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FEDERAL ENERGY REGULATORY COMMISSION

Reliability Technical Conference **Docket No. AD17-8-000**

TESTIMONY OF THE FOUNDATION FOR RESILIENT SOCIETIES

At the June 22, 2017 Reliability Technical Conference
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My name is Thomas Popik and I am chairman and president of the Foundation for Resilient Societies, a non-profit group dedicated to the protection of critical infrastructure, including the North American electric grid. We appreciate this opportunity today to provide testimony on long-term and large-scale disruptions to the bulk power system.

What is a long-term and large-scale disruption to the bulk power system? It is a blackout that:

1. Persists longer than the supplies of backup energy necessary for grid restoration.
2. Covers a geographic area so large that significant outside assistance is impractical.

If a region of the United States were to experience a long-term and large-scale disruption of the bulk power system, other dependent critical infrastructures would likewise be disrupted. Human casualties could be very high, both in percentage terms and in absolute numbers. Recovery could take months or years. Over a large area, deaths could be in the millions.

The United States has never had a long-term and large-scale blackout. In fact, our major blackouts have been approximately 24 hours or less or, alternatively, were mitigated by outside assistance to both electric utilities and humans. The August 2003 Northeast Blackout was certainly large-scale, affecting 55 million people, but most customers were restored within 24 hours, so it was not "long-term." Hurricane Katrina and Hurricane Sandy did not cause long-term and large-scale blackouts under this definition, because significant outside assistance was provided by government agencies and utility mutual assistance groups. The September 2016 Puerto Rico blackout persisted three days, but satellite images show much of the capital city of San Juan and at least some of the rural areas had power within 24 hours.

Long-Term, Large-Scale Blackout Scenario

All of us in this room would be in danger if a long-term, large-scale blackout were to hit the Northeast megalopolis from Boston to Northern Virginia. Suppose that such a cascading outage occurred at 4:00 pm today, right before the evening commute. Cars and trucks running out of fuel would soon block roads. Evacuation of dense urban areas would become impossible. Stocks of petroleum-based fuel would likely run out in hours or days, even for utilities that have emergency resupply agreements with distributors. Essential government services would cease.

Time Points for Long-Term, Large-Scale Blackout of Northeast Megalopolis

- At 4:00pm, the PJM, New York ISO and ISO New England grid operators experience a cascading collapse. Fifty million people between Boston and Northern Virginia lose power.
- By 4:02pm, two minutes after the cascade, every nuclear power plant in the affected area will have tripped or "scrammed," switching to emergency diesel generators. Because U.S. Nuclear Regulatory Commission (NRC) regulations require a stable grid for the operation of nuclear power plants, their contribution to load will be lost for the duration of the outage.
- By midnight, transmission operators will likely lose centralized SCADA control for the approximately one-half of substations that have eight hours or less of backup power.
- Also by midnight, commercial telecommunications will be disrupted because the common guideline for backup power at remote terminals and cell towers is eight hours. Consistent with this commercial practice, eight hours is also the requirement in PJM Manual 36 for "Emergency Power for Non-Utility Owned Communication Systems."
- By 8:00am the next morning, oil, propane, and LNG-fired blackstart generators in the PJM territory may have depleted their 16 run hours of fuel specified by the PJM OATT tariff.
- Also by 8:00am the next morning, transmission operators will likely lose centralized SCADA control for the approximately 40% of substations with 8 to 16 hours of backup power. Without power and communications for substation control by SCADA, technicians with cell or satellite phones must be dispatched to substations to manually operate circuit breakers.
- By 4:00pm on Day 2, much of commercial telecommunications, including cell phones, will be down because the common practice for the duration of emergency fuel supplies at Central Offices is 24 hours. (Some Central Offices may have up to 72 hours of fuel supply.)
- By the end of Day 5, initial fuel supplies for backup power at PJM control rooms will be depleted, according to PJM Manual 01, "Control Center and Data Exchange Requirements."
- By the end of Day 7, the NRC-mandated diesel fuel supply for backup generators at most nuclear power plants will be depleted. Assuming no resupply, without power for cooling, reactor cores will start to overheat and spent fuel pools will begin to boil.
- By the end of Day 30, the spent fuel pools at many nuclear plants will have boiled off their water, making the plants too radioactive for humans to approach. Some spent fuels pools will likely have caught fire, releasing plumes of radioactive material over large areas.

We should ask, "When would this large-scale blackout become unrecoverable?" First, let's look at large-scale blackouts that *were* recoverable. Nearly all of the August 2003 Northeast Blackout was restored in 24 hours. The 2008 Florida Blackout was restored in three hours. The 2011 Southwest Blackout was restored in 12 hours. In 2016, much of Puerto Rico was restored within 24 hours. Experience shows large-scale blackouts of 24 hours or less are probably recoverable.

Blackouts lasting longer than five days may not be promptly recoverable, because backup power for blackstart, control rooms, substation SCADA, and communications will run out.

If a blackout hits here at 4pm today, how long would you stay in the building, hoping for power restoration? How long before helicopters would evacuate key officials from Washington DC?

Declining Resilience of the Bulk Power System

In recent years, ill-considered regulatory policies and risky commercial practices have made the bulk power system far less resilient to long-term, large-scale blackouts. Examples include:

- Extensive use of imported just-in-time energy for electricity, both electric energy supplied by long-distance transmission and natural gas from interstate pipelines.
- Fewer generation plants with energy sources stored on-site, including fewer natural gas-fired plants that are "dual fuel" capable.
- Overreliance on systems with single points of failure, such extra high-voltage transmission substations and interstate natural gas pipelines—including an increasing proportion of gas pipelines that rely on grid electricity for their compressors.
- Insufficient local capacity of spinning generation necessary for system stability, especially when grids have large amounts of variable wind and solar power.
- Industrial control systems and communication networks with inadequate backup power.

Imported Just-in-Time Energy for Electricity

When energy for electricity is imported over long distances and used on a "just-in-time" basis, it causes vulnerability to short-term disruptions in supply. Consider our analysis using 2015 data from the U.S. Energy Information Administration (EIA):

Dependence on Imported Just-in-Time Energy for Electricity

Risk Rank	State	Electricity Consumed in 2015 (GW Hour)	Net Electricity Imports (Exports)	Electricity Generation Using Imported Natural Gas	Total Imported Energy for Electricity
1	Washington DC	12,099	100%	0%	100%
2	Rhode Island	8,200	15%	80%	96%
3	Delaware	13,016	40%	51%	91%
4	Massachusetts	59,367	46%	35%	81%
5	Nevada	38,479	(1%)	75%	74%
6	California	289,703	32%	36%	68%
7	Florida	256,344	7%	61%	68%
8	Vermont	5,885	66%	0%	66%
9	New Jersey	81,931	9%	45%	54%
10	Maryland	66,596	45%	7%	52%
11	Virginia	122,050	31%	20%	51%
12	New York	160,285	14%	35%	49%

Looking at the above table, it is easy to see that some regions are extremely dependent on imported just-in-time energy for electricity—particularly states within Northeast megalopolis from Boston to Northern Virginia. Also at risk are the individual states of Florida and California. Of the states with a high reliance on imported just-in-time energy, we have empirical evidence that New York, Florida, and California are at particularly high risk, because they already have had major cascading outages in 2003, 2008, and 2011 respectively.

Fewer Generation Plants with Energy Sources Stored On-Site

In the past two decades, the number of generation plants with energy sources stored on-site has diminished significantly, causing less resilience to short-term fuel supply disruptions. Much of this shift has been caused by increasing use of cheap natural gas as a generator fuel.

Price-based competition among generators has also accelerated the shift to less resilient generation technologies. In 1996, FERC Order 888 gave states the option of establishing competitive wholesale electricity markets. A key feature of the market system under FERC Order 888 is neutrality among generation technologies. Generators resilient to fuel supply interruption compete with less reliable generators having lower costs or more government subsidies. Resilient technologies include plants that have large quantities of fuel on-site (nuclear, coal-fired, and hydroelectric) or are “dual-fuel” capable (natural gas or fuel oil-fired). Another feasible but rarely-used technology is co-location of electric generation plants with Liquid Natural Gas (LNG) regasification plants. But such fuel resilience raises generator costs.

To quantify use of energy sources stored on-site, we obtained data collected by the U.S. Energy Information Administration (EIA) on Form EIA-860, including data on primary, secondary, and tertiary energy sources. We generally defined generation plants with “energy stored on-site” as hydroelectric, nuclear, geothermal, coal-fired, petroleum-fired, and gas-fired with a backup fuel source such as fuel oil. (We do not include wind and solar generators in the category of “energy stored on-site,” because the wind does not always blow nor does the sun always shine.)

We compared nameplate generation capacity in 1996, the year FERC Order 888 was issued, to the most recent EIA data available, 2015. We also compared generation capacity in the “Traditionally Regulated States” (states in the Southeast, Southwest and Northwest, except for California) to the “Organized Markets” (Eastern and Midwest markets having Regional Transmission Organizations and also California ISO and the ERCOT market in Texas).

The EIA data tells us that in 1996—before establishment of organized electricity markets and before cheap natural gas from fracking—U.S. generation capacity was resilient to short-term fuel supply disruptions. Unfortunately, this resiliency has significantly declined in recent years:

- In 1996, 97% of U.S. generation capacity had its energy stored on-site, but by 2015 only 64% of capacity had its energy stored on-site.
- Only 27% of U.S. generation capacity added in 1997 and later has its energy stored on-site.
- Only 27% of U.S. gas-fired generation capacity added in 1997 and later is “dual-fuel.”

We also used EIA data to compare generation capacity in Traditionally Regulated States to capacity in Organized Markets:

- In 1996, 98% of generation capacity in Traditionally Regulated States had its energy stored on-site while 97% of generation capacity in Organized Markets had its energy stored on-site.
- By 2015, 73% of generation capacity in Traditionally Regulated States had its energy stored on-site while 60% of generation capacity in Organized Markets had its energy stored on-site.
- In Traditionally Regulated States, 40% of generation capacity added in 1997 and later has its energy stored on-site, while in the Organized Markets, only 21% of generation capacity added in 1997 and later has its energy stored on-site.
- In Traditionally Regulated States, 42% of gas-fired generation capacity added in 1997 and later is "dual fuel," while in the Organized Markets, only 20% of new gas-fired generation capacity added in 1997 and later is "dual fuel."

The states of New York and Florida, with major blackouts in 2003 and 2008, respectively, appear to have incented their generation plants to maintain resiliency of energy sources:

- For New York in 1996, 99% of generation capacity had its energy stored on-site; by 2015, this proportion had declined only moderately to 81% of generation capacity having energy stored on-site.
- For Florida in 1996, 97% of generation capacity had its energy stored on-site; by 2015, this proportion had declined to 84% of generation capacity having energy stored on-site.

The states of California and Texas, having had major blackouts in 2011, nonetheless have dramatic declines in the proportion of generation capacity with energy stored on-site:

- For California in 1996, 97% of generation capacity had its energy stored on-site; by 2015, this proportion had significantly declined to 29%. Only 7% of new gas-fired generation added in 1997 and later is "dual fuel."
- For Texas in 1996, 88% of generation capacity had its energy stored on-site; by 2015, this proportion had significantly declined to 33%. Only 4% of new gas-fired generation added in 1997 and later is "dual fuel."

Fuel supply interruptions are not just a theoretical vulnerability. According to the 2017 "State of Reliability" report by the North American Electric Reliability Corporation (NERC), "lack of fuel" was the No. 2 cause of forced generator outages in 2014; in 2015 it was the No. 4 cause.

Overreliance on Systems with Single Points of Failure

Long-distance energy transmission systems can have single points of failure—these include both extra high-voltage transmission substations and interstate natural gas pipelines. Overreliance on systems with single points of failure makes using large quantities of imported "just-in-time" energy a risky everyday practice—and also increases vulnerability to physical attack, cyberattack, solar storms, and electromagnetic pulse.

In 2013, a FERC study reportedly determined that the bulk power system would collapse with loss of only nine high-voltage transmission substations in the continental United States. Interstate natural gas pipelines can also be single points of failure when multiple large capacity generation plants are supplied by a single pipeline. For example, there are single gas pipelines in the U.S. that supply fuel for 5 GW or more of generation capacity. Loss of a single pipeline can cause loss of generation exceeding "N-1" contingency limits within control areas.

Insufficient Local Reserves of Essential Reliability Services

Increasing use of imported electricity, wind generation, and solar photovoltaic power (PV) is causing shortages of local frequency response, mechanical inertia, and reactive power—so-called "essential reliability services" that were once provided by hydroelectric power plants and thermal generators. Reactive power necessary for voltage support cannot be effectively imported over long distance transmission lines. Wind turbines and solar PV are non-dispatchable and therefore unreliable for blackout restoration.

According to California ISO, solar power can supply approximately 8 GW out of 20 GW total system load on a "typical spring day." According to ERCOT, wind generation accounted for almost 40% of system load on March 31, 2017. According to NERC, nearly 1,200 MW of solar PV generation was lost in Southern California on August 16, 2016, due to inverters tripping during transmission line faults. According to California ISO, an estimated 5,600 MW of solar PV generation capacity will be lost on August 21, 2017 when a midday solar eclipse hits. These increasingly frequent events stress local reserves of essential reliability services.

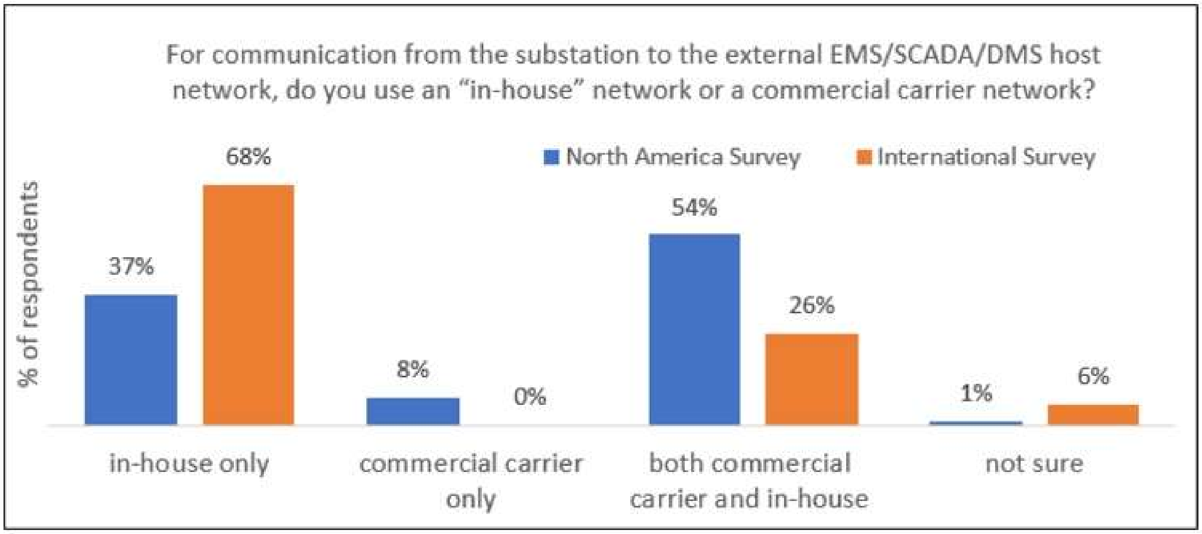
Industrial Control Systems and Communication Networks with Limited Backup Power

Electric utilities have become reliant on Supervisory Control and Data Acquisition (SCADA) and other industrial control systems. Long-distance communications are essential for operation of these wide-area control networks. The duration of backup power is typically 8 to 24 hours.

Normal bulk power system operation requires communications between Energy Management Systems (EMS) in control rooms and substation SCADA, between reliability coordinators and transmission operators, and between transmission operators and generation plants (for automatic generation control). Because some generation is centrally dispatched by large, multi-state electric utilities, there are also communication links between control rooms of these generator operators and their individual generation plants. During a long-term, large-scale blackout, many of these communication pathways will be disrupted. Backup communications, such as cell and satellite phones, require time-consuming manual operations.

An increasing trend is use of cellular networks for SCADA communication to substations. In the United States, the cellular network is dependent on the GPS satellite network for system timing. Moreover, experience has shown that cellular networks can become quickly overloaded during disasters. Highly-loaded cellphone networks consume backup power more rapidly.

A recent survey by Newton Evans Research Company, a market research firm specializing in the electric utility industry, shows that 54% of North American electric utilities use commercial carriers for some of their SCADA communications, while 8% use only commercial carriers:



Source: Newton Evans Research Company, "The World Market Study of SCADA, Energy Management Systems, Distribution Management Systems and Outage Management Systems in Electric Utilities: 2017-2019"

Both commercial carrier and in-house communication networks rely on grid electricity with backup power systems of limited duration. Under common practices, backup power durations for commercial carriers range from eight hours for remote terminals to 24-72 hours for Central Offices. Resupply of fuel for backup generators is often erroneously assumed to be reliable. While public data is not available for backup power durations for utility in-house communications, these durations are likely in the same range as commercial carriers.

Special Reliability Risks for California

The state of California is a poster child for ill-considered regulatory policies that could cause long-term, large scale blackouts. Examples include:

- High dependence on imported electric power—in 2015, 32% of electric energy consumed in California was imported.
- High dependence on imported natural gas for electricity generation—in 2015, 36% of electric energy consumed in California was generated using imported natural gas.
- Overreliance on generation plants that have no energy stored on-site—by 2015, only 29% of generation plants in California had their energy stored on-site, the lowest proportion of any state except Nevada at 24%. Only 6% of new generation plants added in 1997 and later have their energy stored on-site.
- Lack of spinning generation in California that is causing insufficient capacity for ancillary services: regulation up, regulation down, spinning reserves, and non-spinning reserves. For example, in 2015, CAISO experienced 15 intervals of insufficient supply to meet reserve requirements for ancillary services; in 2016, this grew to 26 intervals.

Moreover, the winter natural gas consumption in the LA Basin is greater than the pipeline capacity, as clearly explained in the excellent Exelon article, "Aliso Canyon's Impact on Electric Reliability in Southern California." Simple math shows that local storage capacity is needed and the capacity of storage fields other than Aliso Canyon is insufficient. Still, NIMBYs and politicians want the Aliso Canyon facility permanently closed. FERC has done what it could to alleviate this situation through tariffs and market measures (even for this non-regulated facility), but these are meager substitutes for on-site physical storage and redundant pipeline capacity.

It is probably no coincidence that California has already had a cascading outage for 898,000 customers in September 2005 and another outage for 1.5 million customers in September 2011. If a long-term blackout were to hit Southern California, loss of life could be extreme, because this arid area is dependent on supplies of water from the Sierra Nevada Mountains and Colorado River—water that is pumped using electricity from the bulk power system.

Failure of Electricity Markets to Ensure Resilient Capacity

We have good empirical evidence that competitive electricity markets, as currently designed in the United States, are failing to ensure resilient capacity. This evidence includes accelerating penetration of gas-fired generation in most areas, combined with rapid reduction of dual-fuel capability after issuance of FERC Order 888 in 1996. Significantly, the reduction in dual-fuel capability has been more rapid in Organized Markets than in Traditionally Regulated States.

For both high-level government policymakers and common citizens, it might come as a surprise that a fundamental design feature of competitive electricity markets is the possibility of lost load, i.e., blackouts. Only with this design feature can generators fully recover their fixed costs with high prices during times of electricity scarcity. Of course, electricity market regulators recognize that both high prices and expected loss of load are politically untenable, so price caps and large reserve capacity margins are regularly imposed. The result is so-called "missing money" (missing contribution to fixed costs) for electricity generators.

Separate markets to remunerate generation for reserve capacity are the common remedy for "missing money." Unfortunately, capacity markets inadequately distinguish between resilient capacity (with energy stored on-site) and non-resilient capacity (such as imported electricity and gas-fired generation that is not dual-fuel). Penalties for generator non-performance during times of electricity scarcity are insufficient motivation for resilient capacity, because prospective penalties are often a fraction of overall payments to generators—and always tiny amounts compared to societal losses during a blackout—i.e., lost GDP and human casualties.

For generator operators, the rational economic calculation can be to collect payments for "reliable capacity" and to simply pay penalties for the rare occasions where capacity cannot be delivered as promised. In fact, for gas-fired plants that must compete in daily energy markets, it is almost always cost-prohibitive to pay pipeline operators for firm gas supplies. Nor do the operators of both real-time energy and forward capacity markets always require gas-fired plants to have firm gas supplies in order to bid in the markets. The result of these deliberate market designs is less generation capacity that is resilient to short-term disruptions in supply—such as nuclear, coal-fired, hydroelectric, petroleum-fired, and gas-fired dual-fuel—and more capacity that causes risk of long-term, large-scale blackouts—such as electricity imported on long transmission lines and also gas-fired generation entirely dependent on the unreliable flow of gas from pipelines with single points of failure.

Major blackouts for California and Texas in 2011 are warning signs of market failures—both of these blackouts were indirectly caused by insufficient local generation reserves. For California's 2011 blackout, the initiating event was loss of a transmission line carrying imported power.

Inadequate Electric Reliability Standards

Inadequate electric reliability standards increase the probability of initiating events that could cause long-term, large scale blackouts. Examples of persistent deficiencies include:

- No physical security standards for generation plants and also no physical security standards for control rooms of reliability coordinators.
- No standards for cybersecurity of communication systems outside of Electronic Security Perimeters at substations, including both in-house and commercial carrier communications—despite a specific mandate in the Energy Policy Act of 2005.
- No quantified standards for prudent duration of backup power at control rooms, substations, and communication nodes.
- No quantified standards for duration of fuel availability at blackstart generation plants.
- No standards for protection against short rise-time electromagnetic pulse (E1), both from localized devices and high-altitude nuclear detonations.
- The existing NERC standard for protection against solar storms (aka "geomagnetic disturbance") does not require hardware protection for even one high-voltage transformer within the United States, due to arbitrarily low threat benchmarks.

A persistent barrier to passage of strong reliability standards has been inadequate cost recovery opportunities, especially for generator operators in Organized Markets. Potential mechanisms for cost recovery include FERC-approved tariffs, federal tax credits, direct appropriations for infrastructure improvements, and cost sharing appropriations, as with the Smart Grid Investment Grant program of 2010-2015.

Factors Outside the Authority of FERC

Some factors causing vulnerability to long-term, large-scale blackout are outside the direct authority of FERC. Examples include:

- Interstate natural gas pipelines are not federally-regulated for reliability and security. Currently, economic regulation is by FERC and safety regulation is by the U.S. Department of Transportation. A legislative remedy by the U.S. Congress is needed.
- At the federal level, there are no required backup power durations for remote terminals and Central Offices of commercial communications carriers, even when these facilities are critical to electric grid reliability. The Federal Communications Commission (FCC) should initiate a high-priority remedial rulemaking.
- The Nuclear Regulatory Commission does not require backup power past seven days for nuclear power plants. A remedy in rulemaking or legislation should be enacted.

Recommendations for the FERC Commissioners

To reduce the risk of long-term, large-scale blackouts, we have the following recommendations for the FERC commissioners:

- Under FERC-approved tariffs, remuneration for blackstart generators should require prudent supplies of fuel, consistent with realistic grid restoration timeframes.
- Under FERC-approved tariffs, a portion of capacity markets should be reserved for generators with resilient supplies of energy stored on-site, such as "dual-fuel" plants.
- Under FERC-approved tariffs, prudent levels of local capacity for frequency response, mechanical inertia, and reactive power should be set not just for grid stability during day-to-day operations, but also for reliable restoration from blackouts.
- Under FERC-approved tariffs, gas-fired plants should be required to have gas from multiple pipelines, dual-fuel capability, or co-located LNG regasification plants.
- The NERC system of standards should be revised to correct the deficiencies as outlined in the section of this testimony, "Inadequate Electric Reliability Standards."
- FERC commissioners should advocate before the Congress for federal legislation authorizing energy pipeline reliability and security standards.
- FERC commissioners should advocate before the FCC and Congress for prudent and mandatory durations of backup power for communications systems critical to the bulk power system, consistent with realistic blackout restoration timeframes.

Conclusion

While North America has not yet experienced a long-term, large-scale blackout, policymakers and the public are becoming increasingly aware of this threat and its societal consequences.

In FERC Order No. 672 (2006), the Commission considered the potential harm of reliability standards on competition, ruling "In approving a Reliability Standard, we will ensure that it does not have the implicit effect of either favoring or thwarting either bilateral or organized markets." Now an opposing challenge has arisen, the effect of competition on reliability. Through our capacity analysis of the Organized Markets and Traditionally Regulated States, we have developed good evidence that inadequately designed electricity markets are harming reliability. Better market incentives are needed. The Commission should give as much consideration to emerging reliability issues as it did for competition in Order No. 672.

Many of the factors that increase the probability of blackouts are within the FERC's authority. FERC needs to better integrate reliability considerations into tariff approvals for electricity markets. Electric reliability standards should specifically address the threat of long-term and large-scale blackouts. For factors outside the direct authority of FERC, we ask that the FERC commissioners publicly advocate before the U.S. Congress and other agencies for remedies.

Inaction in protecting the bulk power system against long-term and large-scale blackouts could cause environmental catastrophe and millions of deaths. We hope tragedy can be avoided.

Thank you for the opportunity to testify. I look forward to any questions.