U.S. DEPARTMENT OF
ENERGY
Office of Electricity

Hydrogen and Fuel Cells Technical Advisory Committee

OE Priorities

Michael Pesin
Deputy Assistant Secretary, Advanced Grid R&D

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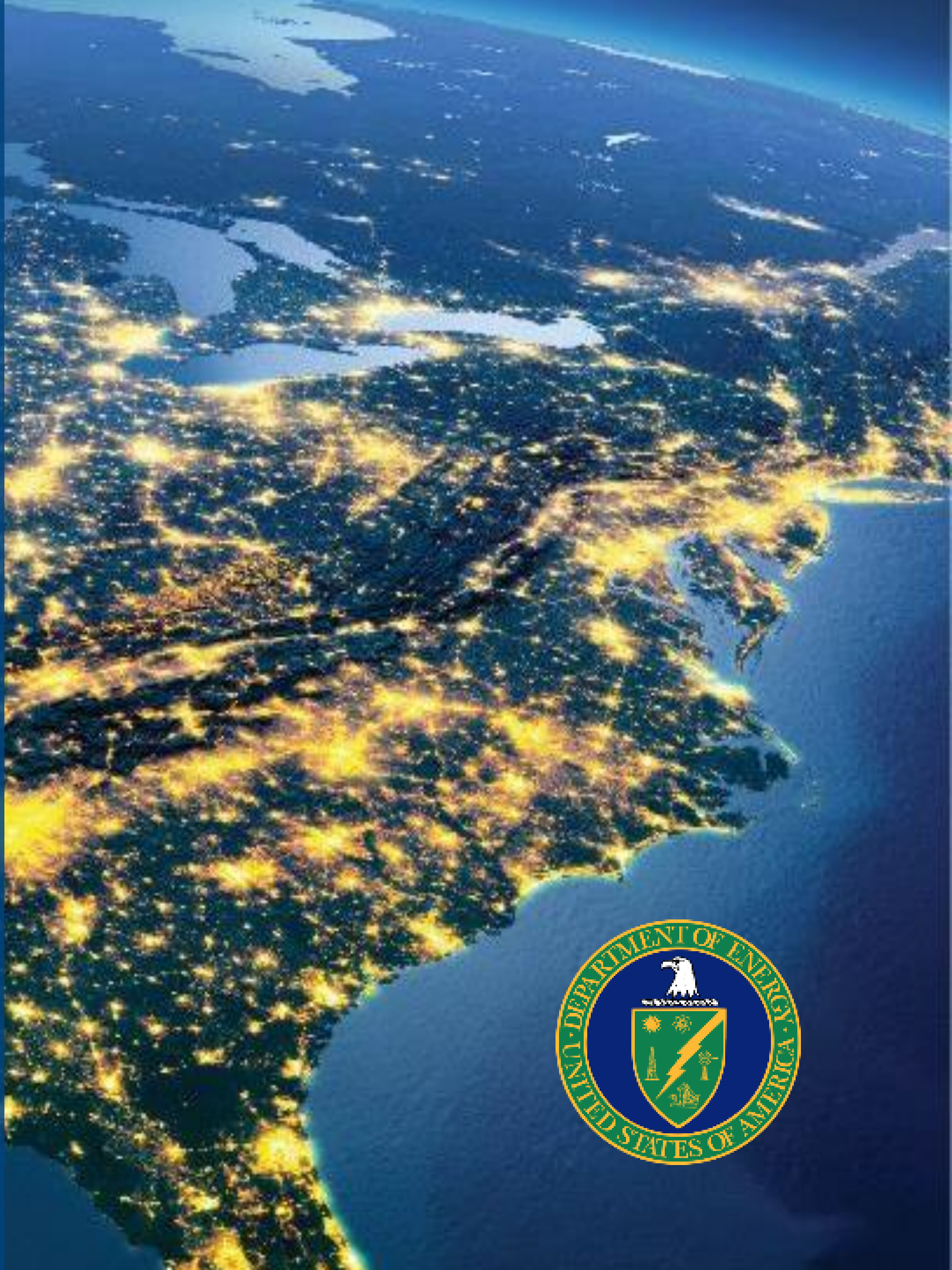
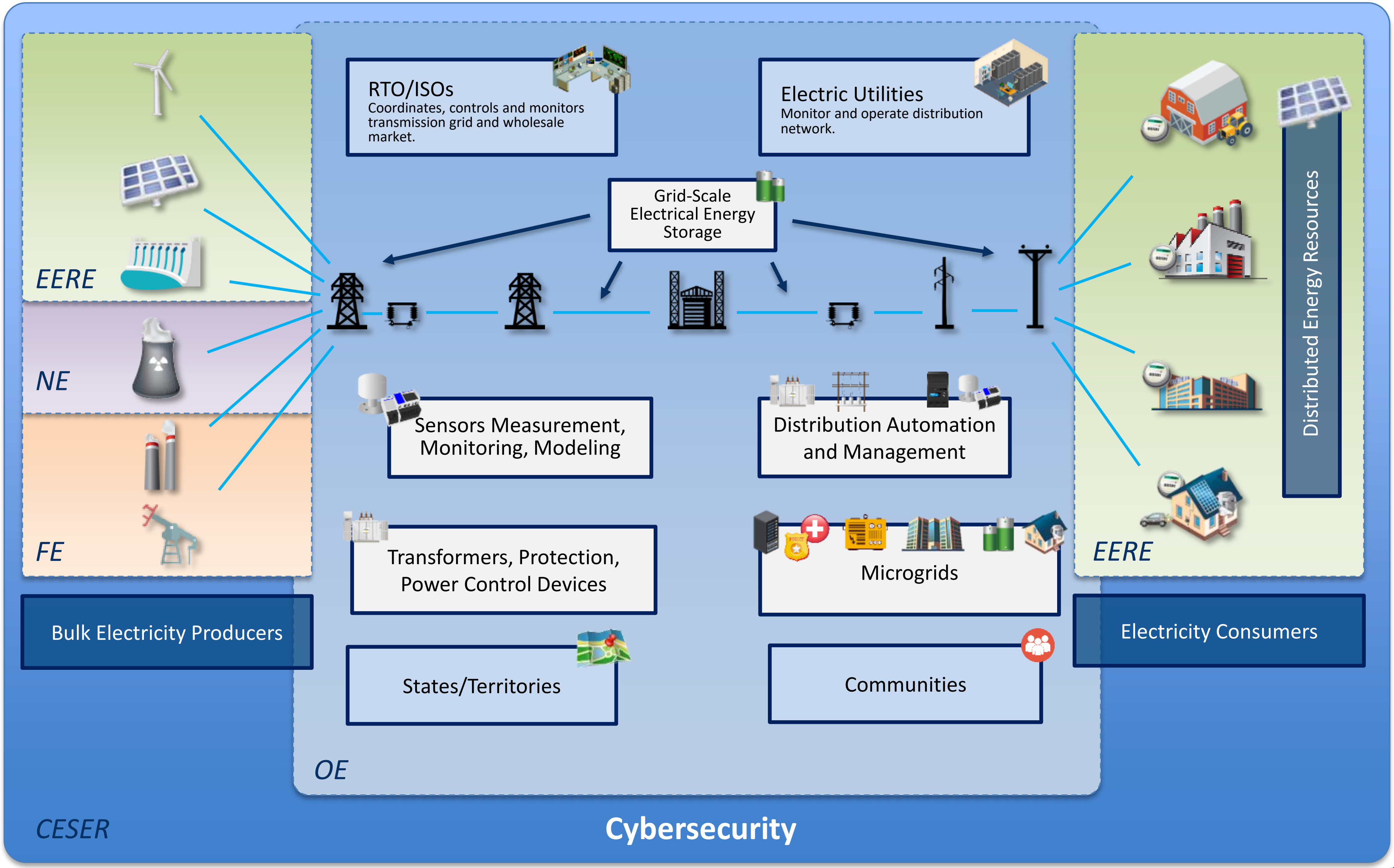
Office of Electricity

- **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



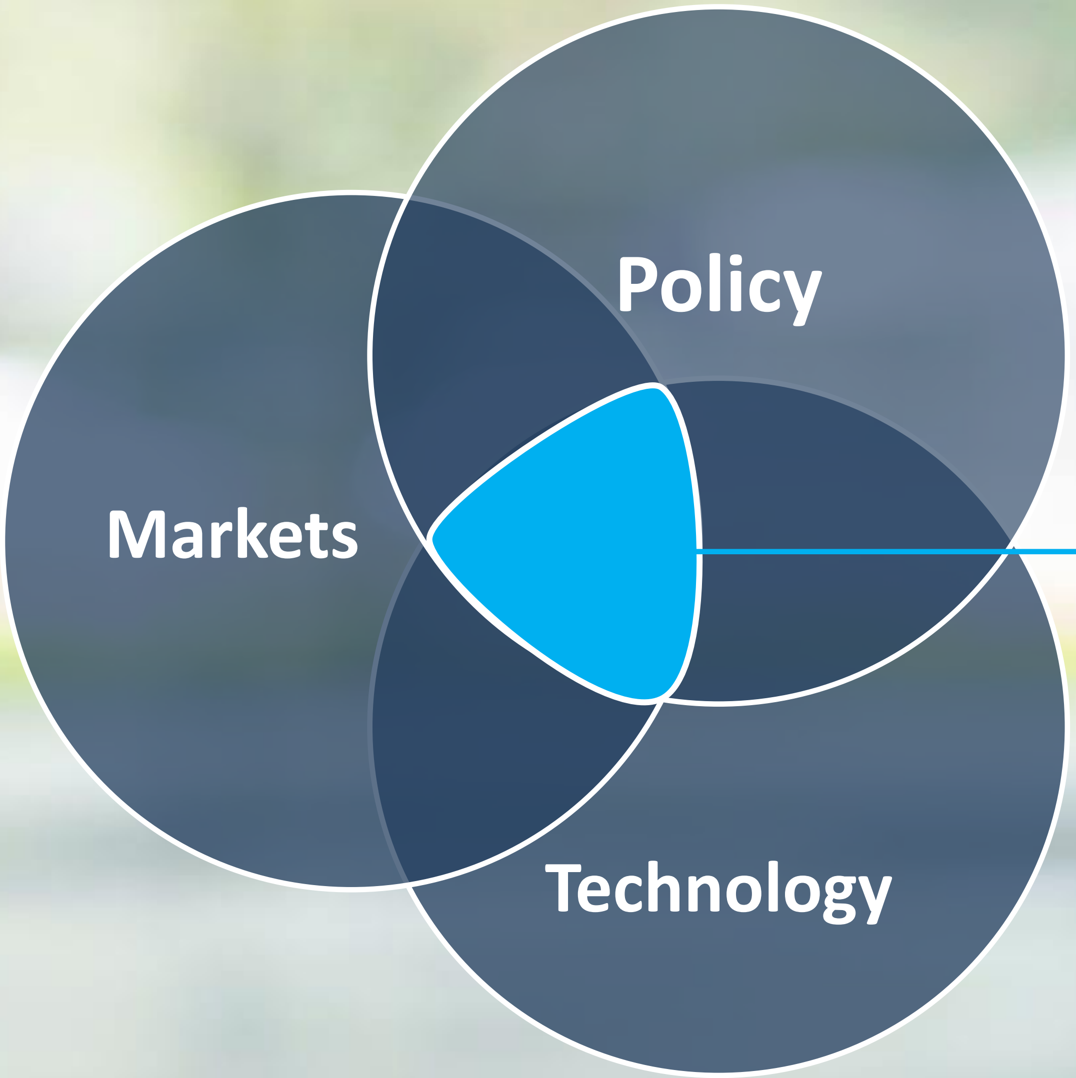
Electric Power Grid



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

North American Energy Resiliency Model

Megawatt Scale Grid Storage

Revolutionize Sensing Technology Utilization

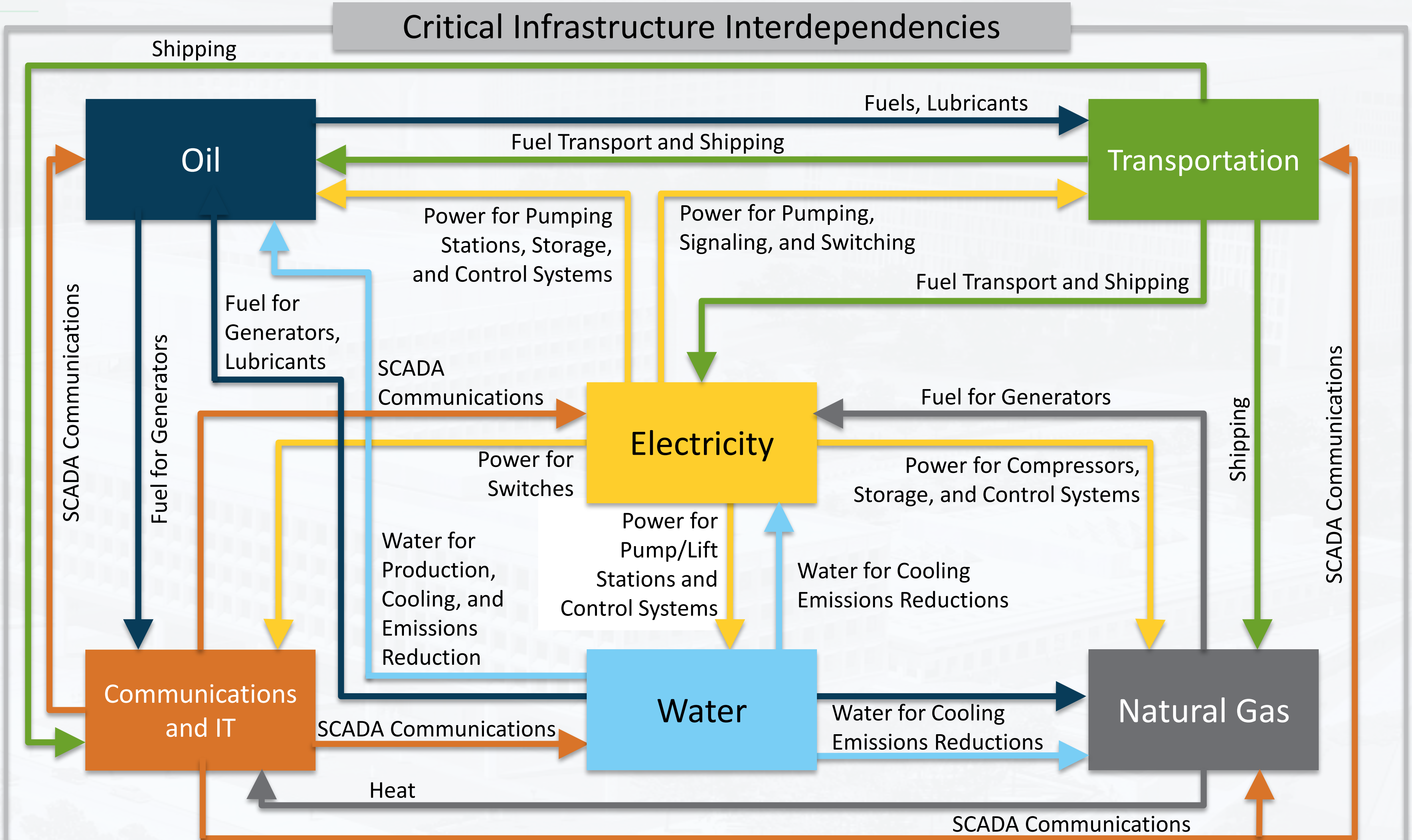
Resilient Transmission Assets

North American Energy Resiliency Model (NAERM)

Working with the national labs and relevant stakeholders, OE will develop an integrated North American Energy Resiliency Model (NAERM) to conduct planning and contingency analysis to address risks in the North American energy system.

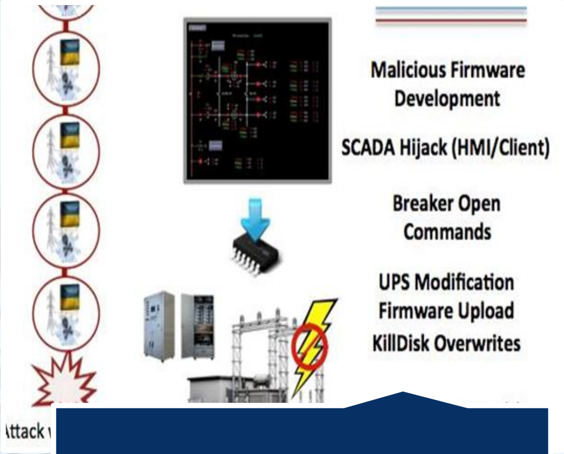
- Incorporate relevant assets of the integrated energy grid.
- Identify potential infrastructure investments to improve resiliency and mitigate risks associated with energy system interdependencies.
- Produce a model that allows for sequencing of events to understand risk across critical energy infrastructure sectors and identifying key energy infrastructure interdependencies.

U.S. Critical Infrastructures Depend on Electricity

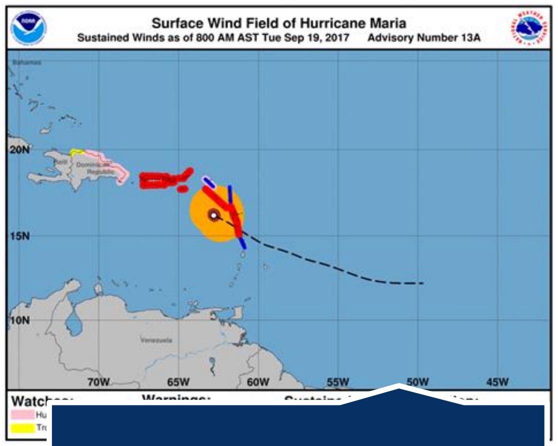


Source: Finster, 2016

Many Threats Facing US Energy Infrastructure

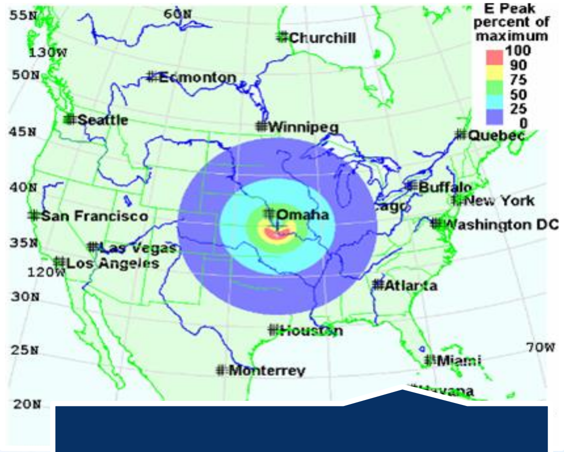


Cyber Attacks



Extreme Weather

Physical Attacks



High Altitude EMP

Ballistic Protection

Protecting US Infrastructure Through Modeling

Vision

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

Mission

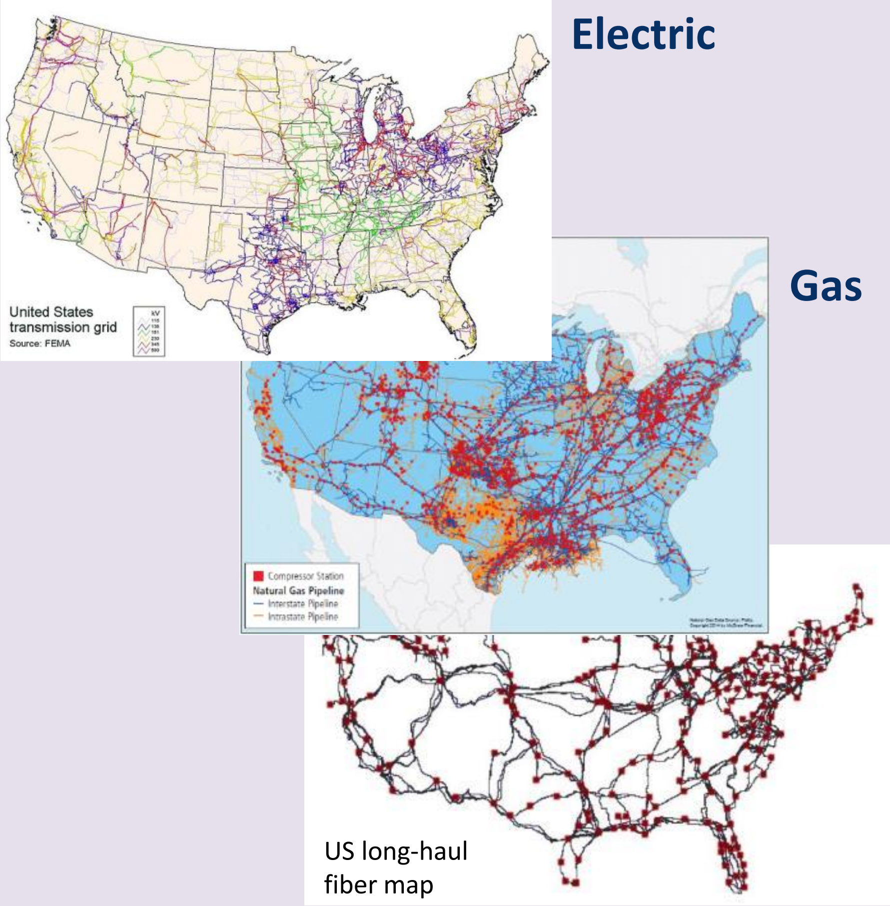
Develop and sustain an engineering-class modeling system to assess the national energy infrastructure.

North American Energy Resilience Model

Electric

Gas

Comms



Advanced Grid Research
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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

OBJECTIVE

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

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.**

Megawatt Scale Grid Storage – Bidirectional Electrical Storage

The goal of the Energy Storage program is to lower system costs while simultaneously defining and articulating the value and benefits storage can provide across the grid infrastructure.

The program accelerates the progression of grid-scale energy storage technology in America to protect our grid and ensure our nation's leadership in an emerging global marketplace.

OE Investment - Beyond Lithium

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
- Compressed-Air Energy Storage
- Flywheels
- Supercapacitors

Megawatt Scale Grid Storage – 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)

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%

Grid Balancing Resources

Electrical Storage

- Batteries
- Pumped Storage Hydro
- Flywheels

Electric Grid

Flexible Generation

- Hydro, Fossil, Nuclear
- Variable Renewable with Smart Invertors

Controllable Loads

- Demand Response
- Smart EV Charging

Taxonomy of Energy Storage Services

Category	Services
Bulk Energy Services	Capacity or Resource Adequacy; Energy Arbitrage
Ancillary Services	Regulation; Load Following; Spin/Non-Spin Reserve; Frequency Response; Flexible Ramping; Voltage Support; Black Start Service
Transmission Services	Transmission Upgrade Deferral; Transmission Congestion Relief
Distribution Services	Distribution Upgrade Deferral; Volt-VAR Control; Conservation Voltage Reduction
Customer Services	Power Reliability; Time of Use (TOU) Charge Reduction; Demand Charge Reduction

Source: Pacific Northwest National Laboratory

Grid Services: Diverse, Complex, Regional, & Dynamically Variable

Service	Operational Objective	Time Scale	Event Duration	Recurrence	Power for Service
Peak Capacity Management	reduce net load to meet an infrastructure constraint	15-min to 1-hour	4-8 hours	10-15 days/yr	supply: up load: down
Capacity Market Value	supply reserve "generation" on demand	15-min to 1-hour	4-6 hours	~5 days/yr	supply: up load: down
Energy Price Response	reduce price spikes by shifting net load to low price periods	5-min	Real-time or day-ahead	continuously	supply: up & down load: down & up
Frequency Regulation	supplement power plants in continually balancing supply & demand	4-sec	continuously	continuously	supply: up & down load: down & up
Spinning Reserve	rebalance supply & demand after sudden loss of generation (or trans.)	~1-min	<2-hour	~15 times/yr	supply: up load: down
Artificial Inertia / Primary Frequency Response	arrest rapid frequency change & re-stabilize it during grid contingencies (usually loss of generation)	~1/60 sec	~1 or 10 -min	continuously	supply: up* & down load: down* & up
Distribution Voltage Management	minimize voltage fluctuations from rapidly changing PV output by injecting or consuming reactive power	~1-min	~1-hour/day	continually; especially on cloudy days	supply: up & down load: down & up

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Michael.Pesin@hq.doe.gov