Grid Modernization Initiative (GMI)

Challenges for Distribution Planning, Operational and Real-time Planning Analytics Workshop

KEVIN LYNN

U.S. DEPARTMENT OF ENERGY

Five Key Trends Driving Grid Transformation

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- Changing mix of types and characteristics of electric generation (in particular, distributed and clean energy)
- Growing demands for a more resilient and reliable grid (especially due to weather impacts, and cyber and physical attacks)
- Growing supply- and demand-side opportunities for customers to participate in electricity markets
- Emergence of interconnected electricity information and control systems
- Aging electricity infrastructure

Creating a 21st Century Grid

Responding to the drivers of change

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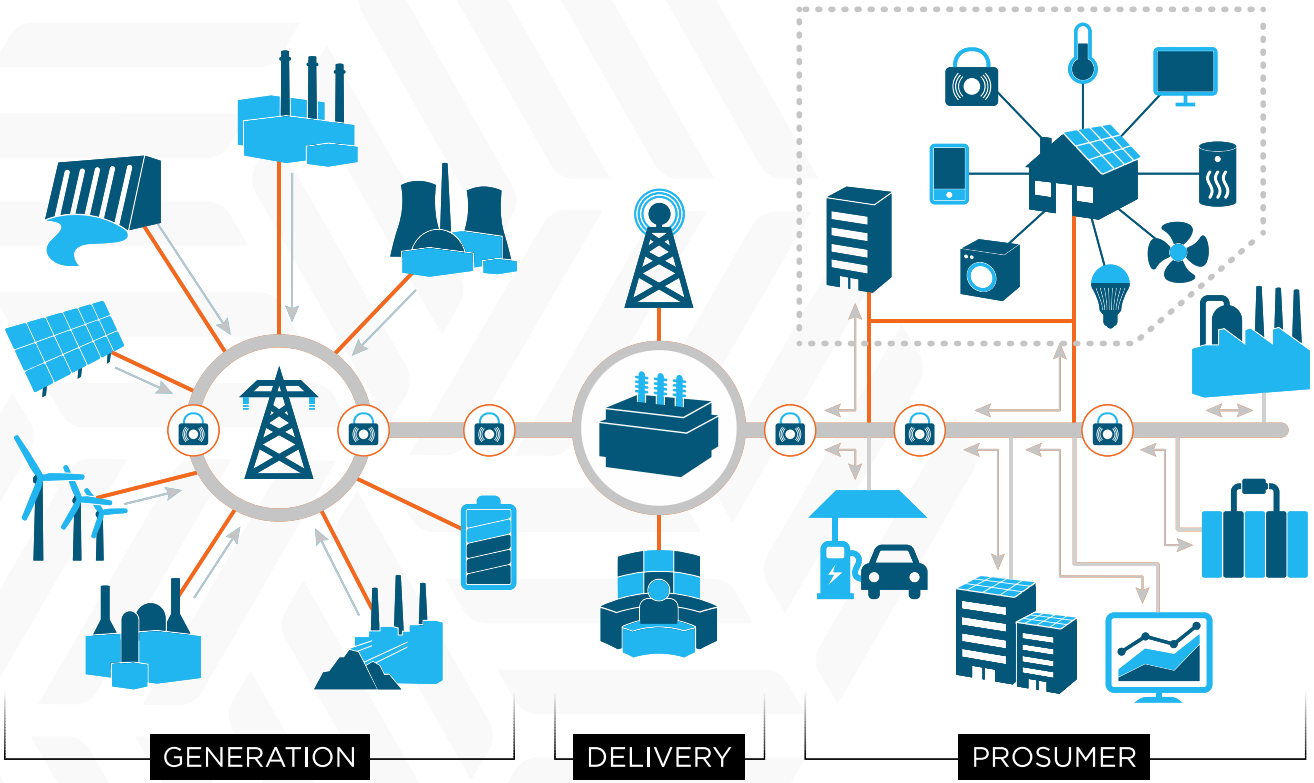

Grid Modernization Initiative (GMI)

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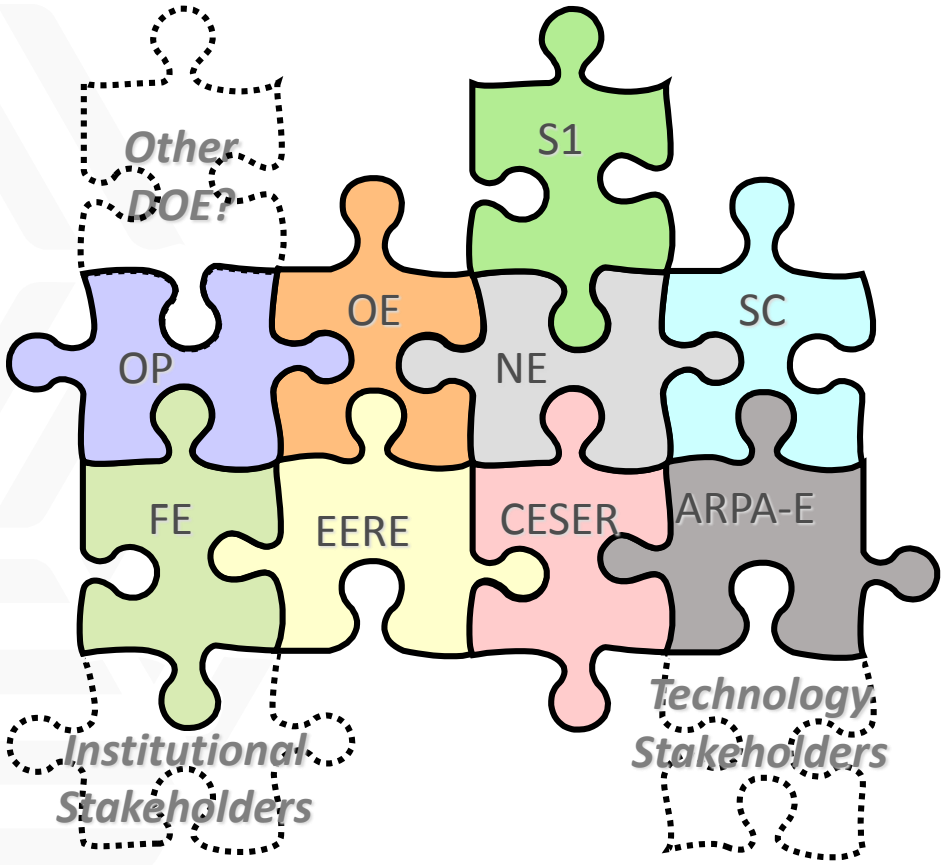
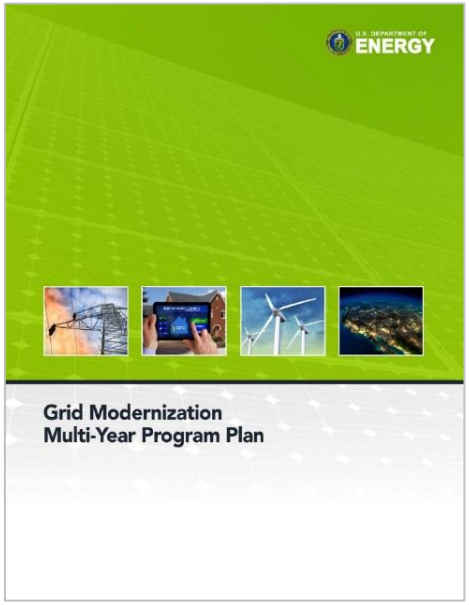
An aggressive and urgent five-year grid modernization strategy for the U.S. Department of Energy (DOE) that:

- **Aligns existing base activities across DOE offices**
- **Defines a vision for the modern grid through an integrated Multi-Year Program Plan (MYPP)**
- **Establishes new activities to fill major gaps in the existing base**
- **Leverages strategic partnerships through a laboratory consortium with core scientific abilities and regional outreach**



Grid Modernization Multi-Year Program Plan (MYPP)

- Design and Planning Tools
- System Operations, Power Flow, and Control
- Sensing and Measurements
- Devices and Integrated Systems
- Security and Resilience
- Institutional Support



Grid Modernization MYPP Integrated Technical Thrusts

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Design and Planning Tools	• Create grid planning tools that integrate transmission and distribution and system dynamics over a variety of time and spatial scales
System Operations, Power Flow, and Control	• Design and implement a new grid architecture that coordinates and controls millions of devices and integrates with energy management systems
Sensing and Measurements	• Incorporate information and communications technologies and advance low-cost sensors, analytics, and visualizations that enable 100% observability
Devices and Integrated Systems	• Develop new devices to increase grid services and utilization and validate high levels of distributed energy resources at multiple scales
Security and Resilience	• Develop resilient and advanced security (cyber and physical) solutions and real-time incident response capabilities for emerging technologies and systems
Institutional Support	• Provide tools and data that enable more informed decisions and reduce risks on key issues that influence the future of the electric grid/power sector

Coordinate the National Laboratories: Grid Modernization Laboratory Consortium (GMLC)

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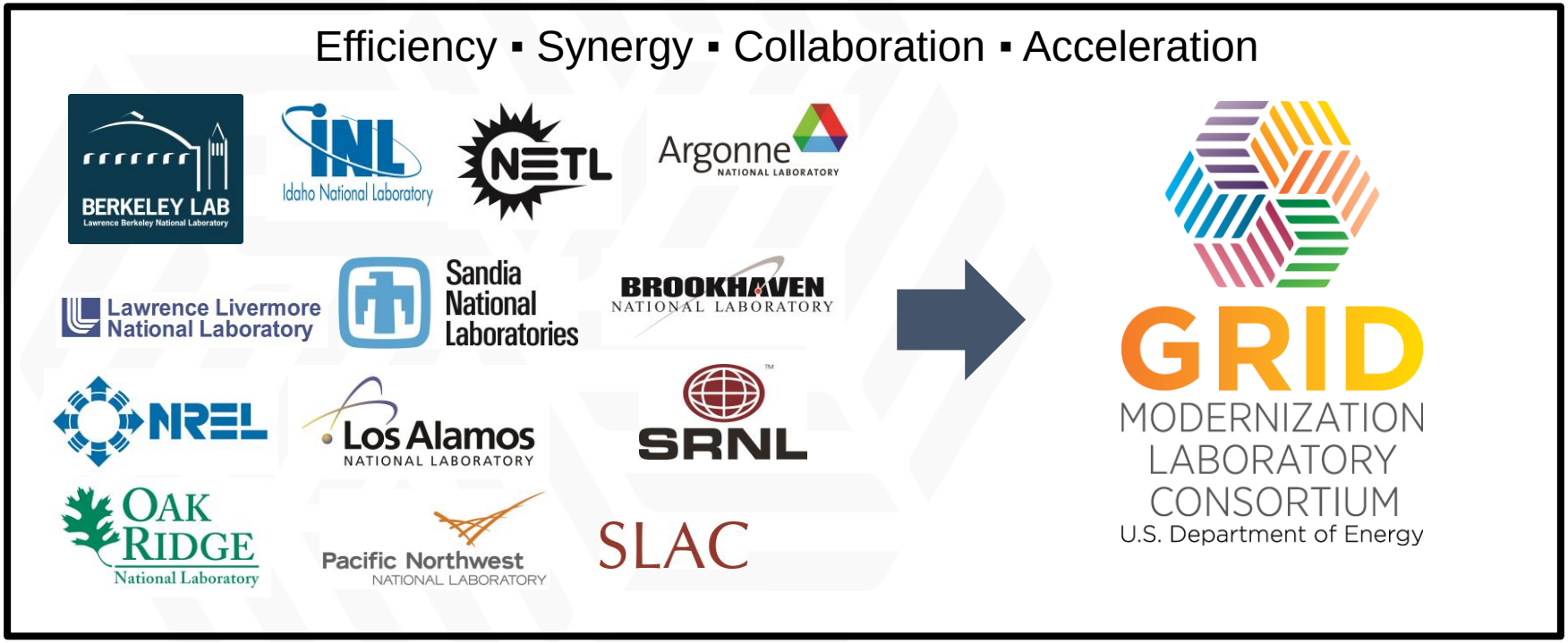
Move from a collection of DOE and lab projects to a DOE-lab consortium model that integrates and coordinates laboratory expertise and facilities to best advance DOE grid modernization goals



GMLC Structure Supporting the Grid Modernization MYPP

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National Lab Lead Integrators

Co-Chairs: Carl Imhoff (PNNL) and Juan Torres (NREL)

Technical Team Lead: Design and Planning Tools

John Grosh, LLNL

Technical Team Lead: System Operations and Control

Jeff Dagle, PNNL

Technical Team Lead: Sensing and Measurements

Tom King, ORNL

Technical Team Lead: Devices and Integrated Systems

Ben Kroposki, NREL

Technical Team Lead: Security and Resilience

Juan Torres, NREL

Technical Team Lead: Institutional Support

Chuck Goldman, LBNL

Lab leads coordinate teams and projects across the GMLC to ensure DOE and the national laboratories are meeting the goals of the Grid Modernization MYPP

Grid Modernization Lab Call 2016

Working across the country

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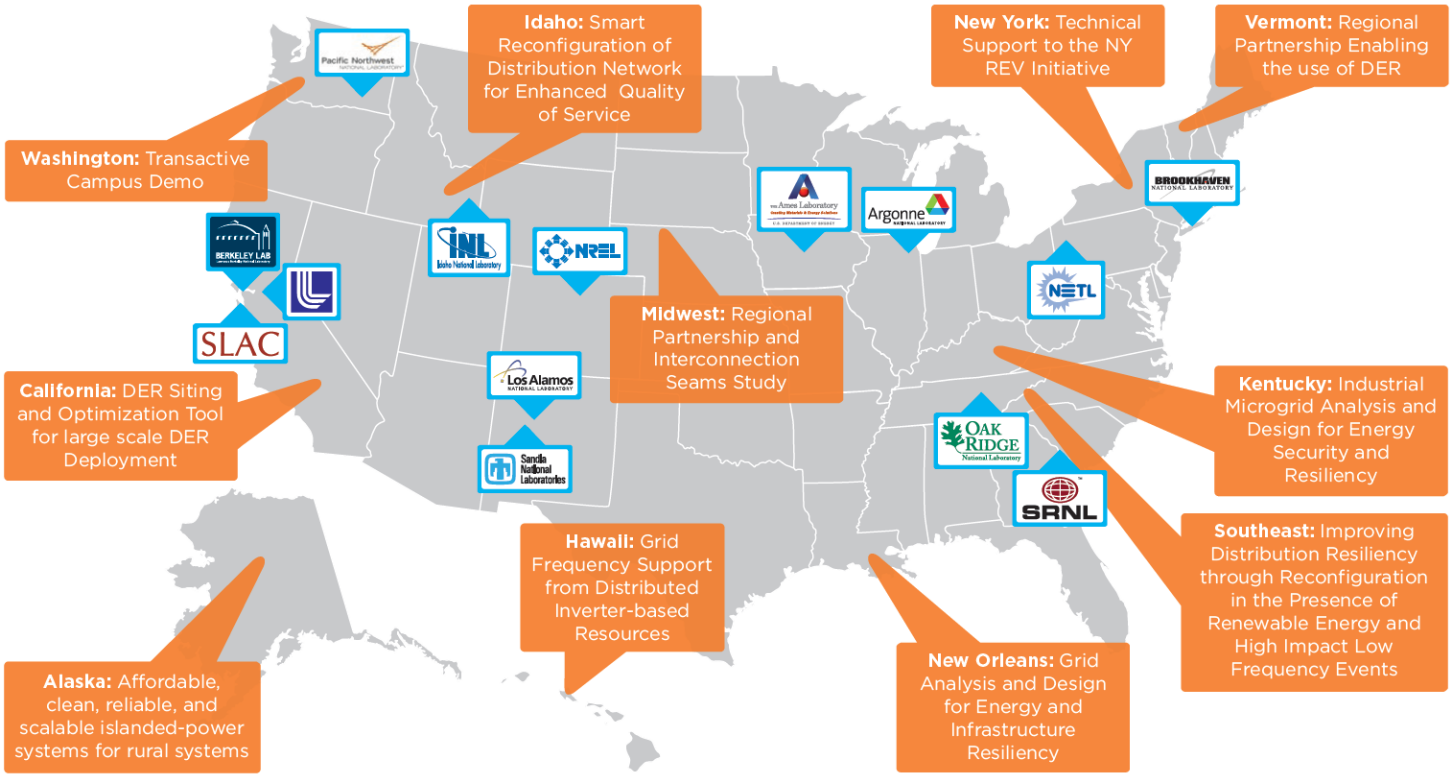

- Up to $220M
- 13 national laboratories
- 88 projects
- 150+ partners

Resilient Distribution Systems

Lab Call Overview

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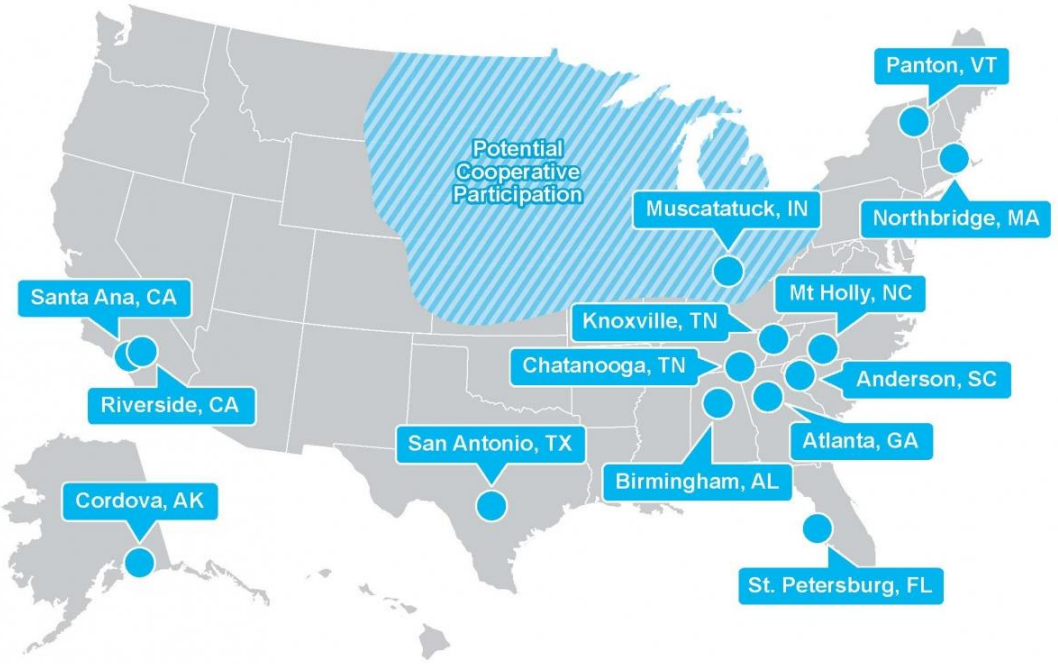
- Seeks to develop and validate innovative approaches to enhance the resilience of distribution systems, including microgrids, with high penetration of clean distributed energy resources (DERs).
- Focuses on field validations, including control/coordination strategies, real-time system monitoring, robust communications infrastructure, grid planning and analytical platforms, and integration of multiple DER technologies.
- Addresses cybersecurity needs in grid technologies from the earliest stages to survive a cyber incident.
- Builds on FY16–18 GMLC Lab Call

- **Period of Performance –** FY18/19/20
- **Total Funding –** $32M



Map of Research Locations for Selected Projects

Design and Planning Tools

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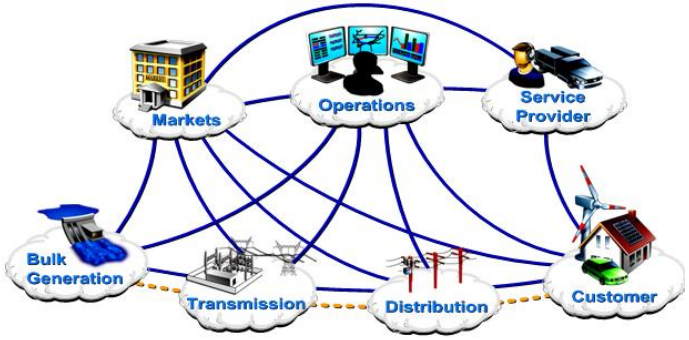
Objective: Drive development of next-generation tools that address evolving grid needs

Expected Outcomes

- A software framework to couple grid transmission, distribution, and communications models to understand cross-domain effects
- The incorporation of uncertainty and system dynamics into planning tools to accurately model renewables, extreme events, etc.
- Computational tools, methods, and libraries that enable a 1,000x improvement in performance



Simulating Interactions across Domains

Computational Speedup

Design and Planning Tools
Summary

GRID MODERNIZATION INITIATIVE
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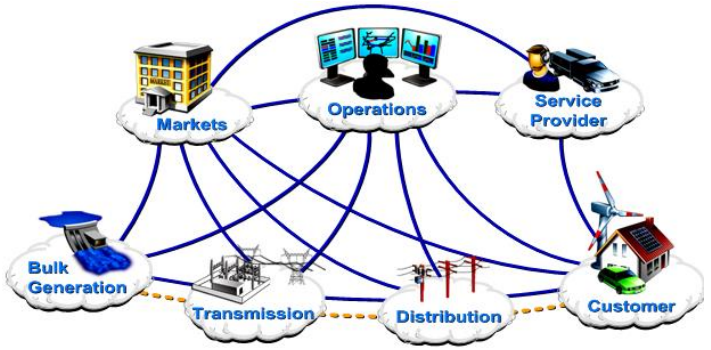
Objective
- Drive development of next- generation tools that address evolving grid needs

Expected Outcomes
- Software framework to couple grid transmission, distribution, and communications models to understand cross-domain effects
- Incorporate uncertainty and system dynamics into planning tools to accurately model renewables, extreme events, etc.
- Computational tools, methods and libraries that enable 1000x improvements in performance

Federal Role
- Attack strategic gaps in tools capabilities
- Partner with industry to demonstrate value
- Work with vendors to transition to practice



Simulating Interactions Across Domains

Computational Speedup

Activities and Technical Achievements

MYPP Activity Description

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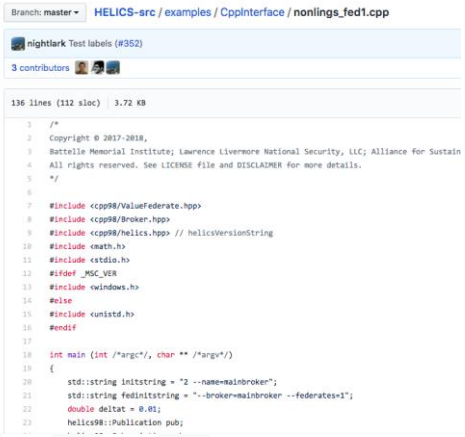
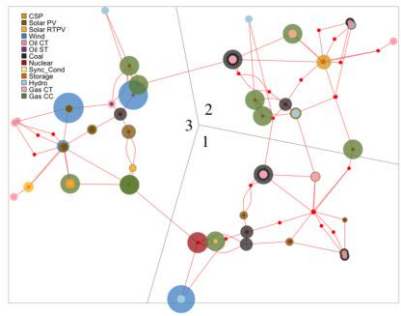
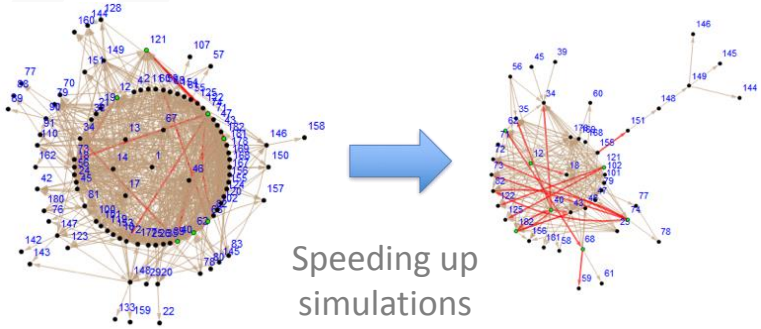
Activity	Technical Achievements by 2020
1. Scaling Tools for Comprehensive **Economic Assessment**	• Enhance performance of stochastic production cost modeling from 100 to 10,000 transmission nodes; expand to include distribution system.
2. Developing and Adapting Tools for Improving **Reliability and Resilience**	• Scalable simulation framework that couples transmission, distribution, and communications systems for integrated modeling at regional scale.
3. Building **Computational Technologies** and High Performance Computing (**HPC**) Capabilities to Speed up Analyses	• Scalable math libraries and tools for enhanced analysis; co-simulation frameworks to support coupling of tools and models, uncertainty quantification, and systems optimization.



Software

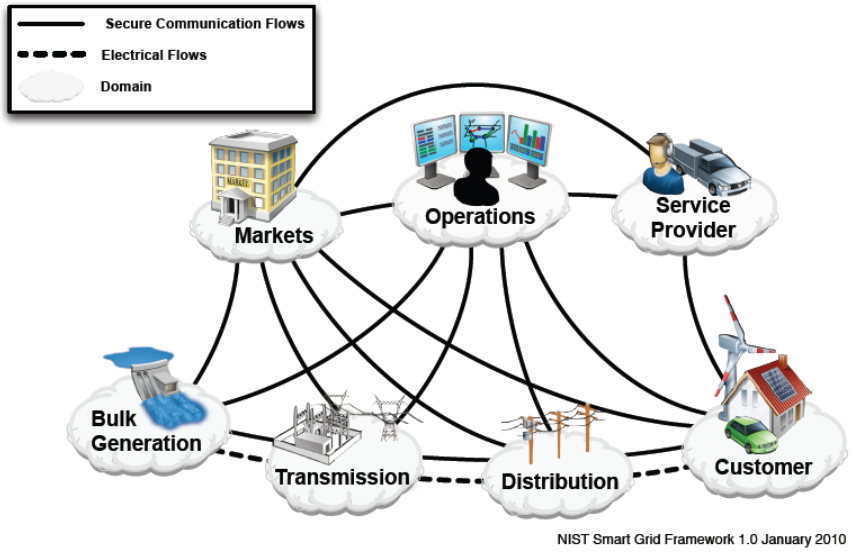


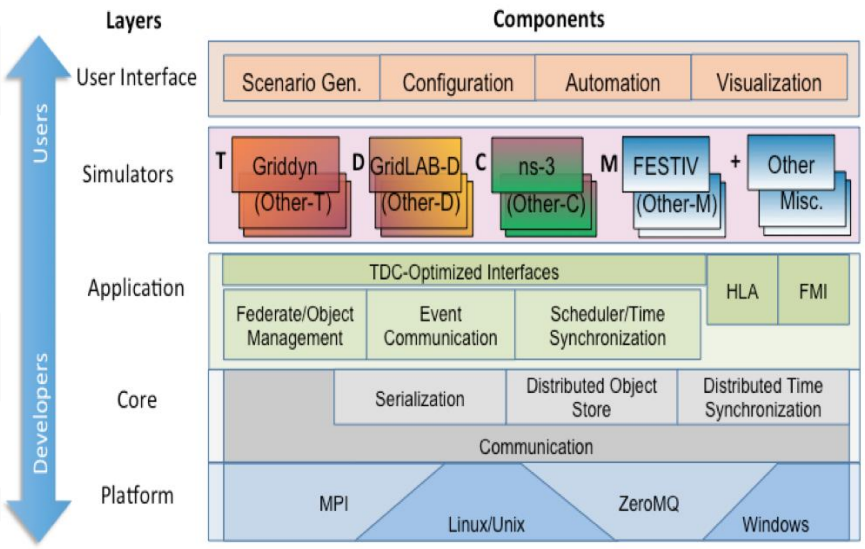
Datasets



Algorithms

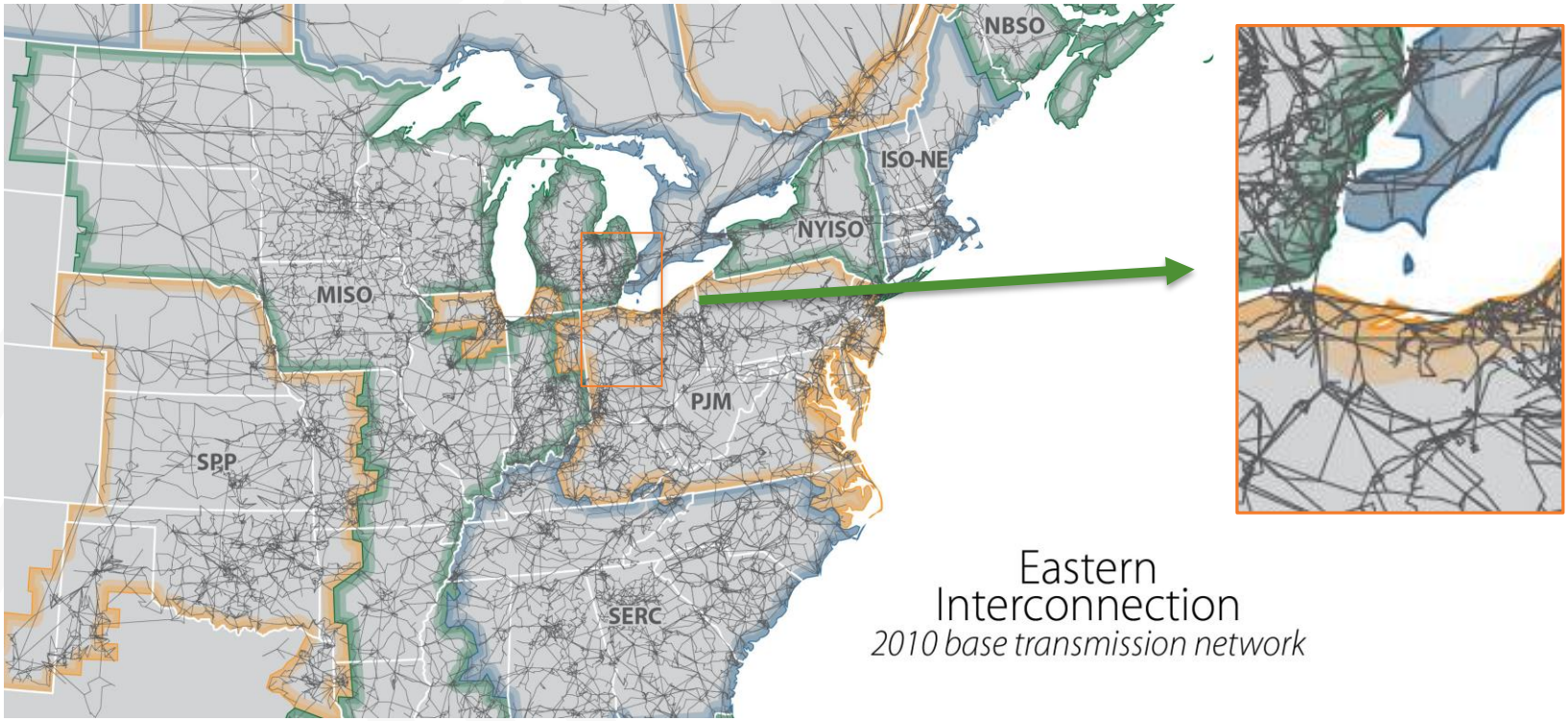
Development of Integrated Transmission, Distribution and Communication Models





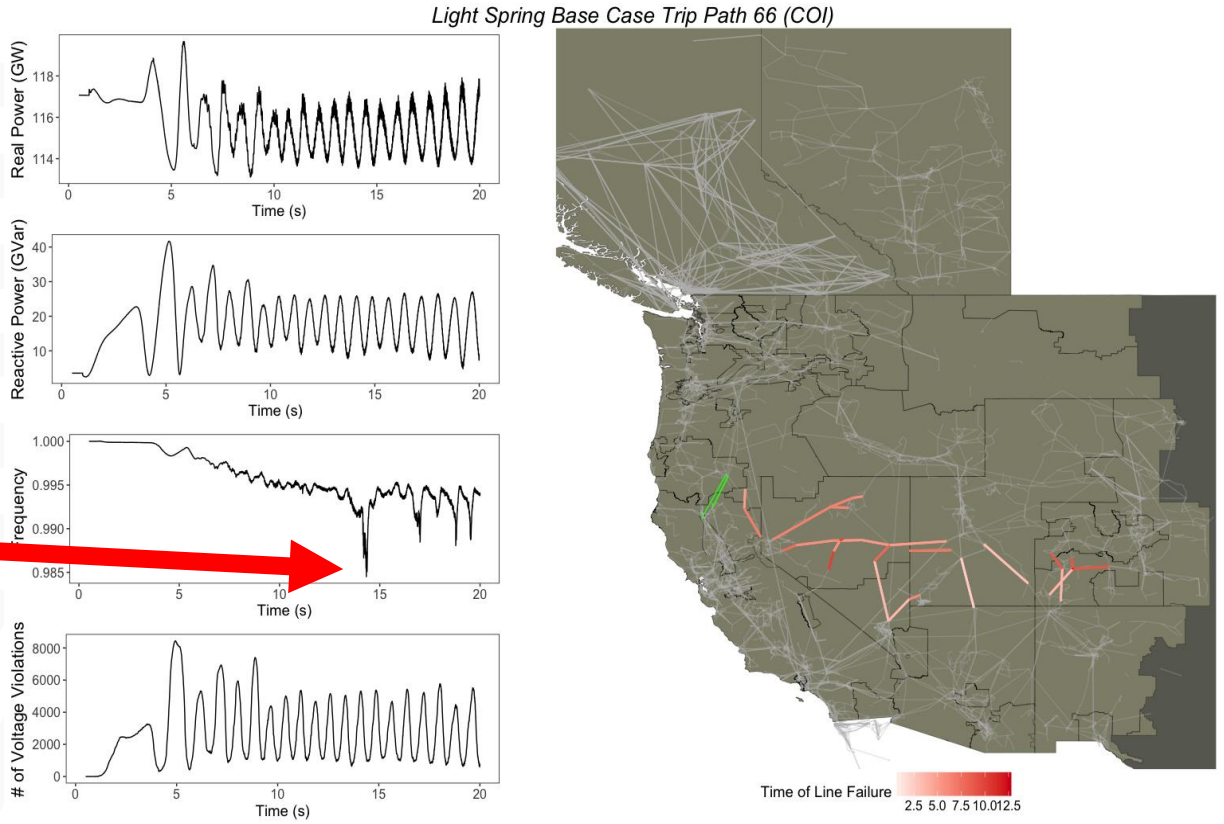
Goal: Create HELICS™, an **open-source co-simulation platform**, enabling interactions between leading commercial & lab developed simulators on a wide range of computing environments (HPC to laptop).

Development of Multi-scale Production Cost Simulation (Lead: NREL)



Goal: Develop scalable algorithms used for deterministic and stochastic production cost models

Extreme Event Modeling (Lead: LANL)



Frequency Event

Goal: Improve performance of tools for modeling cascading outages and develop new approaches for contingency analysis

Accomplishments and Emerging Opportunities

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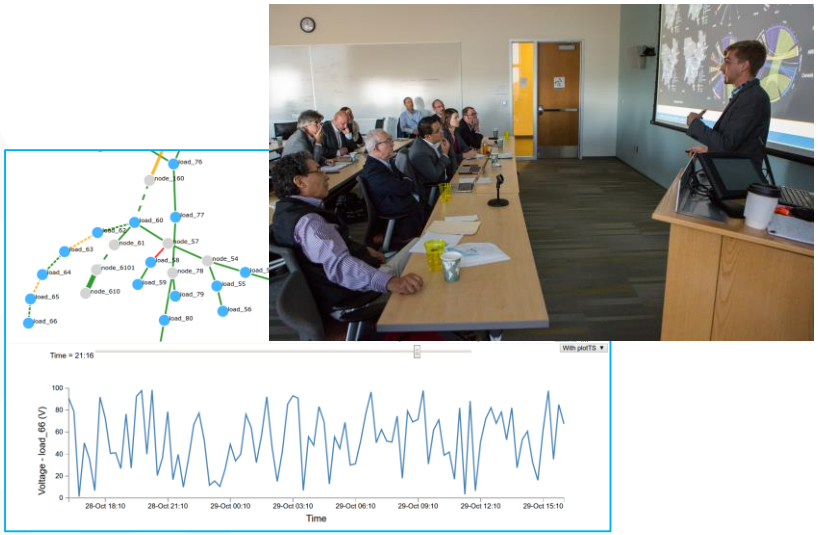
Accomplishments

- **1.4.15: Co-Simulation**
  - Multiple releases of HELICS™, latest at V1.3
  - Hosted webinars and built/presented tutorials
- **1.4.17: Extreme Events**
  - Developed Zone 3 protection models for commercial power flow solvers
  - Demonstrated >6000X for dynamic contingency analysis & 10X for prob. N-k
- **1.4.26: Production Cost Modeling**
  - Developed new algorithms for speeding up PCM, such geographic domain decomposition
  - Implemented and released algorithms in python-based Prescient framework



Next Year

- Increase industry and vendor engagement
- Continued release of software tools on GitHub
- Expand use case development

System Operations, Power Flow, and Control

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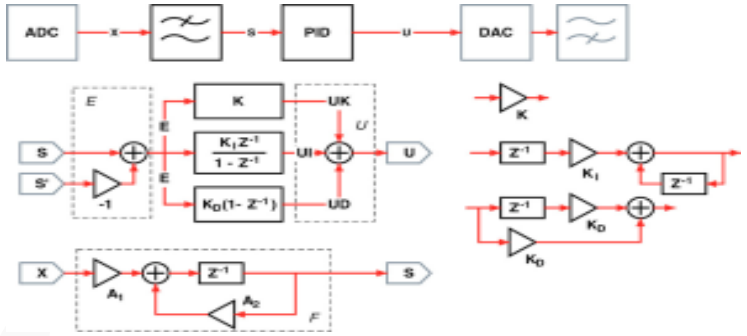
Objective: Develop advanced control technologies to enhance reliability and resilience, increase asset utilization, and enable greater flexibility of transmission and distribution systems

Expected Outcomes

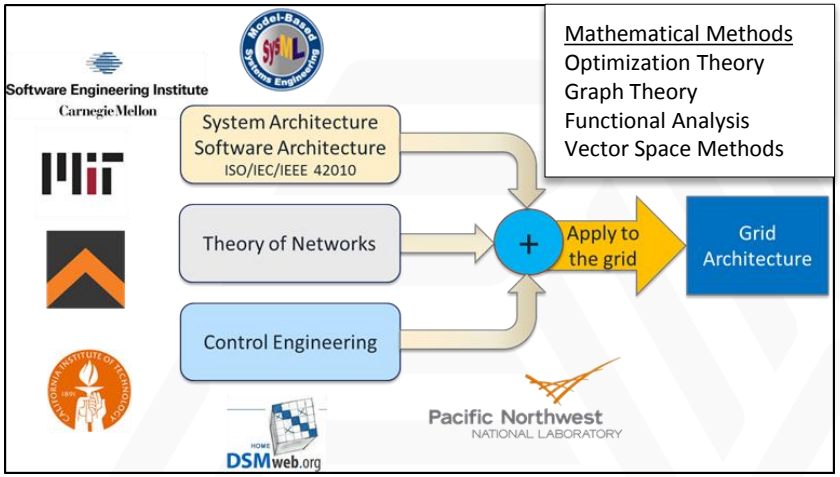
- By 2020, deliver an architecture, framework, and algorithms for controlling a clean, resilient, and secure power grid
  - Leveraging advanced concepts, high performance computing, and more real-time data than existing control paradigms
  - Involving distributed energy resources as additional control elements
- Develop software platforms for decision support, predictive operations, and real-time adaptive control
- Deploy—through demonstration projects—new classes of power flow control device hardware and concepts
- Advance fundamental knowledge for new control paradigms (e.g., robustness uncompromised by uncertainty)

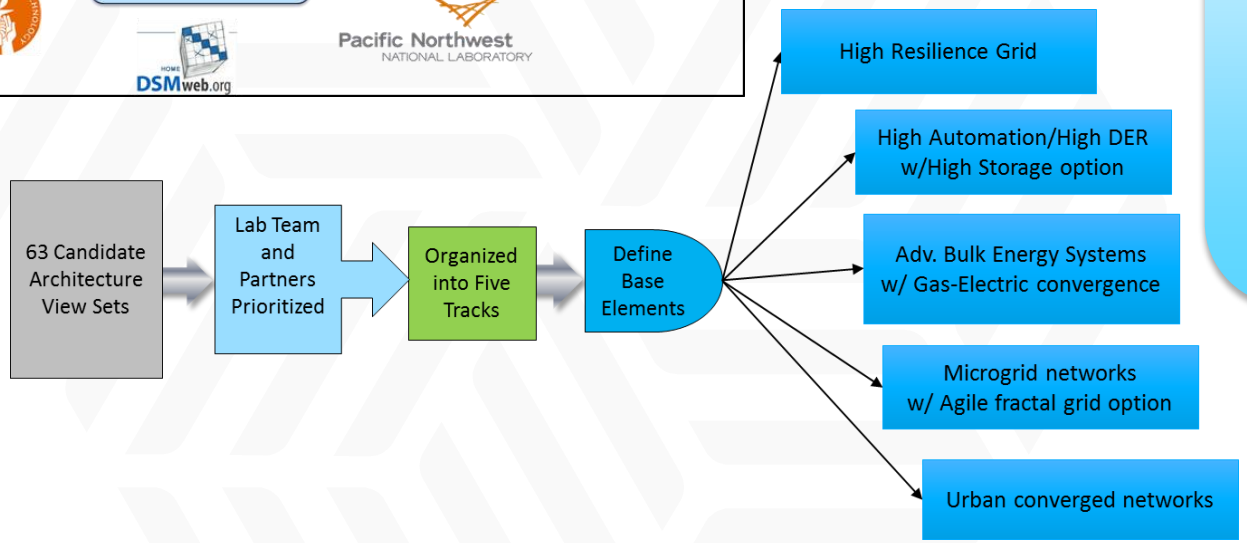


Conventional Controls

Distributed Controls

Grid Architecture





PoP: FY16/17/18

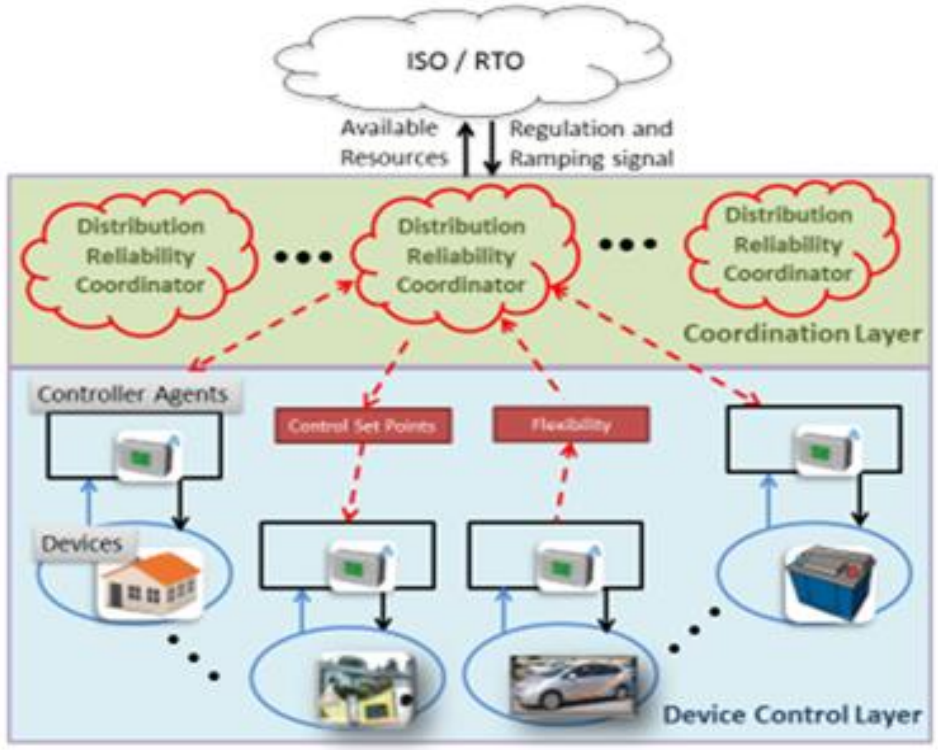
Budget: $3M

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

Partners: EPRI, SEPA, GWU, UTC, Omnetric Group, CA ISO, MISO, SMUD, AMEREN, BPA, ERCOT

Build a new set of five reference architectures for grid modernization, provide to the industry along with the tools they need to adapt them to their needs, and use them to inform the playbook for the GMLC program managers. The result will be superior stakeholder decision-making about grid modernization activities of all kinds.

Control Theory



Candidate hierarchical distributed control architecture based on future distribution reliability coordinator model

PoP: FY16/17/18

Budget: $6.5M

Labs: LANL, PNNL, ANL, INL, NREL, SNL, LLNL, ORNL

Partners: Oncor Electric Delivery, PJM Interconnection LLC, United Technologies Research Center

Develop new control solutions including topologies, algorithms and deployment strategies for transitioning the power grid to a state where a huge number of distributed energy resources are participating in grid control to enable the grid to operate with lean reserve margins. The theoretical aspect of this project will recognize the need to engage legacy control concepts and systems as we transition to more distributed control.

Multi-Scale Integration of Control Systems

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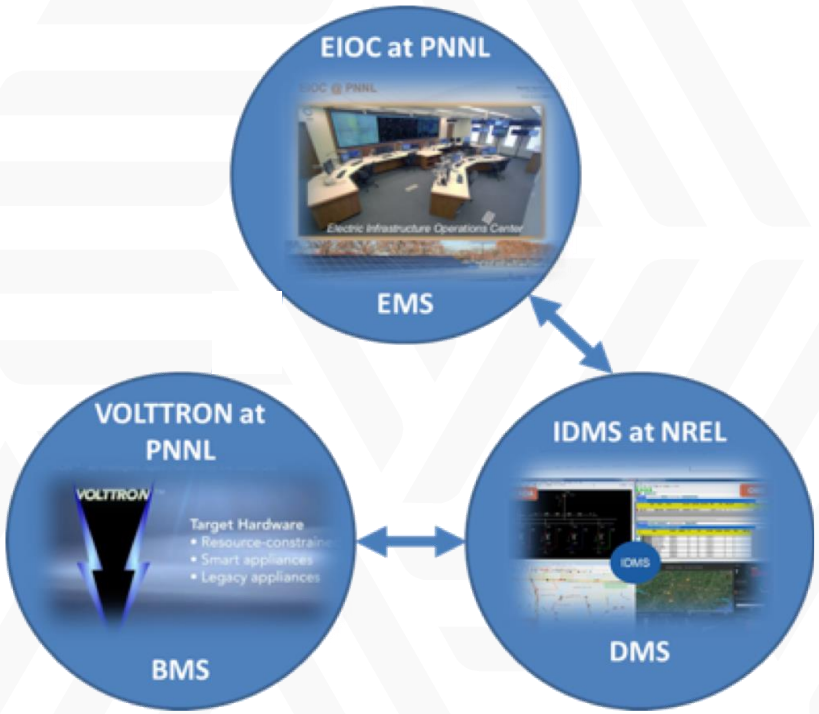
Energy Management System (EMS)



PoP: FY16/17/18

Budget: $3.5M

Labs: ANL, LANL, LLNL, NREL, PNNL, SNL

Partners: GE, Duke Energy, PJM Interconnection LLC

Building Management System (BMS) **Distribution Management System (DMS)**

Create an integrated grid management framework for the end-to-end power delivery system – from central and distributed energy resources at bulk power systems and distribution systems, to local control systems for energy networks, including building management systems.

Sensing and Measurements

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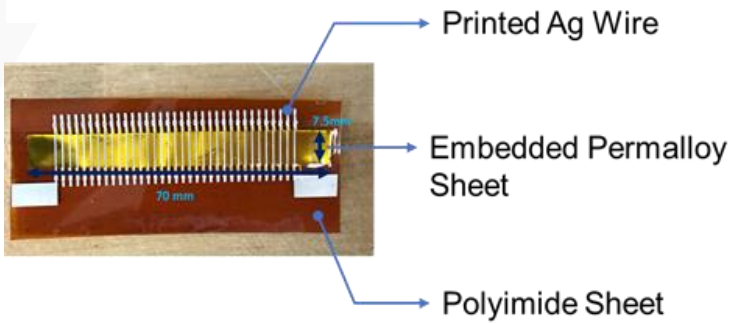
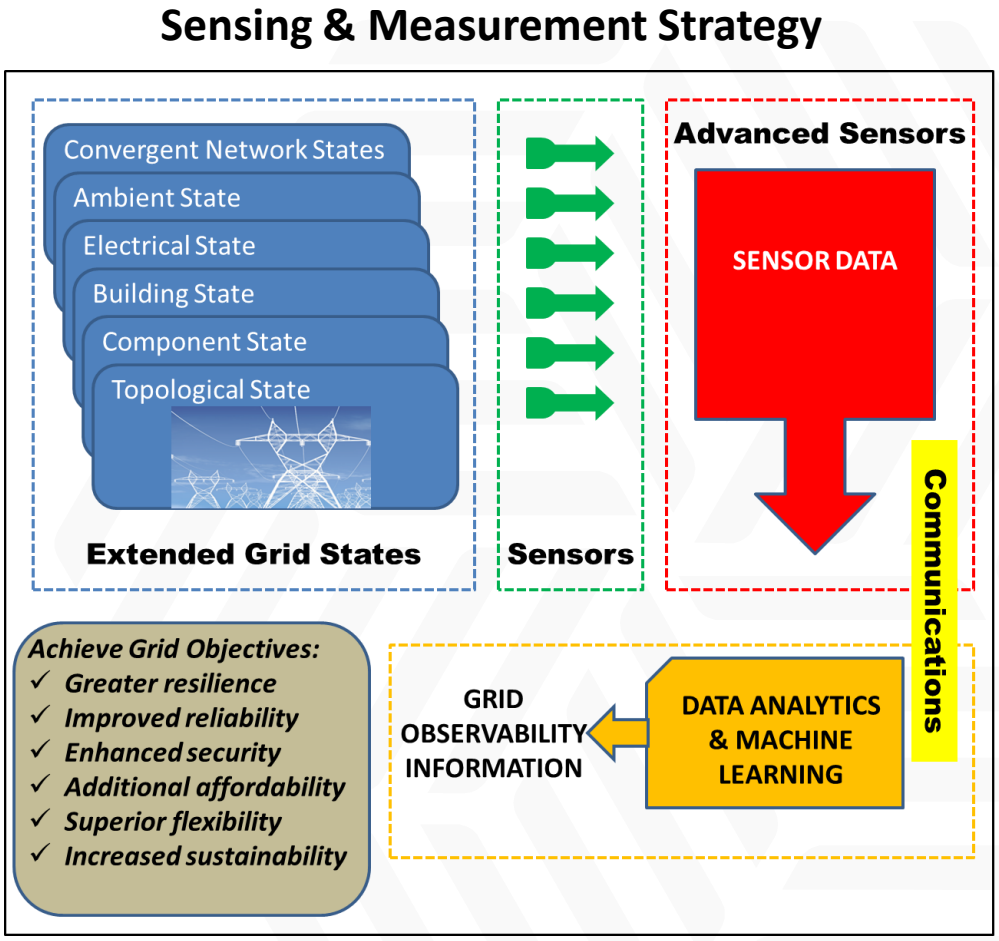
Objective: Create sensor development and deployment strategies to provide complete grid system visibility for system resilience and predictive control

Expected Outcomes

- Advance and integrate novel, low-cost sensors to provide system visibility
- Develop next-generation, low-cost sensors that are accurate through disturbances to enable closed-loop controls and improved system resilience
- Develop real-time data management and data exchange frameworks that enable analytics to improve prediction and reduce uncertainty



Project - Sensing & Measurement Strategy



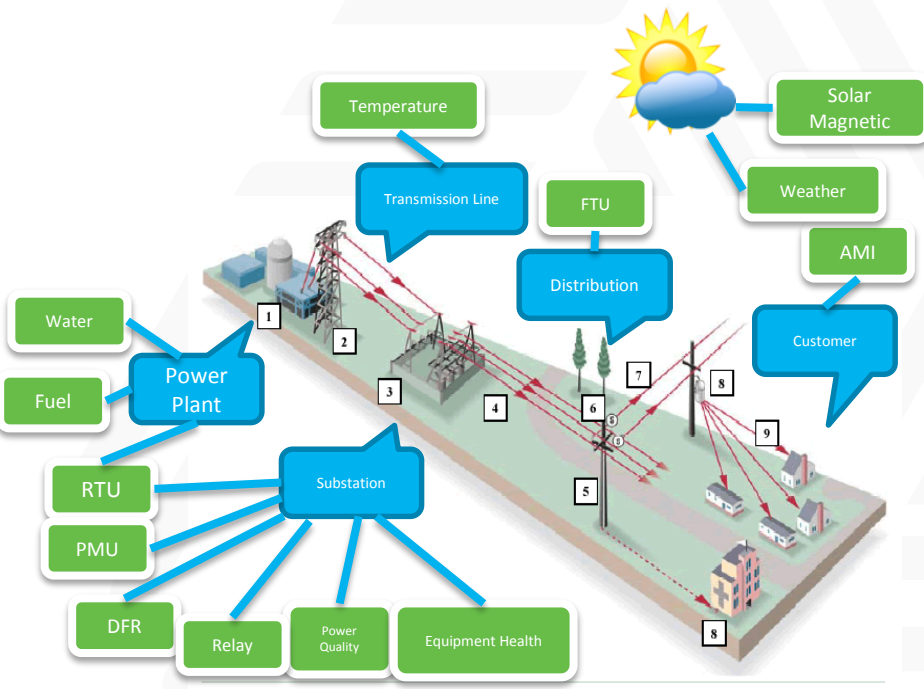
Develop an overall strategy for sensing & measurement including grid states, sensors, communications and data management & analytics. *Without an understanding of the true state of the system, these goals will never be realized.*

This methodology includes: 1) defining the grid state, 2) developing a roadmap and 3) framework to determine sensor allocation for optimal results.

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

Partners: EPRI, Southern Co, EPB, Entergy, OSIsoft, Dominion, TVA, CommEd, NASPI

Project – Advanced Sensor Development



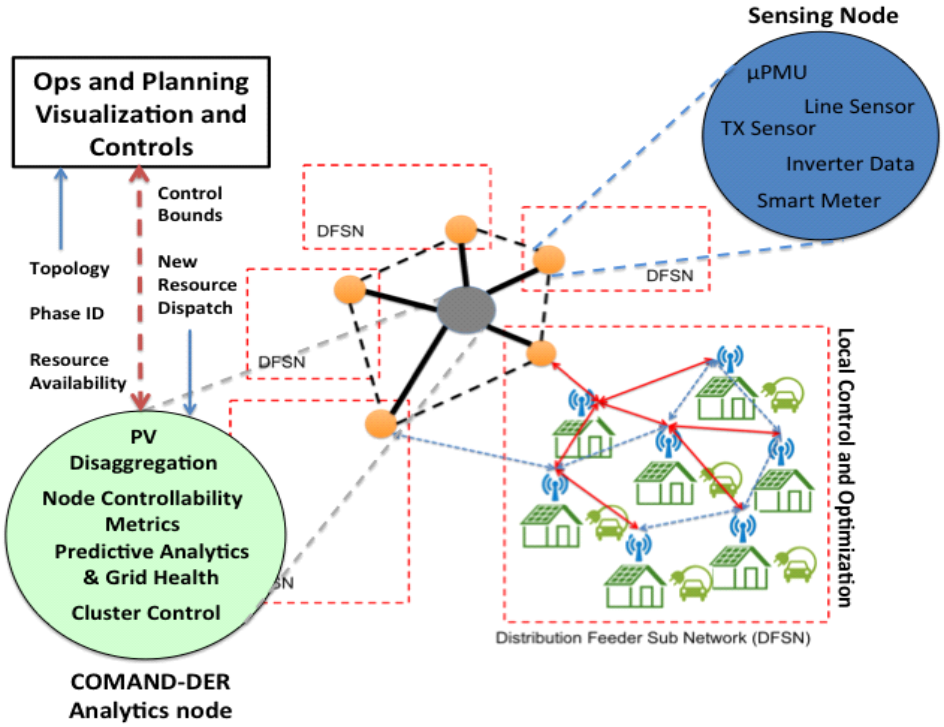
Modified from Duke Energy
https://www.progress-energy.com/florida/home/safety-information/storm-safety-tips/restoration.page?

Increase visibility throughout the energy system including transmission, distribution and end-use by developing low-cost, accurate sensors. Additionally, next generation asset monitoring devices will help determine state of grid components prior to failure.

Labs: ORNL, PNNL, NETL, NREL, SNL, LBNL

Partners: EPRI, University Tennessee, Southern Co, EPB, Entergy, Eaton, SmartSense, National Instruments, Dominion, TVA, ComEd, NASPI

Project – Multi-Scale Data Analytics & Machine Learning



Develop and demonstrate distributed analytics solutions to building-grid challenges, leveraging multi-scale data sets, from both sides of the meter. Evaluate and demonstrate the application of machine learning techniques to create actionable information for grid and building operators, and derive customer benefits from disparate data

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

Partners: OSIsoft, Duke Energy, PG&E, PingThings, PSL, City of Riverside, Hawaiian Electric, Pecan Street, Smarter grid solutions

Road Map of 1.4.9 (ML for distribution grids)

Devices and Integrated Systems

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Objective: Develop and update interconnection and interoperability methods, protocols, standards & test procedures

Focus Areas

- Work across DOE Program offices to develop technologies that provide a **range of grid services**
- Develop and **update interconnection and interoperability methods**, protocols, standards & test procedures
- Conduct technology and **integrated system testing and validation**

Expected Outcomes

- Develop new grid interfaces to **increase ability of new technology to provide grid services** for reliability, resilience and increase utilization of infrastructure
- Coordinate and support the development of interconnection and interoperability standards and test procedures for provision of grid services **across all element of the grid**
- Validate secure and reliability grid operation with **all forms of energy** at multiple scales (microgrids to transmission systems)

Interoperability

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Project Description

Align stakeholders on a strategic vision for devices and systems integration and develop measures and tools to support interoperability

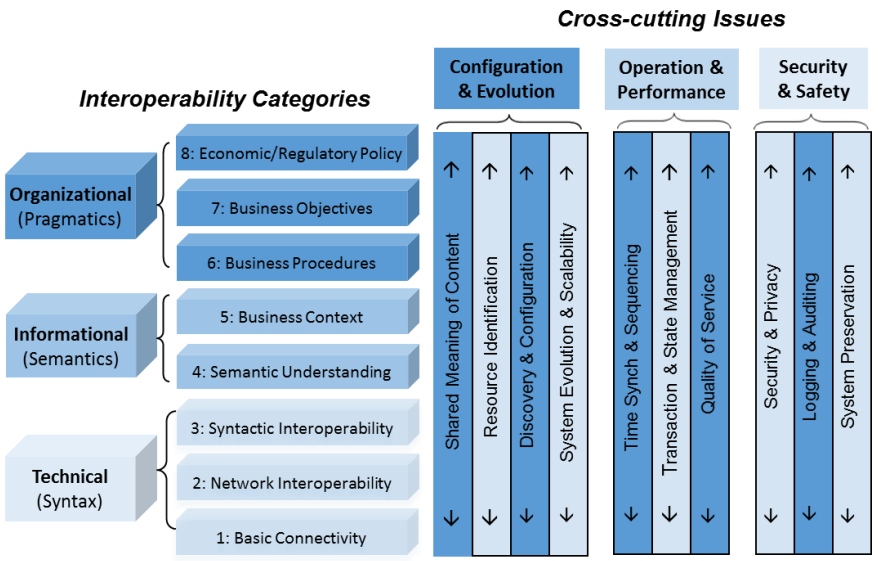
Interoperability is the ability of two or more systems or components to exchange information and to use the information that has been exchanged.
ISO/IEC/IEEE 24765

Value Proposition

- Reduction of cost and effort for system integration
- Improve grid performance, efficiency and security
- Increase in customer choice and participation
- Establishment of industry-wide best practices
- Catalyst of innovation

Partners

- Labs: PNNL, NREL, LBNL, ANL
- Partners: Industry, Industry Associations, Standards Development Organizations, Other Research Organizations



Testing Network and Open Library

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Project Description

Accelerate grid modernization by improving access to National Lab testing infrastructure for grid devices and systems, and related models and tools. Enable national labs to drive innovation more effectively and synergistically.

Value Proposition

- Access to testing resources and validated models is vital to grid modernization
- Make optimal use of vast and growing set of grid-related testing and simulation resources at National Labs and beyond.
- Major opportunities to make an impact by improving information, accessibility, and collaboration

Partners

- Labs: Sandia, INL, NREL, ORNL, LBNL, ANL, PNNL, SRNL, BNL, LLNL
- Others: Utilities, Academia, Manufacturers

Standards & Test Procedures for Interconnection & Interoperability

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Project Description

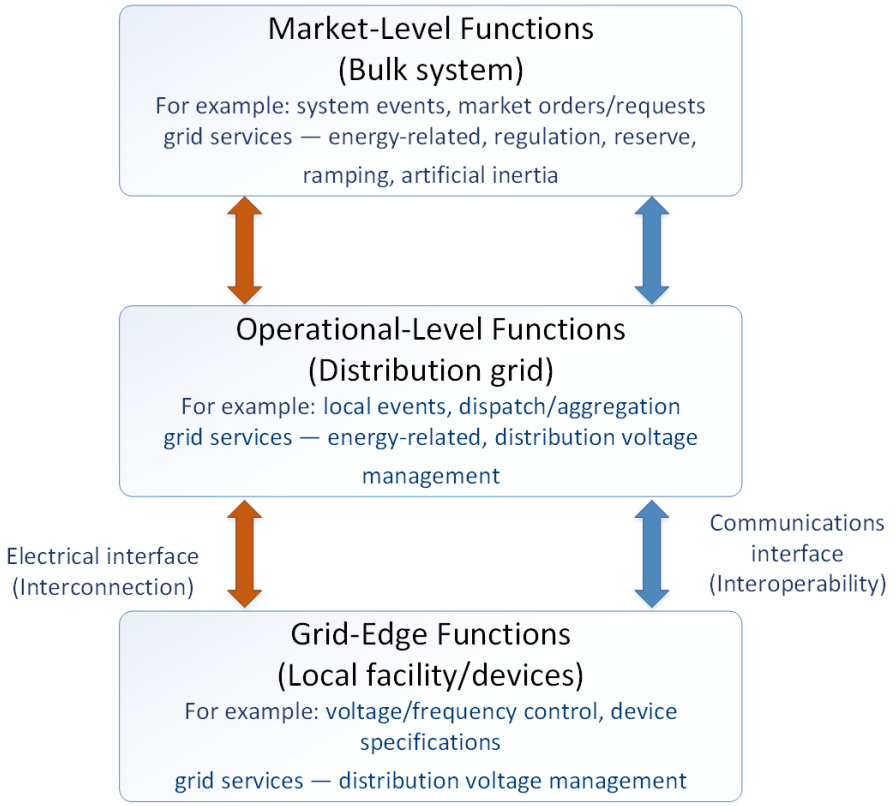
- Accelerate the development and validation of interconnection and interoperability standards
- Ensure cross-technology compatibility & harmonization of requirements for key grid services

Value Proposition

- Improve coordination of modern energy generation & storage devices with the grid
- Enable market expansion through improved interoperability
- Reduce barriers to deployment through improved standards

Partners

- Labs: NREL, PNNL, LBNL, ANL, Sandia, ORNL, INL
- Others: Vendors, utilities, system integrators, standards organizations



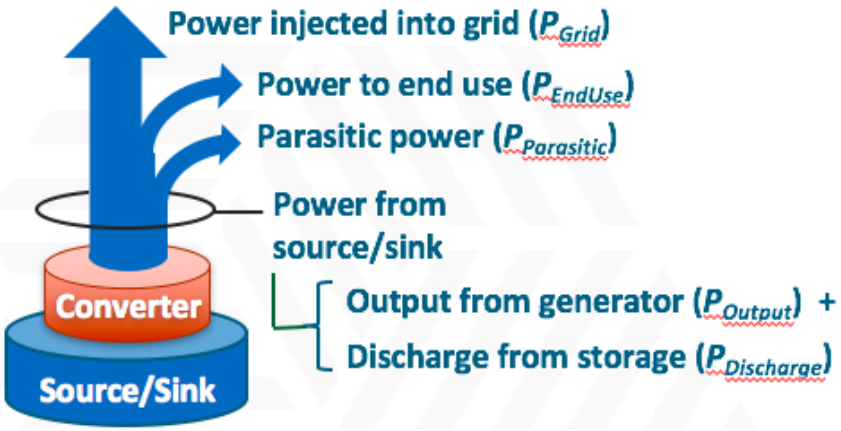
Grid Services

Project Description

- Develop and test high-resolution models of distributed energy resources (DERs) with a standardized interface in the form of a battery-equivalent (BEq) representation, for
- Ready access by planning and operational tools in assessing DERs' ability to provide operational flexibility in the form of valuable grid service at the bulk system and local distribution levels.

Value Proposition **-** Common BEq representation/interface allows:

- Grid operations & planning models to easily & accurately assess DER contributions
- Contribution of DER classes can be "summed"
- Grid control & optimization methods to be shared by across DER types
- Consideration of BEq as a grid flexibility metric
- Level-playing field for evaluating DERs



Partners

- Labs: PNNL, NREL, PNNL, LBNL, ANL, Sandia, ORNL, INL, LLNL
- Others: Vendors, utilities, system integrators, standards organizations

Institutional Support

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Objective: Support and manage 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
- Convene key grid stakeholders as an honest-broker for collaborative dialogues on grid modernization
- Create an overarching 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

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Institutional Support Projects

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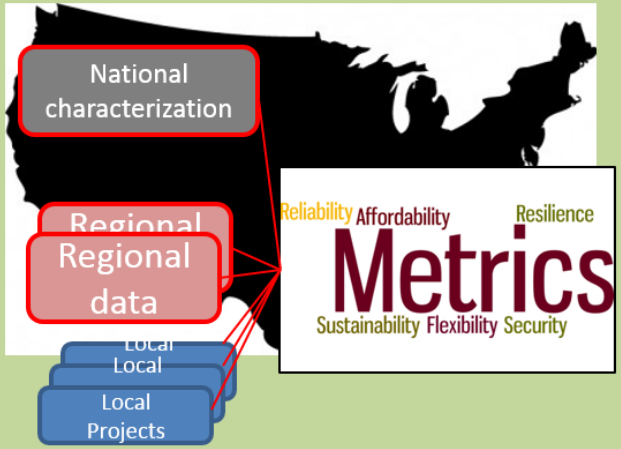
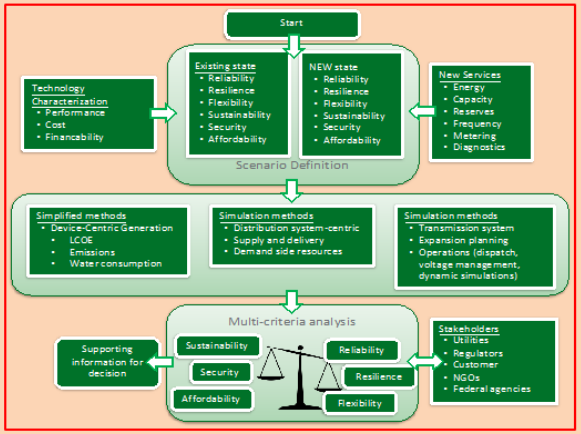
Metric Analysis



Valuation Framework Development

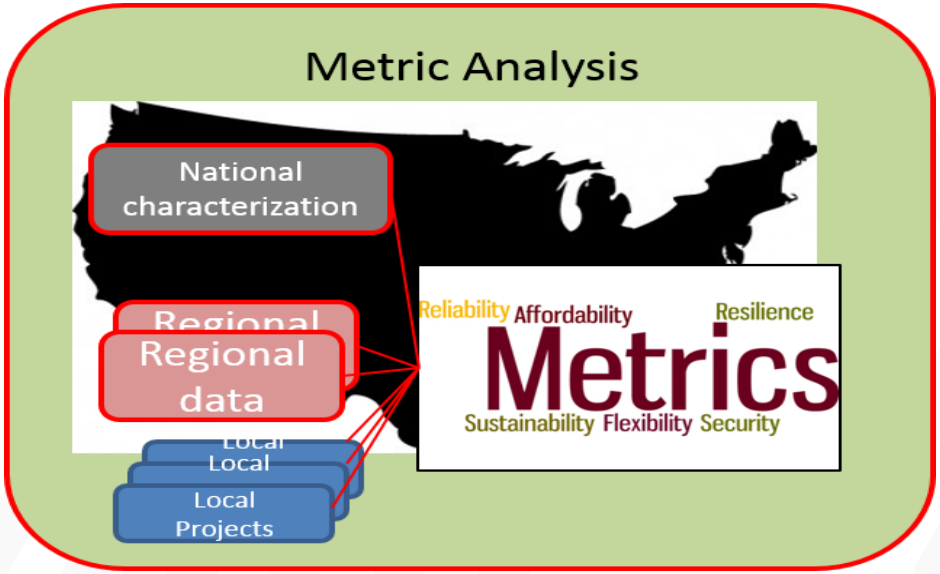


Distribution System Decision Planning

FUTURE ELECTRIC
Utility Regulation

U.S. DEPARTMENT OF ENERGY

Metrics Analysis



PoP: FY16/17/18

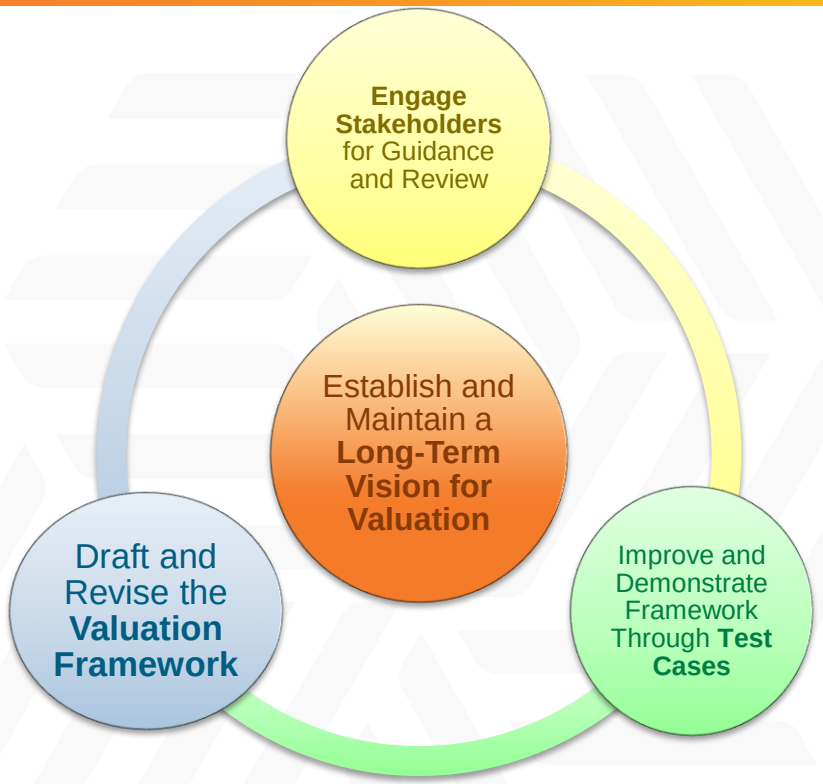
Budget: $4.7M

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

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

Distribution System Decision Support Tool Development and Application

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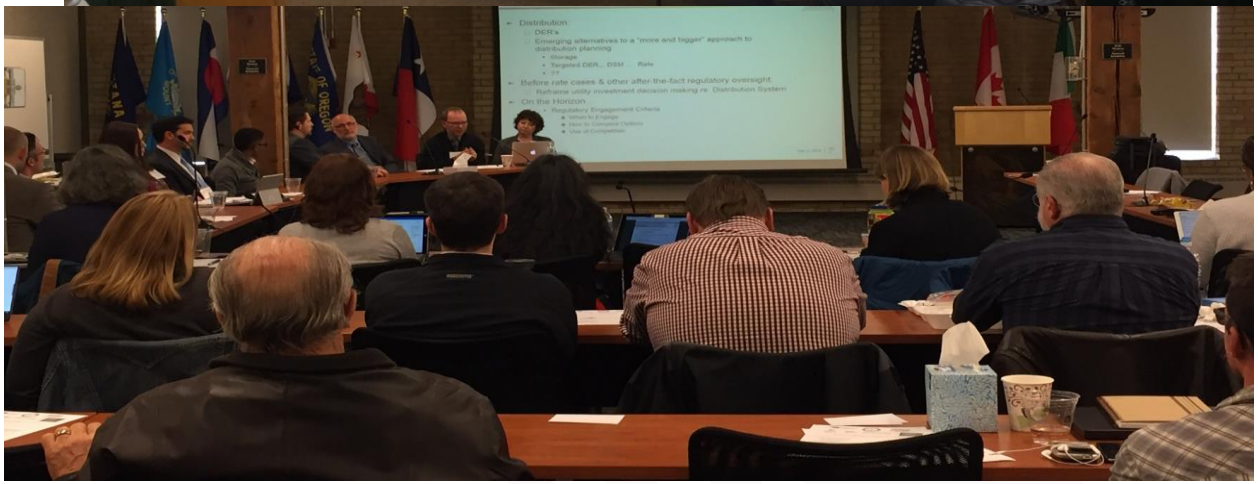

PoP: FY16/17/18

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

Future Electric Utility Regulation

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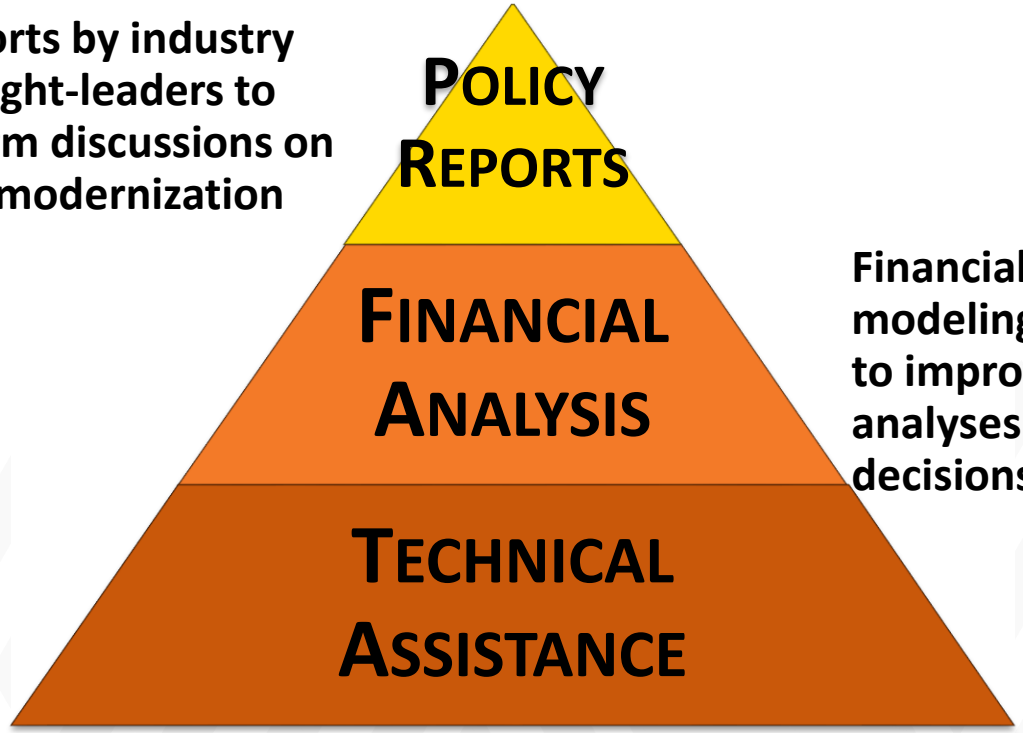
Reports by industry thought-leaders to inform discussions on grid modernization



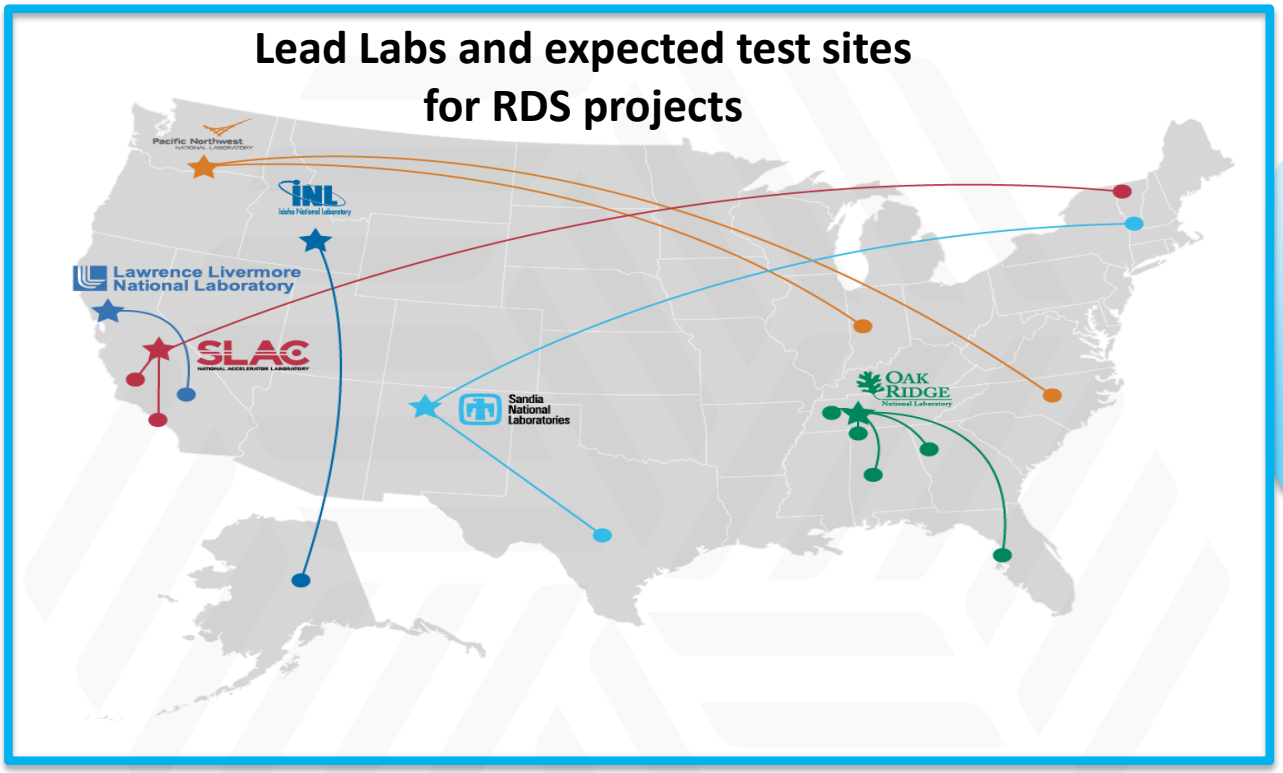
Financial modeling tools to improve analyses and decisions

Direct TA to state PUCs

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

- 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

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

Beyond the Levelized Cost of Energy (LCOE)

LCOE is not a bad metric…but an incomplete one

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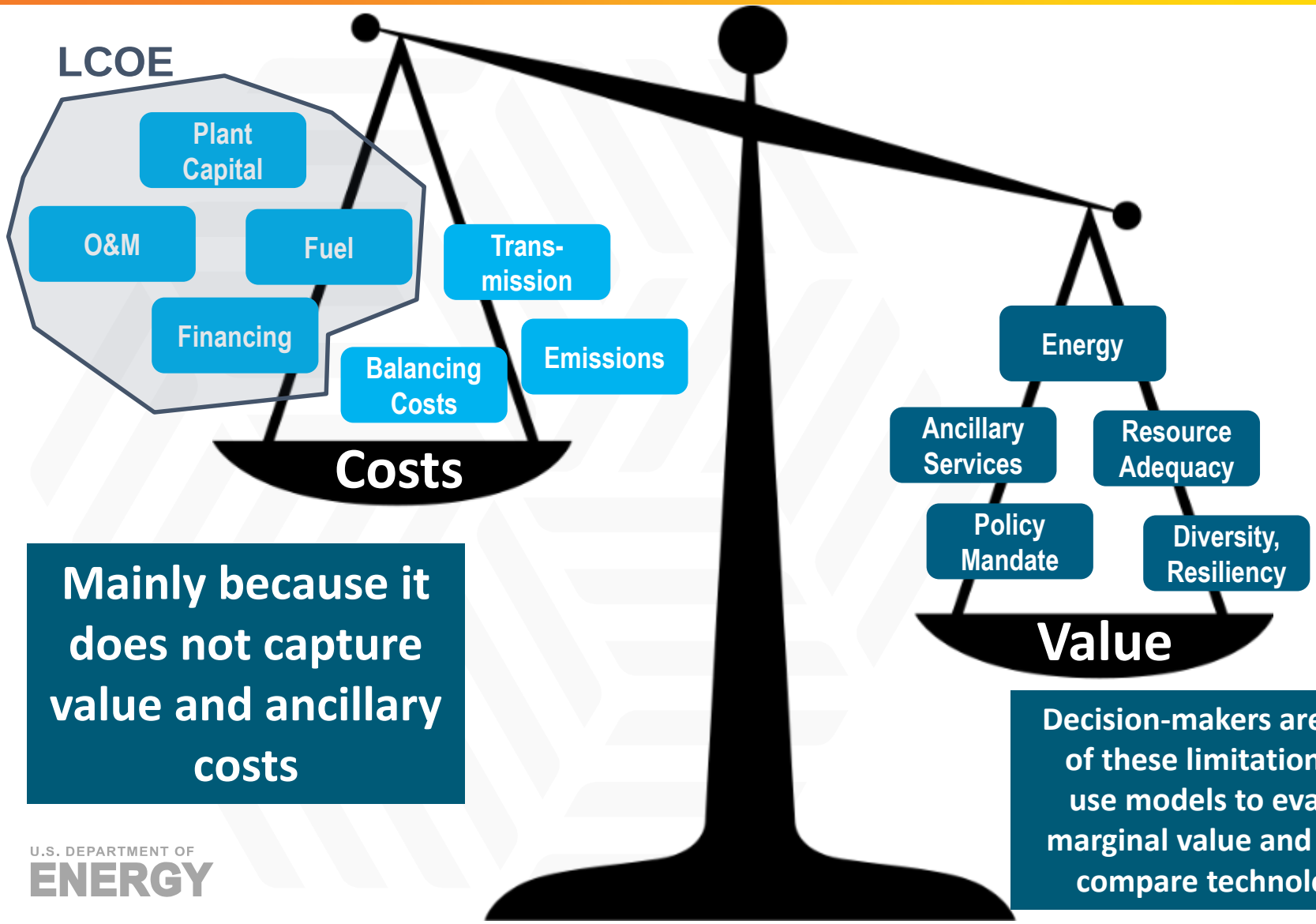

Mainly because it does not capture value and ancillary costs

Decision-makers are aware of these limitations and use models to evaluate marginal value and cost to compare technologies

U.S. DEPARTMENT OF ENERGY

Security and Resilience

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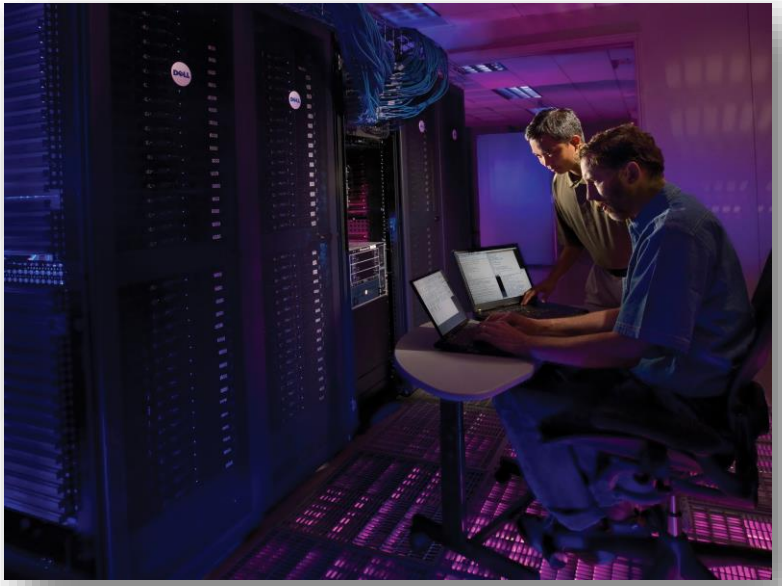
Objective: Provide a pathway to comprehensive multi-scale security and resilience for the nation's power grid

Expected Outcomes

- Holistic grid security and resilience—from devices, to microgrids, to systems
- Inherent security designed into components and systems, not security as an afterthought
- Security and resilience addressed throughout system lifecycle and covering the spectrum of legacy and emerging technologies



Grid Resilience and Intelligence Platform (GRIP)

GRID MODERNIZATION INITIATIVE
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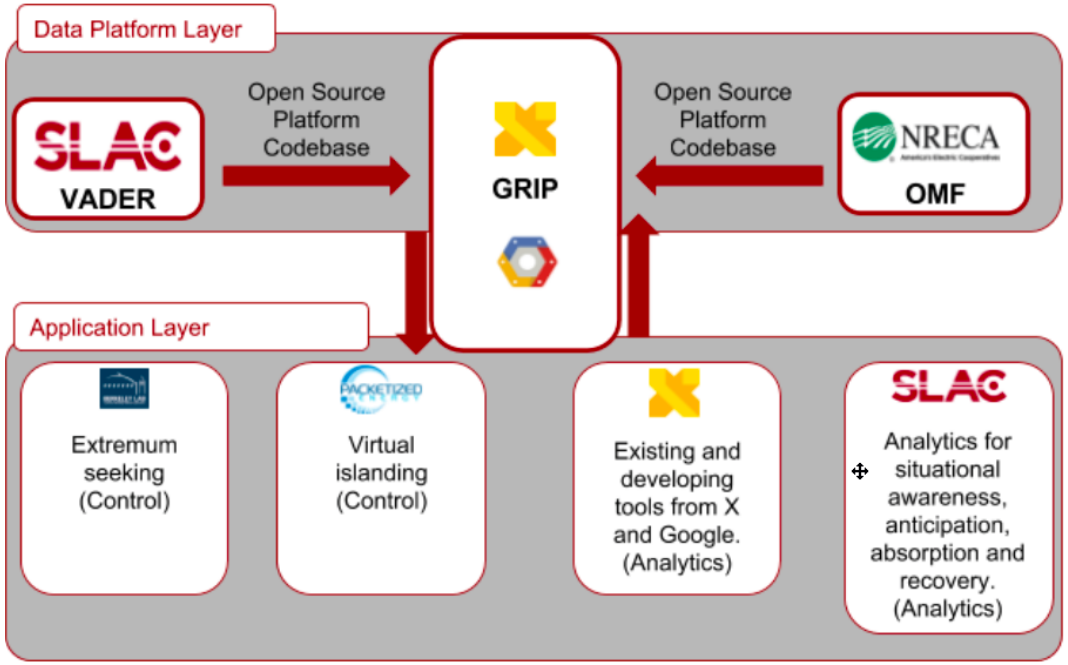
- **Goal:** Develop and validate a new software platform to help operators anticipate, respond to, and recover from extreme events.

- **Labs:** SLAC, LBNL

- **Partners:**
  - National Rural Electric Cooperative Association
  - Southern California Edison
  - Packetized Energy
  - Vermont Electric Cooperative
  - Presence
  - University of California Berkeley
  - Stanford University



Resilient Alaskan Distribution System Improvements using Automation, Network analysis, Control, and Energy storage (RADIANCE)

GRID MODERNIZATION INITIATIVE
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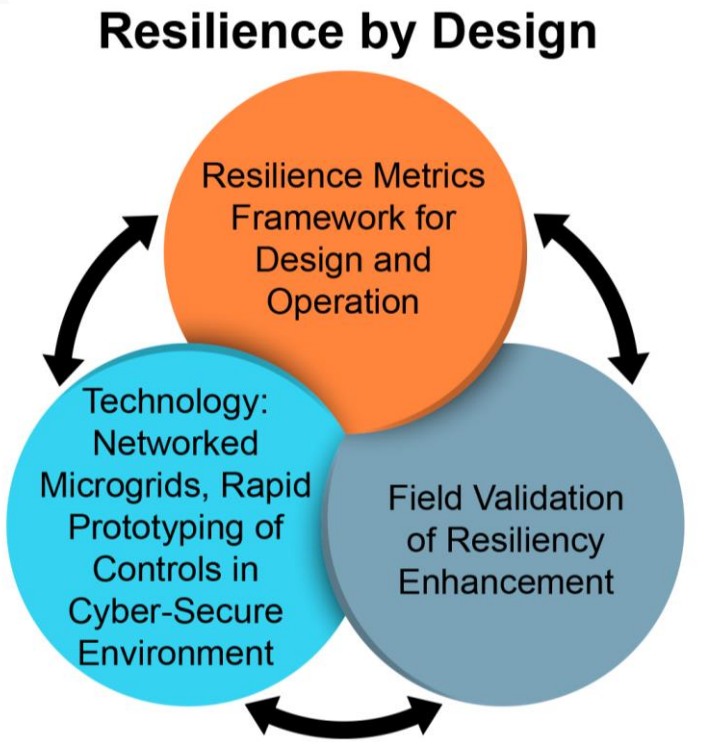
- **Goal:** Increase grid resilience for geographically remote communities using a cyber-secure resilience framework.

- **Labs:** INL, SNL, PNNL

- **Partners:**
  - City of Cordova
  - Cordova Electric Cooperative
  - University of Alaska – Alaska Center for Energy and Power
  - Washington State University
  - Florida State University
  - New Mexico State University
  - Siemens Corporation
  - Alaska Village Electric Cooperative
  - National Rural Electric Cooperative Association



Increasing Distribution Resiliency Using Flexible DER and Microgrid Assets Enabled by OpenFMB (Decentralized FLISR)

GRID MODERNIZATION INITIATIVE
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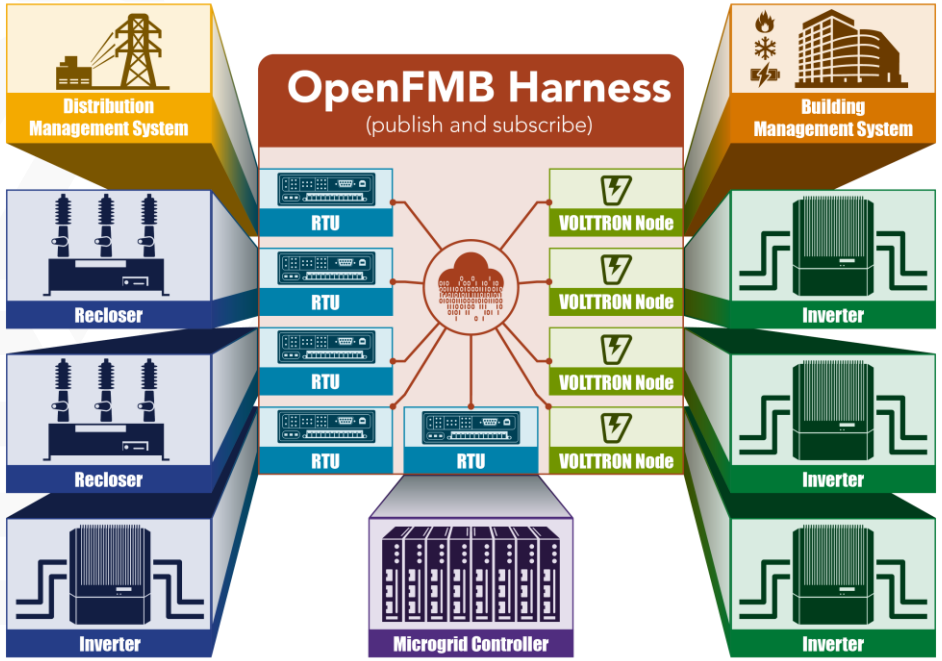
- **Goal:** Develop and test a flexible architecture that coordinates decentralized and centralized assets within a central distribution management system.

- **Labs:** PNNL, ORNL, NREL

- **Partners:**
  - Duke Energy
  - GE Grid Solutions
  - University of North Carolina Charlotte
  - University of Tennessee
  - Smart Electric Power Alliance (SEPA)



Integration of Responsive Residential Loads into Distribution Management Systems

GRID MODERNIZATION INITIATIVE
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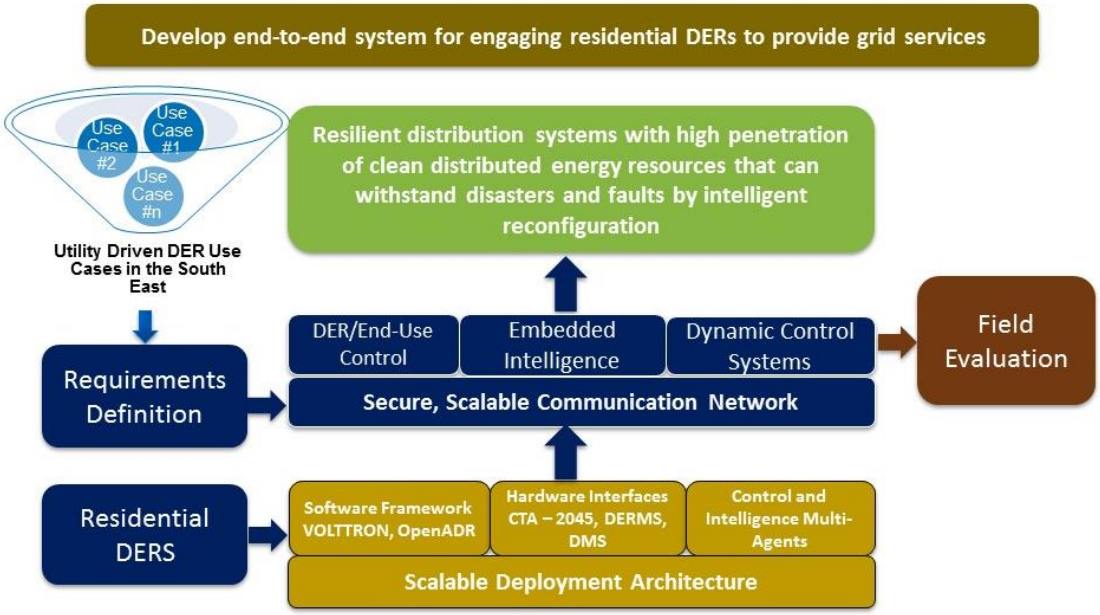
- **Goal:** Provide electric utilities with the necessary software and hardware, all based on open standards, to leverage demand-side management of residential DERs.

- **Labs:** ORNL, PNNL

- **Partners:**
  - Electric Power Research Institute
  - National Rural Electric Cooperative Association
  - Southern Company
  - Tennessee Valley Authority
  - Duke Energy
  - Con Edison
  - Electric Power Board
  - Jackson EMC



CleanStart Distributed Energy Resource Management System (DERMS)

GRID MODERNIZATION INITIATIVE
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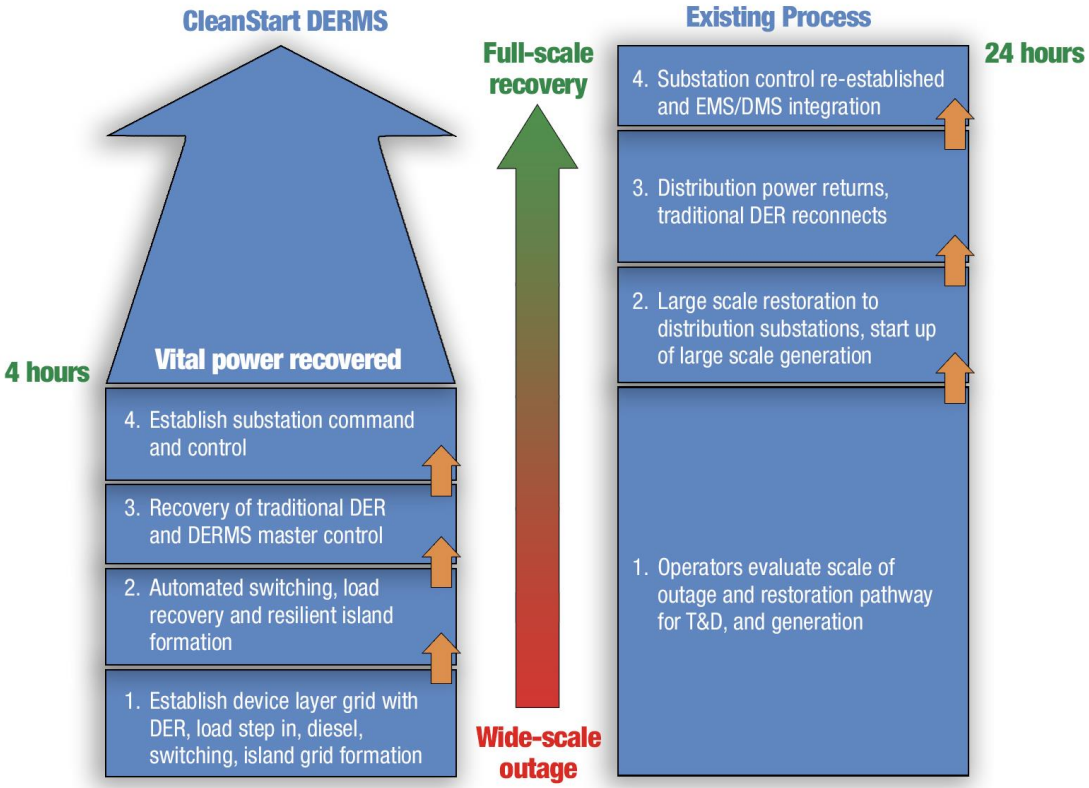
- **Goal:** Design, implement, and validate a novel blackstart and dynamic microgrid solution from DER feeders.
- **Labs:** LLNL, PNNL, LANL
- **Partners:**
  - Smarter Grid Solutions
  - SolarEdge
  - PingThings
  - City of Riverside Public Utility
  - Pacific Gas & Electric
  - University of California Riverside



Consequence-Based Approach for Considering Community Grid Resiliency Investments

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- **Goal:** Develop and validate a new software platform to help operators anticipate, respond to, and recover from extreme events.

- **Labs:** SNL

- **Partners:**
  - CPS Energy, San Antonio
  - The City of San Antonio
  - University of Texas at San Antonio
  - National Grid
  - The City of Buffalo, NY
  - Synapse Energy
  - The 100 Resilient Cities Organization

Thank You

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Contact us at gmi@hq.doe.gov
Visit us at https://energy.gov/gmi

BACKUP SLIDES