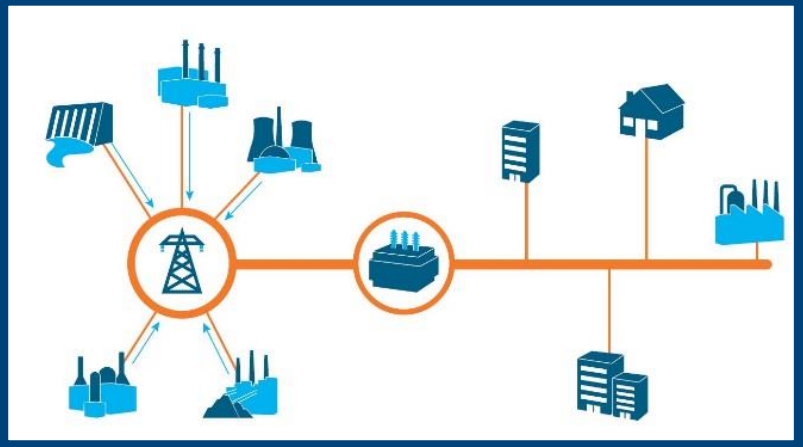
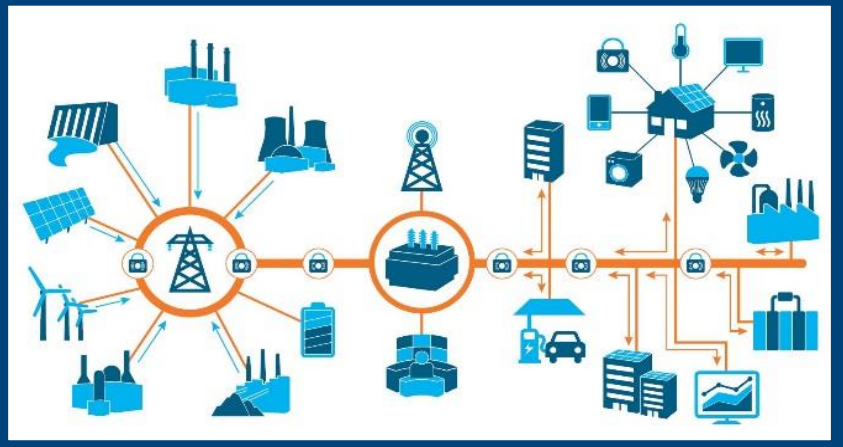


The electricity grid of today

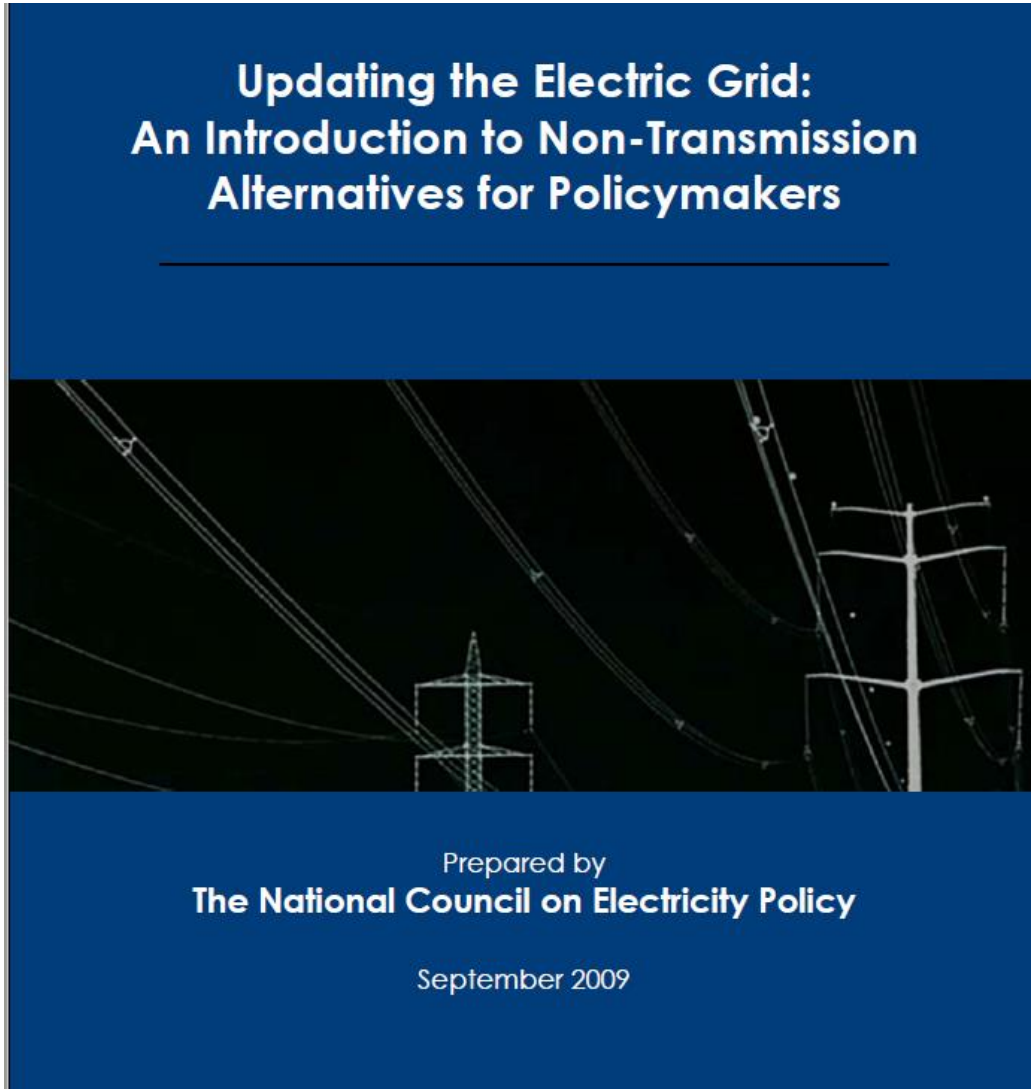


The electricity grid of tomorrow?

DOE Work on the Intersection of the Bulk Power and Distribution Grids

"The Status of Transmission and Distribution System Intersections: A Grid Revolution"
National Council on Electricity Policy Annual Meeting
Denver, CO
May 8, 2018

National Council a Forerunner on this Subject



Growing Distribution-Level Impacts on Bulk Power Grid – Here's One of Many

"Think about a world 10-20 years from now where 20 percent of our resource base is distributed energy resources and we're trying to operate that essentially through the internet. And think about a denial of service [cyber] attack that knocks out the underlying capability of us being able to see those resources. That to me [who has bulk power grid reliability responsibility] feels the same as having a pipeline out of commission."

- Gordon van Welie, president and CEO of ISO New England

Source: E&E News, Oct. 30, 2017

DOE Offices Funding Work with Bulk Power/Distribution Grid Aspect

- **Office of Energy Efficiency & Renewable Energy (EERE)**
  - Solar Energy Technology Office
  - Vehicle Technologies Office
  - Buildings Technologies Office
- **DOE Office of Electricity Delivery & Energy Reliability (OE)**
  - Advanced Grid R&D Division
  - Transmission Permitting and Technical Assistance Division
- **Office of Science**
- **ARPA-E**
- **Multi-DOE Offices: Grid Modernization Initiative**

EERE Solar Energy Technology Office

The *systems integration subprogram* focuses on five research areas to enable seamless integration of solar energy onto a modernized electric grid:

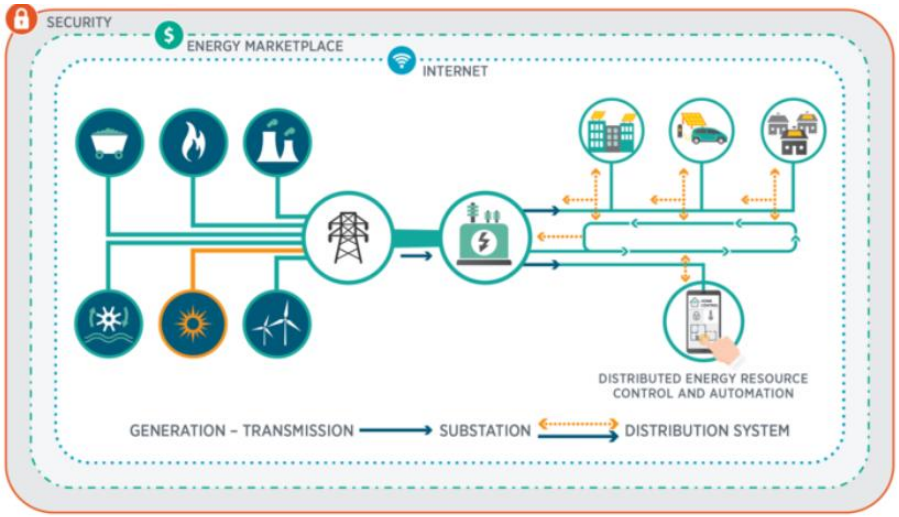
Planning and Operation – Understanding the impacts of increasing penetration of solar energy on grid reliability and power quality and addressing the variability of solar generation and two-way power flows.

Solar + X – Developing best practices for interconnecting and integrating solar with energy storage and synergistic distributed energy resource technologies to achieve higher asset and utilization and value.

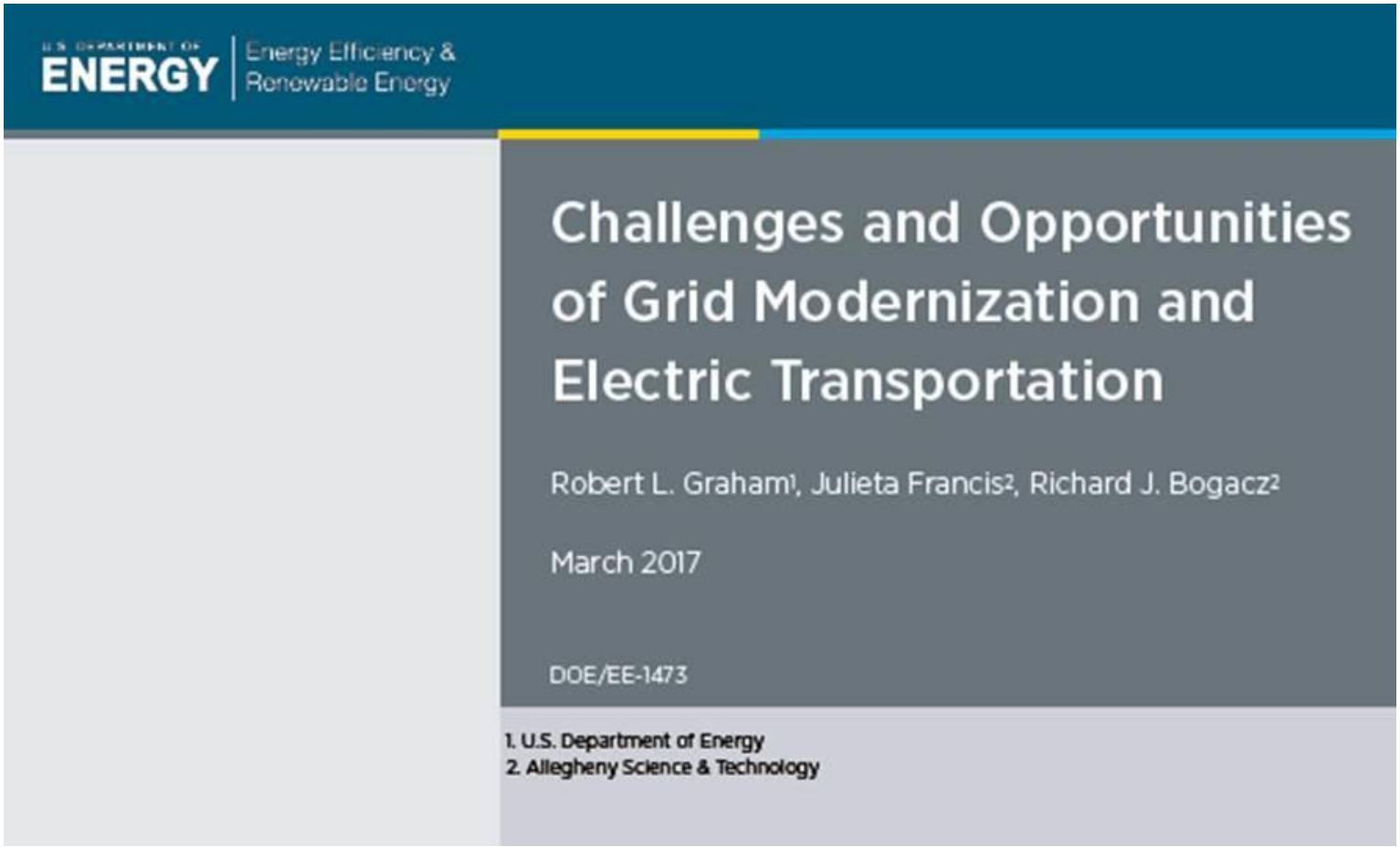
Power Electronics – Researching power electronic technologies such as smart photovoltaic inverters for flexible power flow control.

Sensing and Communication – Enhancing situational awareness of solar generation at the grid edge using advanced information, communication, and data analytic technologies.

Codes and Standards – Informing the standardization of interconnection, interoperability, and cybersecurity for photovoltaics and other distributed energy resource systems.



EERE Vehicle Technologies Office



EERE Building Technologies Office (BTO)

Developing a **Grid-interactive Efficient Buildings (GEB) Strategy** which recognizes:

- Buildings *are underutilized* as flexible, dispatchable electric system resources
- GEB is the intersection of *energy efficiency* and "*smart*" and "*connected*" technologies; "connected" = connected via communications & serving as a responsive resource

Focus Areas:

Cyber-Physical Systems to enhance the ability of buildings to interact with the grid and respond to grid conditions

Modeling to support design, planning and valuation

Component-Based Technologies to improve demand responsiveness

Systems Integration to validate GEB technologies and verify benefits

BTO will leverage GMI/GMLC investments for broader impact

Connected Neighborhoods

Image courtesy of Alabama Power

Smart Neighborhood

- Outside Birmingham, AL
- 62 homes connected to community microgrid (solar, battery storage, natural gas)
- 35% more efficient homes (compared to standard AL new home)

This first of-its-kind transactive residential microgrid in the Southeastern United States is a partnership between Southern Company (Alabama Power, Georgia Power), DOE, Oak Ridge National Laboratory, Electric Power Research Institute, Vivint, Carrier, and Rheem.

The neighborhood's intelligent technology communicates with each home's heating, air conditioning, and water-heating system to determine the best way to provide energy.

Clean Energy and Transactive Campus

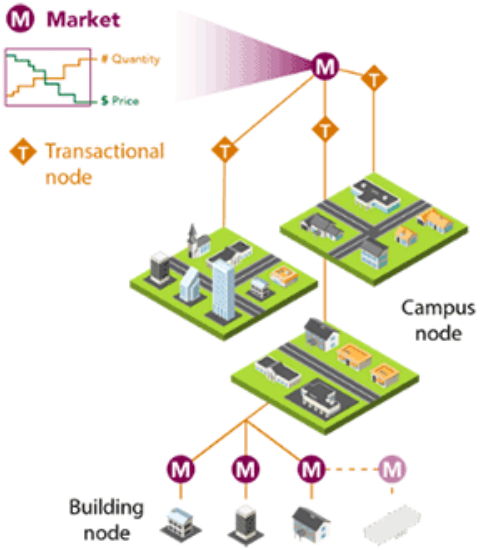


Image courtesy of Pacific Northwest National Laboratory

Transactive Campus R&D

- Coordinate building energy loads
- Integrate distributed energy resources
- Use modeling and simulation for new transactive strategies to balance power grid operation with building's distribution system

This regional partnership seeks to improve efficiency and comfort in buildings, make the grid more reliable, and enhance integration with the grid at the regional scale. This is the first behind-the-meter implementation of transactive energy at this scale, involving multiple buildings and devices.

This project is a partnership between Pacific Northwest National Laboratory, DOE, the University of Washing, Washington State University, Case Western Reserve University, the University of Toledo, and the NASA Glenn Research Center.

OE Advanced Grid R&D Division

- Using data from distribution “microPMU” sensors with already-deployed bulk power PMU sensor network that watches real-time bulk power
- Advanced grid modeling program has a range of funded work to develop next generation algorithms and models that better integrate bulk power and distribution grids. Adoption in commercially available operations and planning modeling software is goal.
- “Transactive energy systems”

OE Advanced Grid R&D Division

Transactive Grid Systems: Addressing the Need for *Grid Flexibility* from Distributed Assets

The Problem:

Grid's generation mix rapidly shifting from entirely dispatchable to significantly variable and stochastic

Operating it reliability and affordability will require vastly increased amounts of *operational flexibility.*

The Opportunity:

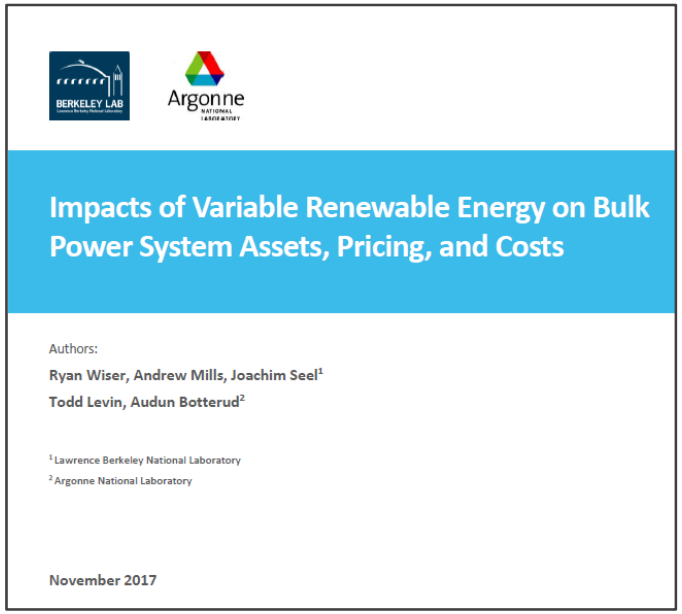
To provide flexibility at reasonable cost, much of it is expected from *distributed energy resources (DERs)*: flexible loads, electrical & thermal storage, smart inverters, electric vehicle chargers, etc.

The Challenge:

- How can we coordinate DERs to provide grid services when they are neither owned nor controlled by the power grid operator?
- How can we ensure DERs provide the predictable, smooth, stable response required?
- *Transactive grid systems* coordinate DERs through transparent, competitive means
  - Real-time ***transactions*** provide feedback required to ***close the "control" loop***
  - ***Achieves global optimization (T&D) consistent with, and driven by, selfish local optimization*** embodied in agents that manage DERs on the customers behalf

OE Transmission Permitting and [States] Technical Assistance Division

- Funds meetings of state electricity officials like today
- Funds studies to inform technical assistance to states
  - New Study: Unpacking the Disconnect Between Wholesale and Retail Rates
  - Impact of VERs on Bulk Power System Assets, Pricing, and Costs

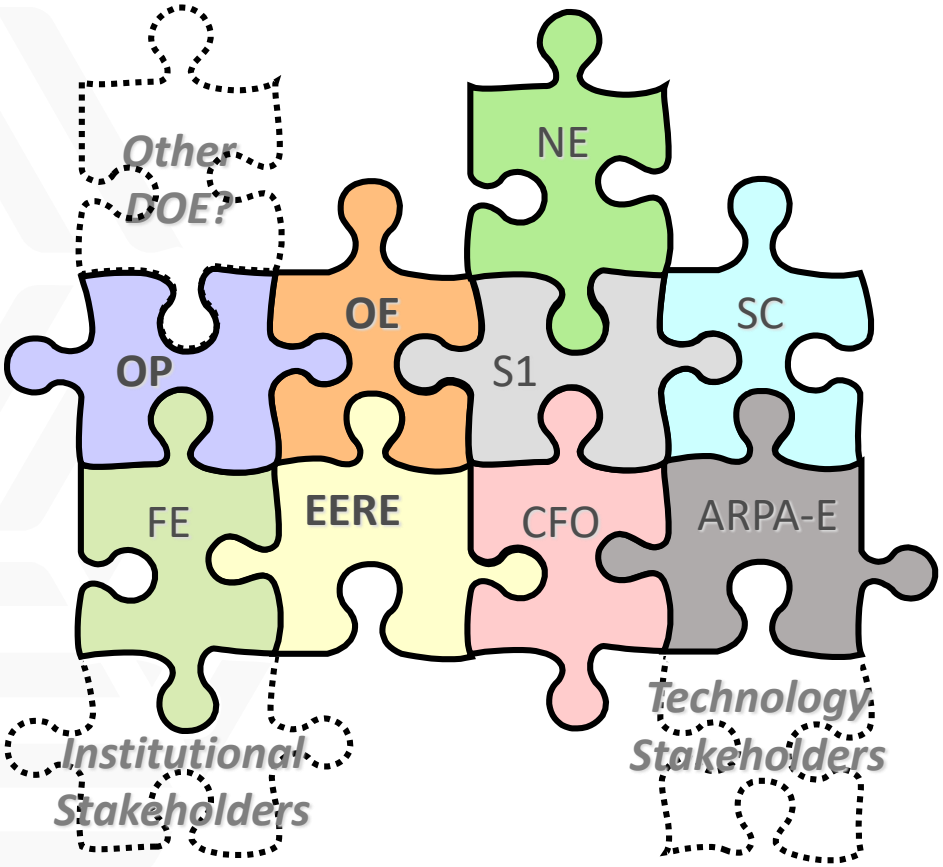


The Grid Modernization Initiative (GMI): Coordination Across Multiple DOE Offices

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

An aggressive five-year grid modernization strategy and focus for the Department that includes:

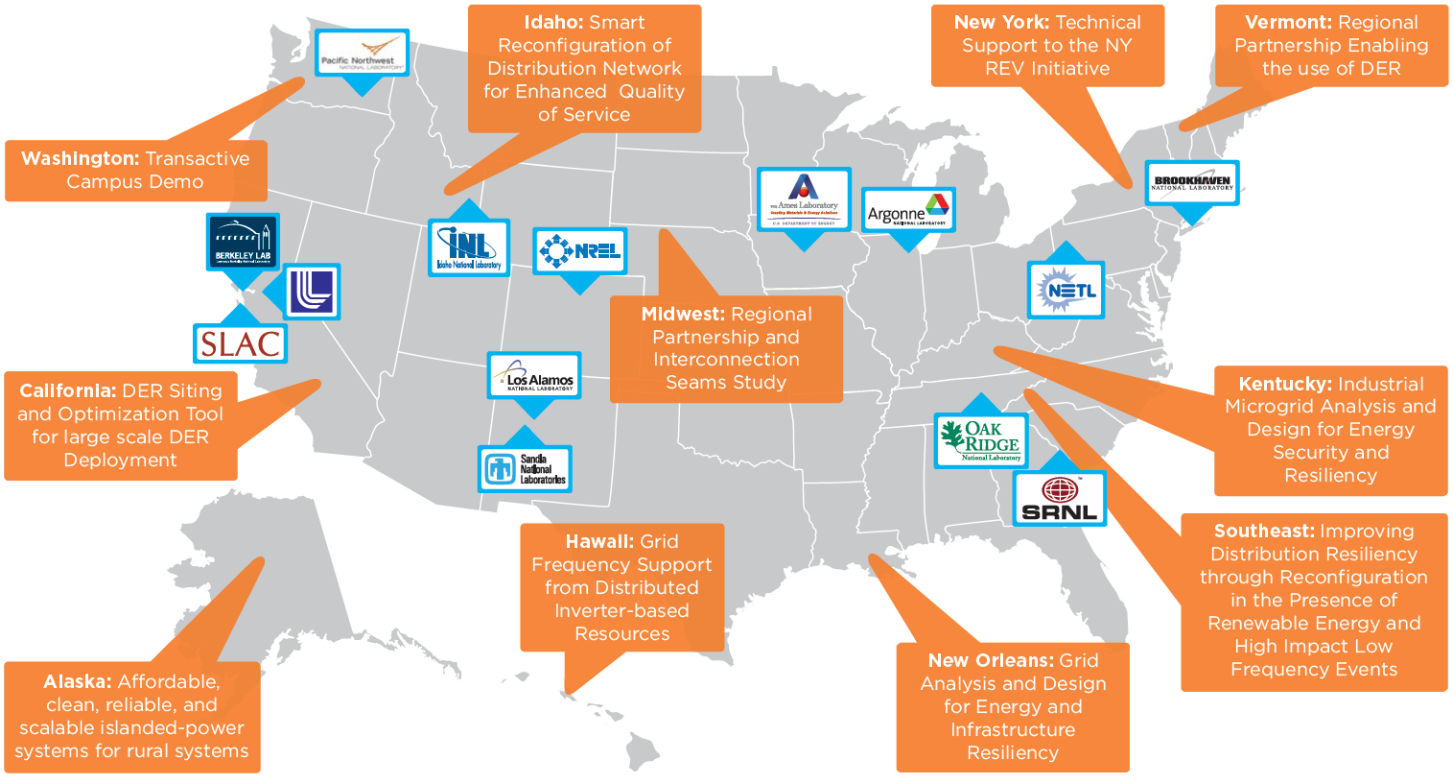
- Coordination and alignment of the existing base activities among Offices
- An integrated Multi-Year Program Plan
- New activities to fill major gaps in existing base
- Development of a laboratory consortium with core specific abilities and regional outreach



Grid Modernization Lab Calls--Two Rounds

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Working across the country with the Grid Modernization Lab Consortium (GLMC)



- $251M multi-year
- 13 national laboratories
- 150+ partners
- 95 projects

34 projects have a bulk power/distribution grid aspect

Examples of GMLC Projects with Bulk Power/Distribution Grid Aspect

GMLC Projects with Bulk Power/Distribution Grid Aspect

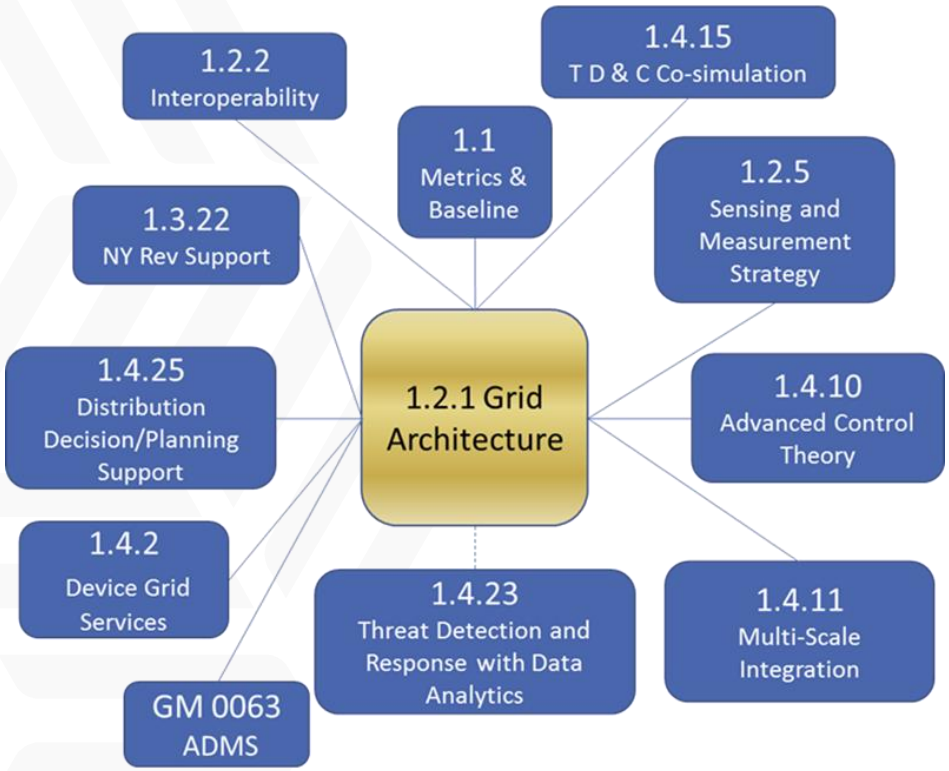
Project 19: Advanced Sensor Development	Increase visibility throughout the energy system including transmission, distribution, and end-use by developing low-cost, accurate sensors. Additionally, next generation asset monitoring devices will help determine state of grid components prior to failure.	ORNL, PNNL, NETL, NREL, SNL, LBNL	EPRI, University of Tennessee, Southern Co, EPB, Entergy, Eaton, SmartSense, National Instruments, Dominion, TVA, CommEd, NASPI
Project 21: Control Theory	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 theory effort will recognize the need to engage legacy control concepts and systems as we transition to more distributed control.	LANL, PNNL, ANL, INL, NREL, SNL, LLNL	Oncor, PJM Interconnection, United Technologies Research Center
Project 22: Multi-Scale Integration of Control Systems (EMS/DMS/BMS)	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.	ANL, BNL, LANL, LLNL, NREL, PNNL, SNL	Alstom Grid, Duke Energy, PJM

GRID ARCHITECTURE

System Operations, Power Flow, and Control

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

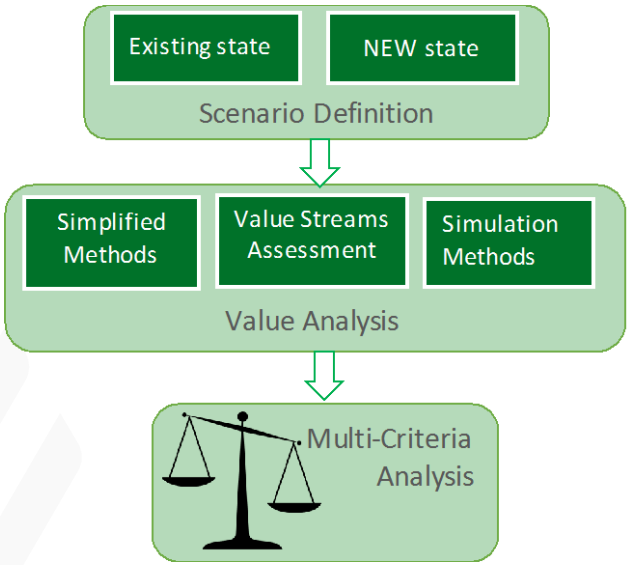
- Working on the application of system architecture, network theory, and related disciplines to the entire grid.
- Principles and guidelines to grid architecture with scenarios, prioritization, and reference models
- Stakeholder driven: common shared terms with EPRI, SGIP, and others



Grid Services and Technologies Valuation Framework Development

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Research focus: 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.



Key Activities

This project will create a generalized framework for the evaluation of value from grid technologies and services, develop a common language for valuation for recording assumptions, methods, and results, and compile test cases of frameworks.

Benefits

This project will create a common language used for grid services and technologies and a tested framework to guide stakeholders and DOE, with the ultimate goal of developing a visionary, systematic, and transparent approach to valuation.

Partners

NARUC

Technical assistance to states on distribution planning includes this meeting's topic as shown here *(plus next slide)*

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

Impacts of DER on Transmission Systems

The Distribution/Transmission interface

John J. Miller, P.E., Randy Berry

Power Systems Consultants - PSC

Part of a broader training course

Distribution Systems and Planning Training for Midwest Public Utility Commissions, Jan. 16-17, 2018

Summary of Impacts on Transmission System

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

- DER negative impacts on Transmission can be mitigated, and DER support for Transmission can be gained by:
  - System planning changes to combine T&D models
  - Holistic system planning process
  - Coordination between D operations and T operations
    - Improved grid utilization during normal and abnormal system conditions
- DER impacts on Transmission offer:
  - Opportunity to introduce new market products
  - Opportunity to introduce improved operating practices
- Reliability, Security, Safety, and Durability must remain primary focus

Future Electric Utility Regulation Reports

Modeled after similar pro-con DOE reports during 1990s restructuring debate

A series of reports featuring *differing opinions* on major current and near-future electricity policy issues that are *not* settled.

The electric sector in the United States is seeing significant changes resulting in new challenges for regulators and other officials that have no easy answers. These reports take a unique point-counterpoint approach to highlight different views on the future of electric utility regulation. Better informed may lead to better decisions.

Completed topics:

1. Electric Industry Structure and Regulatory Responses in a Distributed Energy Resources (DERs) Future
2. Distribution Systems in a High DER Future: Planning, Market Design, Operation and Oversight
3. Performance-Based Regulation in a High DER Future
4. Distribution System Pricing with Distributed Energy Resources
5. Recovery of Utility Fixed Costs: Utility, Consumer, Environmental and Economist Perspectives
6. The Future of Electricity Resource Planning
7. The Future of Centrally Organized Electricity Markets
8. Regulatory Incentives and Disincentives for Utility Investments in Grid Modernization
9. Value-Added Electricity Services: New Roles for Utilities and Third-Party Providers.
10. *Forthcoming:* The Future of Transportation Electrification: Utility, Competitive Market and Consumer Perspectives

https://emp.lbl.gov/projects/feur

Appendix
Listing of 34 GMLC Projects with Bulk Power/Distribution Grid Aspect

GMLC Projects with Bulk Power/Distribution Grid Aspect -1

Project 2: Grid Architecture	Build a new stakeholder-driven architecture for grid modernization, provide it to the industry along with the tools they need to adapt it to their needs, and use it to inform the playbook for GMLC program managers.	PNNL, ANL, NREL, ORNL, LANL, LBNL, LLNL, SNL	GE-Alstom, Electric Power Research Institute (EPRI), GWU, United Technologies (UTC), Smart Grid Interoperability Panel (SGIP), Omnetric Group, California ISO
Project 3: Interoperability	This project provides strategic vision for interoperability endorsed by stakeholders with tools to measure interoperability maturity and the progress of related investments. It prioritizes interoperability gaps and develops an overarching roadmap for stakeholder endorsement.	PNNL, NREL, ANL, LBNL, SNL	SGIP, National Institute of Standards and Technology (NIST), GridWise Architecture Council (GWAC), EPRI, Standards Developing Organizations (SDOs).
Project 5: Grid Services and Technologies Valuation Framework	Develop a widely accepted, well-tested valuation methodological framework for evaluating the collection of value streams (net benefits) that can be provided by different grid-related technologies and services.	ORNL, PNNL, NREL, LBNL, ANL, SNL, LANL	TVA, Eastern Interconnection Planning Collaborative, NARUC/Eastern Interconnection States Planning Council
Project 6: Grid Sensing and Measurement Strategy	Identify measurement requirements along with associated data management and communication systems to enable full visibility of grid system state. This methodology will include defining the grid state, developing a roadmap along with a framework to determine sensor allocation for optimal results.	ORNL, PNNL, NETL, LLNL, ANL, NREL, SNL, LBNL, LANL	EPRI, Southern Co, Electric Power Board of Chattanooga (EPB), Entergy, OSIsoft, Dominion, TVA, ComEd, North American SynchroPhasor Initiative (NASPI)
Project 7: Southeast Consortium	Identify measurement requirements along with associated data management and communication systems to enable full visibility of grid system state. This methodology will include defining the grid state, developing a roadmap along with a framework to determine sensor allocation for optimal results.	ORNL, SRNL	University of Tennessee, EPB, Southern Company, TVA, UNC-Charlotte, Duke Energy, Santee Cooper, Clemson
Project 9: DER Siting and Optimization Tool for California	Deliver to stakeholders an integrated distributed resource planning and optimization platform, hosted online, able to identify meaningful behind-the-meter DER adoption patterns, potential microgrid sites and demand-side resources, and evaluate the impacts of high renewable penetration feeders on the distribution and transmission grid.	ANL, BNL, LBNL, LLNL, NREL, SLAC	California PUC, Pacific Gas and Electric (PG&E), Southern California Edison (SCE), Metropolitan Council of Governments, New York State Energy Research and Development Authority (NYSERDA)

GMLC Projects with Bulk Power/Distribution Grid Aspect - 2

Project 15: Grid Frequency Support from Distributed Inverter-Based Resources in Hawaii	Develop, simulate, validate, and deploy practical solutions in Hawaii that enable distributed energy resources (DERs) to help mitigate bulk system frequency contingency events on the fastest time scale (milliseconds to seconds). Validate the ability of real hardware inverters to support grid frequency in an environment that emulates the dynamics of a HECO power system.	NREL, SNL	Hawaiian Electric Companies, Enphase Energy, Fronius USA, Forum on Inverter Grid Integration issues, Energy Excelerator	$1M proposed over two years
Project 18: Definitions, Standards and Test Procedures for Grid Services	Enable and spur the deployment of a broad range of distributed energy resource (DER) devices by defining a test protocol to characterize their ability to respond to grid signals and define a standard set of grid services and "drive cycles" to describe the capabilities that DERs must have to provide them.	PNNL, NREL, ORNL, SNL, LBNL, ANL, INL, LLNL	Independent Test Labs, EPRI, Standards Organizations, Utilities, Vendors	
Project 19: Advanced Sensor Development	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.	ORNL, PNNL, NETL, NREL, SNL, LBNL	EPRI, University of Tennessee, Southern Co, EPB, Entergy, Eaton, SmartSense, National Instruments, Dominion, TVA, CommEd, NASPI	
Project 20: Integrated Multi Scale Data Analytics and Machine Learning for the Grid	Develop a low cost scalable infrastructure for integrating disparate high fidelity data sources. Machine learning methodologies will be used to assist in transforming data into actionable intelligence. This platform will allow multiple entities to collaborate on data utilization.	LANL, SNL, LBNL, ORNL, NREL, ANL	OSIsoft, National Instruments	
Project 21: Control Theory	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 theory effort will recognize the need to engage legacy control concepts and systems as we transition to more distributed control.	LANL, PNNL, ANL, INL, NREL, SNL, LLNL	Oncor, PJM Interconnection, United Technologies Research Center	
Project 22: Multi-Scale Integration of Control Systems (EMS/DMS/BMS)	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.	ANL, BNL, LANL, LLNL, NREL, PNNL, SNL	Alstom Grid, Duke Energy, PJM	

GMLC Projects with Bulk Power/Distribution Grid Aspect - 3

Project 23: Development of Integrated Transmission, Distribution, and Communication (TDC) Models	Build on best-in-class Lab capabilities to develop an integrated, flexible, open source framework for coupling TDC models and simulations. Validate framework and models on hardware testbed. Demos with partners will include distributed /wide area controls and DER.	PNNL, LLNL, NREL, ANL, ORNL, SNL, INL	SCE, National Grid, PJM, Peak Reliability, NRECA, CAISO, NYISO, ERCOT
Project 28: Development and Deployment of Multi-Scale Production Cost Models	Develop ability to more accurately estimate economic impact of renewables, storage, and other technologies. Research scalable methods for deterministic and stochastic PCM, higher resolution grid models, applications of uncertainty quantification and high performance computing (HPC). New capabilities will be deployed with system planners through PCM workshops.	NREL, SNL, ANL, PNNL, LLNL	MISO, Energy Exemplar, PJM Interconnect, NRECA
Project 29: Future Electric Utility Regulation	Provide technical assistance and policy analysis to state PUCs considering incremental and fundamental changes to electric utility regulation; enhance utility financial analysis modeling tools focused on ratemaking and regulatory issues that arise with increased penetration of DER.	LBNL, NREL, PNNL, SNL, LANL, NETL	National Association of Regulatory Utility Commissioners
Project 1: Virtual Batteries	Develop a characterization methodology to quantify the capacity/availability of virtual storage resources through transactive control of building loads to deliver grid and other transactive services. This work will be conducted in coordination with OE, ARPA-E, and PNNL's Control of Complex Systems Initiative (PNNL LDRD funded).	PNNL	University of Florida, TVA, BPA, and (potentially) UTRC.
Project 3: Economic Dispatch	Design, develop, and field a multi-purpose transactive controller and associated open source algorithms that will ensure real time optimal operation of building equipment, increase electric grid reliability, and lead to the goal of clean, efficient, reliable and affordable next generation buildings and energy systems.	PNNL	
Project 5: Hybrid Inverter	Develop universal transactive driver interface for the Volttron platform to enable near real-time control of DER-based, community scaled power electric.	ORNL	
Project 6: Connected Loads	Develop whole-building transactive, supervisory load control and fault detection and diagnostics for improving the energy efficiency, reducing peak demand, and enabling grid responsive loads.	ORNL	Southern Company, Emerson Climate Technologies

GMLC Projects with Bulk Power/Distribution Grid Aspect - 3

Project 2: Integrated Systems Modeling of the Interactions between Stationary Hydrogen, Vehicle, and Grid Resources	The goal of this project is to establish the available capacity, value, and impacts of interconnecting hydrogen infrastructure and fuel cell electric vehicles to the electric grid. The first objective is to quantify the opportunity of utilizing flexibility from hydrogen systems to support the grid. The second objective is to develop and implement methods to assess optimal system configuration and operating strategy for grid-integrated hydrogen systems. Data products (e.g., equipment costs, market data, vehicle operation and fueling data) will be available for release to help establish a benchmark for future work.	LBNL, NREL, INL	
Project 5: Dynamic Building Load Control to Facilitate High Penetration of Solar Photovoltaic Generation	Responsive loads that can be controlled temporally and spatially to minimize difference between demand and PV production to minimize voltage variation and reduce two-way power flow. Develop models and perform system-level simulation; Model-based control design to generate control software; Controller and communication network development; Unit-level and system-level testing; Field Testing	ORNL	Southern Company, University of Tennessee, Georgia Tech
Project 7: Secure, Scalable, Stable Control and Communication for Distributed PV	The goal of this effort is to develop a distributed control and communications architecture that refines the SunShot Systems Integration communications target metrics by clearly articulating the impact of each metric on the grid. Depending on the application, some metrics may be relaxed significantly, resulting in significant cost savings. For other applications, the metrics may not be sufficient to maintain or improve the stability and security of the power grid with very high penetrations of PV generation (e.g., 2030).	SNL	Montana Tech University
Project 8: Opportunistic Hybrid Communications Systems for Distributed PV Coordination	The objective of the proposed research is a full-scale, operational implementation of the opportunistic hybrid communication system. The system is considered hybrid because it utilizes different communications pathways, such as SCADA systems, satellite communications, and powerline communications. It is opportunistic in that it chooses to route messages through each of these systems based on recent data about latency and availability to ensure reliable message passing. From a PV perspective, the research will allow the current gaps in knowledge on grid performance, phrased in terms of reliability, scalability, interoperability, flexibility, and security, to be filled with measured data from PV systems and other monitoring points in the power system and with robust inferences from state estimation algorithms.	NREL	

GMLC Projects with Bulk Power/Distribution Grid Aspect - 4

Project 10: Frequency Response Assessment and Improvement of Three Major North American Interconnections due to high penetrations of Photovoltaic Generation	Directly addressing the reduced system inertia and frequency response challenge under high (60-90%) solar penetration for all three major grids (WECC, ERCOT, and EI). Technical Approach: 1) Dynamic simulations using power grid models and best-estimated high PV penetration scenarios, 2) Develop grid-support inverter control.	ORNL, NREL	University of Tennessee, GE, NREL
Project 11: Rapid QSTS Simulations for High-Resolution Comprehensive Assessment of Distributed PV Impacts	Goal: Development new and innovative methods for rapid QSTS Simulations to assess Distributed PV impacts accurately. Objective 1: Reduce the computational time and complexity of QSTS analysis to achieve year-long time series solutions that can be run in less than 5 minutes at a time step of 1 second. Objective 2: Develop high-resolution proxy data sets that will be statistically representative of existing measured load and PV plant data and will provide an accurate representation of PV impacts. Objective 3: Improve both the time and accuracy of QSTS analysis in order to make it the industry-preferred PV impact assessment method.	SNL, NREL	Georgia Tech, University of Pittsburgh, EPRI, CYME
Project 12: CyDER: A Cyber Physical Co-simulation Platform for Distributed Energy Resources in Smart Grids	Innovations: a) discrete-event co-simulation platform b) QSTS: Quasi-Static Time Series Co-simulation c) Real-time Data Acquisition for Predictive Analytics, d) FMI: Functional Mockup Interface, e) Ptolemey II: Cyberphysical simulation framework	LBNL, LLNL	SunEdison, ChargePoint
Project 13: An Integrated Tool for Improving Grid Performance and Reliability of Combined Transmission-Distribution with High Solar Penetration	To develop a software tool suite, comprising of three tools, for improving grid reliability and performance of combined transmission-distribution systems under high solar penetration, a) High-fidelity combined transmission-distribution steady-state analysis tool, b) Simultaneous transmission (T) and distribution system (D) dynamic and protection system analysis tool, and c) Distribution system state estimation (DSSE) with AMI, PMU, new sensors, and asynchronous updates.	ANL, RNEL	Illinois Institute of Technology (IIT), Electrocon International Inc., and McCoy Energy
Project 16: Stabilizing the Power System in 2035 and Beyond: Evolving from Grid-Following to Grid-Forming Distributed Inverter Controllers	The aim of the proposed project is to develop distributed inverter controllers which provide a low-resistance path from the current inertia-dominated grid paradigm to a future grid paradigm dominated by low-inertia power systems with 100's of GWs of PV integration.	NREL	UC Santa Barbara, University of Minnesota, Arduino, SunPower, HECO, Schneider

GMLC Projects with Bulk Power/Distribution Grid Aspect - 5

Project 1: Vehicle to Building Integration Pathway	The Vehicle to Building Integration Pathway project will develop and demonstrate pre-normative methods needed to develop a standardized and interoperable communication pathway and control system architecture between Plug-in Electric Vehicles (PEVs), Electric Vehicle Support Equipment (EVSE) and Building/Campus Energy Management Systems (BEMSs) to enable the integration of clean variable renewable sources with workplace PEV charging infrastructure to promote greater PEV adoption. This communications and control platform will provide access to real-time system monitoring information, establish an infrastructure to coordinate intelligent assets, manage energy consumption behind the meter, reduce peak demand charges resulting from vehicle charging, and potentially participate in energy and/or ancillary services markets.	ANL, INL, LBNL, NREL, PNNL	AeroVironment, Bonneville Power Administration, University of Delaware, DTE Energy
Project 2: Systems Research Supporting Standards and Interoperability	The objective of the proposed project is to address the considerable uncertainty regarding the degree to which PEVs can provide grid services and mutually benefit the electric utilities, PEV owners, and auto manufacturers. How can the potential benefits be unlocked without negative unintended consequences? This project will answer this question by leveraging capabilities of multiple national laboratories with vehicle/grid integration (VGI) to perform hardware-in-the-loop (HIL) studies that integrate communication and control system hardware with simulation and analysis activities.	ANL, INL, LBNL, NREL, ORNL, PNNL	Bonneville Power Administration, DTE Energy, Eversource, University of Delaware, Siemens, California Energy Commission, USDRIVE Grid Interaction Technical Team
Project 3: Modeling and Control Software to Support V2G Integration	Determining the feasibility of VGI by quantifying the potential value, cost, complexity, and risks in different implementations of VGI. Allocating available value among stakeholders and determining pathways for electrification of transportation to enable beneficial grid services such as mitigating renewables intermittency.	ANL, INL, NREL, LBNL, ORNL, PNNL	Bonneville Power Administration, California Energy Commission
Project 4: Diagnostic Security Modules for Electric Vehicles to Building Integration	The overall goal of this project is to develop a Diagnostic Security Module (DSM) framework for creating an end-to-end security architecture for the integration of modern Plug-in Electric Vehicle (PEV) with Electric Vehicle Supply Equipment (EVSE) and a BEMS.	INL, ANL, NREL, PNNL	University of Louisiana-Lafayette, ChargePoint, California Energy Commission

GMLC Projects with Bulk Power/Distribution Grid Aspect - 6

Project 5: Understanding the Role of Short-Term Energy Storage and Large Motor Loads for Active Power Controls by Wind Power	The goal of this effort is to develop and test coordinated controls of active power by wind generation, short term energy storage, and large industrial motor drives for providing various types of ancillary services to the grid and minimizing loading impacts and thereby reducing operation and maintenance costs (O&M) and subsequently the cost of energy (COE) generated by wind power. This work will utilize the $30M multi-year DOE investments and unique characteristics of NREL's existing NWTC test site including a combination of multi-MW utility scale wind turbine generators, variable-frequency motor drives (VFD), new 8 MW energy storage testing facility, 1 MW solar PV array, and 7 MVA Controllable Grid Interface (CGI). This combination of technologies allows for the optimization, testing and demonstration of various types of active power controls (APC) by wind power in coordination with other generation sources (including regenerative loads) and energy storage that allows enhancing or, in some cases, substituting the APC services by wind power and reducing impacts on wind turbine component life and thus increasing the availability and reliability of the power supply from wind.	INL, NREL	Clemson University, GE Energy Consulting
Project 1: Open-Source High-Fidelity Aggregate Composite Load Models of Emerging Load Behaviors for Large-Scale Analysis	This work proposes to develop a set of regional-level, scalable open source load models and tools, including large scale aggregate load protection, price responsive demand, advanced load composition data, and next generation load model data tools. The resulting improvements will significantly enhance the regional level power grid's overall stability and reliability	PNNL, LBNL	WECC, MVWG, LMTF, Southern California Edison, BPA
Project 3: Measurement-Based Hierarchical Framework for Time-Varying Stochastic Load Modeling	Leverage practical AMI, SCADA, PMU and laboratory experiment data to develop static, dynamic as well as customer behavior-driven and demand response-enabled load/DG models at component, customer, feeder and substation levels. The developed hierarchical load/DG models will facilitate the development of planning models and integrated transmission and distribution models (Topic 4). Successful completion of this project will deliver a set of load/DG models and commercially-available software tools (PSS/E, CYME, RTDS/OPAL-RT) with the developed models.	ANL	Iowa Energy Center, Siemens, Eaton, ComEd, Alliant Energy, MidAmerican Energy, ERCOT, PJM, City of Ames, Cedar Falls Utilities, Iowa State University, ISU's Electric Power Research Center

Total of 34 projects