

**REPORT OF THE
U.S. DEPARTMENT OF
ENERGY'S POWER
OUTAGE STUDY TEAM**

**FINDINGS AND RECOMMENDATIONS TO ENHANCE
RELIABILITY FROM THE SUMMER OF 1999**

**March 2000
Final Report**

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Notation

This notation list identifies the abbreviations, acronyms, initialisms, and units of measure used in this report. The glossary (Appendix B) provides definitions of some of the terms listed here as well as many others used throughout the report and some others that are related to the field but not expressly mentioned. In the text of this report, terms that are defined in the glossary appear in italics the first time they are used.

ComEd	Commonwealth Edison Company
Con Ed	Consolidated Edison Company
DC	direct current
DOE	U.S. Department of Energy
DPL	Delmarva Power & Light Company
EPRI	Electric Power Research Institute
FACTS	flexible alternating-current transmission system
FERC	Federal Energy Regulatory Commission
GPU	GPU Energy
IR2	Indian River Unit 2
ISO	independent system operator
ISO-NE	ISO-New England
kV	kilovolt(s)
kVA	kilovolt(s)-ampere
kW	kilowatt(s)
LIPA	Long Island Power Authority
MAAC	Mid-Atlantic Area Council (NERC region)
MAPP	Mid-Continent Area Power Pool (NERC region)
MVA	megavolt(s)-ampere
MVAR	megavolt(s)-ampere-reactive
MW	megawatt(s)
MWh	megawatt-hour(s) of electric energy

NARUC	National Association of Regulatory Utility Commissioners
NERC	North American Electric Reliability Council
NYPP	New York Power Pool
PECO	PECO Energy Company
PJM	PJM Interconnection, LLC (formerly Pennsylvania, New Jersey, Maryland Interconnection)
POST	Power Outage Study Team
PSE&G	Public Service Electric and Gas Company
PUC	public utilities commission
R&D	research and development
SCADA	supervisory control and data acquisition
SERC	Southeastern Electric Reliability Council (NERC region)
SPP	Southwest Power Pool (NERC region)
TVA	Tennessee Valley Authority
T&D	transmission and distribution
V	volt(s)
XLPE	cross-linked polyethylene

Executive Summary

Recently, the National Academy of Engineering ranked the twenty greatest engineering achievements of the last century, and, on the basis of its effect on the quality of life, electrification, or electric power, rated first. Having a reliable electric power system has become an essential part of our daily lives, allowing us to enjoy a high quality of life and a vital economy that continues to prosper.

Yet, our electric power system is not infallible. At times, extreme weather conditions, equipment failures, and human errors have interrupted the supply of electricity. And, as the digital age continues to affect our lives more and more, many find an even greater need for high-quality and reliable electric services. In fact, in the summer of 1999, during periods of extreme heat and humidity, power outages and other system disturbances disrupted the lives of millions of people and thousands of businesses in various regions of the country.

In response to public concerns about these problems, the Secretary of Energy brought together a team of experts to study some of last summer's events. This team — the Power Outage Study Team, or POST — consists of experts from the Department of Energy, the national laboratories, and the academic community. The team examined a number of those events in detail and, in this report, recommends a number of actions that the federal government can take to help avoid future outages. What distinguishes this report from documents of the past is that these recommendations take into consideration a new factor — an industry that is undergoing extensive restructuring.

Until recently, the U.S. electric power system consisted primarily of full-service utilities that generated, transmitted, and distributed electricity to customers at rates set by regulators.

But times have changed, and now 24 states and the District of Columbia have passed legislation or issued regulatory orders that permit customers to choose the company that supplies their electricity. Almost every other state is considering the possibility of proceeding in this direction. At the federal level, the Federal Energy Regulatory Commission has also increased the role of competition in generation markets through its implementation of the 1978 Public Utility Regulatory Policies Act and the 1992 Energy Policy Act. Thus, the electric utility industry is following the lead of the telecommunications, airline, and natural gas industries by increasing its reliance on competition. The new electric industry will rely on competitive markets as a basis for making decisions concerning electricity investments, operations, and consumption. Transmission and distribution services are likely to remain regulated.

Competitive markets are expected to herald new efficiencies and dramatic innovations that will save customers money and lead to new electric services. Under

proper guidance, these markets will also improve reliability. However, the mechanisms that protected electric reliability in the past need to be changed along with ongoing market developments.

The power outages and disturbances studied by POST served as a wake-up call, reminding us that reliable electric service is critical for our health, comfort, and the economy. While the new industry structure should improve reliability, as an earlier Department of Energy Task Force on Electric System Reliability recognized, the transition to that new structure presents a risk to reliability. It is essential for continued reliable electric service that we proceed expeditiously through this period of transition.

POST conducted a thorough study of eight outages and disturbances in different parts of the country. The team visited the sites and interviewed the people who were operating the system at the time of the occurrences, obtaining valuable first-hand information and data. Following a detailed analysis of these facts, POST published an interim report, which described the outages and disturbances and discussed the team's findings. The team then conducted a series of three technical workshops, which gave the public an opportunity to comment on appropriate federal actions. Finally, the team examined all of this information and developed its recommendations.

In its interim report, POST found that the reliability events of the summer of 1999 demonstrated that the necessary operating practices, regulatory policies, and technological tools for assuring an acceptable level of reliability were not yet in place. This report outlines some of the changes needed to address the causes of these events.

Many of the recommendations presented in this report address reforms required to enable restructured markets to fulfill their potential to provide improved reliability. Markets should reflect the value of reliability to energy providers and their customers, and to the broader public interest. Both providers and customers should have opportunities to participate in markets for energy and ancillary services — and to profit from that participation. Modified (or new) institutions are needed to monitor and enforce compliance with reliability standards.

Ancillary services include a number of functions, such as reserves and reactive power, that are necessary to support operations of the transmission system.

Other recommendations address the importance of continuing to invest in the development and use of the tools needed for monitoring and maintaining the electric system and for responding to system emergencies. The key to maintaining reliability is information. Improved diagnostic tools, improved data gathering, and real-time modeling of system conditions are needed. These tools can be used to improve maintenance practices and assist operators in identifying and responding to system emergencies. Providers and customers can use real-time power system and market information to manage reliability.

POST has limited its recommendations to federal actions that address the team's findings. Other aspects of reliability and the restructuring process may warrant federal actions but are beyond the scope of this study.

Further, POST's recommendations reflect the basic premise that, while markets and industry should address issues related to reliability, the federal government has a fundamental responsibility for ensuring that the public's interests are fully represented. Moreover, many stakeholders, including state and local governments, share this responsibility. Systems developed by the industry have evolved to protect electric reliability; however, many of these systems need to be overhauled to address the needs of a changing industry. Nevertheless, they are the appropriate starting points for any required changes.

In this report, POST submits twelve recommendations for consideration by the Secretary of Energy. The following recommendations are designed to help avoid future power outages. One or more possible federal actions are suggested along with each recommendation.

1. Promote market-based approaches to ensure reliable electric services.

Restructuring is based on the fundamental principle that competition and markets, not regulators and utilities, result in better investment and operating decisions with respect to generation and consumption of electricity. Mechanisms that will ensure adequate supplies of electricity — and reliable operations — should be designed with this principle in mind. The value of reliability needs to be determined in competitive markets, and customers, as well as energy providers, need to have the opportunity to participate in markets for energy and ancillary services — and profit from that participation. Yet, because electric service is provided through a network, it has aspects of a public good and may be underprovided by private entities. Guidance is needed to ensure that the public interest is adequately captured.

Many states have made significant progress in developing competitive electricity markets. However, efforts in developing market-based mechanisms for promoting electric reliability — for example, allowing customers to participate in energy and ancillary service markets — have been less aggressive. Developers of these mechanisms must explicitly account for the broad geographic scope of today's electricity markets, which can extend across multiple states and regions of the country.¹ Although states have a definite role in regulating utilities and protecting consumers, there is also an important federal role: to improve the operation of power markets by providing leadership, direction, and consistency across the country.

¹ The U.S. electric power system consists of just three distinct interconnections; trade can be conducted throughout an interconnection. For example, a generator in Minnesota can sell to a customer in Florida.

Action for federal consideration:

- *Support the implementation of fair, efficient, and transparent markets for electric power and ancillary services.*

2. Enable customer participation in competitive electricity markets.

The ability of customers to manage their demand in response to market prices is the key to ensuring both reliable electric service and an efficiently functioning, competitive electricity market. POST agrees with public comments received that meaningful customer participation is a prerequisite for achieving the full reliability benefits of restructuring. To more fully participate in a competitive market, customers must be able to see real-time prices (if they choose to do so) and have access to the communication and control technologies that will enable them to participate directly.

Actions for federal consideration:

- *Support the development of market rules that allow customers to supply load reductions and ancillary services in competitive energy markets.*
- *Encourage development of demand management systems that support electric reliability.*

3. Remove barriers to distributed energy resources.

There is currently great interest in relying more heavily on distributed generation technologies to help utilities respond more rapidly to an increased demand for electricity in areas where demand is already high. At the same time, utilities are striving to improve the quality of power to customers. Many argue that barriers impede market-driven acceptance of these technologies. The federal government should target this area for special attention and review and remove these barriers, as needed.

Actions for federal consideration:

- *Support the development of interconnection standards for distributed energy resources.*
- *Support state-led efforts to address regulatory disincentives for integrating customer supply and demand solutions.*
- *Study the potential for using emergency backup generators to reduce system demands to help avoid power outages.*

4. Support mandatory reliability standards for bulk-power systems.

Today, the interconnected electric power system is being transformed from one that was primarily designed to serve the customers of full-service utilities, each integrated across the generation, transmission, and distribution functions, to one that will support a vibrant, competitive market. This change makes the current system of voluntary compliance with reliability standards inadequate for ensuring reliability. Mandatory standards for bulk-power systems are needed to ensure that the “rules of the road” are implemented in a straightforward and balanced manner.

Action for federal consideration:

- *Support the creation of a self-regulated reliability organization with federal oversight to develop and enforce reliability standards for bulk-power systems as part of a comprehensive plan for restructuring the electric industry.*

5. Support reporting and sharing of information on “best practices.”

Many forums for exchanging information on “best practices” for maintaining and operating electric generation, transmission, and distribution systems already exist. However, concerns exist about the consistency of some information (such as reliability indices), the availability of data to all industry stakeholders, and the continued viability of these forums in a restructured industry. The federal government could play an important role in enhancing the definition, collection, and sharing of information. It should work in close partnership with states and other industry stakeholders as it develops this role.

Actions for federal consideration:

- *Promote the use of uniform definitions and measurements for reliability-related information.*
- *Facilitate the collection and sharing of information on reliability-related regulatory issues among state public utility commissions.*
- *Support activities to develop and share information among industry participants on critical resources and industry practices.*

6. Enhance emergency preparedness activities for low-probability, high-consequence events on bulk-power systems.

Emergencies on bulk-power systems affect large geographic areas, involve many stakeholders, and affect millions of customers. The events of the summer of 1999 demonstrated that effective communication and coordination among many parties are critical during times of system emergencies. The federal government should actively support efforts to continually review and improve planning and response capabilities.

Action for federal consideration:

- *Work with regional, state, and local authorities to support continuous improvement in coordination, planning, and preparations to respond to electricity emergencies.*

7. Demonstrate federal leadership through promotion of best reliability practices at federal utilities.

Federal utilities are unique assets that have long pursued many federal and regional objectives, ranging from power production to agricultural and economic development. As part of their role, these utilities have served as research and development catalysts for technological changes within the industry. Piloting new reliability initiatives would be consistent with this historic leadership role.

Actions for federal consideration:

- *Develop and pilot reliability self-assessment procedures.*
- *Support distributed energy resources.*
- *Encourage economic energy efficiency.*

8. Conduct public-interest reliability-related research and development consistent with the needs of a restructuring electric industry.

Industry investments in reliability-related R&D have declined steadily over the past few years. These declines have occurred at least in part because the “clients” for next-generation investments, such as regional transmission organizations, are still in their formative stage. Furthermore, the independent system operators currently do not own the transmission assets and are nonprofit institutions. A stable climate for private investments in longer-range R&D conducted with the public’s interest in mind does not currently exist. Federal investments in public-interest, reliability-related R&D are especially needed during this time of industry transition. POST strongly supports Secretary Richardson’s commitment to increase federal investments in electric reliability R&D as provided for in the Administration’s proposed fiscal year 2001 budget.

Actions for federal consideration:

- *Develop real-time system monitoring, communication, and control technologies.*
- *Create sensors, remote monitoring, and diagnostic technologies for cables and aging transmission and distribution infrastructure.*
- *Integrate customer demand management, distributed generation, and storage technologies.*

- *Improve analytic models for load forecasts, power system simulations, and contingency assessments.*
- *Examine the design and performance of competitive electricity markets.*

9. Facilitate and empower regional solutions to the siting of generation and transmission facilities.

Stable incentives for investing in generation and transmission must be complemented by siting boards that can discharge their responsibilities in a timely and coordinated fashion. Such boards need to address two primary problems. First, policies among agencies, among states, between state and federal agencies, and among federal agencies overlap and sometimes conflict. Second, parochial bodies do not have incentives to seek regional solutions. These problems result in long delays, and they could lead to inefficient and inequitable siting decisions.

Actions for federal consideration:

- *Convene regional summits to initiate and facilitate dialog among regional stakeholders.*
- *Support federal legislation to facilitate state efforts to form regional siting boards.*
- *Raise reliability as an issue (as appropriate) whenever federal permits are required for siting electric facilities.*

10. Promote public awareness of electric reliability issues.

General public awareness of the complex issues associated with maintaining reliable electric service is low. Yet, as demonstrated by the events of the summer of 1999, public interest in reliable electric service is high. Greater understanding of electric reliability issues, including both the frequency and causes of outages and the steps being taken to prevent and limit the consequences of outages, will lead to better-informed decisions. Special attention should be placed on discussing the costs and trade-offs inherent in making reliability investment and operating decisions. Future activities should complement, not replace, existing state, utility, and locally led efforts and be effectively coordinated with them.

Actions for federal consideration:

- *Continue DOE-sponsored independent investigations of significant power outages and other reliability events.*
- *Continue DOE-sponsored forums where stakeholders can meet to discuss reliability issues.*

11. Monitor and assess vulnerabilities to electric power system reliability.

The outages and disturbances studied by POST resulted from unpredicted events that exploited specific weaknesses in physical systems and the planning and operating processes that supported them (e.g., extremely hot weather caused overloads and cable failures). Other electric power system vulnerabilities were identified during POST's studies and technical workshops. In view of the regional and national implications of power outages, known and emerging electric system vulnerabilities need to be studied from a national rather than a local perspective. Studies from a national perspective uniquely belong to the federal government, but studies must be carried out in close partnership with the electric industry.

Actions for federal consideration:

- *Work with industry stakeholders to conduct comprehensive assessments of electric power system vulnerabilities.*
- *Work with industry stakeholders to refine and implement procedures to assess the robustness of the electric system in responding to bulk-power system emergencies.*

12. Encourage energy efficiency as a means for enhancing reliability.

The increased adoption of energy efficiency measures can enhance electric system reliability by reducing demand growth in areas experiencing shortages in electric generation or constraints in electric transmission or distribution. Programs to stimulate adoption of energy-efficient technologies and practices can provide more rapid relief to areas with fast-growing demand. Further, they can do so with fewer negative impacts than would occur during the construction of new generation, transmission, and distribution facilities. Such programs might be especially helpful in areas where growth in electric demand is high; yet, markets for new generation are in their infancy or existing incentives for investments in transmission and distribution are in transition. Technologies and practices that reduce loads during times of peak demand, such as high-efficiency air conditioning and lighting equipment, are especially valuable.

Actions for federal consideration:

- *Work with state and local governments to support development and implementation of cost-effective energy efficiency programs.*
- *Expand existing federal programs to promote energy efficiency.*

Section 1

Introduction

The summer of 1999 was marked by a number of electric power outages and other power *disturbances* in the eastern *interconnection* that occurred during periods of extreme heat and humidity.² These included *distribution system* failures, as well as shortages of power supplies and occurrences of low *voltages* in the *transmission system*. Outages in New York City and Chicago were among the most notable.

In response to public concerns, at the summer meeting of the National Association of Regulatory Utility Commissioners (NARUC), the Secretary of Energy pledged to investigate several recent major electric power disturbances as part of a six-point plan to improve the *reliability* of the U.S. *electric power system*. The Secretary appointed a panel of U.S. Department of Energy (DOE), national laboratory, and academic experts, called the Power Outage Study Team, or POST, to conduct the investigations.

This is the final report of POST's investigation of last summer's electric reliability problems. Six power outages and two power system disturbances that did not result in outages that took place between early June and early August 1999 were studied, and potential federal actions for preventing such events in the future are recommended.

POST members visited the affected *utilities* or operating entities in the fall of 1999 to learn first-hand about the outages and system disturbances. Members interviewed the affected utilities and *system operators*, as well as other local parties, and reviewed available reports and materials that had been prepared following the events. Without exception, all parties cooperated and supported the team's efforts. The events and the POST's findings were described in an Interim Report, dated January 4, 2000.³ Section 2 of this report provides brief summaries of the events drawn from the Interim Report. Section 3 reports POST's 38 findings from the events.

The Interim Report formed the basis for a series of three DOE-sponsored technical workshops at which POST received public comments on recommendations to consider for this final report. Technical workshops were held on January 20 in San Francisco, California; January 25 in New Orleans, Louisiana; and January 27 in Newark, New Jersey. More than 150 individuals attended and, of those, more than 50 offered public comments at one or more of the workshops. In addition, DOE received more than 70 written comments on the Interim Report. Section 4 summarizes the process that the team used to solicit public input.

² Terms that are defined in the glossary (Appendix B) are in italics the first time they are used in the text.

³ The Interim Report can be downloaded from <http://www.policy.energy.gov/>.

Section 5 consists of the team's recommendations to the Secretary of Energy and identifies potential federal actions to help avoid future power outages. The recommendations offered in this report address POST's findings (see Section 3 of this report) from its study of the significant reliability events from the summer of 1999. Other federal, state, and local actions regarding electric reliability are beyond the scope of this report.

Appendix A summarizes the comments that POST received. Appendix B provides a glossary of terms.

Section 2

Summary of Electric Power System Events Studied by POST

The Secretary of Energy appointed POST to review significant power outages and system disturbances that occurred during the summer of 1999 (Table 1). Following this review, the team was directed to suggest actions that the federal government could take to avoid future power outages. Specifically, POST studied six electric power system outages and two other electric power system disturbances that did not lead to outages. Table 1 gives the locations and dates of these events. The sections that follow briefly summarize each event.

Table 1 Summer of 1999: Electric Power Events Studied by POST

Event/Location	Date
<i>Outages</i>	
New York City	July 6 and 7
Long Island	July 3–8
New Jersey	July 5–8
Delmarva Peninsula	July 6
South-Central states	July 23
Chicago	July 30–August 12
<i>Power system disturbances</i>	
New England states	June 7 and 8
Mid-Atlantic area	July 6 and 19

2.1 New England: Generation Deficiency on June 7 and 8

ISO-New England (ISO-NE), which initiated operations on July 1, 1997, is the nonprofit *independent system operator* (ISO) responsible for operating New England's *bulk-power system* and for administering the region's restructured *wholesale electricity market*. The New England electric system encompasses Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

On June 7 and 8, 1999, record-breaking heat and humidity spread across the northeastern United States and much of central and eastern Canada. At that time, many *generating units* were out of service for routine maintenance and refueling in anticipation of high system demands later in the summer. As a result, the New England, Ontario, and New York regions experienced shortages in *reserve electric capacity* and consequent operating *emergencies*.

A combination of emergency responses by ISO-NE, operators of neighboring systems, electricity customers, the governors of several states, and ultimately a break in the weather enabled ISO-NE to maintain a continuous supply of electricity under demanding circumstances. During this event, ISO-NE received sustained transfers of emergency power from as far away as Michigan. ISO-NE reduced voltages, implemented *load* reductions, and received critically important assistance from PJM Interconnection, LLC (PJM), New York, Michigan, Ontario, Quebec, and the Maritime Provinces. Some of these systems encountered their own emergencies on these dates. The emergency subsided on the afternoon of June 8, when conservation measures took effect and air temperatures cooled.

2.2 New York City: Outages on July 6 and 7

Consolidated Edison Company (Con Ed) is a member of the New York *Power Pool* (NYPP) and the Northeast Power Coordinating Council. Con Ed serves the most dense electrical *load pocket* in the world, with more than 3.1 million customers in a 604-square-mile area. The company uses a unique concept, called a distributed network, in which each network operates independently from its neighboring networks and is fed from multiple distribution feeder cables. The networks are designed conservatively so that they can carry load, while being kept energized even if two or three feeders (depending on the load) are lost.

On July 6, 1999, the Washington Heights network in northern Manhattan had to be de-energized for 19 hours after the *distribution network* lost 8 of its 14 feeder cables. The loss of feeders occurred because of heat-related failures in connections, cables, and transformers. Power to 68,000 customers (representing a population of 200,000) was interrupted. The Washington Heights network was re-energized at about 5:00 p.m. on July 7, after repairs had been made.

2.3 Long Island: Outages and Depressed Voltages on July 3–8

The Long Island Power Authority (LIPA) — an organization of the State of New York — acquired the Long Island transmission and distribution (T&D) system from the Long Island Lighting Company in 1998. Keyspan Energy operates the system under contract from LIPA.

From July 3 through 8, service was interrupted to a total of 110,000 LIPA customers for varying periods. A new system *peak load* of 4,340 MW was set on July 5, and that record was broken the following day (July 6) when the peak load reached 4,590 MW (a 9.1% increase over the previous year). On July 6, NYPP ordered a systemwide 5% voltage reduction, and LIPA activated its Commercial Peak Reduction Program and appealed to its other large customers to voluntarily *curtail* their use of electricity. Many organizations and government offices responded by closing early or cutting back on their electricity use. The South Fork of Long Island — an area that has experienced rapid load growth — was on the edge of *voltage collapse*. Voltage collapse probably would have occurred if the *peak demand* had not been reduced as a result of voluntary load curtailment procedures, a 5% voltage reduction, and load decreases associated with

overloaded wire burndowns. The peak load in the South Fork on July 5 was 25% higher than it was in 1998.

2.4 Mid-Atlantic Area: Voltage Declines on July 6 and 19

PJM Interconnection, LLC, is an ISO that serves as (1) the regional transmission provider responsible for transmission planning, (2) a *control area* operator, (3) a *North American Electric Reliability Council (NERC) security coordinator*, and (4) operator of the Mid-Atlantic integrated energy market. PJM is the largest centrally *dispatched* electric power system in North America. The system encompasses New Jersey; Delaware; the District of Columbia; and parts of Pennsylvania, Maryland, and Virginia.

On two occasions in July, the eastern half of the PJM *grid* experienced sudden and steep voltage declines. The first occurred on July 6, during the heat storm that affected much of the East from New England down past the Mid-Atlantic. An all-time-high peak load (51,600 MW), which was not predicted to occur until 2002, was recorded for the PJM grid that day. A similar voltage problem occurred during another period of high loads on July 19.

The integrity of the PJM system was maintained, however, on both July 6 and 19, because emergency actions were put in place to reduce voltage, curtail contractually interruptible customers, start up maximum emergency generation, appeal for voluntary load reductions, and curtail emergency exports. The more rapid recovery on July 19 may be partially explained by PJM's implementation of some of the lessons it had learned on July 6.

2.5 New Jersey: Outages on July 5–8

POST studied three outages that occurred at two New Jersey utilities during the heat wave that took place in early July. Public Service Electric and Gas Company (PSE&G) is a wholly owned subsidiary of Public Service Enterprise Group Incorporated. PSE&G supplies electric and gas service to approximately 5.5 million people in a corridor of roughly 2,600 square miles that runs diagonally across New Jersey, from Bergen County in the northeast to an area below the city of Camden in the southwest. GPU, Inc., is a holding company that owns all of the outstanding common stock of three electric utilities serving customers in New Jersey (Jersey Central Power & Light Company, Pennsylvania-Metropolitan Edison Company, and Pennsylvania Electric Company), which are operated jointly as GPU Energy.

PSE&G suffered outages related to recurrent cable and switchgear troubles at several of its substations and on the 26-kV Bergen County loop. The Hudson Terrace and Citibank substations were shut down once, and the Englewood substation was shut down twice. Up to 10,000 customers at a time were affected for periods of less than one hour each during the service interruptions. Multiple terminator and cable failures affected three of the four transformers at the City Dock substation in downtown Newark, New Jersey. PSE&G shut down the entire substation to protect the remaining transformer

affecting 2,600 customers. Service was restored to several large customers within 2 hours, and service was restored to all customers in less than 11 hours.

Starting on July 5, GPU Energy suffered outages resulting from problems with the four transformers at its Red Bank substation. Two transformers were severely damaged and had to be replaced. *Scheduled* and unscheduled outages affected more than 100,000 customers. Service was restored to all customers by 1:20 a.m. on July 8.

2.6 Delmarva Peninsula: Outages on July 6

Delmarva Power & Light Company (DPL) is a wholly owned subsidiary of Conectiv. DPL provides electricity to approximately 455,300 customers within its service territory, which includes Delaware, 10 primarily eastern shore counties in Maryland, and the eastern shore of Virginia.

The DPL system was severely affected by the first heat wave of July 1999, which for DPL extended from July 3 to July 6. High loads, in combination with various generation outages, produced a capacity shortfall that could not be remedied through energy imports on the transmission system. On the worst day, July 6, DPL implemented rotating outages from 10:30 a.m. until 7:30 p.m. Approximately 138,000 customers experienced outages of varying duration and frequency. Subsequent studies performed by POST (reported in the Interim Report) and others indicate that the DPL operator concerns regarding imminent voltage collapse were well founded.

2.7 South-Central States: Rotating Outages on July 23

Entergy is a vertically integrated power company that serves approximately 2.5 million customers in parts of Louisiana, Arkansas, Texas, and Mississippi. It is a member of the Southeastern Electric Reliability Council and participates in a reserve sharing agreement with the Southwest Power Pool (SPP). Entergy has about one-third of the total SPP load.

On the basis of load forecasts and reports on expected generator *availability* on July 22, Entergy anticipated that it would be able to meet its reserve requirements on July 23, with the curtailment of some interruptible and curtailable retail loads. However, by the morning of July 23, the situation had worsened; load forecasts for the day were slightly higher, while generator availability was lower than anticipated. Throughout the day, equipment problems further reduced generating *capability* at several units. At noon, Entergy made a public appeal for conservation — only its third such request in 20 years. During the afternoon, Entergy received emergency assistance from SPP for more than an hour. As this period of assistance came to an end, *nonfirm capacity purchases* were recalled because of high demands and widespread shortages throughout the region, while additional generation capability was forced out of service. The combination of these events led Entergy to begin curtailing 900 MW of firm load by mid-afternoon. Customer outages occurred on a 20- to 30-minute cycle. Ultimately, more than 550,000 customers experienced at least one outage that afternoon.

2.8 Chicago: Outages on July 30–August 12

Commonwealth Edison (ComEd) is the principal utility subsidiary of its parent company, Unicom. ComEd provides electricity to more than 3.4 million customers in northern Illinois. The ComEd T&D system is typical of transmission and distribution in the electric industry in that it consists mainly of networked underground systems, located primarily in Chicago; overhead systems in urban, suburban, and rural areas; and underground residential systems in urban and suburban areas.

Between July 30 and August 12, three major distribution system outages occurred in ComEd's service territory in Chicago at the Northwest, Lakeview, and Jefferson substations. During a period of intense heat and humidity, ComEd recorded an all-time-high peak demand on July 30. In the late afternoon, the electric system began to experience difficulties. Two separate cable faults at the Northwest substation de-energized transformers, thereby overloading nearby interconnected transformers and causing them to shut down automatically to prevent equipment damage. Seven cable faults in and around the Lakeview substation also caused outages. Over the July 30 to August 1 period, more than 100,000 customers suffered temporary losses of power for up to several hours.

ComEd's Jefferson substation, which serves Chicago's greater downtown area (including businesses in the "Loop") plays a critical role in the *topology* of ComEd's system because it is the sole path of power for six downstream substations. Power interruptions on August 12 to customers served by the Jefferson substation resulted from intentional *load shedding*, which ComEd elected to do to protect overloaded equipment. Transformer problems and multiple cable faults were the primary causes of overloading. The largest number of customers simultaneously without service as a result of the intentional actions taken by ComEd was less than 3,300 (however, since many of these customers are large businesses, the number of people affected was much greater than 3,300). To prepare for service interruptions in the south Loop, ComEd personnel sent warnings about potential emergency power outages; these reached many unaffected customers in the area. ComEd staff suggested that a significant number of customers who did not experience interruptions in electric power chose to suspend business operations in anticipation of possible interruptions.

2.9 Follow-up Activities

The power outages and system disturbances that POST studied have also been subject to follow-up activities by the companies and organizations that experienced them, as well as, in some cases, by local regulatory authorities. Other studies and reviews have been conducted or are underway, and many follow-up actions have been announced and implemented. By design, these activities have been confined primarily to the specific events and companies or organizations affected. In this regard, the national focus of this report complements the local studies because it looks at these events from a national perspective.

Section 3

Summary of POST Findings

POST's study of the events reported in Section 2 resulted in 38 findings, which were specific to the events studied. The 38 findings are presented below by power system event.

3.1 New England

1. **Electricity suppliers respond to market signals, but there is a lag of several years before new generation resources can be placed into service.** Most of the states in New England have implemented some form of competition for the provision of energy services. High electricity prices and several summers of low generation reserves as a result of the early retirement of several nuclear power plants have led generation companies to propose adding more than 30,000 MW of new capacity. This amount represents more than the total existing capacity in the area. Although much of this new capacity will never be built, many are predicting a generation surplus in New England within a few years. Such predictions clearly indicate that this aspect of the generation market is working in New England. However, it does take time to build new generation facilities, and there has historically been a lag between the time when generation is needed and when it becomes available.
2. **Retail customers have limited mechanisms and incentives to conserve energy or resort to alternatives during electricity shortages.** ISO-NE had to resort to public appeals for conservation, including the step of asking the New England governors to close nonessential facilities.
3. **Market rules for system operation during times of system emergencies have not been fully developed or agreed upon by market participants.** The reliability event of June 7 and 8 uncovered many market flaws, including the inability to (1) forecast market *clearing prices* when supplies are scarce and (2) manage pump storage and *must-run resources* that are above the energy clearing price.
4. **Some independent system operators were lacking the needed authority to arrange energy transfers during emergency conditions.** Some of the ISOs involved in the June 8 delivery of emergency power from Michigan to New England did not have well-defined emergency procedures to conduct the transactions.

3.2 New York City

5. **Cable condition is not accurately assessed by conventional diagnostics and practices, which may accelerate cable failure.** Conventional cable testing methods, such as direct-current (DC) high-potential testing, are not always able to detect degradation or incipient failure in cable systems. In fact, the DC high-potential cable testing method being used by Con Ed may actually be aggravating

potential failure spots in the cables. Each spring, Con Ed routinely tests cables all over the city to prepare for the summer peak. Four of the feeder cables from the Sherman Creek substation had been tested in the spring of 1999. Three of the four cables had passed the test but subsequently failed during the July 6 outage. The fourth cable failed the test but was repaired and did not fail during the outage. The fact that three cables that passed the test failed later during the heat storm may be an indicator of a testing deficiency that actually contributes to cable failure.

There is presently a debate in the industry over the best way to test the insulation of distribution cables. Many of Con Ed's 13.8-kV feeder cables are insulated with cross-linked polyethylene (XLPE). Studies suggest that DC high-potential testing on aged cable with this type of insulation may induce failures. The practice of using the DC test on cables has carried over from the time when older paper-oil types of cable insulation that are not degraded by the DC test were used. In the Con Ed feeders, XLPE-insulated cable is sometimes spliced in to replace sections of paper-oil cable, so both cable types can exist in the same feeder.

6. **Real-time data on cable temperature are not available.** The secondary low-voltage distribution system contains a large number of conductors in parallel in many possible combinations. Calculating the power flow and temperature rise for each combination of conductors requires a highly sophisticated analysis. In addition, individual network conductors are protected by fusible links, and there are no remote indications when these links are open. Thus, the thermal model can only really estimate the temperature rise of individual conductors. Real-time data on the actual thermal condition of the network cables (either calculated or measured) is not available.
7. **The harsh environment in which cables are located contributes to reliability problems.** The salt that the city uses on the streets in the winter gets into the cable vaults, manholes, and conduits. Con Ed can actually plot the customer interruption rate versus the tonnage of salt used by the city and find a remarkably good correlation. During its visit to New York, the POST observed that the vaults were also contaminated by oil from car engines and a variety of other trash that fell through the grating. The manholes, vaults, and conduits are also routinely flooded during heavy rains and water main leaks. The combination of salt, water, oil, and constant high humidity is an extremely severe environment for cables. Lead jackets on the cable, which are very effective in these harsh environments, can no longer be used because of environmental concerns.

3.3 Long Island

8. **Load predictions have been inadequate.** Load growth has been unusually rapid. In some areas, the peak load increased more than 25% in the last year. T&D capability has not kept up with load growth. There is a perception that load forecasting has been inadequate over the last two or three years. The review of the capability and condition of the existing infrastructure might not have been adequate. For example,

the predicted 1999 summer peak for the South Fork was 141 megavolts-ampere (MVA), while the actual peak was 167 MVA, 18% higher than the forecast. Although much of the increase resulted from the booming economy, LIPA forecasting methods still appear to be inadequate.

9. **Transformer failure and associated interconnection problems can require lengthy equipment repair times.** LIPA import capability was reduced by 430 MW because two key transformers providing interconnections to the NYPP and New England Power Pool had failed in the spring. These transformers could not be replaced quickly and had to be repaired because they were unique, nonstandard designs. The repair time was on the order of one year. Replacing large transformers requires a very long lead time.
10. **Traditional methods (e.g., construction of new transmission and central generation) for supplying electric power to load pockets were not able to keep up with load growth.** The South Fork of Long Island was on the edge of voltage collapse because new generation and transmission had not kept up with the load growth. Load growth had been extremely rapid, with an increase in peak load up to 25% in one year. There has been local resistance to the construction of new, higher-voltage transmission lines and new generating stations in the area.

3.4 Mid-Atlantic Area

11. **Unit ratings were not consistent with operating performance during periods of high loads.** When PJM called for maximum production of *reactive power*, many generating units were not able to provide levels of *real* and *reactive power* consistent with their expected capabilities. This was evident during both the July 6 and 19 events. Immediately following the event on July 19, PJM instructed all generators to re-rate units for their ability to produce reactive power.
12. **There may not be adequate incentives for reactive power production.** At the time of these events, there were no economic incentives for generators to produce reactive power. In fact, there was a disincentive, since generators operating at full capacity generally have to cut back on real energy production to increase reactive power production (as requested by PJM during these reliability events). Thus, their sales and earnings are reduced. The *Federal Energy Regulatory Commission (FERC)* has since approved a *tariff* for PJM to compensate generators for lost opportunity costs.
13. **Planning tools did not predict significant voltage degradation during periods of high loads.** PJM operators were surprised by each of these events. The severe declines in voltages were not predicted for the operating conditions being experienced. The duration of the voltage decay on July 6 could be an indication of a delayed response to the problem or a lack of adequate policies and procedures to address the issue. When the tools and experience to predict and respond to such events are not available, there is a risk of voltage collapse.

3.5 New Jersey

14. **There are no reliable tests for identifying incipient failures in feeder cables.** PSE&G experienced multiple cable failures at its Englewood and City Dock substations. PSE&G staff informed POST that improved testing methods are needed to identify incipient cable failures, and that the company has begun a pilot program of *low-frequency* discharge testing for paper-insulated and lead-covered cables.
15. **Mechanisms for sharing information on maintenance best practices and equipment performance among distribution utilities were inadequate.** There are few incentives for sharing data on equipment maintenance and performance characteristics. In some cases, research in this area is proprietary and not readily available to all utilities.
16. **Utilities may experience lengthy delays in replacing failed critical equipment.** The GPU system has approximately 50 transformers like the ones that failed at its Red Bank substation, and at the time of those failures, it had only two spare transformers. Luckily, those were stored at the Red Bank substation. Large transformers like these are difficult to move because of their size and weight (more than 200 tons). Replacement or repair of large transformers can take a year or longer. Since the transformer failures at Red Bank, GPU is considering increasing the number of spares it keeps from two to four.

3.6 Delmarva Peninsula

17. **Forecasting methods used by system planners did not accurately predict peak summer loads.** The severity and longevity of the heat and humidity during this reliability event were very unusual. DPL did not plan for the loads associated with these conditions.
18. **Summer ratings for electric generating units were calculated for normal summer temperatures and were not consistent with performance during periods of unusually high temperatures.** During periods of high temperatures and humidity, generating units generally do not perform as well as they do during times of normal temperatures. Peak summer loads are associated with high temperatures and humidity, and it is precisely at that time that unit ratings are critical to reliable operations. Planning and operations need to be based on ratings that are relevant at the time of peak loads.
19. **Retail customers have limited mechanisms and incentives to conserve energy or resort to alternatives during electricity shortages.** DPL's reserves were depleted on July 6, and operators had to resort to rotating outages to reduce load when Indian River Unit 2 (IR2) was forced out of service.
20. **Notice requirements in load management contracts do not permit an efficient response to emergencies.** DPL contracts for interruptible loads are not amenable to quickly responding to generator outages. Contracts for interruptible loads require

advance notice, and, in DPL's case, they limit service interruptions to only six hours. The advanced notice requirement prevented DPL operators from shedding interruptible loads as an immediate response to the outage of IR2. The duration limits prevented the use of interruptible loads in the morning hours, because these loads would then be coming back on line during the afternoon peak.

21. **Reliability criteria for generation reserves were not sufficient to avoid regular power shortfalls.** DPL planning was based on meeting the load associated with the average high summer temperature. Higher-than-average peak summer temperatures, combined with depleted reserves that had resulted from prior outages, left DPL operators with no option but to shed load when IR2 failed.

3.7 South-Central States

22. **Summer ratings and actual capability of generating units are not always consistent.** There are concerns over the determination of summer ratings in comparison with the actual capability shown on July 23. The 500 MW in small deratings is equivalent to a moderate-sized fossil unit.
23. **Problems in anticipation and delays in the application of public appeals limited the effectiveness of the appeals once they were made.** Public appeals for conservation have a limited, temporary effect. Public appeals are most effective when issued with sufficient anticipation. Considering the event of July 23, day-ahead public appeals were not issued because at the time it was thought that reserves would be adequate. Eventually, public appeals were issued prior to the rotating blackouts. Entergy's lack of relative familiarity with the public appeals process was also a constraining factor on the system. Because Entergy had issued only two public conservation notices in the previous 20 years, comprehensive mitigation strategies were not in place, forcing a series of meetings that eventually led to a noon public notice for conservation.
24. **Reliance on nonfirm purchases to meet operating reserve targets results in inadequate reserves during regionwide events of high demand.** Entergy calculated its reserves as a combination of own capacity, firm and nonfirm interchange transactions, and load management. Relying on other members of a reserve-sharing agreement for reserves saves significantly on *operating reserve* costs under most conditions. However, in situations like July 23, reserves are not used in a "normal" mode. Operating reserves can be used any time the firm load is likely to be curtailed. Under conditions of high demand, the probability of firm load curtailment is consequently higher because more members of the reserve-sharing agreement are utilizing their full capability and counting on nonfirm purchases to maintain reserve. Also, any nonfirm purchase under conditions in which power markets are approaching extreme conditions is subject to recall. This greatly increases the uncertainty in peak demand obligations. This observation is not taken into consideration in the analysis of reserve requirements.

25. **Mechanisms for short-term power sales rely on multiple, often manual telecommunications, leading to inefficient and untimely outcomes.** The *short-term* power market and the steps required to enact a transaction present concerns. These problems are associated with timing. The timing during which transactions can be executed presents barriers to solving problems. Typically, for hour-ahead power, the market clears no later than one-half-hour past the hour for the next hour. In the Entergy July 23 case, this meant that information on the imminent loss of White Bluff Unit 1 and the loss of an additional 300 MW of interruptible power from TVA came after this point in the hour (at around 2:30 p.m.). The rules for short-term markets left Entergy unable to acquire additional short-term power until 4:00 p.m.
26. **The generation infrastructure is aging.** Entergy's average unit age is 35 years, while its newest unit currently on line is 20 years old. Currently, Entergy is in the process of adding to its generation capability through a multi-billion-dollar purchasing contract. This addition will increase Entergy's generation capability by approximately 4,800 MW, but the age of its generation capability will remain an issue for Entergy.
27. **Dispatch software problems led to inefficient utilization of limited energy resources.** SPP had a major operating-reserve-sharing software problem that resulted in the inability to "clear" reserve "markets" when the program came across situations of insufficiency. SPP has placed a temporary "patch" into the program to stop attempting to solve an infeasible problem. SPP's solution on July 23 was to perform a series of small transactions between territories to maintain the system economy. The number of manual transactions far outpaced what should have been done.

3.8 Chicago

28. **Load forecasting techniques and associated distribution planning tools failed to adequately accommodate the effects of unusual summer weather conditions as experienced in 1999.** Planning has been based on "average" weather conditions, meaning that load exceeds the design criterion approximately once in every 2 or 3 years. A criterion of 1 in 10 years is more commonplace in the industry. These shortcomings were compounded by further uncertainty in predictions for individual substation load levels. ComEd has now changed to a 99°F, four-hour moving-average peak temperature as a basis for planning.
29. **Emergency preparedness and management plans did not address distribution problems.** Although ComEd had an emergency plan for its bulk transmission and generation system, it lacked a comparable level of preparation for dealing with distribution system problems. The response plans that were in place for extreme, multiple distribution-level contingencies were inadequate. In particular:

- Detailed distribution level load relief and emergency load interruption procedures were incomplete;
 - Under emergency conditions, information flows between the utility and organizations affected by outages were perceived as inadequate by these organizations; and
 - ComEd's planning process has no measure (or metric) for assessing the risk of multiple contingencies.
30. **The distribution system topology is inflexible.** The topology of the urban distribution system lacked flexibility. In particular, its ability to shift load between substations under *contingency* conditions was inadequate. The use of Y joints in cables made it more difficult to locate a fault and increased the effects of cable faults. Inconsistent protection philosophies tended to increase the duration of the outages.
 31. **Substation protection and equipment configuration practices limited flexibility.** Some substation protection and equipment configuration practices also limited flexibility in emergency response situations (which, when coupled with existing equipment protection schemes, could force removal of both a failed transformer and a working transformer paired with it).
 32. **Planned distribution system upgrades were not implemented on schedule.** Distribution system upgrades in progress were not completed in time for the summer peak (e.g., an in-progress 69-kV to 138-kV substation transformer upgrade).
 33. **Real-time information and historical records on distribution system conditions were limited and were not always preserved.** Less than full penetration of supervisory control and data acquisition (SCADA) system technology hindered complete monitoring of distribution system overload conditions. Each of the high-voltage substations (Northwest, Lakeview, and Jefferson) has SCADA. Most of the 4-kV portions of the distribution system that were interrupted as a result of the 12-kV cable failures do not have SCADA. Selection of SCADA data for long-term "warehousing" excluded certain key measurements, such as feeder overloads, which impeded the study of reliability trends. Also, the computer system that records alarms overloaded and lost information that was needed to analyze the outage chronology. (This problem was corrected in the aftermath of the summer outages.)
 34. **Maintenance planning did not consider transformer overload analysis.** Transformer overload analysis and reporting tools were generally not coordinated with maintenance planning and programs.
 35. **Substation maintenance programs did not anticipate component weaknesses.** Many fixed, periodic, substation maintenance programs had been scaled back or

discontinued in transition to a “reliability-centered maintenance” philosophy. However, the collection of data and measurements necessary for successful reliability-centered maintenance was not fully in place (e.g., the dissolved gas analysis of oil-filled cables used to detect internal degradation and incipient failure began only in the aftermath of the summer outages). In general, the ability to predict possible component failures from the inspections that were performed and data that were collected was limited.

36. **Maintenance management contributed to the severity of the outages.** Management of maintenance activities was weak; tracking of inspection and maintenance processes was incomplete and poor; and employee training and skill levels were inappropriately matched to inspection duties (as documented in the case of aerial inspection of transmission conductors and insulators). A large backlog of desired corrective and preventive maintenance activities had accumulated in the year preceding the outages.
37. **Transmission and distribution maintenance expenditures declined over time and became inadequate.** T&D maintenance expenditures declined dramatically and consistently from 1991 to 1998. The decline coincided with other cost pressures faced by ComEd, including those associated with nuclear plant maintenance and industry restructuring.
38. **Several business factors compromised reliability performance.** While many individual “pieces” of reliability activity were in place (e.g., ComEd’s participation in a joint Electric Power Research Institute (EPRI)-led project on reliability data mining), overall reliability performance was compromised by inadequate links between new business strategies (such as reliability-centered maintenance), resource allocation, employee training and supervision, and reliability-relevant data collection and analysis tools currently used in the field.

Section 4

Process for Soliciting Public Input

Following release of the Interim Report on January 4, 2000, POST conducted three technical workshops at which the team heard public comments and recommendations on appropriate actions that the federal government could take to address the findings described in Section 3 of this report. The workshops listed below were organized around the five topics used in the Interim Report to group the findings⁴:

- January 20, 2000: San Francisco, California
 - Transition to Competitive Energy Service Markets
 - Regulatory Policy for Reliable Transmission and Distribution
- January 24, 2000: New Orleans, Louisiana
 - Information Resources
 - Operations Management and Emergency Response
- January 27, 2000: Newark, New Jersey
 - Reliability Metrics, Planning, and Tracking

The workshops were well attended, with more than 150 individuals participating in one or more of the sessions. Attendance reflected a broad cross-section of stakeholders in today's electricity industry, including utilities, ISOs, *marketers*, union representatives, state regulators, local officials, NERC, trade associations, consumer advocates, EPRI, equipment vendors, and industry consultants. The team also received more than 70 written comments through its web site, by mail, and by fax. Appendix A contains an integrated summary of the input received at the technical workshops and via the web site, by mail, and by fax.

POST has found the technical workshops and public comment process to be an invaluable source of input for the development of its recommendations. Around the country, POST observed a deep interest in reliability. In developing its recommendations, the team relied on these comments to supplement and enhance its own analysis and expertise.

⁴ Each workshop also provided opportunities for public comment on any of the other findings and topic areas.

Section 5

Recommendations to the Secretary of Energy

The U.S. electric industry is in a state of transition. Formerly full-service utilities are divesting, merging, and reorganizing in an effort to maximize their opportunities in a restructured industry. New market entrants are seeking to expand their presence within the industry, and new institutions are emerging to operate the grid.

It is uncertain what the industry will look like following restructuring or the time frame in which it will be realized. What is certain is that ensuring reliable electric service will be an essential requirement throughout. The POST members recognize that adequately balancing public interest in reliability with its associated costs will be an ongoing challenge.

The recommendations offered to the Secretary of Energy in this report are based on the findings developed by POST following its study of significant reliability events from the summer of 1999. Some recommendations support ongoing federal programs. Others address areas of new or increased federal involvement. These recommendations for federal actions on reliability are not intended to be all inclusive. Some aspects of reliability are beyond the scope of this report.

POST's recommendations reflect the basic premise that, while markets and industry should address issues related to reliability, the federal government has a fundamental responsibility for ensuring that the public's interests are fully represented. Moreover, many stakeholders, including state and local governments, share this responsibility. Systems developed by the industry have evolved to protect electric reliability; however, these systems need to be overhauled to address the needs of a changing industry. Nevertheless, they are the appropriate starting points for any required changes. For example, POST recommends that the federal government support management of electric grids by a self-regulating reliability organization that has federal oversight to make compliance with reliability standards mandatory.

Further, POST recommends increased federal leadership in selected areas, such as comprehensive restructuring legislation, reliability-enhancing activities by federal utilities, and facilitating regional solutions for siting. The team recognizes that federal leadership in these areas may be controversial but maintains that leadership is essential for ensuring reliability.

It is important to recognize that electric reliability and efficient electricity markets are inextricably intertwined. Just as markets cannot be designed without considering reliability, the mechanisms for reliability in a competitive market cannot be effectively implemented without a clear understanding of how markets will work. As we move toward regional, and even national, electricity markets, regional and national solutions for reliability of the bulk-power system must be considered. In the interest of reliability,

it is imperative that a comprehensive, not a piecemeal, approach be taken, while, at the same time, respecting traditional state roles.

POST also recommends enhancing federal activities in areas where federal roles are already well established, such as in facilitating exchanges of information, conducting public interest R&D, and monitoring reliability issues. The team has identified several areas where increased federal support for these activities is especially warranted at this time. The POST prefaces these actions by noting that effectiveness will be maximized by undertaking them in close partnership with industry stakeholders.

In this report, POST submits twelve recommendations for consideration by the Secretary of Energy. The following recommendations are designed to help avoid future power outages. One or more possible federal actions are suggested along with each recommendation. Following each recommendation are numbers that correlate to the findings in Section 3. Table 2 also lists the recommendations and their associated findings (at the end of this section).

1. Promote market-based approaches to ensure reliable electric services.
(addresses Findings 1–3, 10, 12, 19, and 37)

Restructuring is based on the fundamental principle that competition and markets, not regulators and utilities, result in better investment and operating decisions with respect to generation and consumption of electricity. Mechanisms that will ensure adequate supplies of electricity — and reliable operations — should be designed with this principle in mind. The value of reliability needs to be determined in competitive markets, and customers, as well as energy providers, need to have the opportunity to participate in markets for energy and ancillary services — and profit from that participation. Yet, because electric service is provided through a network, it has aspects of a public good and may be underprovided by private entities. Guidance is needed to ensure that the public interest is adequately captured.

Many states have made significant progress in developing competitive electricity markets. However, efforts in developing market-based mechanisms for promoting electric reliability — for example, allowing customers to participate in energy and ancillary service markets — have been less aggressive. Developers of these mechanisms must explicitly account for the broad geographic scope of today's electricity markets, which can extend across multiple states and regions of the country.⁵ Although states have a definite role in regulating utilities and protecting consumers, there is also an important federal role: to improve the operation of power markets by providing leadership, direction, and consistency across the country.

⁵ The U.S. electric power system consists of just three distinct interconnections; trade can be conducted throughout an interconnection. For example, a generator in Minnesota can sell to a customer in Florida.

Action for federal consideration:

- *Support the implementation of fair, efficient, and transparent markets for electric power and ancillary services.*

Depending on markets to ensure reliability requires well-functioning exchange forums. Energy and ancillary services should be defined uniformly so that performance or delivery can be verified easily. Standard contract terms and conditions are needed to clarify obligations and responsibilities. Prices for energy and ancillary services should be widely available so that buyers and sellers can make informed decisions. ISOs and system operators should be encouraged to make real-time market prices and information on system conditions widely available. Finally, prices should accurately reflect supply and demand. Mechanisms to monitor and curtail abuses of market power must be enhanced. The federal government should ensure that these threshold conditions are met by efforts to create and implement markets for electric services around the country.

2. Enable customer participation in competitive electricity markets.

(addresses Findings 1, 2, 10, 19, and 20)

The ability of customers to manage their demand in response to market prices is the key to ensuring both reliable electric service and an efficiently functioning, competitive electricity market. POST agrees with public comments received that meaningful customer participation is a prerequisite for achieving the full reliability benefits of restructuring. To more fully participate in a competitive market, customers must be able to see real-time prices (if they choose to do so) and have access to the communication and control technologies that will enable them to participate directly.

Actions for federal consideration:

- *Support the development of market rules that allow customers to supply load reductions and ancillary services in competitive energy markets.*

The market rules for competitive energy markets evolved from rules used to govern operations and energy transactions involving large generating units. It is not surprising that many rules assume that generating technologies will provide energy and ancillary services. Functional, rather than technology-dependent, specifications are needed for delivering energy and providing ancillary services so that customers can participate. The federal government should support the development and adoption of market rules that ensure reliability by providing for broad and meaningful customer participation in competitive markets for energy and ancillary services.

- *Encourage development of demand management systems that support electric reliability.*

Price visibility is an important prerequisite for efficient markets. For customers to participate in markets for energy and ancillary services, price visibility must be coupled

with communication and control technologies that enable customers to receive, interpret, and respond to prices. The federal government should support the development and demonstration of demand management technologies, systems, and approaches that will allow customers to participate in competitive energy markets.

3. Remove barriers to distributed energy resources.

(addresses Findings 1, 2, 10, and 19)

There is currently great interest in relying more heavily on distributed generation technologies to help utilities respond more rapidly to an increased demand for electricity in areas where demand is already high. At the same time, utilities are striving to improve the quality of power to customers. Many argue that barriers impede market-driven acceptance of these technologies. The federal government should target this area for special attention and review and remove these barriers, as needed.

Actions for federal consideration:

- *Support the development of interconnection standards for distributed energy resources.*

Interconnection practices for distributed energy resources vary widely across the country. Greater uniformity in these practices should lower installation and operating costs, without diminishing the importance of worker safety, system reliability, and customer protection needs. Industry-led forums, such as those sponsored by the Institute of Electrical and Electronics Engineers, are leading the way in developing a consensus on this subject, largely due to support from DOE. The federal government should continue these efforts — and enhance their effectiveness — by encouraging local jurisdictions to adopt them and by promoting the development of testing and verification procedures.

- *Support state-led efforts to address regulatory disincentives for integrating customer supply and demand solutions.*

Current ratemaking practices are disincentives for distributed resources. In many jurisdictions, reduction of load (through either customer-owned distributed generation or other load-reduction technologies) may be profitable to utility distribution companies only during periods of peak demand. From a customer's perspective, however, investments in these technologies may have an economic value. During periods of peak demand, load reduction could improve reliability by reducing demand on stressed electric systems. The federal government should support state efforts to identify and address mismatches between traditional ratemaking approaches and public policies appropriate for reliability-enhancing distributed energy resources in a restructured electric industry.

- *Study the potential for using emergency backup generators to reduce system demands to help avoid power outages.*

A large installed base of emergency backup generation exists that is currently deployed only after actual power outages. Operating these generators in advance of system emergencies can reduce stress on a system and possibly avoid outages. However, operating these generators to avoid outages is complicated because of the lack of incentives for backup generation owners; the need for demonstrations of communication, control, and system protection technologies; and current environmental restrictions. The federal government should study these issues and, where appropriate, take actions to remove barriers to the use of backup generation to enhance system reliability.

4. Support mandatory reliability standards for bulk-power systems.
(addresses Findings 4, 11, 21, 24, and 36–38)

Today, the interconnected electric power system is being transformed from one that was primarily designed to serve the customers of full-service utilities, each integrated across the generation, transmission, and distribution functions, to one that will support a vibrant, competitive market. This change makes the current system of voluntary compliance with reliability standards inadequate for ensuring reliability. Mandatory standards for bulk-power systems are needed to ensure that the “rules of the road” are implemented in a straightforward and balanced manner.

Action for federal consideration:

- *Support the creation of a self-regulated reliability organization with federal oversight to develop and enforce reliability standards for bulk-power systems as part of a comprehensive plan for restructuring the electric industry.*

Industry-led voluntary reliability standards for bulk-power system operation and planning have worked effectively since their inception. These efforts are the logical and appropriate starting point to change from voluntary to mandatory standards. The federal government should continue its support for this evolutionary process by authorizing the creation of a self-regulated reliability organization with federal oversight to ensure compliance with reliability standards. However, this effort should not be undertaken in isolation. It must be treated as an integral element of a comprehensive plan for restructuring the industry. A piecemeal approach that treats reliability in isolation would compromise reforms needed in other arenas linked to reliability (e.g., more efficient markets, regional operations of grids).

5. Support reporting and sharing of information on “best practices.”
(addresses Findings 5–9, 11, 15–18, 21, 22, 24, 27, and 29–38)

Many forums for exchanging information on “best practices” for maintaining and operating electric generation, transmission, and distribution systems already exist. However, concerns exist about the consistency of some information (such as reliability

indices), the availability of data to all industry stakeholders, and the continued viability of these forums in a restructured industry. The federal government could play an important role in enhancing the definition, collection, and sharing of information. It should work in close partnership with states and other industry stakeholders as it develops this role.

Actions for federal consideration:

- *Promote the use of uniform definitions and measurements for reliability-related information.*

Industry-led groups have developed a number of measurements for reliability. As reliability becomes more of a commodity that customers can select and pay for, increased uniformity in definitions and measurements is needed, and new measures of reliability should be developed. The federal government should promote these efforts.

- *Facilitate the collection and sharing of information on reliability-related regulatory issues among state public utility commissions.*

Oversight and regulation of distribution system reliability are state responsibilities. Among many other things, restructuring is requiring state public utility commissions (PUCs) to re-examine, and, where appropriate, modify policies for reliability. The effectiveness of these state-led activities is enhanced by information sharing among these commissions. The federal government should support these activities by working with national organizations, such as the National Association of Regulatory Utility Commissioners, to facilitate the collection and sharing of information on comparative utility reliability performance, service reliability standards, and regulatory policies and incentives for reliability. Information on reliability policies in other countries, where, for example, utilities are penalized and customers are compensated for outages, may be especially helpful. Similarly, better information on the value customers place on (and their willingness and ability to pay for) reliability should be especially helpful in establishing future regulatory policies for reliability.

- *Support activities to develop and share information among industry participants on critical resources and industry practices.*

In response to concerns that information sharing among utilities may become a greater concern because of restructuring the industry, the federal government should begin to assess existing forums for information exchange and, if necessary, examine ways to enhance them or develop complementary forums. Information on the availability of critical T&D equipment and on best practices for distribution system maintenance should be considered first. Electronic media, such as web sites, should be considered as possible forums for facilitating these exchanges.

6. Enhance emergency preparedness activities for low-probability, high-consequence events on bulk-power systems.

(addresses Findings 3, 4, 9, 20, 23, and 29)

Emergencies on bulk-power systems affect large geographic areas, involve many stakeholders, and affect millions of customers. The events of the summer of 1999 demonstrated that effective communication and coordination among many parties are critical during times of system emergencies. The federal government should actively support efforts to continually review and improve planning and response capabilities.

Action for federal consideration:

- *Work with regional, state, and local authorities to support continuous improvement in coordination, planning, and preparations to respond to electricity emergencies.*

A critical element of emergency preparedness by industry participants is coordination with and among federal, regional, state, and local authorities. The federal government can play an important role in facilitating coordination among these authorities and with the industry in responding to power system emergencies. The federal government should work with these parties to help improve and better coordinate these responses.

7. Demonstrate federal leadership through promotion of best reliability practices at federal utilities.

(addresses Findings 1, 2, and 19)

Federal utilities are unique assets that have long pursued many federal and regional objectives, ranging from power production to agricultural and economic development. As part of their role, these utilities have served as research and development catalysts for technological changes within the industry. Piloting new reliability initiatives would be consistent with this historic leadership role.

Actions for federal consideration:

- *Develop and pilot reliability self-assessment procedures.*

Federal utilities should continue to promote best reliability practices through an ongoing process of self-assessment. In addition, power marketing administrations should continue to support their respective generating agencies in those areas that involve the reliability of hydropower facilities.

Federal utilities should continue to participate in continued development of pilot programs to incorporate new criteria and compliance monitoring for future phases of reliability programs. These programs should provide opportunities for self-assessment,

for monitoring and review of compliance, and for sanctions for noncompliance with established reliability criteria.

- *Support distributed energy resources.*

Federal utilities should support the development and facilitate the installation of distributed energy resources, and they should explore ways for enhancing the reliability of their transmission facilities by these installations. Federal utilities should also ensure that their transmission policies aid in integrating electric distribution systems and energy markets to increase reliability.

- *Encourage economic energy efficiency.*

Federal utilities should strive to implement energy-efficiency measures to reduce the amount of power required to serve growing energy loads. In addition, they should continue to develop programs to encourage their utility customers to invest in energy efficiency.

8. Conduct public interest reliability-related research and development consistent with the needs of a restructuring electric industry.

(addresses Findings 5–8, 13, 14, 17, 28, and 33)

Industry investments in reliability-related R&D have declined steadily over the past few years. These declines have occurred at least in part because the “clients” for next-generation investments, such as regional transmission organizations, are still in their formative stage. Furthermore, the independent system operators currently do not own the transmission assets and are nonprofit institutions. A stable climate for private investments in longer-range R&D conducted with the public’s interest in mind does not currently exist. Federal investments in public-interest, reliability-related R&D are especially needed during this time of industry transition. POST strongly supports Secretary Richardson’s commitment to increase federal investments in electric reliability R&D as provided for in the Administration’s proposed fiscal year 2001 budget.

Actions for federal consideration:

- *Develop real-time system monitoring, communication, and control technologies.*

Currently, individual technologies are available for enhancing reliability and increasing trade over existing transmission lines (including Wide Area Measurement System, flexible AC transmission systems (FACTS), and high-voltage DC transmission technologies). However, continued demonstration of existing technologies, as well as development of new technologies, is needed. Past federal investments in developing and demonstrating some of these technologies, which were discontinued starting in the mid-1990s, should be renewed to facilitate adoption of these technologies when a more stable climate for investment by industry emerges.

- *Create sensors, remote monitoring, and diagnostic technologies for cables and aging transmission and distribution infrastructure.*

POST members heard much discussion regarding the value of improved cable monitoring technologies and the need for better cable diagnostic techniques. At the same time, the team heard that adoption of these technologies and techniques was simply a matter of comparing cost to value, and that on that score, additional investments could not be justified. Federal support for industry-led R&D to lower the costs and improve the reliability of these technologies would clearly improve cable maintenance and reliability.

- *Integrate customer demand management, distributed generation, and storage technologies.*

Currently, efforts to conduct the R&D necessary to support widespread integration of demand management, distributed generation, and storage technologies are limited because parties with the greatest vested interest are constrained in their ability to pursue the necessary research. Utilities, on the one hand, face significant regulatory disincentives to pursue research that, under current regulations, will erode revenues and profits. Distributed energy resource equipment manufacturers lack proprietary information on the design and operation of utility systems to explore promising new approaches. Federally supported R&D activities are needed to explore new methods of integrating and controlling distributed energy resources in ways that enhance system reliability. An important focus of these activities should be development of technologies that would allow these resources to participate directly in competitive markets for energy and ancillary services.

- *Improve analytic models for load forecasts, power system simulation, and contingency assessments.*

Uncertainty is a pervasive element of reliability planning and operations. Methods and data are needed to better understand traditional sources of uncertainty (e.g., weather and equipment performance), as well as new sources introduced by restructuring (e.g., behavior of market participants). Federally sponsored R&D should spur the accelerated transfer and testing of promising techniques from other fields to enhance models used by the electricity industry.

- *Examine the design and performance of competitive electricity markets.*

A special need exists for unbiased public interest research on the design and performance of competitive electricity markets. Interdisciplinary, science-based approaches involving both market economics and power system engineering are required. Federally sponsored R&D should support developing metrics, designing and conducting experiments, analyzing performance, and testing alternatives.

9. Facilitate and empower regional solutions to the siting of generation and transmission facilities.

(addresses Findings 1, 10, and 26)

Stable incentives for investing in generation and transmission must be complemented by siting boards that can discharge their responsibilities in a timely and coordinated fashion. Such boards need to address two primary problems. First, policies among agencies, among states, between state and federal agencies, and among federal agencies overlap and sometimes conflict. Second, parochial bodies do not have incentives to seek regional solutions. These problems result in long delays, and they could lead to inefficient and inequitable siting decisions.

Actions for federal consideration:

- *Convene regional summits to initiate and facilitate dialog among regional stakeholders.*

Dialog among stakeholders is the first step in identifying regional solutions. Because of its national perspective, the federal government could be an important leader in brokering these discussions. The federal government should continue to convene regional summits that provide for meaningful participation by all stakeholders and for equitable resolution of outstanding issues.

- *Support federal legislation to facilitate state efforts to form regional siting boards.*

Empowering regional decision-making boards is a logical complement to summits that initiate dialog among regional stakeholders. The authority of these boards must be final and binding on all parties. Federal legislation should be enacted that will allow states to create these authorities.

- *Raise reliability as an issue (as appropriate) where federal permits are required for siting electric facilities.*

The federal government participates in siting decisions through various federal agencies. These agencies should give appropriate consideration to electric reliability. The Department of Energy could provide guidance to federal agencies regarding the need for and value of electric reliability in siting proceedings.

10. Promote public awareness of electric reliability issues.

(addresses Findings 2, 19, and 23)

General public awareness of the complex issues associated with maintaining reliable electric service is low. Yet, as demonstrated by the events of the summer of 1999, public interest in reliable electric service is high. Greater understanding of electric reliability issues, including both the frequency and causes of outages and the steps being taken to

prevent and limit the consequences of outages, will lead to better-informed decisions. Special attention should be placed on discussing the costs and trade-offs inherent in making reliability investment and operating decisions. Future activities should complement, not replace, existing state, utility, and locally led efforts and be effectively coordinated with them.

Actions for federal consideration:

- *Continue DOE-sponsored independent investigations of significant power outages and other reliability events.*

Stakeholder support for the studies and technical workshops conducted by POST confirms the important role that the federal government plays in increasing the awareness of reliability issues during industry restructuring. The federal government should continue to conduct periodic studies of significant reliability events to identify problem areas and to recommend additional federal actions, as warranted.

- *Continue DOE-sponsored forums where stakeholders can meet to discuss reliability issues.*

As the electric power industry changes, a special need exists for a dialog among stakeholders and information exchanges on reliability issues. Many thoughtful comments have been expressed on options for the future organization of the industry and the reliability issues these options seek to address. The evolution of these ideas is especially needed. Such ideas include the important process of developing consensus for the most promising ideas and holding forums for discussing feedback on what works and what does not work. DOE-sponsored conferences, workshops, and other exchanges would facilitate this process.

11. Monitor and assess vulnerabilities to electric power system reliability.
(addresses Findings 5, 7, 9, 16, 25, and 26)

The outages and disturbances studied by POST resulted from unpredicted events that exploited specific weaknesses in physical systems and the planning and operating processes that supported them (e.g., extremely hot weather caused overloads and cable failures). Other electric power system vulnerabilities were identified during POST's studies and technical workshops. In view of the regional and national implications of power outages, known and emerging electric system vulnerabilities need to be studied from a national rather than a local perspective. Studies from a national perspective uniquely belong to the federal government, but studies must be carried out in close partnership with the electric industry.

Actions for federal consideration:

- *Work with industry stakeholders to conduct comprehensive assessments of electric power system vulnerabilities.*

An appropriate role for the federal government would be to work with industry to assess and analyze vulnerabilities and to develop the technologies and expertise necessary for reducing such vulnerabilities. The federal government has already initiated a series of assessments toward this end, which are being implemented in close partnership with industry. These efforts should be continued.

- *Work with industry stakeholders to refine and implement procedures to assess the robustness of the electricity system in responding to bulk-power system emergencies.*

Well-established procedures are in place for responding to system emergencies. However, they need to be thoroughly tested and updated regularly. In particular, consistency within procedures is needed when many operating entities are coordinating efforts. The federal government should build on efforts initiated during preparations for the Year 2000 to ensure that emergency preparedness remains a high priority. Specifically, the federal government should work with industry to enhance assessment procedures to ensure consistent and coordinated responses to system emergencies.

12. Encourage energy efficiency as a means for enhancing reliability.
(addresses Findings 2, 10, and 19)

The increased adoption of energy efficiency measures can enhance electric system reliability by reducing demand growth in areas experiencing shortages in electric generation or constraints in electric transmission or distribution. Programs to stimulate adoption of energy-efficient technologies and practices can provide more rapid relief to areas with fast-growing demand. Further, they can do so with fewer negative impacts than would occur during the construction of new generation, transmission, and distribution facilities. Such programs might be especially helpful in areas where growth in electric demand is high; yet, markets for new generation are in their infancy or existing incentives for investments in transmission and distribution are in transition. Technologies and practices that reduce loads during times of peak demand, such as high-efficiency air conditioning and lighting equipment, are especially valuable.

Actions for federal consideration:

- *Work with state and local governments to support development and implementation of cost-effective energy efficiency programs.*

Utility demand-side management programs were successful in reducing demand growth during the early 1990s. These activities began to decline, however, as the industry prepared for restructuring. Many states have tried to preserve funding for these

activities concurrent and consistent with the development of competitive markets for energy. The federal government should work with state and local governments to continue and expand these efforts, both to improve reliability in the short term, while markets develop, and, in the long term, to the extent markets do not fully capture the public reliability and other benefits that they offer.

- *Expand existing federal programs to promote energy efficiency.*

The federal government currently conducts research in support of more efficient end-use technologies, promulgates standards for more efficient technologies, and provides weatherization assistance to low-income households. These well-established federal activities should be expanded in ways that are consistent with improving the reliability of the U.S. electric power system through more efficient use of electricity.

Table 2 Summary of Recommendations and Associated Findings

No.	Recommendation	Relevant Findings ^a
1	Promote market-based approaches to ensure reliable electric services.	1–3, 10, 12, 19, and 37
2	Enable customer participation in competitive electricity markets.	1, 2, 10, 19, and 20
3	Remove barriers to distributed energy resources.	1, 2, 10, and 19
4	Support mandatory reliability standards for bulk-power systems.	4, 11, 21, 24, and 36–38
5	Support reporting and sharing of information on “best practices.”	5–9, 11, 15–18, 21, 22, 24, 27, and 29–38
6	Enhance emergency preparedness activities for low-probability, high-consequence events on bulk-power systems.	3, 4, 9, 20, 23, and 29
7	Demonstrate federal leadership through promotion of best reliability practices at federal utilities.	1, 2, and 19
8	Conduct public interest reliability-related research and development consistent with the needs of a restructuring electric industry.	5–8, 13, 14, 17, 28, and 33
9	Facilitate and empower regional solutions to the siting of generation and transmission facilities.	1, 10, and 26
10	Promote public awareness of electric reliability issues.	2, 19, and 23
11	Monitor and assess vulnerabilities to electric power system reliability.	5, 7, 9, 16, 25, and 26
12	Encourage energy efficiency as a means for enhancing reliability.	2, 10, and 19

^a The numbers assigned to the relevant findings correspond to the numbers assigned to the findings in Section 3.

Appendix A

Summary of Public Comments

This appendix summarizes comments received and suggestions made regarding actions that the federal government could take to address the findings of the Power Outage Study Team (POST). These summaries have been categorized to correlate with the five topic areas that were identified in the POST Interim Report¹ and used to structure the discussions at three technical workshops organized by the POST. The summaries reflect comments sent directly to the POST as well as comments offered at the three workshops.

A.1 Transition to Competitive Energy Service Markets

Most of the commenters saw restructuring as being part of the solution for achieving reliable electric service. Commenters who tried to link ongoing restructuring activities with the reliability disruptions of last summer (or to link restructuring with larger trends in areas such as utility staffing and maintenance practices) also offered possible solutions for improving reliability that took restructuring into account. The comments most germane to the industry transition are categorized here into four areas: the effects of competitive energy markets on reliability, customer participation in competitive energy markets, emerging institutions for managing reliability issues in a competitive market, and unique federal roles in a competitive market. Many comments that addressed this topic are also relevant to the other topics and are included in those sections as well.

A.1.1 Effect of Competitive Energy Markets on Reliability

A theme repeated in many comments was that the federal government should recognize that electric markets are the appropriate first line of defense for ensuring reliable electric service. Several commenters mentioned regions of the United States where substantial investments in new electric generating capacity were recently announced. In all cases, these investments were made first in response to the need for new capacity and second in response to the emerging markets, which enable new generating sources to compete to meet these needs. Many commenters were optimistic, believing that ultimately, such competitive markets would be sufficient to ensure adequate long-term investments in generation capacity.

Other commenters suggested that competitive markets are the best mechanism for managing reliability in the short term. An example of the inefficiency created under current non-market-based transmission loading relief procedures was provided. Under these procedures, transactions involving hundreds of megawatts of capacity in one part of the interconnected power system can cause curtailment of transactions involving thousands of megawatts of capacity in another part of the system.

¹ *Interim Report of the U.S. Department of Energy's Power Outage Study Team, Findings from the Summer of 1999, January 2000.*

In reflecting on the voltage drops of July 6 and July 19, Interconnection, LLC (PJM), attributed the more rapid system recovery on July 19 at least in part to market-led curtailments in direct response to the high location-based market prices observed on that day. It was suggested that market participants might have learned from the events of July 6, so that by July 19, they already had plans to respond profitably to prevailing market signals.

PJM also described how, as a result of the events of the summer of 1999, it obtained Federal Energy Regulatory Commission approval to impose a tariff that will provide generators with compensation for reactive power production at the opportunity cost of foregone real power sales. This tariff allows PJM to ensure that its directions to generators to produce reactive power are now consistent with the competing incentives the market offers to produce real power.²

A.1.2 Customer Participation in Competitive Energy Markets

Many commenters suggested that the fact that end-use customers do not participate in competitive markets is a major factor that contributes to short-term energy shortages, such as those that occurred during last summer's heat waves. Reliability depends on a utility's ability to serve a sudden and inflexible surge in electricity demand. These commenters noted that public appeals for conservation get mixed results. What is really needed is a mechanism for balancing the cost of serving an increased load by acquiring more power with the cost of reducing load. Unless customers are given meaningful opportunities (not mandates) to participate, this balance will not be achieved. Instead, market inefficiency will persist, leading to periodic energy shortages and unnecessarily high prices for energy and ancillary services during periods of peak demand.

Some commenters noted that now, when energy and ancillary services are in short supply, generators are the primary beneficiaries of the higher prices for these services. If customers could see these high prices and be able to respond to them by selling their loads in the market, they too could share in the economic rewards. The end result would be threefold: more stable prices for electricity and ancillary services, a reduced need for investment in transmission systems, and more reliable electric service.

Several commenters observed that coupled with the use of competitive markets to get the prices for electric service "right," steps must be taken to ensure that these prices can be seen. Electric reliability has a price, and this price must be visible if customers are to make reasoned, economically efficient decisions about their electric service. One commenter pointed out the need for robust communication infrastructures to convey price information.

² Typically, generators can produce both real and reactive power. At times of peak real power generation, increased reactive power generation (essential for maintaining system stability during high system loads) requires a reduction in real power generation.

Several commenters described emerging efforts to increase opportunities for demand-side participation in competitive electric markets. Some utilities and system operators are experimenting with real-time and price-sensitive interruptible tariffs. However, these opportunities are now primarily available to only the largest customers, because the costs of participation are too high when compared with the savings that are available. Some commenters discussed the need for advances in communication and metering technologies to increase the opportunities for smaller customers to participate.

Some commenters focussed on a related but (in important ways) distinct form of demand-side participation that should be encouraged: distributed energy resources. A federal role in promoting wider adoption of these technologies was suggested. This role would include conducting research and development (R&D) on advanced system integration concepts and supporting near-term activities to remove regulatory barriers that impede adoption of these technologies. The current federal support of efforts to develop interconnection standards was cited as a prime example of an appropriate federal activity that should be continued.

Throughout these discussions, many commenters emphasized that decisions to participate in competitive markets should remain firmly in the customer's control. In other words, in a free market, customers should be empowered to choose how they can best meet their energy needs. Some customers that can adjust their loads might choose real-time pricing or direct participation in markets for energy and ancillary services. Others might choose a fixed price (as in most current utility tariffs). The point is that customers, not regulators, should be making these decisions. But in order to make informed decisions, customers require access to market information and prices. Such access requires actions by the appropriate regulatory authorities.

A.1.3 Emerging Institutions for Managing Reliability in a Competitive Market

A third major theme addressed by commenters was the role of the federal government with respect to the emerging institutions responsible for organizing trade and ensuring reliability in a restructured industry. These comments, by and large, pointed out that the federal government needs to ensure that state and regional conditions are acknowledged and that the primacy of existing state and regional decision-making processes is respected.

The commenters suggested that the federal government should embrace the diversity of approaches already being used and seek to exert its influence in support of existing local, state, and regional institutions. For example, the federal government could become a public member on the boards for independent system operators and thereby influence their evolution.

A.1.4 Unique Federal Roles in a Competitive Market

Commenters pointed to two areas in which the federal government could play a unique role with regard to the transition to competitive markets: (1) federal utilities, including the power marketing administrations, and (2) public awareness.

The federal utilities exert great influence on restructuring activities in their regions. Commenters saw their ability to exert a federal presence in regional developments as a positive way the federal government could promote reliability.

Several commenters observed that the public's level of awareness about electric industry restructuring is low. Disruptions in reliability, such as the events of last summer, fuel public concern that restructuring is somehow to blame for problems. Some commenters suggested that a critically needed and essential role for the federal government is to increase the public's awareness of electric industry restructuring in general and electric power reliability in particular. This role should be undertaken in coordination with industry stakeholders. No one disputed the authority or legitimacy of the federal government in playing a leadership role in providing objective information of this type. In fact, several commenters expressed appreciation for the POST activity and said that it was appropriate and reassuring for the federal government to watch market developments, especially with respect to the their effect on reliability.

A.2 Regulatory Policy for Reliable Transmission and Distribution

Commenters suggested that a number of areas related to transmission and distribution (T&D) regulatory policies should be revisited. These included (1) the roles of industry and government in managing reliability, (2) incentives for investing in transmission system reliability, (3) regional coordination in siting generation and transmission facilities, and (4) state public utility commission (PUC) regulation of electric distribution.

A.2.1 Roles of Industry and Government in Managing Reliability

Commenters expressed strong support for continuing to rely on self-regulation rather than government regulation to manage the reliability of the bulk-power system. However, many of these commenters also acknowledged the limitations of the current voluntary form of reliability management and the need for federal oversight to support mandatory reliability standards. Several commenters explicitly supported the proposal to transform the North American Electric Reliability Council (NERC) into the North American Electric Reliability Organization. In a discussion of the features that mandatory reliability rules should have, one commenter emphasized an open standard-setting process.

A.2.2 Incentives for Investing in Transmission System Reliability

Several commenters pointed out that investments in transmission capacity have not kept up with investments in generation capacity. As a result, parts of the United States may experience delivery problems. These problems increase the risk to system reliability.

Thus, a bigger investment in transmission capacity to support increased trade would also tend to increase system reliability.

These commenters suggested that to a degree, the low levels of investment in transmission capacity now simply reflect the uncertainties currently facing investors. They indicated that hastening or smoothing the transition to competitive markets would largely address this issue. Some commenters mentioned that current earning opportunities are insufficient to support needed investments in transmission capacity. No suggestions for specific federal actions to address this issue were mentioned, beyond those already identified in Section A.1 on the transition to competitive energy service markets.

A.2.3 Regional Coordination in Siting Generation and Transmission Facilities

Somewhat in parallel with comments on financial incentives for investing in transmission capacity, the POST also received many comments on the current difficulties associated with siting generation and transmission facilities. These comments described the many federal, state, and local decision-making bodies that affect siting decisions and the difficulties in working effectively with them. The basic challenge seems to be to ensure that the benefits from regional or more global solutions are shared adequately with individual, more narrowly defined, parochial interests.

Many commenters concurred that improved regional coordination on siting issues is a high priority. Several recommended model state and local siting processes to be considered by other jurisdictions. All acknowledged the difficulties in trying to apply these models in regional or multistate settings.

Recommendations for appropriate federal actions to address siting fell into three areas. First, federal agencies themselves should better coordinate their activities. The U.S. Department of Energy and U.S. Environmental Protection Agency were explicitly mentioned in this context. Second, federal leadership in forming and supporting regional decision-making bodies would be helpful. (Some commenters were pessimistic, believing that such federal efforts would not be successful.) Third, federal support should be provided to develop probabilistic planning tools that could support regional planning activities.

A.2.4 State Public Utility Commission Regulation of Electric Distribution

The POST received many comments about regulatory policies that affect the reliability of electric distribution. The comments uniformly pointed out the primacy of state PUCs in overseeing and regulating the local distribution of electricity. Several observers, while acknowledging the POST review of distribution system outages in the summer of 1999, mentioned that state PUCs were conducting significant investigations of these outages and other ones not considered by the POST.

Commenters advocated that the federal government not attempt to second guess these efforts or seek a greater role in overseeing electric distribution system reliability. A few commenters requested national reliability standards for distribution, but many more strongly urged the federal government to not propose a single, uniform set of national standards. (Additional, more detailed recommendations on appropriate federal actions to support state-led standard-setting for distribution system reliability are discussed in Section A.5 on reliability metrics, planning, and tracking.)

Several commenters recommended appropriate federal actions to ensure the reliability of the electric distribution system, including the collection and dissemination of data on industry best practices. Commenters explicitly mentioned that federal support be given to national organizations that would represent state interests, such as the National Association of Regulatory Utility Commissioners (NARUC), with regard to electric distribution system reliability issues. Support to encourage information sharing among states through organizations such as these was recognized as an important and valuable federal role. Specific forms of information exchange could include the sharing of successful regulatory policies and practices (such as performance-based rate making and direct compensation to customers for outages) from states and other parts of the world. Federal support for efforts and information that would help remove regulatory and technical barriers to distributed generation and increase the role of demand-side participation were already mentioned in Section A.1.2 of this appendix.

A.3 Information Resources

The POST received many comments related to federal actions that could be taken to address the accuracy and exchange of information. The comments focussed on the following types of information: (1) planning and load forecasting criteria, (2) generating unit capabilities, (3) T&D equipment availability and performance, and (4) cable testing techniques. Other forms of information, including information to support market and real-time operations, public notification during system emergencies, and information on reliability metrics and “best practices,” are discussed in other parts of this summary.

A.3.1 Planning and Load Forecasting Criteria

The POST found that inaccurate load forecasts contributed to some of the events reviewed in the Interim Report. Comments related to this issue covered both the actual assumptions on which forecasts are based and the methods used to develop the forecasts from these assumptions.

Several commenters observed that many of the events that occurred in the summer of 1999 happened during record-breaking heat waves that had not been anticipated. Planning that was adequate for normal summer conditions was not adequate for such unusually hot weather. One commenter described how forecasts could be based on recent weather trends instead of long-term averages in an effort to improve accuracy.

Another commenter addressed a more global issue: What assumptions about weather severity should be used for reliability planning? This question was seconded by others,

who observed that increasing electric system reliability entails more costs, and these costs should be considered when the appropriateness of any planning criterion is being determined. The cost of reliability and society's willingness to pay for reliability constitute a theme that surfaced throughout these discussions.

Other commenters pointed out the need for better load forecasting techniques. One commenter expressed a specific interest in federal R&D to improve forecasting techniques for smaller geographic areas. Another mentioned the need to factor uncertainties explicitly into planning processes.

A.3.2 Generating Unit Capabilities

The POST found that difficulties experienced by both PJM and Entergy were exacerbated by inaccurate information about generating unit capabilities. In post-event studies, when more accurate data about these capabilities were used, the conditions that were experienced could be reproduced. Earlier studies based on inaccurate information had failed to predict these conditions. Commenters noted the need for (1) standardized definitions of generator performance characteristics and (2) periodic verifications of generator capabilities. However, the commenters also suggested that market prices should be counted on to provide adequate incentives to generators to maintain performance at levels they determine to be economic.

A.3.3 Transmission and Distribution Equipment Availability and Performance

Several commenters referred to information on the availability and performance of T&D equipment. Some people expressed concerns that industry-organized forums for information exchange were inadequate. Even though competition among distribution and transmission system owners is essentially nonexistent (when compared with competition among generation system owners), this concern was strong, especially among firms that have not divested their generation assets.

Several commenters suggested that there is a need for forums in which information on T&D equipment performance could be shared. Others mentioned that this type of information is not widely available except from vendors, whose business interests could undermine confidence in the accuracy of the information.

Commenters suggested that a valuable role for the federal government would be to support forums that promote the sharing of information on equipment availability and performance. Web-based information exchange vehicles were mentioned. One commenter mentioned that after Hurricane Hugo, common pieces of distribution equipment were labeled with unique identifiers to facilitate inter-firm exchanges.

Most commenters emphasized that the federal government needs to work with industry to develop appropriate information exchange forums. Others specifically cautioned the federal government against pre-empting private parties that might be able to manage information exchanges without requiring taxpayer dollars. The issue of

information exchange is discussed further in Section A.5 on reliability metrics, planning, and tracking.

A.3.4 Cable Testing Techniques

Several commenters discussed the sharing of information on cable testing procedures. One commenter identified an existing industry forum for exchanging information on cable testing techniques and practices. Another indicated that the high potential testing method used in New York had been determined to be worthwhile, and that this determination had accounted for the fact that the testing itself might have caused damage. Several commenters mentioned that federal R&D might be appropriate in this area.

A.4 Operations Management and Emergency Response

The POST received many comments on operations management and emergency procedures. They are grouped under the following headings: (1) emergency planning and operations, (2) training and certification, (3) T&D equipment availability, and (4) reliability-enhancing technologies. Some other comments in this area that address load forecasting and demand-side participation have already been discussed. Others that address best practices are discussed in Section A.5.2.

A.4.1 Emergency Planning and Operations

Many commenters discussed emergency planning and operations. All of them supported the need for advanced plans to support emergency operations. Several described current approaches for testing and upgrading these plans on a regular basis. The involvement and coordination of all affected parties were noted as a key element of successful plans. Clear, mutually agreed-upon, well-rehearsed protocols for actions, especially for public notification, are also essential. Some commenters noted that although all utilities have some form of emergency plan, some of them lack systematic, on-going processes to review and update their plan.

One commenter described factors that influence the effectiveness of public notification procedures. Location is one factor; better responses were observed in rural areas. An increase in the frequency of public appeals for emergency actions leads to a decrease in the effectiveness of these appeals.

Some people suggested that federal assistance in coordinating emergency planning and operations among nonutility and utility parties would be valuable. One commenter cited the need to give utilities more flexibility in complying with federally mandated environmental restrictions during times of system restoration.

Commenters made special mention of the need for assessment or audit procedures to help ensure that reliability-related planning and operating procedures are adequate. Of course, utilities and system operators routinely make advanced preparations to promote reliable operation. The day-ahead and season-ahead load forecasting and system planning

activities already discussed are examples of such preparations. Moreover, NERC, through regional reliability councils, coordinates and integrates the reporting of these preparations.

However, commenters suggested that even more thorough and standardized assessment procedures might be warranted. Formal reporting may also be required to complement or enhance existing reporting requirements. Federal support for improving and disseminating information on these procedures may be needed. However, any federal support for these activities should be coordinated with the electric industry.

A.4.2 Training and Certification

Commenters frequently mentioned the importance of training and certifying operating personnel throughout the electric generation, transmission, and distribution system. They expressed concern that the aging of the workforce, competition for workers from other industries, and business pressures to reduce operating costs had led to shortages of adequately trained personnel, among other things.

At least one commenter noted that many of the staff members who operate recently sold generating plants are, in fact, the same personnel who had operated these plants when they were part of a full-service utility. Some commenters noted that the market incentives to operate plants reliably should ensure that plant personnel are appropriately trained and certified. Others stated that the independent generators do not have operator-training programs similar to those previously provided by the full-service utilities and that there will soon be a shortage of qualified operators.

Some commenters, while acknowledging that operating transmission systems reliably in a competitive market does create new needs for operator training and certification, nevertheless suggested that adequate incentives for reliable transmission system operation, rather than training and certification per se, ought to be the focus of attention. By implication, these comments could be extended to apply to distribution system operation.

Several commenters observed that mature, industry-developed forums and processes for training and certification already exist. They suggested that an appropriate federal role would be to identify industry best practices for worker training and appropriate staffing levels.

A.4.3 Transmission and Distribution Equipment Availability

In addition to being concerned about how information on T&D equipment availability and performance is exchanged (Section A.3.3), several commenters were concerned about the availability of this equipment. The lead times for obtaining large transformers can be very long, and transporting them often involves logistic hurdles.

One commenter wondered if the federal government should stockpile critical T&D equipment. Although this idea seems appealing, the commenter was concerned about the

commercial implications of such an endeavor and suggested managing such stockpiles may not be appropriate for the federal government.

A.4.4 Reliability-Enhancing Technologies

Several commenters offered suggestions that would support an increased reliance on technologies and further development of reliability-enhancing technologies. One offered a radical vision for a future transmission system, in which the current, highly interconnected power systems of the East and West Coasts would be broken into smaller systems through the use of direct-current transmission and flexible alternating-current transmission system (FACTS) technologies. These technologies would allow systems to remain interconnected to support power flows between regions. However, they would also electrically insulate one system from disturbances and thus localize reliability problems.

As mentioned above, others commented more broadly on the appropriate federal role in this area. They suggested that the federal government should limit its role to supporting the development of incentives that will encourage market participants to make their own investments in reliability-enhancing technologies.

One commenter specifically cautioned the federal government against embracing a single national standard for control area operations, such as data management protocols and advanced applications. This commenter suggested that the federal government should respect the fact that some systems in the United States have already made substantial investments in these technologies. The federal government should articulate clearly the objectives that must be met, then allow the industry to determine the best means for meeting them.

Other commenters did identify specific federal R&D priorities in support of more reliable tools and technologies. Improved load forecasting, probabilistic planning, and cable testing tools and techniques have already been mentioned in other sections of this appendix. There is also a need for federal support of basic R&D to develop and demonstrate (1) technologies that can respond flexibly to load growth (including storage and distributed generation) and (2) modeling tools that can more accurately capture the system reliability impacts of induction motors. Commenters emphasized the need to coordinate federal activities with existing industry-led activities.

A.5 Reliability Metrics, Planning, and Tracking

Comments on the topic of reliability metrics, planning, and tracking are grouped under three broad headings: (1) reliability metrics and benchmarking, (2) best practices, and (3) federal reliability reporting.

A.5.1 Reliability Metrics and Benchmarking

Effective reliability management depends on clear articulation of objectives. Performance can then be measured against these objectives through the use of metrics. A

wide variety of reliability metrics are in use today. Several commenters suggested that additional standardization of some definitions is needed so comparisons can be made. They also suggested that federal support for these efforts would be helpful.

Other commenters cautioned that comparisons of utilities on the basis of reliability metrics alone could be misleading. The conditions associated with various electric systems can be quite different, rendering simple comparisons meaningless. For example, vegetation, population density, and weather severity are important conditions that must be accounted for if comparisons are to be meaningful. One commenter described how a company used company-specific benchmarks (further disaggregated by regions within its service territory) in an effort to control for these differences just for its own use (rather than for comparisons with other utilities).

Many commenters spoke forcefully against establishing a single national standard for reliability. In addition to mentioning physical conditions, they also highlighted the fact that distribution reliability falls under the jurisdiction of state and local authorities and is more appropriately regulated by them.

Other commenters pointed out that service reliability (and quality) standards do not yet exist in all jurisdictions. They thought the federal government could play a valuable role in supporting these jurisdictions in their efforts to establish standards. They mentioned the newly established Reliability Subcommittee in NARUC as one venue through which federal support might be provided.

Several commenters, while supporting the sharing of performance information through the use of standardized reliability metrics, also acknowledged the challenges of using this information. NARUC was again mentioned as an organization through which federal support might be directed.

Finally, some commenters observed that the use of reliability metrics makes sense only for frequent events from which reliable statistical trends can be extracted. Many of the most severe outages and troublesome events occur only rarely. Different analytical techniques, such as root cause analysis, are more appropriate for reviewing these events.

A.5.2 Best Practices

The POST received a variety of comments on the subject of best practices. Some have already been discussed in other sections of this summary. This section extends and integrates these discussions to capture a broader perspective on this issue.

What are best practices? Some commenters suggested that best practices could be expressed directly in metrics (e.g., labor-hours for a given task or minimum staffing requirements for certain functions). Other commenters warned that using metrics to express best practices could make the definitions obsolete as technologies and procedures improve. Metrics must be reviewed and revised regularly to capture improvements. Other comments suggested that it is more important to articulate clearly the performance

objectives being sought without referring to the specific steps to be taken to achieve them.

Many commenters spoke of the need to ensure that effective mechanisms for sharing information on best practices are available. Several of them mentioned existing industry-led organizations, such as Edison Electric Institute and NERC, as candidates for coordinating information flow. The development of federal actions for sharing information on best practices should be coordinated with these and other existing forums.

Concerns about the commercial value of information on best practices were expressed. Although these concerns might be significant with regard to generating units, they should be smaller with regard to T&D planning and operations. In fact, as mentioned in Section A.3.3 on information resources for T&D equipment performance, the absence of reliable and easily accessed information on best practices in some areas hinders wider adoption of these practices.

Commenters strongly supported the notion that the implementation of best practices should be seen as an outcome of issues discussed under Section A.2 on regulation for reliable transmission and distribution. They suggested that an appropriate federal role would be to support the collection and dissemination of data on best practices, especially in the area of T&D reliability.

A.5.3 Federal Reliability Reporting

Several commenters addressed current federal requirements for reporting reliability events. One commenter suggested that low compliance with federal requirements was the result of (1) perceptions that the thresholds for reporting were arbitrary, (2) the lack of meaningful sanctions (or the lack of enforcement of sanctions) for failures to report, and (3) perceptions that federal reporting requirements are less important than the reporting requirements of local regulatory bodies and regional reliability councils. Commenters suggested that the federal government revisit current reporting requirements to ensure that they are appropriate for federal uses of the data.

Appendix B

Glossary

This glossary provides definitions of some of the terms listed in the Notation list as well as many others used throughout the report and some others that are related to the field but not expressly mentioned. In the text of this report, terms that are defined in the glossary appear in italics the first time they are used.

Adequacy — Ability of the electric system to supply the aggregate electrical demand and energy requirements of customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements.

Ancillary Services — A number of functions, such as reserves and reactive power, that are necessary to support operations of the transmission system.

Apparent Power — Product of the volts and amperes. It comprises both *real* and *reactive* power, usually expressed in kilovolt-amperes (kVA) or megavolt-amperes (MVA).

Availability — Measure of time that a generating unit, transmission line, or other facility is capable of providing service, whether or not it actually is in service. Typically, this measure is expressed as a percent available for the period under consideration.

Bulk-power System — The portion of an electric power system that encompasses the generation resources, system control, and high-voltage transmission system.

Capability — see Installed Capability and Operable Capability.

Capacity — The rated continuous load-carrying ability, expressed in megawatts (MW), megavolt-amperes (MVA), or megavolt-amperes-reactive (MVAR) of generation, transmission, or other electrical equipment.

Cascading — Uncontrolled successive loss of system elements triggered by an incident at any location. Cascading results in widespread service interruption, which cannot be restrained from sequentially spreading beyond an area predetermined by appropriate studies.

Clearing Price — see Energy Clearing Price.

Contingency — Unexpected failure or outage of a system component, such as a generator, transmission line, circuit breaker, switch, or other electrical element. A contingency also may include multiple components, which are related by situations leading to simultaneous component outages.

Control Area — Electric system or systems, bounded by interconnection metering and telemetry, capable of controlling generation to maintain its interchange schedule with other control areas and contributing to frequency regulation of the interconnection.

Curtailement — Reduction in the scheduled capacity or energy delivery.

Demand-Side Management — Programs that affect customer use of electricity, both the timing (sometimes referred to as load management) and the amount (sometimes referred to as energy efficiency).

Dispatch — Operating control of an integrated electric system involving operations such as assignment of levels of output to specific generating stations and other sources of supply; control of transmission lines, substations, and equipment; operation of principal interties and switching; and scheduling of energy transactions.

Distribution Network — A network of electrical lines from a substation (which is the terminus of the transmission network) to a series of transformers (and eventually to the ultimate customer).

Distribution System — Portion of an electric system that “transports” electricity from the bulk-power system to retail customers, consisting primarily of low-voltage lines and transformers.

Disturbance — Unplanned event that produces an abnormal system condition.

Electrical Energy — The generation or use of electric power by a device over a period of time, expressed in kilowatt-hour (kWh), megawatt-hour (MWh), or gigawatt-hour (GWh).

Electric System or Electric Power System — An interconnected combination of generation, transmission, and distribution components that make up an electric utility, an electric utility and one or more independent power producers (IPPs), or group of utilities and one or more IPPs.

Electric Utility — Corporation, person, agency, authority, or other legal entity or instrumentality that owns or operates facilities for the generation, transmission, distribution, or sale of electric energy primarily for use by the public and is defined as a utility under the statutes and rules by which it is regulated. An electric utility can be investor-owned, cooperatively owned, or government-owned (owned by a federal agency, crown corporation, state, provincial government, municipal government, and public power district).

Emergency — Any abnormal system condition that requires automatic or immediate manual action to prevent or limit loss of transmission facilities or generation supply that could adversely affect the reliability of the electric system.

Energy Clearing Price — The price at which the market is able to match the last unit of energy a specific seller is willing to sell with the last unit of energy a specific purchaser is willing to buy.

Federal Energy Regulatory Commission (FERC) — Independent federal agency within the U.S. Department of Energy that, among other responsibilities, regulates the transmission and wholesale sales of electricity in interstate commerce.

Firm Power or Purchase — Power or power-producing capacity intended to be available at all times during the period covered by a guaranteed commitment to deliver, even under adverse conditions.

Forced Outage — Removal from service availability of a generating unit, transmission line, or other facility for emergency reasons or a condition in which the equipment is unavailable because of unanticipated failure.

Frequency — Rate, in cycles per second (or Hertz, Hz), at which voltage and current oscillate in electric power systems. The reference frequency in North American Interconnections is 60 Hz.

Generation Reserves — see Reserve.

Generating Unit — An electric generator together with its prime mover (e.g., steam from boiler).

Grid — System of interconnected power lines and generators that is managed so that the generators are dispatched as needed to meet the requirements of the customers connected to the grid at various points. Gridco is sometimes used to identify an independent company responsible for the operation of the grid.

Independent System Operator (ISO) — A neutral operator responsible for maintaining the generation-load balance of the system in real time. The ISO performs its function by monitoring and controlling the transmission system and some generating units to ensure that generation matches loads.

Installed Capability — Seasonal (i.e., winter and summer) maximum load-carrying ability of a generating unit, excluding capacity required for station use.

Interconnection — When capitalized, any one of the major electric system networks in North America. When not capitalized, the facilities that connect two systems or control areas. In addition, an interconnection refers to the facilities that connect a nonutility generator to a control area or system.

Interruptible Rate — Electricity rate that, in accordance with contractual arrangements, allows interruption of consumer load by direct control of the utility system operator or by action of the consumer at the direct request of the system operator. It usually involves commercial and industrial consumers. In some instances, the load reduction may be

affected by direct action of the system operator (remote tripping) after notice to the consumer in accordance with contractual provisions.

Load — A consumer of electric energy; also the amount of power (sometimes called demand) consumed by a utility system, individual customer, or electrical device.

Load Pocket — Geographical area in which electricity demand sometimes exceeds local generation capability and in which there is an electricity import limitation as a result of transmission constraints.

Load Shedding — The process of deliberately removing (either manually or automatically) preselected customer demand from a power system in response to an abnormal condition in order to maintain the integrity of the system and minimize overall customer outages.

Market Clearing Price of Electricity — see Energy Clearing Price.

Marketers — Commercial entities that buy and sell electricity.

Must-Run Resources — Generation designated to operate at a specific level and not available for dispatch.

Network Distribution — Method of distributing electric power to a densely populated area, where a network or grid of low-voltage conductors covers an area of several city blocks to a few square miles. The grid is solidly connected and is fed from multiple distribution feeders.

Nonfirm Capacity, Power, or Purchase — Power or power-producing capacity supplied or available under a commitment having limited or no assured availability.

Nonspinning Reserve — Generation capacity that is not being utilized but that can be activated and used to provide assistance with little notification.

North American Electric Reliability Council (NERC) — A not-for-profit company formed by the electric utility industry in 1968 to promote the reliability of the electricity supply in North America. NERC consists of 10 Regional Reliability Councils and one Affiliate whose members account for virtually all the electricity supplied in the United States, Canada, and a portion of Baja California Norte, Mexico. The members of these Councils are from all segments of the electricity supply industry — investor-owned, federal, rural electric cooperative, state/municipal, and provincial utilities, independent power producers, and power marketers. The 10 NERC Regional Reliability Councils are East Central Area Reliability Coordination Agreement, Electric Reliability Council of Texas, Florida Reliability Coordinating Council, Mid-Atlantic Area Council, Mid-America Interconnected Network, Mid-Continent Area Power Pool, Northeast Power Coordinating Council, Southeastern Electric Reliability Council, Southwest Power Pool, and Western Systems Coordinating Council. The Affiliate is the Alaskan Systems Coordination Council.

Open-Access Same-Time Information System (OASIS) — An electronic posting system for transmission access data that allows all transmission customers to view the data simultaneously.

Operable Capability — The portion of installed capability of a generating unit that is in operation or available to operate in the hour.

Operating Reserve — That capability above firm system demand required to provide for regulation, load forecasting error, equipment forced and scheduled outages, and local area protection. It includes both spinning and nonspinning reserve.

Peak Demand or Load — The greatest demand that occurs during a specified period of time.

Power Pool — Entity established to coordinate short-term operations to maintain system stability and achieve least-cost dispatch. The dispatch provides backup supplies, short-term excess sales, reactive power support, and spinning reserve. Historically, some of these services were provided on an unpriced basis as part of the power pool members' utility franchise obligations. Coordinating short-term operations includes the aggregation and firming of power from various generators, arranging exchanges between generators, and establishing (or enforcing) the rules of conduct for wholesale transactions. The pool may own, manage, and/or operate the transmission lines (i.e., wires) or be an independent entity that manages the transactions between entities. Often, the power pool is not meant to provide transmission access and pricing or to provide settlement mechanisms if differences between contracted volumes among buyers and sellers exist.

Reactive Power — Portion of electricity that establishes and sustains the electric and magnetic fields of alternating-current equipment. Reactive power must be supplied to most types of magnetic equipment, such as motors and transformers. It also must supply the reactive losses on transmission facilities. Reactive power is provided by generators, synchronous condensers, or electrostatic equipment such as capacitors and directly influences electric system voltage. It is usually expressed in kilovars (kVAR) or megavars (MVAR).

Real Power — Rate of producing, transferring, or using electrical energy, usually expressed in kilowatts (kW) or megawatts (MW).

Reliability — Degree of performance of the elements of the bulk-power system that results in electricity being delivered to customers within accepted standards and in the amount desired. Reliability may be measured by the frequency, duration, and magnitude of adverse effects on the electric supply. Electric system reliability can be addressed by considering two basic and functional aspects of the electric system — adequacy and security.

Reserve — Electric power generating capacity in excess of the system load projected for a given time period. It consists of two sources: spinning reserve and supplemental reserve.

Retail Sales — With regard to the electric industry, electrical energy supplied for residential, commercial, and industrial end-use purposes. Other small end-use classes, such as agriculture and street lighting, also are included.

Schedule — Agreed-upon transaction size (megawatts), start and end time, beginning and ending ramp times and rate, and type required for delivery and receipt of power and energy between the contracting parties and the control area(s) involved in the transaction.

Security — Ability of the electric system to withstand sudden disturbances, such as electric short circuits or unanticipated loss of system elements.

Security Coordinator — One of 23 entities established by NERC with the responsibility and authority to direct actions aimed at maintaining real-time security for a control area, group of control areas, NERC subregion, or NERC region.

Short-Notice or Short-Term Transaction — Transaction for the transfer of net energy from one region to another, made with little time between the transaction and the transfer (typically, less than one hour).

Spinning Reserve — Ancillary service that provides additional capacity from electricity generators that are on line, loaded to less than their maximum output, and available to serve customer demand immediately should a contingency occur.

Stability — Ability of an electric system to maintain a state of equilibrium during normal and abnormal system conditions or disturbances.

Supplemental Reserve — Ancillary service that provides additional capacity from electricity generators that can be used to respond to a contingency within a short period, usually 10 minutes.

System — see Electric System.

System Operator — Individual at an electric system control center whose responsibility it is to monitor and control that electric system in real time.

Tariff — Schedule detailing the terms, conditions, and rate information applicable to various types of electric service.

Topology — Structure and layout of a system.

Transmission — Interconnected group of lines and associated equipment for the movement or transfer of electric energy between points of supply and points at which it is transformed for delivery to customers or is delivered to other electric systems.

Unit — see Generating Unit.

Unit Commitment — Process of determining which generators should be operated each day to meet the daily demand of the system.

Utility — see Electric Utility.

Volt-Ampere-Reactive (VAR) — Unit of measure of the power that maintains the constantly varying electric and magnetic fields associated with alternating-current circuits. See Reactive Power.

Voltage — The unit of measure of electric potential.

Voltage Collapse — An event that occurs when an electric system does not have adequate reactive support to maintain voltage stability. Voltage collapse may result in outage of system elements and may include interruption in service to customers.

Wholesale Electricity Market — Purchase and sale of power, according to agreements with varying lengths and lead times, among power marketers, power producers, and other wholesale entities.