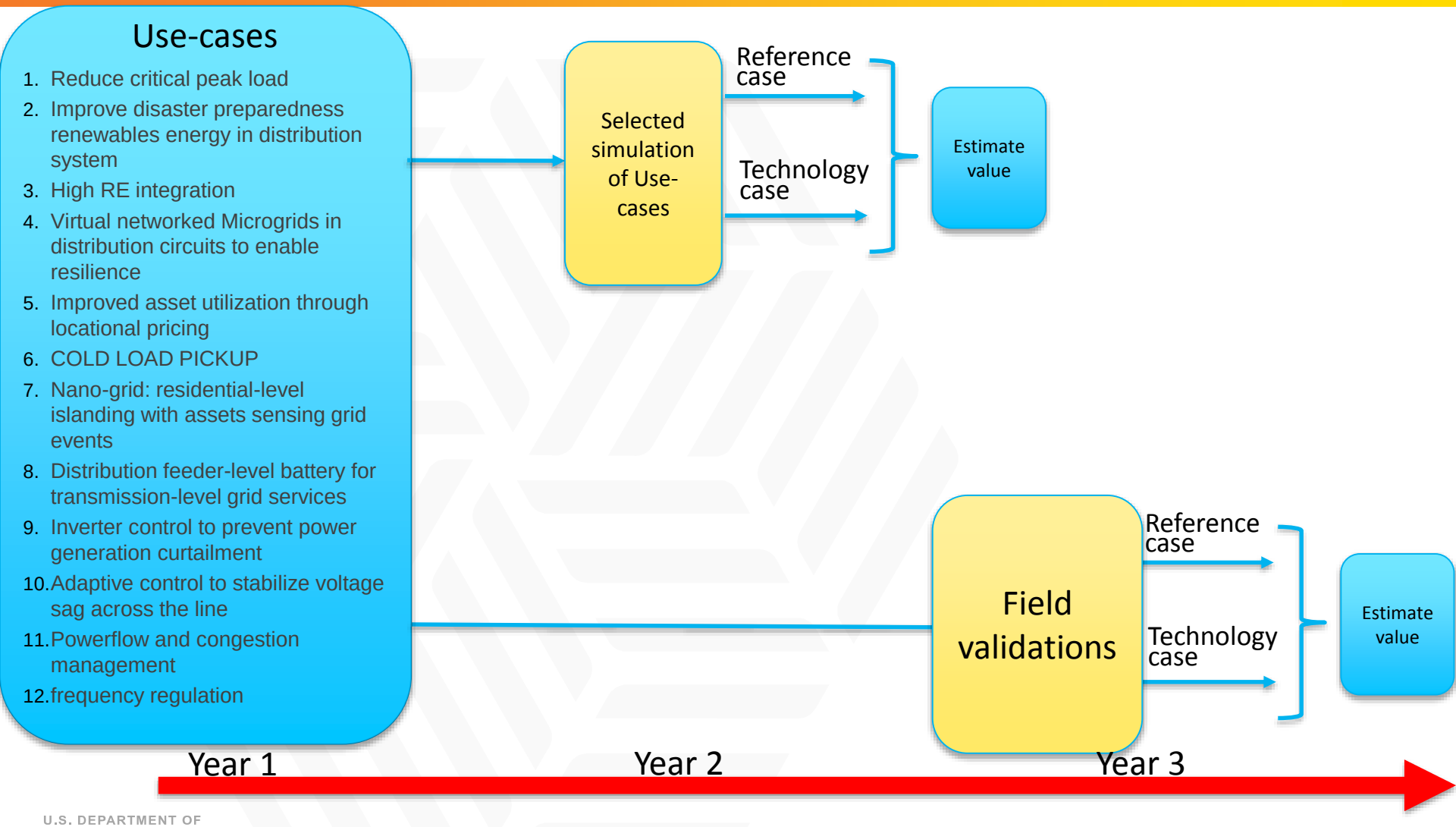


Use-cases

1. Reduce critical peak load
2. Improve disaster preparedness through real-time situational awareness and distribution operations planning
3. High penetration of renewables energy in distribution system
4. Virtual networked Microgrids in distribution circuits to enable resilience
5. Improved asset utilization through locational pricing
6. Reduce outage and recovery times through intelligent COLD LOAD PICKUP
7. Nano-grid: residential-level islanding with assets sensing grid events
8. Distribution feeder-level battery for transmission-level grid services and enabling distribution resilience
9. Inverter control to prevent power generation curtailment due to control of distribution level voltage control assets
10. Adaptive control of DERs on a distribution radial line to stabilize voltage sag across the line
11. Powerflow and congestion management
12. Load control to support frequency regulation

GMLC1.5.7: LVAT

Example: ORNL-led: Integration of Responsive Residential Loads into Distribution Management Systems (cont.)



GMLC1.5.7: LVAT
Challenges of Project

- Projects are very diversified with respect to
  - Technology maturity
    - Components are available, but the controls and configurations are often novel
    - Conceptual system designs and underlying technologies are novel
  - Each RDS project progresses at its own pace; LVAT analysis needs to adjust to actual schedule of each RDS project
  - LVAT collaboration strategies with RDS teams needs to be flexible (e.g., NDA requirements mean greater distance)
- Methodological challenges
  - Estimating economic losses of outages >24 hours are complex (LVAT will address)
  - Impacts of long-term outages (>1 week) to communities are not known (LVAT will NOT address directly)
  - Definition of threat scenarios are not well defined in some RDS projects
    - Threat scenario issues (e.g., estimating probability of occurrence and exposure are difficult to assess in reference case)
- Working with state regulators
  - Engagement strategy likely to vary across RDS projects dependent on use-cases and technology stage of commercial development

Next Steps

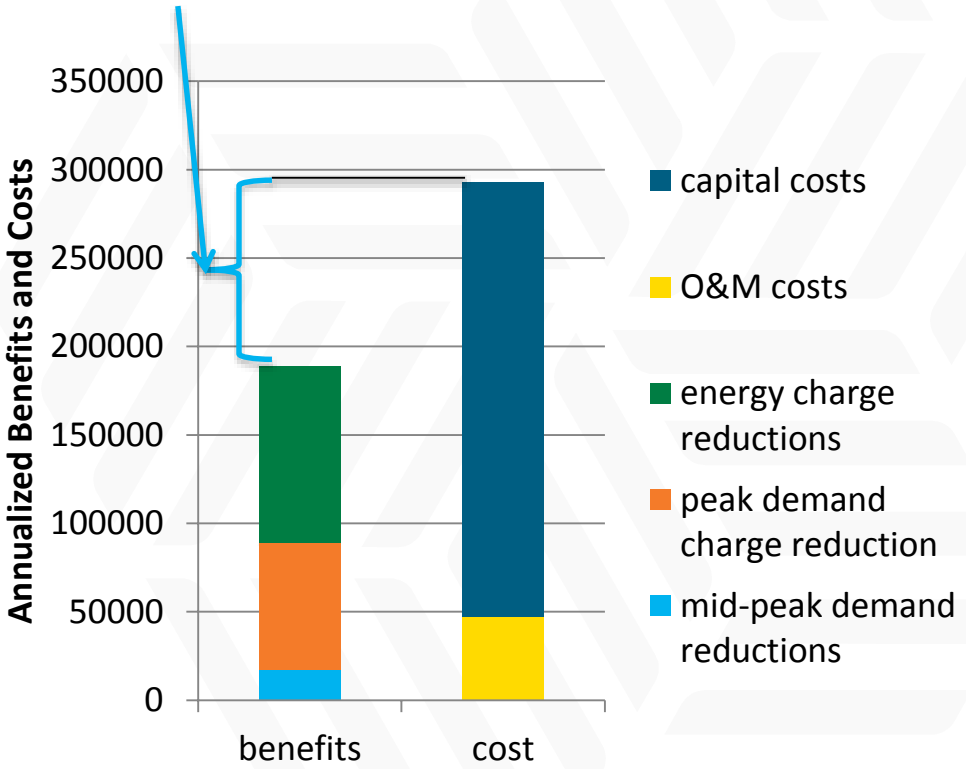
- Continue to work with RDS
  - Discuss use-cases and metrics for valuation
  - Explore opportunities for early simulations of use-cases
    - ORNL
    - PNNL
- Adjust existing valuation methods to RDS project and use-case
- Continue to coordinate with SNL Designing Resilient Communities project
  - Participate in external coordination network that supports SNL project Stakeholder Advisory Group
  - Contribute to institutional support analysis (e.g., alternative utility business models that support resilience investments; including resilience metrics in utility integrated resource plans)

Backup Slides

Estimation of Resilience Value for avoidance of interruptions over weeks

Indirect Method to Estimate Resilience Benefit

Resilience "Breakeven" benefit for Cost-effectiveness



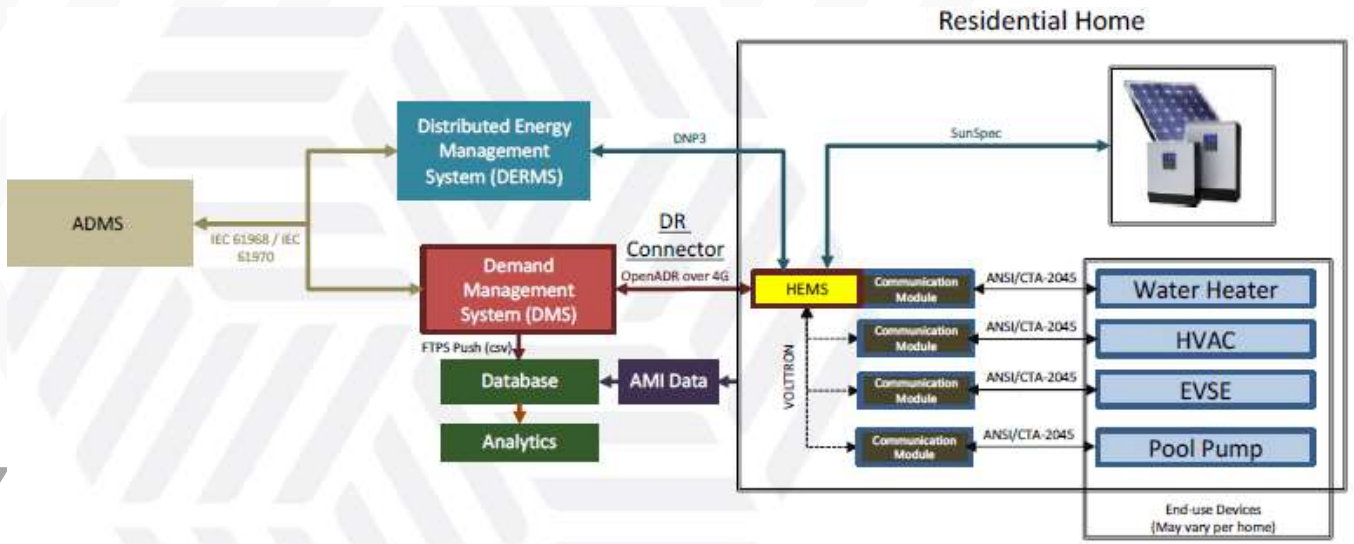
- Value of avoided outages for several weeks requires complex analysis of disruption of community services. (outside scope of LVAT)
- Proxy method will be applied based on "breakeven" benefits for cost-effectiveness.

ORNL: Integration of Responsive Residential Loads into Distribution Management Systems

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

- Objective:
  - Validate low-cost, open-source, interoperable home energy management system (HEMS) in residential homes to provide grid-services
- Innovation:
  - Low-cost hardware and software for connecting and controlling end-use devices in homes (DMS/DERMS)
- Test sites:
  - Chattanooga, TN (TVA)

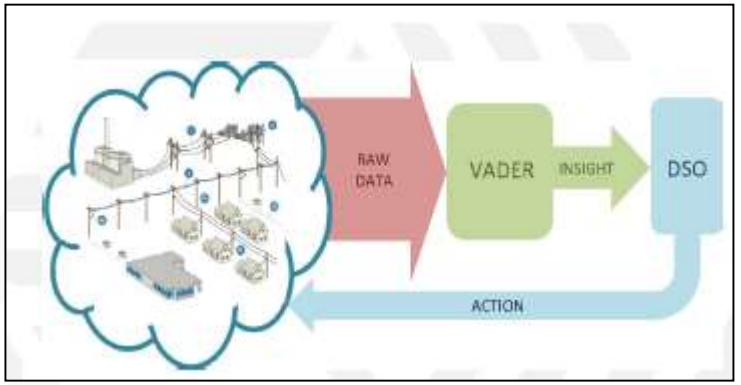


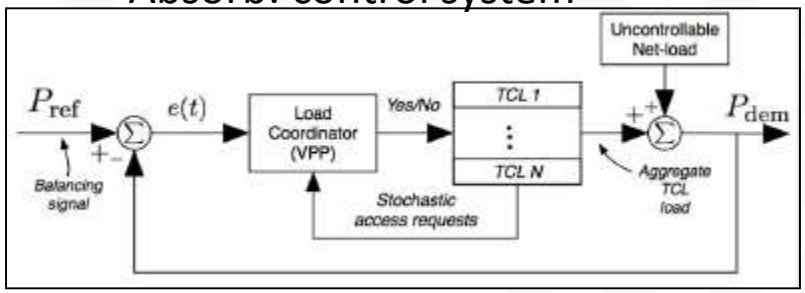
SLAC: Grid Resilience and Intelligence Platform (GRIP)

- Objective:
  - Demonstrate how to anticipate, absorb and recover from grid events
- Innovation:
  - Anticipate: Big data and machine learning approaches for anticipating threats
  - Absorb: Control technology with and without communications
  - Recover from events through backup technologies
- Test sites:
  - Vermont - Green Mountain Power
  - California - Riverside Public Utility

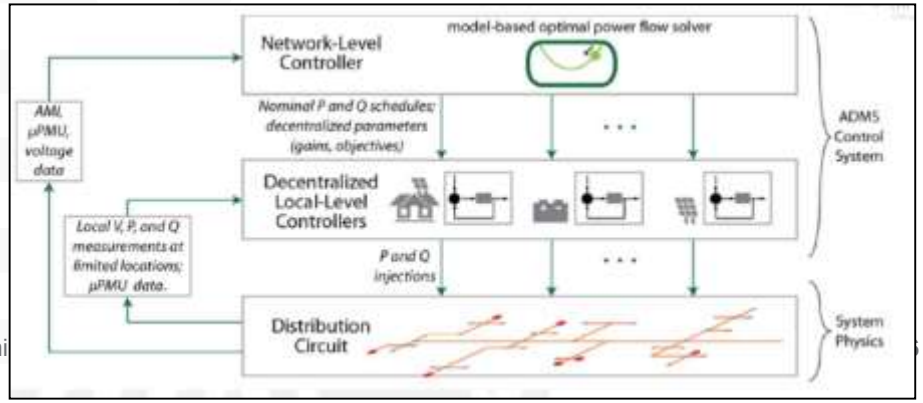
Anticipate: Big Data



Absorb: control system

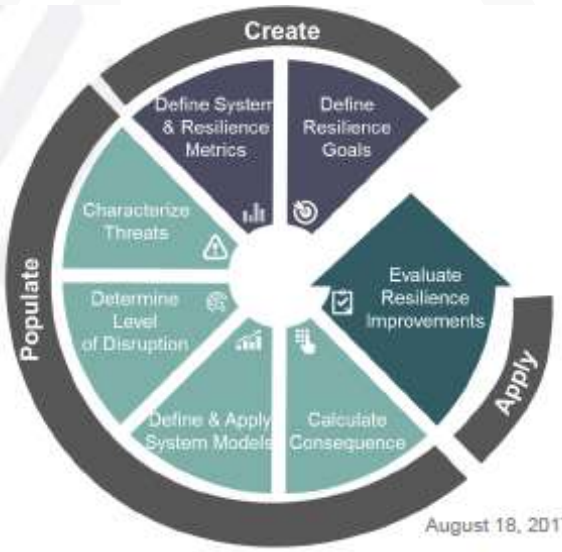


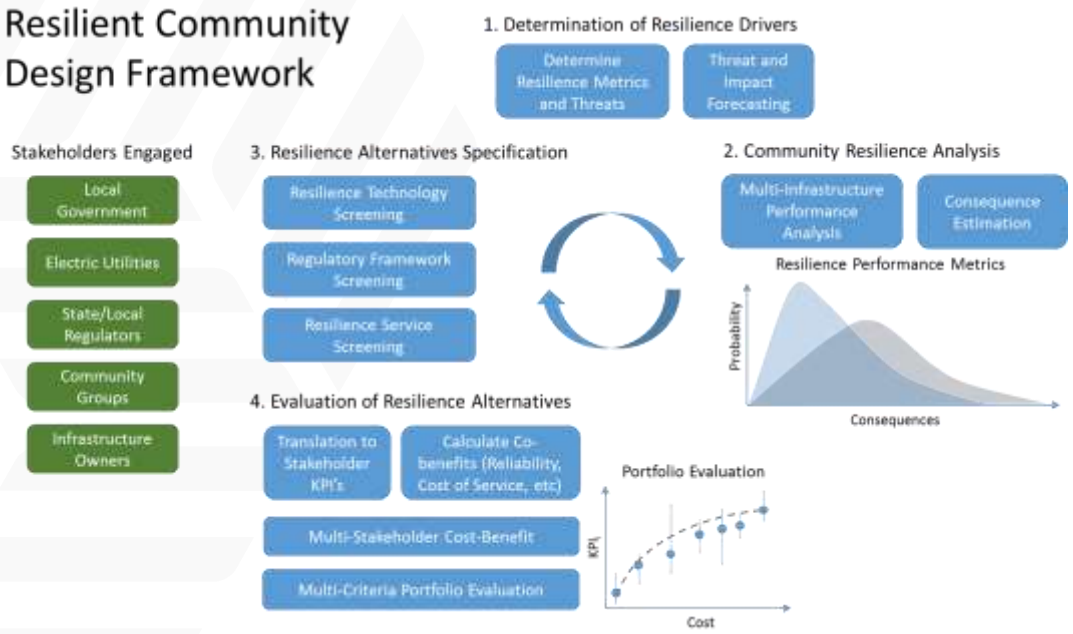
Recover: hierarchical distributed control



SNL: Designing Resilient Communities

- Technology to be tested: developing and demonstrating a framework that aligns community resilience planning with grid investment planning
- Innovation: Design and valuation of technology, regulatory frameworks, and retail services within an overall community resilience portfolio
- Case study sites:
  - San Antonio, TX with CPS energy
  - Buffalo, NY with National Grid





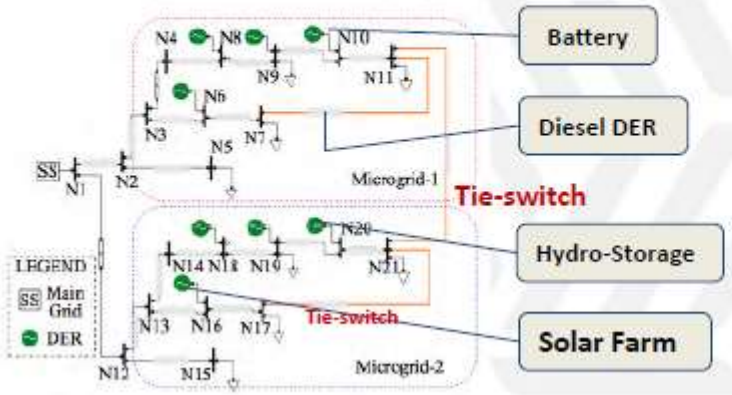
INL: Resilient Alaskan Distribution System Improvements Using Automation, Network Analysis, Controls, and Energy Storage

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

- Objective:
  - Validate secure operations of tightly-coupled and loosely-coupled microgrids in islanded and grid-connected modes
- Innovation:
  - Integrated state-of-the-art devices for resilient operation
- Test site:
  - Cordova, AK

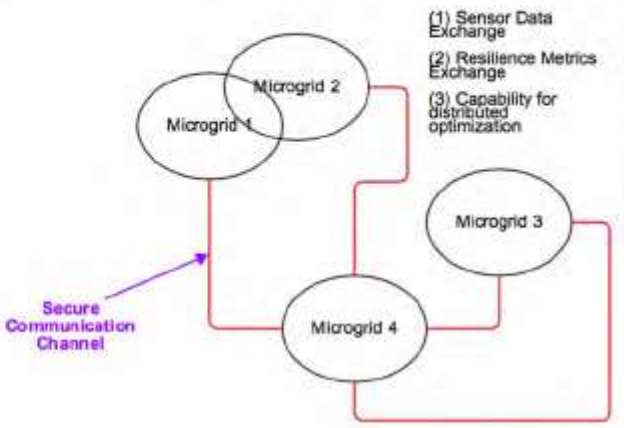
Tightly-coupled Microgrids

[as the case of City of Cordova, Cordova Electric Coop]



Loosely-coupled Microgrids

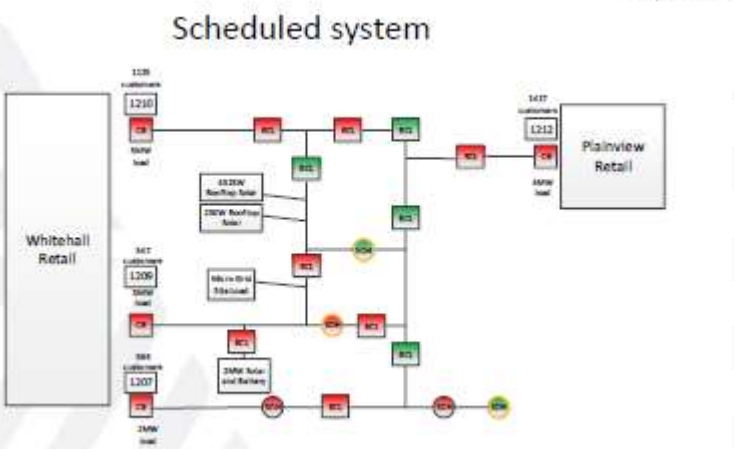
[geographically dispersed Alaskan villages]



PNNL: Increasing Distribution System Resilience using Flexible DER and Microgrid Assets Enabled by Open Field Message Bus (OpenFMB)

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

- Objective:
  - Validate new architecture, controls, planning and operational strategies of distributed devices
- Innovation:
  - Next generation of fault location, isolation and service restoration
- Test site:
  - Anderson Civic Center, Anderson, SC: Duke Energy



LLNL: CleanStart DERMS

- Objective:
  - Validate at scale DER-driven mitigation, blackstart, and restoration strategies
- Innovation:
  - Predictive analytics
  - DER controls for blackstart and restoration
- Test sites:
  - Riverside, CA utility