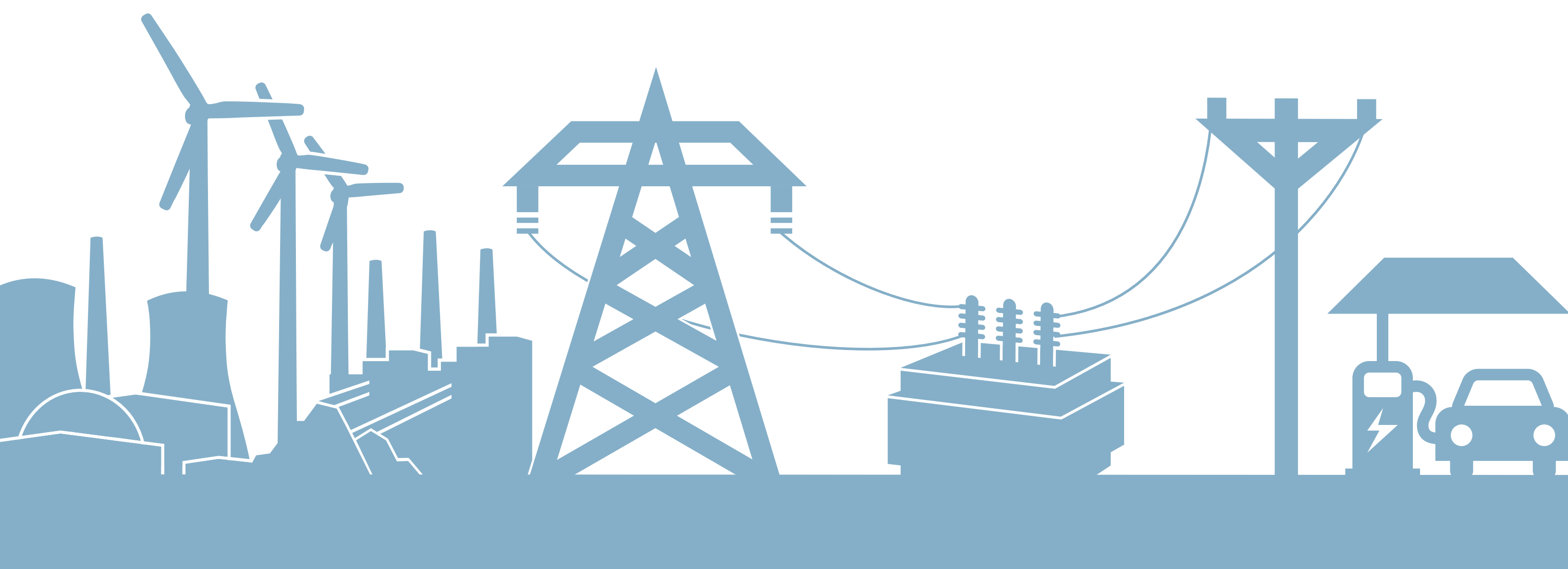
2017 Grid Modernization Peer Review Report

Foundational Projects and Technical Area Portfolio Review



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Chairs' Letter

Dear Colleagues,

The Grid Modernization Initiative (GMI) coordinates activities with offices and programs across the United States Department of Energy (DOE) with the goal of developing the tools and technologies that measure, analyze, predict, protect, and control the grid of the future.

As part of the GMI, the Grid Modernization Laboratory Consortium (GMLC) strives to streamline and optimize collaborative efforts with the national labs to modernize the nation's grid by bringing together leading experts, technologies, and resources. In January 2016, the DOE announced funding of up to $220 million over three years for the GMLC and its more than 100 strategic partners. Funding supports critical research and development in advanced storage systems, clean energy integration, standards and test procedures, and a number of other key grid modernization areas outlined in the Grid Modernization Multi-Year Program Plan (Grid Modernization MYPP). This effort also recognizes the need to balance regional perspective while defining and developing a coherent, national strategy.

On April 17-20, 2017, the DOE held its first annual Grid Modernization Peer Review. In addition to hearing from utilities, vendors, and state and local representatives on their vison of grid modernization over the next ten years as well as the challenges and opportunities associated with that vision, DOE formally peer reviewed thirty GMLC projects across six key technology areas. We believe in the importance of accountability and stewardship, and so we actively manage projects for outcomes and impact. The peer review process is an invaluable opportunity for external stakeholders to rigorously evaluate the technical approach, progress, relevance, and overall merit of all the projects in the GMI portfolio.

On behalf of the Department, we are pleased to announce the release of the 2017 Grid Modernization Initiative Peer Review Report. Projects are organized by the six technical areas, as defined in the Grid Modernization MYPP.

We would very much like to thank the sixteen reviewers representing industry, academia, nonprofit organizations, and government. These subject matter experts include some of the most experienced and knowledgeable professionals in the grid community. Results from this peer review were instrumental in providing guidance for programmatic decision making and will also impact future budget and funding opportunity decisions.

Thanks for your interest. See you next year!

William Parks
Chair, Grid Modernization Initiative

Kevin Lynn
Co-Chair, Grid Modernization Initiative

Acronym Guide

ADC	Aggregated Device Controller
ADMS	Advanced Distribution Management System
AMI	Advanced Metering Infrastructure
ARPA-e	Advanced Research Projects Agency – Energy
BMS	Building Management Systems
C2M2	Cybersecurity Capability Maturity Model
CAISO	California Independent System Operator
CEC	California Energy Commission
CSEISMIC	Complete System-Level Efficient and Interoperable Solution for Microgrid Integrated Controls
CIM	Common Information Model
DER	Distributed Energy Resource
DMS	Distribution Management Systems
DOE	Department of Energy
EMS	Energy Management Systems
EDP	Electric Distribution Planning
FINDER	FINancial Impacts of Distributed Energy Resources
FLISR	Fault Location, Isolation, and Service Restoration
GMI	Grid Modernization Initiative
GMLC	Grid Modernization Laboratory Consortium
GMLC-OL	Grid Modernization Laboratory Consortium Open Library
GMLC-TN	Grid Modernization Laboratory Consortium Testing Network
GRID MYPP	Grid Multi-Year Program Plan
GRID DATA	Generating Realistic Information for the Development of Distribution and Transmission Algorithms
GWAC	GridWise® Architecture Council
HECO	Hawaiian Electric Companies
HELICS	Hierarchical Engine for Large-Scale Infrastructure Co-Simulation
HVAC	Heating, ventilation and air conditioning
ICCP	Inter-Control Center Communications Protocol
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEEE DNP3	Institute of Electrical and Electronics Engineers Distributed Network Protocol
LG&E	Louisville Gas & Electric
NOLA	New Orleans, Louisiana
NESCOR	National Electric Sector Cybersecurity Organization Resource
PI	Principal Investigator
PCM	Production Cost Model
PFO	Power Flow Optimizers

PG&E	Pacific Gas and Electric
PMU	Phasor Measurement Units
PUC	Public Utility Commission
PV	Photovoltaic
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
TDC	Transmission, Distribution, and Communication
UNCC	University of North Carolina Charlotte
WECC	Western Electricity Coordinating Council

Introduction

In April 2017, the U.S. Department of Energy's (DOE's) Grid Modernization Initiative (GMI) conducted its first external peer review of the projects awarded to the GMLC to execute a diverse portfolio of technologies to modernize the nation's grid. The portfolio is organized into six technical pillars which reflect the DOE Grid Modernization Multi-Year Program Plan for as described below. The 2017 Project Peer Review took place April 18–21, 2017, outside of Washington, D.C., in Arlington, Virginia. Thirty Foundational Projects of the 87 publicly funded projects in the portfolio were evaluated. The entire portfolio was reviewed in the Poster Session on the first day.

Foundational Projects (Category 1) are larger, multi-lab, holistic cross-cutting projects that receive support from multiple DOE office and programs. Due to the cross-cutting nature of these topics and projects, the projects are closely coordinated by the GMLC. ***Program Office Specific Project***s (Category 2) address their Program Office specific requirements for grid modernization, not covered sufficiently well or specifically in the Foundational Platform Activity Topics.

The peer review process enables external stakeholders to provide feedback on the responsible use of taxpayer funding and develop recommendations for the most efficient and effective ways to accelerate the development of grid modernization technology in the industry and community. The planning and execution of these reviews were completed over the course of eight months, and this report includes the results of the peer review.

The six technology areas reviewed during the 2017 Project Peer Review are as follows (in alphabetical order):

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

A total of 30 projects across six technology areas were reviewed by a total of sixteen (16) external experts from industry, academia, other government agencies, and the non-profit sector. Each review panel developed overall recommendations regarding the focus, management, and impact of the projects in each technology area. In addition, a team of lead reviewers recommended overall guidance for GMI based on the peer review. Results of the 2017 Peer Review have been, and will be, used to help inform programmatic decision making, modify or discontinue existing projects, guide future funding opportunities, and support other budget and strategic planning objectives.

GMI Project Peer Review

The 2017 GMI Project Peer Review was implemented over the course of four days with two simultaneous review sessions of the 30 Foundational projects. Over the course of the Project Peer Review, participants also heard overview presentations on each technology area, as well as presentations on key crosscutting topics, security and resilience, devices at the edge of the grid, and the growing grid modernization support for institutions. This format brought together reviewers and GMI staff, program managers across 12 technology offices at DOE, 13 national laboratories with principal investigators (PIs), and other stakeholders along the grid modernization supply chain, which creates synergy across technology areas and enables the cross-fertilization of ideas and expertise, while providing for a more comprehensive review process.

Review Planning

Upon initiation of the review process, an internal GMI Peer Review Planning Committee was designated with the responsibility for coordinating all aspects of the review process, from initiation through completion. This internal group then identified and recruited peer reviewers to represent perspectives of academia, industry, the financial community, and end users. A team of support contractors from BCS Incorporated, AetherQuest Solutions, and Energetics provided overall planning support, built the reviewer evaluation system, facilitated development of report materials, and compiled and drafted the Peer Review Final Report.

Reviewers

The 2017 GMI Peer Review was completed by sixteen external experts from industry, academia, other government agencies, and the non-profit sector. Reviewers were selected on the basis of technical expertise and high-level qualifications in their designated technology area. Efforts were made to ensure balance within the review panel by including a mix of reviewers from the public, private, and university sector, with a range of expertise in the many sub-focus areas within each technology area.

Reviewers were also required to sign legal agreements stipulating an absence of a conflict of interest with the projects that they reviewed. Peer reviewer selections were made by the internal planning committee and GMI's Directors. Reviewers were asked to evaluate projects based on specific criteria.

All of the feedback from the reviewers help shape the focus, scope, and strategic direction of GMI's portfolio. Each reviewer examined projects in one or two technical areas, reviewing between 6 and 13 projects each. In addition to reviewing individual projects, the reviewers also participated in an open discussion about a technical area following the conclusion of project reviews in that technical area. Finally, reviewers conferred with their lead reviewer and discussed their overall thoughts and recommendations in their assigned technical areas.

Lead Reviewers

The GMI Peer Review Planning Committee chose a lead reviewer in each of the six technical areas to represent the overall portfolio thoughts and recommendations of all the reviewers assigned in each technical area. The lead reviewer compiled the input and presented their collective findings to GMI and DOE leadership on the last day of the review. In addition, the lead reviewers provided additional insight of how to overcome obstacles based on their expansive experience.

Evaluation Criteria

Reviewers were asked to evaluate projects based on specific criteria. The evaluation criteria (see Table A) and descriptions below served as the standard template for the evaluation of each project. Projects received scores and comments on the first five criteria described below, with the lowest score of 1 and the highest score of 10. The last criteria, *Overall Impressions*, were written responses and had no score. *Project Relevance* was not weighted in the overall score as the projects' scope, objectives, and goals were determined prior to the project commencing and should not reflect the overall score of the project performance.

Table A: Evaluation Criteria: Score and Weighting by Project

Criteria	Score	Weight
Project Relevance	1–10	0%
Approach	1–10	25%
Progress, Accomplishments, and Impact	1–10	50%
Project Integration and Collaboration	1–10	15%
Future Work	1–10	10%
Overall Impressions	No Score	No Weight

Project Relevance

Projects were evaluated on the degree to which they:

- Contribute to meeting the platform goals and objectives of the Grid Multi-Year Program Plan.
- Align relevantly to the Grid Modernization Initiative, Grid MYPP goals, and relevance for the overall grid industry.

Approach

Projects were evaluated based to which they:

- Describe the history, context, and high level objectives of the project effectively;
- Describe the technical and management approaches overall;
- Explain the approach including management approach, use of milestones for monitoring progress, and any unique aspects of the approach;
- Address critical success factors (technical, market, business) which define technical and commercial viability; and
- Discuss the top 2-3 potential challenges (technical and non-technical) to overcome in achieving successful project results.

Progress, Accomplishments, and Impact

Projects were evaluated on the degree to which they:

- Describe the progress made in meeting project objectives and following the project management plan;
- Describe the most important technical accomplishments achieved (from the last review to the present for sun-setting and existing projects, or progress to date for new projects);
- Benchmark the progress versus previously reported results from the GMI Program Review; and
- Benchmark the accomplishments against the technical targets (if applicable).

Project Integration and Collaboration

Projects were evaluated on the degree to which they:

- Demonstrate how the project is working with other GMLC projects, noting any enhanced work in which this project has helped other projects; and
- Demonstrate how the project is working with other grid work outside of GMLC projects.

Future Work

Projects were evaluated on the degree to which they:

- Explain what it is the plan to do through the end of the project with emphasis on the next 18 months;
- Highlight upcoming key milestones; and
- Address how any decision points during that time and any remaining issues.

Overall Impressions (Not Scored)

Reviewers were asked to provide an overall written assessment of the project based on the above criteria. No score is given in this criteria.

Reviewers' comments contained in this report represent only those comments provided in the Overall Impressions criterion. Reviewers' comments are summarized in each project section; however, a full, verbatim input of comments for each project are available upon request.

About the Grid Modernization Initiative

Why is Grid Modernization Important?

Access to electricity is so critical to a robust economy that the National Academy of Engineering states that electrification is the greatest engineering achievement of the 20th century. However, the grid of today does not have the attributes necessary to meet the demands and opportunities of tomorrow.

Five key trends challenging the capacity of the grid are driving this transformation:

1. Changing types and characteristics of electric generation;
2. Growing demands for a more resilient, reliable, and cyber secure grid;
3. Growing supply-side and demand-side opportunities for customers to participate in electricity markets;
4. Emerging electricity information and control systems; and
5. An aging electricity infrastructure.

Efforts to meet those challenges and further modernize the grid may result in new opportunities in efficient energy utilization, economic growth, and, ultimately, the protection and well-being of our citizens. By encouraging innovation and early stage development, the federal government can help the United States overcome the uncertainties of the power sector and lead to greater reliability, resiliency, affordability, and security. The federal government is in a unique position to work with states, industry, and other stakeholders to help enable grid modernization and to invest in these efforts through research and development, analysis, and outreach.

Grid Modernization Initiative

In June 2014, after years to convening, consulting, and planning, the U.S. Department of Energy (DOE) established the Grid Modernization Initiative (GMI) to develop a holistic vision for grid modernization across the department. GMI represents a comprehensive partnership among DOE, the national laboratories, industry, and stakeholders to accelerate the development of technology, modeling analysis, tools, and frameworks, helping to enable grid modernization adoption across the United States. Primary funding support comes from DOE's Offices of Electricity Delivery and Energy Reliability (OE), Energy Efficiency and Renewable Energy (EERE), and Energy Policy and Systems Analysis (EPSA). These offices, along with the national laboratories, implement GMI projects.

GMI also works closely with external public private partnerships, including more than 100 companies, utilities, research organizations, state regulators, and regional grid operators. A large indicator of the initiative's success is measured through the implementation of its projects via its partners.

The Grid Modernization Initiative's vision is the following:

The future grid will solve the challenges of seamlessly integrating conventional and renewable sources, storage, and central and distributed generation. It will provide a critical platform for U.S. prosperity, competitiveness, and innovation in a global clean energy economy. It will deliver ***resilient, reliable, secure, affordable flexible, and sustainable*** *electricity to consumers where they want it, when they want it, how they want it.*

The traditional grid architecture is based on large-scale generation remotely located from consumers, hierarchical control structures with minimal feedback, limited energy storage, and passive loads. A modern grid must have:

- Greater *resilience* to hazards of all type;
- Improved *reliability* for everyday operations;
- Enhanced *security* from an increasing and evolving number of threats;
- Additional *affordability* to maintain our economic prosperity;
- Superior *flexibility* to respond to the variability and uncertainty of conditions at one or more timescales, including a range of energy futures; and
- Increased *sustainability* through additional clean energy and energy-efficient resources.

In partnership with the Grid Modernization Laboratory Consortium (GMLC), in 2016, DOE released a detailed blueprint for modernizing the grid, the Grid Modernization Multi-Year Program Plan, which identifies six main technical thrusts:

- **Design and Planning Tools:** Develop the next generation of tools focused on three areas: economic assessment tools required for policy analysis, expansion planning, and day-ahead planning; reliability and resilience tools for design and engineering energy delivery in a resilient and secure manner; and computational technologies and infrastructure required to produce detailed and accurate answers and vastly extend the computational power available for analysis.
- **Devices and Integrated Systems:** Develop devices and integrated systems, coordinate integration standards and test procedures, and evaluate the grid characteristics of both individual devices and integrated systems to provide grid-friendly energy services at a variety of scales.
- **Institutional Support:** Inform and support high priority grid modernization challenges and needs identified by electric power industry stakeholders, with particular emphasis on state policymakers and regional planning organizations. Support an over-arching stream 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.
- **Security and Resilience:** Improve the resilience of the electric sector by developing physical and cybersecurity solutions; analyze criticality and assess impacts to minimize risk; provide solutions for

supply chain risks (specifically for transformers); and provide situational awareness/incident support during energy-related emergencies.

- **Sensing and Measurements:** Develop tools and strategies to determine the type, number, and placement of sensors on distribution grids to provide operators the visibility for specific utilities and feeders. This will include advanced methods to determine system states not directly accessible by measurement and estimation methods for broad grid visibility. Develop frameworks to integrate sensors into grid systems for solar irradiance, forecasting, and market data, and data from interfacing infrastructures such as electrified transportation.
- **System Operations, Power Flow, and Control:** Develop future grid architectures to inform development of new operations and control concepts, and improved analytics and computation for grid operations and control. Develop power flow controllers that will permit fine adjustment of power flow and multi-directional flow as well as flow control devices that can optimize transmission flows.

Grid Modernization Lab Consortium

DOE formed GMLC to better utilize expertise and insight of individuals across the department's national laboratories. GMLC is a strategic partnership that brings together leading experts and resources across thirteen national laboratories to collaborate on grid modernization projects. This new, crosscutting approach ensures that DOE's research and development investments and capabilities are coordinated efficiently and synergistically. GMLC also supports DOE by consolidating resources, identifying gaps, updating the Grid Modernization Multi-Year Program Plan (Grid MYPP), and providing regional breadth.

Grid Modernization Lab Call

In 2016, DOE announced the Grid Modernization Lab Call, a comprehensive $220 million, three-year plan to mobilize eighty-eight projects across the country that bring together more than one hundred companies, utilities, research organizations, state regulators, and regional grid operators. GMLC and its partners execute the robust lab call. The GMI team is also involved with many other grid-related funding opportunities at DOE.

Grid Modernization Multi-Year Program Plan

Through the Grid MYPP, DOE looks to coordinate a portfolio of activities to help set the nation on a cost-effective path to a resilient, secure, sustainable, and reliable grid that is flexible enough to provide an array of emerging services while remaining affordable to consumers.

Written in late 2015, the Grid MYPP defined a vision for the modern grid and identified key challenges and opportunities for the future. The direction and priorities outlined in by the Grid MYPP drew upon DOE's previous work, specific DOE program activities, continued emphasis on public-private partnerships. The overview descriptions of the six technical areas described throughout this report were formulated while writing the Grid MYPP, and the prospective research and development activities are focused on achievements targeted for completion by 2020.

Format of the Report

Information in this report has been compiled, as follows:

Peer Review Report Introduction: This section contains overview information on the peer review process, roles and responsibilities, review criteria, and GMI's portfolio.

Grid Modernization Chapter Information: This section contains overview information about grid modernization, the Grid Modernization Initiative, the Grid Modernization Laboratory Consortium, Grid Modernization Lab Call, and the Grid Modernization Multi-Year Program Plan

Technology Area Chapter Introductory Information: This section contains overview information for each technology area including background information, goals, and context for the projects reviewed within each technology area. A scoring chart, which includes the overall score for each project reviewed in the technical area, concludes this section.

Peer Review by Project Information: The project information contain approximately two pages which summarize the results of each project evaluated during the 2017 review process including the following elements: individual project information overviews final score charts, reviewer overall impressions summaries, and DOE Follow Up.

Information about each project includes:

- Project Title, Principal Investigator (PI), Project Run Time, and DOE Work Breakdown Structure (WBS) number for each project are listed. The WBS number for each project is for internal DOE classifying only and has no indication of project size, scope, or ranking.
- Project descriptions of all reviewed projects were compiled from the abstracts submitted by the PIs for each project. In most cases, abstracts were edited to fit within the space allotted.
- Scoring charts depict the average reviewer scores for each criterion.
- Reviewer overall comments represent the reviewer comments as provided in the overall impressions criteria response. Any word noted in quotations are exact words expressed by the reviewer.
- DOE follow up represent the responses and actions that the department will enact in the future in response to the reviewer comments.

Technology Area Portfolio Overview Panel Discussion: This section contains a summary of the discussion of the technology area with the panel of peer reviewers and the technology area lead which occurred after the review of the projects. Any word noted in quotations are exact words expressed by the reviewer.

Technology Area Review Lead Reviewer Portfolio Discussion: This section contains the summary of discussion led by the lead reviewer to DOE leadership the last day of the Peer Review. The discussion, compiled by the lead reviewer for each technology area, in consultation with the other reviewers, based on the results of a closeddoor, facilitated discussion following the conclusion of the technology area review, listed the strengths, weaknesses, and recommendations for improving the portfolio. Consensus among the reviewers was not required, and reviewers were asked to include differences of opinion and dissenting views. Any word noted in quotations are exact words expressed by the lead reviewer.

Technology Area Overviews and Peer Review Findings by Project

Design and Planning Tools Portfolio

About Design and Planning Tools

Today's design and planning tools for the electrical grid cannot handle uncertainty, even as they rely on simplifying the underlying physics of power systems and typically run on desktop personal computers or small servers. While more capabilities are added to these tools, they do not take advantage of modern computing techniques, and they will ultimately be unable to keep pace with the increasing complexity of the grid.

The *Design and Planning Tools* focus has three main activities designed to support innovation and advancements in these tools. Each activity has specific goals and target achievements to be completed by 2020.

Activity 1: Scaling Tools for Comprehensive Economic Assessments

Goal: Develop next-generation design and planning tools for economic assessments at all time scales—from day-ahead planning, to long-term procurement of infrastructure—with significantly higher spatial and temporal resolutions, integrated transmission system and distribution system modeling, lower modeling uncertainty, and reduced run times.

Target achievements:

- Expand stochastic production cost models from 100 to 10,000 transmission nodes—a factor of 100—and integrate distribution systems into the models.
- Develop easy-to-use decision support tools—enabling cost-benefit analyses of policies and regulations—based on complex high-performance computing analyses that incorporate new technologies such as demand response and energy storage.
- Scale up stochastic tools for modeling electric and gas system interdependencies—from 1,000 electric and 100 gas nodes today, to 60,000 electric and 1,000 gas nodes by 2020.

Activity 2: Developing and Adapting Tools for Improving Reliability and Resilience

Goal: Develop next-generation design and planning tools that will sufficiently address reliability and resilience as the grid becomes more complex. Some applications of these tools include ensuring fault tolerance, designing protection systems, diagnosing faults and blackouts, and assessing the impact of high-consequence events such as electromagnetic pulses, geomagnetic disturbances (generally caused by solar flares), and cyber or physical attacks.

Target achievements:

- Develop a scalable simulation framework that combines transmission, distribution, and communications systems for integrated modeling at the regional scale.

- Develop data-driven tools that automate the construction and validation of models of devices, loads, generation, and customer behavior— making it easier to build models of utility systems. Improve the performance of contingency analysis tools by a factor of 500 to capture extreme events and enable the automated analysis of cascading events.

Activity 3: Building Computational Technologies and High-Performance Computing Capabilities to Speed up Analyses

Goal: Employ advanced computing technologies to reduce the time for solving complex grid models, substantially extend the complexity and volume of scenarios analyzed, enhance the performance of existing tools, and provide data repositories for analysis and code development.

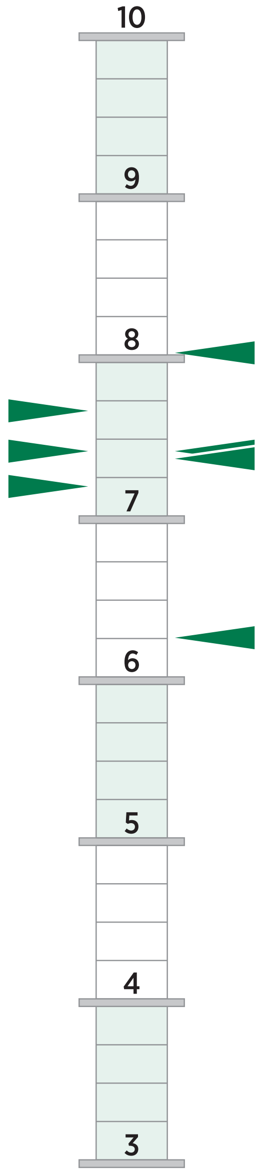
Target achievements:

- Establish five regional high-performance computing and data centers for grid modernization that include selected commercial grid software and grid datasets to support model development and validation and comprehensive policy analyses.
- Develop scalable math libraries and tools for enhanced analyses, as well as co-simulation frameworks to support the coupling of tools and models, the quantification of uncertainty, and the optimization of systems.
- Conduct six “prototype-to-practice” projects every year to drive industry adoption of these new tools.

Overall Scores

Of the 30 Foundational projects reviewed in the GMI Portfolio, seven projects were reviewed as part of the Design and Planning portfolio review. Projects were ranked on a 1-10 scale, with a "1" being the lowest possible score and a "10" being the highest score for a criteria. Reviewers provided ratings on each project's 1) project relevance to GMI's mission and goals, 2) approach, 3) progress, accomplishments, and impact, 4) integration and collaboration, and 5) next steps.

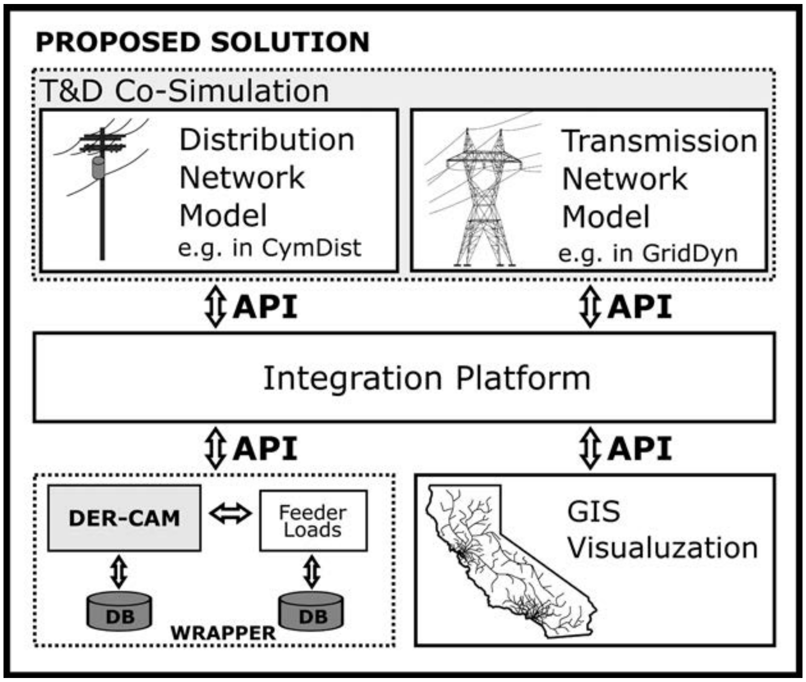
Project summary scores for Design and Planning are shown below. The arrows indicate project rankings.



Design and Planning Scores Range

DER Siting and Optimization Tool for California

WBS #:	1.3.05
Principal Investigator:	John Grosh
Project Run Time:	June 2016-September 2017



Proposed solution approach for the DER Siting and Optimization Tool for California.

Project Description

This project will deliver an integrated distributed resource planning and optimization platform, hosted online, to the California Public Utilities Commission, California Investor Owned Utilities, and other relevant stakeholders. The platform should be able to identify meaningful, behind-the-meter DER adoption patterns, potential microgrid sites, and demand-side resources, and it should evaluate the impacts of high renewable penetration feeders on the distribution and transmission grid.

The *DER Siting and Optimization Tool for California* project directly aligns with the Grid MYPP technical achievements by delivering a software solution to support statewide goals in California to integrate 15 GW of DERs, including 12 GW of renewable energy on distribution systems. It will complement the existing distribution resources plans developed by utilities in California by addressing key issues relevant to integrating demand-side resources. These issues include locational aspects, DER operational strategies, thermal benefits of DER and microgrids, and how customers' collective actions can contribute to optimize demand-side resources—making integrating demand-side resources more comprehensive than the existing distribution resources plans.

Reviewers' Overall Comments

Multiple reviewers agreed that, given the need in industry to better understand the quality, volume, and intensity of DER penetration on the distribution side, the project had potential and a good vision for approaches to DER siting in California. One reviewer noted, however, the project team needed to more clearly articulate how this project differed from previous efforts from Southern California Edison (SCE) and San Diego Gas & Electric (SDG&E) on the same topic. Reviewers agreed that co-simulation of transmission and distribution is important, but several felt that the applicability or scalability of the work outside California was not clearly defined. Other reviewers, however, noted that the project was a "perfect" fit for California given its renewable energy goals and approved of the project team's planned approach and understanding of the state's planning processes for distribution and transmission. One reviewer requested additional information from the project team on how local stakeholders (e.g., SCE, Pacific Gas and Electric (PG&E), California Independent System Operator (CAISO), and California Energy Commission (CEC)) are involved in the project.

Reviewers recommended the team consult with the expected user base of the tool and develop use cases to more clearly articulate how the tool will be utilized as well as identifying the intended audience for this product. One reviewer recommended the team dedicate additional time and effort into examining uncertainty on the customer side for DER installation, arguing that it is "crucial" to solve the handling of DER in the planning process. Another reviewer was concerned about the computing requirements of the project deliverables, specifically wondering if high-performance computing was required, which could limit project deliverable use in the field. Reviewers recommended the project team consider the Western Electricity Coordinating Council (WECC) base cases as the baseline and disaggregating and making fewer assumptions on the distribution network, as a less-detailed distribution model could decrease the credibility of the results.

DOE Follow up

As the project team concludes this project, the team should document how the work in this project, especially the approach and use cases, can be replicated or extended to other states and region.

Alaska Microgrid Partnership

WBS #:	1.3.21
Principal Investigator:	Ian-Baring Gould
Project Run Time:	March 2016-September 2017

Integrating intermittent resources into existing diesel systems, combined with fluctuating demand, can cause strain on the microgrid system if controls and hardware are not upgraded as well.

Project Description

Alaska faces unprecedented challenges in modernizing its rural energy infrastructure. Across the state, there are approximately 200 isolated microgrid systems that are not connected to larger grids, with most of these systems relying almost exclusively on imported fuel (primarily diesel) to meet electrical, space/water heating, and transportation requirements. These communities, whose populations range from 50 to 6,000 people, are primarily composed of native Alaskans, have some of the highest energy costs in the nation (up to 10 times the national average), arguably have the lowest power reliability, and are the least resilient, with impacts due to failure or supply disruptions often lasting days to months.

Because of their remoteness, microgrids are expensive to build and maintain, and the fuel imported into the communities is a high-priced commodity. It is a goal of many Alaskans to integrate renewable energy, efficiency, and storage into these microgrids—with the expectation that the new technologies will reduce a community's reliance on diesel fuel, while improving reliability and resiliency. Currently, about 40 communities have deployed a renewable system; however, there are still significant challenges to overcome. Integrating intermittent resources into existing diesel systems, combined with fluctuating demand, can cause strain on the microgrid system if controls and hardware are not upgraded as well. Often, energy storage or demand management systems can be deployed to smooth the sometimes abrupt changes in generation or demand, but this is frequently accompanied with higher initial costs and leads to more complicated operations and maintenance requirements. The purpose of the *Alaska Microgrid Partnership* project is to address these significant challenges and advance the development of the next generation of hybrid power systems for isolated communities. Outputs of this project include developing a process for reducing imported energy consumption by at least 50% in remote microgrids in Alaska, identifying investment opportunities, creating implementation methodology for other communities, and position two pilot communities to increase private and public funding.

The overarching goal of this project is to significantly reduce diesel fuel consumption in Alaska's remote microgrids while improving overall system affordability, reliability, security, and resilience.

Reviewers' Overall Comments

Reviewers were split on this project; several thought it was a good project, with a holistic approach, good milestones, and a "great" vision. Others, however, felt the project was "insufficiently ambitious," it lacked applicability outside of Alaska, and it did not feature any new innovations in design or planning tools. One reviewer noted that it was unclear how applicable findings would be to similar climate zones given "inadequate" details on collaboration with international stakeholders such as the World Bank, Millennium Challenge Corporation, United States Agency for International Development, and International Finance Corporation who might be able to take project findings to other communities in similar climate zones.

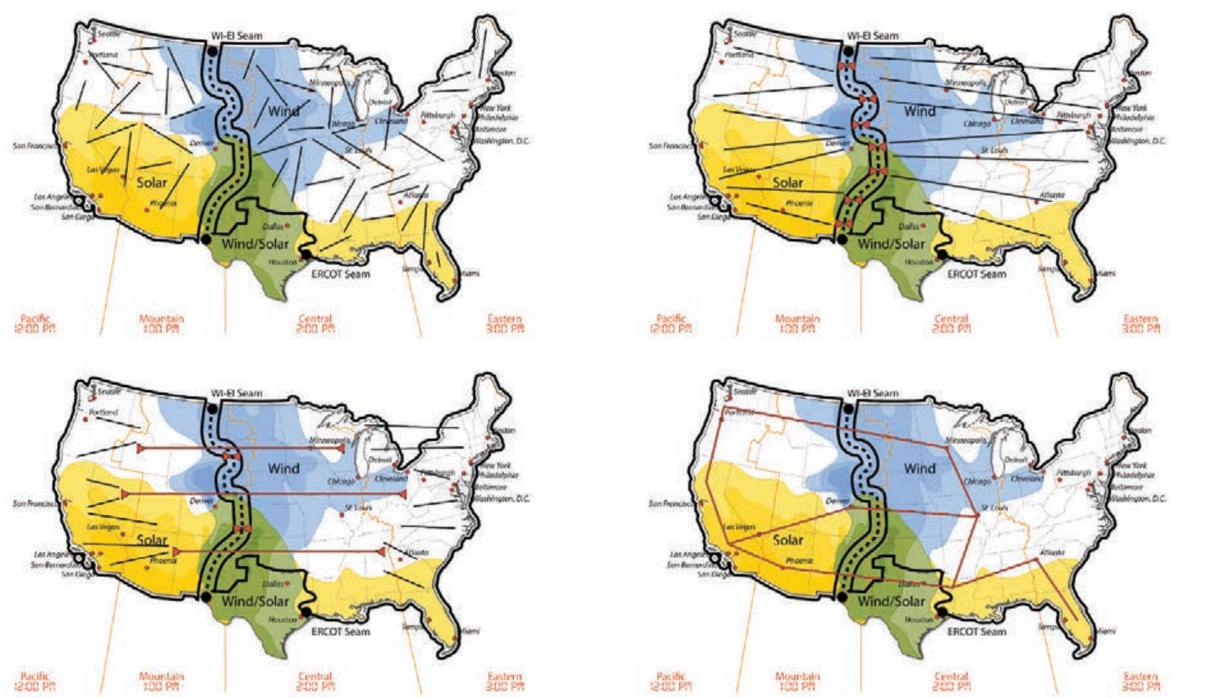
Several reviewer comments focused on the feasibility of the project's envisioned future funding models, recommending the team identify alternative future funding mechanisms. One reviewer noted that the team appeared to propose a model where the least profitable projects identified in the gap identification process of the "community readiness" stage would be addressed first with federal, state, or non-profit funding, and the private sector would come in later for more profitable project financing, which they said did not appear to be a viable or sustainable approach given the lack of details on how private-sector financing will occur.

DOE Follow Up

The project team should continue project scope as planned with the goal to ensure the project results are applicable to a broad range of communities both in Alaska and beyond.

Midwest Interconnection Seams Study

WBS #:	1.3.33
Principal Investigator:	Aaron Bloom
Project Run Time:	March 2016-October 2017



Conceptual representation of the four transmission futures in the United States.

Project Description

The central United States has an abundant amount of energy resources. Strong winds across the Great Plains, coupled with high-quality solar PV and concentrating solar power resources are close to new natural gas resources and growing electricity demand. Despite the regional abundance of diverse natural resources, there are three major seams in the U.S. power system that limit the nation's ability to maximize resource value and facilitate a more reliable, resilient, sustainable, and affordable U.S. electricity system.

Existing financial and operational practices already facilitate large-scale coordinated power system activities within the three U.S. interconnections. States allow considerable resource sharing across the Eastern Interconnection. However, despite the presence of transmission technologies that can facilitate long-distance energy transmission at low losses and existing high-voltage direct-current (HVDC) facilities located along current borders, very little electrical power is transferred between the interconnections. This hinders the efficient development of diverse generation resources in regions with rich natural gas, wind, and solar resources. Furthermore, a lack of transmission capacity across these seams inhibits the nation from balancing load patterns and managing weather events across the contiguous United States. The opportunity to more efficiently balance generation and load resources across the "seams" using a significant upgrade in transmission may be economically justifiable. The *Midwest Interconnection Seams Study* analyzes a range of transmission scenarios that aim to decrease the cost of serving U.S. electricity demand by facilitating more efficient transfers of electricity across the country.

Reviewers' Overall Comments

Reviewers were split on this project. Several thought it was a good project that was much needed, represented a public service thanks to its technical vision, and was an "excellent" demonstration of the tools and techniques previously developed under grid modernization programs. Others argued it did not use any innovative planning techniques or tools and lacked key details, including describing the problem to be solved and its importance, impact, and relevance. Specifically, one reviewer questioned why the study was using a production cost model to build the simulated HVDC lines, as the key challenges in building HVDC are cost, permitting, and timelines—factors that can't be modeled in production cost models. This reviewer requested additional information on cost allocation, detailed reliability analyses, and viable market impact reviews that are necessary for valid study conclusions.

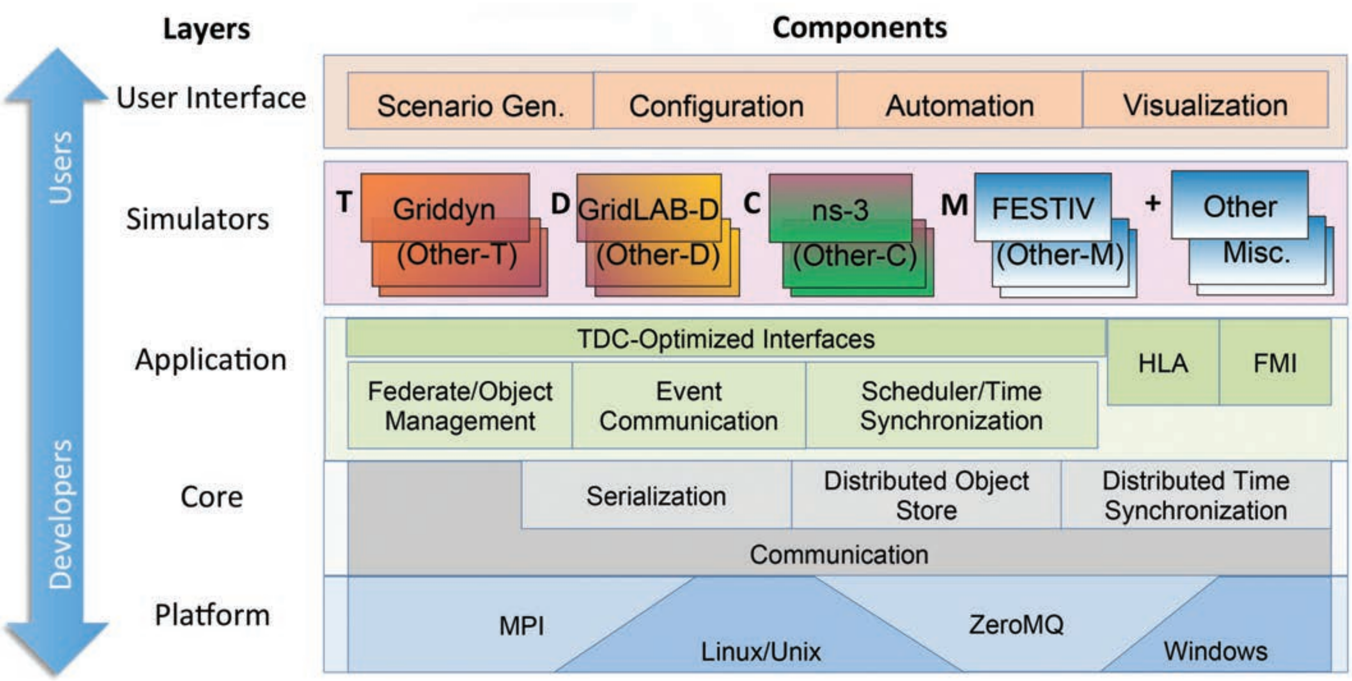
One reviewer recommended that validating next-generation best practices in grid planning was a necessary next step to encourage their use by grid planners in the private sector. Another reviewer recommended that the project team more clearly communicate the recommendations stemming from this study.

DOE Follow Up

Based on the feedback, the GMI team investigated the stakeholders' sentiment and relevance of this project. A project partner, Western Area Power Administration is eager to get the results of this project for planning purposes. Two other partners, Midcontinent Independent System Operator and Southwest Power Pool, are interested in continuing and building upon the work in this project. Issues such as permitting and construction timelines can be investigated in future efforts once the potential for economic benefits are established.

Development of Integrated Transmission, Distribution and Communication Models

WBS #:	1.4.15
Principal Investigator:	Henry Huang
Project Run Time:	April 2016-October 2018



HELICS (Hierarchical Engine for Large-scale Infrastructure Co-Simulation) platform is designed to be modular and flexible to future needs.

Project Description

Significant amounts of variable, and increasingly distributed generation, as well as other distributed resources, are expected to enter the U.S. electrical infrastructure. To operate the power system with a leaner reserve margin, distributed generation resources must play a role in maintaining—or improving—system resiliency and reliability. This requires new control and protection systems, along with supporting communication networks. However, currently industry lacks modeling and simulation capabilities to understand such transmission, distribution, and communication (TDC) interdependency. The *Development of Integrated Transmission Distribution and Communication Models* project will improve confidence in deploying systems that will meet, or exceed current reliability, efficiency, and cost-effective benchmarks.

To overcome this challenge, the project will create a flexible and scalable open-source, co-simulation framework to fill this gap. The project will integrate simulation models designed for separate TDC domains to simulate regional and interconnection-scale power system behaviors at unprecedented levels of detail and speed. The target is to model a 50,000-node transmission system with millions of distribution nodes, coupled with 100,000 communication points. This simulation should enable planning studies in a turnaround time of minutes to hours, instead of days with today's simulation technologies.

This comprehensive TDC simulation tool is fundamental for investment decision making by industry. It's also important to help quantify the impact of the ever-increasing, high-penetration variable generation on power grid reliability and resiliency.

Reviewers' Overall Comments

Reviewers agreed this was an appropriate and promising project that one said was at the "heart" of the GMLC effort, namely it addresses a major need within industry, and if it's successful, it could make a major impact on industry. Reviewers pointed to the need for new simulation technologies based on improved computing capabilities that would enable simulating a large grid to better plan to address the major issues facing the power industry today.

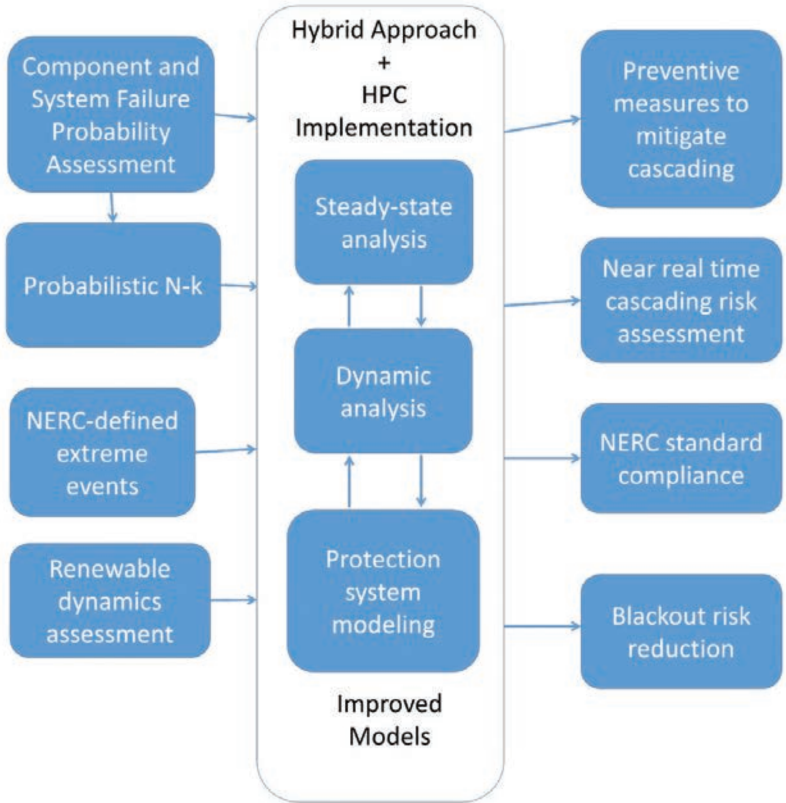
Reviewers agreed that the Hierarchical Engine for Large-Scale Infrastructure Co-Simulation (HELICS) could become a critical tool in TDC planning if it can demonstrate various risks between system components in current grid architectures. However, one reviewer recommended the project team conduct additional literature review on existing state-of-the-art TDC planning and simulation models and other industry efforts that are addressing TDC modeling challenges. Reviewers also wanted additional detail on how the HELICS platform interfaces with existing commercial software and on how the communications infrastructure is modeled within HELICS.

DOE Follow Up

The GMI team is pleased that the labs conducted due diligence prior to creating the HELICS tool. The project should continue as planned in Year 2.

Extreme Event Modeling

WBS #:	1.4.17
Principal Investigator:	Russell Bent
Project Run Time:	April 2016-April 2019



Process flow for modeling extreme events.

Project Description

Catastrophic situations, such Superstorm Sandy, Hurricane Katrina, and the 2003 Northeast blackout, pose an enormous threat to the nation's electric grid and the socioeconomic systems that depend on reliable delivery of power. Utilities are unable to adequately plan and prepare for such events, despite the economic costs and social hardships they cause.

One primary bottleneck that impedes progress for such planning and preparation is the ability to model extreme events. In this project, the project team addresses two key aspects of extreme events in energy: sequential component failure (cascading) and near simultaneous component failures (N-k contingencies). The team uses a novel combination of existing capabilities, high-performance computing, and new capabilities to improve the computational efficiency of models and simulations to address modeling inadequacies and to incorporate probabilistic approaches to deliver significant advances in extreme event modeling.

The *Extreme Event Modeling* project will deliver a prototype tool that simulates multiple component failures up to 500 times faster than existing approaches. Current tools are 10–100 times slower than real time—leaving planners with insufficient time to analyze and prepare for high-consequence events. This tool includes capabilities for probabilistic N-k, and executes from existing trusted commercial power software.

Reviewers' Overall Comments

Reviewers agreed that this project is ambitious and has a potentially large impact at targeting better capital investments that provide a reliable and resilient grid at a reasonable cost. One reviewer thought highly of the project team's metrics that will be used to measure the impact of the project upon completion. Another reviewer questioned the multiple sub-projects listed in the project's work plan, arguing that not all appeared to be relevant to extreme events and noting that efforts might be better spent focusing on one or two main tasks and developing products that can be used or built upon at the end of the project.

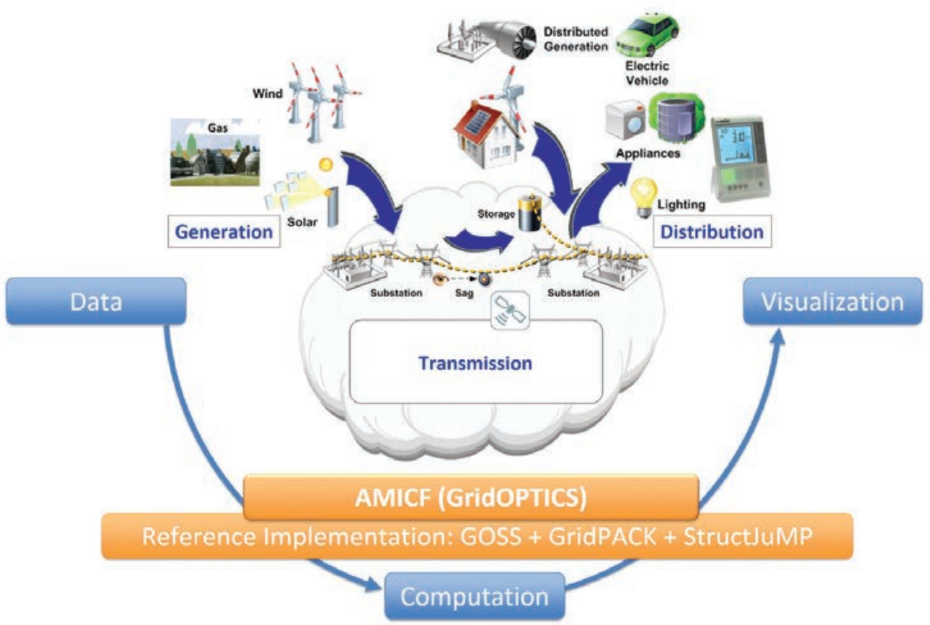
Reviewers recommended additional attention to the project's planned work, specifically focusing on how the project team will disseminate the tools and techniques they develop to industry stakeholders. One reviewer recommended that the project team spend additional time and effort on literature review of state-of-the-art research, especially in probabilistic cascade identification and model reduction, and the team consider the best improvements achievable over current practices. Another reviewer recommended that the project team spend additional time on the question of granularity—noting that the more granular the data, the more complex the model, and that the team needs to strike a good balance.

DOE Follow Up

While this is a very important effort, the team should focus on making a the project more focused and cohesive. Also, the team should add a dynamic power flow capability in the model.

Computational Science for Grid Management

WBS #:	1.4.18
Principal Investigator:	Mihai Anitescu
Project Run Time:	April 2016-March 2019



Complexity in grid and energy systems demands new computational framework and solvers.

Project Description

The power grid continues to increase in complexity, in good part by the growing use of DERs, for example, storage and solar power. Compounding this complexity are the vastly increased dynamics that these DER's introduce, as well as greater uncertainty surrounding supply and demand results when computationally modeling the integration of wind, storage, and solar power.

The *Computational Science for Grid Management* project helps to solve these challenges by developing and deploying new algorithms and solutions for grid optimization, uncertainty, and dynamics. Key to this effort is an advanced framework that allows prototyping computationally intense analyses 10 times faster, as well as open-source solutions that compute 100 times faster by harnessing parallelism. The project team is also identifying use cases where they can demonstrate the framework and solutions at scale.

The algorithms and solutions will be key to supporting efforts by utilities to assess renewable variability effects in operations and planning. They will also be important to helping DOE understand the effects of renewable energy variability on reliability in the power grid.

Reviewers’ Overall Comments

Reviewers called this project “exciting” and “important,” with a potential for significant impact in grid modernization. One reviewer argued that the project needs additional literature review and comparison to emerging state-of-the-art solutions for grid optimization.

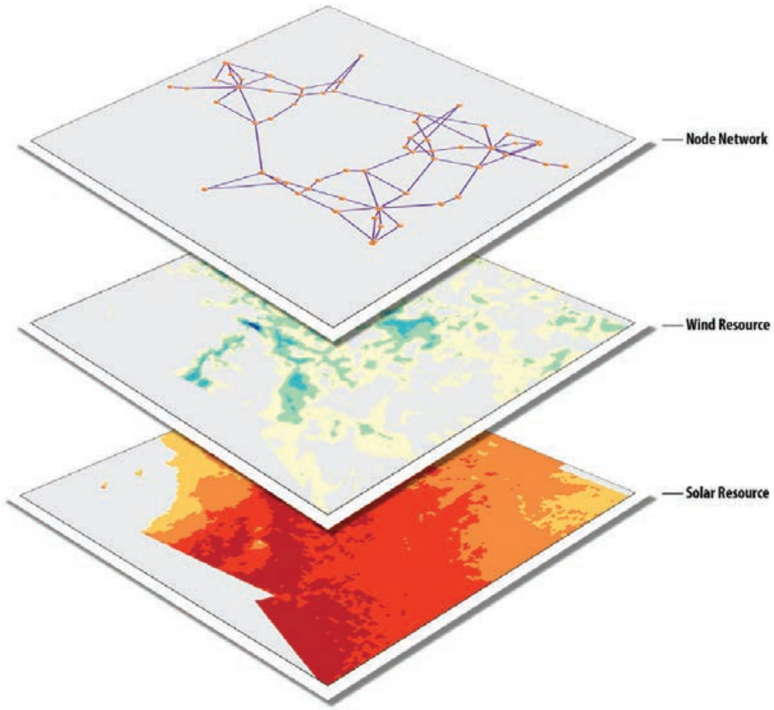
Reviewers appreciated the project’s successes to date in developing simulation technologies and recommended developing a plan to ensure that project deliverables become routinely used in academic and industry circles. Multiple reviewers recommended the project team continue to partner with industry and keep a focus on issues of scalability, such as reliability, accuracy, and impact on solve time. One reviewer suggested further trial work with actual vendor software to help demonstrate speed-up and robustness available from the project deliverable, while another recommended developing university power engineering course descriptions or modeling that could be tailored around using these tools.

DOE Follow Up

The GMI team will follow up with industry to see if there is interest to continue the project’s work, possibly with a partner, in the future. Additionally, elements of this work will continue through the Advanced Grid Modeling Program.

Development and Deployment of Multi-Scale Production Cost Models Devices and Integrated Systems

WBS #:	1.4.26
Principal Investigator:	Aaron Bloom
Project Run Time:	March 2016-October 2018



Computational tools will accelerate existing PCM simulations.

Project Description

The complexity and resolution required to model the modern power system is rapidly increasing. The widespread introduction of resources, such as wind and solar power, motivates the need to study both the impact of uncertainty in production and specific deployment scenarios. DERs, demand response, new bulk power generation, inter-sectoral dependencies, and evolving consumer preferences further contribute to the need to develop new production cost modeling (PCM) capabilities to address growing uncertainty and system complexity.

Many power system planners and reliability coordinators have indicated that to plan for the rapidly changing electricity system, they must be able to simulate a broad range of highly detailed power system scenarios. Traditionally, planners and coordinators have been forced to choose between conflicting goals when performing (PCM)-based analyses: model fidelity, the ability to address uncertainty, and execution time. Reducing model resolution and/or ignoring uncertainty, in turn, detrimentally impact the relevance of the simulations, but decrease execution time. Similarly, long execution times limit the number of scenarios that planners and reliability coordinators can analyze.

The *Development and Deployment of Multi-Scale Production Cost Models Devices and Integrated Systems* project is working to reduce the time required by industry to analyze future power system scenarios through PCM, while considering higher-fidelity representations of the underlying systems. By developing and leveraging advanced computational tools and delivering the tools and expertise through industry outreach, the project team is introducing significant acceleration of existing PCM simulations, as well as demonstrating and deploying the tools to address uncertainty associated with high renewables penetrations.

Reviewers' Overall Comments

Most reviewers scored this project highly, calling it a "great success" and a "good" project to ensure more accuracy in legacy tools, which one reviewer argued accuracy is a major concern given the relatively few commercial tools in use by industry, and "anything" this project could do would be impact. Another reviewer, however, was unclear on the benefits and potential impact of the project, arguing that it appeared to be a majority internal optimization effort to reduce simulation run time. The same reviewer wondered if the high-performance computing requirements could severely limit the model's widespread application. Additionally, it was pointed out that a key benefit of this model is the reduced production simulation run time; however, production cost simulation models are often not needed in a time-sensitive manner, so the benefits may be less than expected.

Reviewers recommended that the project team spend additional efforts developing a plan to deploy the capabilities, and that they develop or further build out data they provide to industry. Additionally, one reviewer recommended developing scenario use cases to aid with deployment. Another reviewer suggested that stochastic simulation could have benefits and that the team investigate what the impact from this project could be to that effort.

DOE Follow Up

The project team should continue project scope as planned.

Design and Planning Tools Portfolio Overview Discussion

After the project reviews, project principal investigators, DOE project staff, and interested stakeholders discussed the broader Design and Planning Portfolio. Design and Planning Tools Technical Lead John Grosh led the conversation.

The remarks made by Grosh served to differentiate between projects that are focused on specific GMI program objectives, and those that are more general. Grosh discussed the loose coordination that exists between the Foundational and the Program Office Specific projects as many of the principal investigators involved contribute to projects of each kind.

Grosh noted the diversity that exists among the various projects within the portfolio. He further commented that the portfolio contains projects that explore the transmission system, protection, cascading failures, linking interconnects, software developments, cross-domain explorations, grid-to-vehicle integration, and load modeling. Despite the diversity, Grosh explained that many projects saw common hurdles—including common issues around data sets and data access, non-disclosure agreements and data security, the potential for using a common data repository, strategies around releasing software, and the use of open-source development as a software strategy.

Following Grosh's remarks, the reviewers and other attendees participated in a robust dialogue addressing current efforts to provide data access to researchers and to commercialize software that has been developed using DOE support. Participants noted prior examples of successful commercialization, including Linux, GridLab-D, Homer, and a suite of tools for solar photovoltaic modeling.

It was noted that while the utility industry is large and complex, there are only a very few software vendors supporting the industry. Participants expressed that larger vendors were likely to incorporate new software features that were developed by researchers, as opposed to adopting an entire software package. It was also noted that the project portfolio would benefit from the results of the Advanced Research Projects Agency-Energy (ARPA-e) Generating Realistic Information for the Development of Distribution and Transmission Algorithms (GRID DATA) program.

Devices and Integrated System Testing Portfolio

About Devices and Integrated System Testing

Devices and systems on both sides of the electric meter can help the grid function more efficiently, manage variable generation, and be more resilient under adverse conditions.

The *Devices and Integrated System Testing* focus has four main activities designed to support innovation and advancements in these technologies. Each activity has specific goals and target achievements to be completed by 2020.

Activity 1: Develop Advanced Storage Systems, Power Electronics, and Devices

Goal: Increase electric grid flexibility, reliability, resiliency, and asset utilization by making step changes in the performance of grid-connected devices and technologies.

Target achievements:

- Develop power electronics-based converters for renewable, distributed energy and energy storage systems.
- Decrease the cost of grid-scale energy storage systems to less than $300/kWh by developing technology advancements and metrics for safety, reliability, and performance.
- Enable buildings, large building loads, and electric vehicle charging systems to regulate energy more effectively, including self-diagnosing performance, forecasting energy needs, characterizing available flexibility, and providing capacity, energy, and ancillary services to the grid.
- Develop grid infrastructure technologies—such as advanced switches, wires, cables, and transformers—that can improve the efficiency and reliability of the electric grid by 10%.

Activity 2: Develop Standards and Test Procedures

Goal: Work with standards development organizations to accelerate the development and validation of standards and test procedures for device interoperability, performance, and safety.

Target achievements:

- Update standards and test procedures that characterize the ability of devices to provide a full range of grid services.
- Develop standards and test procedures for microgrids, storage, and other systems.

Activity 3: Build Testing Capabilities / Test and Validate Devices

Goal: Develop a testing infrastructure and validate device performance in both the laboratory and the field using the developed standards and test procedures.

Target achievements:

- Provide testing facilities, establish frameworks, and manage component model libraries in collaboration with universities and industry groups.
- Develop methods to couple hardware-in-the-loop devices with advanced simulations and evaluate systems at a variety of scales.
- Characterize a wide variety of technologies to validate that individual devices can provide a range of grid services.

Activity 4: Test and Validate Integrated Systems at Multiple Scales

Goal: Ensure that integrated systems of devices and controls are able to connect, communicate, and operate in a coordinated fashion at multiple scales.

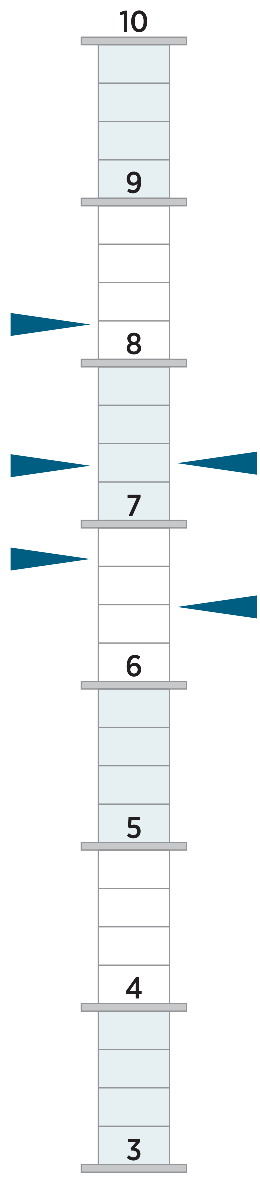
Target achievements:

- Validate multi-scale systems that enable 100% renewable energy integration at the local level and 35% at the bulk system level.
- Validate transactive control constructs that coordinate distributed generation, storage, and controllable loads to reduce reserve margins by 33%.
- Validate 10% outage reductions by using advanced distribution system configurations (including microgrids) and fault location, isolation, and service restoration (FLISR) systems.
- Conduct field demonstrations of energy storage, providing multiple grid services cost effectively.

Overall Scores

Of the 30 Foundational projects reviewed in the GMI Portfolio, five projects were reviewed as part of the Devices and Integrated Systems portfolio review. Projects were ranked on a 1-10 scale, with a "1" being the lowest possible score and a "10" being the highest score for a criteria. Reviewers provided ratings on each project's 1) project relevance to GMI's mission and goals, 2) approach, 3) progress, accomplishments, and impact, 4) integration and collaboration, and 5) next steps.

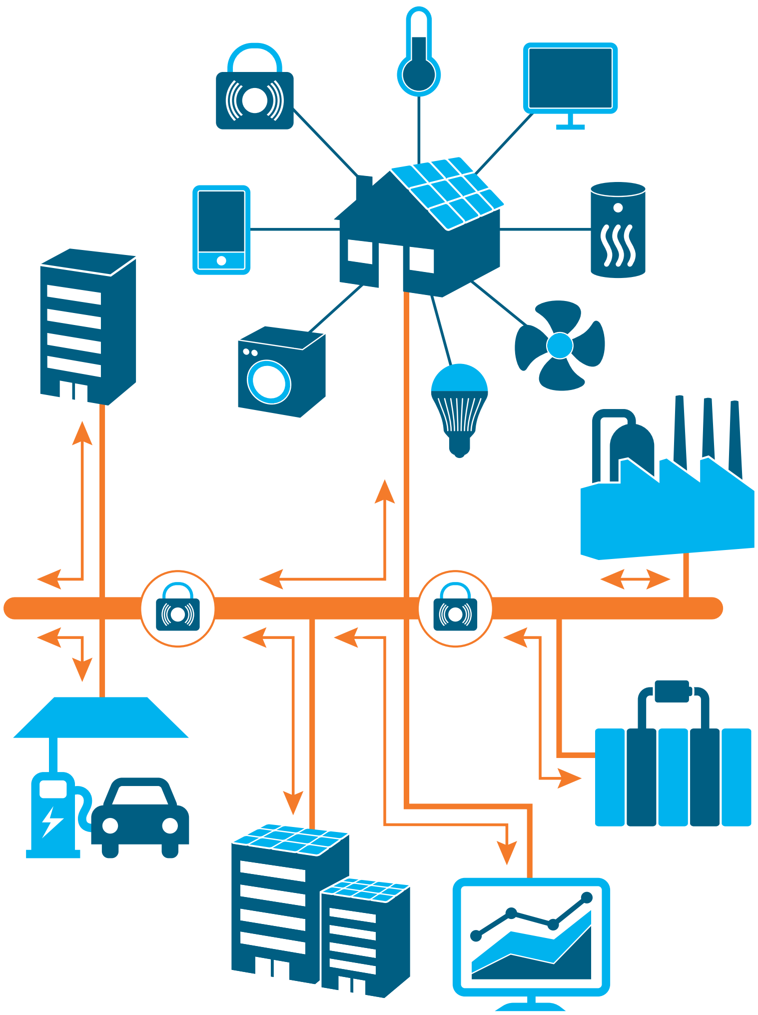
Project summary scores for Devices and Integrated Systems are shown below. The arrows indicate project rankings.



Devices and Integrated Systems Scores Range

Interoperability

WBS #:	1.2.2
Principal Investigator:	Steve Widergren
Project Run Time:	April 2016-March 2019



The increase of multiple devices and the Internet of Things create challenges for device interoperability on the grid.

Project Description

For efficient grid operation, the broader electricity industry must have access to general interoperability requirements, methodologies, and tools that simplify the integration, communication, and security between the many devices and systems on the grid. The project, *Interoperability*, will establish a strategic vision for devices and systems on the grid to exchange and use information.

Energy infrastructure should be flexible enough to accommodate changes in response to new, expected, or unexpected internal or external system drivers. The project team will collaborate with industry to articulate general interoperability requirements, as well as the methodologies and tools needed to simplify the integration and cyber-secure interaction among the various devices and systems that comprise the electric power grid. The work includes looking at related end-use systems such as buildings, electric vehicles, and distributed energy resources.

The ultimate goal of this project is to advance adoption of interoperable products and services in the energy sector, align stakeholders on a strategic vision, and develop measures and tools to support interoperability of devices and systems on the grid. Project outputs include reports, tools, and a path set for industry accepted standards of device and system interoperability on the grid.

Reviewers' Overall Comments

Reviewers were mixed on this project; several felt the overall objective was good, relevant, and a "key" foundational project for the GMLC that would inform the path towards meaningful interoperability. One reviewer agreed that the activity was important, but questioned what research and development needs the project is addressing. Reviewers gave the team's approach high marks and one noted that early progress had been made, pointing to the project's draft reports on Strategic Vision, Roadmap Methodology, and Interoperability Maturity Model. However, one reviewer worried there was inadequate consideration of risk mitigation from the project team.

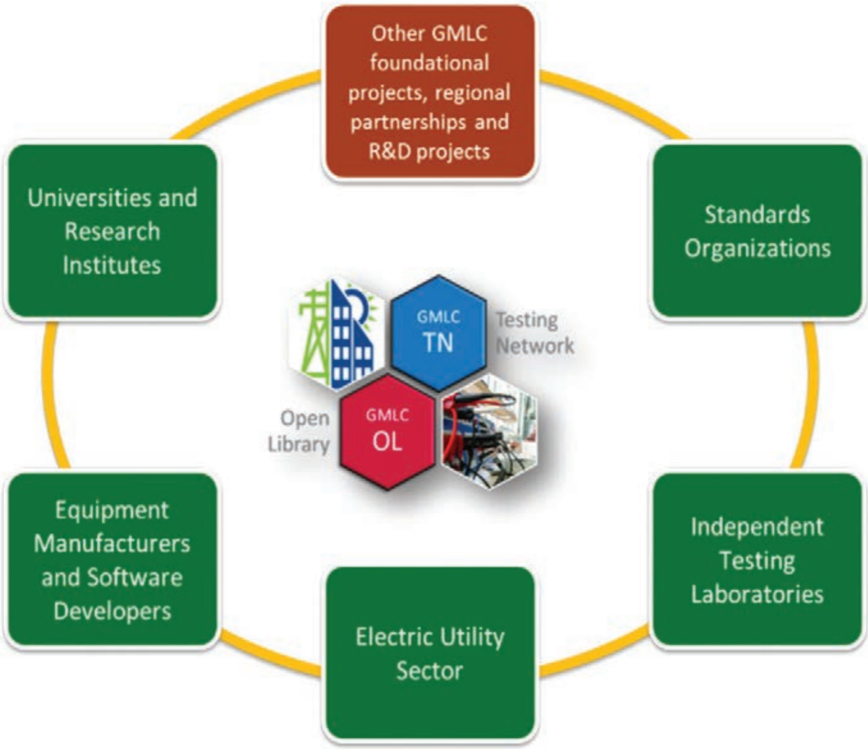
One reviewer recommended that the project team consider adopting a baseline measure for open standards and that the team identify metrics to measure progress to 2020. Several reviewers recommended increasing engagement with industry, with one noting the team did not adequately represent the vendor community or other implementing entities. One reviewer specifically pointed to the need to consider existing utility system integration protocols, as utilities and vendors will not adopt new interoperability protocols that require expensive integration with existing resources. Overall, these reviewers wanted to see a clearer use case for industry from project outcomes and have a clearer path for the implementation of interoperability rather than the team's commitment toward being interoperable.

DOE Follow Up

Continue project as planned by focusing finalizing the draft reports, working on tools, and setting path for industry accepted standards of grid device and system interoperability. The project team should focus on more stakeholder engagement as the success of this project is correlated to industry adoption of the recommended path proposed by this team.

Grid Modernization Laboratory Consortium (GMLC) Testing Network

WBS #:	1.2.3
Principal Investigator:	Matt Lave
Project Run Time:	April 2016-April 2018



The work in GMLC Testing Network and Open Library project will integrate and collaborate with multiple stakeholders.

Project Description

The *GMLC Testing Network* project closes the gap in accessibility to validated models for grid devices, simulation tools, and corresponding full documentation. Limited availability of test-related resources for interconnection and interoperability (procedures, scripts, and equipment specifications) is another gap that hinders the adoption of best testing practices and standards. Through concerted, facilitated industry engagement, this effort will drive standardizing and adopting best practices related to device characterization, model validation, and simulation capabilities.

Expected outcomes of this project include better accessibility to testing resources within the national laboratories, academia, and industry; better accessibility to grid-related validated models and simulation tools; and accelerated grid technology development, validation, standardization, and adoption.

This project will benefit consumers as well as U.S. industry engaged in grid modernization. Outputs of this project include a Grid Modernization Laboratory Consortium Testing Network (GMLC-TN) including a Grid Testing Network Catalog and a Grid Modernization Laboratory Consortium Open Library (GMLC-OL) bring to bear the best-in-class capabilities available at the national laboratories to accelerate grid modernization.

Reviewers' Overall Comments

Reviewers agreed that this project's approach to facilitate DOE's testing capabilities and modeling resources more accessible to stakeholders was valuable. Reviewers pointed to strong progress in documenting capabilities to date in the draft Testing Network Catalog and one argued that both the Open Library and Testing Network would be useful for GMLC projects in the future. Another reviewer liked the Network Catalog draft as a "simplified approach" for external users to access national laboratory facilities.

Several reviewers expressed reservations about the project's applicability to industry and other external stakeholders. One reviewer recommended that the project team think about the specific devices or applications that they will test and then catalog the capabilities required for that test. Industry, this reviewer argued, requires a total solution for a single device, not just testing for selected applications. Another reviewer expressed reservations that the project outcomes were developing new, networked capabilities, but rather lists of existing facilities and software packages that already exist.

One reviewer wanted additional details from the project team on the level of testing envisioned by the Testing Network—was it early stage, pilot level, deployment level, or some mixture of all three? Additionally, this reviewer wanted additional details on what documentation and instruction would accompany models within the Open Library to give users a better understanding of which models to use for specific queries or purposes. Another reviewer recommended the project team develop a management and communication plan for the Open Library that was informed by academic and industry stakeholders. In the future, this reviewer recommended bringing all partners contributing to the project together on an annual basis to discuss project objectives and future steps. A third reviewer recommended the team develop better project success metrics, specifically recommending the team consider the question "What level of industry participation is considered a success and how will be get there?" This, the reviewer argues, will help ensure that the project's deliverables are picked up and used as intended.

DOE Follow Up

The project scope will be narrowed to concentrate on developing the catalog, the open library, and a maintenance plan for the work after this project concludes. In addition, there should be follow-up discussion with industry and potential users of the testing network to enhance the interface and accessibility of information.

Grid Frequency Support from Distributed Inverter-Based Resources in Hawaii

WBS #:	1.3.29
Principal Investigator:	Andy Hoke
Project Run Time:	April 2016-September 2017

Hawaii leads the nation in the portion of electricity produced from distributed solar photovoltaics (PV). This high level of PV penetration, in combination with Hawaii's geographical isolation, results in an array of challenges in grid frequency stability and grid reliability.

Project Description

Hawaii leads the nation in the portion of electricity produced from distributed solar photovoltaics (PV). This high level of PV penetration, combined with Hawaii's geographical isolation, results in an array of engineering challenges as detailed in Hawaii Public Utility Commission Docket 2014-0192. These challenges include issues with grid frequency stability and grid reliability.

The goal of this project is to investigate, develop, and validate ways that distributed PV and storage can support grid frequency stability starting a few line cycles after a contingency event. This project will result in a broad regional partnership to work with the Hawaiian Electric Companies (HECO) on the use of fast distributed energy resource (DER)-based frequency response to ensure grid stability.

The team will analyze the impact of DER-based frequency support by simulating both over-frequency and under frequency events in a variety of HECO grid scenarios. The project will also develop and validate new control methods to improve inverter-based frequency support capabilities and performance. The project team will compare the data gathered from the simulations, power-hardware-in-the-loop testing, and field testing to inform their final results. The project's final report will include lessons learned and provide recommendations on the use of DERs for grid frequency support.

Reviewers' Overall Comments

Reviewers agreed that the project's ability to validate models, complete a power system simulation, and use the results to provide input into the IEEE 1547 standards process for fast frequency regulation from PV inverters was noteworthy. Several reviewers agreed that this project provided an important first step in developing adaptation services from groups of DERs. Several reviewers noted there is still a lot more progress in grid frequency support needed, including working with system dispatchers to accept the frequency response capabilities of rooftop PV units, incorporate them into system operational processes, and determine how to best coordinate services with groups of DERs so as not to overreact or inject oscillatory modes into the grid.

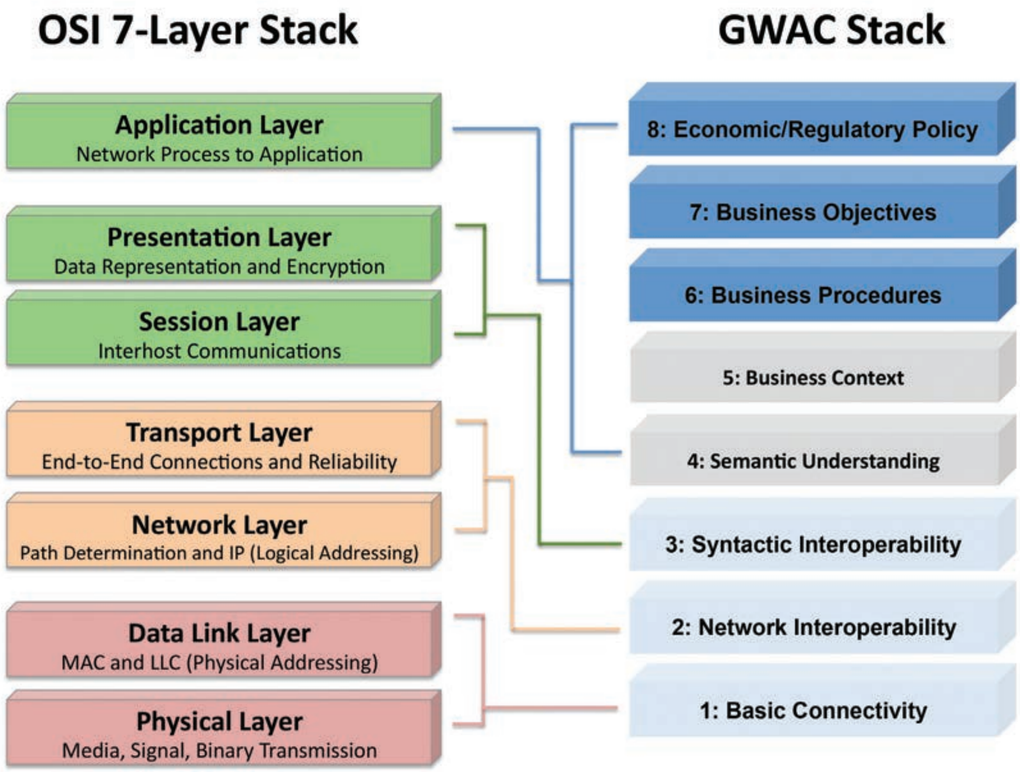
One reviewer recommended extending the project another year to complete sub-task 4.4: field installation of all inverters at the HECO site, and ensure the project team would be able to share validated models and any generic datasets generated. Another reviewer remarked that the work on this project was so specific to Hawaii that there was no comparing the constraints felt on the Hawaiian grid to any mainland grid, thus offering little relevance to grid modernization issues nationwide. A third reviewer recommended that the project team consider the cost and communications infrastructure requirements, as well as who would pay for those costs to achieve project objectives.

DOE Follow Up

The team should continue the project planned by gathering data and testing in the field if possible. DOE and GMLC will discuss how to use the progress achieved in this project for possible future work.

Standards and Test Procedures for Interconnection and Interoperability

WBS #:	1.4.01
Principal Investigator:	David Narang
Project Run Time:	March 2016-March 2018



Connecting Communications to Interoperability. (Source: *GMLC Gap Analysis for DER Interconnection and Interoperability Standards and Test Procedures report*)

Project Description

Next-generation smart grid technologies include distributed generation, battery storage, electric vehicles, and dispatchable loads, among others. To achieve widespread deployment of these technologies on the electric grid without compromising grid reliability, safety, or security, the devices must be able to connect and exchange data on the grid. Standards for interconnection and interoperability enable that coordination, allowing these devices to smoothly connect and communicate with the electric grid during normal operation and unexpected events.

The *Standards and Test Procedures for Interconnection and Interoperability* project's overarching goal is to help develop and validate interconnection and interoperability standards for new and existing electrical generation, storage, and loads that ensures cross-technology compatibility, harmonization of jurisdictional requirements, and ultimately enabling high deployment levels without compromising grid reliably, safety, or security. Outputs from this project include near-term actions to improve and validate standards for smart grid technologies, a gap analysis and method for prioritizing different technologies, and a developing new conformance test procedures for key grid technologies and services.

Reviewers' Overall Comments

Reviewers described this project as "ambitious" and "strategic" foundational project had important objectives that could have a large impact on grid integration of new technologies in a safe, reliable, and cost-effective fashion. Reviewers noted that there are multiple opportunities for new distributed energy resources if the project team can figure out how to overcome the challenges of interoperability and standards. One reviewer was concerned that the project team's use of the GridWise® Architecture Council (GWAC) Interoperability Context-Setting Framework "stack" alongside the lack of an explicit middleware layer could hinder progress, recommending the team acknowledge at least an "implicit" middleware layer in their work. Another reviewer noted that grid operators need end-to-end solutions, and so the project team should consider documenting and communicating examples of success demonstrations.

One reviewer noted that GMLC support for standards that enable grid interoperability and modernization provides "needed continuity" throughout the standards process, where it could be "uncertain" relying on industry participation alone. Another reviewer remarked that industry buy-in is "critical" and should not be understated. A third reviewer noted that partnership with standard development organizations had not yet demonstrated any commitments to adopt the work of the project team.

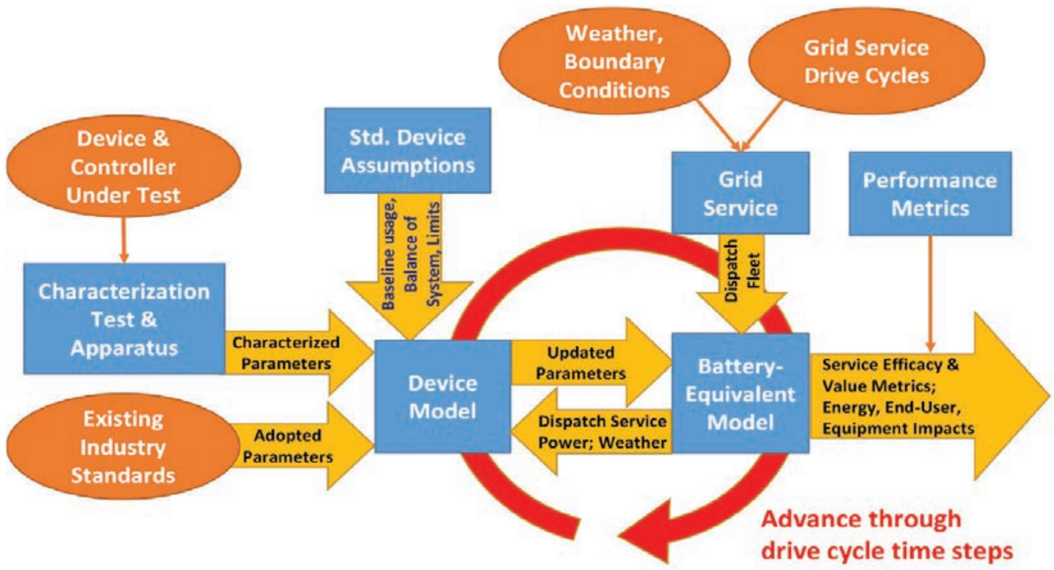
One reviewer recommended assessing the capability to follow up on gaps in standards identified for project success to ensure that the standards analysis framework can be adopted and used in a substantive, consistent fashion. Another reviewer remarked that with the test procedures development work projected for the end of the project performance period, it was difficult to evaluate technical work done to date. A third reviewer recommended the project team include electricity distribution system communication in their priorities as case studies, such as including the Institute of Electrical and Electronics Engineers Distributed Network Protocol (IEEE DNP3) standard that demonstrate the applicability of secure communication solutions, which need to be documented, shared, and promoted.

DOE Follow Up

The GMI team and the project team will meet to discuss narrowing the project's scope in order to better focus on which strategic opportunities the team should pursue.

Definitions, Standards, and Test Procedures for Grid Services

WBS #:	1.4.02
Principal Investigator:	Rob Pratt
Project Run Time:	April 2016-April 2019



General framework and approach of the project.

Project Description

The overarching goal for the *Definitions, Standards, and Test Procedures for Grid Services* project is to enable and spur the deployment of a broad range of distributed energy resource (DER) devices with the proven ability to provide the flexibility required to operate a clean and reliable power grid at a reasonable cost. This flexibility is largely embodied in grid services that power plants provide, but increasingly reflected in wholesale market products or utility programs in which DERs participate. The project's objectives address the primary barriers that will limit devices' abilities to provide such services at scale in the future power grid. The project will address DERs by defining a test protocol to characterize their ability to respond to grid signals.

Existing grid services include ancillary services (regulations, reserves) that keep the grid in supply-demand balance—managing peak loads to reduce infrastructure capacity requirements and managing wholesale purchase and production costs. Industry also envisions new reliability services from DERs (such as artificial inertia and participation in remedial action schemes) that enhance the reliability and stability of the bulk grid and new distribution-level services such as mitigating rapid voltage changes and reverse power flows from high solar PV penetrations. The project will define a standard set of grid services and "drive cycles" that describe the capabilities that DERs must have.

Reviewers' Overall Comments

Reviewers agreed that this project was a useful first step in developing ancillary services for a wider range of grid-connected devices. Because this project seeks to develop test procedures and protocols, reviewers noted the need for industry commitment and participation to ensure project deliverables are used. Specifically, one reviewer recommended that all deliverables should be easily adapted into testing processes by standardized testing agencies.

One reviewer recommended the team pay additional attention to developing tools and resources for those who want to use the deliverables from this project, making sure that there is clear guidance to determine which protocols are needed for applications of each device. Another recommended the team develop use cases for grid services based on generic device characterizations. Additionally, one reviewer noted that in several cases, solutions cost more than the market is willing to pay, recommending that the project team take stakeholder and market information into account and prioritize test protocol development appropriately. Therefore, they recommended that the project team reduce the number of devices to prioritize technologies that will help meet GMI program objectives for 2020 and reflect values derived in related GMLC projects, e.g., the priorities set in the *Standards and Test Procedures for Interconnection and Interoperability* project.

DOE Follow Up

The GMI team and project team will discuss a revised scope by narrowing device classes and continuing work on the battery model—to which all grid services should be connected.

Devices and Integrated Systems Portfolio Overview Discussion

After the project reviews, project principal investigators, DOE project staff, and interested stakeholders discussed the broader Devices and Integrated Systems Portfolio. Devices and Integrated Systems Technical Lead Ben Kroposki led the far-ranging discussion that touched on topics across the Devices and Integration Systems area, including engaging with industry on standards and testing work, concentrating on early stage research and development, crosscutting road mapping efforts for systems, and foundational investments in power electronics and energy storage.

When discussing the overall technical area portfolio, participants in the room discussed how program-specific projects had informed the development of IEEE 1547. Participants discussed how going forward, it will be interesting to see the influence of GMLC projects on standards that will, in turn, influence current research on control algorithms. Attendees also discussed the benefits of increased intra-DOE office, inter-lab, and external industry engagement on the GMI foundational topic areas, noting that with increased collaboration, the chances of project deliverables incorporated and making a difference increases—but for a cost.

The group also discussed the lack of research on power electronics and energy storage in this technical area. Stakeholders noted that these technologies could be used across a wide variety of power generation resources, providing an opportunity for foundational projects where multiple programs could use the results. DOE program managers noted that there is ongoing internal and programmatic work on energy storage technology research and development. Participants questioned if there was a GMI role for specific grid-connected storage work that might represent a gap in current DOE program work. Similarly, reviewers in the room suggested that there might be a coordinating role for GMLC to track the power electronic-based applications for the grid space occurring both within DOE and in industry.

This tied into a larger discussion of the potential need for a roadmap or strategy for work in the device area, similar to road mapping efforts conducting in other GMI technical areas. One reviewer suggested matching grid applications with actual device developments would be a useful first step as a way to help industry, grid industry, owner, operators, and organizations make sense of the landscape for purposes of grid modernization.

Attendees also discussed the portfolio's lack of projects focusing on systems testing. One reviewer noted that the project portfolio included more projects on device testing than systems testing. Kroposki noted that in the initial call for proposals, several systems testing projects were proposed but did not score as highly as device testing projects. He believed that as time goes on, there will be a re-balancing to systems projects, as device projects were more of a near-term need.

Institutional Support Portfolio

About Institutional Support

State policymakers, regulatory agencies, and regional planning organizations play a critical role in shaping both the direction and pace of grid modernization, but many state regulatory agencies are hard pressed to address the complex issues related to grid modernization and the deployment of distributed energy and renewable resources. Thus, the demand for objective technical assistance and information on grid modernization is high and likely to increase.

The *Institutional Support* focus has four main activities related to objective technical assistance and information on grid modernization. The first two activity areas focus on expanding efforts to provide high-quality technical assistance, primarily targeted to state energy agencies and regional planning organizations. The third technical area focuses on activities that analyze the potential impacts of (and barriers faced by) emerging technologies on grid operations and markets, and it develops analytic methods and tools to value distributed energy resources. The fourth technical area focuses on research on the future of electric utility regulation. Each activity has specific goals and target achievements to be completed by 2020.

Activity 1: Provide Technical Assistance to States and Tribal Governments

Goal: Provide independent and unbiased technical assistance to state and tribal policymakers on existing and emerging issues in the electricity sector as related to grid modernization.

Target achievements:

- Provide technical assistance to all states and tribes to inform their decision making for electricity policy—and accelerating policy innovation in at least seven states.
- Provide technical analyses to at least 10 states—including guidance on how to consider new technologies such as distributed energy resources—allowing them to establish formal processes to review utility distribution system plans.
- Assist at least 10 other states in developing comprehensive energy system plans.

Activity 2: Support Regional Planning and Reliability Organizations

Goal: Provide technical expertise to support the integration of new technologies into the grid and provide unbiased information, analyses, tools, and resources that help regional planning and reliability organizations develop their capabilities to address key grid modernization issues.

Target achievements:

- Support regional planning and reliability organizations in developing institutional frameworks, standards, and protocols for integrating new grid-related technologies.

- Coordinate a regional long-term planning process that uses standardized planning assumptions and publicly available databases of transmission topology and regional resource data.
- Facilitate long-term regional planning in each U.S. interconnection.

Activity 3: Develop Methods and Resources for Assessing Grid Modernization for Emerging Technologies, Valuation, and Markets

Goal: Provide analyses, case studies, and tool development for decision makers to facilitate stakeholder engagement and address the challenges posed by increasing the deployment of emerging technologies on the electric grid, particularly more distributed energy resources. This will reduce the risks and better inform investment decisions regarding emerging technologies enabled by grid modernization.

Target achievements:

- Develop new methods for valuing distributed energy resources and services.
- Develop analysis tools and methods that facilitate states and tribes' integration of emerging grid technologies into their decision making, planning, and technology deployment.
- Track grid modernization progress in states and tribes through standardized data collection methods and performance and impact metrics.

Activity 4: Conduct Research on Future Electric Utility Regulations

Goal: Provide analysis and modeling tools and technical assistance to state regulators, utilities, and industry stakeholders to support analyses of key issues facing state public utility commissions (PUCs) related to new business models for electric utilities.

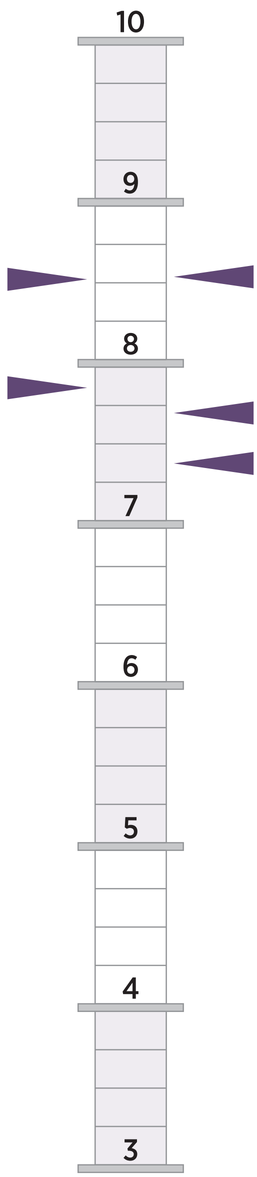
Target achievements:

- Provide technical assistance to at least eight state PUCs and utilities on ratemaking alternatives using DOE-supported financial analysis tools, other analytic resources, or stakeholder-convened discussions.
- Provide technical assistance to at least five states and utilities that are considering fundamental changes to the existing regulatory model. Provide technical assistance to at least five states that are considering allowing third-party access to customers' hourly interval load data and pricing of value-added services, which could spur new energy services markets.

Overall Scores

Of the 30 Foundational projects reviewed in the GMI Portfolio, five projects were reviewed as part of the Institutional Support portfolio review. Projects were ranked on a 1-10 scale, with a "1" being the lowest possible score and a "10" being the highest score for a criteria. Reviewers provided ratings on each project's 1) project relevance to GMI's mission and goals, 2) approach, 3) progress, accomplishments, and impact, 4) integration and collaboration, and 5) next steps.

Project summary scores for Institutional Support are shown below. The arrows indicate project rankings.



Institutional Support Scores Range

Foundational Metrics Analysis for GMLC Establishment

WBS #:	1.1
Principal Investigator:	Michael Kintner-Meyer
Project Run Time:	April 2016-September 2018

Metrics are being developed to help the electricity industry assess and measure success in grid modernization.

Project Description

The Foundational Metric Analysis for GMLC Establishment project will establish a methodology of developing and using metrics for assessing the evolving state of the U.S. electricity system and monitoring progress in modernizing the system. The goal is to develop an initial set of definitions and establish a baseline with historic values that together describe the past and current states of the electric grid within a selected area. This project, when successful, will develop an established methodology for computing those metrics leading to broad acceptance by the stakeholder community including Congress, the Administration, and other national and regional policymakers and regulators. These metrics will not only provide stakeholders with a consistent way to measure outcomes of grid modernization, they will also help quantify specific targets for DOE grid modernization activities (as established in the Grid MMYPP).

Summary of Reviewers' Overall Comments

Reviewers noted the importance of this project to the long-term viability of grid modernization, calling the project work "critical" and "essential." Specifically, reviewers noted that the regulatory and policy community needs assistance to better evaluate the costs and benefits of grid investment to meet future needs within a changing landscape of consumer use and production patterns, changing generation technologies, and the invention of new and more effective sensing and analytic tools. Reviewers agreed that a key component to help stakeholders evaluate future investments requires having metrics available that provide stakeholders with options. One reviewer noted that this work is unique within the research community, as no other organizations would be able to complete this level of analysis, coordination, review, and reporting.

Several reviewers offered suggestions on how to ensure the work continues to be used in the future, mostly focusing on developing test cases that align with state goals or other large stakeholder group goals that could increase transferability of project findings. This project's work to develop tools for measuring the capabilities of the electric grid, one reviewer pointed out, may also be useful toward assessing new grid designs.

DOE Follow Up

Work to date has concentrated on understanding and defining the metrics identified. Future work should also consider how these metrics are intertwined and interact with one another. Additionally, the team should continue to expand regional and state dialogue on metric definition and use.

Grid Services and Technologies Valuation Framework Development

WBS #:	1.2.4
Principal Investigator:	Patrick O'Connor
Project Run Time:	April 2016-October 2018

The valuation framework will guide power system stakeholders in quantifying and interpreting the diverse costs and benefits associated with power system investments.

Project Description

Across the diverse electric power industry, stakeholders utilize independent methodologies to value investment decisions—ranging from the residential purchase of a smart thermostat, to grid-scale investments in generation and transmission assets by utilities, regulators, private power producers, and market/grid operators. The current valuation approaches are "consistently inconsistent," relying upon differing, assumptions with respect to economic and engineering inputs, time, geographic, and power system scales. As well, some of the assumptions are opaque due to the on the closed-source inner workings of black-box modeling tools.

To address the inconsistencies and lack of transparency across existing valuation methodologies, the team working on the *Grid Services and Technologies Valuation Framework Development* project is working toward a comprehensive and transparent methodology to value the services and impacts of grid-related technologies. The project's framework will be based on a systematic approach to the definition and documentation of scale, scope, and assumptions that define any valuation or modeling activity. Successful development of this framework would allow electricity-sector stakeholders to conduct, interpret, and, most importantly, compare valuation studies with high levels of transparency, repeatability, and extensibility. The valuation framework has to be useful to assess regulated investments (transmission and distribution, generation, efficiency programs, load management), as well as investments by private-sector entities (e.g., merchant generators, load aggregators, end-users). Government and non-government organizations may also find it useful for examining, comparing, and making decisions regarding new and existing grid-related technologies.

The project intends to produce credible reference material and products which will provide a more transparent paths to conduct and compare valuation studies. Primary outputs of this project consist of a decision process report to guide the construction and interpretation of valuation studies and a valuation taxonomy and methodology catalog to support transparency and compatibility between studies.

Summary of Reviewers' Overall Comments

Reviewers commended this project's "ambitious" objectives and goals that could provide new clarity for decisions makers when facing valuation decisions. Reviewers noted that it is well known that the electric grid needs modernization to provide continued services, especially in a changing landscape of new and advancing technologies. A consistent valuation framework (or "methodology" as one reviewer suggested) helps the community increase transparency on valuation decisions by providing a structured, known approach for all in the community and addresses the "fundamental questions" of how to make rational investments in the face of uncertainty. One reviewer pointed out that the project findings could help stakeholders learn from others with similar valuation questions and be able to identify gaps or needs for future analysis.

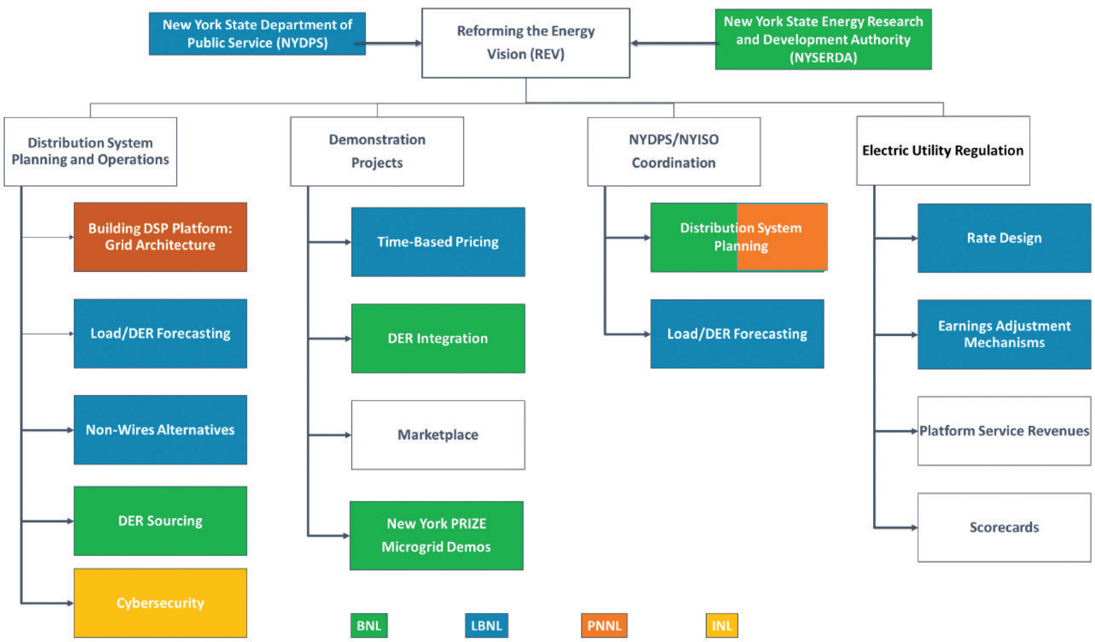
Several reviewers suggested that the project results could be very useful for non-technical stakeholders or stakeholders who lack technical resources; one noted that consistent valuation methodologies also serve to advance dialogue on modeling approaches, especially those that lack technical resources for independent modeling. Another reviewer stated that the project team should consider selecting a test case that has a known valuation approach that can be captured using the methods developed from this project to give the community a clearer understanding of how to use the new methodology. A third reviewer recommended the project team continue outreach to a wide community of stakeholders to increase support for deployment and dissemination in the later parts of the project plan.

DOE Follow Up

Based on feedback, DOE reviewed the project's language and realized that word choice set a level of expectation beyond the scope of the is project. This project was a framework development and not a framework for grid services and technologies, which is a much larger effort. The project team should engage with additional stakeholders on a valuation process in the last year and a half of the project.

Technical Support to the New York State Reforming the Energy Vision (REV) Initiative

WBS #:	1.3.22
Principal Investigator:	J. Patrick Looney
Project Run Time:	May 2016-September 2017



The REV Team, consisting of multiple national laboratories, will help address many of the key challenges facing grid modernization.

Project Description

The State of New York's overall demand for electricity is slowing, but its gap between peak load and base load, which diminishes the overall efficiency of the state's electricity system, is growing. By creating electricity markets at the distribution layer, the *Technical Support to the New York Reforming the Energy Vision (REV) Initiative* project seeks to enable significantly increased levels of distributed energy resources—including renewable generation, demand response, and energy storage—to help manage peak load, drive greater system efficiency, and increase reliability and resilience of the grid.

REV aims to make New York one of the early adopters of available advanced grid technologies. This will require addressing some of the key questions regarding grid modernization, including what business models work and why, as well as which technologies provide the most benefit and how to implement them. REV offers an important and unique opportunity to participate in a ground-breaking effort to develop future utility business models and gain insights on grid modernization. The goals of this project are to support REV by providing technical guidance to state regulators, policy makers, and stakeholders to address the challenges associates with establishing a Distributed System Platform envisioned by REV, obtain insights on business models that work, and compiling lessons learned from this initiative.

Reviewers' Overall Comments

Reviewers agreed that New York REV represents some of the most cutting-edge grid modernization work in the United States; by providing technical assistance to New York, reviewers agreed that it was extremely valuable for lessons learned from the experience to be documented and shared for other localities interested in lessons learned for their own grid modernization goals. One reviewer noted that New York's experience in dynamic pricing, performance-based regulation, and grid architecture could be very useful for other stakeholders.

One reviewer wanted additional information from the project's team on how they would characterize and disseminate that information while maintaining confidentiality. Another reviewer suggested that developing standard product offerings for states based on lessons learned could be very useful for future technical assistance. A third reviewer suggested that a global report on similar efforts (including European efforts) might be useful to broaden the scope of potential lessons learned.

DOE Follow Up

The project's team should finish the project as planned with providing technical support to REV for the remainder of the project period. The team should also document lessons learned to benefit other states/entities who are looking to modernize their electricity systems.

Distribution System Decision Support Tools

WBS #:	1.4.25
Principal Investigator:	Mike Coddington
Project Run Time:	April 2016-September 2018

Joe Eto presents on reliability metrics and planning at a training for New England public utility commissions on distribution systems and planning, Sept. 27-29, 2017. GMLC and the National Association of Regulatory Utility Commissioners, led the first in a series of regional training sessions.

Project Description

The *Distribution System Decision Support Tools* project identifies a comprehensive menu of strategies that facilitate and support enhanced utility distribution system planning. This menu includes guidance on how to consider and incorporate non-wires alternatives, distributed energy resources, and advanced grid components and systems.

The project team is educating and providing technical assistance for state regulatory agencies, such as public utilities commissions (PUCs), as well as rural electric cooperatives, municipal utilities, and investor-owned utilities. The team also identifies and applies new tools and methods to address significant gaps in existing and emerging electric distribution planning (EDP) approaches.

The project's goal is to plot a path for the next generation of distribution planning tools and practices. The project will also establish a training program on integrated distribution system planning for state utility regulators and provide technical assistance to the electric utility industry, especially small- and mid-size utilities. The outcomes of this project will be represented in guides, reports, and educational events that will help utilities and regulators envision the capabilities they will require from the next generation of distribution planning tools and practices.

Reviewers' Overall Comments

Reviewers noted the importance of advanced planning and moving intelligent tools and techniques into wider use within the United States. Many states and utilities (with several reviewers focusing their comments on public power entities) lack resources to conduct advanced decision making tools for future distribution planning. One reviewer noted that in many cases, information on advanced planning and how to address rising issues, such as higher concentrations of installed distributed energy resources, is not readily available or unique to a specific utility. Another thought this project was valuable for filling a "necessary void" in distribution planning given that current tools and systems are not designed for new technologies.

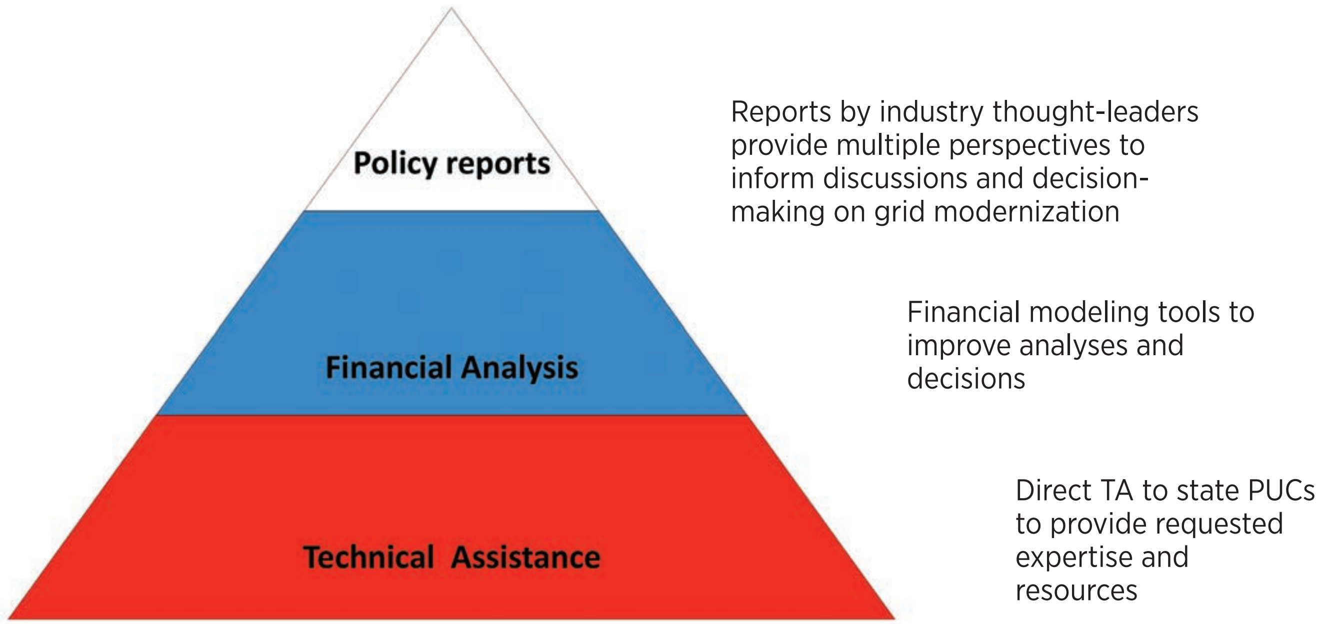
One reviewer suggested the project could benefit from a deeper understanding of public power entities and how work within those entities can illustrate potential value propositions. Another reviewer suggested that the project team outline and institute a way to gain feedback from distribution planning stakeholders after distribution training for policymakers has occurred to better understand its effectiveness. It was also suggested that in the summary report on emerging distribution planning practices, the project team list specific tools and rank them by maturity if possible.

DOE Follow Up

The team should continue project as planned, creating guides, reports, and educational events to help utilities and regulators with their distribution planning. The project team should connect with the *Transactive,* and *Grid Services and Valuation* project teams to see if the projects' work can complement each other.

Future Electricity Utility Regulation

WBS #:	1.4.29
Principal Investigator:	Lisa Schwartz
Project Run Time:	April 2016-October 2018



The approach to the Future Electric Utility Regulation project.

Project Description

The *Future Electricity Utility Regulation* project assists states in addressing regulatory, ratemaking, financial, business model, and market issues related to grid modernization in the power sector. These issues include adapting electric utility regulation and ratemaking to new technologies and services, assessing potential financial impacts on utility shareholders and customers, and investing in infrastructure that enables customer engagement and provides incentives to utilities to achieve their own grid modernization goals.

The goal of this project is to improve states' abilities to consider alternative regulatory and ratemaking approaches to invest in grid modernization. In addition, the project's work will better tie utility earnings to consumer value, economic efficiency, and other public policy goals. Project outcomes include improved financial analysis tools, direct technical assistance in the forms of tools and reports, and webinars by industry thought-leaders who will provide diverse views on issues facing the power sector.

Reviewers' Overall Comments

Reviewers thought highly of the project team's efforts and goals within this project, stating that the project is making technical assistance already provided to states "more valuable" and that the new tools and reports the project is developing could help the regulatory community plan and prepare for the changing operational and regulatory environment. Multiple reviewers praised the project's approach of developing reports with multiple perspectives on evolving utility regulation and ratemaking and noted the project's clear links to overall GMI goals.

One reviewer noted that this project is providing information and resources to public utility commissions that no one else is addressing and suggested that the project team seeks detailed feedback on the effectiveness of the technical reports and trainings delivered. Another reviewer thought the development and enhancement of the FINancial Impacts of Distributed Energy Resources (FINDER) model could be incredibly useful and fill a significant void for commission staff and others involved in conducting financial evaluations. A third reviewer noted additional details from the project team on approach, critical success factors, and challenges would be useful. One recommendation was for the project ream to connect with existing utility training programs to integrate project findings and potentially implement a "train the trainer" program where states could train other states.

DOE Follow Up

The team should continue project as planned, working on the technical assistance in the form of tools and reports to assist state utility regulators.

Institutional Support Portfolio Overview Discussion

After the project reviews, project principal investigators, DOE project staff, and interested stakeholders discussed the broader Institutional Support Portfolio. Institutional Support Technical Lead Chuck Goldman led the conversation.

Reviewers reiterated their comments, stating that they generally thought the portfolio had good projects that were moving in the right direction, with several citing the work "impressive" and "critical." Reviewers recommended continuing to reach out to a wide range of stakeholders—not just utilities, but also consumer advocates and states—to make sure knowledge gained from this work is being picked up around the country. Several reviewers highlighted the importance of communicating project work and findings with states, as they are the ultimate decision makers; however, not all states are in the same place along the grid modernization pathway. Therefore, feedback from a range of states would be critical to understanding gaps and challenges, especially when creating universally appropriate deliverables and products that will be utilized across the nation.

The difficulty and value of the work was stressed multiple times; reviewers discussed how these projects are helping to move the United States toward grid modernization. Project outcomes, one reviewer said, could be baseline work for hundreds of billions of dollars in decisions and help people make smarter decisions. Reviewers appreciated the technical area is for addressing key gaps facing grid modernization—valuation and metrics—and noted that the *Grid Services and Technologies Valuation Framework Development* project team seemed focused on the right things.

Discussion across the room touched on how unique this technical area is for DOE, especially given the challenges of effectively communicating project results to technical and non-technical audiences. Learning to communicate project goals, actions, and results more broadly will help disseminate information, which is more vital than ever given the speed of grid modernization in some locations. Reviewers noted that given the stated timelines of project and GMI outcomes, the clearer and earlier the communication, the better chance that states, regulators, and decision makers will be able to understand and implement relevant aspects of the work to their goals and needs.

Security and Resilience Portfolio

About Security and Resilience

Recent weather events, physical attacks, and cyberattacks on the nation's electrical grid have led to Presidential Policy Directives and an Executive Order to secure the grid.

The Security and Resilience focus has five main activities based on the National Institute of Standards and Technology cybersecurity framework that align with DOE strategies in the Infrastructure Security and Restoration Program and the Cybersecurity for the Energy Delivery Systems Program. Each activity has specific goals and target achievements to be completed by 2020.

Activity 1: Improve the Ability to Identify Threats and Hazards

Goal: Anticipate threats and hazards to the grid, while gaining an understanding of the vulnerabilities to all hazards, as well as their potential consequences.

Target achievements:

- Expand the existing cybersecurity model (C2M2) to anticipate threats and include all hazards, such as physical hazards, and perform onsite pilot assessments.
- Create enhanced sensors for information-sharing devices in the Cybersecurity Risk Information Sharing Program and create a security data repository.

Activity 2: Increase the Ability to Protect Against Threats and Hazards

Goal: Provide effective protection and resilience of the grid by developing standards for analyzing component and system resilience—creating and disseminating tools for resiliency planning, hardening components against attacks, and instituting an inherently resilient communications system.

Target achievements:

- Develop standards, methods, testing, and evaluation procedures for grid designs that are resilient to physical and cybersecurity attacks.
- Develop and demonstrate communications for emerging energy technologies, control system models, and logistical optimization techniques to minimize outage durations.
- Develop grid components that are inherently protective of grid services during any hazardous event.

Activity 3: Increase the Ability to Detect Potential Threats and Hazards

Goal: Proactively call out system vulnerabilities or attacks by applying system status characterization, machine learning, and high-throughput analytics for the entire grid life cycle, from planning and design to operations. Also, address the human cognitive components of responding to threats identified through the life cycle process.

Target achievements:

- Build modeling and simulation capabilities to approximate the operating profiles of grid operations from a cyber and physical security standpoint for the full system life cycle.
- Develop real-time cyber and physical data analytics and cognitive learning across the grid system life cycle and demonstrate the ability to detect potential threats in two regional exercises.

Activity 4: Improve the Ability to Respond to Incidents

Goal: Improve the power grid's ability to predict, respond to, and adapt to all hazards and threats by developing methodologies and frameworks that assess system degradation, advance utility preparations based on predictions, and transform the grid to keep operating during hazardous events.

Target achievements:

- Develop and deploy prototypes that assess infrastructure degradation, identify cyber and physical attacks, and adapt to the behavior of grid technologies to maintain critical grid operations.
- Develop methodologies and frameworks that provide diverse attack recognition and a mixed response on multiple timescales—optimizing the operational priorities to reduce the grid's response time.

Activity 5: Improve the Grid's Recovery Capacity and Time

Goal: Maintain plans for grid resilience and the restoration of electric sector capabilities and services following an all-hazards event.

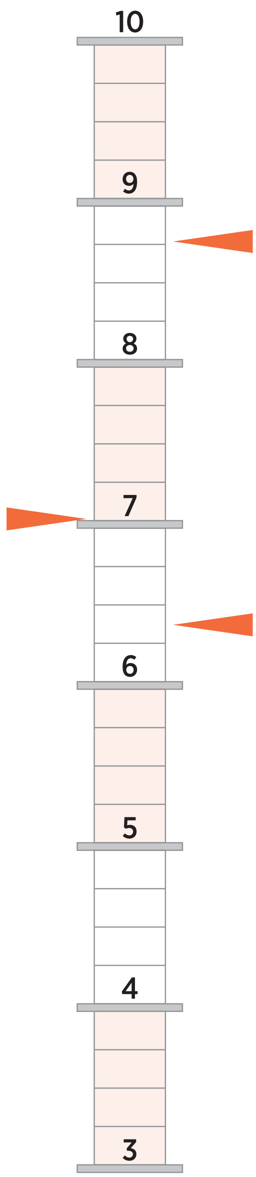
Target achievements:

- Develop designs and standards for advanced substations, transformers, and support technologies that facilitate improved portability and rapid recovery from natural disasters.
- Develop hardened, fail-safe, wireless communications for grid control systems that resist cybersecurity attacks and electromagnetic disturbances.

Overall Scores

Of the 30 Foundational projects reviewed in the GMI Portfolio, three projects were reviewed as part of the Security and Resilience portfolio review. Projects were ranked on a 1-10 scale, with a "1" being the lowest possible score and a "10" being the highest score for a criteria. Reviewers provided ratings on each project's 1) project relevance to GMI's mission and goals, 2) approach, 3) progress, accomplishments, and impact, 4) integration and collaboration, and 5) next steps.

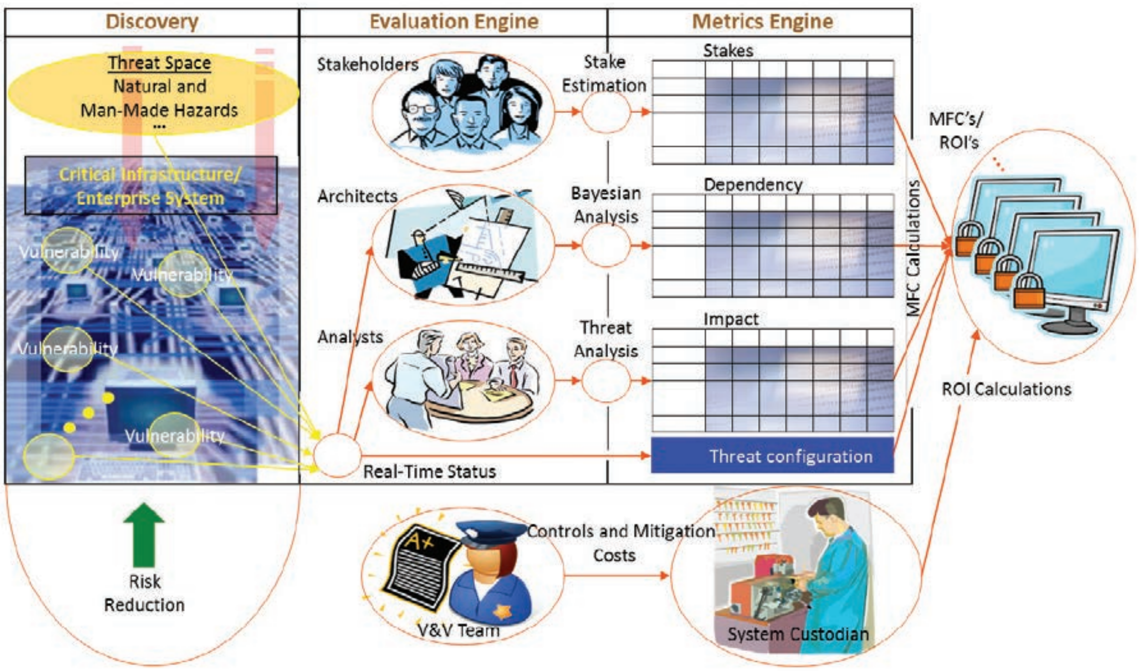
Project summary scores for Security and Resilience are shown below. The arrows indicate project rankings.



Security and Resilience Scores Range

Industrial Microgrid Analysis and Design for Energy Security and Resiliency

WBS #:	1.3.04
Principal Investigator:	Ben Ollis
Project Run Time:	April 2016-September 2017



Technical detail of the project process.

Project Description

United Parcel Service (UPS) is interested in developing an industrial microgrid to serve its 50-MW peak World-Port facility to increase reliability and strengthen the surrounding grid through advanced microgrid control schemes. The *Industrial Microgrid Analysis and Design for Energy Security and Resiliency* project provides a roadmap for UPS and other industries interested in microgrid technologies by laying out the technical, institutional, and regulatory challenges associated with developing an industrial microgrid.

GMLC and UPS are assessing microgrid capabilities at UPS's largest hub, WorldPort in Louisville, Kentucky, the world's most technically advanced facility of its kind. Together, they will investigate the risks, costs, and benefits of a microgrid at the UPS WorldPort and Centennial Hub facilities in Louisville. This project will involve Louisville Gas and Electric (LG&E) throughout the entire process so that the utility will understand how industrial customers use microgrids and they interact with electric grid.

The expected outcomes of this project include producing technical documents to assist UPS and other industrial companies in overcoming institutional barriers and assessing their capabilities to implement a microgrid at their facilities. The project outcomes will also give prominence to the interaction between an industrial customer interested in pursuing a microgrid and a utility that might be hesitant to commit to adopting such a technology, a scenario that industries and utilities across the country are likely to face.

Reviewers' Overall Comments

This project was generally viewed positively by reviewers, who approved of the clear approach and the fact that the project addresses the resilience and reliability requirements of industrial facilities. One reviewer thought highly of the team's use of availability as a reliability metric and the inclusion of physical security concerns. Several reviewers, however, were concerned that the project did not sufficiently address cybersecurity concerns.

Several reviewers questioned the team's collaboration, with both external stakeholders (such as the local utility) and internal (such as other GMLC projects), asking for additional information on partnership activities. Multiple reviewers questioned if the project team's scope was too narrow by working with only a single company, fearing that situations faced in the project were not general enough and that other companies would not be able to reproduce the results—making the project less relevant to stakeholders across the industry. Another reviewer, however, felt the partnership with UPS helped to make sure industry requirements were accounted for, which could make dissemination to other industry stakeholders more successful. Reviewers also noted that it would be a significant challenge for the project team to disseminate the knowledge to a broader audience given the sensitivities of business operations.

DOE Follow Up

The project team should finish project as planned, working on the technical documents to help industries that are interested in microgrids, navigate institutional and regulatory challenges. The project team should ensure the deliverables in this project can be used as resources for others entities such as cities and campuses.

Grid Analysis and Design for Energy and Infrastructure Resiliency for New Orleans

WBS #:	1.3.11
Principal Investigator:	Robert Jeffers
Project Run Time:	June 2016-March 2017

This color-coded schematic of New Orleans indicates where critical infrastructure in the area does not exist (red); exists but is less than required by users (yellow); or exists and meets user-defined requirements (green).

Project Description

This project was developed to help identify a set of cost-effective options for enhancing grid operations and community resilience in New Orleans, Louisiana (NOLA). The project is executed through several major tasks, including infrastructure impact modeling and analysis; design and integration of grid modernization options; transactive control feasibility study; and resilience cost/benefit analysis. NOLA, Entergy, and relevant stakeholders have set risk-informed, cost-effectiveness recommendations for grid resilience enhancement. These recommendations have been delivered in the form of conceptual designs that can then be utilized by NOLA, Entergy, and state and federal agencies to rank energy infrastructure improvement options and set improvement implementation and funding priorities.

This project will provide detailed information and conceptual models that can help NOLA and other cities prepare for, prioritize, and execute grid resilience projects in Infrastructure Impact Modeling and Analysis. Resilient

Power Distribution Modeling and Analysis, Integration of Distributed, Renewable, Energy Storage, and Energy Efficiency Options, and Cost/Benefit Analysis.

Reviewers' Overall Comments

Reviewers gave this project high scores, noting that it is high priority—not just in addressing problems in a major U.S. city using microgrids, but also looking toward larger infrastructure resilience issues. Resilience, one reviewer said, is "critical" for grid operations during emergencies such as hurricanes. The project team's approach to get different groups across NOLA together to identify locations and communities where grid vulnerabilities were most critical was an important accomplishment. Reviewers generally agreed that the technical analysis looked sound and the project team's progress in a short amount of time was impressive. They also appreciated the strong collaboration with the City of New Orleans, hoping that it would result in the city implementing project practices upon project completion.

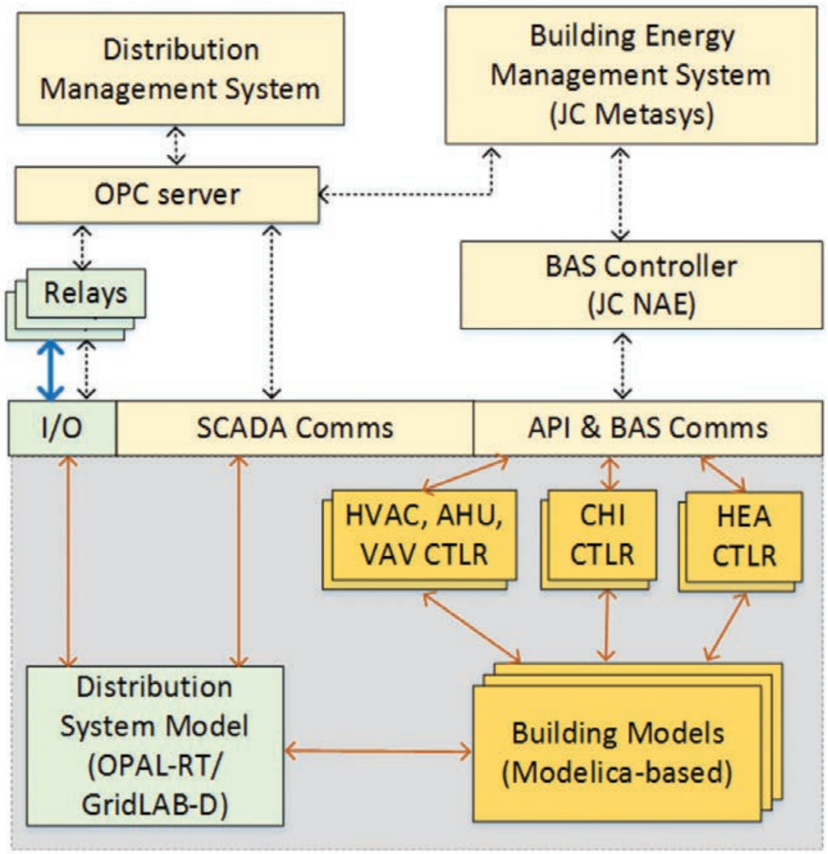
The ability of the project team to generalize its results was a concern for multiple reviewers, who feared that the technical lessons learned might not be applicable to other major U.S. cities.

DOE Follow Up

There is no specific follow up to this project, as this project has concluded. DOE will reflect upon the results of this project when planning for future R&D projects.

Threat Detection and Response with Data Analytics System Operations and Control

WBS #:	1.4.23
Principal Investigator:	Jamie Van Randwyk
Project Run Time:	April 2016-March 2019



Testing Buidings-to-Grid testbed architecture in real time simulation.

Project Description

Being able to differentiate cyber threats from non-cyber threats will help operators make determinations about the type of incident and the root cause to help them formulate more accurate response and mitigation plans. The *Threat Detection and Response with Data Analytics* project involves developing advanced analytics on operational technology cyber data to detect complex cyber threats in the power grid.

As part of this effort, the project team is evaluating which sensor data is most valuable and could provide the biggest positive impact for grid resiliency and security in the event that a threat is successfully detected. In addition, the team is developing analytics to identify emerging cyber incidents on the power grid using the sensor data obtained.

The project team will evaluate which sensor data is the most valuable, develop analytics to identify emerging cyber incidents, differentiate cyber grid incidents, and test analytics with industry. These actions will produce outcomes that will help differentiate between cyber and non-cyber-caused incidents using available cyber data. Further, the results of this data will help the development of commercial tools that will help power operators make the most appropriate response during an event.

Reviewers' Overall Comments

Reviewers expressed concern with this project's approach and progress to date, with several noting that they could not see a clear path forward toward meeting overall project goals. While reviewers generally agreed that distinguishing cyberattacks from physical events would help grid operators identify appropriate and timely actions during disturbances, reviewers were not convinced the project team's approach to data analysis would result in reproducible solutions that would be able to keep up-to-date in a grid with ever-evolving technologies, devices, and parameters that could produce false positives.

One reviewer questioned the use of the National Electric Sector Cybersecurity Organization Resource (NESCOR) failure scenarios given that they are very high level and do not explore existing or potential methods for threat amelioration. The reviewer suggested the project team explore other cybersecurity standards and guidelines for collecting critical data and performance information through various estimates and analyses, such as International Electrotechnical Commission (IEC) 62351-7. Other cyber-security standards could provide useful guidance and information that could be validated through state estimation and power flows.

DOE Follow Up

DOE recommends a major re-scope of the project. GMI team members will convene to redevelop the scope of the project to redefine the objectives of this project, while complementing the broader cybersecurity effort at the department.

Security and Resilience Portfolio Overview Discussion

After the project reviews, project principal investigators, DOE project staff, and interested stakeholders discussed the broader Security and Resilience Portfolio. Security and Resilience Technical Lead Juan Torres led the far-ranging discussion that touched on topics across the security and resilience area, including partner and outreach efforts, communication of project findings, risks to the grid from power interdependencies, and standards.

Reviewers started by discussing that resilience is more than resiliency to natural events, but also contingency on the power side, with one arguing that interdependency did not appear to be represented in the GMI project portfolio. Along those lines, reviewers noted that resilience must also include the ability to catch mistakes and inadvertent problems to avoid outages cascading from the bottom up. One reviewer mentioned, as increased distributed energy resources and connected control systems enter the grid, there are increased vulnerabilities on the edge of the grid in which a coordinated attack or change in behavior could negatively affect the grid drastically.

The group also discussed the portfolio's engagement with stakeholders, with several in the audience talking about the need for better communication to external groups to ensure that project findings are disseminated. Several recommended fellowships or other opportunities for embedding technical staff from the national labs at utilities and end-use groups for better two-way information sharing. Other suggestions included attending more organizational working groups and annual meetings, meeting with leading utilities, attending industry trade shows, interacting with the IT industry, and learning from other government organizations (such as the military).

Several questioned why there were only three foundational GMLC projects in such a major focus area. Similarly, one reviewer recommended deeper interaction with standards organizations—international or domestic—that might be able to incorporate security holistically or across multiple efforts. Stronger interoperability standards, for example, could also ensure system security. Others noted they were surprised there were fewer activities on the transmission side than the distribution side. Finally, one audience member asked, with respect to microgrid analysis, if there were some "no regrets" solutions that could be integrated into current distribution planning and design criteria that would help get distribution networks ready for microgrids in the future.

Sensing and Measurement Portfolio

About Sensing and Measurement

To assess the grid's health in real time, predict behavior and potential disruptions, and quickly respond to events, it is necessary to understand parameters throughout the electric infrastructure, from generation to the end user. Supporting advances in system operation and control requires improved sensing and measurements across these spatial scales and at multiple time scales, from microseconds to hours and days.

The Sensing and Measurement focus has six main activities designed to support innovation and advancements in these technologies. Each activity has specific goals and target achievements to be completed by 2020.

Activity 1: Improve Sensing for Buildings and End Users

Goal: Enable buildings to communicate with grid controlled systems and to offer grid services, while continuing to serve occupants and keep sensitive information secure.

Target achievements:

- Develop an open architecture for building energy management systems, and develop low-cost sensors that enable building owners and end users to assess the state of their energy assets.
- Develop secure wireless technologies to accelerate the integration of low-cost wireless communications with advanced sensors.

Activity 2: Enhance Sensing for Distribution Systems

Goal: Develop sensors, visualization techniques, and tools to better determine the distribution grid status.

Target achievements:

- Develop and demonstrate new, low-cost sensors for distribution-level electrical state and status monitoring that can operate in normal and off-normal conditions.
- Develop a visibility strategy for distribution grids that incorporates an extended view of the network—including the state and topology of the power system, whether assets are operating or not, the operating temperature of the grid assets, etc.

Activity 3: Enhanced Sensing for Transmission Systems

Goal: Develop detailed, system-wide monitoring of the transmission system and external effects, including weather events for predictive failure analysis.

Target achievements:

- Develop advanced synchrophasors that are reliable during transient events, as well as steady-state conditions, and can be upgraded remotely.

- Develop novel, inexpensive sensors and algorithms for electric grid components to monitor their health, real-time loading (including environmental factors such as heat), and accumulated stress that could lead to component failure.

Activity 4: Develop Data Analytics and Visualization Techniques

Goal: With grid data volumes expected to grow exponentially in the next few years, identify the most important parameters for turning this data into actionable intelligence.

Target achievements:

- Develop a real-time data management system for ultra-high volumes of grid data, with the ability to identify and compensate for inaccuracies and errors.
- Develop techniques and software tools that allow system operators to visualize generators, loads, and system parameters across the electric infrastructure.
- Develop measuring and modeling techniques for estimating and forecasting renewable generation both for centralized and distributed generation.

Activity 5: Demonstrate a Unified Grid Communications Network

Goal: Develop a communication infrastructure capable of managing the anticipated explosion of grid data traffic that supports the automation of the power grid—improving reliability and safety in the face of high renewable penetrations and cybersecurity threats.

Target achievements:

- Incorporate communications models into grid simulation and management tools, and improve the dynamic management of data flows to minimize latency in protection and control systems.
- Develop and demonstrate a unified grid and network management framework, and build a demonstration network using state-of-the-art networking technology.

Activity 6: Regional and Crosscutting Initiatives

Goal: Create a federal network for sharing grid data, and develop regional and national infrastructures for environmental sensing and forecasting.

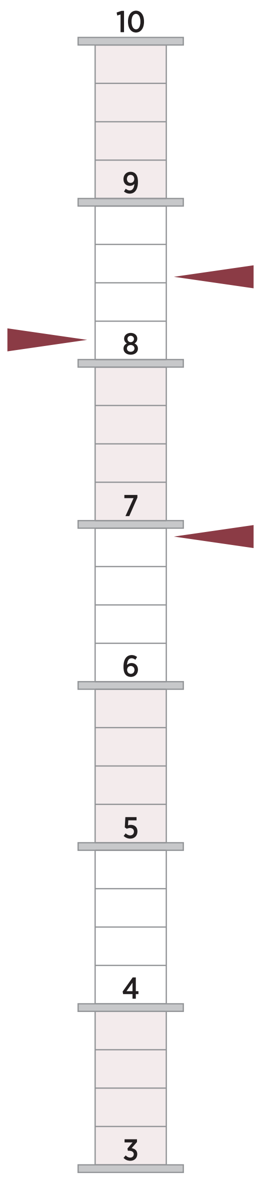
Target achievements:

- Provide real-time information on solar and wind generation and building loads at high spatial and temporal resolution.
- Provide minutes-to-days-ahead forecasts of solar and wind generation and loads.
- Incorporate environmental sensors that identify and predict weather-related effects to mitigate infrastructure impacts or to prevent widespread disturbances.

Overall Scores

Of the 30 Foundational projects reviewed in the GMI Portfolio, three projects were reviewed as part of the Sensing and Measurement portfolio review. Projects were ranked on a 1-10 scale, with a "1" being the lowest possible score and a "10" being the highest score for a criteria. Reviewers provided ratings on each project's 1) project relevance to GMI's mission and goals, 2) approach, 3) progress, accomplishments, and impact, 4) integration and collaboration, and 5) next steps.

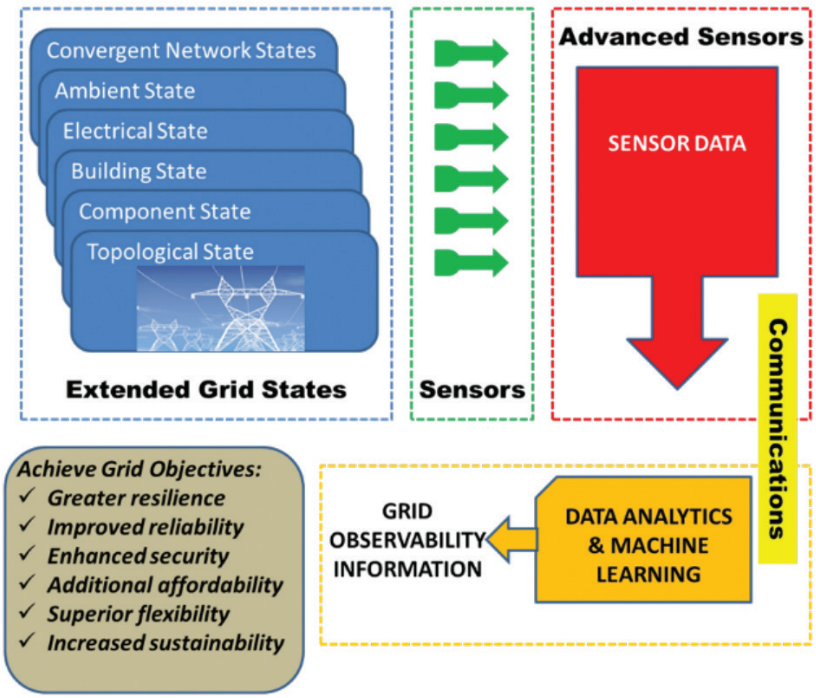
Project summary scores for Sensing and Measurement are shown below. The arrows indicate project rankings.



Sensing and Measurement Scores Range

Grid Sensing and Measurement Strategy Methodology

WBS #:	1.2.5
Principal Investigator:	Tom Rizy
Project Run Time:	April 2016-April 2019



The grid and grid services relationship with advanced sensors and data analytics.

Project Description

The power system that once provided electric power from central power plants to distributed loads using high-voltage transmission and lower-voltage distribution networks now consists of distributed generation and energy storage, as well as conventional and renewable generation sources throughout the system. The distributive and additive sources of energy require an ability to measure and characterize the state of the system at a much higher fidelity and resolution than before, from generation through end-use.

The *Grid Sensing and Measurement Strategy Methodology* project is working on the foundation to accommodate this new system state: building a cohesive strategy to develop and deploy low-cost, multi-modal sensing and monitoring devices with improved accuracy. Equally important is minimizing measurement uncertainty and ensuring adequate deployment coverage for complete observability of the power system, with the final piece involving getting the measurements to the control systems via a robust, secure, and resilient communications system. Therefore, this work is focused on an approach to define the requisite parameters to measure, devices needed to measure these parameters, communication requirements to transfer data, and the ability to manage the data and turn said data into actionable information.

Reviewers' Overall Comments

Reviewers agreed that sensing and measurement is a fundamental "enabler" for grid modernization across a variety of applications, including control systems, visualization, and big data analytics. Reviewers noted that sensing and measurement touches on many other GMLC projects and GMI goals, making this work complex and valuable if comprehensive and well-conceived strategies for guiding and prioritizing developing and deploying sensing and measurement for the future grid is successful. One reviewer praised the project's approach to roadmapping as making the issues, desired outcomes, and programmatic efforts clear, understandable, and measurable, while another wanted to see additional examples of extended grid states and additional detail on project approach presented.

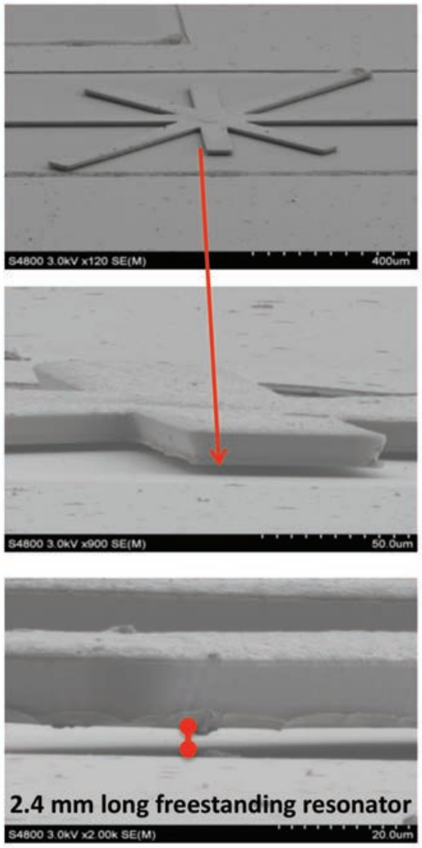
One reviewer recommended developing a tool for sensor placement optimization to enhance the value of the work. Another reviewer recommended accelerating the work, asking if it was possible to complete in two years instead of three. A third reviewer recommended more information on success metrics, as well as anticipated challenges and mitigation.

DOE Follow Up

The project team should continue project scope as planned: focus on an approach to define the requisite parameters to measure, devices needed to measure these parameters, communication requirements to transfer data, the ability to manage the data and turn data into actionable information.

Advanced Sensor Development

WBS #:	1.4.04
Principal Investigator:	Yilu Liu
Project Run Time:	April 2016-March 2019



The project team developed a first-of-its-kind electrochemically deposited (ECD) cobalt ion (CoFe) alloy with a high degree of magnetostriction. (CoFe Starburst Resonator is patent pending)

Project Description

Increased situational awareness of the vast U.S. electrical system is critical to achieve the grid modernization objectives. The foundation to meeting these objectives requires the ability to measure and characterize the system at much higher fidelity and resolution.

The project *Advanced Sensor Development* project will work on three primary areas:

- End Use - Developing low-cost sensors and algorithms to use building-level data to provide utility-scale visibility of grid reliability;

- Transmission and Distribution - Developing advanced phasor measurement unit (PMU) algorithms for ultra-fast transient measurement during disturbances, and integrate PMU algorithms into optical transducers for high-accuracy steady state monitoring; and
- Asset Monitoring—increasing device security and compatibility while eliminating electrical wires at the sensing location.

Reviewers' Overall Comments

Reviewers agreed that this project's work is fundamental to enable other major elements of grid modernization, but it was difficult to fully understand at times due to the broad and diverse project scope of developing advanced sensors. One reviewer noted that developing sensors and conceptualizing virtual sensors addressed a critical need for a functioning future grid and was also valuable for both normal and emergency grid functions. Another noted that the availability of low-cost sensors are very important to grid modernization, and that industry and grid operators/owners require more visibility into new operational use cases. Reviewers thought highly of the project team and their technical expertise given the early progress on several important sensor technology developments, including low-cost current sensing and new asset monitoring sensing.

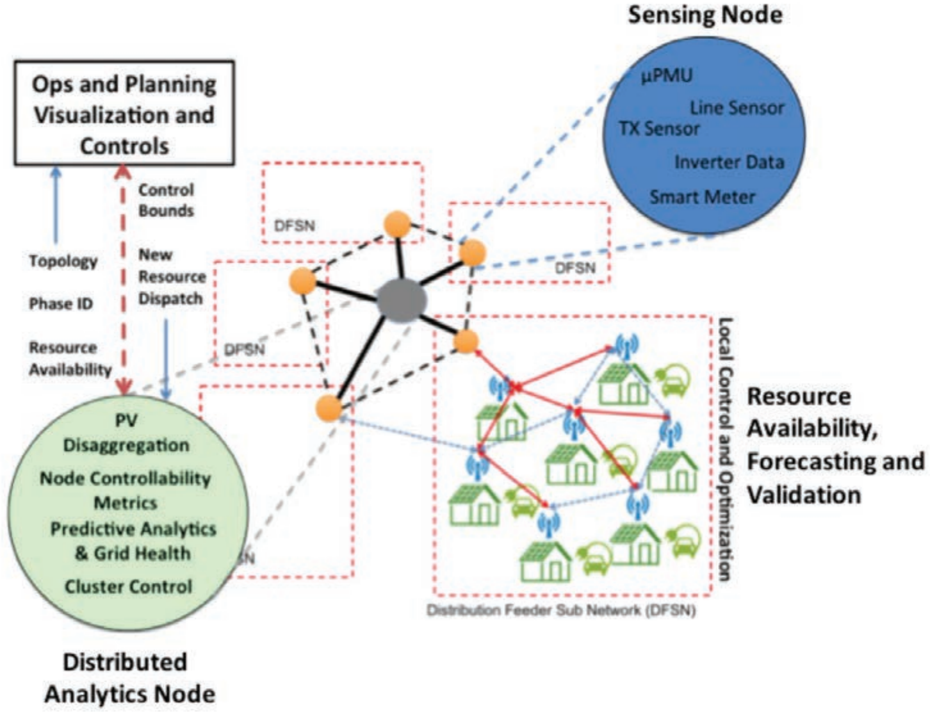
Due to the broad scope of the project, several reviewers recommended that the project team present additional information, including context for each sensor under development (what each sensor measures and for what purpose). Additionally, reviewers requested additional information on current engagement with other the other five GMI technical areas, and they recommended new engagement with the research and industry communities to broaden research and collaboration opportunities.

DOE Follow Up

The GMI team wants the project team to focus on developing early stage sensor technologies that are clearly in need but not currently being developed, and to consider broadly applicable sensor platforms. The team should consider narrowing the class of sensors being pursued, and prioritize work that is aligned with the roadmap being developed.

Integrated Multi-Scale Data Analytics and Machine Learning for the Grid

WBS #:	1.4.09
Principal Investigator:	Emma Stewart
Project Run Time:	May 2016-April 2019



Overall approach for the project Integrated Multi-Scale Data Analytics and Machine Learning for the Grid.

Project Description

This project's overarching goal is to create advanced, distributed data analytics capability within the GMLC to support distribution grid and building operators. While there has been significant development of analytics methods with streaming data at the transmission level, distribution and buildings level analytics are in the elementary stages. Machine learning is a fundamental tool for analysis development, and will allow new levels of visibility and resource integration to be achieved using open and utility datasets at both the building and distribution level. *Integrated Multi Scale Data Analytics and Machine Learning for the Grid* develops the necessary framework to promote and integrate a larger distributed analytics activity utilizing existing and new data sources developed through both private and DOE partnerships.

The project will demonstrate the ability to synchronized disparate data sources from the distribution system and buildings and apply machine learning techniques to fully enable important distributed applications such as transactional energy, failure prediction, resilience applications, and a BMS/DMS integration. Industry identifies these use cases as crucial for a modernized grid, and advanced analytics will be an important tool for successful implementation.

Reviewers' Overall Comments

Reviewers agreed that distributed analytics and machine learning are clearly aligned with the Grid MYPP and are "relevant and vital" elements of the future, modern grid. Reviewers praised the project team's "excellent" approach, work plan, and clear explanation of value and reasons for their use case choices. One reviewer noted that the potential impact could be very large, and despite the high risk, the project team should continue. Another reviewer noted the value of the project team's use cases reflecting actual challenges faced today or challenges that industry will have to address soon.

One reviewer recommended the project team consider issues of data quality in their work, specifically recommending amending the approach to include the handling and effects of poor, inconsistent, or bad data as machine learning and data analytics are only as good as the underlying data. Additionally, this reviewer recommended the team consider related practical data analytics needs—such as computational requirements and data communications—to achieve overall project goals. Another reviewer recommended the team consider future hand-offs or pathways to commercialization going forward. While the project team is partnering with industry, this reviewer was unclear how these partnerships were expecting to change over time.

DOE Follow Up

The project team should continue project scope as planned. DOE will also look for future opportunities to improve and expand work in this area.

Sensing and Measurement Portfolio Overview

After the individual project reviews, project principal investigators, DOE staff, and interested stakeholders discussed the broader Sensing and Measurement Portfolio. Sensing and Measurement Technical Lead Tom King led the far-ranging discussion that touched on topics across the Sensing and Measurement technical area, including data quality, device placement, communications requirements for the future grid, and communications research and development needs.

Participants in this session started the discussion by emphasizing the importance data quality, which has the potential to lead applications, development, and analysis astray if based on bad data. One stakeholder discussed the need to have data quality considered from the ground-up, not as an afterthought or something to be treated after the project has ended. Another noted that data was a fundamental underlying problem facing grid research and applications.

Stakeholders also discussed the need to consider that an optimal placement strategy is not always feasible. Participants noted experience in developing and placing Phasor Measurement Units (PMU), where project teams would extend time and effort to develop optimal placement algorithms, then maintenance staff would install these sensors in areas that made the more sense for their needs. Applying lessons learned from that experience, stakeholders recommended considering sensor placement along a spectrum, from practical to optimal, to improve data collection.

The need for an overarching communications vision was debated in the room, with some stakeholders discussing the very practical needs industry is facing when considering future communications requirements. Specifically, stakeholders discussed the challenges associated with communications infrastructure due to increasing non-utility owned infrastructure (such as DERs) and third-party communication networks. Other stakeholders questioned communications needs across multiple dimensions, including long-distance, at the distribution level, and within buildings.

Finally, stakeholders discussed the crosscutting nature of sensing and measurement technologies across the GMI portfolio, noting that there are many opportunities for collaboration among projects.

System Operations, Power Flow, and Control Portfolio

About System Operations, Power Flow, and Control

As the nation's electric grid transitions from one that is centrally controlled, with one-way delivery of power from central-station power plants, into one that features both distributed generation and distributed control systems based on advanced communications, new approaches are needed to enhance reliability and efficiency. There is opportunity to harvest advanced technologies to optimize the operation of the system and react to off-normal conditions in a way that preserves system reliability and improves resilience.

The *System Operations, Power Flow, and Control* focus has three main activities designed to support innovation and advancements in these technologies. Each activity has specific goals and target achievements to be completed by 2020.

Activity 1: Develop a New System Architecture and Control Theory

Goal: The existing grid architecture has developed organically and has grown so complex that it is impossible to make any significant change with a full understanding of the consequences. To address this issue, this activity will develop a modern grid system architecture and an associated control theory.

Target achievements:

- Develop an architectural model that encompasses all major elements of the grid and allows people from various industry segments and geographic regions to view the grid in the most appropriate way for them.
- Develop advanced control theories and algorithms—including wide-area control strategies—to improve grid flexibility, adaptability, and resilience, while not compromising reliability or security.

Activity 2: Develop Coordinated System Controls

Goal: Create a next-generation grid operating system that functions like an autopilot system. Through grid-level integration of energy management systems (EMS), distribution management systems (DMS), and building management systems (BMS), this system will operate with less reserve margin, dramatically enhancing the energy and economic efficiency of the system.

Target achievements:

- Develop a prototype, next-generation EMS that has fast and automated control mechanisms, allowing the grid to operate reliably, even without full backup capacity for all the power being transmitted (the so-called N-1 criterion).
- Incorporate probabilistic, risk-based approaches into the next-generation EMS, DMS, and BMS platforms, and develop a framework for integrating the platforms.

Activity 3: Improve the Analytics and Computations for Grid Operations and Control

Goal: Power systems are operated today using the same conservative approaches that have been used for decades, resulting in an underutilized grid infrastructure, higher energy costs to consumers, and expensive or difficult deployment of new grid technologies. This activity will develop a new suite of power grid analytics for grid control and system modeling, and it will draw on parallel and distributed computing algorithms that run on advanced computational platforms.

Target achievements:

- Evaluate current and future grid operating conditions to make decisions in short time frames, despite a high degree of uncertainty in system inputs.
- Automate grid protection and control with predictive capabilities, advanced computations, and parallel processing, including the non-linear optimization of highly stochastic processes.
- Provide decision support to control room operators through advanced, much faster computations, and pinpoint visualizations for situational awareness.

Activity 4: Develop Enhanced Devices for Power Flow Control

Goal: Develop low-cost, efficient, and reliable power electronic devices for power flow control, potentially eliminating wasteful loop flows and helping to decrease grid congestion.

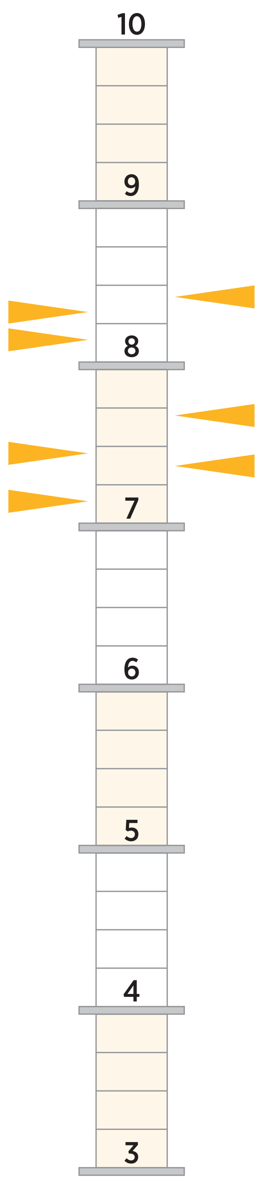
Target achievements:

- Draw on wide bandgap devices and inverter-coupled technologies for power flow control—enabling them with advanced controls, communication protocols, and computational methods.
- Following tests and simulations, publish a report detailing the potential operational and economic impact of employing advanced power electronics to control power flows on the grid.

Overall Scores

Of the 30 Foundational projects reviewed in the GMI Portfolio, seven projects were reviewed as part of the System Operations, Power Flow, and Control portfolio review. Projects were ranked on a 1-10 scale, with a "1" being the lowest possible score and a "10" being the highest score for a criteria. Reviewers provided ratings on each project's 1) project relevance to GMI's mission and goals, 2) approach, 3) progress, accomplishments, and impact, 4) integration and collaboration, and 5) next steps.

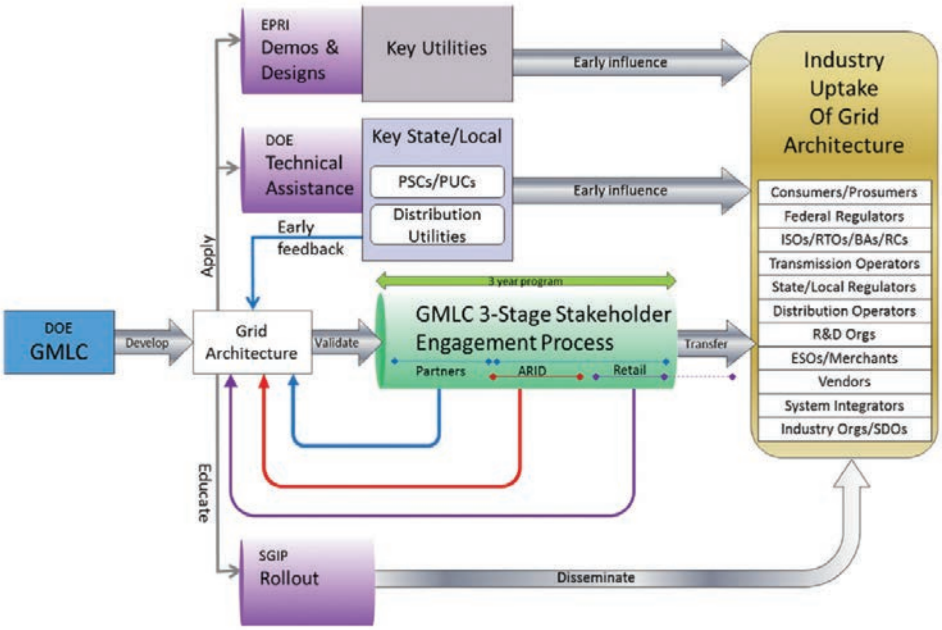
Project summary scores for System Operations, Power Flow, and Control are shown below. The arrows indicate project rankings.



System Operations, Power Flow, and Control Scores Range

Grid Architecture

WBS #:	1.2.1
Principal Investigator:	Jeff Taft
Project Run Time:	March 2016-October 2018



The Grid Architecture project provides methods and tools to the electric industry, such as architectural views containing structure drawings, specifications, and component models that describe the future design of the power grid.

Project Description

Modernization of the US power grid is hampered by mounting complexity; decision-making is consequently highly risky and in the recent past has led to stranded investments and lost opportunities for value creation. The purpose of the proposed project is to expand and apply the discipline of Grid Architecture to achieve the following big outcomes:

1. Provide a used and useful framework for the GMLC projects;
2. Enable superior grid stakeholder decision-making to reduce risk of poor functionality and stranded investments; and
3. Build stakeholder consensus around a DOE-convened vision of grid modernization, expressed as a new grid reference architecture.

The *Grid Architecture* project provides a set of architectural depictions, tools, and skills to the utility industry and its extended stakeholders to develop a national consensus on grid modernization and to provide a common basis for roadmaps, investments, technology and platform developments, and new capabilities, products, and services for the modernized grid. Project activities include building stakeholder consensus around a DOE-convened vision of grid modernization, expressed as a new set of grid reference architectures; enabling superior stakeholder decision making to reduce the risk of poor functionality and stranded investments; providing a used and useful framework for GMLC projects; and establishing and achieving industry acceptance for the use of project work products and methodologies for grid modernization.

Reviewers' Overall Comments

Reviewers agreed that this project addresses critical gaps in grid modernization efforts, with one calling it a "critical platform" for thinking about and articulating a view of the future grid. One reviewer noted that current project deliverables were not clear, saying they could not easily envision what a draft architecture looks like. Several reviewers praised the project team's engagement with industry stakeholders, though one reviewer questioned if the project team had considered or assessed previous stakeholder work on smart grid architecture.

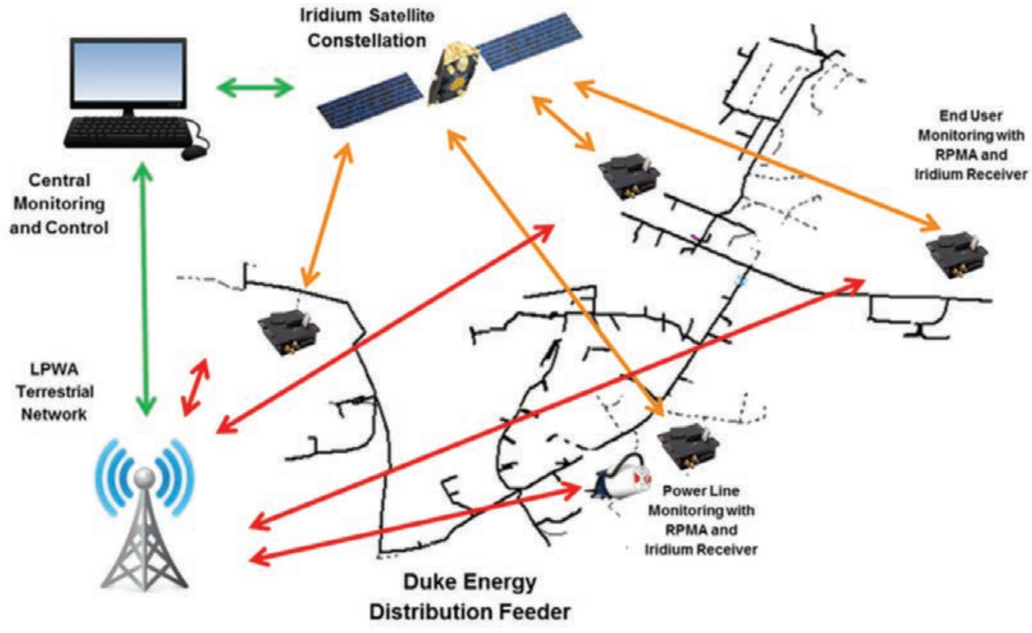
Several reviewers expressed concern regarding future plans to rollout project deliverables from concept to implementation by industry stakeholders, noting that little information was shared and the methodology appeared lacking or vague. Two reviewers recommended the project team devote resources to thinking about how the grid will transition from its current state to the future state and what grid architecture would look like in that transition.

DOE Follow Up

The project team should work on taking the abstract concept of grid architecture to actionable steps. The team should also work on communicating the grid architecture discipline to regulators and decision makers. DOE notes that program work on the Distribution System Planning Platform is targeted at engaging regulators and states.

Southeast Regional Consortium

WBS #:	1.3.01
Principal Investigator:	Joe Cordaro
Project Run Time:	April 2016-March 2017



Dual wireless network demonstration on Duke Energy's distribution feeder.

Project Description

GMLC formed the *Southeast Regional Consortium* with regional stakeholders, including utilities, academia, regulatory agencies, and industry. The consortium is focused on improving distribution system resiliency while increasing the concentration of DERs.

GMLC is testing advanced sensing, communication, and controls to monitor the health of the distribution grid, increase system visibility during extreme events, and take action to mitigate system impacts. In close collaboration with University of North Carolina Charlotte (UNCC), Duke Power and the Center for Advanced Power and Engineering Research, GMLC tests how a combined terrestrial and space based wireless network can be utilized to allow for resilient grid sensing and control during routine and major network outages due to severe weather events and terrorist attacks (cyber and/or physical). In addition, Chattanooga Electric Power Board, National Instruments, SmartSenseCom, and GMLC focus on developing and validating key distributed controls, sensing, and time-sensitive data transfer technologies needed to improve power system resilience and efficiency and increase distributed generation concentration with the eventual goal of testing at the distribution system level.

Reviewers’ Overall Comments

Reviewers called this project “practical,” “well-conceived,” and an “outstanding effort with a lot to show.” The reviewers generally agreed that the project was executed well and complimented praised the team’s stakeholder inclusion efforts. One reviewer rated the team’s approach highly, noting that it is directly applicable to and can be used by other geographic regions—even if the technology choices may vary. Reviewers also appreciated the optical step-distance and praised the team’s stakeholder inclusion efforts. Reviewers also praised the optical step-distance protection and Complete System-Level Efficient and Interoperable Solution for Microgrid Integrated Controls (CSEISMIC) distributed controls concepts, saying they might be very useful to other GMLC projects as well.

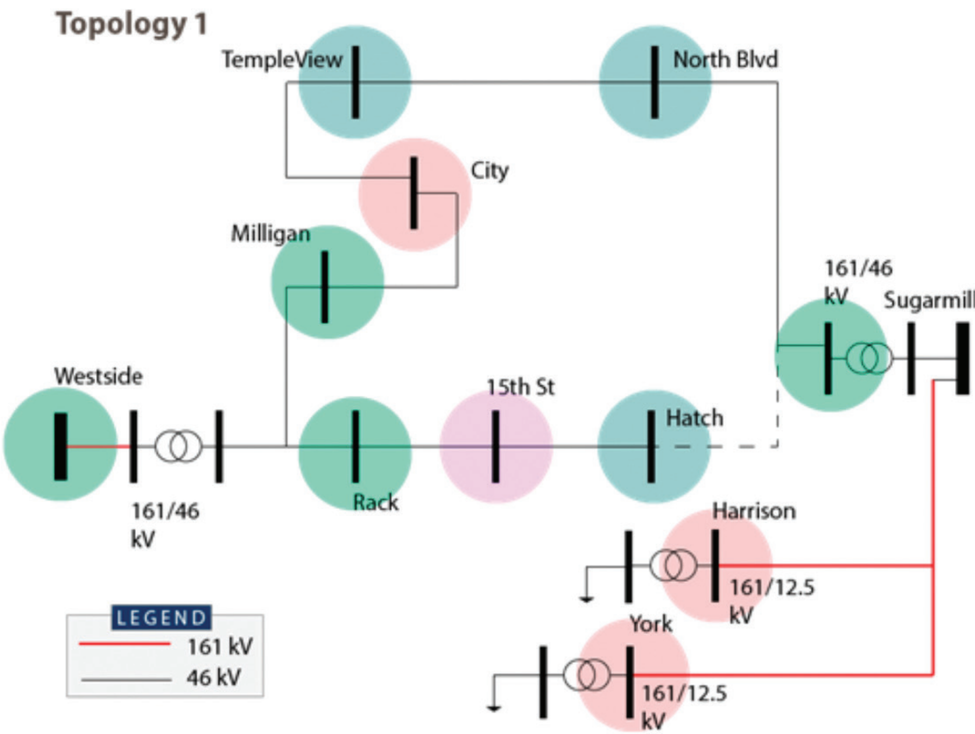
Reviewers agreed that the team’s accomplishments to date were impressive, with one recommending an extension of the project’s period of performance to capitalize on research and progress. Another reviewer recommended that developing microgrids could be a follow-on action from this project, though the implementation timeline could be long.

DOE Follow Up

The project team should continue the project scope as planned with the goal of developing and validating key distributed controls, sensing, and time-sensitive data transfer technologies needed to improve power system resilience and efficiency and enable more distributed generation on the power system.

Smart Reconfiguration of Idaho Falls Power Distribution Network for Enhanced Quality of Service

WBS #:	1.3.09
Principal Investigator:	Rob Hovsapian
Project Run Time:	June 2016-December 2017



Placement of distribution PMUs in the Idaho Falls Power grid.

Project Description

The principal goal of *Smart Reconfiguration of Idaho Falls Power Distribution Network for Enhanced Quality of Service* is to accelerate grid modernization by providing technical assistance to northwestern states in the United States, utilities, and other stakeholders that are facing key emerging grid modernization challenges. The Northwest is rich in hydroelectric power generation, which primarily serves loads in a large geographical region that includes Idaho, Washington, Oregon, and Montana. This project demonstrates the use of smart reconfiguration and protection system methods for enhancing the quality of power service for the Idaho Falls Power (IFP) distribution network, located in Idaho Falls.

This project aims to test the use of advanced methods for enhancing the quality of power service for the IFP distribution network, located in Idaho Falls. The project uses real-time software simulations and real-time, hardware-in-the-loop-based testing, as well as experiments, to develop methods for smart reconfiguration, smart islanding, and intelligent demand response using the loads as a resource. An example of work includes an investigation into black start, a technical concept for restoring an electric power station or part of the grid without relying on the external transmission network.

Reviewers' Overall Comments

Reviewers agreed this project was focused, had a high degree of collaboration, and could be impactful, though several questioned how well the work done for Idaho Falls would transfer to other utilities given the specificity of the results. Additionally, one reviewer was unclear how this project supports GMI's goal of major cost reductions. Another questioned how much of the work was new to this project versus how much was building on previous work, such as PMU placement. A third reviewer wanted additional information on how some of the modeling could be done within GridLab-D and on the criteria for locating PMUs. Distribution PMUs, one reviewer suggested, could be an added value to DER management, even though it is unclear how such high-fidelity phasor data will be used in the project. Reviewers liked the inclusion of a hardware-in-the-loop simulation to validate concepts and the investigation into black start, an area one reviewer said needs studies.

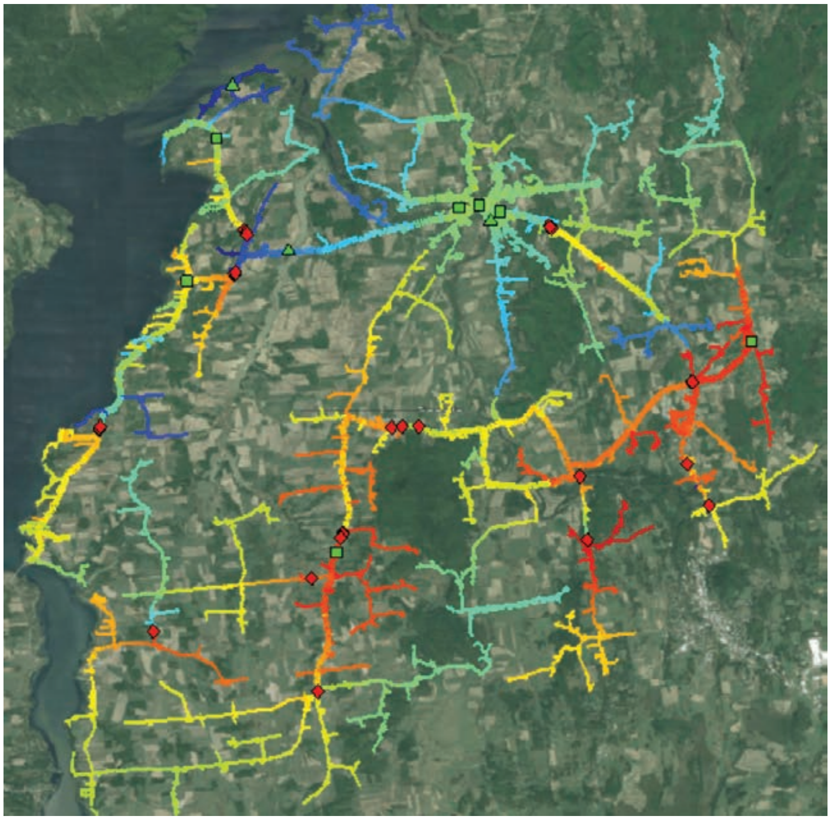
Reviewers suggested that the project team look further into the role of next-generation sensors and enhanced grid state. One reviewer recommended de-emphasizing prior work such as PMU placement. Another reviewer noted that locations of DERs could be incentivized as a means to defer utility construction costs, but not necessarily for resilience purposes.

DOE Follow Up

As the project team concludes this project, the project team should continue the project scope as planned with the goal of building intelligent algorithms and controls to enhance the quality of service for the IFP distribution network. The team should also coordinate with the *Foundational Metrics Analysis for GMLC Establishment* project to discuss how to measure improvements in reliability.

Vermont Regional Partnership Enabling the Use of DER

WBS #:	1.3.10
Principal Investigator:	Robert Broderick
Project Run Time:	April 2016-September 2017



Study feeders for the project will help improve the hosting capacity for PV.

Project Description

The project, *Vermont Regional Partnership Enabling the Use of DER*, provides technical support and analysis to the State of Vermont and its electric utilities meet the ambitious goal of obtaining 90% of its energy from renewable sources by 2050 by modeling and optimizing DER and energy storage integration and improving load forecasting. Significant changes in Vermont's distribution-system architecture and operations are needed to mitigate the impacts of high penetrations of variable generation and DERs such as voltage violations, equipment failures, thermal overloads, and safety and reliability issues. This integrated approach to enable the high penetration of renewables at the distribution level will serve as a template for other utilities across the United States. The project addresses these challenges in three areas:

1. ***Energy Storage (ES) Optimization.*** Deployed with the proper controls and incentives, both utility-owned and distributed, ES can be a significant driver of both residential- and utility-scale photovoltaics (PV), helping shave peak loads and mitigate the impacts of variable generation. This project will include a pioneering analysis of ES efficacy as an enabler and driver of high-penetration renewable generation. Working with industry partners, the team will develop a set of advanced controls for aggregating and optimizing ES; demonstrate optimal ES system siting and sizing; and undertake an analysis of ES' economic benefits, which will help drive deployment and more effective state-level policy.

2. ***Broadly Adoptable Holistic Approach to DER Optimization.*** This coordinated research effort by the national labs, in collaboration with Vermont stakeholders and national innovators, will develop, test, and deploy an innovative technical approach to DER integration and control. Our approach will address multiple challenges simultaneously, including the negative impacts on grid performance and load management created by high-penetration DER and the need for cost-benefit analyses of key strategies such as ES implementation. While the project focuses on Vermont and its distribution topologies, drawing on Vermont utility supervisory control and data acquisition (SCADA) and advanced metering infrastructure (AMI) data, the research results will be broadly applicable.

3. ***Support for Vermont, at the Vanguard of Grid Modernization.*** Vermont is a leading state targeting grid modernization themes, with its statewide AMI, recent SCADA upgrades, and to a renewables-intensive future. This project, which involves the national labs working in partnership with state and local organizations (industry, academia, utilities, state regulators, etc.) will help Vermont meet its ambitious goals and, in doing so, will provide a regulatory and policy model for other states and utilities to follow.

Reviewers' Overall Comments

Reviewers thought this project's progress toward completing tasks was impressive given its aggressive and ambitious timeline. Reviewers had mixed opinions on the applicability of the results to other geographic areas, with one arguing that the tools developed from the case study would help generalize results and another noting that not all approaches would be directly applicable, but future work with other New England utilities might help identify more generic approaches for other models. One reviewer called out the team's approach to DER integration modeling as noteworthy, including the use of Advanced Metering Infrastructure (AMI) data and weather forecasting, but warned that some of the modeling will need to be more dynamic than AMI data could provide with the advent of new DER capabilities and mandatory functions.

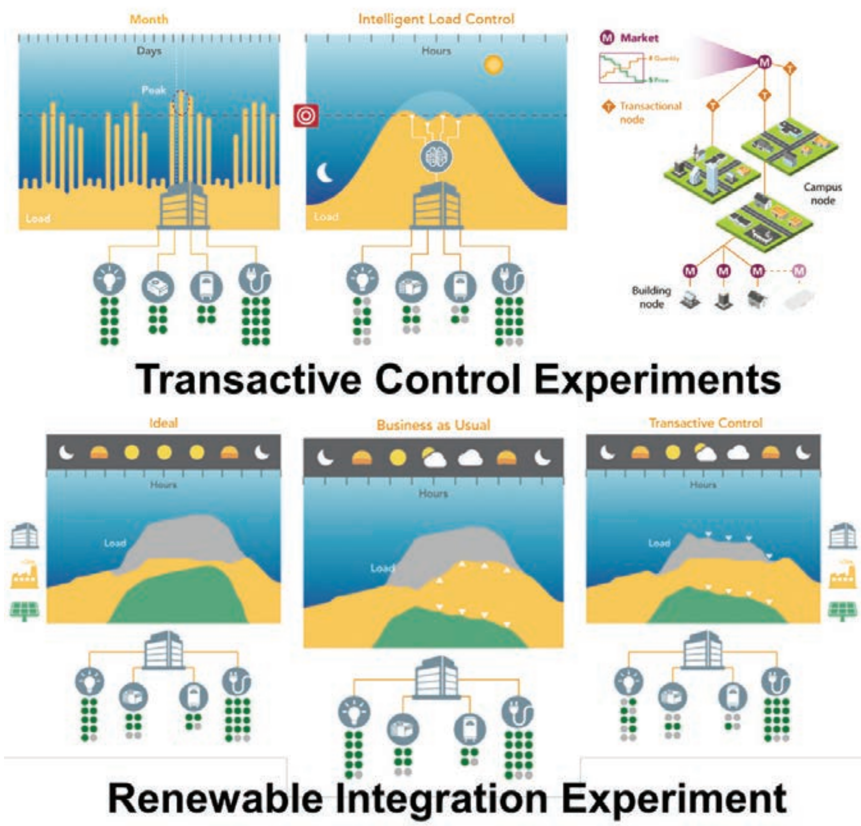
One reviewer recommended extending the project to allow the team to work on a higher level of integration and additional demonstrations. Another reviewer recommended the team develop and implement information dissemination plans to ensure project results are transferred to a broader audience.

DOE Follow Up

The GMI team will convene with others at DOE to discuss how to tie in previous DOE-Vermont work with this project. Further, the GMI team will follow up to see how to use this work after this project concludes. The team should consider sharing their findings with neighboring states that are also looking at DER in their state energy planning.

Transactive Campus Demonstration

WBS #:	1.3.99
Principal Investigator:	Srinivas Katipamula
Project Run Time:	October 2015-October 2017



Deployment of peak-load management and transactive control buildings (top image). Migration of short-term imbalance from distributed renewable generation using flexible building loads (bottom image).

Project Description

Pacific Northwest National Laboratory is teaming with Washington State University and the University of Washington to form a multi-campus network and conduct research that advances transactive control of DERs in the *Transactive Campus Demonstration* project. Transactive control work could include building loads, energy storage systems, smart inverters for PV solar systems, and electric vehicles.

Key goals of the research include (1) demonstrating how significant energy cost savings are possible in commercial buildings and (2) integrating renewables at a regional scale by using the transactive control technology to coordinate a number of energy assets. Although the ultimate goal of the research will address coordination at four physical scales—single building, single campus, multi-campus, and community micro-grid—the first phase of the work will only test transactive controls at the building scale.

DOE project funding for the project are matched by an investment by the Washington Department of Commerce through the Clean Energy Fund. These funds will be used to establish testbeds (e.g., PV panels, smart inverters) and procure control and communication equipment, enabling each of the team partners to configure their campus to support research.

Reviewers' Overall Comments

Reviewers approved of the project team's fractal approach, collaboration with non-DOE funding partners, and focus on utilizing buildings to provide ancillary services to enable a more resilient grid with a high penetration of DERs. One reviewer noted that they could easily see how results from this project could be used in other geographic locations, such as California, who has a building energy use reduction goal.

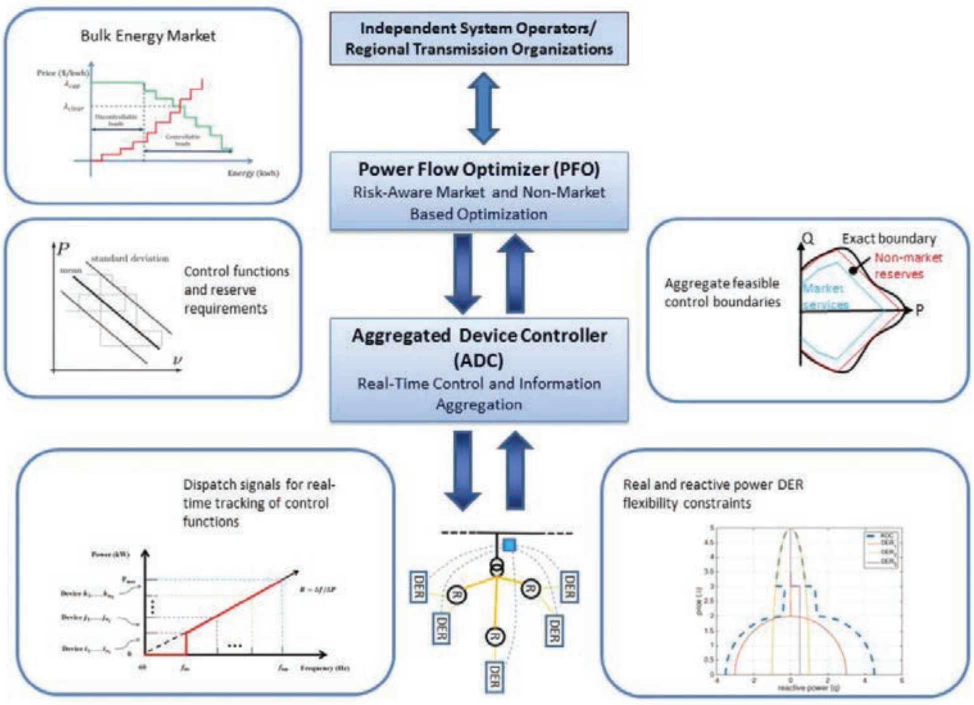
One reviewer wanted to see additional information on ancillary services such as frequency support and voltage support, which could be very useful for other GMLC projects. This reviewer recommended the project team assess some of the smart inverter functions for use in the ancillary services market given that they are becoming mandatory in the next few years. Another reviewer wanted to see more synergy between partners on this project.

DOE Follow Up

In year 2, the GMI team should include the use of transactive components in other markets. The team is encouraged to include PV inverter coordination is part of the ongoing effort.

Control Theory

WBS #:	1.4.10
Principal Investigator:	Scott Backhaus
Project Run Time:	April 2016-April 2019



Interfaces for Power Flow Optimizers (PFO) and Aggregated Device Controller (ADC) systems.

Project Description

The increasing penetration of variable renewable power generation (both centralized and distributed) in many electrical transmission and distribution power systems is changing the operational paradigm for balancing load and providing reactive power for regulating voltage. These changes are driving an emerging transition to leverage a large latent capability in the grid to control DERs, which include distributed generation, battery storage, and loads.

To address these concerns, the project team is working to develop and deploy solutions that allow a vast number of DERs to participate in "grid control," enabling the grid to operate with leaner power reserve margins—meaning more reliably and cost effectively for stakeholders (e.g., utilities and consumers).

The *Control Theory* project develops new solutions in grid control topologies, algorithms, and strategies that will alleviate the impacts of large DER deployments to the power grid and help to maintain the most efficient and cost-effective power operating margins by developing synergistic control theory and system architecture; hierarchical, decentralized, distributed, and risk-aware control; and simulated at-scale testing.

Reviewers' Overall Comments

Reviewers called this project forward looking, groundbreaking, and based on sound engineering principles. One reviewer noted that projects that develop new algorithms, models, and tools, like this project, are critical to moving to the next generation of capabilities, as expanding existing systems will have always limitations.

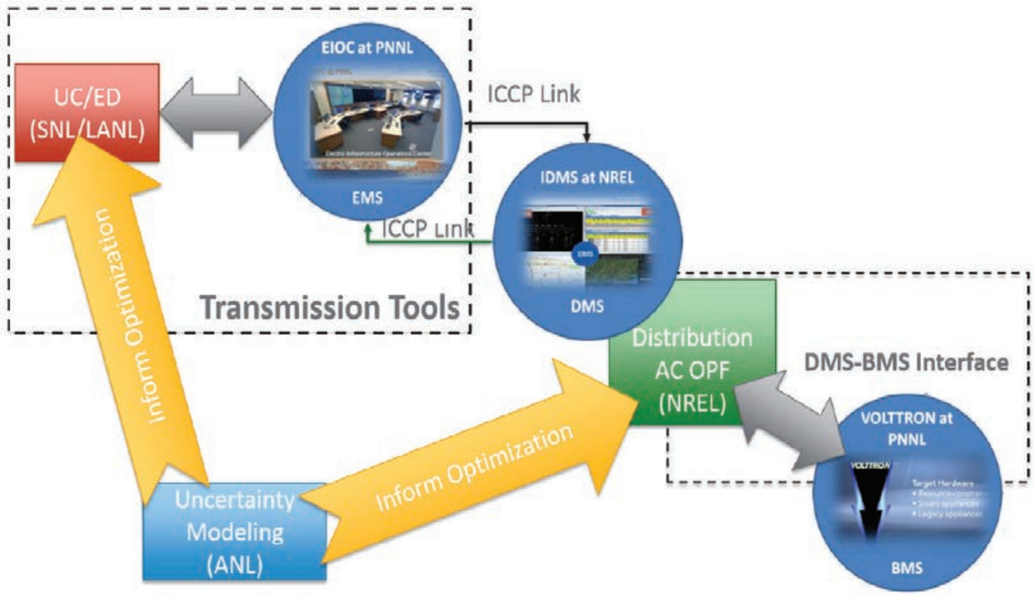
One reviewer questioned the project's theory of developing the capabilities of aggregated device controllers (ADCs) placed strategically in the power grid to optimize it with respect to constraint and congestion. Specifically, the reviewed was concerned about the assumption of no congestion between the ADCs and DERs, which, the reviewer argued, does not properly take the dynamic nature of DERs nor the DER owner/operator priorities into account. This reviewer recommended taking smart and autonomous capabilities of DERs into account rather than assume rather than assume ADCs will take all control.

DOE Follow Up

The project team should continue the scope as planned with the goal of developing new solutions in grid control topologies, algorithms, and strategies that will alleviate the impacts of large DER deployments to the power grid and help to maintain the most efficient and cost-effective power operating margins.

Multi-Scale Integration of Control Systems (EMS/DMS/BMS)

WBS #:	1.4.11
Principal Investigator:	Liang Min
Project Run Time:	May 2016-December 2018



Energy Management Systems (EMS), Distributed Management Systems (DMS)/Building Management Systems (BMS) System Architecture.

Project Description

The current approach to electric power system operations and controls was developed during the last three to four decades using a piecemeal approach, within narrow functional silos, and well before the development of modern computational capabilities. The rapid growth of renewable power generation, the increased use of electric vehicles, and the growing need to integrate customers with the power system are rendering the current generation of grid operating systems obsolete.

The *Multi-Scale Integration of Control Systems* project creates an integrated grid management framework akin to having an autopilot system for the grid's interconnected components—from central and distributed energy resources at bulk power systems and distribution systems, to local control systems for energy networks, including building management systems (BMS). The team is developing an open framework to coordinate energy management system (EMS), distribution management system (DMS), and BMS operations. In addition, the project demonstrates the open framework and new operations applications.

Reviewers' Overall Comments

Reviewers thought that the project's integrated grid management framework for the end-to-end power delivery system had an "elegant" solution. Reviewers thought highlight of this project's high-level objectives and project plan, though one reviewer requested additional information on the value proposition offered by multi-scale integration of control systems. Another reviewer questioned the use of the Inter-Control Center Communications Protocol (ICCP) protocol for data exchange, suggesting that ICCP 61850 or Common Information Model (CIM) might be more appropriate in the future for multi-scale integration of control systems. This reviewer recommended that the project team consider developing additional use cases to determine the types of information that need to be exchanged, along with performance requirements to allow audiences to assess which protocols could best meet different requirements.

One reviewer warned that demonstrating and deploying project deliverables may be very challenging due to the major changes they represent, and another agreed that while challenging, integration demonstration projects such as these are "key" to helping states with higher concentrations of DERs make the transition successfully.

DOE Follow Up

The project team should continue the scope as planned creating an integrated grid management framework.

Systems Operations, Power Flow, and Control Portfolio Overview

After the individual project reviews concluded, project principal investigators, DOE project staff, and interested stakeholders discussed the broader Systems Operations Portfolio. Systems Operations Technical Lead Jeff Dagle led the conversation that touched on topics across the systems operations area, including engaging with industry, better communicating project results, , and sharing the latest work in transactive energy.

Many of the stakeholders in the room thought that the portfolio in this technical area looked good and the project work was valuable. One stakeholder called the Systems Operation technical area the "best example of synergy" possible between the labs and suggested further engaging universities to reach goals faster. Dagle agreed that there is a need to include universities more going forward and hopefully there would be more opportunities to link university projects and GMLC projects.

Participants began by discussing transactive energy, with one stakeholder noting the need to define the value of switching to transactive systems compared to current, legacy systems; the stakeholder also highlighted the need to compare that value against the costs of making the switch. Dagle noted the importance of considering the timespan for work—moving to a transactive system is a long-term goal, but in the meantime, legacy systems that provide ancillary services must continue to work as expected. Some DOE work is focused on near-term technical support that helps address near-term challenges; other work, including transactive control, control theory, and ADMS, is foundational for mid- and long-term actions (10, 15, or 20 years out).

Dagle argued that it would be relatively easy to develop a transactive energy framework with discrete and distinct levels, each having its own constraints and communication needs. However, he warned, this simple framework can quickly become complicated when trying to account for new grid services. Market requirements for new grid services are still emerging and add complexity to system operations. Though many of these services provide useful functionality, it is still unclear how these services will be monetized. Without a meaningful way to describe their value, it is impossible for electric power industry stakeholders to plan and execute the long-term process required to implement transactive services.One reviewer argued that where Dagle saw complexity, he saw simplification with the emergence of the GMLC grid architecture reference documents; he continued by stating that moving toward commonly understood consensus with different vocabularies and skills would be beneficial.

Stakeholders continued to return to the need to better define "value," especially when paired with the need for better communication of project activities and results to the wider community. One reviewer noted that given that industry is moving forward rapidly with new standards, requirements, and capabilities, communicating with industry is key—both to incorporate new findings into GMLC research and to push GMLC findings into industry actions and discussions. It was suggested that this technical area might benefit from being able to clearly articulate why this technical area is working on the projects it has selected and what the value is for each to help tie business cases to technical approaches going on across the portfolio.

Dagle noted that the engagement within the technical area relies heavily on industry partnerships. He pointed to the six regional meetings held to discuss the Grid MYPP as an opportunity to incorporate geographically diverse viewpoints into the next update to the Grid MYPP. Another GMLC stakeholder noted that GMI is working to get the entire grid "ecosystem" together in the hopes of realizing the vision of collaborating and leveraging unique assets within the lab system. Combined with utilities and vendor partnerships to help visualize, test, compare, and contrast new models, this collaborative approach will ideally shorten the time to innovation. One reviewer argued that there is a need to adopt a paradigm of continual improvement, not perfection or optimization. This can only happen by communicating new findings, papers, concepts, and research.

Lead Reviewer Portfolio Discussion Summary

After the Grid Modernization Peer Review formally ended, DOE staff, GMLC Technical Leads, and lead peer reviewers for each technical area met the morning of April 21 to discuss lessons learned from the event. The event was led by Bill Parks (Chair) and Kevin Lynn (Co-Chair). The intent of the session was to gauge initial reactions from peer reviewers (prior to final submission of formal review) and to offer feedback on this first-time event.

Reviewers from the Institutional Support technical area thought this technical area had "good projects" moving in the right direction. The lead reviewer praised the collaborative aspect of the GMLC projects reviewed over the last three days, noting that each laboratory has skills and abilities to offer towards the overall goal of grid modernization. They argued there is a need for clear communication from project staff, especially noting the need for meaningful communication of successes and accomplishments for new technical work. As a part of this communication, they recommended additional engagement within the larger community, including with state stakeholders and interest groups, to ensure that other states working on this don't start from scratch but are able to pick up the work being done by these projects. One specific suggestion offered was organizing mentorship between states to help pass lessons learned from leading states (who are benefitting from GMLC technical assistance) and emerging states in a "train-the-trainer" format.

Reviewers from the Security and Resilience technical area stressed that partnership with industry is key for findings from this work to be incorporated into the real world. Reviewer feedback focused on the private sector's skill at software security, arguing the research opportunity for the lab is to look towards the future and understand where utilities and other standard organizations need to be heading towards. Security, they argued, is more than device security – it's also strong interoperability standards to ensure that overall systems are secure and devices are only responding to the right queries. Reviewers were concerned that this area might not be adequately covered within the current portfolio of GMLC projects and noted the need for security to be holistically incorporated into all GMLC projects.

Reviewer feedback for the Sensing and Measurement technical area observed that the communications aspect of the Grid Multi-Year Program Plan (Grid MYPP) appeared lacking in the GMLC projects reviewed that week, recommending DOE consider that gap moving forward. Discussion also put emphasis on DOE's role in data quality, noting that poor feedback could stymie potentially great applications and the need to ensure overall quality is addressed when working on developing new sensor technologies. Overall DOE strategy and roadmaps were felt to be very valuable, with reviewers noting that GMLC efforts in this field needs to be able to demonstrate context and purpose in the market for its project work. Reviewers recommended additional engagement with industry, especially vendors, manufacturers, and academic institutions in the course of sensor development.

Within Devices and Integrated Systems, reviewers noted that national laboratories are strong in this area but suggested more focus on early-stage research and development. Device development, reviewers argued, should be guided by a larger roadmap with clear objectives and targeted performance metrics. Reviewers questioned if there should be future foundational investments in power electronics and energy storage coordinate across DOE rather than in individual program areas (as it is currently). Reviewers suggested that GMLC help focus on inter-lab coordination, where DOE could help to engage with industry on issues such as testing and standard development work.

In Systems Operations, Power Flow, and Control, reviewers praised the overall portfolio of projects reviewed. They cautioned that individual demonstration projects need to be generalized so that they can be easily picked up and used by others regions and states across the U.S. Reviewers also questioned the lack of analytics and computation for grid operation and control and power flow projects – two areas explicitly noted in the Grid MYPP (though they prioritized potential future work in analytics and computation over power flow research questions). Reviewers also cautioned that transactive work in this field remains a challenge, where many view it as complicating rather than simplifying. Reviewers praised the foundational work done in grid architecture and requested the program work to make the material more accessible to the community.

The final technical area discussed was Design and Planning. Reviewer feedback in this area discussed the need for open-source software whenever possible, ideally with tools that have standardized interfacing that will make it easier for existing vendors to adopt new tools developed in GMLC work. Reviewers stressed the need to lower the barrier to adoption from utilities, who all have different needs and capabilities. Open-source software and open data repositories are two key considerations for meeting that need. Reviewers also argued that they believed that the design and planning space is ripe for an overarching planning strategy or roadmap and could really benefit from government (not just DOE, but also FERC and NERC) leadership. Using its convening authority, they argued, this is an area where GMLC could help lead to more robust planning criteria and standards to help enable grid modernization advancements.

Finally, reviewers noted that projects need to incorporate economic aspects (costs, benefits, and opportunities) from their work and be able to communicate clearly with audiences. The room also identified several gaps in the existing project portfolio, including data analytics, a broader communications roadmap, and improving external communications to stakeholders. One other specific recommendation was in the next update of the Grid MYPP with updates from the regional workshops conducted in early 2017.

Thank You

Peer Reviewers are vital to the success of projects and programs at DOE. Their input provides GMI with a powerful and effective avenue for enhancing the management, relevance, effectiveness, and productivity of the grid modernization project portfolio. Although they were unpaid, the reviewers committed to reviewing hundreds of pages prior to the review, as well as several hours after the actual review for follow-up actions. For their subject expertise and selfless actions, DOE—especially the GMI leadership team—would like to express it's profound thanks to the GMI Peer Reviewers:

Reviewer	Affiliation
John Adams	Electric Reliability Council of Texas
Tracy Babbidge	Connecticut Department of Energy and Environmental Protection
Dave Bakken	Washington State University
Venkat Banunarayanan	National Rural Electric Cooperative Association
Anjan Bose*	Washington State University
Frances Cleveland	Xanthus Consulting
Lisa Dignard-Bailey*	Natural Resources Canada
Matthew Gardner	Dominion Energy
Michael Gravely	California Energy Commission
Rick Meeker*	Nhu Energy
Craig Miller*	National Rural Electric Cooperative Association
Reynaldo Nuqui	ABB
Terry Oliver*	Bonneville Power Administration
Subhash Palaru*	Western Area Power Administration
Heather Sanders	Southern California Edison
Michael Winka	New Jersey Board of Public Utilities

**Lead Reviewer*

We would also like to thank DOE's General Counsel and Contracting Officers who provided guidance with GMI's first Peer Review, as well as the National Energy Technology Laboratory for managing travel reimbursements. Finally, we would like to thank BCS Incorporated, Energetics Incorporated, and AtherQuest Solutions for providing support to this review.

Glossary

Cascading – A series of components or networks, the output of each of which serves as the input for the next.

Microgrids – A small network of electricity users with a local source of supply that is usually attached to a centralized national grid but is able to function independently.

Power Systems – A network of components deployed to supply, transfer, store, and use electric power. An example of an electric power system is the grid that provides power to an area.

Reserve Margins – An energy producer's capacity to generate more energy than the system normally requires.

Synchrophasors – Time-synchronized numbers that represent both the magnitude and phase angle of the sine waves found in electricity, and are time-synchronized for accuracy.

Transactive Energy – The control techniques used to manage the flow or exchange of energy within an existing electric power system in regards to economic and market based standard values of energy.

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