Reliability Metrics and Reliability Value-Based Planning

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Overview of this presentation

- Reliability Metrics
- Major Events (IEEE Std. 1366 definition)
- Reliability vs. Resilience
- Reliability Value-Based Planning
- The Interruption Cost Estimate (ICE) Calculator
- Considerations for Reliability Planning Emerging from Recent LBNL Research
- Bibliography

Electricity reliability is measured by the annual average amount of time and frequency that the lights are out

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System Average Interruption Duration Index

$$\text{SAIDI} = \frac{\text{total duration of sustained customer interruptions } (\geq 5\text{min each})}{\text{number of customers served}}$$

System Average Interruption Frequency Index

$$\text{SAIFI} = \frac{\text{frequency of sustained customer interruptions } (\geq 5\text{min each})}{\text{number of customers served}}$$

Customer Average Interruption Duration Index

$$\text{CAIDI} = \frac{\text{SAIDI}}{\text{SAIFI}}$$

Momentary Average Interruption Frequency Index

$$\text{MAIFI} = \frac{\text{frequency of momentary customer interruptions } (< 5\text{min each})}{\text{number of customers served}}$$

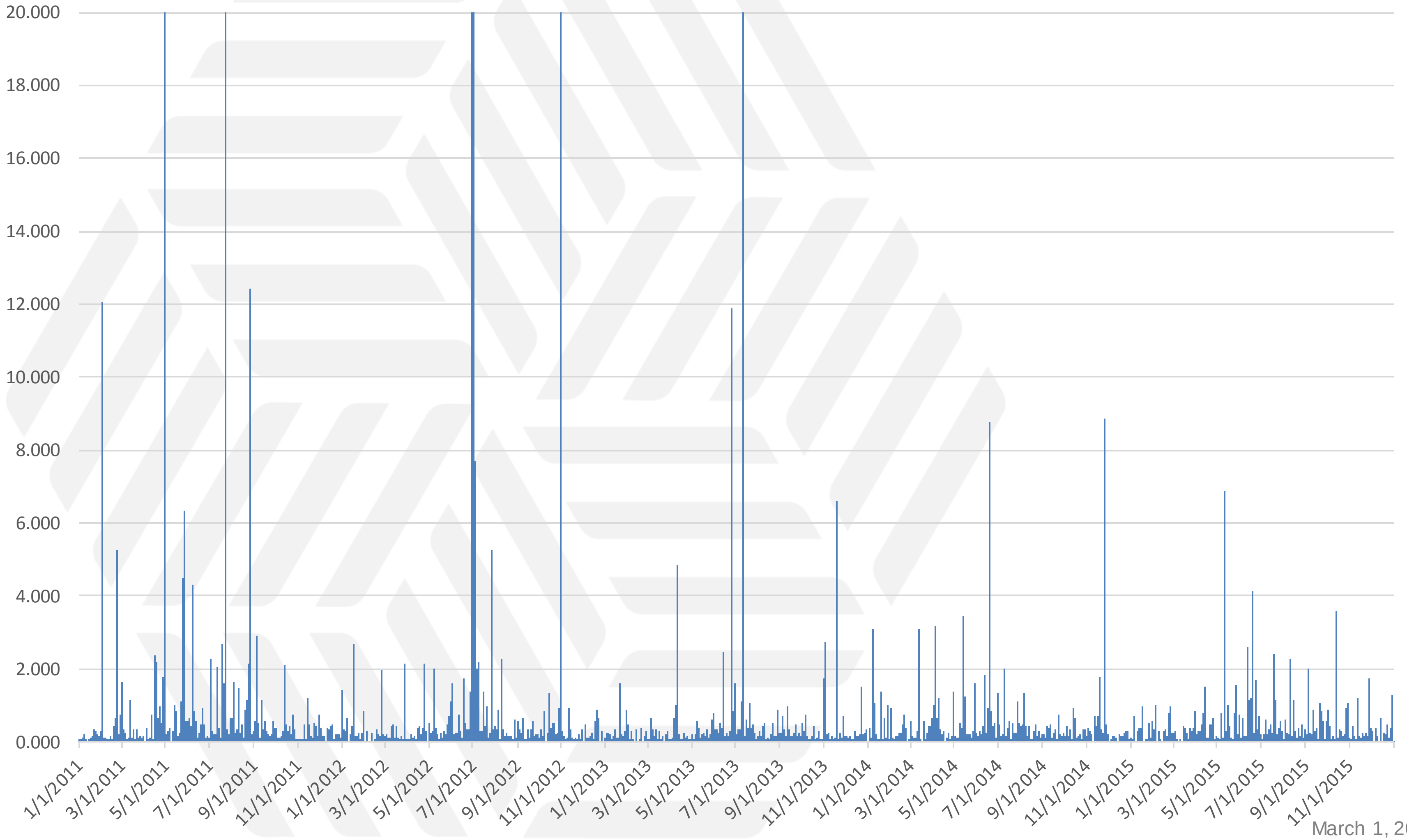
Information Reported to EIA for 2015

IEEE Standard 1366	Investor Owned	Cooperative	Municipal
Number of utilities reporting	137	296	117
% of U.S. sales by type of utility	51%	47%	43%
SAIDI with Major Events	237	302	115
SAIDI without Major Events	136	159	50
SAIFI with Major Events	1.4	2.8	0.9
SAIFI without Major Events	1.2	2.1	0.7

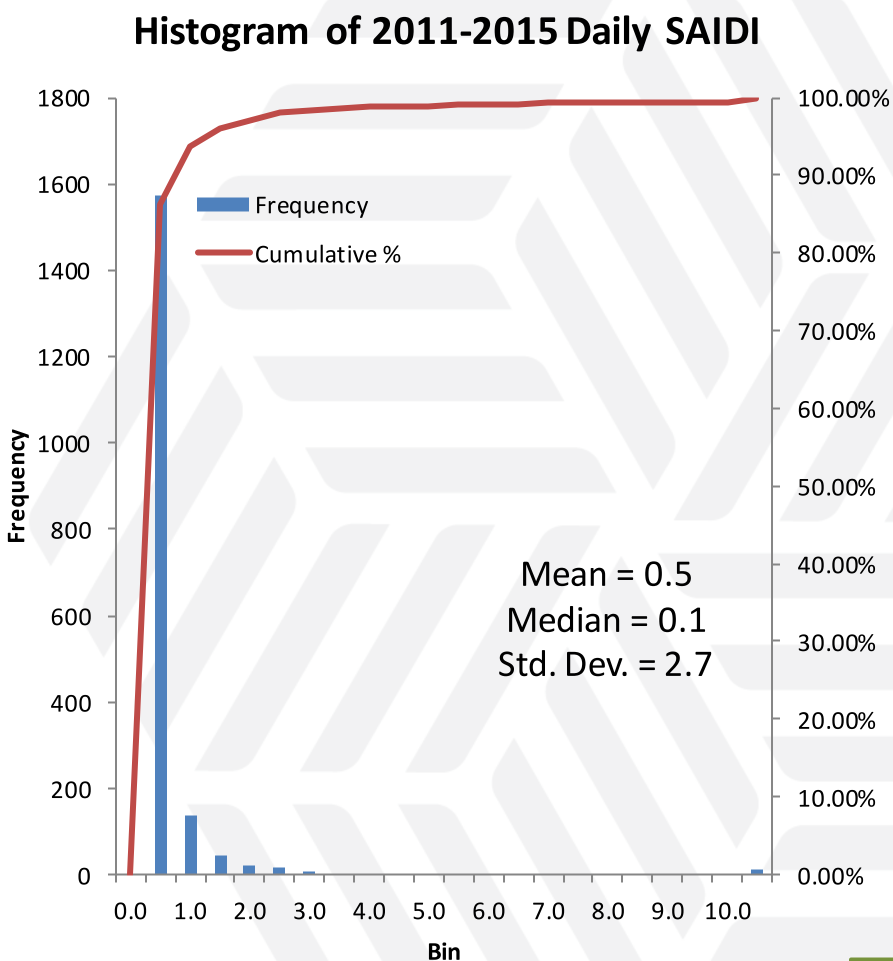
IEEE Standard 1366

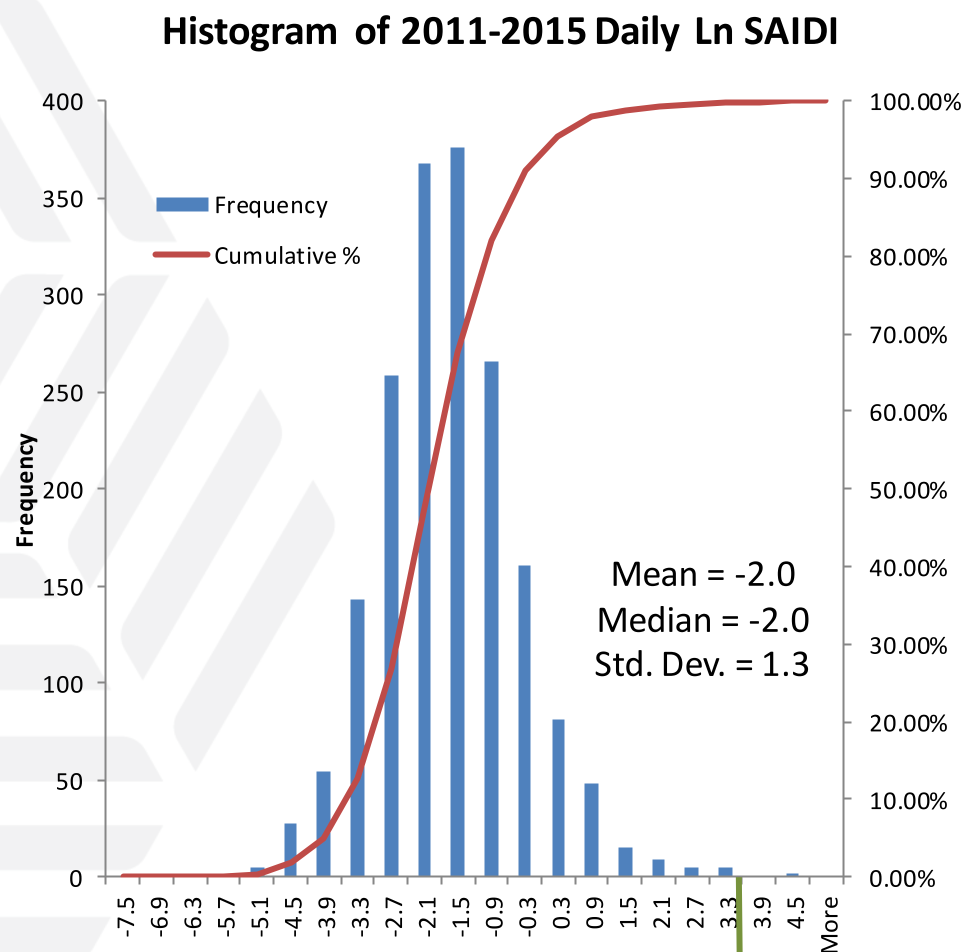
- ► First developed in 1998 to define reliability indices; amended in 2003 to add a consistent approach for segmenting Major Event Days (amended again in 2012; MED definition unchanged)
- ► Uses 2.5*beta to estimate a threshold daily SAIDI, Tmed, above which a Major Event Day is identified
  - Tmed = exp (α+2.5β)
  - Beta = log-normal standard deviation
  - Alpha = log-normal statistical mean
- ► For a ***normal*** distribution:
  - Multiplying beta (the standard deviation) by 2.5 covers 99.379% of the expected observations (assuming a one-sided confidence interval)
  - For a year of daily observations, this translates to an expectation of 2.3 Major Event Days per year
- ► *But, utility daily SAIDI data are not "perfectly" normally distributed*

Daily SAIDI for 5 years (2011-2015)



Daily SAIDI Re-Ordered from Lowest to Highest

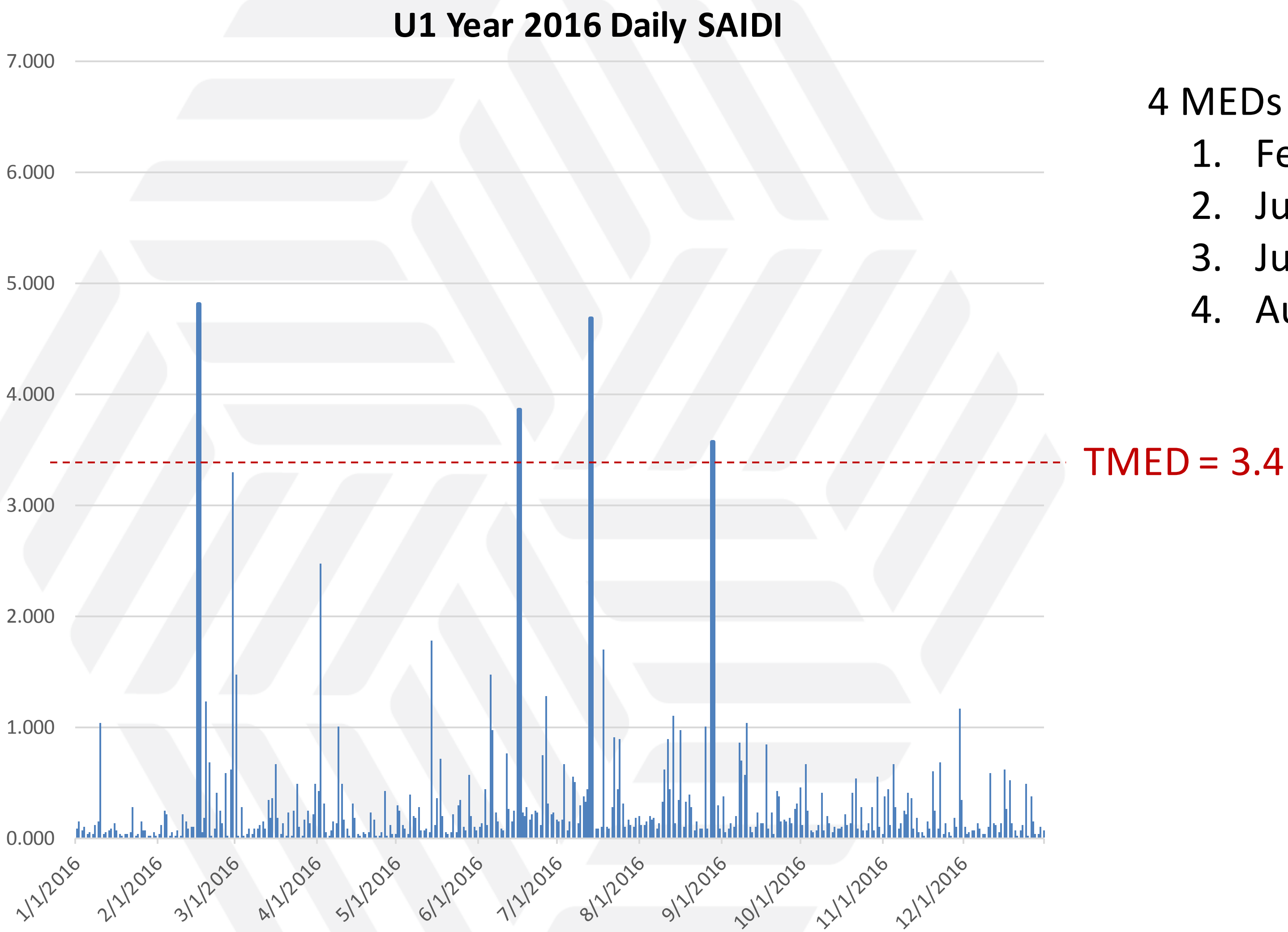




$$T_{med} = e^{(\text{mean} + (2.5*\text{std. dev.}))}$$

Tmed = 3.4

Daily SAIDI for 2016 → 4 MEDs



4 MEDs in year 2016:

1. Feb 16
2. Jun 16
3. Jul 13
4. Aug 28

Reliability vs. Resilience – features, metrics, actions

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	Reliability	Resilience
Common features/ characteristics	Routine, expected, normally localized, shorter duration interruptions of electric service Larger events will make it into the local headlines	Infrequent, unexpected, widespread/long duration power interruptions, often with significant corollary impacts Always national headline worthy
Metrics	Well-established, annualized (SAIDI, SAIFI, MAIFI), with provisions for "major events" Rarely include non-electricity impacts	Non-standardized, event-based (number of customers affected; hours without electric service) Routinely include non-electricity impacts (e.g., costs to firms; health and safety impacts)
Actions to improve	1. Plan and prepare; 2. Manage and endure event(s); 3. Recover and restore; and 4. Assess, learn, and update plan.	No qualitative difference But generally larger in scope/cost (see below)

Reliability vs. Resilience – decision-making

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	Reliability	Resilience
Entities involved in decision making	Electric utility and its regulator/oversight board, primarily	Electric utility and regulator But also and routinely in conjunction with parties that have responsibilities for other critical infrastructures, including local/regional/state/federal agencies/authorities, and communities/elected officials
Factors affecting decision making	Actuarial records on frequency of exposure – widely understood risks: insurable Well-understood/tested practices/approaches Understood to be an expected cost of doing business	No actuarial basis to establish likelihood of occurrence – widely varying perceptions of risk/exposure: un-insurable Limited opportunities to "test" strategies Large dollar amounts/extraordinary expenditures may require special approval/vote Political judgements essential

Introducing Reliability Value-Based Planning

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- The pace of electricity grid modernization efforts will be determined by decisions made by electric utilities, their customers, and local communities/states to adopt new technologies and practices
- An important motivation for these actions will be maintaining or improving the reliability and resiliency of electric service
- From an economic perspective, the justification for these actions will therefore, depend, at least in part, on:
  - The cost of the actions under consideration;
  - The impact they are expected to have on reliability or resilience; and
  - The value these impacts have to the utility, its customers, and the community/state
- Better information will enable, but does not guarantee, better decisions and remember… we will never have perfect information

Value-Based Reliability Planning is a means for taking the cost of interruptions borne by customers into utility planning decisions

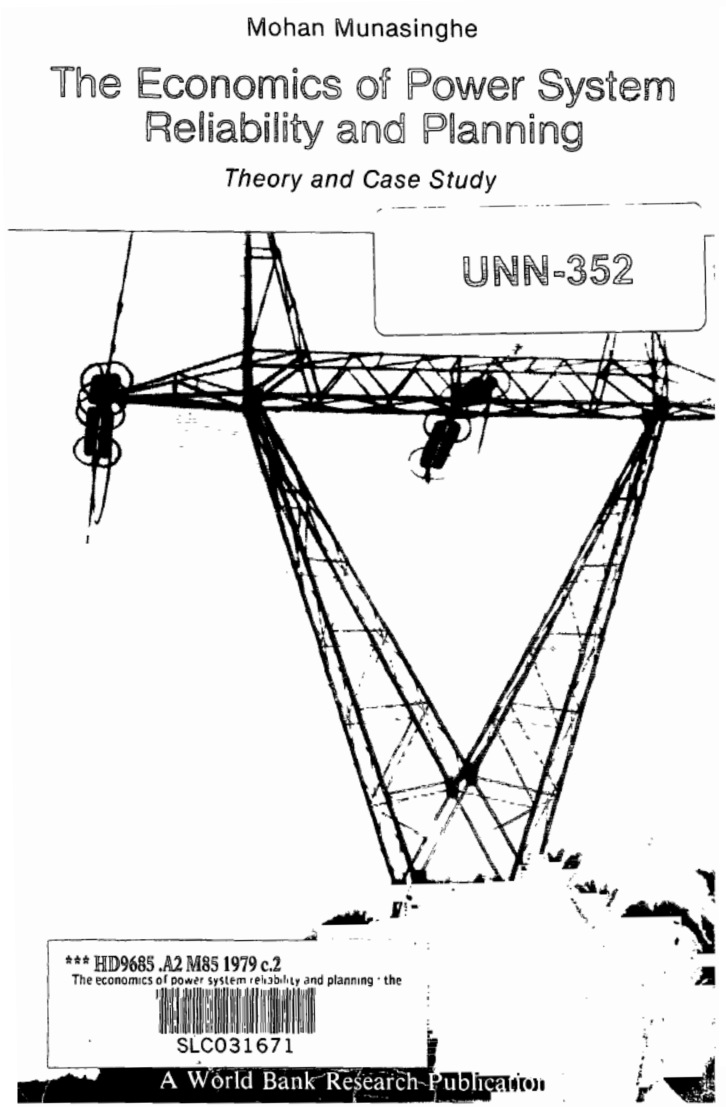
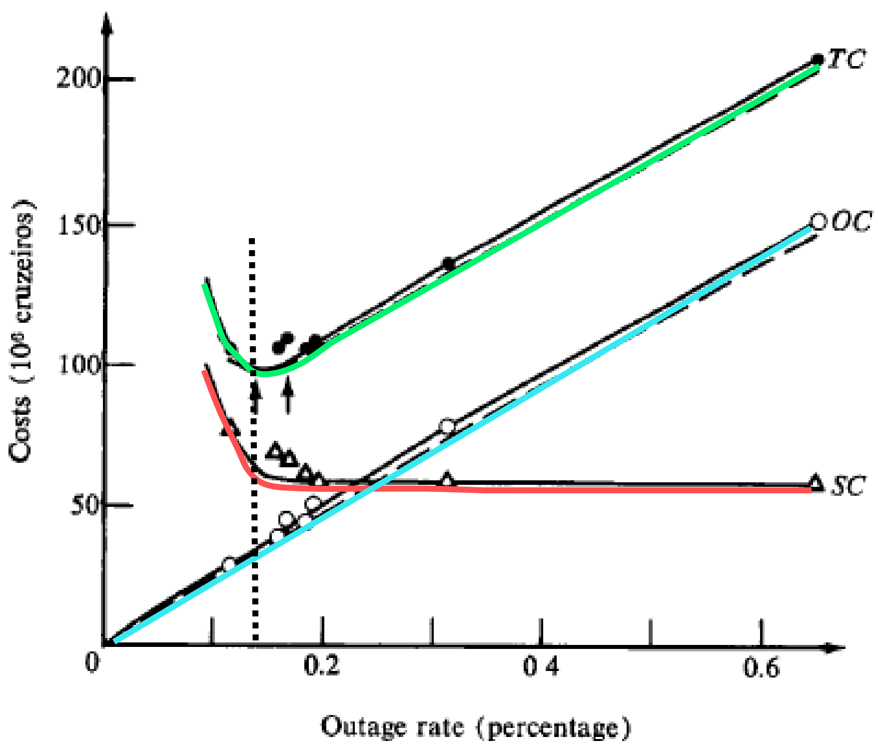


Figure 13.1. *Optimization of the Outage System: Costs Versus Outage Rate*

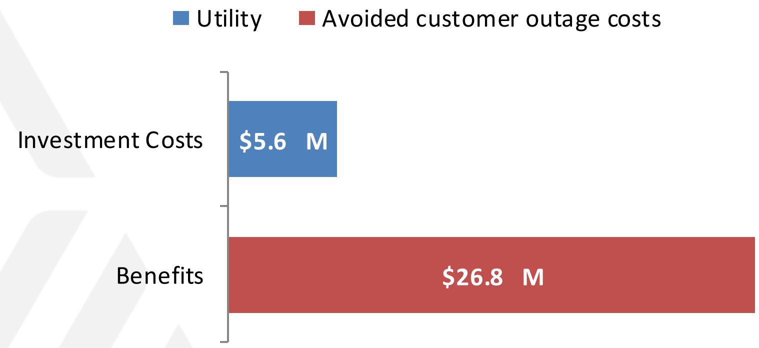


Note: SC = distribution system supply costs; OC = global outage costs; and TC = total costs. The plotted data points and solid lines refer to efficiency priced costs; the broken lines indicate the costs in terms of social prices.

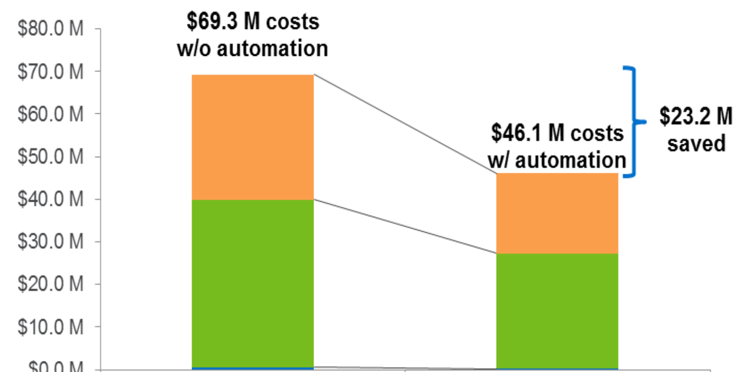
Value-Based Reliability Planning example: Distribution Automation

- Utility: EPB of Chattanooga
- Customers Impacted: 174,000 customers (entire territory)
- Investment: 1,200 automated circuit switches and sensors on 171 circuits
- Reliability Improvement:
  - SAIDI ↓45% (from 112 to 61.8 minutes/year)
  - SAIFI ↓51% (from 1.42 to 0.69 interruptions/year) (between 2010 and 2015)

Annual Costs and Benefits



Avoided Cost of Severe Storm



	Pre-Automation	Post-Automation
Large C&I	$29.4 M	$18.8 M
Small C&I	$39.3 M	$27.1 M
Residential	$0.6 M	$0.2 M

ICE Calculator: http://icecalculator.com

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Interruption Cost Estimate Calculator

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The Interruption Cost Estimate (ICE) Calculator is a tool designed for electric reliability planners at utilities, government organizations or other entities that are interested in estimating interruption costs and/or the benefits associated with reliability improvements.

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Use the ICE Calculator to:

- Estimate Interruption Costs
  Estimate the cost per interruption event, per average kW, per unserved kWh and the total cost of sustained electric power interruptions.
- Estimate Value of Reliability Improvement in a Static Environment
  Estimate the value associated with a given reliability improvement. The environment is "static" because the expected reliability with and without the improvement does not change over time.
- Estimate Value of Reliability Improvement in a Dynamic Environment
  Estimate the value associated with a given reliability improvement. The environment is "dynamic" because the expected reliability with and without the improvement changes over time based on forecasts of SAIFI, SAIDI and CAIDI.

This tool was funded by the Lawrence Berkeley National Laboratory and Department of Energy. Developed by Freeman, Sullivan & Co.

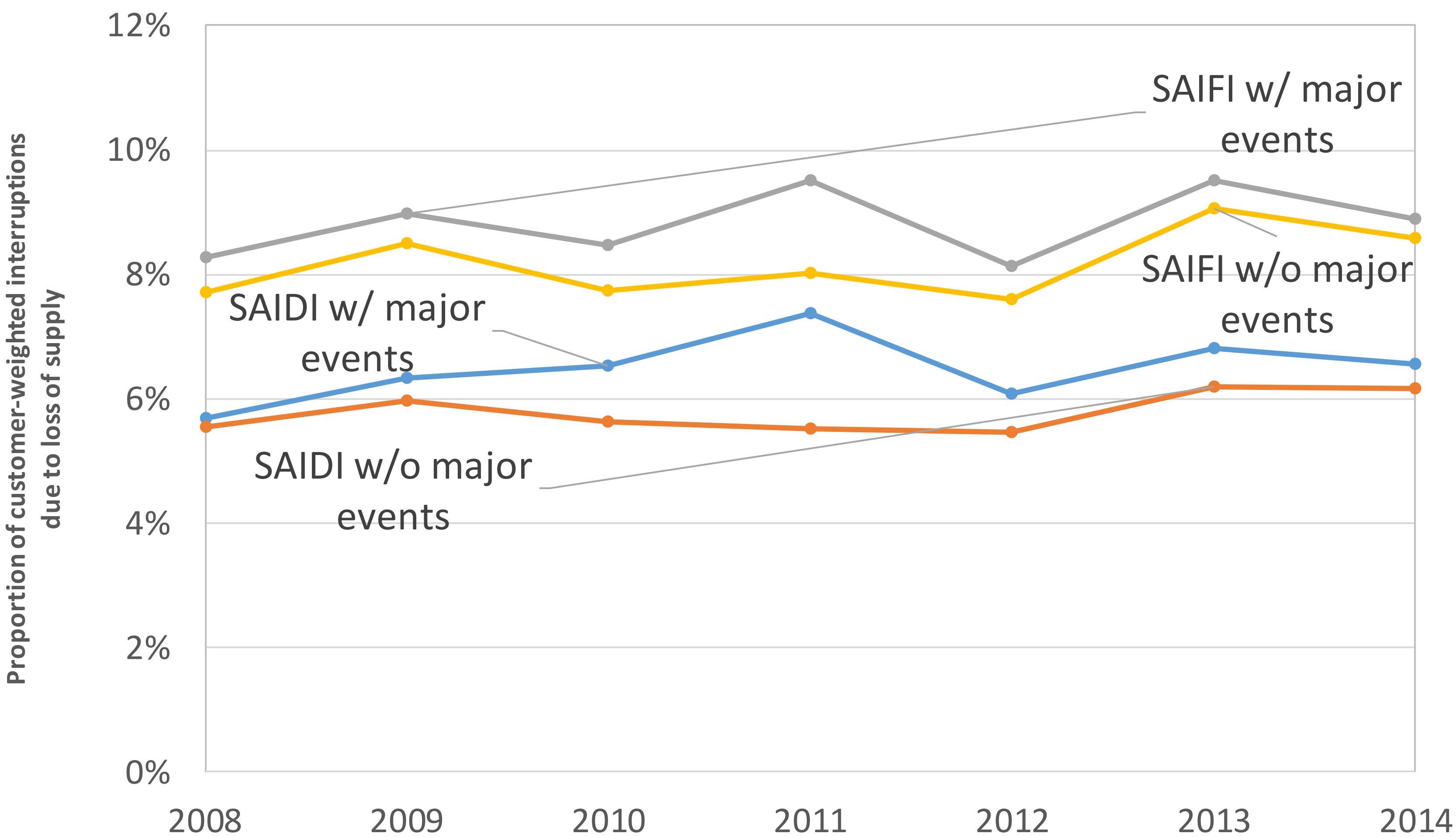
Learn more about the federal initiatives that support the development of the technologies, policies and projects transforming the electric power industry on SmartGrid.gov.

The Costs of Power Interruptions

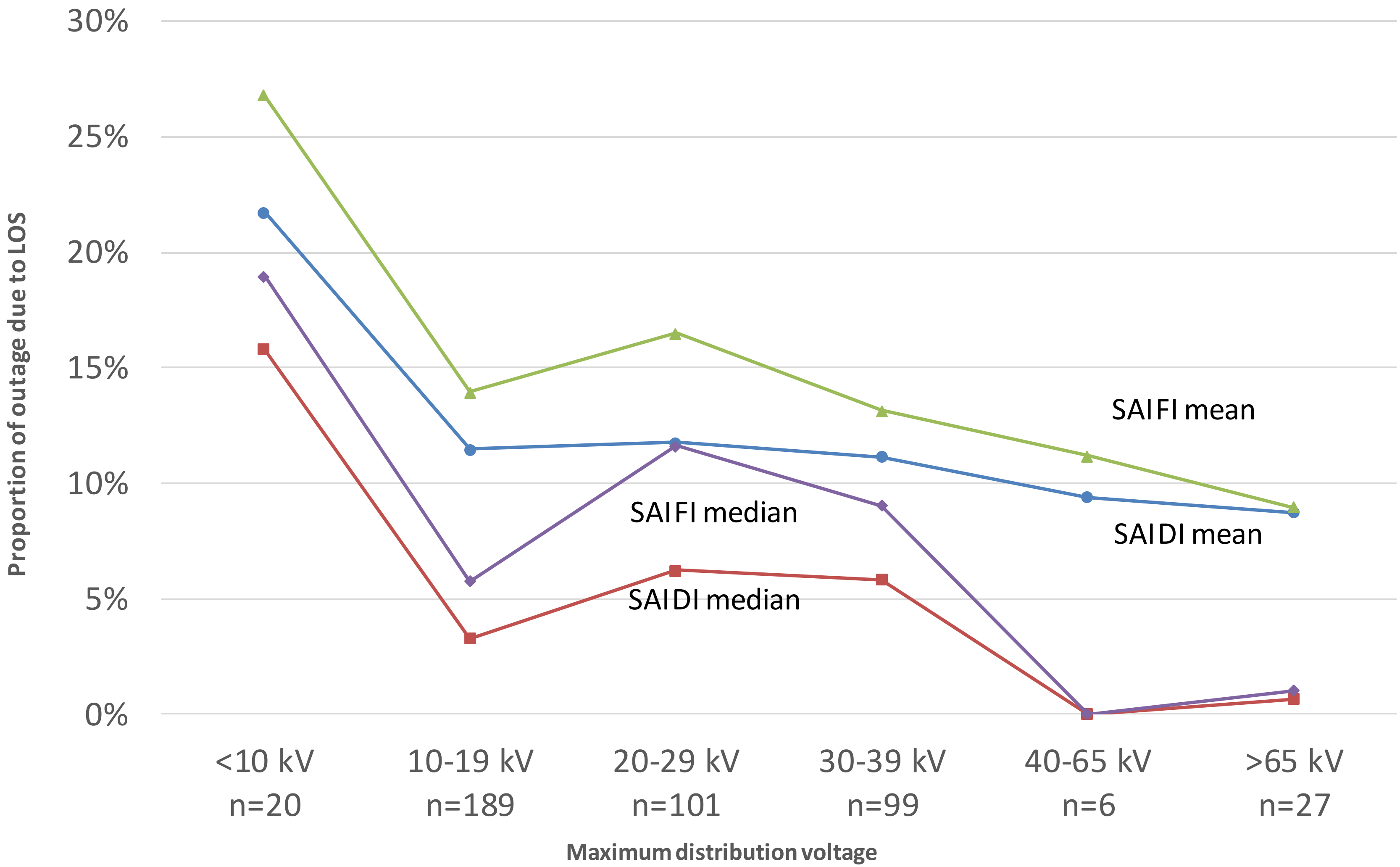
Varies by type of customer and depends on when and for how long their lights are out

Interruption Cost	Interruption Duration				
	Momentary	30 minutes	1 hour	4 hours	8 hours
Medium and Large C&I					
Morning	$8,133	$11,035	$14,488	$43,954	$70,190
Afternoon	$11,756	$15,709	$20,360	$59,188	$93,890
Evening	$9,276	$12,844	$17,162	$55,278	$89,145
Small C&I					
Morning	$346	$492	$673	$2,389	$4,348
Afternoon	$439	$610	$818	$2,696	$4,768
Evening	$199	$299	$431	$1,881	$3,734
Residential					
Morning	$3.7	$4.4	$5.2	$9.9	$13.6
Afternoon	$2.7	$3.3	$3.9	$7.8	$10.7
Evening	$2.4	$3.0	$3.7	$8.4	$11.9

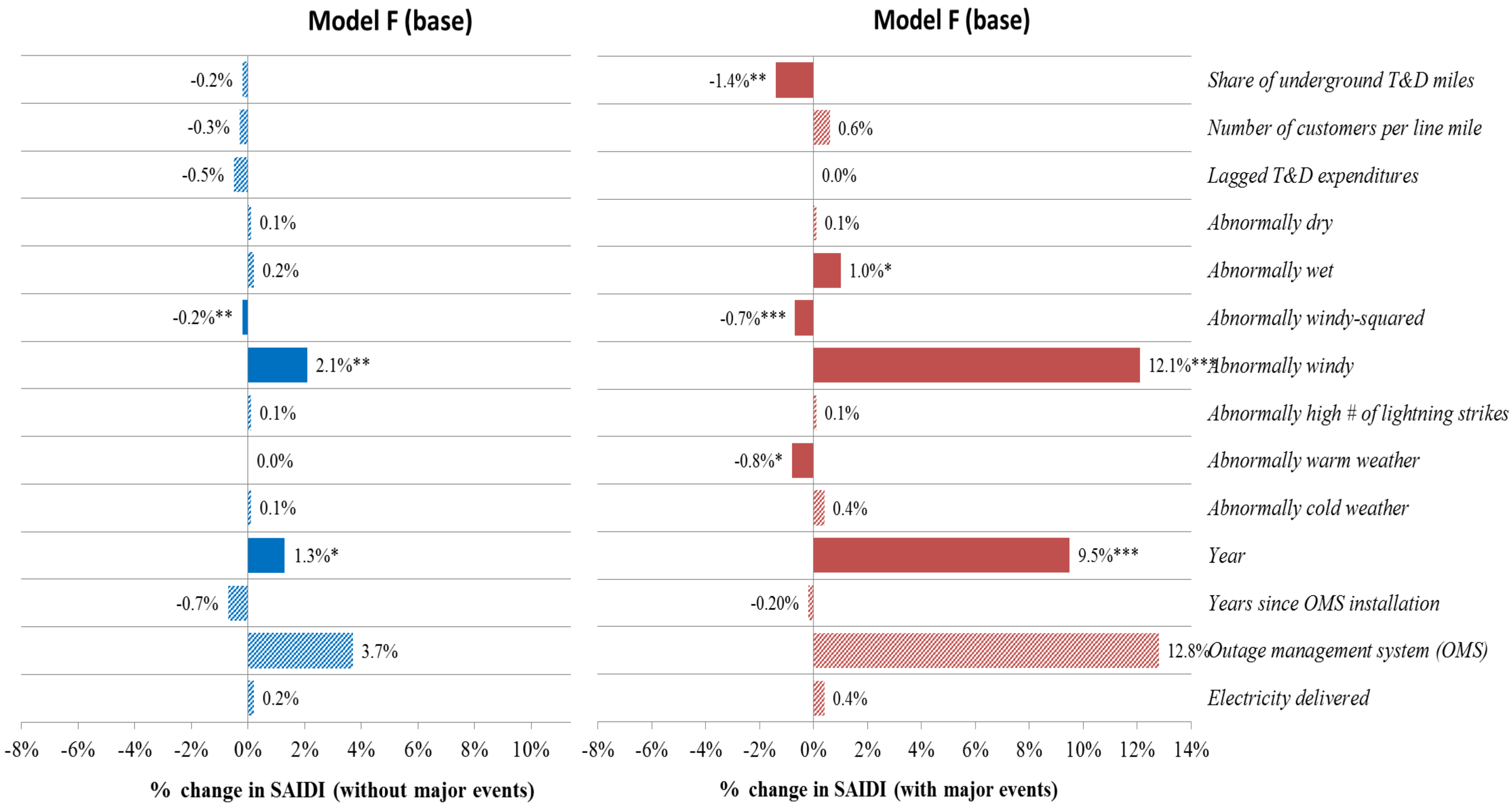
Customer-weighted proportion of SAIDI and SAIFI due to loss of supply (2008-2014, n = 73)



SAIDI and SAIFI due to loss of supply vs. maximum reported distribution voltage

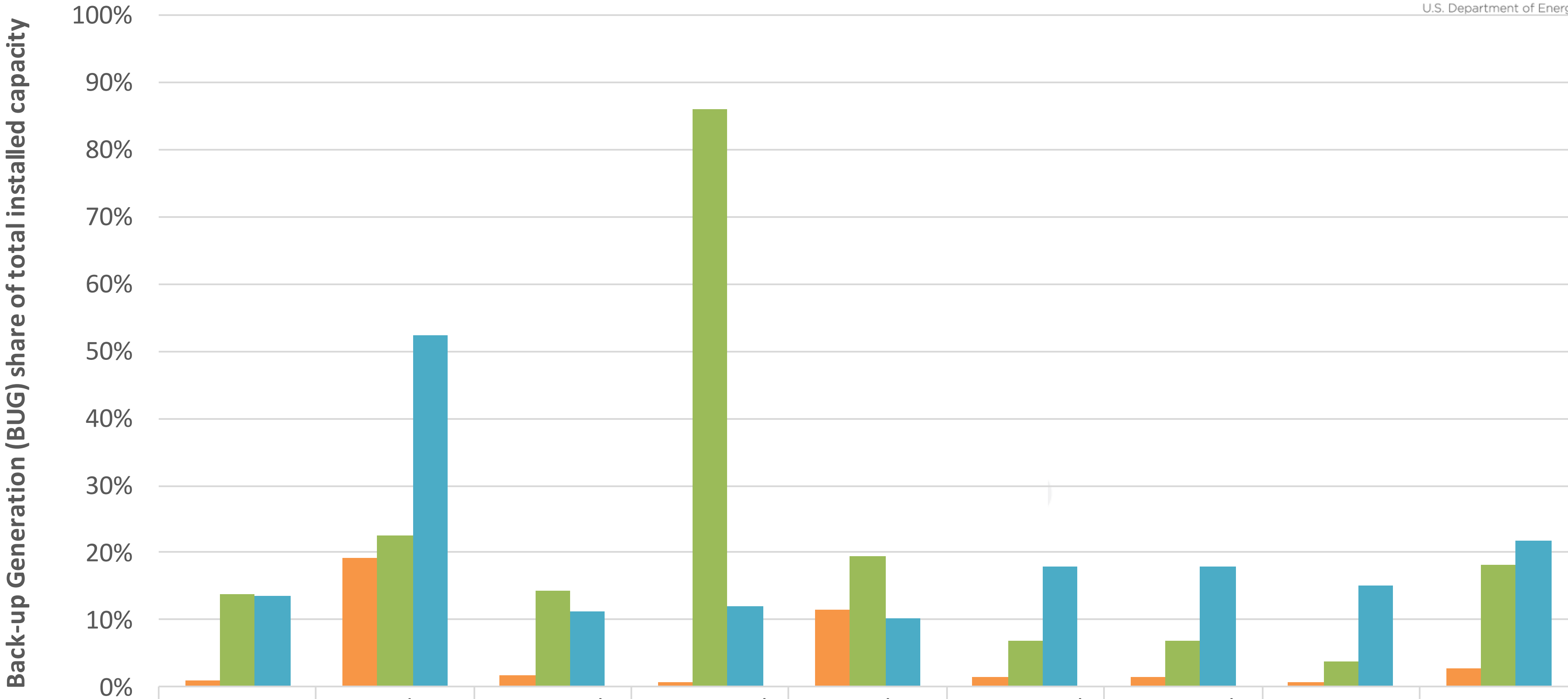


LBNL finds that reliability is getting worse due to increased severity/frequency of major events



Source: Larsen, P. K LaCommare, J. Eto, J. Sweeney. Recent Trends in Power System Reliability and Implications for Evaluating Future Investments in Resiliency. Energy 117 (2016) 29-46. http://dx.doi.org/10.1016/j.energy.2016.10.063

Installed Capacity of Back-up Generation



	New England	Mid-Atlantic	East North Central	West North Central	South Atlantic	West South Central	East South Central	Mountain	Pacific
Residential	1%	19%	2%	1%	11%	1%	1%	1%	3%
Commercial	14%	23%	14%	86%	19%	7%	7%	4%	18%
Industrial	14%	52%	11%	12%	10%	18%	18%	15%	22%

Source: Frost and Sullivan. 2015. "Analysis of the US Power Quality Equipment Market." Berkeley California: Lawrence Berkeley National Laboratory. LBNL-1003990. August. Accessible at: http://eetd.lbl.gov/sites/all/files/lbnl-1003990.pdf

Some themes to keep in mind

“What's measured improves”
— Peter F. Drucker

“Delegating your accountabilities is abdication”
— Michael E. Gerber

“Not everything that can be counted counts,
and not everything that counts can be counted”
— Albert Einstein

Bibliography

- LaCommare, Kristina Hamachi, Peter H. Larsen, and Joseph H. Eto. *Evaluating Proposed Investments in Power System Reliability and Resilience: Preliminary Results from Interviews with Public Utility Commission Staff*., 2017.https://emp.lbl.gov/sites/default/files/lbnl-_1006971.pdf

- Larsen, Peter H.. "A Method to Estimate the Costs and Benefits of Undergrounding Electricity Transmission and Distribution lines." *Energy Economics* 60, no. November 2016 (2016): 47-61. https://emp.lbl.gov/sites/default/files/lbnl-1006394_pre-publication.pdf

- Larsen, Peter H., Kristina Hamachi LaCommare, Joseph H. Eto, and James L. Sweeney. *Assessing Changes in the Reliability of the U.S. Electric Power System*., 2015. https://emp.lbl.gov/sites/default/files/lbnl-188741.pdf

- Eto, Joseph H., Kristina Hamachi LaCommare, Michael D. Sohn, and Heidemarie C. Caswell. "Evaluating the Performance of the IEEE Standard 1366 Method for Identifying Major Event Days View Document." *IEEE Transactions on Power Systems* 32, no. 2 (2016).

- Sullivan, Michael J., Josh A. Schellenberg, and Marshall Blundell. *Updated Value of Service Reliability Estimates for Electric Utility Customers in the United States*., 2015. https://emp.lbl.gov/sites/default/files/lbnl-6941e.pdf

- https://emp.lbl.gov/research/electricity-reliability