
Office of Electric Transmission and Distribution

TRANSFORMING THE GRID TO STRENGTHEN ELECTRIC RELIABILITY AND THE ECONOMY

December 2003



United States Department of Energy

Summary

Blackouts serve as powerful reminders of the critical role electricity plays in the everyday lives of the American people.

On August 14, 2003, a widespread blackout in the Great Lakes region affected 50 million people in 8 states and 1 Canadian province. Who can forget the photographs of darkened skylines and widespread traffic jams? It shut down 259 power plants, caused 3 deaths, and left 1.5 million people in Cleveland, Ohio without water for several days. It cost the U.S. economy \$4.5-12 billion in lost business activity.

It would be wrong to consider the August 14th blackout a singular, isolated event. Unfortunately, the number and severity of electric blackouts across America has increased in the last decade. No region has been spared. Some of the events have been weather-related. Others have been caused by faulty equipment or inadequate maintenance. Most, like the August 14th event, have multiple causes that include inadequate situational awareness on the part of grid operators and the failure of grid reliability organizations to provide effective diagnostic support.

To address the blackout challenge, and to modernize America's electric delivery systems, action must be taken in several key areas:

- Aging capital equipment and infrastructure
- Uncertainty in policies and the regulatory framework
- Difficulty in building investor confidence and attracting capital investment
- Constraints in power supplies and delivery systems to meet growth in demand

America cannot afford to let this blackout trend continue. The electricity sector is too vital to public health and safety, and to the national economy.

President Bush has recognized the need to modernize America's electric delivery system. The National Energy Policy includes 22 recommendations to improve electric generation, transmission, distribution, and end-use. In addition, Secretary of Energy



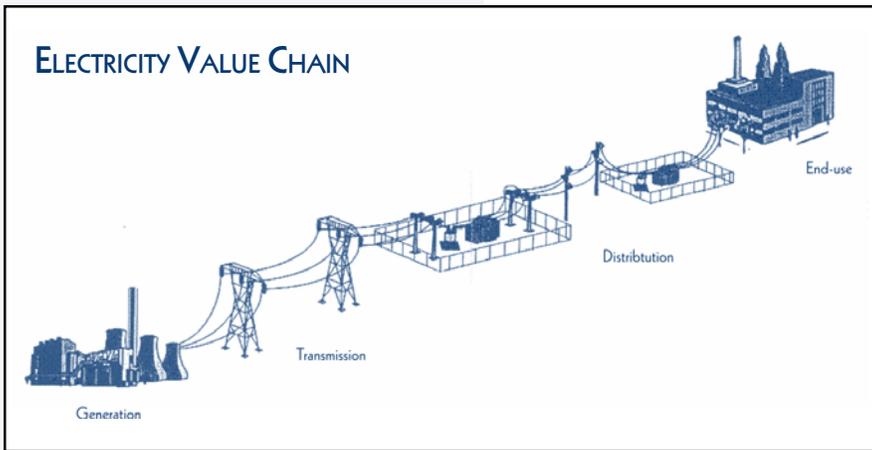
"...it's clear that the power grid needs an overhaul. It needs to be modernized. As we go into an exciting new period of American history, we want the most modern electricity grid for our people... we need more investment; we need research and development..."

*George W. Bush
September 15, 2003*

AUGUST 14, 2003 BLACKOUT

- 1** Canadian Province affected
- 3** deaths attributed to the blackout
- 8** U.S. states affected
- 12** airports partially or completely closed
- 259** power plants shut down
- 700** flights cancelled nationwide
- 9,266** square miles affected
- 61,800** MW of power lost
- 1.5 million** Cleveland residents without water
- 50 million** people affected
- \$4.5-12 billion** in lost economic activity





Spencer Abraham provided the President with 51 specific recommendations for modernizing America’s electric delivery system in the National Transmission Grid Report. The Energy Department’s newly formed Office of Electric Transmission and Distribution has engaged industry, the states, universities, national laboratories, and interest groups

in the development of a National Electric Vision and Electric Delivery Technologies Roadmap to guide public-private partnerships in a national grid modernization effort.

Opportunities

Grid modernization affects the entire electricity value chain: generation, transmission, distribution, and end-use. The aim is to increase supplies, improve reliability and security, improve efficiency and modernize conservation, and reduce environmental impacts.

Grid modernization is a substantial undertaking, given the fact that America’s electric system is capital-intensive and far-reaching:

- 10,000 power plants generate electricity
- 157,000 miles of high voltage transmission lines deliver electricity
- 3,100 utilities distribute electricity
- 131 million commercial, industrial, and residential customers use electricity

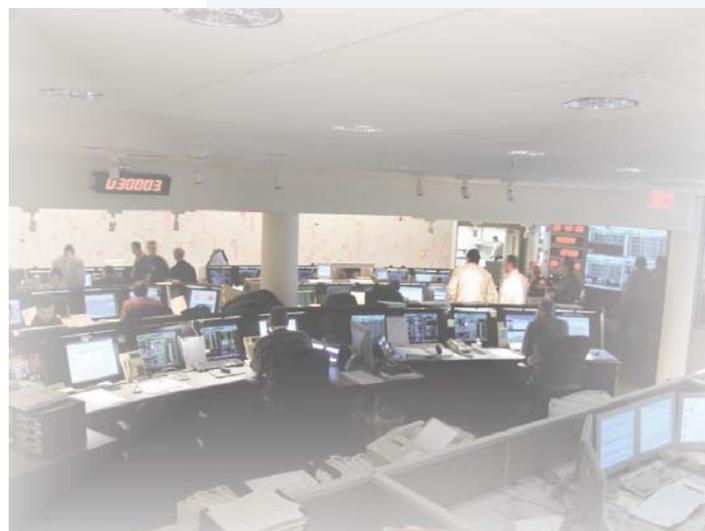
The result is an electricity sector that is responsible for about \$800 billion in total assets that yield almost \$250 billion in revenues annually. The electricity sector is a cornerstone of the American economy and is a critical factor in producing opportunities for a prosperous, healthy, and secure quality-of-life for all Americans.

“Grid modernization affects the entire electricity value chain: generation, transmission, distribution, and end-use.”



Challenges

There has been a substantial decline recently in the level of research and development spending by the electric power industry. These decreases have not been offset by increases in federal and state spending, nor by expanded research programs by equipment manufacturers or others with a direct stake in the Nation's electricity infrastructure. The flow of new ideas from laboratories into the marketplace has not been as strong in electric power as it has been in other industries like telecommunications and information technologies.



Electric assets are capital-intensive and long-lived, so the capital stock turnover process is relatively slow. One way to manage the financial risks is to keep existing equipment in service for as long as possible. As a result, much of the nation's electricity infrastructure of power lines, substations, switchyards, and transformers has been in service for 25 years, or longer.

As a result of these and other factors, America has been under-investing in the modernization of the electricity system. There are electricity technologies that are ready today to help modernize the grid. Unfortunately, they are not being used widely, primarily because of uncertainty — uncertainty about future regulations, uncertainty about financial risks and returns, and uncertainty about the performance of new technologies, tools, and techniques. With a backdrop of uncertain cost recovery and investor concerns about future financial performance, the business case for new electric systems must be “bullet-proof” for managers to decide to proceed with grid modernization improvements.

The regulatory framework governing electricity markets is in the midst of significant change, affecting many of the factors that determine the long-term viability of electric systems: the jurisdiction of federal and state agencies; the role of regional entities; the siting and permitting of electricity facilities; capital formation; consumer and public-purpose programs; and the balance between regulation and competition. The restructuring of utility systems in response to evolving regulatory regimes is

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“Addressing these challenges properly requires a national approach.”

proceeding in a “patchwork” fashion, state-by-state, across the country. Proposals for national electricity legislation have been before Congress since 1996, but none have passed.

Even without a changing regulatory framework, the electricity sector is generally slow to accept new technologies. One of the legacies of traditional monopoly-based utility regulation has been a lack of incentives for innovation and entrepreneurial activity. In addition, maintaining reliable grid operations is a top industry priority. As a result, electricity planners and operators are generally reluctant to use new approaches until they have proven their worth, and their impacts on grid operations and worker safety are fully tested and known.

On the horizon are even better technologies – such as high-temperature superconductivity, power electronics, and advanced composite conductors – that use advanced materials and new designs to increase efficiency, reduce environmental impacts, and expand the capabilities of grid operations. However, for these to be developed and accepted in the marketplace, significant technical challenges must be addressed. For example, their costs must be lowered, their reliability and durability increased, and their performance improved.

Addressing these challenges properly requires a national approach. The states, along with utilities, equipment manufacturers, and consumers have critical roles to play. A comprehensive strategic plan requiring partnerships among industry, local, and federal government must be implemented.

Federal Leadership

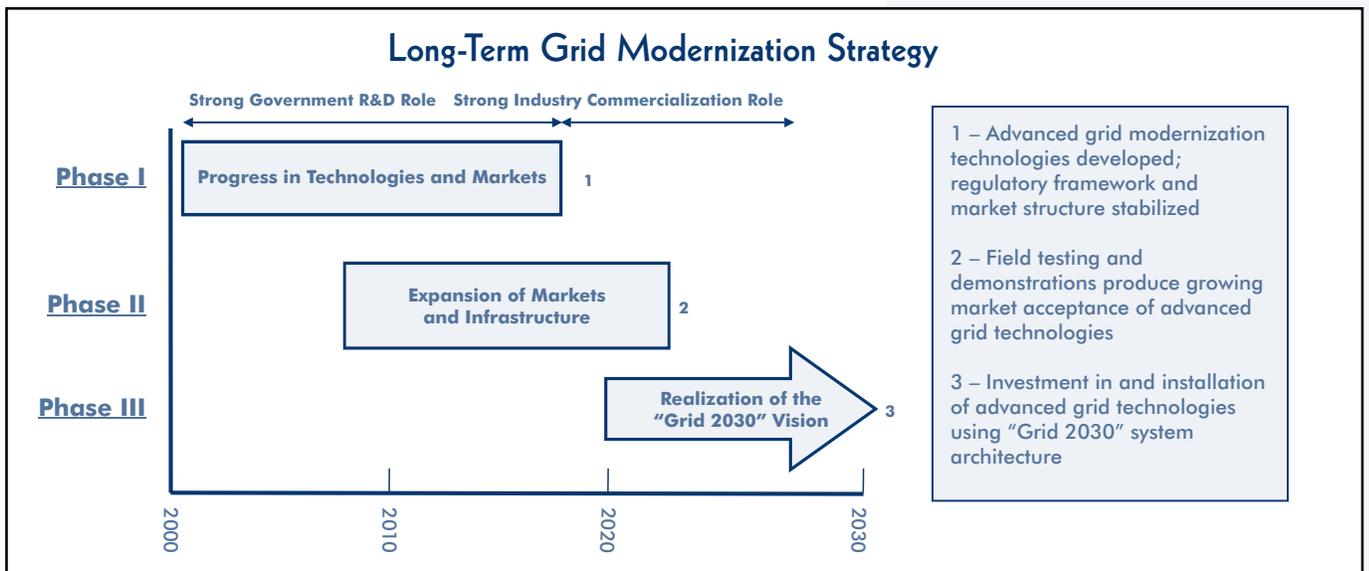
The Federal commitment to affordable, reliable, and universally available electricity is long-standing and well-established. Historically, it has involved regulation of wholesale electricity markets to facilitate interstate commerce and protect consumer interests. It has involved the financing, construction, and operation of electric facilities, particularly in rural and impoverished areas. It has also involved research, development, and demonstration of advanced electric technologies to reduce costs, improve reliability, and protect the environment. By any measure, these actions have benefited the American people enormously.

“GRID 2030” VISION

“Grid 2030” energizes a competitive North American marketplace for electricity. It connects everyone to abundant, affordable, clean, efficient, and reliable electric power anytime, anywhere. It provides the best and most secure electric services available in the world.



Source: “Grid 2030” A National Vision for Electricity’s Second 100 Years, July 2003



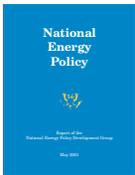
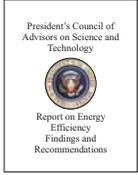
The Bush Administration has made modernization of the electric grid one of its top energy priorities.

Modernization requires progress in regulatory policies, markets, and technologies. Administration guidance is provided in a series of recent policy documents:

- May 2001 Report of the Energy Policy Development Group
- May 2002 National Transmission Grid Study
- September 2002 Transmission Grid Solutions Report
- June 2003 Report of the President's Council of Advisors on Science and Technology

The Administration recognizes that grid modernization cannot be accomplished by federal efforts alone. A national "vision and roadmap" process has been launched to engage industry, states, and other stakeholders in a coordinated national effort to strengthen America's electricity sector. In particular, it is important that the federal government work closely with the states, which regulate the local distribution of electricity, to implement the "vision and roadmap". This process has produced "Grid 2030," a national vision of America's future electric system, and the National Electric Delivery Technologies Roadmap, an action agenda for collaboration on public and private grid modernization activities.

ELECTRICITY POLICY GUIDANCE

<p><i>Report of the Energy Policy Development Group</i></p>  <p>May 2001</p>	<p><i>National Transmission Grid Study</i></p>  <p>May 2002</p>
<p><i>Report of the Secretary's Electricity Advisory Board</i></p>  <p>September 2002</p>	<p><i>PCAST Report</i></p>  <p>June 2003</p>

A Comprehensive National Strategy

The newly created Office of Electric Transmission and Distribution has been tasked by the Bush Administration to:

“Lead a national effort to modernize and expand America’s electric delivery system to ensure a more reliable and robust electricity supply, as well as economic and national security.”

The scope of activities includes research, development, demonstration, technology transfer, electricity modeling, policy analysis, and outreach. With the national vision and roadmap as a guide, the Office’s activities focus on areas that complement and support the work of electric power industry stakeholders, state utility programs, the Federal Energy Regulatory Commission, national laboratories, and universities.

For example:

- High temperature superconductors have the potential to revolutionize electric power delivery in America. Transmitting large amounts of power through compact underground corridors, even over long distances, with minimal electrical losses or voltage drop, could significantly enhance the overall energy efficiency and reliability of the electric system, while reducing fuel use, air emissions, and physical footprint. Superconducting technologies can be used to strengthen links between control areas to boost current carrying capacities and help prevent outage cascades. Superconducting systems can be used in equipment that crosscuts the entire electric power value chain including generators, cables, transformers, storage devices, synchronous condensers, and motors.
- The ability to monitor and manage real-time operations and implement automated control algorithms in response to changing system conditions is paramount for ensuring reliable and efficient grid operations. Information management, wide-area measurement, disturbance recognition, and visualization tools are just beginning to be developed and used by grid operators to process real-time information, accelerate response times to problems in system voltage and frequency levels, and achieve compliance with

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reliability and security standards. These are keys to detecting grid problems and responding to them before widespread blackouts can occur.

- With proper, safe installation, distributed energy resources are capable of acting as auxiliary power sources during peak demand times, disturbances, and outages. Development of interconnection technologies and standards will enable seamless integration of distributed energy with the local electric distribution system and loads. Electric distribution in America is generally characterized by low asset utilization, power quality and disturbance problems that are too high for many customers, a lack of innovation resulting in a limited range of customer service offerings, and insufficient use of distributed resources to address peak demands. Industry standards for utility interconnection typically require distributed energy devices to disconnect rather than help when a contingency occurs on a distribution or transmission system that threatens voltage or frequency requirements.
- Breakthroughs that dramatically reduce the costs of electricity storage systems could revolutionize the design and operation of the electric power system. Peak load problems could be reduced, consumer costs lowered, electrical stability improved, and power quality disturbances eliminated. Stored power can be applied at the power plant, in support of the transmission system, at various points in the distribution system, and on particular appliances and equipment on the customer's side of the meter.
- The government can partner with states in strengthening their regulatory frameworks, working together to remove impediments to grid modernization, spur innovation, and attract more investment to the electricity sector. Utility business practices need to change to



NATIONAL ELECTRIC DELIVERY TECHNOLOGIES ROADMAP ACTION AGENDA FOR GRID MODERNIZATION

- **Design "Grid 2030" Architecture**
Conceptual framework that guides development of the electric system from transmission to end-use
- **Develop Critical Technologies**
Advanced conductors, electric storage, high-temperature superconductors, distributed intelligence/smart controls, and power electronics that become building blocks for "Grid 2030"
- **Accelerate Technology Acceptance**
Field testing and demonstrations that move the advanced technologies from the laboratory and into the "tool kit" of transmission and distribution system planners and operators
- **Strengthen Market Operations**
Assessing markets, planning, and operations; improving siting and permitting; and addressing regulatory barriers bring greater certainty and lower financial risks to electric transactions and investment
- **Build Partnerships**
Leveraging stakeholder involvement through multi-year, public-private partnerships; working with States to address shared concerns

Source: National Electric Delivery Technology Roadmap, Draft October 2003



become more aggressive in developing and testing new technologies, tools, and techniques. As an independent broker of policy, market, and technology information and analysis, the federal government can provide technical assistance to state and regional agencies. State agencies need to accelerate their evaluations of rules, regulations, codes, and standards and revise those that inadvertently interfere with the introduction of new technologies and the emergence of competitive solutions and more efficient market operations.

Electric transmission and distribution planners and operators need better analysis tools for addressing grid bottlenecks and to assess the relative merits of alternative policies and technologies. Advanced electric system modeling is needed to provide decision makers with updated and accurate information.

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Innovative Federal Action

“GridWorks”

The electric grid is a system of millions of interconnected subsystems, components, and devices. Growing demand for electricity has placed strains on our aging infrastructure. As a result, the electric system has become limiting. The Department’s new GridWorks initiative will modernize key grid components such as transformers, conductors, switchgear, and protective devices, and to develop technologies that leap-frog the existing infrastructure, overcoming today’s constraints. Systems engineering, development of cross-cutting technologies, and testing and demonstration of advanced components are needed to match electric system requirements with the attributes of new technologies to mobilize equipment manufacturers and spur innovation.

“GridWise”

Advanced communications, control methods, and information technologies are largely absent from customer electricity systems, leaving electric system planners without valuable information for integrating customer and grid operations. The Department’s new “GridWise” initiative will spur the use of real-time information. Integrating distributed intelligence, using sensors and “smart” appliances with demand response

programs will maximize reliability and system efficiency and give customers new choices. GridWise will define an information “architecture” that incorporates new electric and information technologies in grid operations, thereby accelerating market acceptance and optimizing system performance.

Superconductivity

High temperature superconducting materials can be used in advanced designs of a variety of electric equipment, including wires and cables, motors, generators, and transformers. The potential advantages are enormous. Not only are high temperature superconducting wires half the size of conventional conduction materials, they experience half the losses and have three to five times the current carrying capacity of conventional equipment. Because of the absence of electrical resistance, super-efficient electric systems are possible. The Department’s program activities in high temperature superconducting materials are capable of revolutionizing the electric system by improving energy efficiency and its resilience to power outages. Further research is needed to develop and test superconducting electric components such as motors, generators and transformers to lower costs and increase reliability; to improve second generation superconducting wire to enhance mechanical properties such as flexibility and ruggedness, and to reduce alternating current losses and to reduce costs and increase manufacturability; and to improve the efficiency and lower the costs of cryogenic systems for a wide variety of superconducting applications.

Electric Markets

The regulatory framework which governs electric market planning and operations is not functioning as well as it needs to be. Regulatory uncertainty clouds decision making and interferes with the inflow of capital investment. Federal, regional, and state policy makers do not have the information they need to address the regulatory and policy needs of the electric industry in a timely and cost effective manner. There are a number of key issues to address: the proper balance between competition and regulation, federal-state jurisdiction, multi-state entities, streamlined siting and permitting, regional planning, and rate making and rate design. The implementation of the Department’s program activities could have a profound effect on the electric markets. First, data and models are needed to evaluate transmission bottlenecks and other anomalies that

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threaten system reliability. Technical assistance is needed in electric systems planning and operational support to state public utility commissions, state legislatures, regional state associations, regional transmission organization and independent systems operators, and Governor's offices. Finally, analysis of alternative policies and proposals for grid modernization and competitive market operations require further development.

Benefits to the Nation

An expanded and modernized grid will virtually eliminate electric system constraints as an impediment to economic growth and will, in fact, encourage economic development, consumer benefits, and job creation. It will also reduce environmental impacts, encourage alternative energy sources, and — of major importance — significantly reduce the Nation's vulnerability to terrorist attack.

As stated in the National Transmission Grid Study, wholesale markets save consumers \$13 billion annually, but grid constraints cost billions more. Robust national markets for electric power will encourage economic growth, create new jobs, and open avenues for attracting capital to support infrastructure development and investment in new plants and equipment. New business models will emerge for both small and large companies for a wide variety of new products and services for electricity customers, distributors, transmitters, and generators.

More energy efficient transmission and distribution will reduce line losses and help mitigate air pollution and greenhouse gas emissions. More economically efficient system operations and the expanded use of demand-side management techniques will reduce the need for spinning reserves and will lower environmental impacts. A modernized national electric grid will facilitate the delivery of electricity from renewable technologies such as wind, hydro, and geothermal resources that have to be located where the resources exist, which is often remote from load centers.

The new grid will provide faster detection of outages, load imbalances, frequency and voltage problems, and other faults. It will also enable automatic responses to them, and rapid restoration systems. All of these features will improve the security

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of the grid, making it less vulnerable to physical attacks from terrorists. Greater integration of information and electric technologies will include strengthened cyber-security protections. Expanded use of distributed energy resources will provide reliable power to military facilities, police stations, hospitals, and emergency response centers. This will help ensure that “first-responders” have the ability to continue operations even during worst-case conditions.

Expanding transmission capacity will reduce bottlenecks and the risks of outages from power supply constraints. Greater use of distributed generation will lessen the percentage of generated power that must flow through transmission and distribution systems, reducing strain on the grid. Higher levels of interconnection with Canada and Mexico will strengthen America’s ties with these nations and boost security through greater economic cooperation and interdependence.

Managing for Results

The President’s Management Agenda and the Government Performance and Results Act contain principles for ensuring program success through results-oriented procedures and practices. One of the aims of the Electric Delivery Technologies Roadmap is to provide an organizing framework for the Office of Electric Transmission and Distribution to work with its partners in industry and the states to address the President’s economic and electricity policy priorities and provide a management tool for measuring progress and ensuring accountability toward achievement of the “Grid 2030” vision.

The multi-year program plan builds on the Roadmap and focuses on what the Office’s research and development program will do in the next five fiscal years. It outlines performance goals, annual targets, activities, and resource requirements to achieve the Office’s mission and the program’s goals. Clear, quantifiable targets provide managers with control levers for tracking progress and holding performers accountable.

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A COORDINATED EFFORT.....

- Offices of Fossil Energy, Energy Assurance, Nuclear Energy, and Energy Efficiency and Renewable Energy
- Power Marketing Administrations
- Federal Energy Regulatory Commission (FERC)
- North American Electric Reliability Council (NERC)
- Regional, State, and Local Agencies

"All of us should dedicate ourselves to great goals: We are not here to mark time, but to make progress, to achieve results, and to leave a record of excellence."

President George W. Bush

Annual peer reviews of program activities have been a critical management tool for eliminating unproductive research and development pathways and focusing resources on the most promising technology development efforts with the best performers and the most results. Over the next five years, peer reviews will be an even more important management tool.

For energy security, economic security, and protection of the environment, America needs to increase investment in the modernization and expansion of the electric grid.

Conclusion

For energy security, economic security, and protection of the environment, America needs to increase its investment in the modernization and expansion of the electric grid. In an effort to focus scarce federal resources, provide leadership and support to industry, and coordinate the efforts of several federal agencies with those of state regulators and policy makers, the Bush Administration has created the Office of Electric Transmission and Distribution in the U.S. Department of Energy. The Office will lead a national grid modernization and expansion effort. It will require an integrated approach that combines technology development, technology transfer, modeling and analysis, and education and outreach activities in a new public-private partnership. Marshalling the collective resources of industry with those of federal and state government agencies the Office will affect measurable change, providing the tools for reducing the number and severity of blackouts, creating new jobs and economic growth, protecting the environment, expanding consumer choices and protecting our national security.



