U.S. DEPARTMENT OF ENERGY
Office of Electricity

NAS Study Goals and Office of Electricity Relevant Activities

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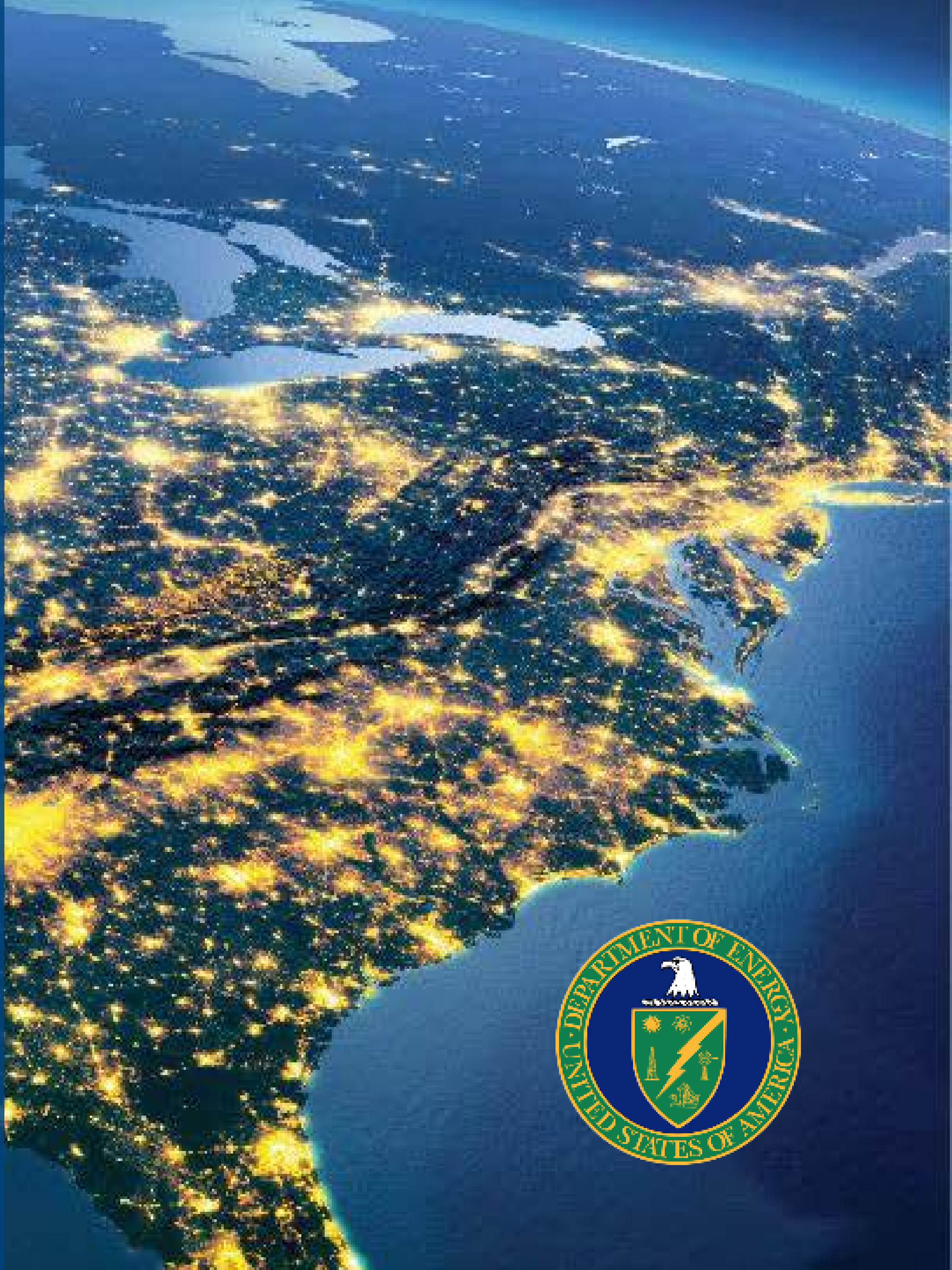
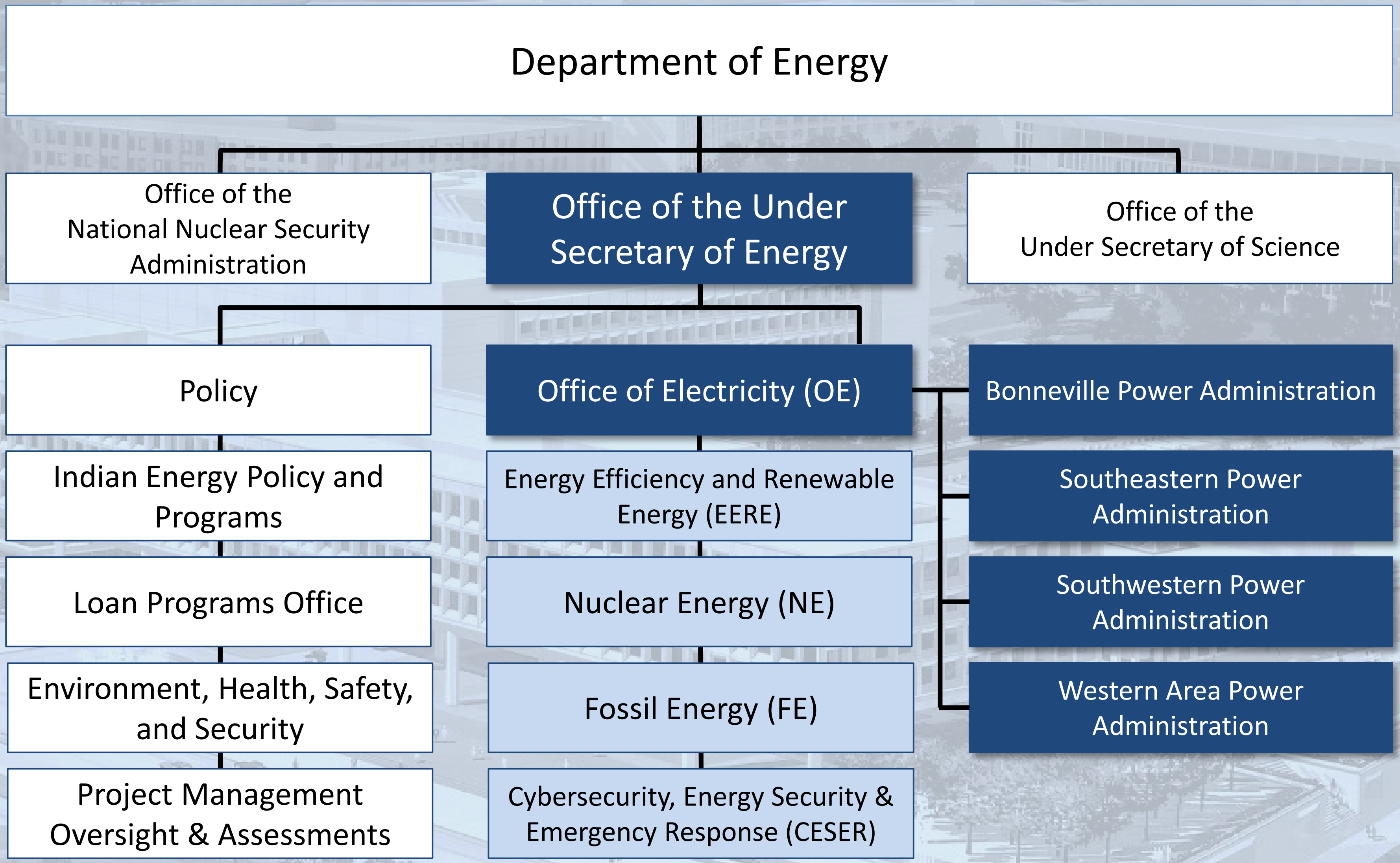
Office of Electricity

- Provide national leadership to ensure a secure, resilient and reliable energy delivery system.
- Develop technologies to improve the infrastructure that brings electricity into our homes, offices, and factories.
- Support development of the federal and state electricity policies and programs that shape electricity system planning and market operations.
- Drive electric grid modernization and resiliency through research, partnerships, facilitation, and modeling and analytics.

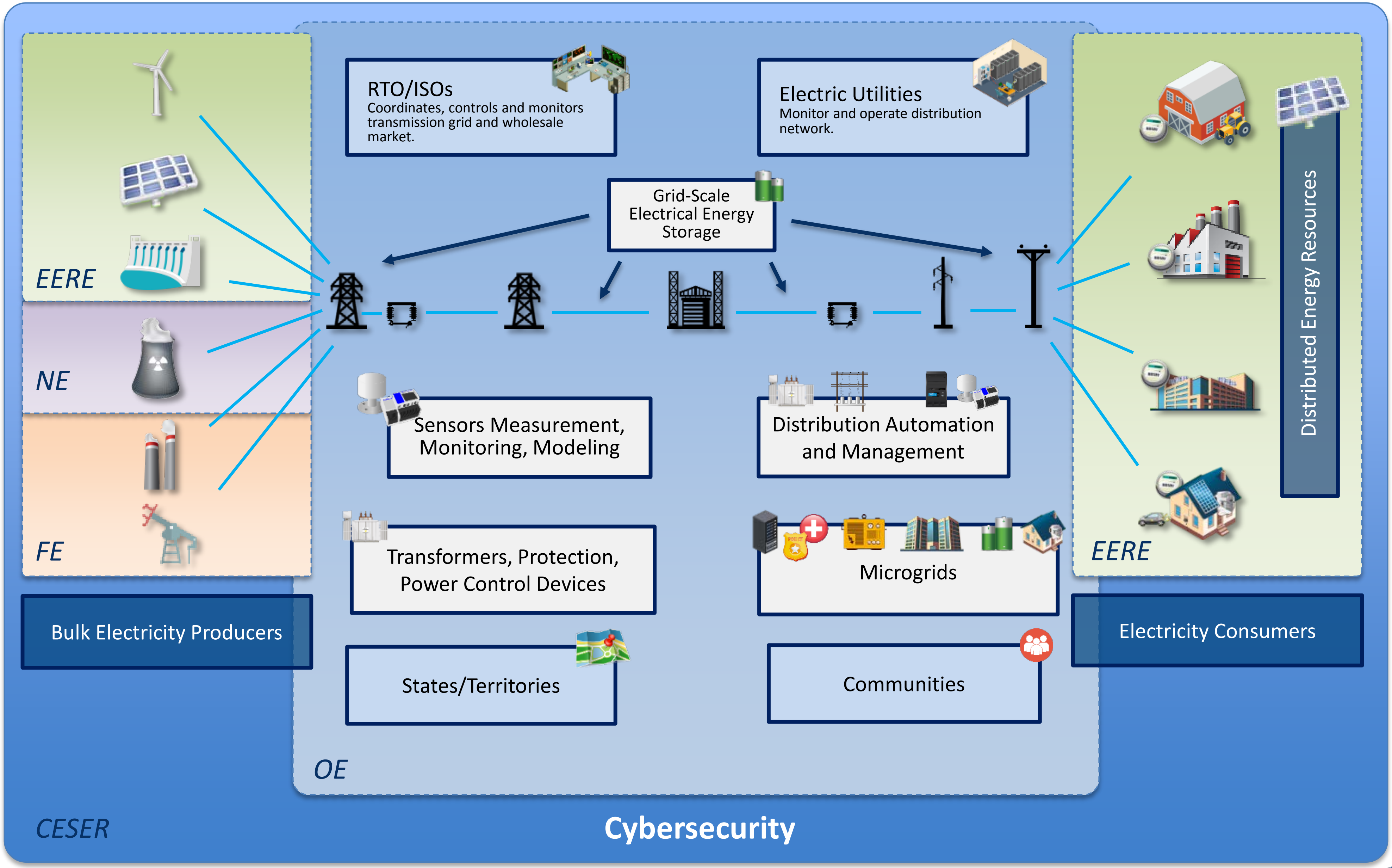
energy.gov/oe



OE Within DOE



Electric Power Grid

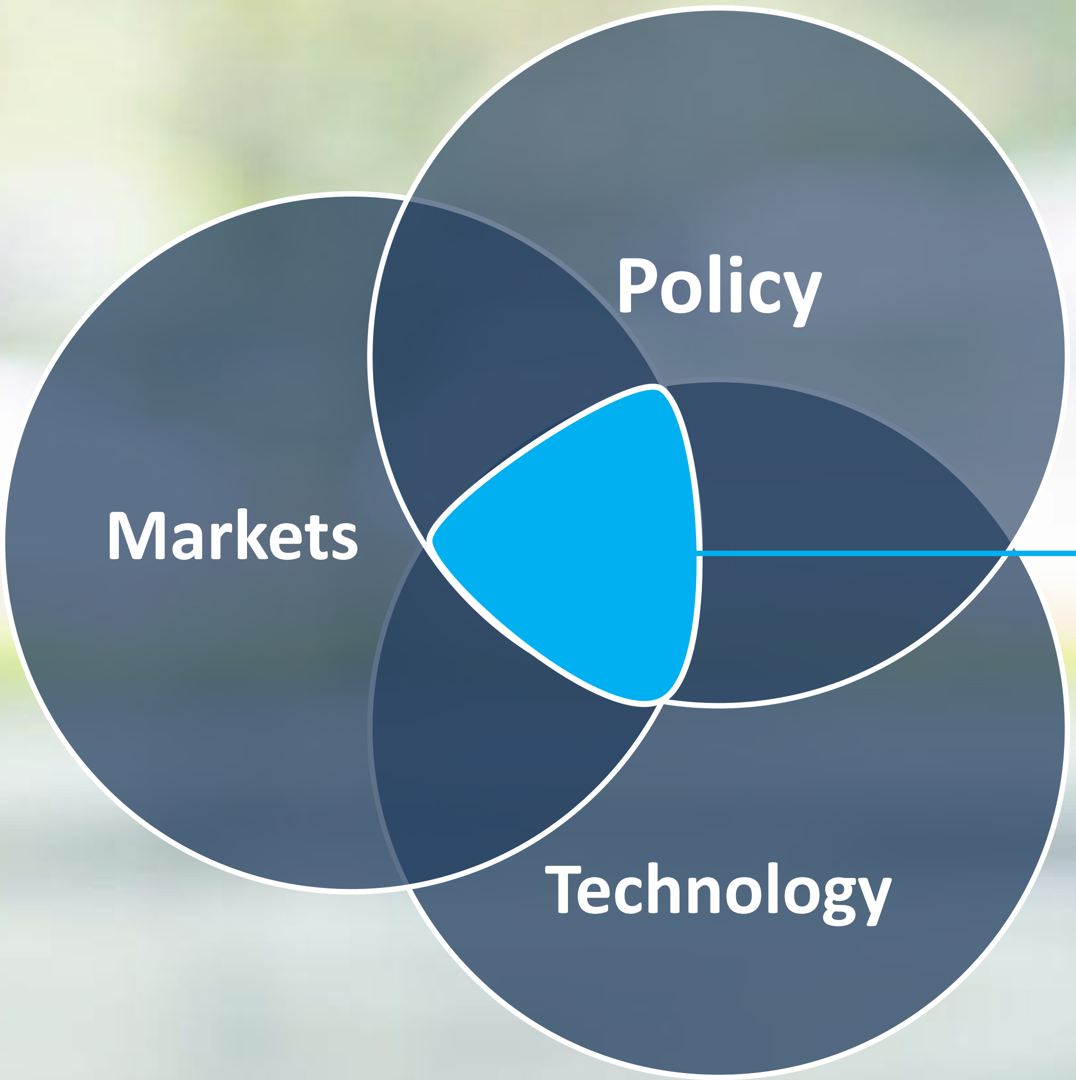


Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

Advanced Grid R&D Programs At-A-Glance

Grid Controls and Communications	*Transmission Reliability and Resilience*	Synchrophasors		Advanced Grid Modeling	High-Fidelity & Low-Cost Sensors
	Resilient Distribution Systems	Advanced Distribution Systems	Advanced Microgrids	Dynamic Controls and Communications	
Grid Systems and Components	*Transformer Resilience and Advanced Components*	Advanced Power Grid Components			
	Energy Storage Systems	Energy Storage			

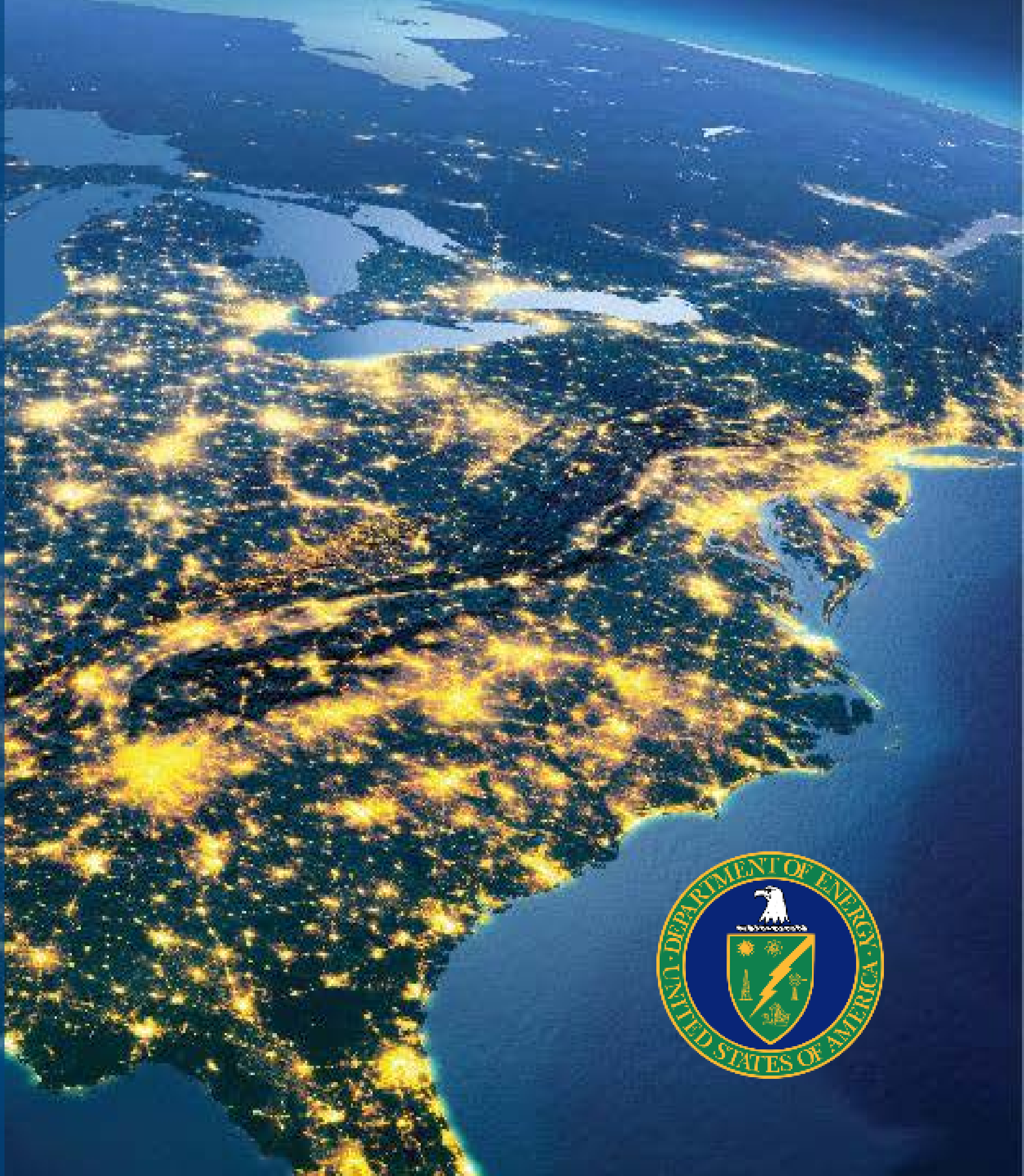
Grid Technology Commercialization



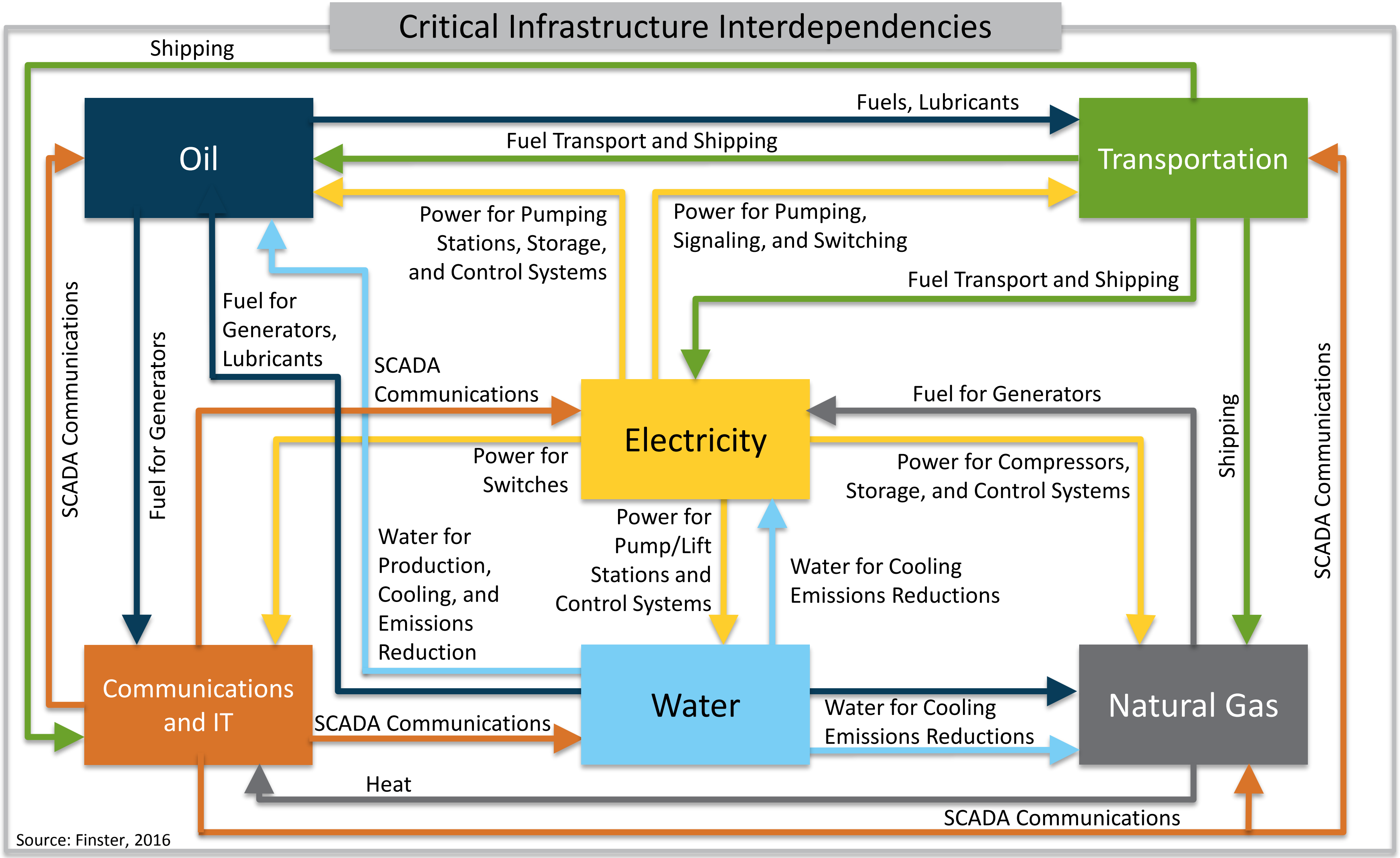
Interaction between Policy, Markets, and Technology.

OE Key Priorities

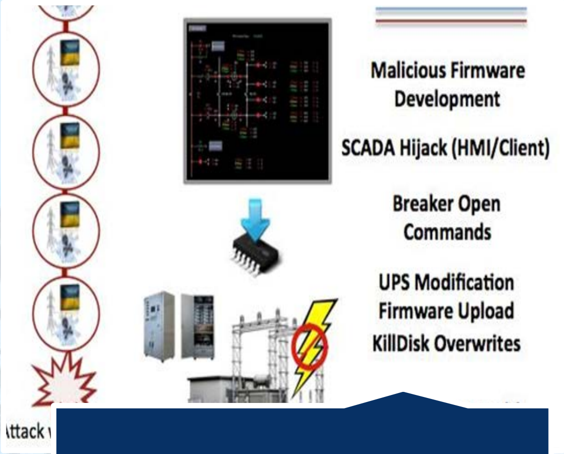
1. North American Energy Resiliency Model
2. Megawatt Scale Grid Storage
3. Revolutionize Sensing Technology Utilization
4. Resilient Transmission



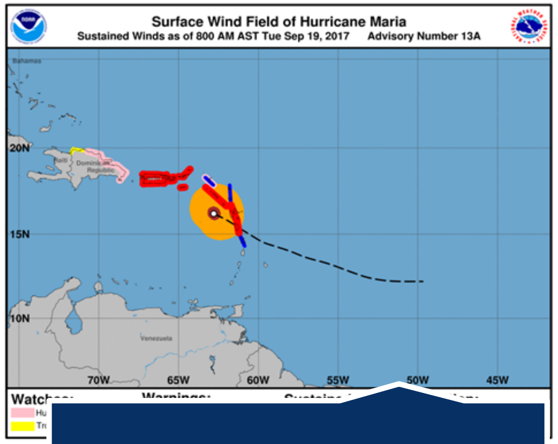
U.S. Critical Infrastructures Depend on Electricity



Many Threats Facing US Energy Infrastructure

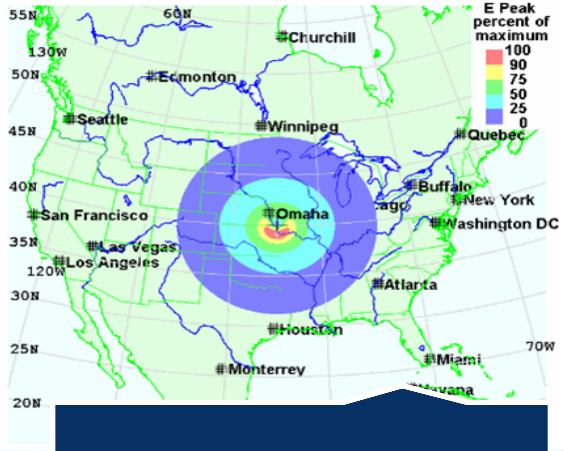


Cyber Attacks



Extreme Weather

Physical Attacks



High Altitude EMP

Ballistic Protection

1. Protecting US Infrastructure Through Modeling

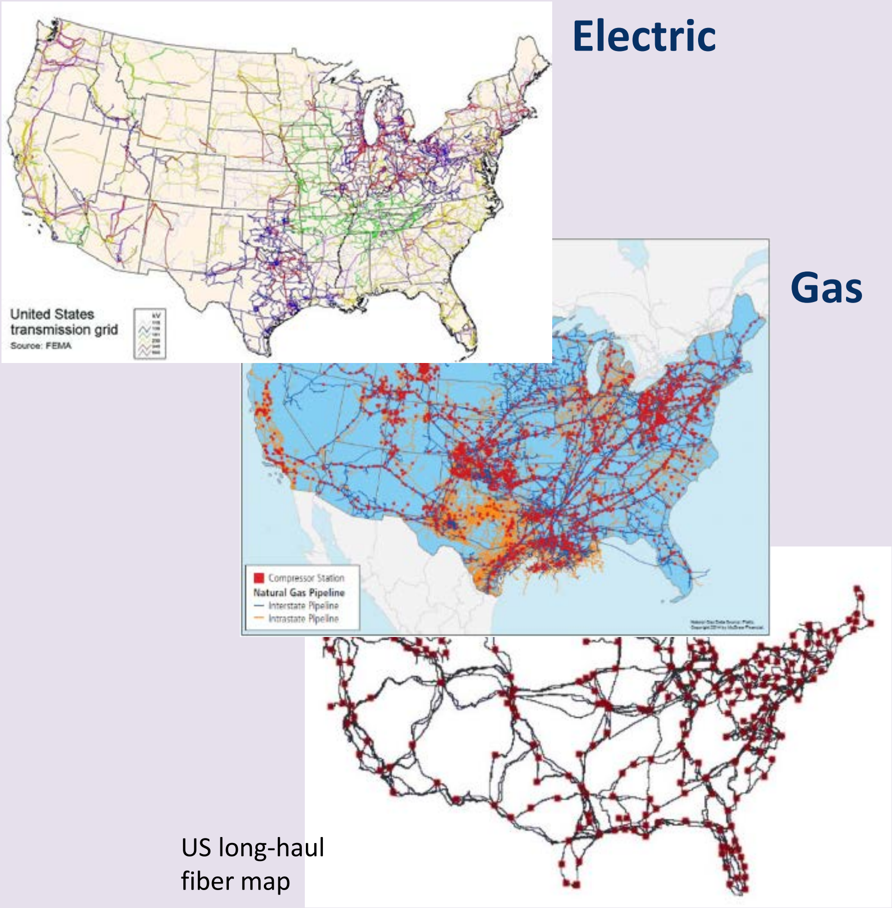
Vision

Rapidly predict consequences of known and emerging threats to national energy infrastructure.

Mission:

Develop and sustain an engineering-class modeling system to assess the national energy infrastructure.

North American Energy Resilience Model



Electric

Gas

Comms

US long-haul fiber map

North American Energy Resiliency Model (NAERM)

Combine Long-term Planning…

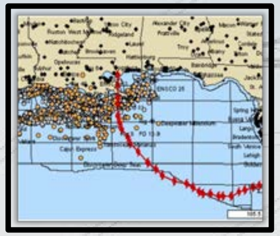
- Develop strategies in operations, planning, and research to support national resiliency

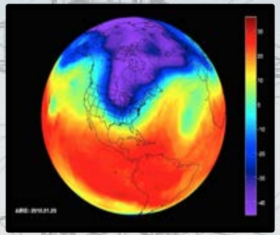
with Real-time Situational Awareness

- Understand resource needs during natural or man-made hazard

Oil Embargo, 1973


Northridge Earthquake, 1994


Katrina, 2005

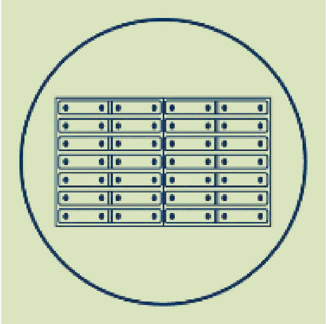

Polar Vortex, 2019

✓ Incorporate relevant assets of the integrated energy grid.

✓ Identify potential infrastructure investments to improve resiliency and mitigate risks associated with energy system interdependencies.

✓ Produce a model that allows for sequencing of events to understand risk across critical energy infrastructure sectors and identifying key energy infrastructure interdependencies.

2. Megawatt Scale Grid Storage – Bidirectional Electrical Storage



To lower system costs while simultaneously defining and articulating the value and benefits storage can provide across the grid infrastructure.

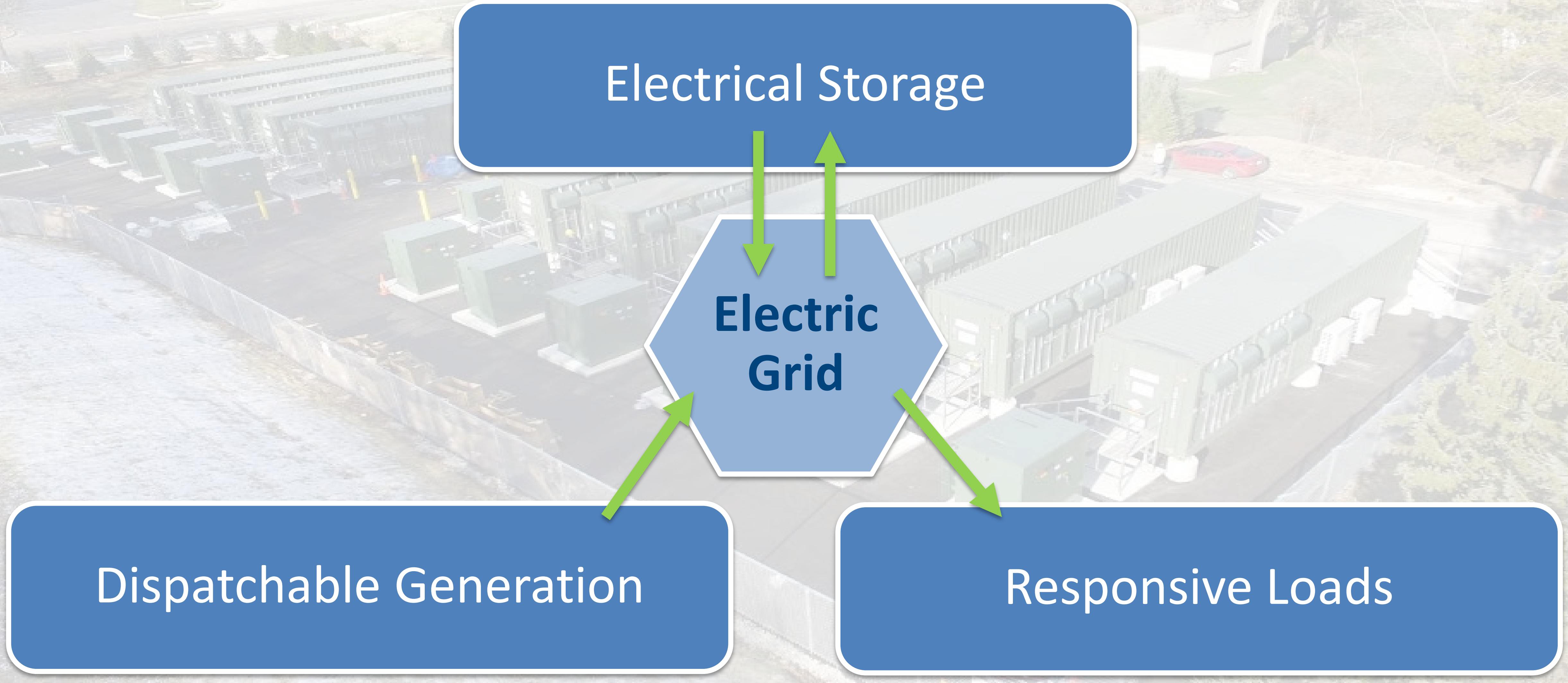
Cost and Performance Priorities

1. Redox-Flow batteries with earth-abundant organic materials ***(target = ~$100/kwh)***

2. Transforming Zinc-Manganese Dioxide batteries to charge and discharge without significant degradation ***(Target = ~$25/kwh)***

3. Sodium-based batteries that closely match Lithium-Ion's capacity **(30% cost reduction over current market)**

Grid Balancing Resources



OE Investment - Beyond Lithium

At the end of 2017 - Over 80% of U.S. large-scale battery storage power capacity is currently provided by batteries based on lithium-ion chemistries. (U.S. Energy Information Administration, Form EIA-860, Annual Electric Generator Report.)

Scale – Safety - Cost

Batteries

- Aqueous Flow
- Sodium-Ion
- Zinc-Manganese Dioxide

Compressed-Air Energy Storage

Flywheels

Supercapacitors

Storage Economics and Policy Implementation

- ❑ Capacity
- ❑ Arbitrage
- ❑ Regulation
- ❑ Spin/Non-Spin Reserves
- ❑ Voltage Support
- ❑ Black Start
- ❑ Congestion Relief
- ❑ T&D Upgrade Deferral
- ❑ Power Reliability
- ❑ TOU Energy Charge Reduction
- ❑ Demand Charge Reduction

The Cost of a Storage System depends on the Storage Device, Power Electronics, and Balance of Plant

The Value of a Storage System depends on Multiple Benefit Streams, both monetized and unmonetized

Energy Storage Device
25-50%

Power Electronics
20-25%

Balance of Plant
20-25%

Program Goals and Key Partnerships

Support further cost reductions through advanced materials, novel chemistries and design improvements

Improving the ability of storage to monetize the value of storage to the grid.

Provide critical information to form the basis of larger scale planning and valuation models for storage

Accelerate the pace of innovation in America to maintain our leadership throughout the world.

3. Revolutionize Sensing Technology Utilization

VISION

Enable timely diagnosis, prediction, and prescription of all system variables and assets, during normal and extreme-event conditions, to support national security and national public health and safety

Develop, integrate, and revolutionize the use of high-fidelity, fast-acting sensor technologies and advanced data analytics in electricity delivery—from transmission to distribution to end-use load

OBJECTIVE

Sensor Technologies and Data Analytics Program

Enhanced Power System Resilience

Objective: Enable power systems to better predict, respond to, and recover from critical events, achieving improved system visibility and operational awareness

Incipient Failure/Fault Detection

Objective: Enable real-time health monitoring, and determination of probability of failure and estimated time-to-failure, of critical grid assets at T&D levels, rather than relying on run-to-failure and schedule-based maintenance

Detecting and Forecasting Behind-the-Meter DER Impacts

Objective: Develop new and improved sensors, optimally deployed with advanced analytics and enhanced sensor networks to detect, characterize, and forecast DERs and their impacts to enable their integration into electric power systems at high penetration levels

Monitoring for Critical Infrastructure Interdependencies

Objective: Investigate, develop, and demonstrate technologies applicable to real-time monitoring of critical infrastructure interdependencies

4. Resilient Transmission Assets

Pursue electricity-related policy issues by carrying out statutory and executive requirements, while also providing policy design and analysis expertise to states, regions, and tribes.

Critical Energy Infrastructure Information

- **CEII program enables DOE to obtain valuable information from the private sector with additional reassurance that the data will be protected from disclosure.**

- **The data and information will enhance the Department’s ability to fulfill its responsibilities in to secure the bulk-power system.**

Resilient Distribution Systems

Advanced Distribution Systems

- Platform
- Testbed
- Applications
- Industry Engagement and Crosscut Activities

Advanced Microgrids

- Remote, Off-grid Microgrids
- Grid-connected Microgrids
- Networked Microgrids
- Resiliency Tools
- Standards and Testing

Dynamic Controls & Communications

- Policy and Market Design
- Business Models and Value Realization
- Conceptual Architecture Guidelines
- Strong Interfaces and Partners

Advanced Distribution System Program

Platform

- Develop open-source platform
- Connect to operational systems
- Framework for benefits evaluation

Testbed

- Span multiple vendors and management/data systems
- Integrate legacy and new

Applications

- Develop initial application suite
- Baseline safety, resilience and reliability, and integration

Industry Engagement and Crosscut Activities

- Enable the design and analysis of control algorithms for DERs
- Protect customer energy usage data
- Manage intermittence at distribution voltage levels

Advanced Microgrid Program

CORE

Remote, Off-grid Microgrids

- Active control of electrical and thermal energy
- Standardized methods for system designs and performance monitoring
- Integration of local energy sources

Grid-connected Microgrids

- Planning/design tools
- Operations/control tools
- Integration w. distribution systems
- Standardized cost/performance data

Networked Microgrids

- Tools for planning and evaluation with new modeling, simulation, and optimization capabilities
- Enabling implementation in cities and regionally

CROSSCUT

Resiliency Tools

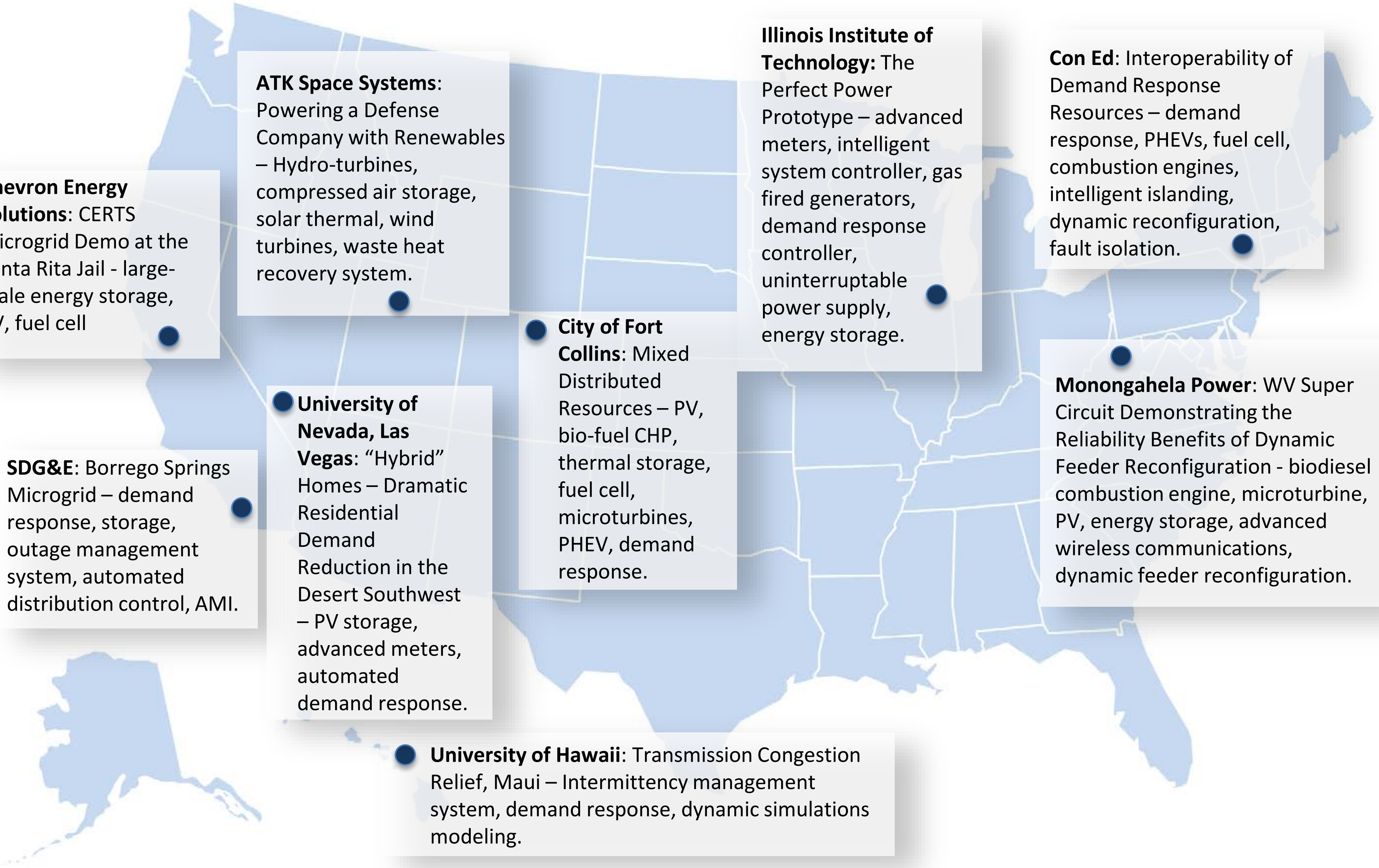
- Pre-event preparation
- During-event detection and mitigation
- Post-event response, recovery, and remediation

Standards and Testing

- New and revised microgrid standards
- Standardized test methods & testing

Advanced Microgrid Demonstration Projects

Renewable and Distributed Systems Integration Projects



Chevron Energy Solutions: CERTS Microgrid Demo at the Santa Rita Jail - large-scale energy storage, PV, fuel cell

ATK Space Systems: Powering a Defense Company with Renewables – Hydro-turbines, compressed air storage, solar thermal, wind turbines, waste heat recovery system.

Illinois Institute of Technology: The Perfect Power Prototype – advanced meters, intelligent system controller, gas fired generators, demand response controller, uninterruptable power supply, energy storage.

Con Ed: Interoperability of Demand Response Resources – demand response, PHEVs, fuel cell, combustion engines, intelligent islanding, dynamic reconfiguration, fault isolation.

SDG&E: Borrego Springs Microgrid – demand response, storage, outage management system, automated distribution control, AMI.

University of Nevada, Las Vegas: “Hybrid” Homes – Dramatic Residential Demand Reduction in the Desert Southwest – PV storage, advanced meters, automated demand response.

City of Fort Collins: Mixed Distributed Resources – PV, bio-fuel CHP, thermal storage, fuel cell, microturbines, PHEV, demand response.

Monongahela Power: WV Super Circuit Demonstrating the Reliability Benefits of Dynamic Feeder Reconfiguration - biodiesel combustion engine, microturbine, PV, energy storage, advanced wireless communications, dynamic feeder reconfiguration.

University of Hawaii: Transmission Congestion Relief, Maui – Intermittency management system, demand response, dynamic simulations modeling.

Dynamic Controls & Communications Program

Policy and Market Design

- Continued reliability
- Understand volatility of generation and demand
- Varying timescales and cost effectiveness

Business Models and Value Realization

- Understanding of customer value streams
- Understand DER transactions

Conceptual Architecture Guidelines

- Clear structure
- Establish traditional and distributed interfaces

Strong Interfaces and Partners

- Enhance intra-grid information and value flows
- Ensure "docking" with critical partners at the grid edge.

Transmission Reliability and Resilience

50 million people were without power in 2003 due to cascading failures on the electric grid across 8 states. We cannot provide reliable electricity without synchrophasors and the applications that use the data from those sensors.

Synchrophasors

The successful coordination in grid modeling research will lead to a new era of operations and planning. These tools will be essential during this era of major change to our energy system.

Advanced Grid Modeling

Advanced Synchrophasor Program

North American Synchrophasor Initiative

- Realize promise of synchrophasor technology
- Facilitate intelligent deployment of synchrophasors

Advanced Application Development

- Automatic switchable network for reliable early warning for informed remedial reaction
- Reliability monitoring and NERC compliance tools
- Oscillation behavior

Reliability and Models

- Research, develop, and implement electricity infrastructure and market simulations

Equipment Standards

- Data quality
- Device calibration (NIST)

Advanced Grid Modeling Program

Data Management & Analytics

- Facilitate standardizing data
- Create an environment for data sharing
- Build capability to handle Big Data

Mathematical Methods & Computation

- Increase pace to information
- Reduce computational strain

Models & Simulation

- Rapid
- Accurate
- Precise
- Interfacing

Advanced Components Program Areas

Market & System Impact Analysis

- Understand system impacts of new technologies and functions
- Techno-economic analysis for costs/benefits of advances

Component Design & Development

- Design and prototype components with enhanced features/functions
- Field validations to demonstrate and evaluate new capabilities

Monitoring, Modeling & Testing

- Develop embedded sensors and intelligence to improve reliability
- Testing and model validation to understand limits and performance

Applied Materials R&D

- Evaluate and develop new materials and devices that underpin advanced components

2015: OE - EERE

$220M ***over 3 years for 88 projects***

13 ***National Laboratories***

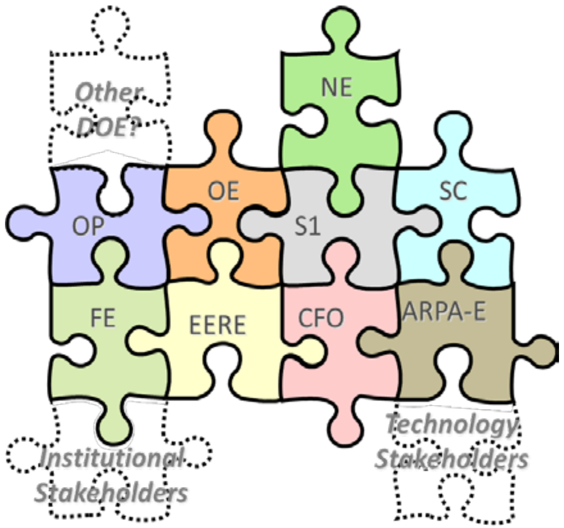
100+ ***Industry & Academia Partners***

Goal

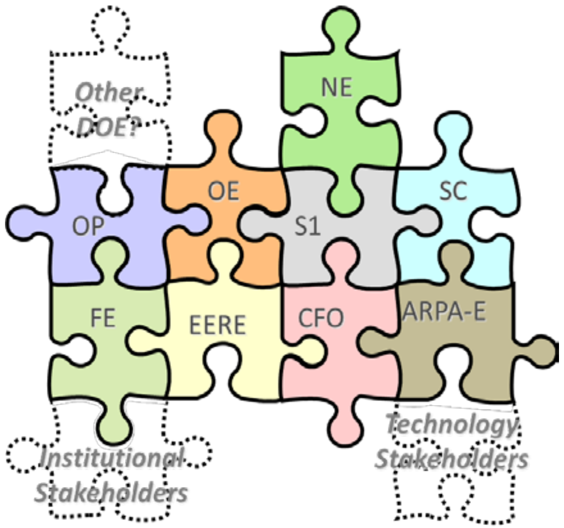
Bring together leading experts, technologies, and resources to collaborate on the goal of modernizing the nation's grid.

Benefits

- **More efficient use of resources;**
- **Shared networks;**
- **Improved learning and preservation of knowledge;**
- **Enhanced coordination and collaboration;**
- **Regional perspective and relationships with local stakeholders and industry.**



Grid Modernization Initiative



2019: OE – EERE –FE – NE - CESER

An aggressive and urgent five-year grid modernization strategy for the Department of Energy 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

Grid Modernization Initiative

Grid Modernization Laboratory Consortium

Move from a collection of DOE and lab projects to a DOE-Lab Consortium Model that integrates and coordinates laboratory expertise and facilities to advance DOE Grid Modernization goals.

Efficiency, Synergy, Collaboration, Acceleration

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

NAS Report: Modernizing the U.S. Electric System

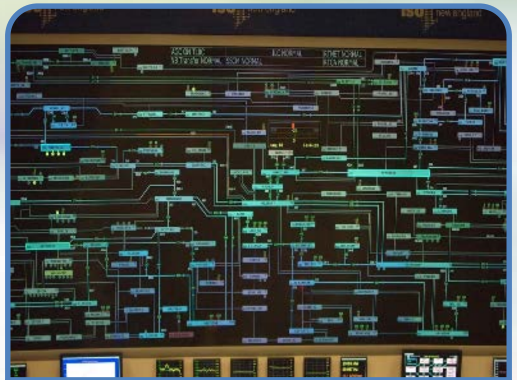
Generation resources, their operational characteristics, and what capabilities will be required in energy infrastructure to provide reliable and resilient service;

End use, including technologies for intelligent load control, and their implications for grid modernization investments, and

Interdependencies with other infrastructure systems such as natural gas, telecommunications, and transportation systems.

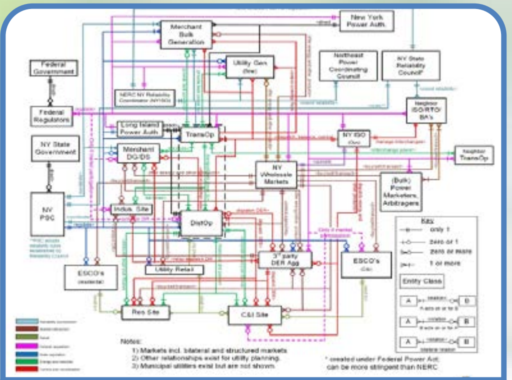
Report Recommendation Categories

Technologies



Planning and Operations

Business Models



Grid Architecture

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