OFFICE OF ELECTRICITY
FY 2019 ACCOMPLISHMENTS

TOP FY 2019 ACCOMPLISHMENTS:
- **Developed the North American Energy Resilience Model (NAERM):** OE developed a static NAERM to understand risks to infrastructure and identify needed investments to improve system resilience across Canada, the U.S. and Mexico. The NAERM will be a first-of-its-kind energy resilience model that will enhance situational awareness across multiple critical sectors, including electric and gas.
- **Approved a Critical Decision for the Grid Storage Launchpad (GSL):** OE approved the critical decision-1 for the GSL in August 2019, which releases the project to proceed into the baseline development phase. The GSL will validate new technologies at earlier maturity stages and lower the time and expense of storage chemistry innovations.
- **Advanced Electricity Industry Technology and Practices Innovation Challenge (EITPIC)**: OE launched this contest to seek innovative ideas on how existing procedures and practices can be modified or replaced to improve grid operations. OE awarded over $300,000 to seven submissions tackling topics such as improving situational awareness in the power grid, incorporating technology such as augmented reality into grid operations, and improving the speed and quality of data.
- **Finalized a Rule on Critical Electric Infrastructure Information (CEII)**: OE is in the last stages of finalizing the rule implementing DOE's CEII designation authority under the Federal Power Act. The rule establishes administrative procedures intended to ensure stakeholders and the public understand how the Department would designate, protect, and share CEII.
- **Defense Critical Energy Infrastructure (DCEI):** Designed and executed requirements for DCEI communications encompassing both emergency communications solutions with measurement notifications.

RESEARCH & DEVELOPMENT FINANCIAL ASSISTANCE AWARDS:
- **Innovative R&D in Big Data, Artificial Intelligence (AI) and Machine Learning:** OE announced awards of nearly $7 million to improve existing knowledge and discover new insights and tools for better grid operation and management. These projects are expected to inform and shape the future development and application of faster grid analytics and modeling, better grid asset management, and sub-second automatic control actions that will help system operators avoid grid outages, improve operations, and reduce costs.

GRID SCALE ENERGY STORAGE ACHIEVEMENTS:
- **Award for a New Rechargeable Battery Chemistry:** A team from Sandia National Laboratories (SNL) and the City University of New York Energy Institute was recognized with the 2019 Environmental Protection Agency/American Chemical Society Green Chemistry Award for their OE-funded work on the development of low-cost rechargeable zinc manganese oxide batteries.
- **Award for an Innovative and Cheaper Battery:** Dr. Michael Aziz and Roy Gordon of Harvard University were awarded the 2019 international Eni Energy Frontiers award. Their OE-supported research into novel flow battery technologies resulted in a new kind of battery that is far cheaper and more innovative than others currently available.[a]

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[a] https://www.eni.com/en_IT/media/2019/07/eni-awards-innovation-in-energy-winners-of-the-eni-award-2019-announced#

- **Improved Flow Battery Capabilities:** Researchers at the PNNL demonstrated novel aqueous soluble phenazine-based chemistry in a prototypical flow battery stack. The stack operated at 100 mA/cm^2 and achieved an energy efficiency of approximately 80% with a projected cost of less than \$250/kWh for a 1 MW/4 MWh system. The work was patented based on results of the vanadium/vanadium flow battery development program. The stack enables vanadium-based flow batteries to operate at 400 mA/cm^2 while achieving energy efficiencies over 75%. (PNNL)
- **Proof of Concept for Low-Cost Long-Duration Energy Storage:** Researchers at ORNL have demonstrated a proof-of-concept high–energy-density sodium-ion-based non-aqueous redox flow chemistry targeted for long duration energy storage using low-cost and earth-abundant phosphorus anode and organic mediators.
- **New High-Density and High-Efficiency Battery Charger:** A team from SNL and the University of Texas-Austin has demonstrated a gallium nitride-based 10 kW 3-phase flow battery bidirectional charger with high density (40 kW/in^3) and about 97% efficiency.

MICROGRID AND RESILIENCY ACHIEVEMENTS:
- **Stochastic Optimization for Grid Resilience:** Lawrence Livermore National Laboratory (LLNL), with OE funding, developed a stochastic optimization technique that can better allocate black start resources (pre-outage) and develop restoration sequences (post-outage) to improve the resiliency of the electrical grid. By building a mathematical framework that accounts for uncertainty and explicitly incorporates the knowledge of system operators, the tool enables planners to efficiently plan system upgrades to improve the ability of the system to recover from outages.
- **Urban Resilience Pilot:** A partnership project with the 100 Resilient Cities Organization, the City of New Orleans, and Entergy New Orleans used OE-funded microgrid R&D tools developed by DOE's national laboratories to conduct an in-depth analysis of microgrid designs to provide both resilience solutions (for extreme events) and blue-sky solutions (for normal operations).
- **Microgrids Designs to Support Resiliency in Puerto Rico:** SNL and ORNL worked together to evaluate microgrid technical designs for four multi-customer industrial microgrids to support resiliency for critical facilities.
- **Progress for Connected Communities:** ORNL and the Georgia Power Smart Neighborhood hosted a ribbon-cutting ceremony for their microgrid project of 46 high-performance townhomes with controllable HVAC and water heater, as well as in-home battery energy storage and rooftop solar. Each home contains a critical load panel able to be fed by storage and solar in the case of grid outage. At the Alabama Smart Neighborhood microgrid site, a microgrid controller was demonstrated with the ability to disconnect from the bulk grid in response to an event and then resynchronize seamlessly while sustaining power availability.
- **Resilient Distribution Systems (RDS):** Through the Grid Modernization Lab Consortium, the Office of Electricity and the Office of Energy Efficiency and Renewable Energy awarded seven projects to teams of National Laboratories partnered with industry to develop and validate innovative approaches to enhance the resilience of electric distribution systems, including microgrids, with high penetration of clean Distributed Energy Resources (DER) in 2019.
- **Electricity Distribution System Resilience**: OE launched an effort in partnership with states and electric utilities to develop a framework to inform grid resilience strategies, planning, and implementation decisions for communities around the Nation. The framework will support informed state and utility policy, technology, and infrastructure investment decisions in the face of increasingly complex risk assessments, vulnerability analyses, significant uncertainty in available information upon which to act, and the daunting range (and cost) of needed resilience measures. DOE will work with its partners to advance a practical, stakeholder-driven, and

organized set of grid resilience planning considerations and recommendations based on best practices that maintain an emphasis on the value of resilience investments to electricity customers. The framework will be released in 2020.

TOOLS AND MODELING ACHIEVEMENTS:
- **Improved Frequency Data Transmission and Visualization:** Frequency Monitoring Network (FNET)/GridEye is a strategically important DOE effort to help the North American Energy Reliability Corporation (NERC) increase its situational awareness and data source quality assurance. During FY 2019, Oak Ridge National Laboratory (ORNL) helped NERC develop the tools for FNET/GridEye one-second interconnection average data direct feed.
- **Co-Simulation Tool Enables Bulk Power System Reliability Studies:** Through OE funded work, Argonne National Laboratory developed transmission and distribution (T&D) co-simulation software in cooperation with NERC. Using the tool, NERC and the transmission system entities explored the full-spectrum impact of distributed energy resources (DERs) on the bulk power system and can now perform day-to-day planning, operational, and control studies for high-DER-penetration scenarios, which helps ensure secure and reliable grid planning and operations. The tool also enabled studies with physically realistic scenarios on actual T&D network models.
- **A New Autonomous Energy Grid Paradigm to Enhance Resiliency, Security, and Reliability:** Supported by OE, NREL developed a proof-of-concept centralized algorithm for frequency control. This work takes into consideration the physical dynamics of the power grid for optimization algorithm design, overcoming a critical bottleneck in the literature.
- **Optimal Resilient Distribution System Modeling:** An open-source software tool, named LPNORM (the Los Alamos National Laboratory, Pacific Northwest National Laboratory, and National Rural Electric Cooperative Association [NRECA] Optimal Resiliency Model), has been deployed for free use by the nation's utilities to help enhance resilience of their distribution feeders against extreme weather events. This tool is a unique combination of existing and new modeling capabilities that, based on the utility-defined resiliency criteria, can make recommendations on the initial design of distribution circuits and upgrades to existing distribution circuits and communication systems.
- **Implementation of National Resilience Framework:** A web-based interface platform for hosting modeling tools – including the Hurricane Electrical Assessment Damage Outage Tool (HEADOUT), Telcofast, NGFast, and EPfast – was developed for system operators and other stakeholders. A well-structured framework to enhance the resilience of the nation's electric grid in response to expected vulnerabilities and hazards is being implemented jointly with stakeholders such as Independent System Operators and Regional Transmission Organizations. The implementation includes testing new and/or enhanced tools in actionable exercises with stakeholders. These tools support real-time resilient grid operational advancements in gas-electric interdependency modeling, large-scale emergency preparedness, and integration across transmission and distribution interface.
- **Quantifying System Resilience**: A modeling and analysis framework was developed to assess the vulnerability and resilience of the grid and identify specific grid components that can be improved. The innovative physics-based approach combined with probabilistic risk assessment has caught the attention of utilities such as Idaho Falls and Duke Energy. The tool can be used to analyze corrective action based on the adaptive capabilities of grid components to better manage contingencies.
- **3D Printed Magnetic Steel**: Demonstrated the feasibility of using additive manufacturing techniques to create magnetic cores that can be used in the next-generation of transformers.

Prototype cores, leveraging a Hilbert space geometry, were developed and characterized that perform better than non-grain-oriented steel.

- **Novel Direct Current (DC) Models and Methods**: Developed a suite of high-fidelity models, control methods, and tools for voltage source converter -based high- and medium-voltage DC technologies, including multi-terminal applications, to better assess their dynamic performance and explore the additional value streams they can provide, such as frequency response, congestion relief, and voltage control. These results will enable stakeholders to make better-informed decisions regarding the use of DC systems and technologies.
- **Environmentally Neutral Automated Building Electric Energy (ENABLE) Platform**: The ENABLE platform provides direct flexible control of individual loads and sources for modularity and scalability of various higher and lower power levels. It also serves as the electric grid gateway, or an energy router, to the buildings for smart power management. A prototype was designed, built, and successfully tested at power levels up to 5 kW, and the measured maximum efficiency was 94.4%. This concept can enable hybrid AC and DC systems to facilitate installation of net-zero homes or microgrids.
- **Tapless Voltage Regulating Transformer (TAREX)**: The TAREX is based on the concept of a saturable-core reactor, magnetically regulating the voltage on the secondary side, and thus eliminating the need for a mechanical tap changer. Voltage regulation by the dc-biased magnetization was proven for the first time and operating mechanisms were extensively analyzed using multiple modeling and testing approaches. This work helped to expand the design and operating knowledge for this new type of grid component.
- **Expansion of the Regulatory and Permitting Information Desktop (RAPID) toolkit for transmission:** In FY 2019, OE, in partnership with the NREL, expanded RAPID to include the last 17 states and all Canadian provinces. The RAPID Toolkit makes regulatory and permitting information rapidly accessible from one location by providing links to permit applications, processes, manuals, and related information. Its goal is to facilitate communication between project developers and permitting agency personnel, among permitting agencies at all jurisdiction levels, and among all project stakeholders—including the public.
- **Enhancing the Energy Zones Mapping Tool's online, geospatial analysis capabilities:** The Energy Zones Mapping Tool (EZMT) is a free public geospatial analysis tool that supports siting analyses for a variety of energy resources and linear corridors. In partnership with ANL, suitability models were extended from the Eastern Interconnection to the full lower 48 states, including land-based and offshore wind, concentrating and photovoltaic solar, and corridor suitability. These user-adjustable models rapidly map areas that may be suitable for these technologies based on many siting criteria. Also, the ability to import and export analysis areas and corridors was added, which makes it easier to use the EZMT with other GIS systems and data. The EZMT has a large library of energy mapping data and recent updates to it include adding another transmission line layer, updating all the layers from the Energy Information Administration, and many other layer updates.
- **Improving Grid Reliability against Drought Effects:** OE supported the Western Electricity Coordinating Council and the Electric Reliability Council of Texas in their long-term grid reliability planning. Using advanced modeling and analysis tools, drought-related risk to thermoelectric and hydroelectric plant operations was assessed. Additionally, grid expansion plans for new generation assets were developed that minimize system disruptions caused by an uncertain and changing water future.

DISASTER RECOVERY ACHIEVEMENTS:
- **Puerto Rico Disaster Recovery Technical Assistance**: OE provided technical assistance from several National Laboratories for Puerto Rico and the U.S. Virgin Islands to support recovery

from Hurricane Maria. Areas of focus included work in infrastructure interdependencies, bulk power system, transmission, and distribution and behind the meter:

- o Provided an island wide communications architecture/design with budget to bring the current communications infrastructure back up to pre-hurricane status while providing a solution for emergency management.
- o Oversaw the successful execution, design, and coordination of 20 microPMU installations island wide within the PREPA substation network.
- o Oversaw the successful execution, design, and coordination of 6 microPMU installations within the island while providing a system for workforce training with University of Puerto Rico. This installation and data is open and available for use/view to the public.

INFRASTRUCTURE ACHIEVEMENTS:
- **Improving the Permitting Process for Major Infrastructure Projects:** OE continued to lead the Department's effort to implement Executive Order (EO) 13807: Establishing Discipline and Accountability in the Environmental Review and Permitting Process for Infrastructure Projects. EO 13807 is intended to improve the timeliness, predictability, and transparency of the Federal environmental review and authorization process for covered infrastructure projects.
- **Presidential Permit for Nogales Interconnection Project**: OE issued a Presidential Permit to Nogales Transmission, L.L.C. for construction, operation, maintenance, and interconnection of an electric transmission project crossing the U.S.–Mexico border in Nogales, Arizona. The project adds up to 300 megawatts of transmission capacity, opening a new market between Arizona and Mexico.
- **Electricity Export Authorizations**: OE issued, under section 202e of the Federal Power Act, 19 export authorizations for entities to export electricity to Canada and eight for entities to export electricity to Mexico. These authorizations are necessary for entities to export electricity over the U.S. border after OE finds that the issuance would not affect electricity supply or negatively impact cross border transmission facilities.
- **Electricity Advisory Committee (EAC)**: The EAC met three times during FY 2019. The members of the committee developed several sets of recommendations aimed to improve DOE programs focused on electricity R&D and policy. Recommendations included coordination between the electricity transmission and distribution systems, policy considerations for grid resilience, and the congressionally required 2018 Biennial Energy Storage Review. These recommendations helped to better inform the Department's leadership to enhance ongoing work or begin new projects that would further the Department's mission.

OUTREACH:
- **Good Neighbor Environmental Board**: OE represented the Department on the U.S. Environmental Protection Agency's Good Neighbor Environmental Review Board (GNEB), a Federal advisory committee for environmental and infrastructure issues along the U.S. border with Mexico.
- **Recognizing women in clean energy through the U.S. Clean Energy Education and Empowerment (C3E) Initiative**: OE led the Department's role in the U.S. C3E Initiative, which seeks to close the gender gap and increase the participation, leadership, and success of women in clean energy fields. OE worked with DOE's three university partners to execute a successful 7th Annual U.S. C3E Women in Clean Energy Symposium during which eight outstanding women across the clean energy spectrum of careers, and one lifetime achievement award winner, were recognized.
- **State Electricity System Planning**: OE partnered with the National Association of Regulatory Utility Commissioners and the National Association of State Energy Officials to launch an

initiative to develop state-led pathways toward a more resilient, efficient, and affordable grid. As new distributed and other technology investments interact with the grid, they require innovative oversight strategies to overcome unprecedented electricity system complexities and avoid unnecessary costs to energy customers. Sixteen diverse states are participating in developing approaches to better align energy resource, distribution, and transmission system planning processes, moving toward more effective infrastructure planning and an integrated and optimized electricity system.

CONFERENCES AND WORKSHOPS:

- **Conference on Security Investments for Energy Infrastructure:** DOE and the Federal Energy Regulatory Commission co-hosted a technical conference in 2019 on Security Investments for Energy Infrastructure to discuss security practices to protect energy infrastructure. The purpose of the conference was to discuss current cyber and physical security practices used to protect energy infrastructure and explore how federal and state authorities can provide incentives and cost recovery for security investments in energy infrastructure, particularly the electric and natural gas sectors.
- **Next-Generation Distribution System Platform (DSPx) Initiative**: In FY 2019 OE hosted five workshops for state utility commissions and supported the grid modernization planning efforts of five state commissions and several utilities.