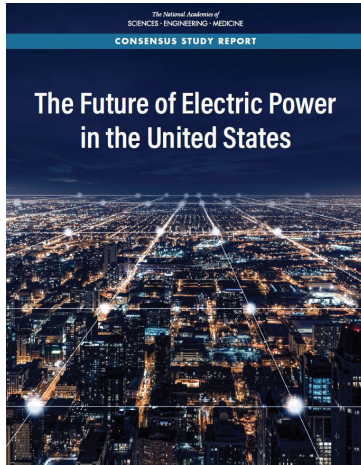




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## The Future of Electric Power in the United States



Electric power is essential for the lives and livelihoods of all Americans, and the need for electricity that is safe, clean, affordable, and reliable will only grow in the decades to come. At the request of Congress and the Department of Energy, the National Academies convened a committee of experts to undertake a comprehensive evaluation of the U.S. grid and how it might evolve in response to advances in new energy technologies, changes in demand, and future innovation.

*The Future of Electric Power in the United States* presents an extensive set of policy and funding recommendations aimed at modernizing the U.S. electric system. The report addresses technology development, operations, grid architectures, and business practices, as well as ways to make the electricity system safe, secure, sustainable, equitable, and resilient.

### DRIVERS OF CHANGE

While it is difficult to anticipate what the future U.S. electric power system will look like, the committee identified a number of social, technical, and economic forces that hold the potential to bring about change in the U.S. power system.

- **Possible large growth in future demand for electricity.** The broadly anticipated push for deeper electrification of the buildings, transportation, and industrial sectors could lead to very different patterns and levels of electricity demand over the next few decades.
- **Efforts to decarbonize the U.S. economy and eliminate the emission of conventional pollutants.** This will require a dramatic shift away from fossil fuel technologies to low or zero-emission sources of electricity across energy, transportation, buildings, and industrial sectors.
- **Developments at the edge of the grid such as distributed generation, storage, microgrids, energy-management resources, and energy efficiency measures.** This is driven by the growing availability of commercial technologies such as rooftop solar energy and battery storage, as well as concerns about supply vulnerability in the face of natural or human-based disruptions.
- **Grid stability challenges arising as a result of high penetrations of non-dispatchable sources of generation such as wind and solar.** The intermittent nature of wind and solar complicate the operation of power systems and create challenges of both insufficiency and excess. Solutions could include dispatchable and just-in-time zero-emission power generation, energy storage, and demand response technologies.

- ***A desire to reduce social inequities.*** Paying for adequate energy is a heavy burden on many low-income households, and many existing fossil fuel plants are in communities that have been disproportionately impacted by negative health effects from their emissions. As the electricity system evolves, care should be taken to ensure that electricity is universally available and affordable, and that disadvantaged communities are not unfairly burdened.
- ***Concerns about the impacts of the energy transition on employment.*** While the transition to a sustainable and cleaner electricity grid will mean some job losses, many traditional jobs in the electric sector will remain relevant as the grid evolves, and increases in renewables, energy efficiency, and security will be a source of new employment opportunities. Job placement and retraining for displaced workers will be needed as well as federal policy to help meet and understand future workforce challenges.
- ***The globalization of supply chains.*** Many suppliers of electricity system equipment have chosen to move their manufacturing and development overseas. Plans for expanding electricity infrastructure in the U.S. need to be cognizant of this changing geopolitical environment.

## MAJOR NEEDS FOR THE FUTURE U.S. ELECTRIC POWER SYSTEM

The report makes forty recommendations to meet five major needs for the future U.S. electric power system, as summarized below. For a full list of recommendations sorted by actor (Department of Energy, Congress, State Entities, and Industry), download the full report at [nap.edu/25968](https://nap.edu/25968).

***Need #1: Improve our understanding of how the electric power system is evolving.*** The U.S. electric system is undergoing rapid changes due to new technologies, efforts to decarbonize, and new patterns of electricity consumption. The nation needs to invest in research to support these changes, including analytical tools to understand how the grid of the future will behave and how operators and policy makers can ensure its continued reliability and resilience. Specific recommendations call for:

- Multi-year government support for key **electricity research initiatives** such as grid modernization and technology development
- Sustained collaboration across national labs, academia, utilities, and industry to carry out **large-scale grid simulations**
- Development of **better grid architectures; updated regulations, policies, standards; and better assessments** of how technologies may affect grid architectures, based on insights gained from large-scale simulations and field experiments.

***Need #2: Ensure that electricity service remains clean and sustainable, and reliable and resilient.*** In the coming decades, reducing carbon emissions and other environmental impacts of electricity generation will remain a major challenge. It will also be important to increase the resilience of the grid to natural disasters and targeted attacks. Meeting these challenges will require continued investment in critical power system elements such as long-distance transmission, reliability requirements for the natural-gas delivery system, and improved cybersecurity capabilities and information-sharing. Specific recommendations call for:

- A joint task force with the authority to **investigate in a timely manner why a significant physical and/or cyber disruption occurred** and identify lessons learned.
- A central entity to **oversee the reliability and security of the nation's natural gas delivery system.**

- Support across the government for the evolution, planning, and **siting of regional transmission facilities** in the United States.
- Research and development on **low-carbon technologies, storage systems, power electronics, and control technologies** to enable real-time control of the grid.
- Cybersecurity research, training, and regulations to **increase grid resilience and develop secure components**
- Mechanisms for communicating and **reporting potential security risks** to stakeholders in a timely manner as well as exercises to improve grid security.

*Need #3: Improve understanding of how people use electricity and sustain the “social compact” to keep electricity affordable and equitable in the face of profound technological challenges.* Changes in the grid reveal opportunities for new services and configurations of electric resources, but these changes can also have large impacts on customers and low-income communities. It is crucial to develop our understanding of how people use electricity and devise regulatory responses to evolve and strengthen social compacts to deliver electricity fairly and affordably. Specific recommendations call for:

- Regular evaluation of how new rate structures and other policies will affect **equity issues**.
- **Behavioral and social science research** needed to inform policy and technology development.
- **Funding to support vocational, professional, and academic training programs** for the current and future workforce in the electricity sector.
- **Investment in analyses to better address equitable worker transitions** across the electricity sector, including wage impacts from job displacement and retraining.

*Need #4: Facilitate innovations in technology, policy, and business models relevant to the power system.* Understanding how electricity consumers behave, how devices and energy services can be aggregated for supply, and how such trends affect system loads is emerging as one of most profound technological challenges and opportunities facing the future of the grid. Increasing numbers of distributed devices also motivate the need for advanced situational awareness and control at the grid edge. Technology, policy, and business models must be flexible enough to coordinate and respond to changing conditions for large-scale and local-level electricity services. Specific recommendations call for:

- Support for **social science research and policy analysis** to identify and evaluate alternate models for the retail segment of the electric system.
- **Seed grants to support innovative state programs** on new business models.
- **Expanded funding for loans, loan guarantees, and grants** to provide equivalent opportunities for investment in local utility infrastructure development for publicly owned utilities, including municipal electric utilities, cooperative utilities, and tribal utility authorities.
- Accelerated investigations into what technical and business changes are needed to **enable significant deployment of distributed energy resources and to address equity issues** related to energy access and clean energy.
- Regulatory reform to allow utilities to recover the costs of larger R&D budgets and **encourage the adoption of new technologies**.

**Need #5: Accelerate innovations in technology in the face of shifting global supply chains and the influx of disruptive technologies.** Many power system technologies were first developed in the U.S., but supply chains for most critical components have now moved overseas. Massive new private and public investments are needed for cutting-edge technologies on which the future grid will depend. In this, the U.S. must balance competing goals to capitalize on global innovation while ensuring U.S. control and access to critical grid technologies. Specific recommendations call for:

- **Doubled funding for basic science research** broadly related to electric power and **tripled funding for applied development and demonstration.**
- Better **regulatory tools for dealing with imported equipment** and cross-border ownership of firms producing critical equipment for the grid, as well as a program for **manufacturing critical technologies within the U.S.**
- Strategies to support **international collaborations on pre-competitive energy research** and technology development.
- Development of technologies to enable the high levels of **automation needed in the future grid.**

## DOWNLOAD THE REPORT AND RELATED PUBLICATIONS AT THE NATIONAL ACADEMIES

- *The Future of Electric Power in the United States* (2021): [nap.edu/25968](https://nap.edu/25968)
- *Accelerating Decarbonization of the U.S. Energy System* (2021): [nap.edu/decarbonization](https://nap.edu/decarbonization)
- *Communications, Cyber Resilience, and the Future of the U.S. Electric Power System: Proceedings of a Workshop* (2021): [nap.edu/25782](https://nap.edu/25782)
- *Models to Inform Planning for the Future of Electric Power in the United States: Proceedings of a Workshop* (2020): [nap.edu/25880](https://nap.edu/25880)
- *Enhancing the Resilience of the Nation's Electricity System* (2017): [nap.edu/24836](https://nap.edu/24836)

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