ARPA-E DAYS Kick-off
OE Priorities

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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

RTO/ISOs
Coordinates, controls and monitors transmission grid and wholesale market.

Electric Utilities
Monitor and operate distribution network.

Grid-Scale Electrical Energy Storage

Sensors Measurement, Monitoring, Modeling

Distribution Automation and Management

Transformers, Protection, Power Control Devices

Microgrids

States/Territories

Communities

Bulk Electricity Producers

Electricity Consumers

Cybersecurity

EEERE
NE
FE
OE
CEEER

Distributed Energy Resources
## Advanced Grid R&D Programs At-A-Glance

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<th>Transmission Reliability and Resilience</th>
<th>Synchrophasors</th>
<th>Advanced Grid Modeling</th>
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<td>Resilient Distribution Systems</td>
<td>Advanced Distribution Systems</td>
<td>Advanced Microgrids</td>
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<td>Transformer Resilience and Advanced Components</td>
<td>Advanced Power Grid Components</td>
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<td>Grid Systems and Components</td>
<td>Energy Storage Systems</td>
<td>Energy Storage</td>
<td>High-Fidelity &amp; Low-Cost Sensors</td>
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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

Critical Infrastructure Interdependencies

- **Oil**: Fuels, Lubricants
- **Electricity**: Power for Pumping Stations, Storage, and Control Systems
- **Water**: Water for Production, Cooling, and Emissions Reduction
- **Communications and IT**: SCADA Communications
- **Natural Gas**: Fuel for Generators, Lubricants
- **Transportation**: Fuel Transport and Shipping

Source: Finster, 2016
Many Threats Facing US Energy Infrastructure

- Cyber Attacks
- Extreme Weather
- Physical Attacks
- High Altitude EMP
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
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.
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
   \(\text{target} = \sim \$100\text{/kwh}\)

2. Transforming **Zinc-Manganese Dioxide** batteries to charge and discharge without significant degradation
   \(\text{target} = \sim \$25\text{/kwh}\)

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

- Energy Storage Device: 25-50%
- Power Electronics: 20-25%
- Balance of Plant: 20-25%

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

- Capacity
- Arbitrage
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Grid Balancing Resources

- **Electrical Storage**
  - Batteries
  - Pumped Storage Hydro
  - Flywheels
  - Supercapacitors, superconducting magnetic energy storage

- **Flexible Generation**
  - Hydro, Fossil, Nuclear
  - Variable Renewable w/Smart Invertors

- **Controllable Loads**
  - Demand Response
  - Smart EV Charging
Taxonomy of Energy Storage 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

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