Electricity Reliability:

PROBLEMS, PROGRESS AND POLICY SOLUTIONS

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GALVIN ELECTRICITY INITIATIVE

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The Galvin Electricity Initiative was launched by former Motorola CEO Robert W. Galvin to transform our electric power system into one that is reliable, efficient, secure and clean, and meets the needs of 21st century consumers. In 2011, the Initiative continues to spark a migration toward a consumer-driven electric power system that is based on quality leadership. The goal is to promote grid modernization through policy reform and the development of Perfect Power smart microgrids that place top priority on serving consumers and businesses with reliable, high-quality, clean power. For more information about the Galvin Electricity Initiative, visit *www.galvinpower.org*, "like" the Initiative on Facebook (*www.facebook.com/galvinpower*) and follow the Initiative on Twitter at *http://twitter.com/perfectpower*.

Executive Summary

As electricity is entwined with every aspect of day-to-day life, the issue of reliability is paramount. In addition to the inconvenience experienced by consumers during prolonged periods without electricity service, a power outage can literally mean the difference between life and death. From specialized care equipment such as dialysis machines to everyday heating and cooling devices like air conditioners or furnaces, the impact of a power interruption on consumers can be significant. Interruptions can result in fatalities, injuries, days of lost productivity and thousands of dollars in production losses and equipment repairs.

At GridWeek 2010, one utility executive said, "Utilities have a tradition of pursuing perfect employee safety, but we haven't turned that thinking toward the customer experience." When compared to our global competitors — most notably Japan — the U.S. has not kept pace in terms of reliability, and this gap comes at a significant cost. For a comparison of reliability between the U.S. and European countries, see Table 1.[1] Some studies estimate that power interruptions cost the U.S. economy about $150 billion each year, or 4 cents/kWh (see Section 3).

Fortunately, several innovative utilities and municipalities have made dramatic improvements in reliability without raising costs. This was accomplished in part by leveraging advanced quality methods such as Six Sigma and systems thinking. These entities include Naperville, Ill.; Austin Energy; Chattanooga, Public Service New Mexico, and Calgary, as well as campus settings such as the Illinois Institute of Technology and the University of California, Santa Barbara. These success stories reveal the art of the possible and the path to perfection.

It is the goal of the Galvin Electricity Initiative to create a roadmap to more efficient and reliable practices that serve the individual customer and the community as a whole — practices that pay for grid improvements with savings from eliminating waste.

In the search for workable solutions, the Initiative examined practices in the EU and more progressive states in the U.S. and suggests the following policy reform best practices should be adopted to address power safety, reliability and power quality deficiencies while also attracting investment and innovation:

1) **A comprehensive set of consistent performance metrics should be developed and reported on a local government or microgrid level.** This would allow communities across the country to benchmark grid performance. These metrics also should reveal areas for improvement and identify leverage points, whereby small investments produce dramatic reliability improvements. The definition of a sustained outage should include major events such as storms.

    a. **Reliability metrics should include at a minimum SAIFI, SAIDI, CAIDI, CEMMI-4, CELID-8, and MAIFI for the entire system and include all interruptions (e.g., major storms).** These metrics should be reported by voltage level (e.g., below 34kV, 34kV to 138kV, and above 138kV) and by substation for each local government, for large developments and for customers served by a single meter or substation. Each category reflects fundamentally different design and cost structures.

[1] Council of European Energy Regulators ASBL. (2008). *4th Benchmarking Report on the Quality of Electricity Supply*. Brussels: Council of European Energy Regulators (CEER), ASBL, 28 rue le Titien, 1000 Bruxelles, Arrondissement judiciaire de Bruxellese, RPM, 0861.035.445.

b. **Emphasis on momentary interruptions should be significantly increased.** As smart grid plans are implemented and more data on momentary interruptions becomes available, it should become easier to assess momentary outages and track improvements. The industry should consider additional metrics focused on momentary outages.

c. **Reliability metrics should include the reporting and trending of power quality events.** These include, at a minimum, voltage dips and swells, harmonic distortions, phase imbalance, and dropped phase(s).

d. **Utilities should include separate cost reporting categories** to provide detail regarding the effectiveness of investments in reliability improvements. This includes developing new cost sub-codes, separate from expense and capital, for reporting operations, maintenance, repairs and improvements. These new cost codes should be reported system-wide, for various voltage levels, by substation and by major customers/cities, as outlined in recommendation 1a.

e. **Utilities should report public deaths or injuries** caused by power interruptions or interactions with the distribution system. This should not include incidents downstream of the utility meter or in the home or customer facility.

f. **Reliability metrics and reporting should be continuously refined.**

g. **Urban, rural and suburban circuits should be classified separately.** Urban, suburban and rural circuits have different customer expectations, customer densities and threats. It does not make sense to have the same rules for all circuits in a utility's jurisdiction.

2) **After establishing a baseline, create reliability targets or standards that ensure that all local governments, large developments and large customers receive similar service** in terms of reliability, power quality and cost.

3) **A portion of the collected distribution rates should be applied to local grid improvements** in coordination with a local government improvement plan. Some communities have not had improvements to their local distribution systems for 20 to 50 years. Local governments with reliability indices twice the average could receive greater allocations.

4) **Expand and strengthen rules that limit the use of existing ratepayer fees for subsidizing distribution system expansion for new development.** Using existing ratepayer fees to subsidize new development or acquire private distribution systems drains limited resources from improving the existing system. An unintended consequence of subsidizing new development is less efficient, local all-electric designs. When electricity distribution is provided for free, other more efficient design options cannot compete.

5) **Implement rules to allow local governments to invest in system improvements using long-term, on-bill financing mechanisms.** See Illinois ComEd Rider LGC as an example.[2]

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[2] Commonwealth Edison Company. (2008, December 16). *Rider LGC Local Government Compliance Adjustment.* Retrieved from ComEd.com: https://www.comed.com/sites/customerservice/Documents/RiderLGC.pdf

6) **Implement rules that allow utilities to engage in power quality and reliability service contracts for customers that wish to pursue performance better than current standards.** Power-quality contracts are used in both the U.S. and Europe to supply higher-quality power to customers who are willing to pay for it.

7) **Consider encouraging the use of continuous improvement/quality methods in all aspects of operations, including smart grid programs.** These proven methods include developing performance metrics and goals, as well as applying process mapping, failure modes and effects analysis, failure mode ranking and innovative solution set development and planning. The application of these methods eliminates waste and rework, while helping identify unintended consequences.

Waste in the Electric Industry

The reporting of repair costs or waste is critical to justifying investment in system reliability improvements. Major U.S. corporations measure waste and then invest to eliminate waste. The justification for investment is the elimination of the annual costs of waste. For example, if a utility is spending $100 million to repair overhead lines that fail each year because of storm damage, they could justify investing $700 million or more to move vulnerable system components underground where they would not be susceptible to storms.

Table 1: International Comparison of 2007 Reliability Indices

COUNTRY	SAIDI	SAIFI
United States	240	1.5
Austria	72	0.9
Denmark	24	0.5
France	62	1.0
Germany	23	0.5
Italy	58	2.2
Netherlands	33	0.3
Spain	104	2.2
UK	90	0.8

Source: Council of European Energy Regulators ASBL. (2008). *4th Benchmarking Report on the Quality of Electricity Supply.* Brussels: CEER.

Glossary

AMI — automated meter infrastructure, but generally refers to an automated or smart-metering system

Automated reclosers — an older technology device used to automatically restore power to faulted circuits

CAIDI — customer average interruption duration index

CAIFI — customer average interruption frequency index

CEER — Council of European Energy Regulators

CELID-X — customers experiencing longest interruption durations; CELID-8 is the percentage of customers who experienced outages exceeding 8 hours

CEMI-X — customers experiencing multiple interruptions; a measure of the percentage of customers who experienced X interruptions

CEMMI-X — customers experiencing multiple momentary interruptions; a measure of the percentage of customers who experienced X momentary interruptions

DOE — the U.S. Department of Energy

EPRI — Electric Power Research Institute, a collaborative research institute for the electric utility industry

IEEE 1366 — A guide published by IEEE that defines distribution reliability standards and the factors that affect their calculations

GIS — geographical information system, a computerized system that allows users — such as utilities — an opportunity to display data in a geographical manner

High voltage — system components rated greater than 34 kV

IEEE — Institute of Electrical and Electronics Engineers

IOU — investor-owned utility

LBNL — Lawrence Berkeley National Laboratory

MAIFI — momentary average interruption frequency index

Momentary outage — an outage with a duration shorter than a sustained outage

Power quality — a measure of the purity of the electric waveform on powerlines. A power quality event, which is not the same as an outage, occurs when one of the waveforms differs from a pure sinusoidal waveform or one or two phases of power are lost. Measurements that can quantify power quality are harmonic distortion and peak-to-peak voltage. Power quality events can last from a few cycles to a few seconds and can be caused by lightning strikes, falling trees, utility operations and operations from other customers such as disturbances from starting a large motor.

PUC — Public Utility Commission

SAIDI — system average interruption duration index

SAIFI — system average interruption frequency index

SCADA — Supervisory Control and Data Acquisition is a monitoring and control system used to supervise an industrial system such as an electric grid. A SCADA typically includes a user interface to help users visualize the system being monitored and understand what is happening.

Smart grid — a mechanism for delivering power from generators to consumers using modernized digital technology that takes advantage of self-healing systems and operating transparency. The Initiative characterizes smart grid technologies and features into four areas: 1) High-voltage smart transmission and distribution systems; 2) Low-voltage smart distribution systems; 3) Advanced metering and smart metering; 4) In-home devices and networks.

Sustained outage — an outage that lasts longer than a specified amount of time. SAIDI, SAIDI and CAIDI are all based on sustained outage. The duration of a sustained outage varies from state to state. IEEE-1366 defines the duration of a sustained outage to be 5 minutes.

T&D — transmission and distribution

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1 Introduction

The Northeastern blackout that took place on August 14, 2003, and numerous other devastating outages since then, have raised public awareness of electricity grid reliability and energy security in the U.S. In response, the Galvin Electricity Initiative began researching electricity distribution practices in the U.S., Europe and Asia. We discovered that conscientious legislators and utility regulatory commissions across the country were requiring the implementation of reliability metrics and standards. However, definitions, measures and standards vary significantly and the U.S. continues to fall behind developed nations in terms of electricity reliability. And while some argue that the costs of improved grid reliability are too high, the truth is that the expense of repetitive customer interruptions and system repairs are far greater.[3]

A major obstacle to reform is the prevailing view that outages are a fact of life — a force of nature, and thus uncontrollable. To make matters worse, there is a perception among industry stakeholders that improved reliability requires higher rates. The cities of Naperville, Ill., and Chattanooga, Tenn., dispelled this myth by dramatically improving reliability without raising rates. Their utilities sought leverage and a better way; they were able to reinvest savings from eliminating waste, shift spending to the local distribution system and eliminate the practice of subsidizing new development.

To further confuse the issue, the electric industry has recently been promoting the smart grid as way to improve reliability and efficiency. While this may be the case, many smart grid programs lack specific safety, reliability and power quality performance metrics and goals. Metrics would reveal how smart grid investments benefit consumers and in what quantity. It is difficult for the average consumer to know if this innovation will dramatically improve the reliability and quality of power they receive.

The recommendations in this report outline policy reform best practices deployed by innovative states and countries. These reforms aim to produce improved grid reliability, efficiency and smart grid oversight management — paid for by eliminating waste and requiring that new load pays its own way.

> "Technology has no inherent value; technology defines its value by what result it achieves in terms of improving the customer experience."
>
> – Robert Galvin, as CEO of Motorola

These policies are crafted to encourage the engagement of local governments and the application of continuous improvement methods, innovation and new thinking that produce dramatic improvements in performance without increasing costs. These policies also encourage community participation in the planning and implementation of local system improvements. This will lower the cost of investment by coordinating infrastructure upgrades with local infrastructure improvements (e.g., roads, water and telecommunications).

[3] O'Neil, D. (2004). "Valuing Reliability: Estimating the Value of Avoiding the Risks Associated with T&D Reliability Failures," Navigant Consulting. Presentation to the Edison Electric Institute Customer Operations Executive Workshop.

2 Why Focus on Reliability?

The original purpose of the electricity grid was to supply power to the light bulb. Today, the grid provides power to a wide variety of critical applications. It:

- Powers life-support systems in residences as in-home care expands;
- Powers the essential life-saving services in hospitals;
- Powers heating and cooling now critical to life and safety for many Americans;
- Powers the communications needed for consumers to call for help and emergency crews to respond accordingly;
- Powers critical devices such as the pumps that protect New Orleans, other cities, businesses and homes from flooding;
- Powers the processes in water treatment plants needed to supply safe drinking water;
- Powers the communication towers and central telephone stations essential in the communications infrastructure;
- Powers the digital/continuous process industries that are the lifeblood of an industrial society; and
- Powers elevators or escalators used for egress during an emergency situation.

The effects of power outages go beyond the annoyance experienced from the outage itself. In addition to being responsible for deaths and injuries when they interfere with elements of day-to-day life, outages pose a real public safety hazard. When an area of a city loses power, police and firefighters must be diverted from protecting neighborhoods to recovery operations and to make sure citizens are safe. When the power fails, many residents turn to candles for light and generators for power—both of which introduce an inherent danger. Similarly, the transportation infrastructure is compromised as traffic lights go dark and police are diverted to direct traffic.

Finally, the overhead exposed electricity system presents a significant safety hazard when live powerlines are downed, threatening anyone who comes in contact with them.

The economic toll of outages reaches beyond lost productivity. A multi-day outage can cost residents hundreds of dollars in lost food and can damage furniture, carpets and other personal items when sump pumps stop working. Power outages also cost local businesses thousands of dollars in lost sales, interrupted manufacturing, lost data and spoilage.

Further, as a nation we face significant outages every year. O'Neil Management Consulting, LLC compiled a list of major outages dating back to 1997. As Table 2 shows, not only are major outages happening, they are becoming more frequent.

Table 2: Major Outages
1997-Present

EVENT DATE	TYPE	COMPANY
January 1997	Ice storm	Entergy Gulf States (TX)
July 1999	Heat wave	Com Ed, Con Ed, PSE&G
July 2001	Thunderstorm	Indianapolis Power & Light
December 2002	Ice storm	Duke Energy
February 2003	Ice storm	Progress Energy
August 2003	Blackout	Northeastern North America
October 2003	Hurricane Isabel	PHI (Pepco, Delmarva)
December 2003	Snow storm	PacifiCorp (Utah P&L)
August - September 2004	Hurricanes Charley, Frances, Ivan, Jeanne	FPL, Progress, Southern
July - September 2005	Hurricanes Dennis, Katrina, Ophelia, Rita, Wilma	Entergy, Southern, Progress, SCANA, FPL
January, July, September 2006	Wind storms Heat wave	Con Ed – Westchester Con Ed – Northwest Queens
July 2006	Wind storm	Ameren
December 2006	Wind storm	Puget Sound, Seattle City Light
January 2008	Winter storm	PG&E
August 2008	Hurricane Gustav	Entergy, CLECO
September 2008	Hurricane Ike	CenterPoint, Entergy
December 2008	Ice storm	National Grid, NU
January 2009	Ice storm	From Texas to Massachusetts, affecting all of the states in between and leaving most of Kentucky in the dark for several days

Source: O'Neil Management Consulting, LLC. (2009). Review of Major Outages. 4th Annual Infocast Conference on Emergency Preparedness and Service Restoration for Utilities. Houston.

3 Cost of Unreliable Electricity

With varying degrees of success, attempts have been made to assess the cost of unreliable electricity. Reports by the Electric Power Research Institute (EPRI) and the U.S. Department of Energy (DOE) have estimated the cost of electricity outages at $30 – $400 billion per year[4] — quite a large range.

According to the Lawrence Berkeley National Laboratory (LBNL), the economic losses resulting from unreliable electricity total approximately $80 billion per year, not including power quality events.[5] After a sensitivity analysis of their models, however, the costs could range from $30 – $130 billion. LBNL analyzed the assumptions made in prior estimates and developed their own framework for assessing the cost of outages.[6] This analysis also included the cost of momentary interruptions, whose impact on today's digital economy is disproportionately large.

The residential costs estimated by LBNL seem low considering the cost of food spoilage, dispatching police and fire personnel, evacuating and securing senior citizens and ancillary damage, such as the kind caused by sump pump failure. In addition, LBNL did not consider the cost of power quality issues.

Figure 1: Hidden Cost of Poor Power Reliability

Source: Joseph M. Juran Center for Quality at the University of Minnesota Carlson School of Management

$150 billion in economic losses due to outages is equivalent to adding 4 cents per kWh of costs to consumers nationwide.[7] However, because the industry does not track economic losses resulting from outages and interruptions, these costs remain hidden, making it more difficult to justify investment into improved reliability.

[4] Primen. (2001). *The Cost of Power Disturbances to Industrial and Digital Economy Companies.* Consortium for Electric Infrastructure to Support a Digital Society. Madison: EPRI.

[5] LaCammare, K.H., & Eto, J.H. (2004). *Understanding the Cost of Power Interruptions to U.S. Electricity Consumers.* Ernest Orlando Lawrence Berkeley National Laboratory, Energy Analysis. Berkeley: University of California Berkeley.

[6] Lawton, L., Sullivan, M., Van Liere, K., Katz, A., & Eto, J. (2003). *A Framework and Review of Customer Outage Costs: Integration and Analysis of Electric Utility Outage Cost Surveys.* Population Research Systems, LLC and Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley: University of California Berkeley.

[7] U.S. Energy Information Adminstration. (2010). *Annual Energy Outlook 2010.* Department of Energy.

Six Sigma quality experts discovered that the cost of poor quality is not readily apparent — specifically, many businesses do not measure the costs associated with quality. Though attempts have been made to quantify costs, the electricity sector does not measure or track the costs incurred by customers from a loss of electricity. Without knowing precisely the cost of interruptions, utilities cannot justify investments needed to reduce interruptions and their associated costs. Figure 1 provides a glimpse of the hidden costs of electricity interruptions. These include economic losses and the impact of interruptions on regional economic development. Cities and utilities today are competing for people and business, and their electricity system can be a marketing asset or a liability.

3.1 Power Outages: A City Manager's Perspective

In 2009, the Initiative engaged more than 50 local governments to learn how the grid serves their communities. City leaders started by sharing what consumers and business wanted from the grid. Consumers expect the grid to be reliable, businesses want the grid to stop damaging equipment, and everyone wants cleaner power and less fossil fuel use. Residents also think that utility poles and wires are a blight and want tree cutting to stop.

City leaders acknowledged that power interruptions put communities at significant risk. Electricity is critical to residential safety — heating, cooling or medical support and outages tax first responders. City leaders acknowledged that power outages also have a significant economic impact as local business operations are interrupted. Leaders expressed frustration with power quality and reliability, citing numerous complaints by businesses experiencing equipment damage and lost productivity due to voltage sags, loss of a single phase and voltage dips and surges. Power interruptions that were once a minor inconvenience are now major events for cities, businesses and residents. Though reliability metrics for a particular utility may be close to average for the region, cities complain about pockets of poor reliability where customers experience outages much more frequently than system-wide averages.

City residents are in a constant battle with utility tree-trimmers who, without notice, appear in people's backyards clear-cutting trees and shrubs that are very important to residents. Residents are also sensitive to the poles and wires that litter the landscape.

Overall, cities are not satisfied with the lack of system improvement and the slow pace of change. Spurred by inaction or slow progress by utilities, states and cities are taking matters into their own hands. This includes working with their legislators to change the rules to empower concerned communities and consumers so they can take action. Some communities have battled their utilities to acquire the local distribution system themselves so that they can develop and implement improvement plans. Others are investing in moving the overhead distribution system underground.

3.2 Power Outages: A Business Perspective

In the city of Hodgkin, Ill., several business leaders and city representatives requested that the Galvin Electricity Initiative help guide them in dealing with power reliability problems. Hodgkin serves a large commercial and industrial base. Because of the power problems in the area, the United States Postal Service had built its own power plant to supply its electricity independent of the grid. Several local businesses were contemplating leaving the community because of the numerous power outages and their impact on product quality and cost.

At the initial meeting, business leaders expressed concern about not only the cost of outages but also about power quality. Hodgkin was experiencing dropped phases, voltage dips and repeated power surges because of repeated recloser operation into faulted lines. The power outages and power quality events were costing some business several hundred thousand dollars per year in damaged equipment. In addition, individual businesses had already spent several hundred thousand dollars in attempts to protect their equipment from power outages and power quality events, although these efforts were unsuccessful.

From the information that the Initiative gathered from community leaders regarding power interruption, restoration and power quality, it appeared that automatic recloser switches contributed to the problem. An automatic recloser switch opens when it senses a momentary fault. After a few seconds, the switch attempts to close back in. If the fault clears (e.g., a tree branch touches the line but then clears) the switch remains closed and customer power is restored. If the fault does not clear, the switch opens and closes two more times before locking open. Each time the switch closes into a fault, every facility on the energized side of the fault experiences a power quality event that can damage equipment.[8] So the recloser switch improves the utility outage duration index but also causes power quality events and equipment damage that are not recorded or tracked. Businesses and residents suffer while utilities receive credit for reducing outage duration.

More expensive intelligent reclosers can sense if a fault has cleared the circuit without closing into the circuit. These smarter technologies reduce the power quality events caused by attempting to reclose into a faulted circuit and help protect customer equipment. However, because momentary outages and power quality events are not tracked, utilities are rewarded for deploying the manual recloser switches.

4 What Can Be Done?

One municipality that has been able to dramatically improve the reliability of their electricity system and reduce the cost of power for their customers is the Chicago suburb of Naperville.

In the early 1990s, Naperville's municipal utility was not performing well and the city council held a vote on whether to sell it to the larger, area-wide utility. At this time, three or four customer outages per year were common. The sale was defeated by only one vote in the city council and the municipal utility leadership decided instead to pursue perfect power reliability without raising costs. They started applying the concepts behind what is today known as Six Sigma or quality improvement. Over a period of almost 20 years, the local grid was transformed into one of the most reliable suburban grids in the country — without raising rates.[9]

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[8] Primen. (2001). *The Cost of Power Disturbances to Industrial and Digital Economy Companies.* Consortium for Electric Infrastructure to Support a Digital Society. Madison: EPRI.

[9] Galvin Electricity Initiative. (2010, April). *Naperville Case Study.* Retrieved from Galvin Electricity Initiative: http://www.galvinpower.org/galvin-conducts-naperville-smart-grid-initiative-case-study

In fact, Naperville maintained lower rates than the region-wide utility, even while investing tens of millions of dollars a year into continuous improvement. Their first step was to install a Supervisory Control and Data Acquisition system so that they could evaluate loading on their circuits and develop plans for problem areas. Over the course of the next decade, they ran powerlines underground and implemented a new "high-reliability design" that involves circuit looping and deployment of multiple sectionalizing smart switches on each loop. This allowed faults to be sensed and isolated, minimizing or eliminating outages. Later on in the process, Naperville started using their SCADA combined with a Geographic Information System to pinpoint problems that allowed their operators to either fix problems remotely or dispatch linemen to the problem areas quickly.

For utilities in growing areas, it can be difficult to invest in the existing system, as a large portion of T&D capital allocations are used for system expansion. Naperville alleviated this problem by using a "pay your own way" rate mechanism that required new buildings to pay for any system changes needed to serve them. Cost recovery for new development was accomplished via a temporary rate rider (e.g., 1 cent per kWh) that is levied until all utility costs are recovered, usually in three to five years.

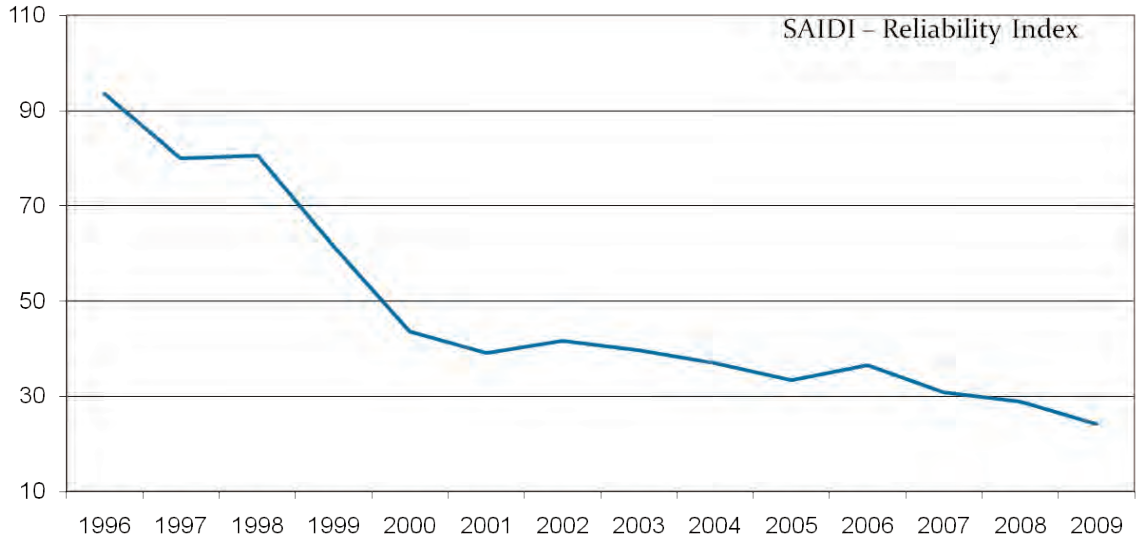
Table 3 shows the current status of Naperville's smart grid program and Figure 2 shows Naperville's SAIDI since 1996. As the data show, dramatic improvements were made. These improvements were accomplished by applying continuous improvement methods to establish a new, more reliable design philosophy (i.e., underground, loop and sectionalizing switches). In this process, Naperville applied metrics, set goals, monitored performance and identified the root causes of problems. Naperville continuously improved performance through refinements that mitigated the problems as they emerged.

Table 3: Naperville Smart Grid Process

SMART GRID SUBSYSTEM	PERCENT COMPLETE
SCADA	100%
Looping	80%
Underground	>90%
Distribution Automation	75%
Substation Automation	70%
AMI	2 Pilot Projects
Communication Infrastructure	70%

Source: *http://galvinpower.org/galvin-conducts-naperville-smart grid-initiative-case-study*

Figure 2: Naperville SAIDI Improvements



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Average No. Customers	41,714	43,905	46,160	48,214	50,251	51,525	52,825	54,149	54,844	55,551	56,086	56,432	56,747	56,789
SAIDI - Index (Minutes)	93.60	80.00	80.60	61.60	43.60	39.22	41.73	39.76	36.88	33.45	36.54	30.88	28.94	24.24

Source: *http://galvinpower.org/galvin-conducts-naperville-smart grid-initiative-case-study*

5 Who Pays for Improved Reliability?

Some industry stakeholders have argued that higher rates are required to improve the reliability of electricity service. Naperville serves as a model of how to achieve dramatic improvements in system reliability without raising costs. Consumers are already paying utilities to manage system operation and performance through distribution charges. However, collected distribution monies are being siphoned away from local reliability improvements by system expansion, new development, inefficiency and recurring repairs. A review of one Illinois utility revealed that the majority of improvement spending went to system expansion on the high voltage system while most outages resulted from failures on the local low voltage system.[10]

Illinois implemented reliability metrics and standards in 1998. Regulators realized a few years later that they needed detailed information on improvement spending by voltage level. A review of this data revealed that the majority of improvement spending is allocated to system expansion and improvements to the high-voltage system – while most outages resulted from failures on the local low-voltage system.[11]

> *ComEd's capital spending budget was $750 million. Some "$350 million to $400 million of that is spent meeting the needs of people who open new office buildings, new homes and new factories," Rowe said. "It seems like the capital expenditures are exceeding what we are getting from doing it. It suggests* ***we ought to learn how to meet those requirements more intelligently****."*
>
> *– John Rowe, CEO of Exelon Corporation, Chicago Tribune, January 30, 2003*

Another example is Pepco — a utility that has been battered by storms that have created widespread and long power outages. They announced their Comprehensive Reliability Enhancement Plan in September of last year.[12] Of particular note is that of the planned $320 million in improvement spending for the next five years, $180 million or 56 percent is for system expansion.

An unintended consequence of subsidizing new development is less efficient, local, all-electric designs. When electricity distribution is provided for free, other more efficient design options cannot compete. The City of Naperville's "pay your own way" rate mechanism eliminates ratepayer subsidy of new development.

To make matters worse, utilities do not continuously track the impacts of outages, which could be used to justify targeted investments. This includes 1) injuries and deaths, 2) tracking recovery and repair costs separate from maintenance or operations costs, and 3) tracking economic losses to families and businesses when power goes out. Without this information, it is more difficult to justify system

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[10] Illinois Commerce Commission. (2010). *Electric Reliability Reports.* Retrieved from Illinois Commerce Commission: http://www.icc.illinois.gov/electricity/electricreliability.aspx

[11] Illinois Annual Reliability Reports http://www.icc.illinois.gov/electricity/electricreliability.aspx

[12] Pepco. (2010, October 7). *Pepco Unveils Reliability Enhancement Plan for the District of Columbia.* Retrieved from Pepco.com: http://www.pepco.com/welcome/news/releases/archives/2010/article.aspx?cid=1552

improvements that would eliminate outages. Reporting repair costs separately will provide utilities with hard evidence regarding savings that can be produced by investing in improvements that eliminate repairs.

While grid operators can eliminate waste, increase the efficiency of operations, and shift spending to more impactful improvements, local conditions may warrant special riders to achieve the desired levels of reliability or specific local needs. In addition, some large customers or local governments may require higher levels of reliability and power quality. Illinois allows local governments to specify reliability improvements such as undergrounding of circuits and to pay for these improvements through a special rider or tariff. In other cases, grid operators are empowered to enter into power quality contracts.[13]

To maximize the value of existing consumer rates, consider the following:

- Require that new customers pay their own way through a special rider that is applied over a limited period.
- Require greater detail on spending by voltage level and substation in these areas: 1) operations and maintenance, 2) improvement spending, 3) repair cost, and 4) outage impacts. These proposed new cost codes would not replace the two main cost codes currently used by utilities – capital and expense. Instead, these would be new sub-cost categories.
- Establish a rider that enables large customers and local governments to accelerate grid improvements or pursue higher levels of reliability or power quality than are required by legislated standards.
- Require the use of proven Six Sigma quality methods that focus on systems analysis to reveal small changes that have a large impact on performance. This includes investing in improvements that eliminate waste.

6 Overview of Safety, Reliability and Power Quality Metrics

In general, European performance metrics and targets are further ahead than U.S. regulations.[14] Rules are specified in varying degrees of detail; i.e., per system operator, region, feeder, customer, urban/rural or underground/aerial. Most countries in Europe include major events in their metrics, but major events tend to have much stricter definitions than in the U.S. For example, a snowstorm in Greece would be considered a major event, but a snowstorm in Sweden would not. In fact, the regulatory philosophy in Europe is that the system should be designed to handle normally expected conditions in its region — high winds, ice storms, snowstorms or high temperatures. Europe has been using outage indices for several years and has been ratcheting up requirements as its grid has improved.

Recently, European regulators have started to require that customers receive a minimum level of service — a requirement not typically found in the U.S. Large areas with poor reliability can be hidden in system-wide indices. Minimum performance guarantees ensure that every customer receives the minimum as

[13] Commonwealth Edison Company. (2008, December 16). *Rider LGC Local Government Compliance Adjustment.* Retrieved from ComEd.com: https://www.comed.com/sites/customerservice/Documents/RiderLGC.pdf

[14] Council of European Energy Regulators ASBL. (2008). *4th Benchmarking Report on the Quality of Electricity Supply.* Brussels: CEER.

defined by the local regulations. European regulations also include a component of continuous improvement in their regulations, meaning that the requirements are made stricter over time.

Some European utilities offer power-quality contracts for those customers who want a higher-than-standard continuity of service or power quality than is required by regulations. These contracts are currently nonstandard but European regulators are looking to expand their use, particularly because they were found to be an efficient way to increase power quality without imposing excessive costs on the general tariffs. Some regulators have power-quality boards that hear complaints about poor power quality and may even oversee voltage monitoring at sites with power-quality complaints.

In terms of safety, utilities track and report deaths and injuries in accordance with OSHA standards. OHSA also tracks deaths related to workers from other industries contacting powerlines. The United States Department of Labor, Bureau of Labor Statistics reports that about 100 people a year die from contact with powerlines. Australia appears to be the only country that reports public deaths or injuries caused by power interruptions or interactions with the distribution system.[15] For comparison purposes, the railroad industry reports all deaths or injuries caused by trains in accordance with the Federal Railroad Administration's Accident/Incident Reporting Requirements.

The U.S. electricity industry uses several indices to measure electricity system safety, reliability and power quality. However, LBNL and others have pointed out that there is a lack of consistency in reporting and there is no national comparison or rating system that would hold utilities accountable for their performance.[16] For example, some utilities report reliability metrics with major outages, while others do not. In fact, many utilities and the commissions that regulate them have different definitions of what constitutes a major outage or even an outage itself. The following were identified as the most common and comprehensive performance metrics from Europe and the U.S. state rules. The first five indices are based on sustained outages and MAIFI is for momentary interruption. Sustained interruptions, as defined by IEEE-1366,[17] are those that last more than five minutes and momentary interruptions are those that last less than 5 minutes. However, data for different states may be defined differently, as not every utility or utility commission uses IEEE-1366. In general, the European countries define sustained interruptions as outages lasting three minutes or more. Both the IEEE and LBNL studies referenced herein reveal that the definition of a sustained outage does not significantly impact reliability indices. Interruptions include a loss of a single phase on three-phase power.

> **SAIDI** — System average interruption duration index, represents the sum of customer-sustained outage minutes per year divided by the total customers served.
>
> **SAIFI** — System average interruption frequency index, represents the number of customer interruptions divided by the total customers served.

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[15] Australian Electrical Regulatory Authority Council. (2005-2006). Electrical Incident Data: Australia and New Zealand. http://www.erac.gov.au/downloads/Erac%202005-2006.pdf.

[16] Ito, J.H., & LaCommare, K.H. (2008). Tracking the Reliability of the U.S. Electric Power System: An Assessment of Publicly Available Information Reported to State Public Utility Commissions. Berkeley: Ernest Orlando Lawrence Berkeley National Laboratory.

[17] IEEE Power and Engineering Society. (2004). *1366 IEEE Guide for Electric Power Distribution Reliability Indices.* New York: The Institute of Electrical and Electronics Engineers Inc.

CAIDI — Customer average interruption duration index, for the group of customers that actually had one or more interruptions and how long (on average) the interruptions lasted. The figure represents the total number of customer interruption durations divided by the total number of customers interrupted.

CEMI-X — Customers experiencing multiple interruptions, a measure of the percentage of customers who experienced X interruptions. CEMI-3 is the percentage of customers who had three or more interruptions.

CELID-X — Customers experiencing longest interruption durations. CELID-8 is the percentage of customers who experienced outages exceeding 8 hours.

MAIFI — Momentary average interruption frequency index, represents the system-wide average number of momentary outages per year and is the number of momentary customer interruptions divided by the total customers served. A momentary interruption is typically defined as any interruption that is less than the definition of a sustained outage.

CEMMI-X — Customers experiencing multiple momentary interruptions is a measure of the percentage of customers who experience X momentary interruptions.

The way various U.S. states use these reliability indices creates several problems. First, specific customers may experience outages that exceed the normal system-wide indices for the utility. Pockets of poor reliability, meaning areas with a large frequency or annual duration of outages, won't impact the system-wide reliability indices.

Second, most regulators evaluate only SAIDI and SAIFI. Some of the actions used to reduce SAIFI and SAIDI may cause the number of momentary outages to increase. For example, this can be the case when the system is designed using automated reclosers. Some recommend that SAIFI, SAIDI and MAIFI should be evaluated together.[18] Unfortunately, only 13 states require the reporting of MAIFI and only on circuits where it is practicable.[19]

Adding MAIFI to the list of reliability indices would improve the overall reliability picture, though these indices together may not be sufficient for assessing the total cost of unreliability. Unfortunately, most utilities do not have the equipment installed to measure MAIFI. New SCADA and smart meters being proposed under the smart grid umbrella should enable utilities to measure MAIFI. These indices, however, only count events when the line voltage drops to zero for three to five minutes, not necessarily power quality events.

This is a crucial distinction to make because power quality events or out-of-specification voltages can also pose significant costs to customers. As mentioned earlier, power quality events can last from a few cycles to a few seconds and can be caused by lightning strikes, falling trees, utility operations and operations

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[18] Ito, J.H., & LaCommare, K.H. (2008). Tracking the Reliability of the U.S. Electric Power System: An Assessment of Publicly Available Information Reported to State Public Utility Commissions. Berkeley: Ernest Orlando Lawrence Berkeley National Laboratory.

[19] Based on a Galvin Electricity Initiative assessment of state electricity utility commsision rules published on the Internet as of February 2011 and Davies Consulting Inc. (2005). *State of Distribution Reliability Regulation in the United States.* Washington D.C.: Edison Electric Institute.

from other customers. Another infrequently reported power quality event is the loss of a phase due to a blown fuse. Dropping one phase may not interrupt power, but it might lead to damaged motors and other equipment, causing financial losses for customers.

Reliability metrics should include the reporting and trending of power quality events. These include:

- Voltage dips and swells
- Harmonic distortions
- Phase imbalance or lost phase(s)

The system of reliability metrics currently in place is too variable and too diffuse to allow for the establishment of benchmarks and standards. Fortunately, the U.S. can learn from the rest of the world, which is tracking ahead when it comes to these measurements.

6.1 Reporting and Trending

The U.S. has set reliability requirements[20] for the bulk transmission system; some of the newer, tougher standards are in response to the August 14, 2003, blackout. However, reliability standards for the distribution system in the U.S. are much less stringent and not as well coordinated. Even though 25 states[21] impose reliability requirements on local distribution operators, the standards vary significantly and in many cases are fairly lax compared with European expectations.

According to an LBNL report,[22] 37 utility commissions have some type of reliability reporting system in place where either the utility reports its own reliability indices or the utility provides the commission with outage data. Establishing requirements for utilities to report and implement trend reliability metrics is an important first step. As commissions, cities, consumer groups and utilities review this data, they can learn how to improve the systems.

City officials — a group of stakeholders likely to feel the brunt of power outages — would like to see more refined reporting at the level of sub-regions, substations, feeders and circuits serving their communities. In some cases, utilities may provide cities with reports showing outage per circuit, but these reports do not make it easy to identify locations or causes. Reporting by circuit alone does not help one understand all the pieces of the puzzle. Some smaller cities may be powered by substations that are outside of the city's jurisdiction, which makes some of this reporting difficult.

The Initiative has found instances where a city has not had any improvements to the local grid for more than 50 years. In other cases, cities cannot find out from the utility how much O&M, repair or improvement dollars have been spent in their area.[23]

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[20] North American Electric Reliability Corporation. (2009). *Reliability Standards for the Bulk Electricity System of North America.* Princeton: NERC.

[21] Based on a Galvin Electricity Initiative assessment of state electricity utility commission rules published on the Internet as of February 2011 and Davies Consulting Inc. (2005). *State of Distribution Reliability Regulation in the United States.* Washington D.C.: Edison Electric Institute.

[22] Ito, J.H., & LaCommare, K.H. (2008). Tracking the Reliability of the U.S. Electric Power System: An Assessment of Publicly Available Information Reported to State Public Utility Commissions. Berkeley: Ernest Orlando Lawrence Berkeley National Laboratory.

[23] These cities include Hinsdale, Oak Park and Lincolnwood, Illinois, as well as the Northwest and DuPage Councils of Government, also in Illinois.

6.2 Targets and Standards

Reliability targets or standards are one way to change current and older practices and to encourage utilities to improve reliability. Reliability targets are standards that utility performance is measured against, and some regulators (for example, Massachusetts) have implemented penalties if minimum standards are not met. According to the Initiative's research, of the 25 states that have established reliability targets, 20 have implemented some form of penalty (see Table 4).[24] Some have specified targets for each utility or region in the utility territories (Massachusetts, New York, Pennsylvania, Texas and Delaware). New York has established operational goals and minimum performance standards for utility territories.

However, there are cases in which the reliability requirement is a SAIFI of 6, or about **three times** the national average. This might explain why, even in states with reliability standards, reliability has not improved appreciably.

[24] Based on a Galvin Electricity Initiative assessment of state electricity utility commission rules published on the Internet as of February 2011 and Davies Consulting Inc. (2005). *State of Distribution Reliability Regulation in the United States.* Washington D.C.: Edison Electric Institute.

Table 4: Reliability Reporting Methods

REPORTING REQUIREMENT	IEEE 1366	EUROPE	U.S.
Targets/Standards	No	Yes	25 states
SAIDI	Yes	Yes	35 states
SAIFI	Yes	Yes	37 states
CAIDI	Yes	Yes	33 states
CEMI-X	Yes	No	5 states (DE, FL, MI, UT, WA)
CELID-X	No	No	1 states (DE)
MAIFI	Yes	Yes	13 states (required when practicable)
Interruption definitions	Sustained – more than 5 minutes	Long – more than 3 minutes	Varies between states
Power quality	N/A	• Supply voltage variations • Voltage swells • Voltage dips • Rapid voltage changes • Flicker • Voltage unbalance • Harmonics	• 26 states regulate frequency • 31 states regulate voltage • 8 states regulate phase imbalance • 5 states regulate harmonics • WI regulates voltage sags and swells • Many states use the ANSI C84.2 standard for their power quality regulation
Penalties	No	Yes	20 states
Rewards	No	Yes	5 states (CA, MA, MI, RI, VT)

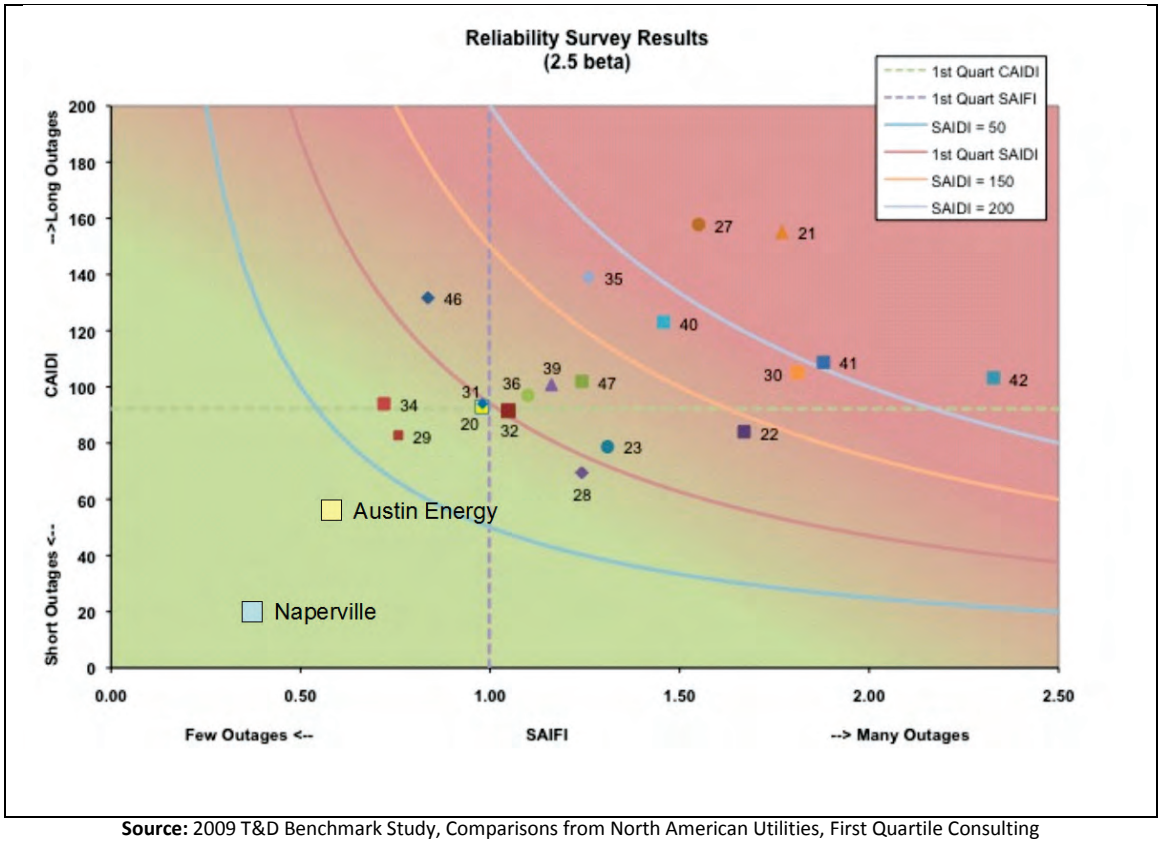
(IEEE Power and Engineering Society, 2004) (Council of European Energy Regulators ASBL, 2008) (Davies Consulting Inc., 2005)

6.3 Performance Benchmarking

LBNL's October 2008 report assessing electric reliability throughout the U.S. focused on three reliability indices: SAIFI, SAIDI and MAIFI.[25] In researching this report, LBNL contacted PUCs in all 50 states plus the District of Columbia. Only 37 PUCs responded, as not all states require public reporting of reliability data. All of the 37 states responding and the District of Columbia required reporting of SAIFI, SAIDI, and/or CAIDI. CAIDI, along with SAIFI, can be used to derive SAIDI. Thirteen states required reporting of MAIFI. Twenty-one of the reporting PUCs formally defined major events.[26]

LBNL also collected data on the U.S. transmission system and compared it to the data reported by the utility commissions. One of LBNL's key findings was that **the majority of power outages are not attributed to the transmission or area-wide high-voltage distribution system, but are instead due to events that affect the local low-voltage distribution system.**

Figure 3: CAIDI versus SAIFI



Source: 2009 T&D Benchmark Study, Comparisons from North American Utilities, First Quartile Consulting

[25] Ito, J.H., & LaCommare, K.H. (2008). Tracking the Reliability of the U.S. Electric Power System: An Assessment of Publicly Available Information Reported to State Public Utility Commissions. Berkeley: Ernest Orlando Lawrence Berkeley National Laboratory.

[26] Based on a Galvin Electricity Initiative assessment of state electricity utility commission rules published on the Internet as of February 2011 and Davies Consulting Inc. (2005). *State of Distribution Reliability Regulation in the United States.* Washington D.C.: Edison Electric Institute.

In Figure 3, First Quartile Consulting shows a comparison of U.S. utilities. The graph is broken into quadrants using a cutoff for SAIFI of 1.00 for "few outages" versus "many outages" and a cutoff of just over 90 CAIDI minutes for "short outages" versus "long outages." The graph indicates that very few utilities fall into the first quartile of few outages and short outages. Figure 3 also shows curves of constant SAIDI. The SAIDI = 50 curve crosses into the first quartile and the first quartile SAIDI curve, which is close to SAIDI = 100, just touches the crossing of the first quartile CAIDI line and the first quartile SAIFI line.

As Figure 3 shows, Naperville and Austin Energy have exceptional reliability.

Another way to look at U.S. reliability indices is by region. Table 5 shows a summary of reliability data from across the nation based on the U.S. Census divisions. The last row of the table shows an estimate for the reliability indices for the power system based on major electrical events. LBNL's report includes discussions on factors that can affect the data shown in the table such as differences in reporting requirements between PUCs and the inclusion of major events. However, the table does indicate that a majority of customer outages are due to local events, as LBNL's estimated transmission system SAIFI (0.07) is well below that for typical utilities.

Table 5: Summary of U.S. Regional Reliability Data, Some With and Without Major Events

CENSUS DIVISION	SAIDI (MINUTES)	SAIFI	MAIFI
New England	198	1.44	No Data (ND)
Middle Atlantic	225	1.28	ND
East North Central	498	1.46	ND
West North Central	166	1.31	5.11
South Atlantic	320	1.86	11.1
East South Central	ND	ND	ND
West South Central	134	1.38	ND
Mountain	118	1.22	ND
Pacific	296	1.99	3.4
U.S. Average	**244**	**1.49**	**6.55**
Events		**0.07**	**ND**

Source: Tracking the Reliability of the U.S. Electric Power System: An Assessment of Publicly Available Information Reported to State Public Utility Commissions. (October 2008). LBNL Report 1092E.

A review of five European countries revealed the SAIDI and SAIFI performance shown in Table 6. These countries also put greater emphasis on power quality.

Table 6: European Reliability Performance, With Major Events

COUNTRY	SAIDI	SAIFI
Austria	72	0.9
Denmark	24	0.5
France	62	1.0
Germany	23	0.5
Italy	58	2.2
Netherlands	33	0.3
Spain	104	2.2
UK	90	0.8

Source: Council of European Energy Regulators ASBL. (2008). *4th Benchmarking Report on the Quality of Electricity Supply.* Brussels: CEER.

One problem with reporting average data for a state or even for a utility is that it does not address whether the served area is urban, suburban or rural. For instance, a state or utility may have an average SAIFI of 2 and have 25 percent of its customers in an urban area with a SAIFI of 0.2. Downtown areas tend to be wired with underground spot networks, which are more reliable and costly than radial overhead networks found in suburban and rural areas.

Using the data provided in the example here, the SAIFI for the rest of the state or territory would be 2.6.[27] The point is, average indices can hide pockets of poor reliability, or even larger areas of poor reliability, if the system includes an area with exceptional reliability such as a major urban center. Utilities may be asked by their PUCs to report data for different regions in their territory, but this still may not provide enough resolution to identify pockets of poor reliability.

[27] (25% x 0.2 + 75% x 2.6) = 2, the regional SAIFI. 25 percent of the customers have a SAIFI of 0.2 and 75 percent of the customers have a SAIFI of 2.6, even though the weighted SAIFI for the region is 2.

Table 7: Outage Causes and Their Contribution to Reliability

CAUSES OF OUTAGES	IMPACT PERCENTAGE
Major Events	80.6%
Trees	5.6%
Distribution Equipment Failure	4.0%
Other	2.6%
Planned Interruptions	1.3%
Acts of Public	1.2%
Weather-Related	1.1%
Transmission Outages	1.1%
Lightning	1.1%
Substation Outages	0.9%
Animals	0.5%
Generation Outages	0.0%

Source: 2009 T&D Benchmark Study, Comparisons from North American Utilities, First Quartile Consulting.

First Quartile Consulting analyzed causes of outages in the U.S. (see Table 7). Major events account for the largest portion of outages. Major events are widespread outages typically caused by some type of natural phenomenon such as a large storm. For instance, a large, powerful thunderstorm may cause high winds that damage powerlines, but also could cause tree limbs to break and fall on them. Given that major events are a significant contributor to system reliability, they should be included in the definition of a sustained outage of interruption.

Major events are widespread and are defined differently in each state. While the causes of outages vary somewhat from region to region, it is interesting to note that the top three causes of outages — excluding major events— were trees, distribution equipment failures and other. This explains why tree trimming is a prominent part of the O&M budget for most, if not all, utilities.

Though transmission-related outages only account for 1.1 percent of all outages, there has been a high level of focus on the transmission system. Part of this is justified because if a section of the transmission system goes down, large sections of customers and even entire states can be left without power.

Most businesses strive to find a way to reduce costs or waste and invest money to do so. As regulated entities, most IOUs may not be allowed to invest in technologies or methods that would ultimately end up reducing waste and life cycle costs. This leads to further inefficiencies and hampers innovation. For

instance, what if someone developed a lower-cost way to install distribution lines underground? Then, when replacing broken lines and poles, the utility could lay the new section underground.

Additionally, many communities have programs for repaving alleyways and streets. Improvement costs could be reduced by coordinating planned electricity system changes with planned sewer, water and road repair or construction.

Undergrounding Cables

Placing the distribution lines at ground level or underground reduces exposure of the wire cables to weather, trees and public acts. Additionally, undergrounding cables improves the esthetics of the neighborhood and many newer communities require that new cables be underground. The Galvin Electricity Initiative has found in discussions with utilities that they have differing opinions on the cost and benefits of undergrounding power lines. According to one utility, it costs $5M per mile to underground distribution cables; another utility claims it only costs $50K per mile. One reason for the cost discrepancy is that some utilities are coordinating undergrounding with other local infrastructure projects. One city offered to install conduit with each road improvement for use at a later date.

What does the electricity industry and the customers it serves want the electricity system to look like in 100 years, in 200 years? Unless we start now, even if it is one circuit per year, the unsightly, overhead electricity system will still be here two centuries from now and the continuous costly fight to keep putting it back up after every storm will continue.

6.4 Performance Reporting, Leveraging Continuous Improvement

Utilities can leverage standard quality methods to uncover small changes that produce dramatic improvements in reliability performance. These methods include:

- Determining what is critical to quality (CTQ) from the customers perspective — Voice of the Customer
- Process mapping CTQ's and developing measures that quantify performance or the cost of poor quality
- Failure Modes and Effects Analysis (FMEA) for each process step
- Error proofing, innovative problem solving and solution set generation
- Prioritization and implementation

The path to improved performance using quality methods begins with defining the customer's needs and a set of metrics that provides evidence that the system has improved. The next step is to perform system mapping to identify the most severe and highest probability failure modes. This provides insight into the most impactful solutions — small improvements that impact the greatest number of customers.

> "Quality is fundamentally about looking at products through the eyes of the customer."
> — *Jim Buckman, formerly with the Joseph M. Juran Center for Leadership in Quality*

Several state reliability policies require the reporting of the worst performing circuits. Quality or continuous improvement methods reveal that reporting of reliability metrics can reveal leverage points. This could include reporting by:

- Voltage level
- Substations
- City or local government
- Underground vs. overhead
- Urban, suburban and rural customers

Utilities can then focus their limited resources on finding solutions that impact a greater number of customers.

7 Reliability Standards — Policy Reform Best Practices and Recommendations

The balance between reliability and costs is an age-old debate that is not easily settled. The Initiative is not advocating instant reliability improvements or "nine nines" availability[28] to all consumers, but rather policies that lead to a continuous improvement process that can produce dramatic system improvements immediately and perfection over time. A factor to consider in determining policy is the amount of effort required by a state commission to manage a particular policy once implemented versus a more self-regulating policy placed on the utility. To help address these issues, the Initiative examined practices in the EU and more progressive states in the U.S.

This approach is intended to shed light on performance and spending to reveal opportunities for improvement and to find leverage. This includes identifying waste — such as repairing cables that repeatedly fall down or tree trimming — to justify expenses for improving the grid. As most businesses strive to eliminate waste, they are usually willing to invest in a new technology for its reduction. Likewise, the electricity industry (utilities and regulators) should be willing to make investments to reduce future waste.

In summary, the Initiative recommends the following policies to improve reliability in the U.S.:

1) **A comprehensive set of consistent performance metrics should be developed and reported on a local government or microgrid level.** This would allow communities across the country to benchmark grid performance. These metrics also should reveal areas for improvement and identify leverage points, whereby small investments produce dramatic reliability improvements. The definition of a sustained outage should include major events such as storms.

    a. **Reliability metrics should include those listed in Table 8 and include all interruptions (e.g., major storms).** These metrics should be reported by voltage level (e.g., below 34kV, 34kV to 138kV, and above 138kV) and by substation for each local government, for large developments and for customers served by a single meter or substation. Each category reflects fundamentally different design and cost structures.

    b. **Emphasis on momentary interruptions should be significantly increased.** As smart grid plans are implemented and more data on momentary interruptions becomes available, it should become easier to assess momentary outages and track improvements. The industry should consider additional metrics focused on momentary outages. One such metric could be to measure the number of customers who experience more than a given number of momentary outages per year.

    c. **Reliability metrics should include the reporting and trending of power quality events.** These include, at a minimum, voltage dips and swells, harmonic distortions, phase imbalance, and dropped phase(s).

[28] Availability is the percentage time continuous power is available to the consumer. Nine nines is technical jargon and refers to the number of decimal places that a nine occurs in the availability number (99.9999999%). A system with nine nines availability has very high reliability.

Table 8: Recommended Reliability Metrics

SAIFI	Measures system-wide outage frequency for sustained outages
SAIDI	Measures annual system-wide outage duration for sustained outages
MAIFI	Measures frequency of momentary outages. Momentary outages and the power surges associated with them can damage consumer products and hurt certain business sectors.
CAIDI	Measures average duration of sustained outage per customer.
CEMI-3	Measures the percentage of customers with three or more multiple outages. This metric helps to measure reliability at a customer level and can identify problems not made apparent by system-wide averages.
CELID-8	Measures the percentage of customers experiencing extended outages lasting more than 8 hours
Power Quality	Power quality metrics include voltage dips/swells, harmonic distortions, phase imbalance and lost phase(s).

d. **Utilities should include separate cost reporting categories** to provide detail regarding the effectiveness of investments in terms of reliability improvements. This includes developing new cost sub-codes, separate from expense and capital, for reporting and trending operations, maintenance, repairs and improvements. These new cost codes should be reported system-wide, for various voltage levels, by substation and by major customers/cities, as outlined in recommendation 1a.

e. **Utilities should report public deaths or injuries** caused by power interruptions or interactions with the distribution system. This does not include incidents downstream of the utility meter or in the customer facility.

f. **Reliability metrics and reporting should be continuously refined.** The Initiative has found that in most cases the reporting is performed at a fairly high level, and would recommend finer reporting on both reliability and costs. Reporting at the level of sub-region, local government, or substation can help provide insights that are more meaningful. The intent of this refinement is to give regulators further insight into where problem areas might be and where future spending should occur. Many commissions are reporting at the circuit level and requiring that the worst 1 – 10 percent of circuits be improved. This approach may miss larger system improvements or issues that could have a greater overall impact on reliability metrics. Consider instead requiring that utilities identify the worst 1 – 10 percent of substations to be improved.

g. **Urban, rural and suburban circuits should be classified separately.** Urban, suburban and rural circuits have different customer expectations, customer densities and threats. It does not make sense to have the same rules for all circuits in a utility's jurisdiction. For instance, it is illogical to hold the same reliability requirements for a rural circuit as would be required for an urban circuit, as the cost per customer would be much higher for the rural customer.

2) **After establishing a baseline, create reliability targets or standards that ensure that all local governments, large developments and large customers receive similar service in terms of reliability, power quality and cost.** These are reliability targets that the utility will be measured against. States such as Massachusetts and New York already have implemented penalties for utilities that do not comply. Rewards for improving reliability performance also should be considered.

3) **A portion of the collected distribution rates should be applied to local grid improvements** in coordination with a local government improvement plan. Some communities have not had improvements to their local distribution systems for 20 to 50 years. The Initiative has found evidence that improvement spending has focused on the high-voltage level, mostly for system expansion. Yet most outages occur at lower voltage levels in the distribution system. This occurs because the utility is not incented, under current rules and regulations, to improve the existing distribution systems. One way to avoid this is to require that a certain amount of collected O&M rates be spent each year at the local level, based on actual reliability performance. Local governments with reliability indices twice the system average would be allocated a greater percentage of the collected rates.

4) **Expand and strengthen rules that limit the use of existing ratepayer fees for subsidizing system expansion and upgrades needed to accommodate new development.** Using existing ratepayer fees to subsidize new development or acquire private distribution systems drains limited resources from improving the existing system. An unintended consequence of subsidizing new development is less efficient, local all-electric designs. When electricity distribution is provided for free, other more efficient design options cannot compete. Consider a "pay your own way" rate mechanism for buildings to eliminate ratepayer subsidy of new development.

5) **Implement rules that enable local governments to invest in system improvements using long-term, on-bill financing mechanisms and investment that can be recovered** through a local special rider, similar to water and road improvements.[29] Imagine a state with no local governments. What would its roads look like? What would be the quality of services such as refuse pickup? Essentially, large monopoly utilities operate without any local governance or planning. Empowering local governments to play a greater role in electricity service will allow the coordination of large infrastructure and improved planning, thereby lowering the cost of system improvement and improving performance while holding utilities more accountable to local needs.

6) **Implement rules that allow utilities to engage in power quality and reliability service contracts for customers that wish to pursue performance better than current standards.** Power-quality contracts are used in both the U.S. and Europe to supply higher-quality power to customers who are willing to pay for it. Power quality contracts are used in both the U.S. and Europe to supply higher-quality power to customers who are willing to pay for it. In Europe, this arrangement was found to be an efficient way to increase power quality without adding costs on the general tariffs.[30] Naturally, these contracts should only apply when the customer or group of customers request power reliability or quality above and beyond regulated minimum requirements.

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[29] ComEd Rider LGC at https://www.comed.com/sites/customerservice/Documents/RiderLGC.pdf

[30] Council of European Energy Regulators ASBL. (2008). *4th Benchmarking Report on the Quality of Electricity Supply.* Brussels: CEER.

7) **Consider encouraging the use of continuous improvement/quality methods in all aspects of operations, including smart grid programs.** Most industries now use quality methods to improve their operations and business processes. Quality principles can be used to identify reliability improvements that provide large benefits for lower costs in addition to optimizing the life-cycle costs of the improvements. These proven methods include developing performance metrics and goals, as well as applying process mapping, failure modes and effects analysis, failure mode ranking, and innovative solution set development and planning. The application of these methods eliminates waste and rework while helping identify unintended consequences.

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