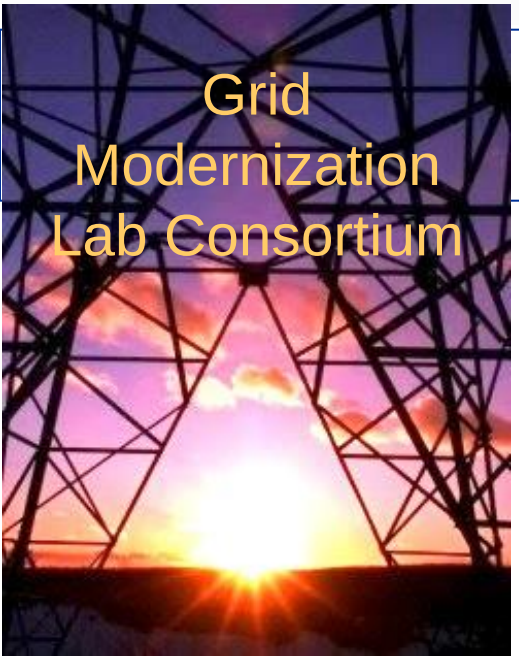

U.S. DEPARTMENT OF ENERGY

Grid Modernization Cross-cut Initiative

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Context for Grid Modernization

- Time of transition
  - System observability and controllability transitioning rapidly
  - Growth in intelligent devices at systems edge challenging traditional paradigms
  - Complexity increasing due to variable generation, transition from coal to gas, intelligent loads, natural phenomena, increased human risk
- Public / private partnership viewed as fundamental to grid modernization
  - Grid viewed as central to clean energy future; DOE and White House understand importance in delivering solutions at regional level in partnership with industry and states.
  - Industry increasingly challenged regarding R&D and long-term focus
  - Regulators challenged to innovate the traditional regulatory utility model
  - National Labs able to aim mid and long-term; support DOE leadership in fundamental policy considerations
- Vendors, utilities and universities are key stakeholders for guiding the translation from discovery to commercial implementation
  - Important to DOE and Lab advisory groups to guide strategy
  - Key partners in regional demonstrations and channel for national benefit

Grid Modernization Vision

The future grid provides a critical platform for U.S. prosperity, competitiveness, and innovation in a global clean energy economy. It must deliver ***reliable, affordable,*** *and* ***clean electricity*** *to consumers where they want it, when they want it, how they want it.*

Enhance the Security of the Nation

- Extreme weather
- Cyber threats
- Physical attacks
- Natural disasters
- Fuel and supply diversity
- Aging infrastructure

Sustain Economic Growth and Innovation

- New energy products and services
- Efficient markets
- Reduce barriers for new technologies
- Clean energy jobs

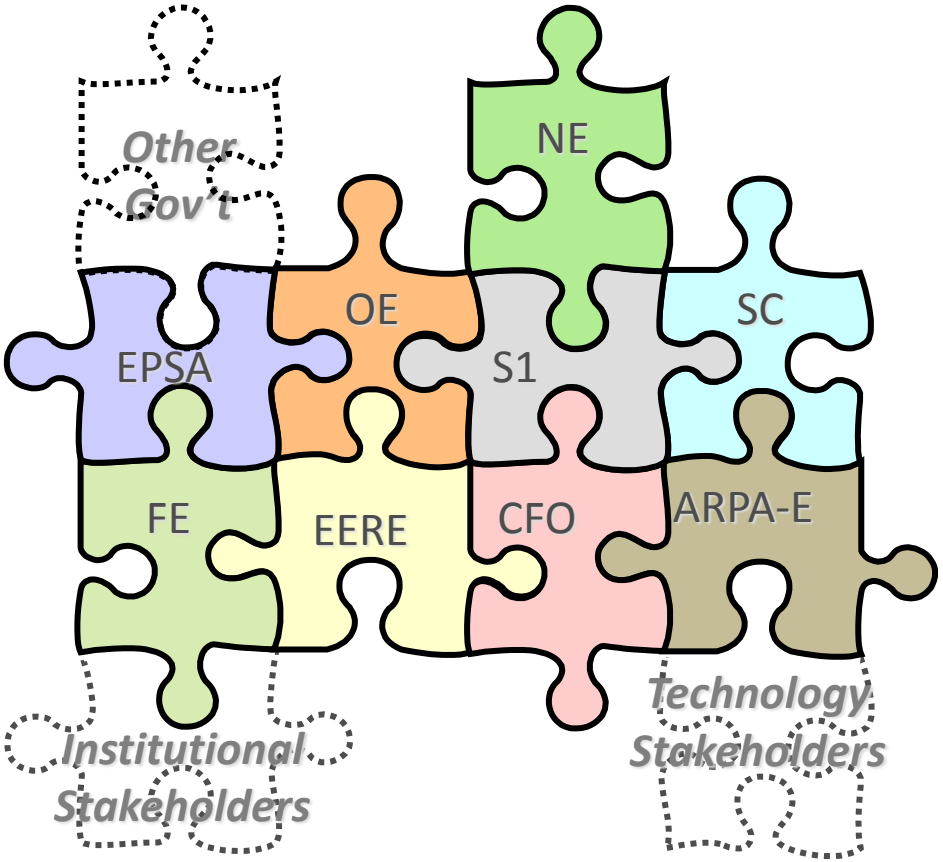
Achieve Public Policy Objectives

- 80% clean electricity by 2035
- State RPS and EEPS mandates
- Access to reliable, affordable electricity
- Climate adaptation and resilience

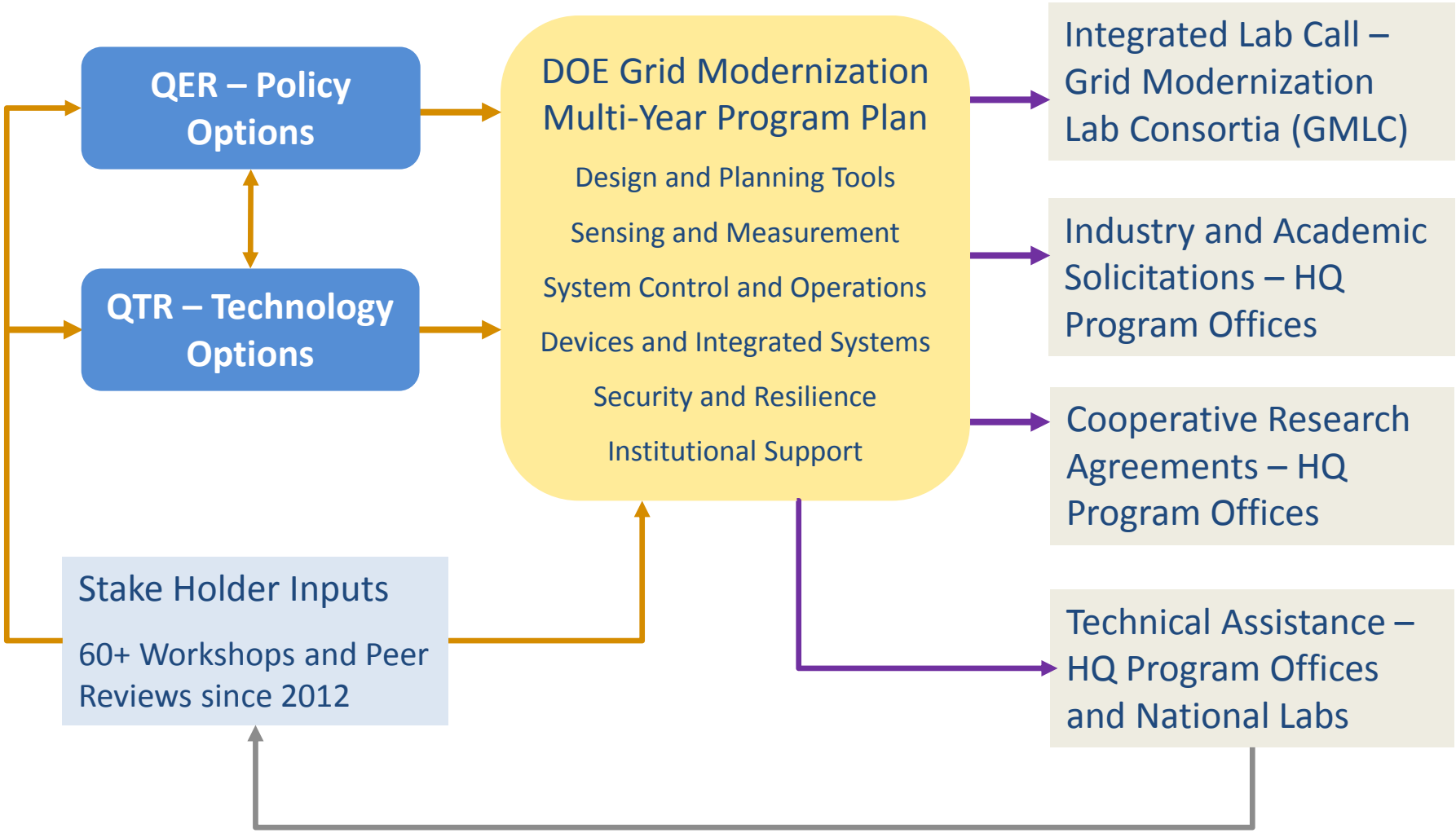
Grid Modernization Initiative

An aggressive five-year grid modernization strategy that includes

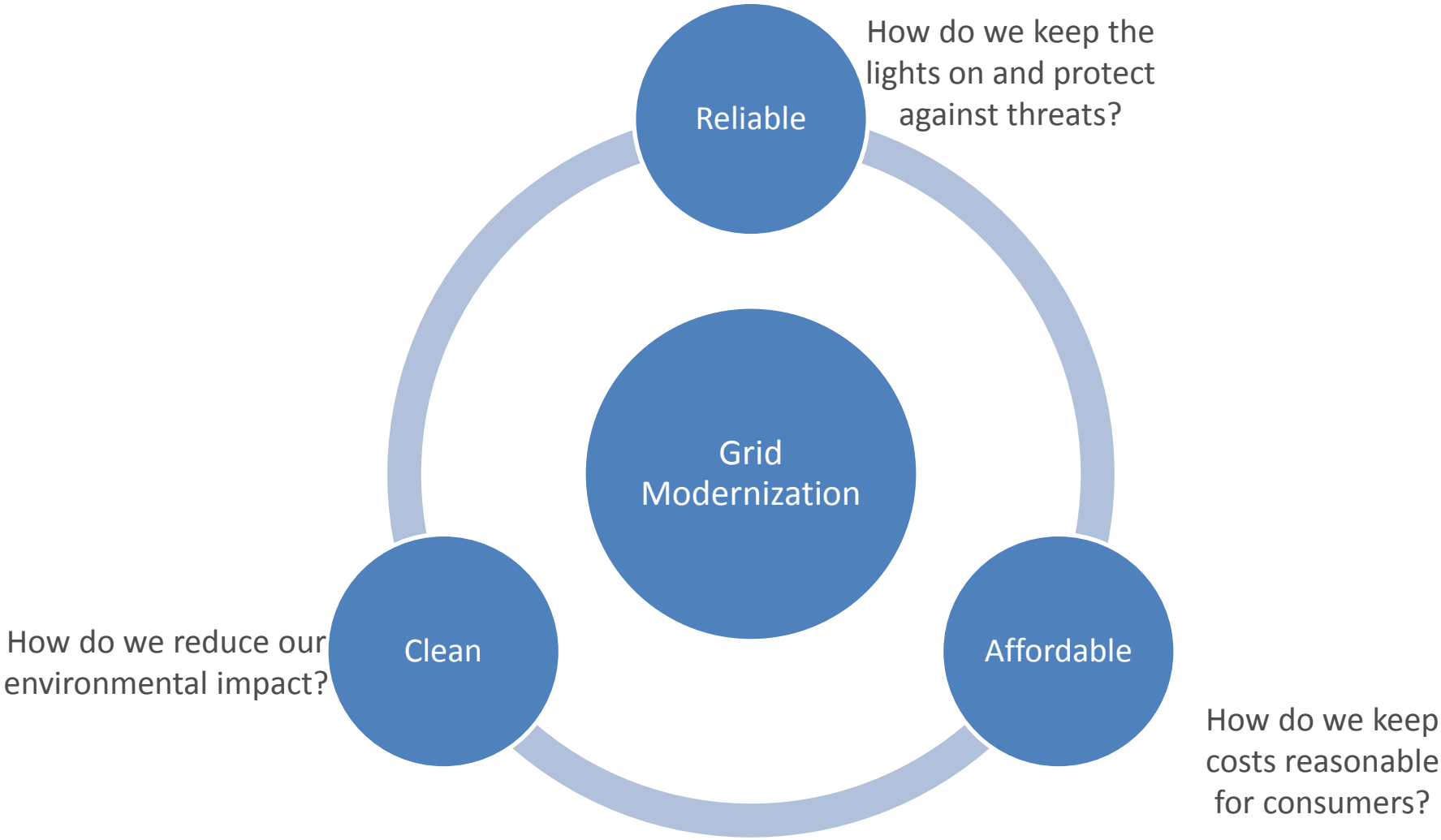
- Alignment of the existing base activities among the Offices
- An integrated Multi-Year Program Plan (MYPP)
- New activities to fill major gaps in existing base
- Development of a laboratory consortium with core scientific abilities and regional outreach



Connectivity to Other DOE Activities



Key Attributes of a Modernized Grid



National Goals and Outcomes

- This new crosscutting effort will build on past successes and current activities to help the nation achieve at least three key outcomes within the next ten years:
  - > **Reliability:** *10% reduction in the economic costs of power outages*
  - > **Affordability:** *33% decrease in cost of reserve margins while maintaining reliability*
  - > **Clean:** *50% cut in the costs of Distributed Energy Resources integration*

- If achieved, these three key outcomes would yield more than $7 billion in annual benefit to the U.S. economy

- In addition, our efforts will ensure the future modernized grid is a flexible platform for innovation by entrepreneurs and others who can develop tools and services to empower consumers and help them make informed energy decisions.

DOE Major Achievements

- **Major Achievement #1 – Lean Bulk Power Systems**
  - **Reliable**: Maintain reliable operations with <=10% reserve margin;
  - **Clean**: Systems include >33% variable energy resources;
  - **Affordable**: New capability for grid operators to leverage and manage distribution-level grid services will require less generation reserve
- **Major Achievement #2 – Clean Distribution Systems**
  - **Clean, Reliable**: Demonstrate reliable and affordable feeder operations with >50% DER penetration
  - **Reliable**: Coordinated microgrid(s) control for resilience (20% fewer outages, 50% shorter recovery time)
  - **Affordable**: Distributed, hierarchical control for clean energy and new customer-level innovation for asset utilization
- **Major Achievement #3 – Grid Planning and Analytics**
  - **Reliable**: Use coupled T&D grid planning models with 500x speed-up to address specific grid issues
  - **Clean**: Develop with stakeholders new data-driven approaches to DER valuation and market design
  - **Affordable**: Work with States to more rapidly evaluate new business models, impacts of policy decisions

Building on our integrated technical thrusts

Technology Innovation

Institutional Alignment	•Evaluate regulatory and policy options and implications of various grid ownership and operations models – support utility and regulatory reform through technical assitance
Design and Planning Tools	•Develop planning tools that integrate transmission and distribution and system dynamics and can use high performance computing platforms - deliver 500x speed-up
System Control and Power Flow	•Increase ability to coordinate and control up to millions of devices and integrate with energy management systems – coordinate millions of devices; enable one-minute contingency analysis at the interconnect scale
Sensing and Measurements	•Develop sensors, analytics, and visualizations that enable 100% observability of generation, loads and system dynamics across the electric system – develop low cost sensors at all scales, handle 1000x data volumes, visualization tools, dynamic accuracy
Devices and Integrated Testing	•Develop advanced grid control and integration devices and validate integrated systems that can optimize operations at high variable RE penetrations and provide high reliable service – validate 50-100% DG penetration scenarios on feeders
Security and Emergency Response	•Develop advanced security (cyber and physical) solutions and real-time incident response capabilities – capable of identifying cyber events in real-time and analyzing within 12 hours.
Risk Mitigation through Multi-scale Pilots	•Develop megawatt-scale demonstrations that show transfer of the technologies developed through R&D activities into the field linked to policy and market decision tools

System Operations, Power Flow, and Control

Advanced control technologies to enhance reliability and resilience, increase asset utilization, and enable greater flexibility of transmission and distribution systems

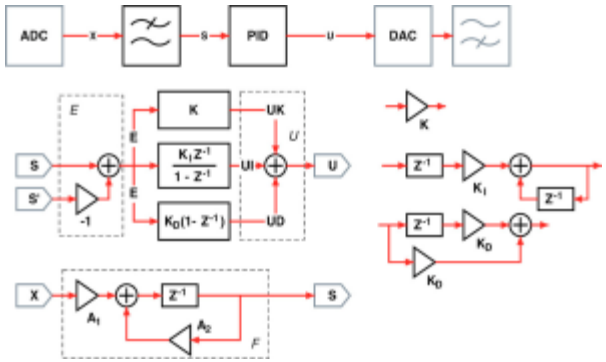
Expected Outcomes

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

Federal Role

- Convening authority to shape vision of advanced grid architecture, including new control paradigms for emerging grid to support industry transformation
- Deliver system engineering and other supporting capabilities from the National Laboratory System to research & develop integrated faster-than-real-time software platforms and power electronics controls

Conventional *controls*

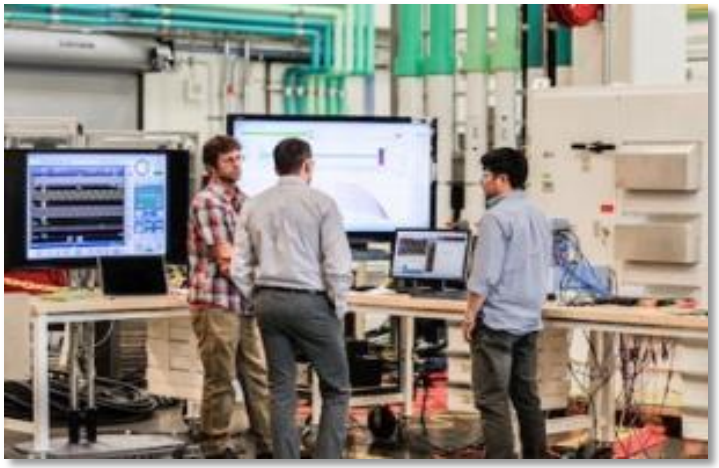


Distributed *controls*

Activities and Technical Achievements

Activity	Technical Achievements by 2020
1. Develop Architecture and Control Theory	• Comprehensive architectural model, associated control theory, and control algorithms to support a variety of applications to improve grid flexibility, future adaptability, and resilience while not compromising operational reliability or security. • Wide-area control strategies to improve reliability, resilience, and asset utilization.
2. Develop Coordinated System Controls	• New control grid operating system designs reflecting emerging system control methodologies. • Framework(s) for integrating the next generation energy management system (EMS), distribution management system (DMS), and building management system (BMS) platforms.
3. Improve Analytics and Computation for Grid Operations and Control	• Future and real-time operating conditions with short decision time frames and a high degree of uncertainty in system inputs can be evaluated. • Automation with predictive capabilities, advanced computational solvers, and parallel computing. This includes non-linear optimization of highly stochastic processes. • Decision support to operators in control rooms through pinpoint visualization and cognitive technologies.
4. Develop Enhanced Power Flow Control Device Hardware	• Low-cost, efficient and reliable power flow control devices that enable improved controllability and flexibility of the grid.

Device and Integrated Systems Testing



- **Develop devices & integrated systems**
- **Coordinates integration standards & test procedures**
- **Evaluates characteristics of both individual devices & integrated systems to provide energy services at a variety of scales**
- **Devices**: individual technologies that connect to the grid including: PV, CSP, wind, EVs, electricity & thermal storage, building loads, appliances, HVAC systems, lighting, fuel cells, electrolyzers, CHP/BCHP, engines, microturbines, wires, cables, switches, transformers, etc. Device local controllers (DER controllers, building EMS) are covered in this area. Sensors are covered in Sensor area. Power flow controllers are covered in System Operations area.
- **Integrated Systems:** Integrated systems contain multiple devices/technologies integrated to achieve an energy goal. Examples: buildings, aggregated fleets, microgrids, campus energy systems, subdivisions, distribution circuits, multiple distribution circuits, regional electric grids that include sub transmission & transmission systems.
- **Energy services:** value-added services & transactions for device & system owners include both energy services & ancillary services (e.g. frequency & voltage support, spinning reserves, etc.) with the electric grid & with other parties.

Device and Integrated Systems Testing

Helping meet high-level GMLC Goals

Reducing Customer Outages

- Developing cost effective energy storage that can provide local area backup power
- Testing & evaluating microgrid concepts that provide improved customer reliability

Decreasing Operating Reserves

- Developing renewable generation, distributed generation, storage & controllable loads that can provide reserves to bulk power system at economic cost
- Developing interconnection & interoperability standards & test procedures to characterize devices' ability to provide reserves
- Validating that renewable generation, distributed generation, storage & controllable loads can provide reserves for bulk power system

Reducing Integration Costs

- Developing smart interfaces to renewable generation, distributed generation, storage & controllable loads that can reduce interconnection costs
- Develop interconnection & interoperability standards that streamline processes & reduce renewable energy integration costs
- Advanced components & key materials critical for enabling next generation of devices (capacitors, packaging materials, magnetic materials, etc.)

Security and Resilience

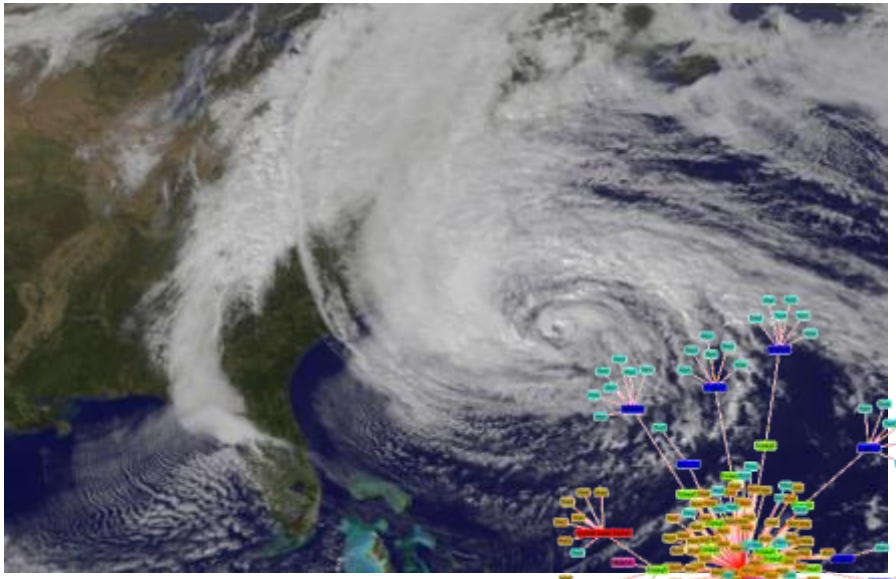
Providing a pathway to holistic and comprehensive security and resilience for the nation's power grid

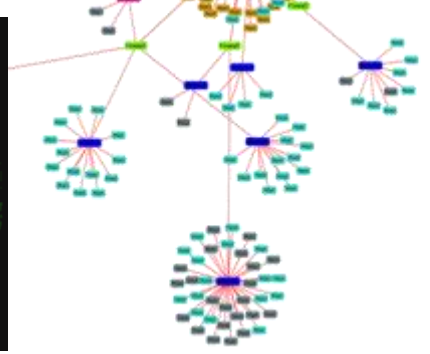
Expected Outcomes

- Holistic grid security and resilience, from devices to systems
- Inherent security designed into components and systems vs security as an afterthought
- Security and resilience addressed throughout system lifecycle and covering the spectrum of legacy and emerging technologies

Federal Role

- Lead and establish security and resilience research programs to develop technology solutions and best practice guidance
- Improve adoption of security and resiliency practices, and provide technology-neutral guidance
- Inform stakeholders of emerging threats and help address threats appropriate for government response





Security and Resilience Activities & 2020 Achievement Targets

Activity	Technical Achievements by 2020
6.1. Improve Ability to Identify Threats and Hazards	• An all hazards approach for threat identification and emergency response, which is accepted and implemented by the energy sector.
6.2. Increase Ability to Protect Against Threats and Hazards	• Standards, methods, testing and evaluation procedures for physical and cyber security enabled designs. • Development, demonstration and field validation of novel energy, communication and control system models and logistical optimization techniques. • Grid components which are inherently protective of grid services to all-hazards.
6.3. Increase Ability to Detect Potential Threats and Hazards	• Advanced cyber-physical data analytics and cognitive learning, spanning time scales and data sources across the system lifecycle, to enable proactive and real-time information flow by the end of FY20.
6.4. Improve Ability to Respond to Incidents	• Methodologies and architectures frameworks which assess system degradation to all hazards, provide diverse attack recognition and mixed-initiative response on multiple timescales, and optimize operational efficiencies/priorities for the power grid.
6.5. Improve Recovery Capacity/Time	• Advanced substation and transformer designs and standards that facilitate improved transformer portability and rapid substation recovery. • Hardened fail-safe and wireless communications capabilities and devices for grid control systems that resist impacts from cyber, geomagnetic disturbance, and electromagnetic pulse events.

Design and Planning Tools

Drive next generation of tools to accurately perform cost-benefit trade-offs and improve reliability of design for deployment new smart grid and renewables

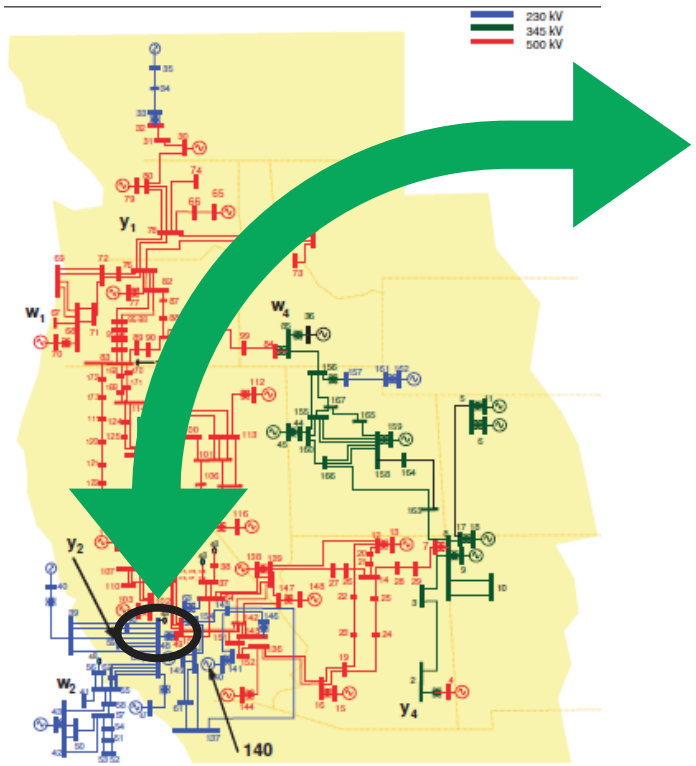
Expected Outcomes by FY20

- Coupling grid transmission, distribution, and communications models to understand cross-domain effects
- Computational tools, methods and libraries that enable 1000X improvements in performance for electric production cost simulation
- Incorporate uncertainty and system dynamics into reliability planning tools to accurately capture effects of renewable generations

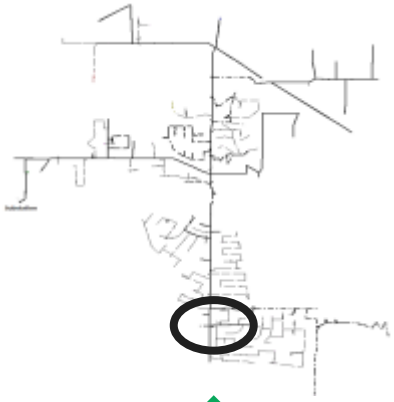
Federal Role

- Apply Natl. Lab advanced computing capabilities to develop next gen tools
- Facilitate stakeholder engagement in R&D and transition to practice

Interconnect



Feeder



Residential Houses

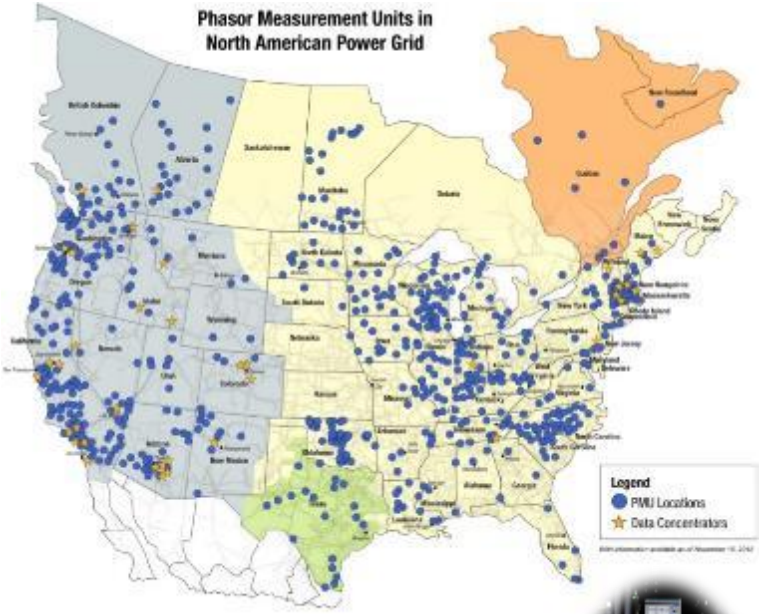
Planning and Design Tools Activities & 2020 Achievement Targets

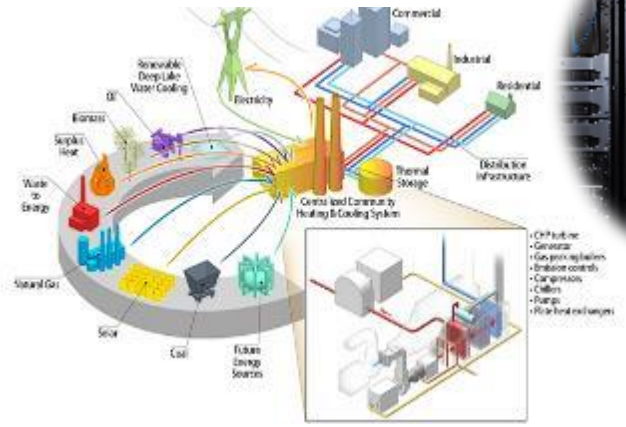
Activity	Technical Achievements by 2020
1. Scaling Tools for Comprehensive Economic Assessment	• Enhance performance of stochastic production cost modeling from 100 to 10,000 transmission nodes; expand modeling to include distribution system. . • Easy-to-use decision support tools based upon complex HPC results that enable cost-benefit analysis for regulators and institutional analysis. • Improve scaling of stochastic tools to model electric and gas system inter-dependencies from 1,000 to 60,000 electric and 100 to 1,000 gas nodes.
2. Developing and Adapting Tools for Improving Reliability and Resilience	• Scalable framework to couple transmission, distribution, communications models for integrated analysis at regional scale • Data-driven tools to automate construction and validation of models of devices, loads, generation, and customer behavior. • Improve of performance of contingency analysis tools by 500x to capture extreme events; enable automated analysis of cascading events. • Develop standards and libraries to couple hardware-in-the-loop (HIL) devices with HIL devices and with HPC systems at a national scale
3. Building Computational Technologies and High Performance Computing (HPC) Capabilities to Speed up Analyses	• Scalable math libraries and tools for enhanced analysis; co-simulation frameworks to support coupling of tools and models, uncertainty quantification, and systems optimization. • Federation of five computational centers established to host grid software, manage access controls, provide data sets for model development and validation, and support analysis for Institutional Support. • Six “prototype-to-practice” projects conducted every year to drive adoption of research results into industry.

Vision: Grid Sensing & Measurement

System Visibility for Enhanced Resiliency and Control

- **Expected Outcomes**
  - Demonstrate novel, low-cost sensors (e.g. under $10/sensor in buildings) to provide nearly 100% observability across the entire electric delivery system by 2020
  - Develop real-time data management and data exchange framework that enables analytics to improve prediction and reduce uncertainty by 2020
  - Develop next generation sensors that are accurate through disturbances to enable closed-loop controls and improved system resiliency by 2020
- **Federal Role**
  - Accelerate the development and deployment of low-cost sensors and a data analytics framework for the next generation grid
  - Ability to transfer data interoperably, securely including frequency coordination with the FCC





Grid Sensing & Measurement Activities & Technical Achievements

Activities	Technical Achievements by 2020
3.1. Improve Sensing for Buildings & End-users	Develop low cost sensors (under $10 per sensor) for enhanced controls of smart building loads and distributed energy resources to be "grid friendly" in provision of ancillary services such as regulation and spinning reserve while helping consumers understand benefits of energy options.
3.2. Enhance Sensing for Distribution System	Develop low cost sensors (under $100 per sensor) and ability to effectively deploy these technologies to operate in normal and off-normal operations Develop visualization techniques and tools for visibility strategy to help define sensor type, number, location, and data management. Optimize sensor allocation for up to 1,000 non-meter sensing points per feeder.
3.3. Enhance Sensing for the Transmission System: Develop Agile Prognostics and Diagnostics for Reliability & Asset Management	Develop advanced synchrophasor technology that is reliable during transient events as well as steady state measurement. Develop low cost sensors to monitor real-time condition of electric grid components.
3.4. Develop Data Analytic and Visualization Techniques	Provide real-time data management for the ultra-high velocities and volumes of grid data from T&D systems. Enable 100% visibility of generation, loads and system dynamics across the electric system through the development of visualization techniques and software tools Develop measurement and modeling techniques for estimating and forecasting renewable generation both for centralized and distributed generation for optimizing buildings, transmission, storage and distribution systems.
3.5. Demonstrate unified grid-communications network	Create a secure, scalable communication framework with a coherent IT-friendly architecture that serves as a backbone for information and data exchange between stakeholders and decision makers.

Institutional Support

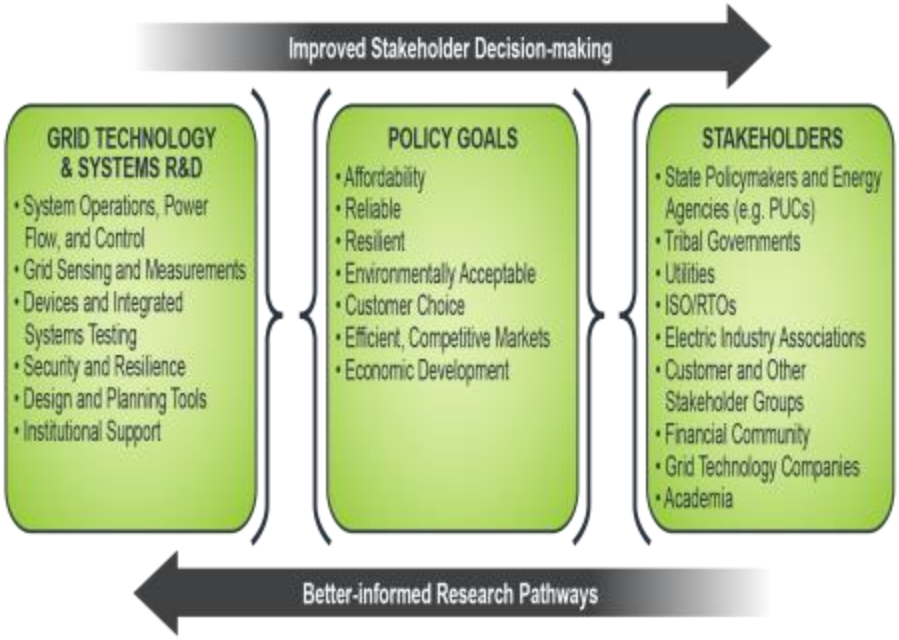
Enable regulators and utility/grid operators to make more informed decisions and reduce risks on key issues that influence the future of the electric grid/power sector

Expected Technical Achievements by 2020

- Accelerated state & federal policy innovation due to enhanced State and Regional technical assistance
- Methods for valuation of DER technologies and services are defined and clearly understood by stakeholders and enable informed decisions on grid investments and operations
- 3-5 states have adopted fundamental changes and 8-10 states have adopted incremental changes to their regulatory structure that better aligns utility interests with grid modernization and clean energy policy goals

Federal Role

- Provide independent, unbiased technical assistance (e.g., information and analysis tools)that address key grid-related policy, regulatory, and market issues
- Create an over-arching stream of grid-related "institutional" analysis, workshops, and dialogues to raise awareness of the need for grid modernization



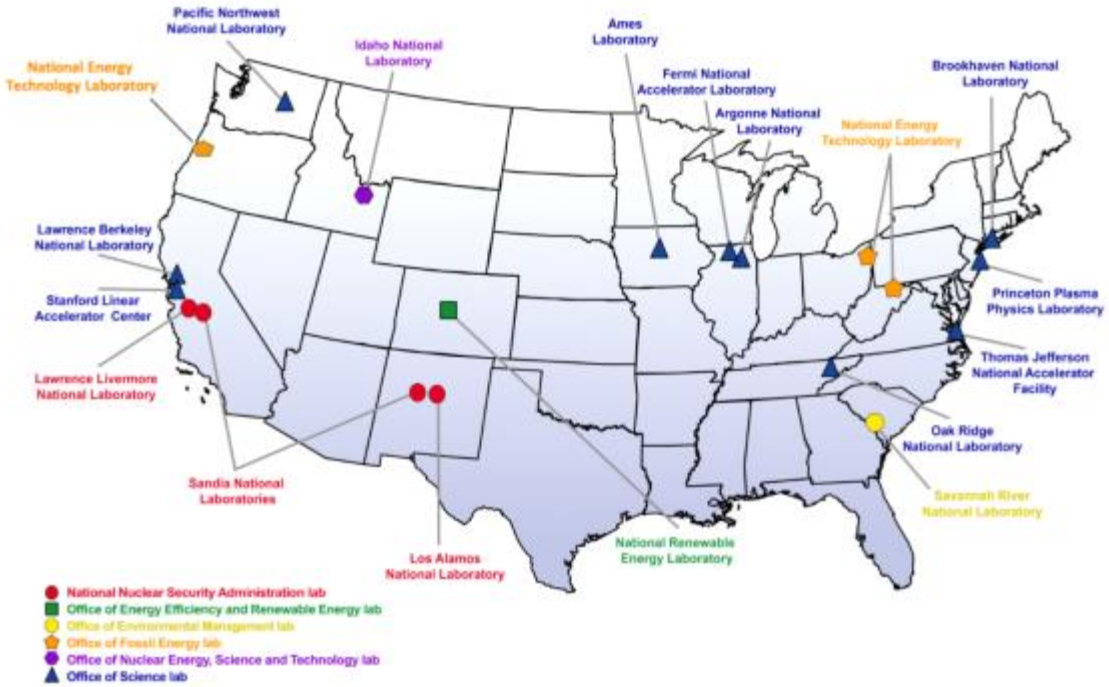
Institutional Support
Activities & 2020 Achievement Targets

Activity	Technical Achievements by 2020
Provide Technical Assistance (TA) to States and Tribal Governments	• TA to all states and tribes to inform their electricity policy decision making and accelerate state policy innovation. • Technical support to at least 10 states that allows them to establish formal processes to review utility distribution system plans, including guidance on consideration of non-wires alternatives, DER, and advanced grid systems. • At least 10 other states have developed comprehensive energy system plans.
Support Regional Planning and Reliability Organizations	• Facilitated long-term regional planning in each U.S. interconnection. • Assisted regional planning organizations in developing institutional frameworks, standards, and protocols for integrating emerging technologies. • Coordinated regional long-term planning process that uses standardized, publicly available databases of transmission and regional resource data and planning assumptions.
Develop Methods and Resources for Assessing Grid Modernization: Emerging Technologies, Valuation, and Markets	• New methods for valuation of DER technologies and services that are defined and clearly understood by stakeholders and enable informed decisions on grid investments and operations. • Analysis tools and methods that facilitate states/tribes' integration of emerging grid technologies into decision-making, planning, and technology deployment. • New Grid Modernization performance and impact metrics and data collection methods, which are used by states to track progress.
Conduct Research on Future Electric Utility Regulations	• 3-5 states have adopted fundamental changes and 8-10 states have adopted incremental changes to their regulatory structure that better aligns utility interests with grid modernization and clean energy goals.

Engaging with Stakeholders

Stakeholder Engagement

- FY15 regional dialogues regarding MYPP
- Gather regional input on grid modernization interests and priorities (FY15 and FY16)
- Future call for regional grid modernization partnerships for demonstrations
- Annual Grid Modernization summits, MYPP updates, solicitations to provide technical assistance



Developing Regional Partnerships using the National Laboratory Complex

What's Next?

- Industry and academia access to DOE grid research continues via traditional pathways
- National Lab engagement will be blend of competitive FOAs, GMLC calls and AOP pathway.
- GMLC advisory groups for each of six technical areas formed 2015
- Regional discussions held with stakeholders thru December 2015
  - Strategy input
  - Frame regional priorities for grid modernization
- Welcome stakeholder input on how best to accelerate ecosystem of innovation between labs, universities, vendors and early adopter utilities

Next year will see energy policy legislation drafted, Grid Modernization Initiative launched and regional discussions regarding grid mod priorities initiated. Vendors have important role in contributing to the planning and execution of grid modernization!