U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Beyond Batteries

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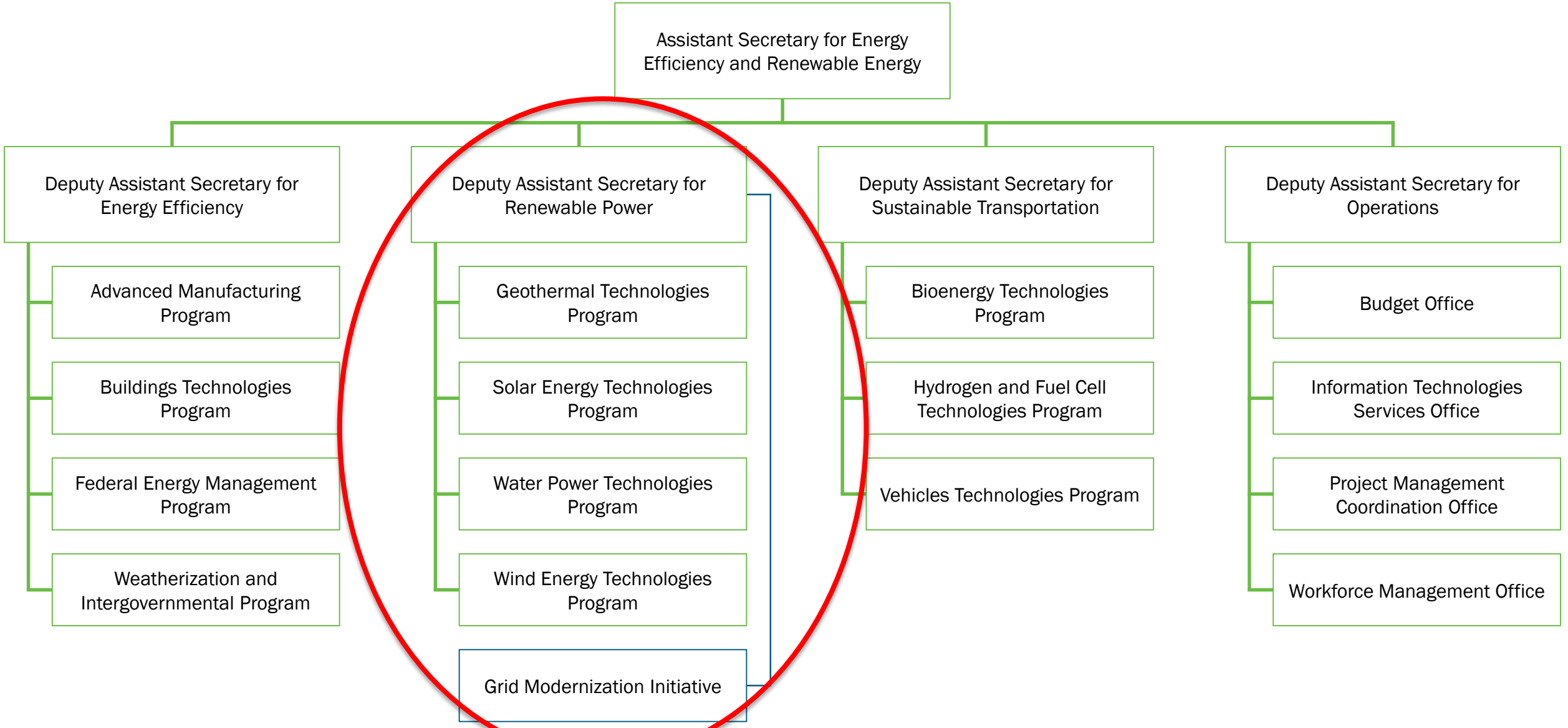
Office of Energy Efficiency and Renewable Energy



Renewable Power…and Reliability

The overarching objective of the Renewable Power portfolio is to enable the adoption of affordable, reliable and renewable electricity options to the nation's energy mix, allowing for regional optimization, maximizing the use of indigenous resources, and contributing to a resilient, reliable, and secure electricity grid.

Geothermal Technologies Office

Solar Energy Technologies Office

Water Power Technologies Office

Wind Energy Technologies Office

Grid Modernization Initiative (GMI)

Technology Innovation

- Reduce costs of energy production through early stage R&D
- Development of new technologies

Device Validation & Analysis

- Analyze and validate new technology to inform R&D
- Utilization of National Laboratory facilities and capabilities

System Integration

- New technologies that can improve grid services
- Grid integration activities coordinated with Office of Electricity and Reliability

Geothermal Energy

Enhanced Geothermal Systems (EGS)

Hydrothermal

Low Temperature and Co-Produced Resources

GTO works to overcome technical challenges to the increased use of geothermal energy…

- Geothermal resources are geographically complex
- Exploration risk accelerates the “cost of money”
- Drilling is expensive in basement rock; ensuring well-bore integrity over decades is challenging

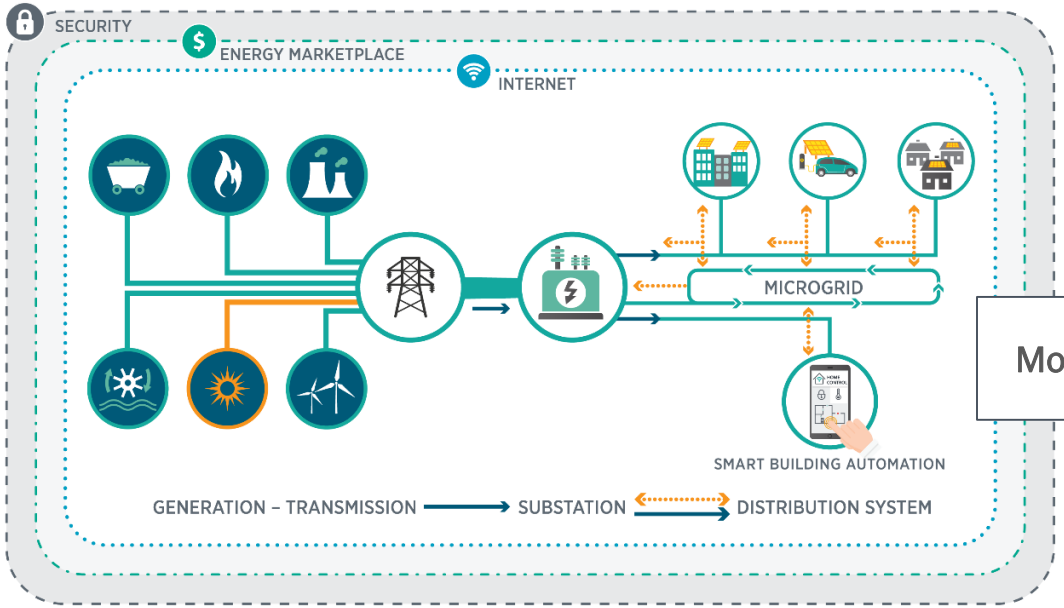
…by investing in research for:

- **Enhanced Geothermal Systems** (creating a resource where one doesn’t already exist)
- **Deep Direct Use** (using heat of ground everywhere for direct heating and cooling)
- **Play Fairway Analysis** (statistical data sets combined to reduce exploration risk)
- **Subsurface Technology and Engineering Research** (integrated areas of subsurface technology research)

Solar Energy

Photovoltaics (PV) convert light to electricity no moving parts, works even on cloudy days

Concentrating Solar Power (CSP) converts heat to electricity and can store energy



Modern Grid: 2 Way Electricity Flow

Water Power

Water Power Technologies

Hydroelectric Dams

Pumped Storage

Marine Energy

How does EERE support Water Power?

Invests in **new technologies** to reduce costs and allow more development

Provides **tools for industry** to make designs and operations more efficient

Supports **infrastructure for testing** new systems and turbines

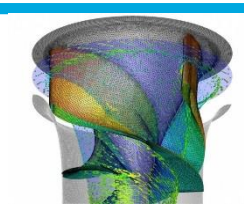
Facilitates **regulatory reform** to simplify licensing and ease deployment

2010

Established First Marine Research Centers at U.S. Universities

Assessment of U.S. Non-powered Dams

First National Assessments of Marine Energy Potential



Validated performance of fish-friendly turbines (Alden)

1st Grid-Connected Tidal Demo in U.S. (ORPC)

Successful low-impact hydropower technology commercial demo (Natel)

Completed Wave Energy Prize, increased energy-capture 5x

Improved regulatory processes for federal non-powered dams

Development of U.S. wave energy test facility initiated

Hydropower Vision Report

2017

Wind Energy

Land-based

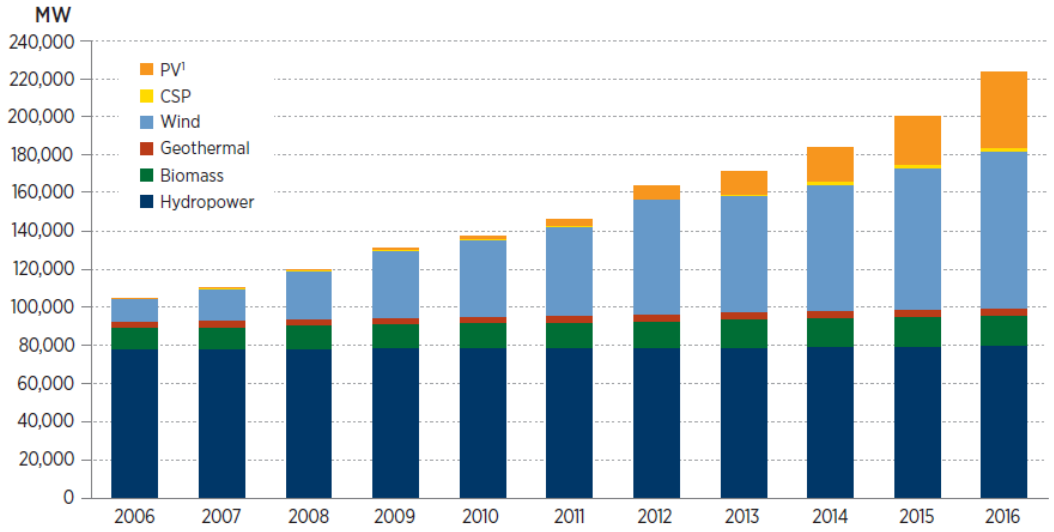
Offshore

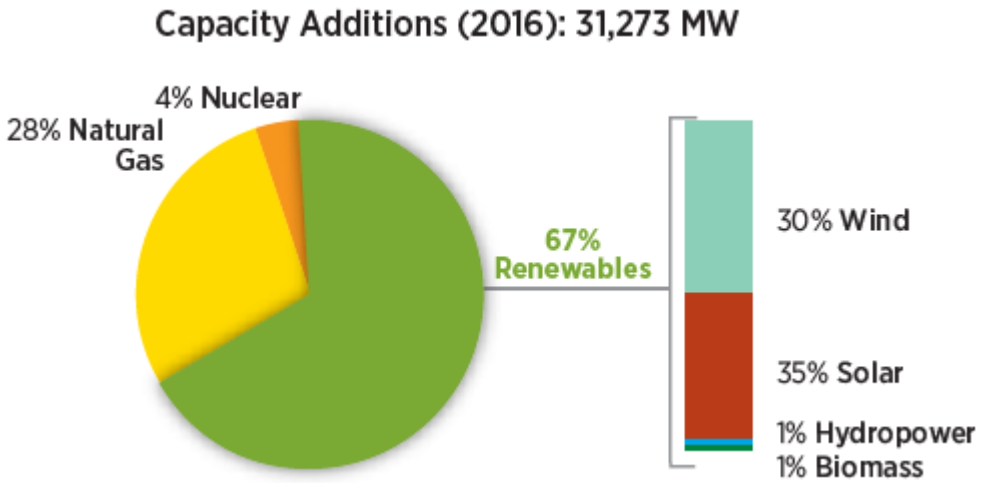
Distributed

- The Wind Energy Technologies Office aims to accelerate U.S. deployment of clean, affordable, reliable, and domestic wind power **across all 50 states** to promote national security, economic growth, and environmental quality
- Office RD&D activities are applicable to **utility-scale land** and **offshore wind** markets, as well as **distributed** turbines—typically interconnected on the distribution grid at or near the point of end-use

Renewables Landscape

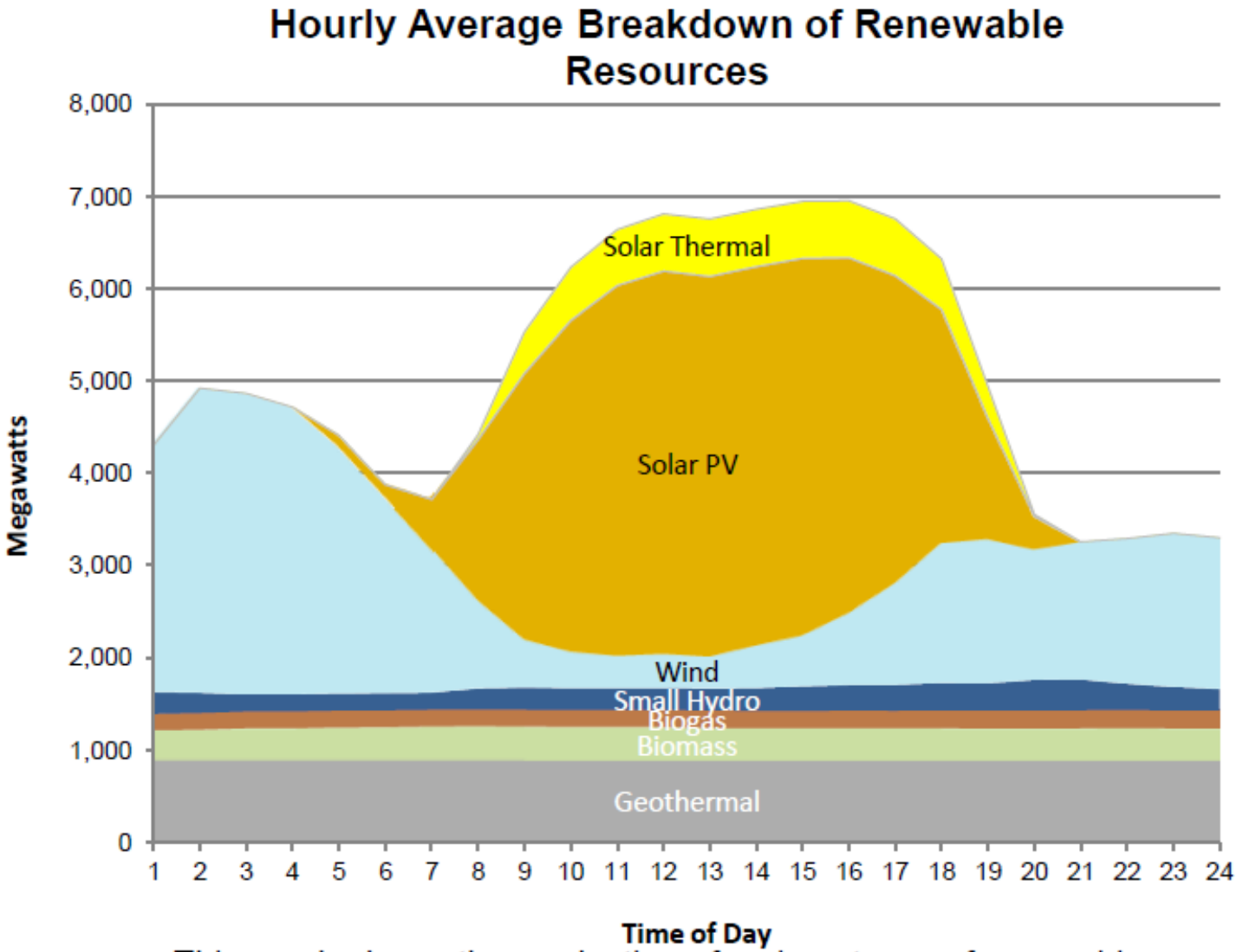
- Cost reductions
  - Since 2010, the cost of solar PV has **dropped more than 70%** and the cost of installing a solar electric system is **50% less**, driving installation increases across the country.
  - Since 2011, the cost of concentrating solar power has **dropped more than 40%**, from $0.21/kWh to $0.12/kWh.
  - The unsubsidized cost of wind energy has **dropped 90%** from 1980 to 2016
- Electricity Generation
  - Annual electricity generation from solar and wind has increased by a **factor of 11** since 2006.
  - Accounted for **over 15%** of U.S. electricity generation in 2016.
  - Accounted for **12.4%** federal energy consumed in FY 2016
- Capacity Growth
  - U.S. electric power energy consumption saw a slight decrease from 2015 to 2016, and yet, renewable energy accounted for **67% of U.S. electricity capacity additions** in 2016.
  - Installed global renewable electricity capacity continued to increase, and it represented 31% of total electricity capacity worldwide in 2016.





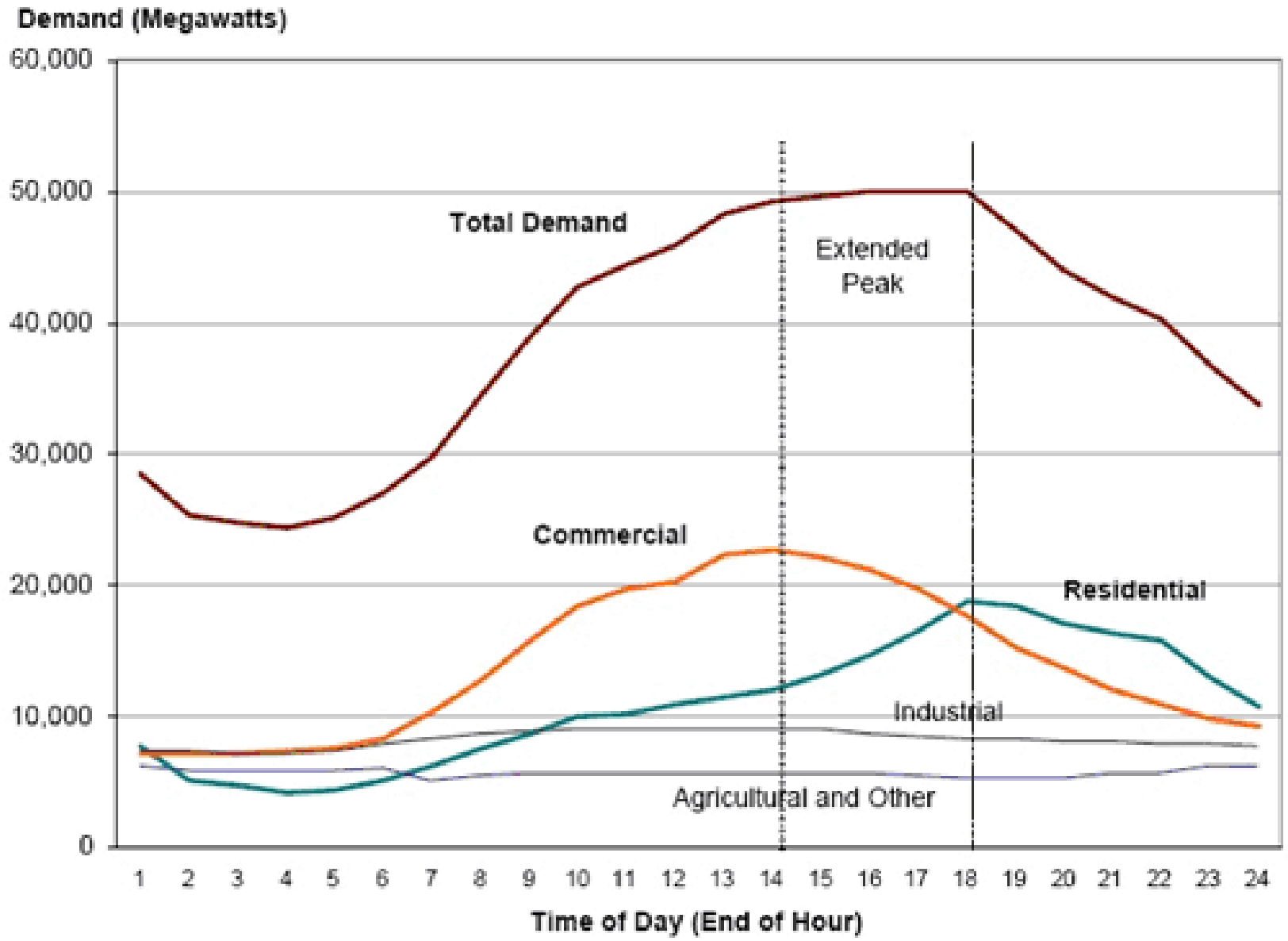
Source: 2016 Renewable Energy Data Book, NREL

Challenges

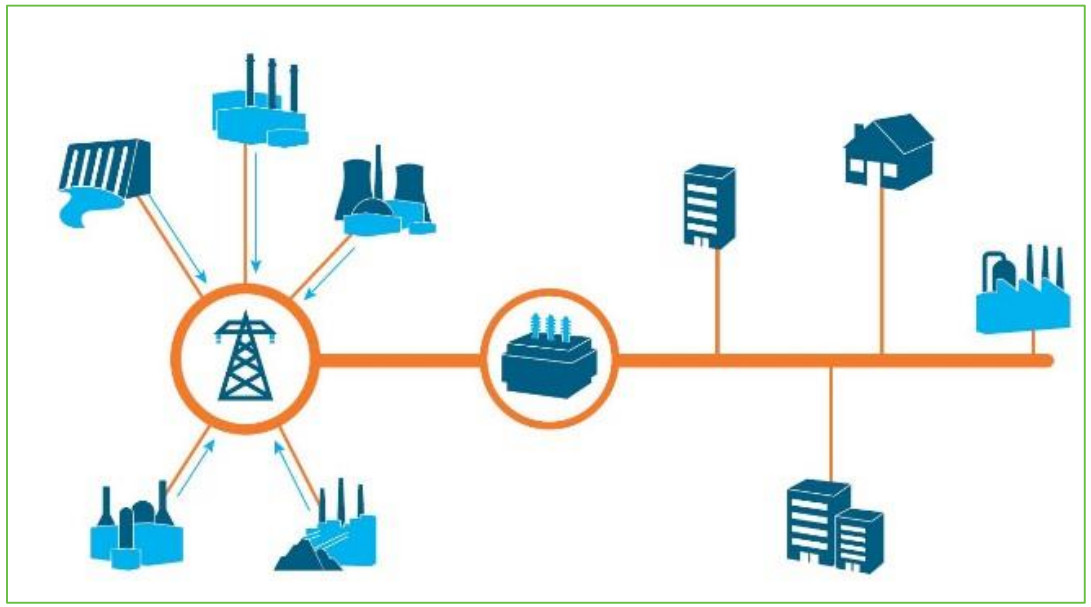


This graph shows the production of various types of renewable generation across the day.

Electricity Demand is not Flat

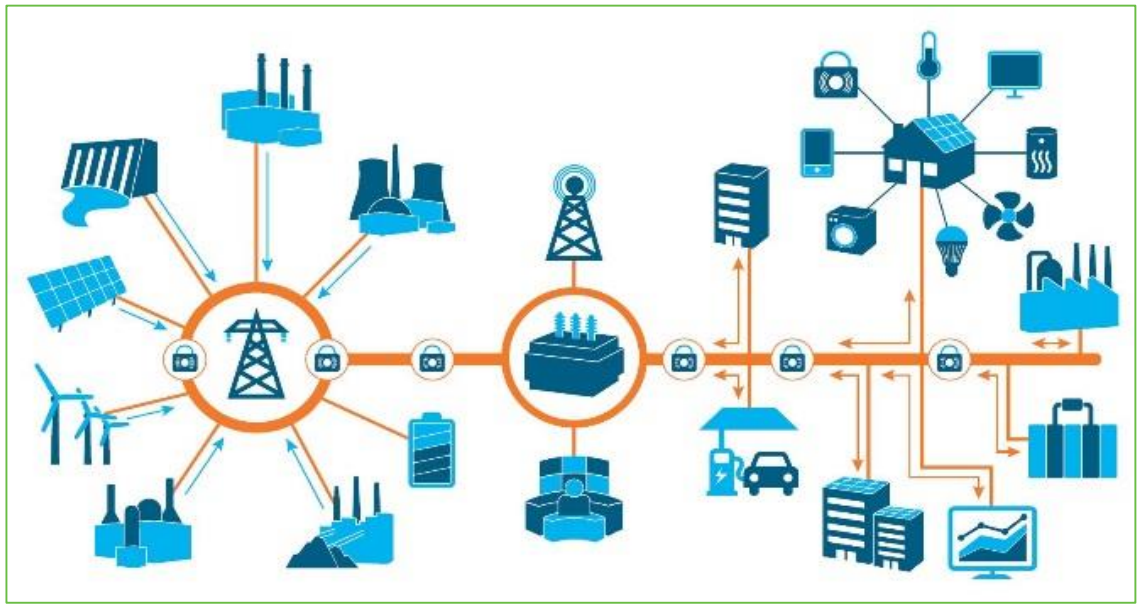


Grid of Today and Tomorrow



The grid of the 20th century

- Centralized generation
- Susceptible to extreme events
- Limited consumer options
- Limited visibility



The modernized grid of the 21st century

- Centralized and decentralized generation
- Resilience through microgrids
- Consumer choice
- Visibility from generation to the grid edge

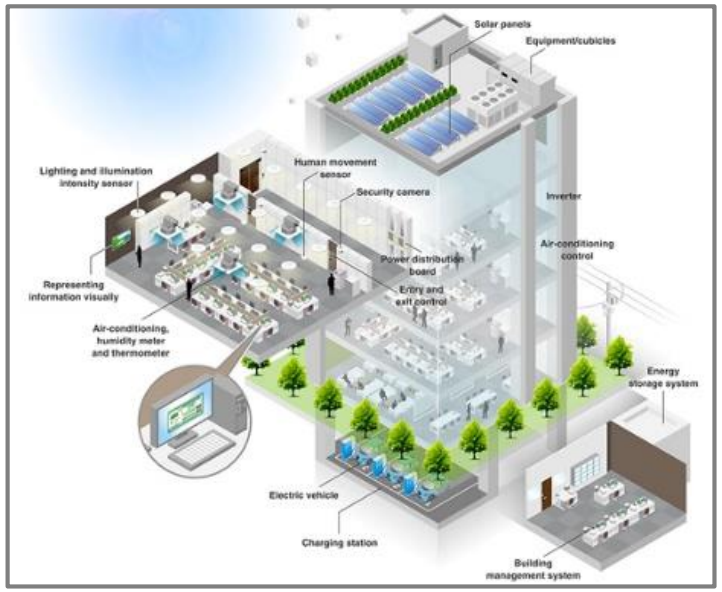
Why Beyond Batteries?

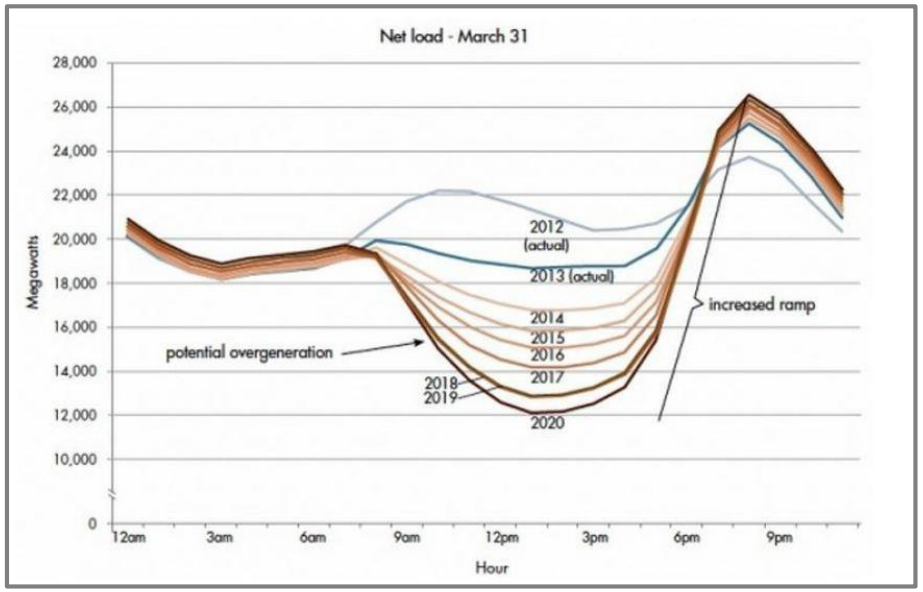
- Energy storage is essential to maintaining the reliability, resilience, and security of our energy systems.
- Energy storage solutions are not limited to large, utility-scale batteries; they are a suite of capabilities that provide a number of services to the grid, and that can be achieved in other ways.
- Advances in other storage technologies, along with technologies that allow us to better coordinate power generation and end-use, will allow us to effectively mimic many of the benefits of large-scale batteries, optimize use of existing assets to provide grid services, and increase grid reliability and resiliency.

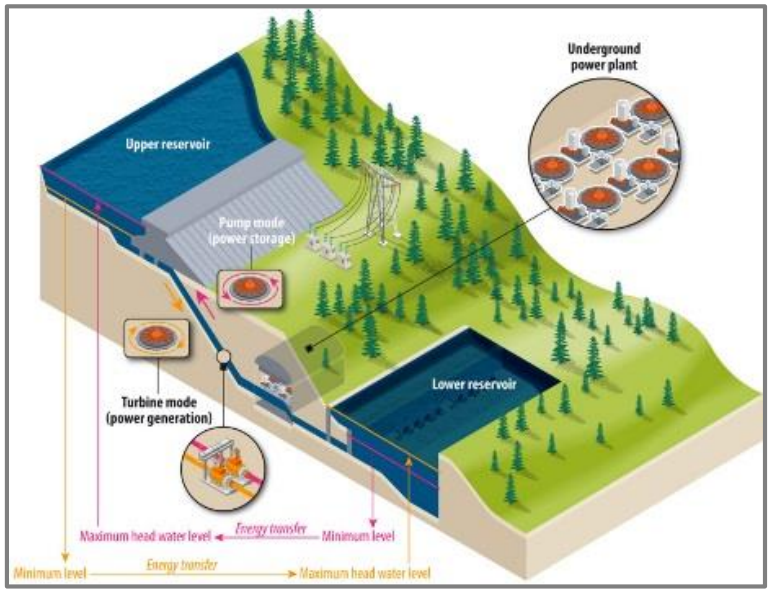
What is Beyond Batteries?

As part of the Grid Modernization Initiative, Beyond Batteries focuses on advances in controllable loads, hybrid systems, and new approaches to energy storage to increase the reliability and resiliency of our energy systems.

- Broad, holistic view of energy storage outside of large, utility-scale batteries
- Enhanced focus area within the GMI, building on success of previous GMI projects
- Resiliency, Reliability, and Affordability from Variability







Controllable Loads

- **Focuses on the fundamental advances in power electronics for building components and distributed solar systems, automated building and device sensors, and advanced production capabilities to optimize these systems to provide reliability and resiliency to the grid.**
  - Development of new power electronics technologies integrated with building components and distributed solar and solar+storage systems
  - Technologies for wide-bandgap power electronics that incorporate storage controls, lower manufacturing costs, and leverage unique U.S. capabilities for scalable domestic manufacturing.

Secure and Reliable Hybrid Systems

- **Focuses on advancing to the forefront of reliable energy systems incorporating a mix of conventional generation, renewables, storage, and controllable loads into energy systems that exceed today's reliability standards while improving resilience and cyber security.**
  - Technologies and approaches for the integration of electric vehicles, combined heat and power systems, hydrogen fuel cells, and building loads, among others
  - Technologies to allow larger, baseload energy generation like geothermal and hydropower to operate more flexibly and provide grid services
  - Analysis of applying new Critical Infrastructure Protection (CIP) Reliability Standards to major energy assets and what additional vulnerabilities remain.
  - Work in this area will leverage significant capabilities at existing facilities across the DOE enterprise for integrated pilot-scale testing and validation.

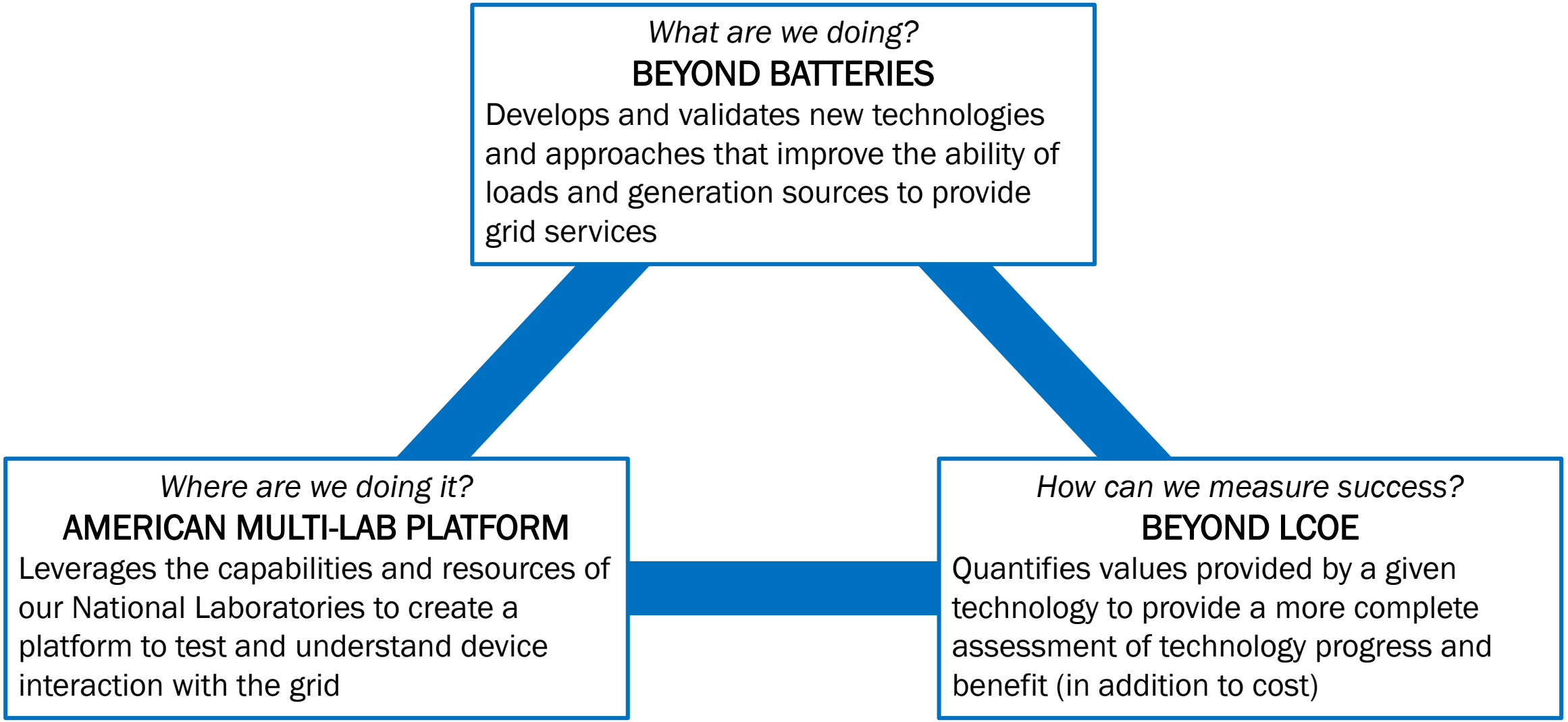
New Energy Storage Technologies

- **Focuses on work to develop new, early stage storage technologies, including:**
  - Technologies and approaches to using buildings and building components to store energy as part of solution sets for Resiliency-Security portfolio planning.
  - Development and validation of pumped storage hydropower technologies, including innovative turbine-motor-generator configurations, integrated system designs that are new to the industry, state-of-the-art components, and standardized, modular concepts designs.
  - High-temperature materials for thermochemical storage and fuels to increase efficiency, new designs for thermochemical processes, and improved efficiency and durability of components.
  - Development of entirely new, innovative storage technologies designed in partnership with domestic suppliers and manufacturers.

Implementation

- **Managed through existing Grid Modernization Initiative structure to ensure coordination and avoid overlap**
  - Existing collaboration with Office of Electricity
  - Working to expand GMI to bring in the Offices of Fossil and Nuclear Energy
- **Beyond Batteries envisioned as requiring significant private sector involvement**
  - Much of work likely to be awarded through competitive solicitation
  - Laboratory-Led work likely to include emphasis on private sector coordination
- **Current Beyond Batteries proposal is EERE, but collaboration across DOE envisioned**
  - Facilitated by use of existing GMI structure
  - Natural connections to Fossil and Nuclear in hybrid systems and others

Part of a Three-pronged Approach



Current Activities in Beyond Batteries

- **Buildings**
  - Thermal storage technologies that improve building's ability to shift and shed load
  - Tools to enhance demand flexibility and resiliency
  - Quantification of building's ability to interact with the grid at a specific moment
- **Geothermal**
  - Research into systems pairing low temperature geothermal with other power generation sources including solar and fossil fuels
  - Analysis of compressed air storage at geothermal sites incl. thermal management of reservoirs
- **Water**
  - Hydropower grid valuation initiative
  - Technologies to optimize hydropower and pumped storage flexibility and contribution to the grid

Thank You

What have you been doing to modernize energy systems in your state?

What are your greatest challenges with integrating new technologies?

What challenges can DOE help overcome to allow increased utilization of renewable power?

Where do you see cost issues associated with greater use of renewable power (grid issues, State Regulatory issues, etc.)?

How can DOE work with you best?