NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Modernizing the Grid for a Low-Carbon Future

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Western States Energy Policy Workshop
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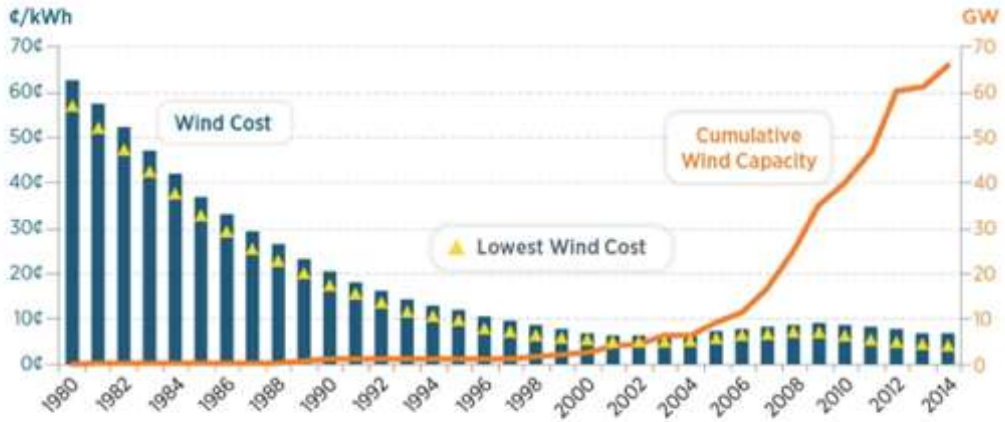
WHY GRID MODERNIZATION?

The existing U.S. power system has served us well…

but our 21st Century economy needs a 21st Century grid.

GROWTH IN VARIABLE RENEWABLES

Land-Based Wind Power



Notes: 1 gigawatt (GW) = 1,000 megawatts (MW). All costs shown are inflation adjusted to dollar year 2014 and exclude the production tax credit (PTC). Wind capacity as reported by market reports.[2] "Wind Cost" represents estimated levelized cost of energy from a representative wind site, and "Lowest Wind Cost" represents costs derived from power purchase agreements from good to excellent wind resource sites in th

Solar PV: Utility-Scale

Notes: All prices are in $/W$_{DC}$ and inflation adjusted to dollar year 2014. 1 gigawatt (GW) = 1,000 megawatts (MW). Prices as reported in market report.[17] "Utility-scale" cumulative installations as reported in source in GW$_{DC}$.[18]

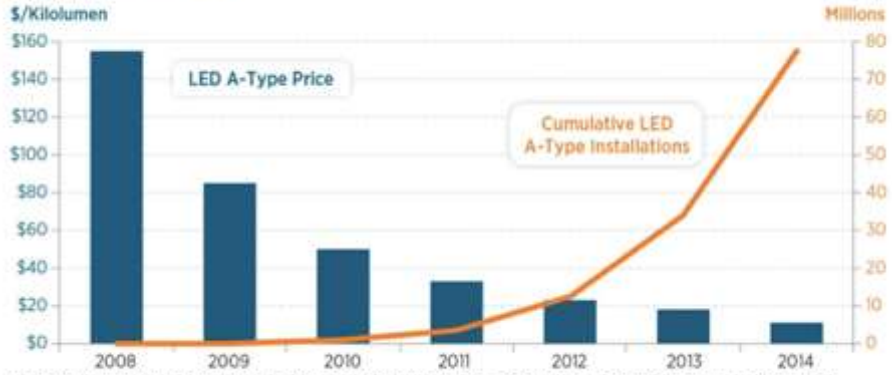
Source: DOE "Revolution Now", 2015

NEW CUSTOMER DEMANDS

Solar PV: Distributed Generation

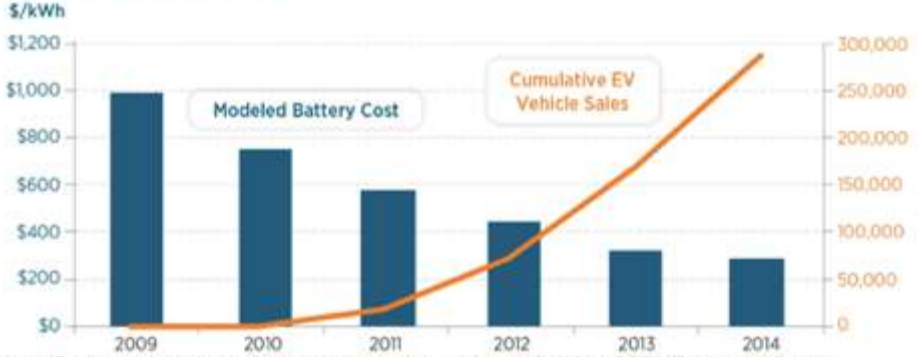
Notes: All prices are in $/W$_{DC}$ and inflation adjusted to dollar year 2014. 1 gigawatt (GW) = 1,000 megawatts (MW). Capacity weighted average as reported by market report for residential systems only.[32] Non-residential systems are typically larger and have lower reported prices. Capacity is cumulative distributed residential and non-residential capacity, in GW$_{DC}$.[33]

LED Lighting



Notes: Kilolumen is a measure of visible light output by a source. Price data is in nominal dollars as reported in internal tracking report.[42] Cumulative LED A-type bulb installations as reported in market report.[43]

Electric Vehicles



Notes: Costs are modeled costs for high-volume battery systems, derived from DOE/UIS Advanced Battery Consortium PHEV Battery development projects and are representative of nominal dollars. Sales as reported by market tracker, here "EVs" include all plug-in hybrid and battery plug-in vehicles.[32]

Source: DOE "Revolution Now", 2015


OKAY...
NOW WHAT?!
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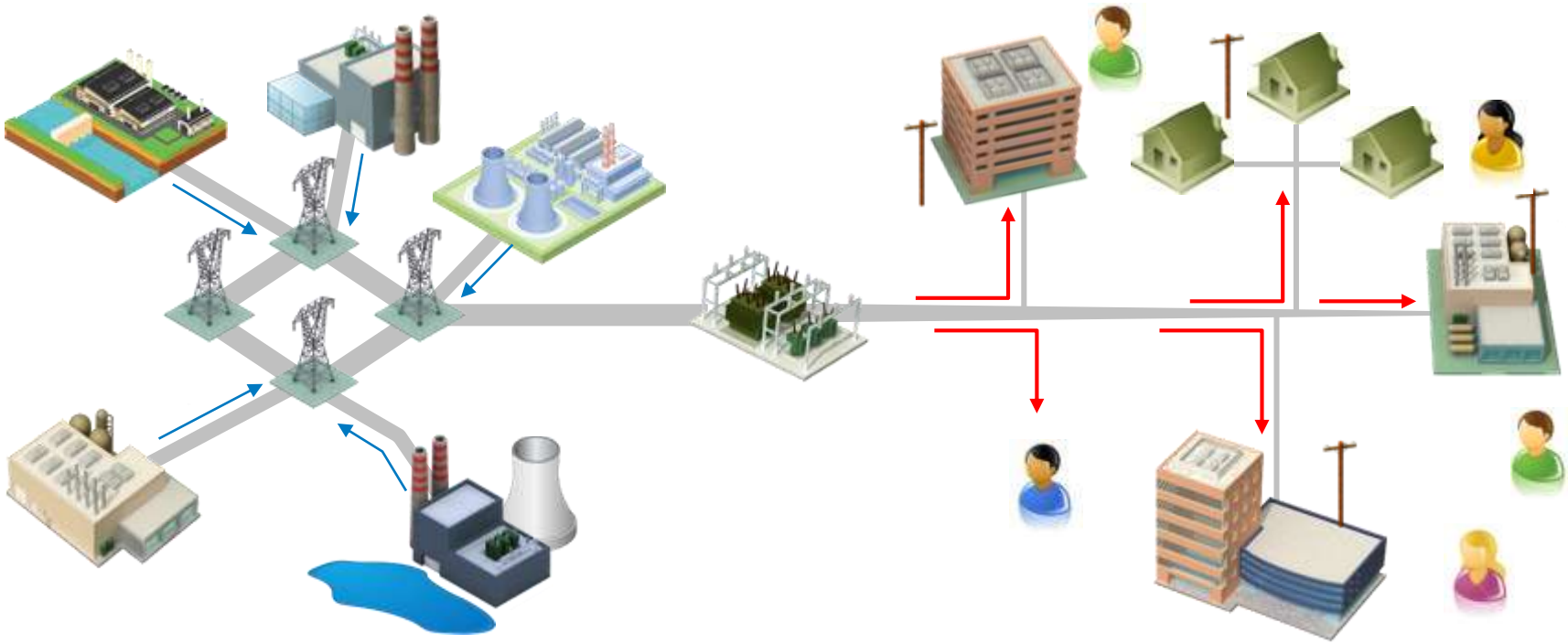
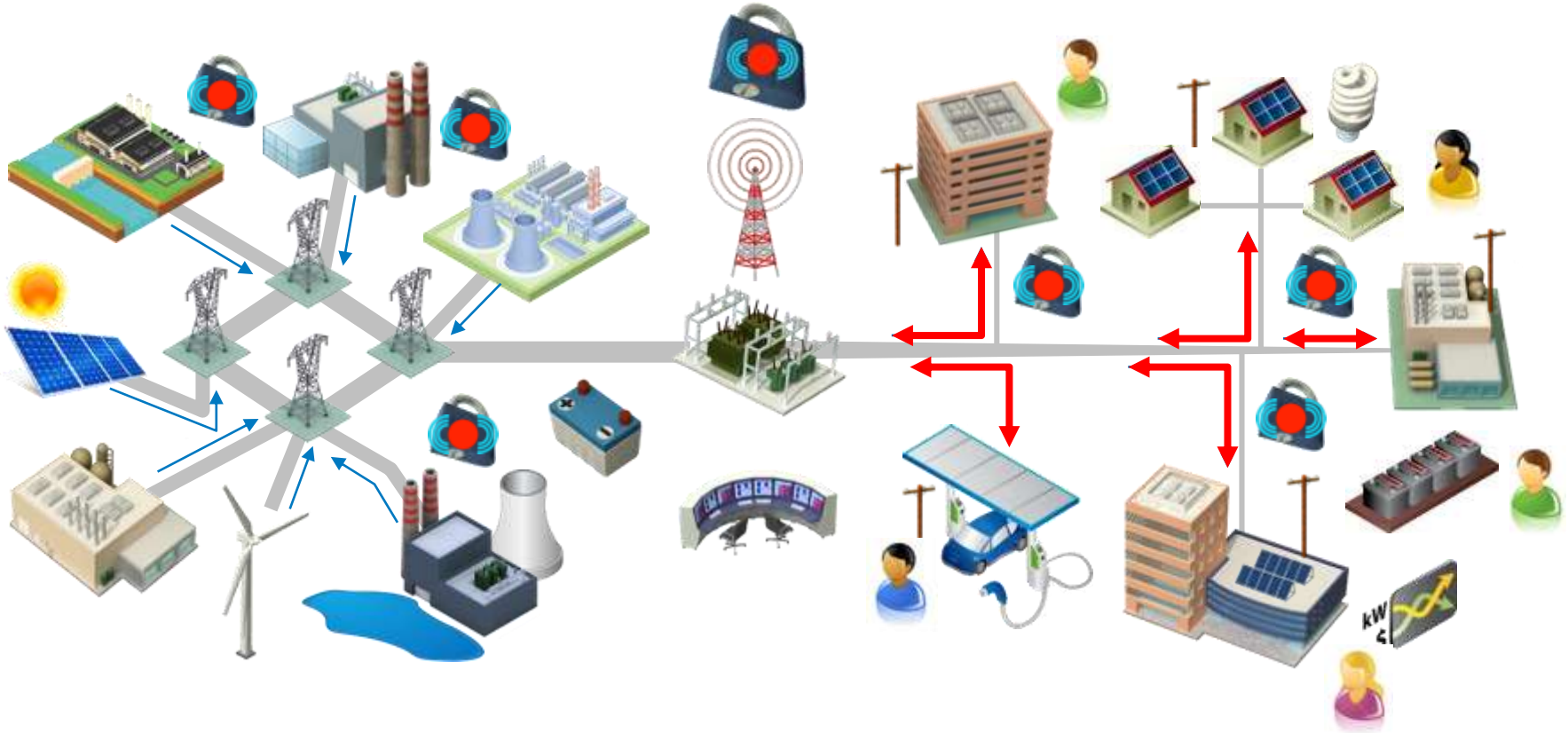
THE GRID OF THE PAST



Generation **Delivery** **Customer**

Source: EPRI, 2009

THE GRID OF THE FUTURE

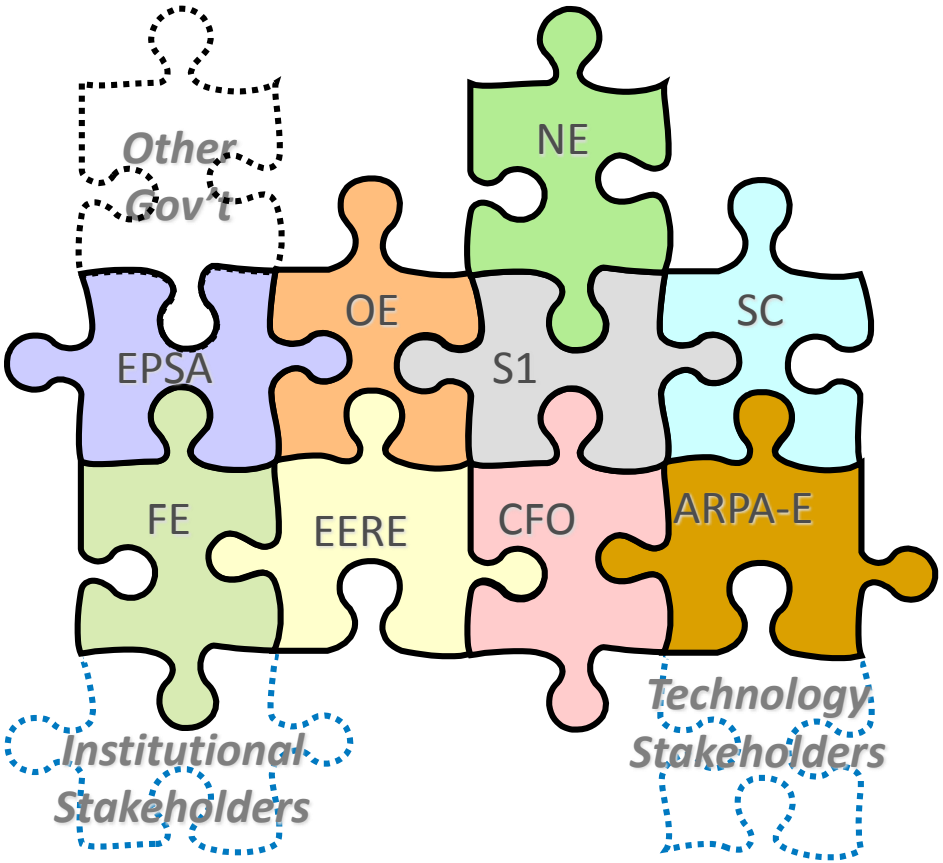


Source: EPRI, 2009

DOE GRID MODERNIZATION INITIATIVE

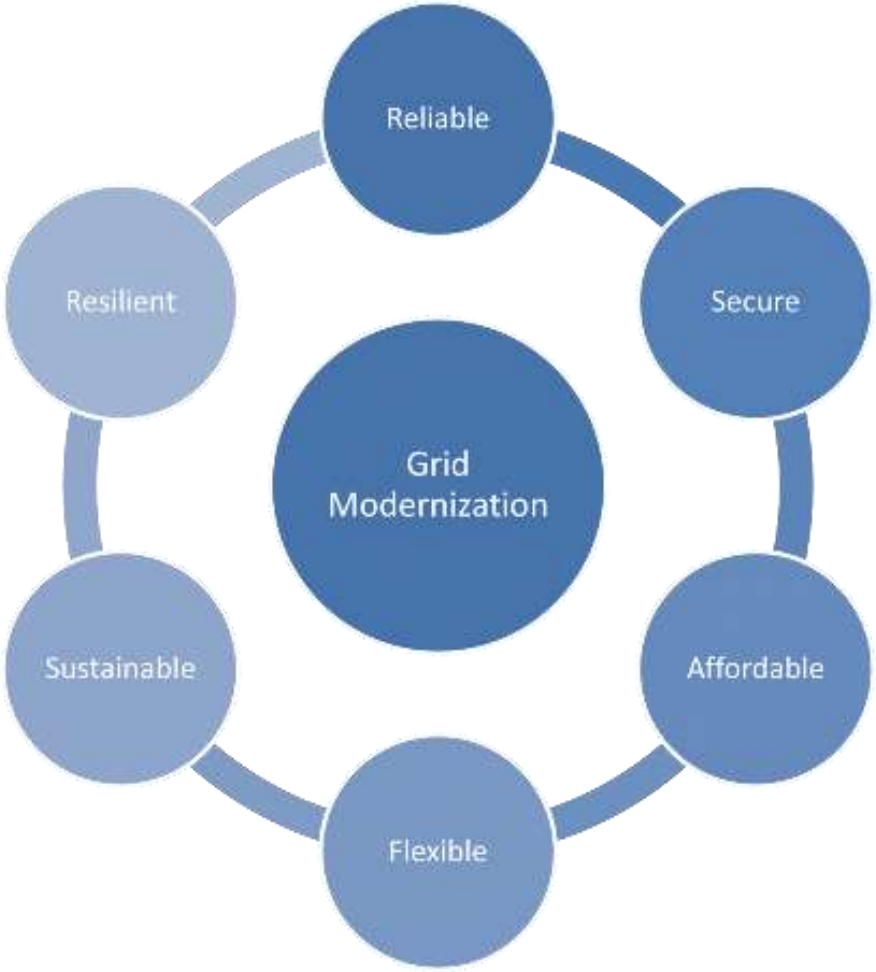
An aggressive five-year grid modernization strategy for the Department of Energy that includes

- **Alignment of the existing base activities among DOE 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**



GRID MODERNIZATION VISION

- A future grid that will solve the challenges of seamlessly integrating conventional and renewable sources, storage, and central and distributed generation.
- The future grid as a critical platform for U.S. prosperity, competitiveness, and innovation in a global clean energy economy.
- A future grid that will deliver **resilient, reliable, flexible, secure, sustainable,** and **affordable** electricity to consumers



GRID MODERNIZATION MULTI-YEAR PROGRAM PLAN

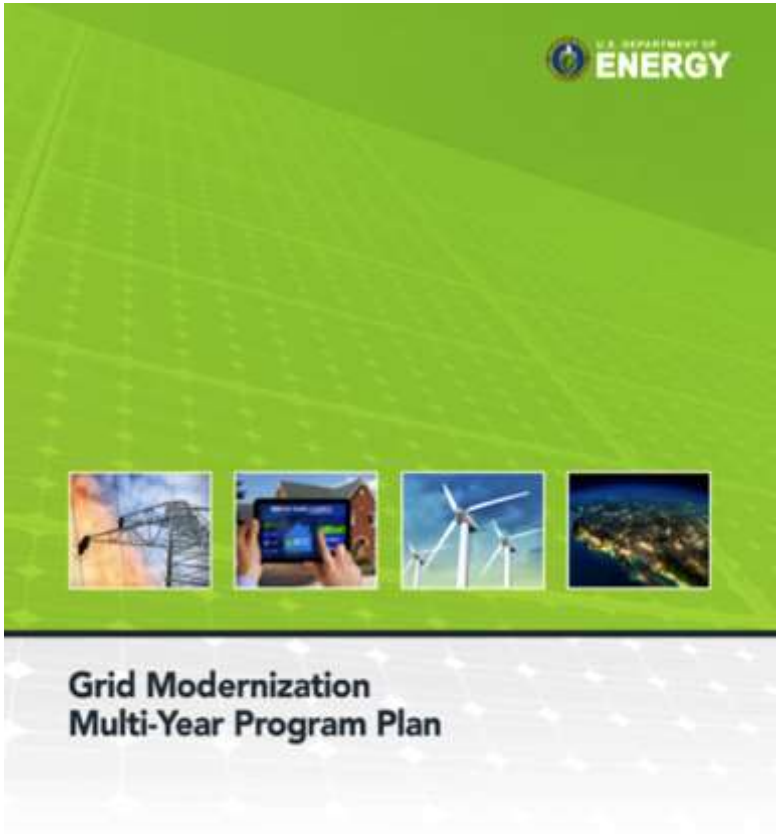
http://energy.gov/downloads/grid-modernization-multi-year-program-plan-mypp

Foundational R&D

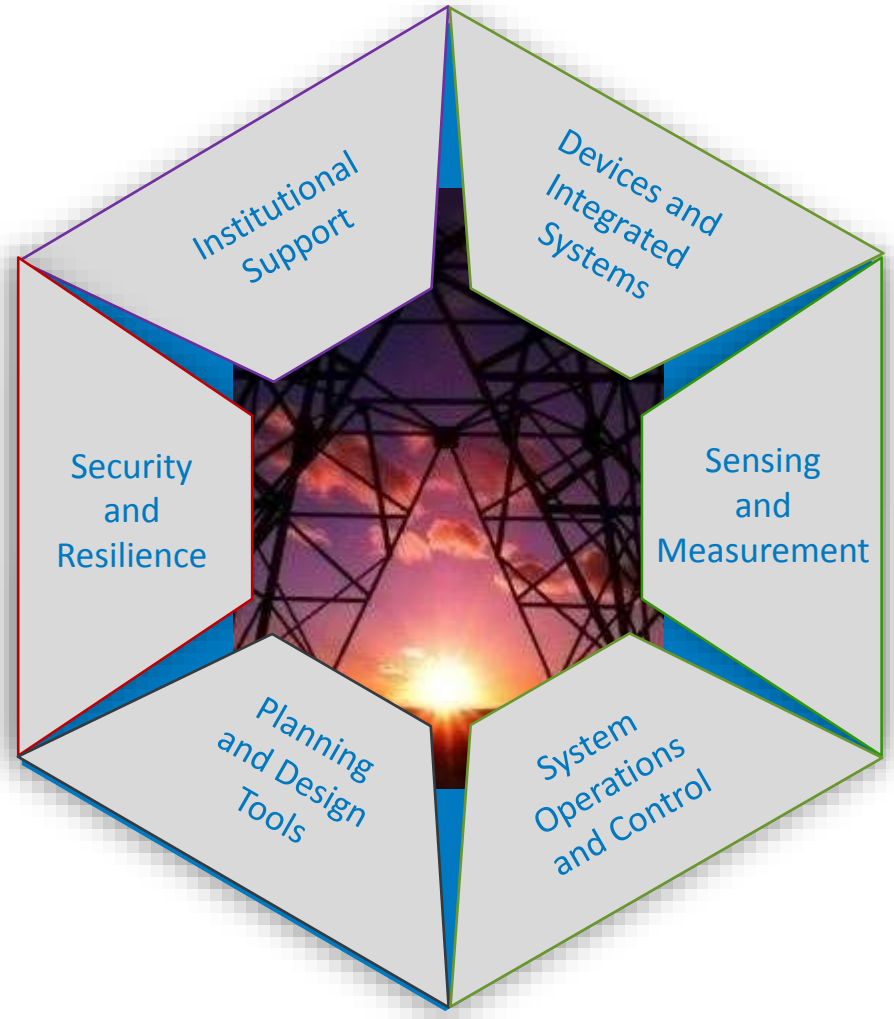
- Devices and Integrated Systems
- Sensing and Measurement
- System Operations and Control
- Design and Planning Tools
- Security and Resilience
- Institutional Support

Regional Demonstrations

- Low Reserve Margin Demo
- Clean Distribution Feeder
- Grid Analytics Platform



GRID MODERNIZATION LABORATORY CONSORTIUM



87 projects, $220M over 3 years

DEVICES AND INTEGRATED SYSTEMS

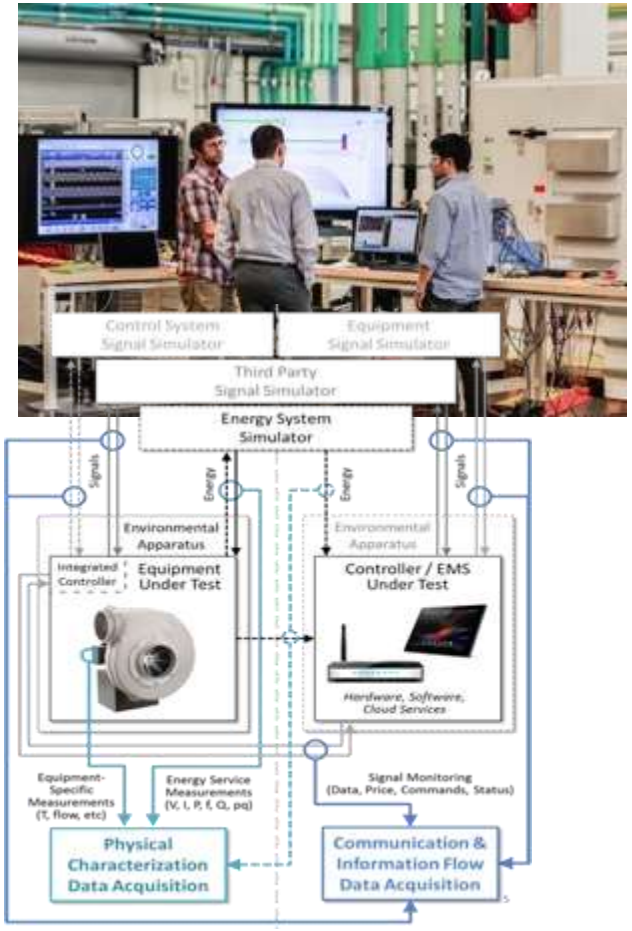
Characterization and testing of energy technologies for providing grid services to improve system affordability, reliability and sustainability

Expected Outcomes

- Develop new grid interface devices to increase ability to provide grid services and utilization
- Develop common interoperability and interconnection standards and test procedures for industry / vendor community
- Validate secure and reliable grid operation with high levels of variable generation at multiple scales

Current Projects

- Develop advanced storage systems, power electronics, and other grid devices;
- Create a single network of Laboratory and academic testing and validation facilities;
- Develop common standards and test procedures;
- Publish a library of device models for emerging grid components; and
- Conduct multi-scale system integration and testing



SENSING AND MEASUREMENT

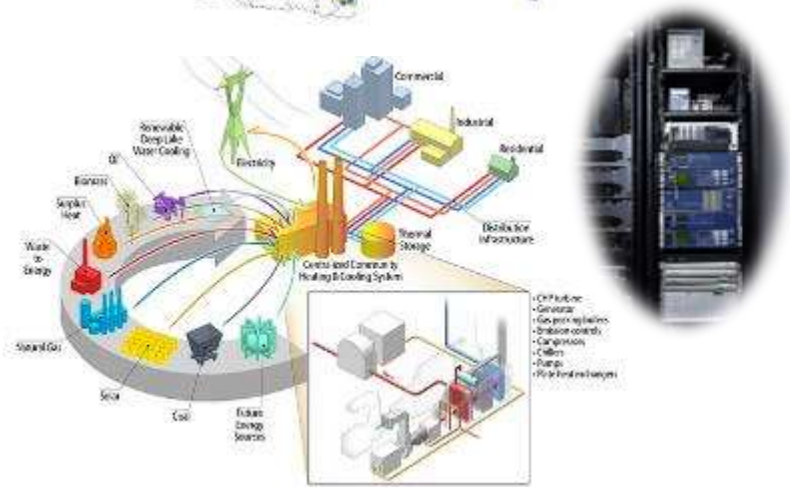
Sensor development and deployment strategies to provide complete grid system visibility for resilience and prediction

Expected Outcomes

- Advance and integrate novel, low-cost sensors to provide system visibility
- Incorporate new data streams (e.g. weather)
- Develop real-time data management and data exchange frameworks that enable data analytics
- Develop next-generation sensors that are accurate through disturbances to enable closed-loop controls and improved system resilience

Current Projects

- Develop a national strategy for achieving full electric system observability;
- Reduce costs and improve performance of sensors for all parts of the grid (devices, distribution, bulk);
- Apply advanced multi-scale data analytics and machine learning techniques to the grid; and
- Incorporate wind/solar forecast data into grid operations.



SYSTEM OPERATIONS AND CONTROL

Advanced real-time control technologies to enhance the reliability and asset utilization of transmission and distribution systems

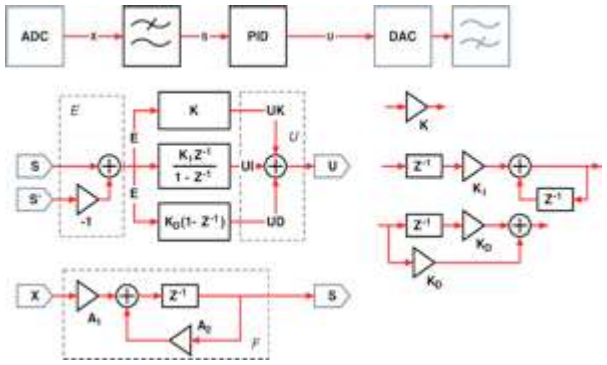
Expected Outcomes

- Architecture, algorithms, and control frameworks for a clean, resilient and secure grid
- Advanced operations software platform for predictive operations & real-time adaptive control
- New power flow control device hardware and concepts
- Fundamental knowledge for new control paradigms

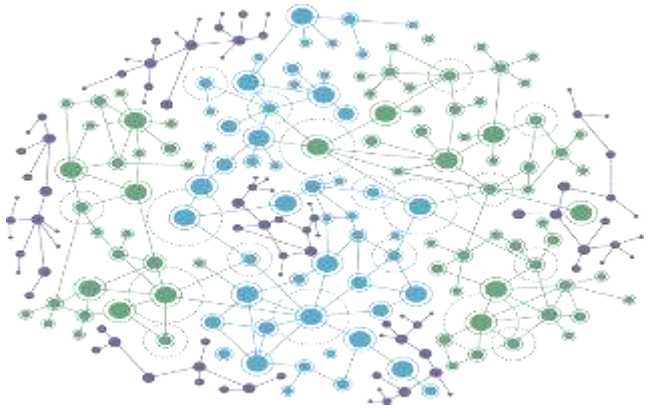
Current Projects

- Develop grid architecture and control theory, particularly for highly distributed systems;
- Develop coordinated system controls across multiple time and space scales (EMS/DMS/BMS);
- Create an open-source platform and testbed for advanced distribution management; and
- Demonstrate advanced control technologies in several regional use cases

Conventional *controls*



Distributed *controls*



PLANNING AND DESIGN TOOLS

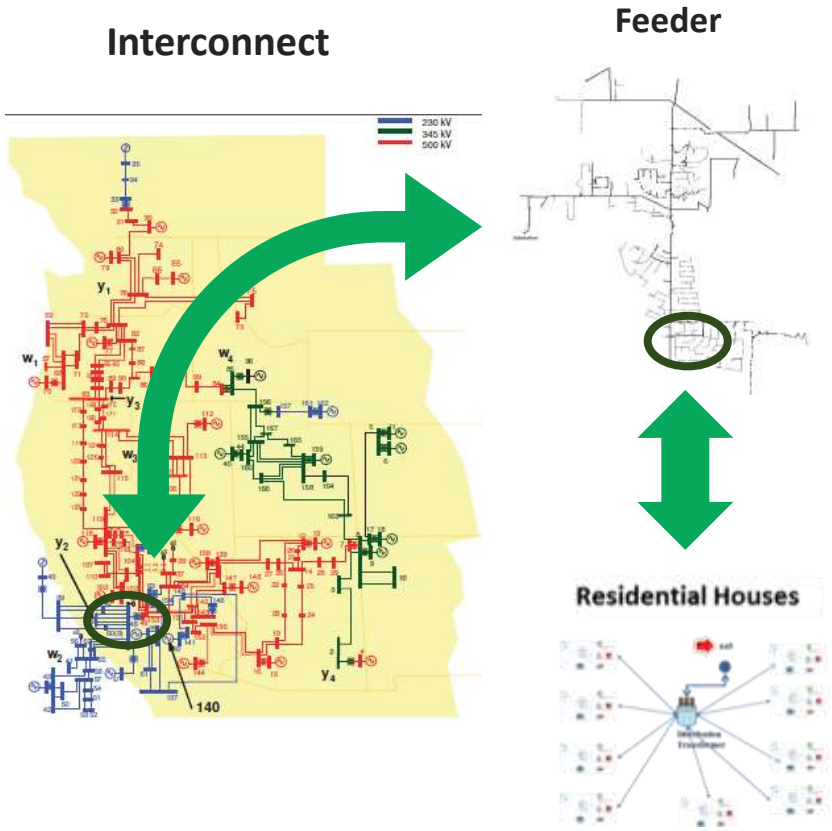
Next generation tools to accurately perform cost-benefit trade-offs and improve reliability of design for deployment new smart grid and renewables

Expected Outcomes

- Incorporate uncertainty and system dynamics into planning tools to accurately capture effects of renewable generation
- Computational tools, methods and libraries that enable 1000x improvements in performance for analysis and design
- Couple grid transmission, distribution, and communications models to understand cross-domain effects

Current Projects

- Develop multi-scale production cost models with faster mathematical solvers;
- Integrate transmission, distribution and communication planning models; and
- Explore new approaches for load modeling using available sensor data.



SECURITY AND RESILIENCE

Improve ability to identify, protect, respond and recover from all hazards and threats potentially impacting grid function

Expected Outcomes

- Holistic grid security and resilience, from devices to micro-grids to systems
- Inherent security designed into components and systems, not security as an afterthought
- Security and resilience addressed throughout system lifecycle including legacy and emerging technologies

Current Projects

- Threat detection and response with data analytics;
- Cyber security approaches for renewables, DER and smart inverters;
- Distribution system restoration tools for natural disaster recovery; and
- Tools for improved outage forecasting from tropical cyclones and other weather events.

INSTITUTIONAL SUPPORT

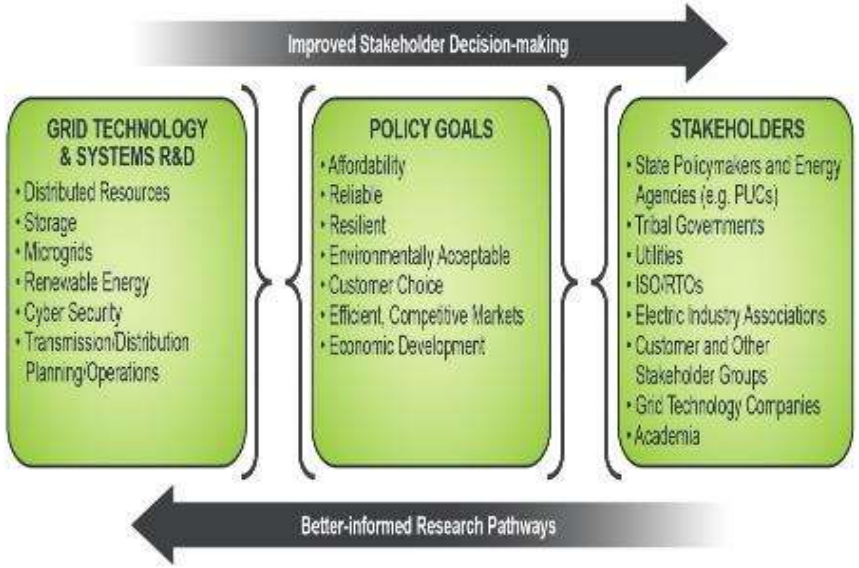
Information and analysis for stakeholders to enable more informed decisions on key issues that influence the future of the modernized grid

Expected Outcomes

- Accelerated policy innovation due to enhanced State and Regional technical assistance
- States adopt changes to their regulatory model that better align utility interests with grid modernization and/or clean energy policy goals
- Methods for valuation of DER technologies and services are defined and clearly understood

Current Projects

- Define quantitative metrics for assessment of grid modernization progress;
- Develop new tools to support distribution system decision making;
- Engage stakeholders in determining how to best value DER and services they provide; and
- Assess potential future electric utility regulations.



REGIONAL DEMONSTRATIONS

Three types of public-private partnerships that will accelerate transition of Foundational R&D outcomes to widespread deployment at scale

Lean Reserve Bulk Power Systems

Goals:

- Reliable operations with <=10% reserve margin; >33% variable wind, solar
- New capability for grid operators to leverage and manage distribution-level grid services
- Data-driven tools for precise, predictive real time grid operations

Target Partners:

- Transmission Utilities
- System Operators

Clean Distribution Systems

Goals:

- Demonstrate reliable and affordable feeder operations with >50% DER penetration
- Coordinated microgrid(s) control for resilience (20% fewer outages, 50% shorter recovery time)
- Distributed, hierarchical control for clean energy and new customer-level services

Target Partners:

- Distribution utilities
- Cities and municipalities with ambitious clean energy goals

Grid Planning and Analytics

Goals:

- Use coupled T&D grid planning models with 1000x speed-up to address specific grid-related issues
- Work with States to evaluate new business models, impacts of policy decisions

Target Partners:

- States and local regulators
- Distribution utilities
- New market participants

CURRENT REGIONAL PARTNERSHIPS

GRID MODERNIZATION WILL HAVE NATIONAL IMPACT

Drivers of Change

- Changing Electricity Supply Mix
- Threats to Resilience and Reliability
- New Market Opportunities for Consumers
- Information and Control Technologies
- Aging Infrastructure

Foundational R&D

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

Regional Demonstrations

- Low Reserve Margin Demo
- Clean Distribution Feeder
- Grid Analytics Platform

Modernized Grid

Our path to a modernized grid to power American leadership in the 21st Century

FOR MORE INFORMATION

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