New Approaches to Estimating the Economic Impacts of Power Outages

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Selected Reliability/Resilience Research at Berkeley Lab

Reliability and Resilience Metrics

- EIA Form-861 – mandatory reliability reporting by all US electric utilities
- IEEE Distribution Reliability Working Group - technical review of IEEE Std. 1366 "major event day" classification
- NERC Performance Analysis Subcommittee – prepares annual State of Reliability report

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Economic Value of Reliability and Resilience ***(today's discussion)***

- **Interruption Cost Estimate (ICE) Calculator**
- **Leading national initiative to update the ICE Calculator with sponsorship from US electric utilities**
- **Reviewing regulatory treatment of utility expenditures to address resilience**
- **Pioneering new methods to estimate the economic impacts of widespread, long-duration power interruptions**

IEEE

ICE CALCULATOR

Reliability vs. Resilience: features, metrics, actions

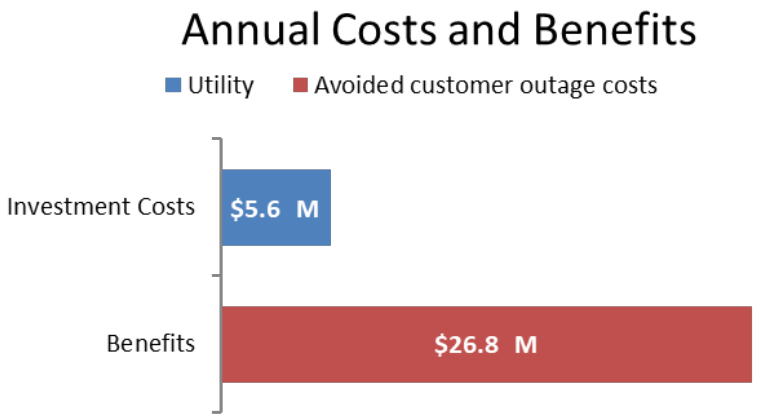
	Reliability	Resilience
Common features/ characteristics	• Routine, expected (though, not “planned”), normally localized, shorter duration interruptions of electric service • Larger events will make it into the local headlines	• Infrequent, unplanned, widespread/long duration power interruptions, often 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	• Familiar, but non-standardized, and generally 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 next slide)

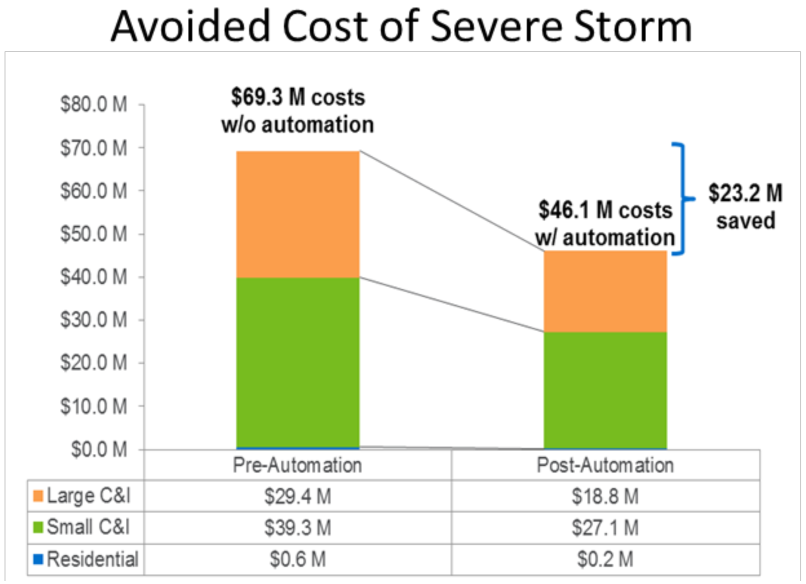
Reliability vs. Resilience: decision-making

	Reliability	Resilience
Entities involved in decision making	• Electric utility and its regulator/oversight board, primarily	• Electric utility and regulator; many times, acting in response to State legislative direction or Governor's orders • 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" risk • Limited opportunities to test strategies in the field • Large dollar amounts/extraordinary expenditures may require special approval/vote • Political leadership critical

Example of Reliability Value-based Planning

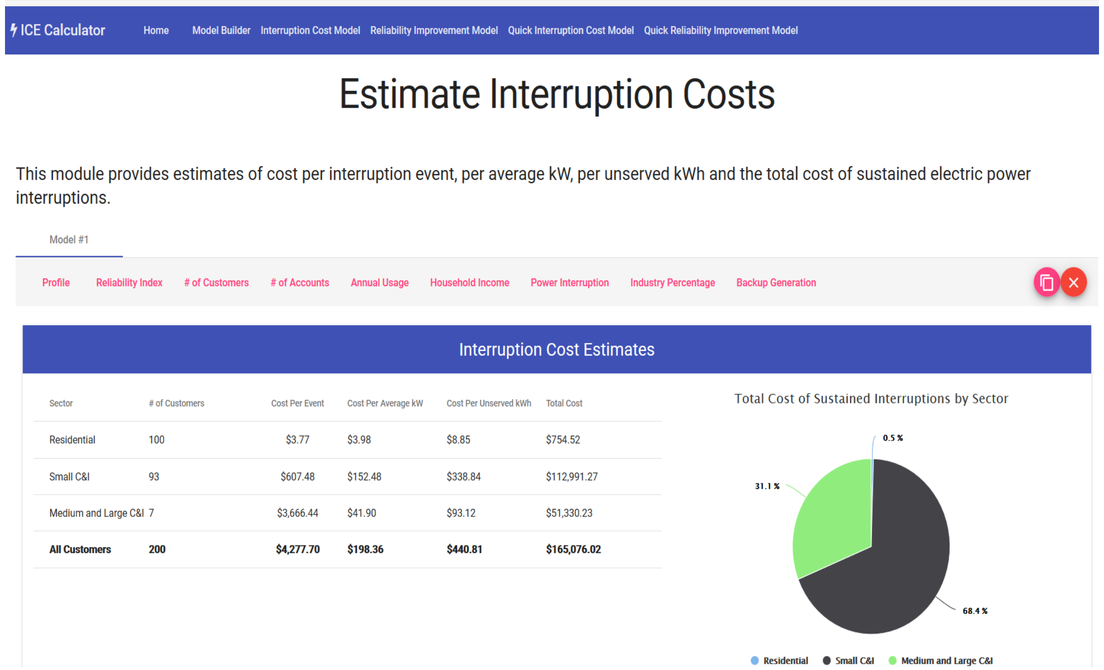
- Utility: EPB of Chattanooga
- Investment: 1,200 automated circuit switches and sensors on 171 circuits
- Reliability Improvement:
  - SAIDI ↓45% (from 112 to 61.8 minutes/year)
  - SAIFI ↓51% (from 1.42 to 0.69 interruptions/year) (between 2010 and 2015)





ICE Calculator Developed to Support Reliability Value-Based Planning

- Berkeley Lab's Interruption Cost Estimate (ICE) Calculator is the leading and only publicly-available tool for estimating the customer cost impacts of power interruptions
- ICE Calculator has been used to:
  - ❑ provide a basis for discussing utility reliability investments with regulators
  - ❑ assess the economic impact of past power outages
  - ❑ estimate total costs of power outages for U.S.



http://www.icecalculator.com/

ICE Calculator: 100,000+ utility-sponsored surveys of the costs customers incur when the lights go out

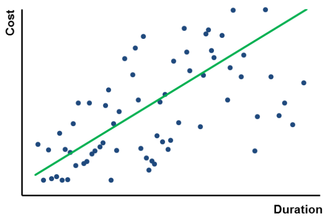
Forecast of Reliability

- SAIFI (frequency)
- SAIDI (mins. interrupted)
- w/ and w/o investment

Customer Survey Meta-database

- 34 surveys
- 10 utilities
- 1989-2012
- N=105,000

Econometric Meta-analysis



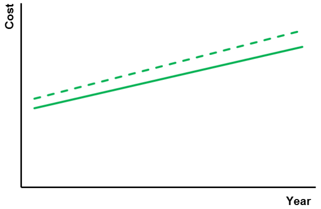
- Med/large C&I
- Small C&I
- Residential
- Other factors

ICE CALCULATOR

Customer Characteristics

- Customer class
- Usage (kWh)
- Industry

Forecast of Customer Outage Costs



- ICE Calculator output
- w/ and w/o investment

Updated analysis with new surveys and model coefficients published in 2015
https://emp.lbl.gov/publications/updated-value-service-reliability

National Initiative to Update the ICE Calculator

- Currently, the utility survey-based information relied on by the ICE Calculator is:
  - ❑ Dated—many of the surveys are 25+ years old
  - ❑ Not statistically-representative for all regions of the U.S.
  - ❑ Not appropriate for estimating costs of widespread, long-duration (> 24 hour) interruptions
- With encouragement from DOE and support from Edison Electric Institute, ***Berkeley Lab has launched a national initiative to update the ICE Calculator with sponsorship from U.S. utilities***

Utility Company	Survey Year	Number of Observations: Medium and Large C&I			Min. Duration (Hours)	Max. Duration (hours)
		Medium and Large C&I	Small C&I	Residential		
Southeast-1	1997	90			0	1
Southeast-2	1993	3,926	1,559	3,107	0	4
	1997	3,055	2,787	3,608	0	12
Southeast-3	1990	2,095	765		0.5	4
	2011	7,941	2,480	3,969	1	8
Midwest-1	2002	3,171			0	8
Midwest-2	1996	1,956	206		0	4
West-1	2000	2,379	3,236	3,137	1	8
West-2	1989	2,025	5		0	4
	1993	1,790	825	2,005	0	4
	2005	3,052	3,223	4,257	0	8
	2012	5,342	4,632	4,106	0	24
Southwest	2000	3,991	2,247	3,598	0	4
Northwest-1	1989	2,210		2,126	0.25	8
Northwest-2	1999	7,091		4,299	0	12

Planned Outcomes

- Upgraded ICE Calculator will:
  - more accurately value reliability investments that reduce/avoid interruptions lasting up to 24 hours
  - reflect utility recommendations that improve the tool's design and performance (e.g., incorporate API for direct connection to utility or third-party planning software)
  - be branded as ICE Calculator 2.0—to communicate that this an upgrade to an existing tool that is widely cited in support of utility regulatory filings related to investments in reliability/resilience

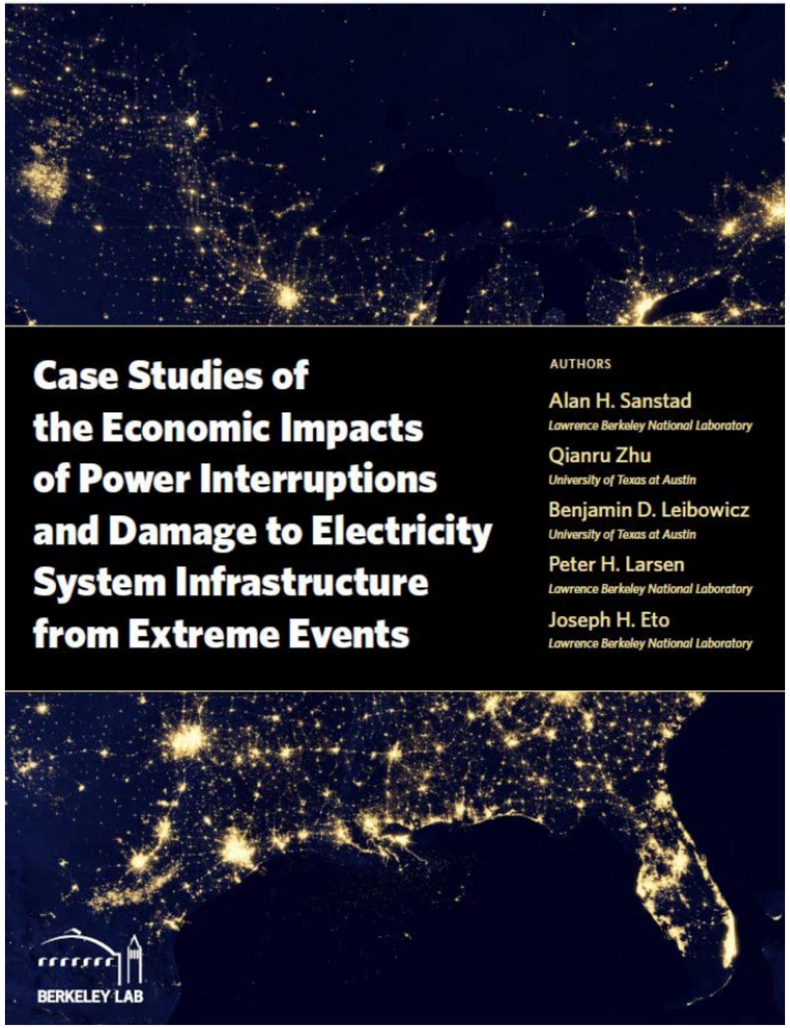
- **Berkeley Lab will use information from supplemental survey questions to continue to pioneer alternative methods for estimating the economic impacts of widespread outages lasting longer than 24 hours**

- Long-term goal of incorporating economic impacts of widespread, long duration outages into the ICE Calculator (Phase II)

Recent Berkeley Lab Report on Role of Economic Information in Resilience Decisions

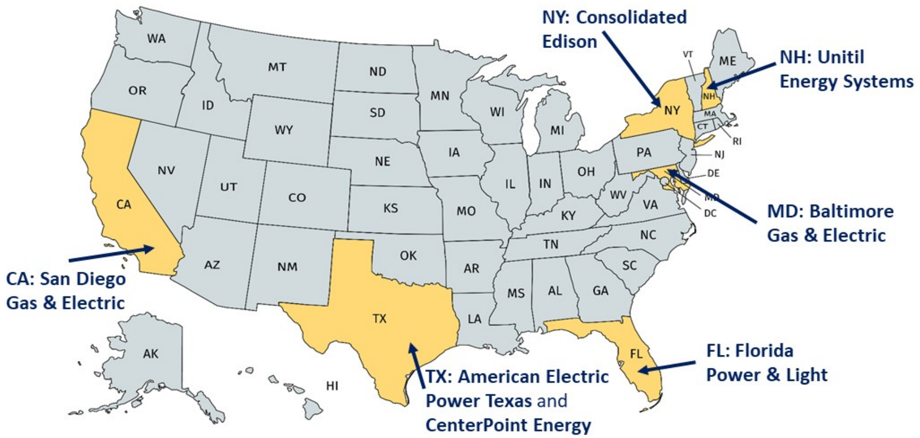
- *Long-duration, widespread power interruptions* (LDWIs) are those lasting days, weeks or longer, and affecting entire utility service territories or larger regions—often caused by extreme weather

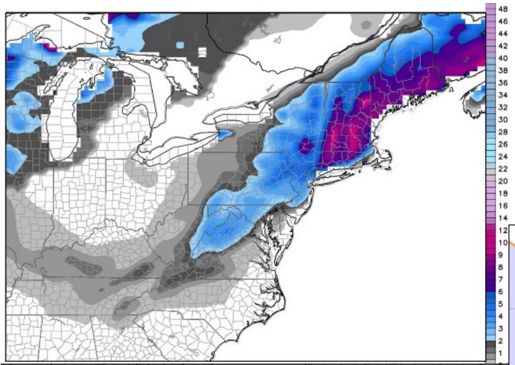
- **There is a growing need on the part of utilities and policymakers for information on the:**
  1. **Economic impacts of LDWIs**
  2. **Costs and benefits of investments to mitigate such impacts**

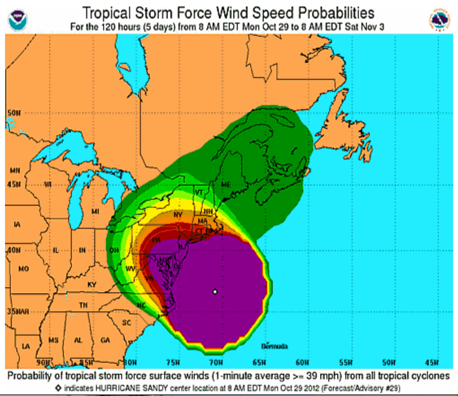


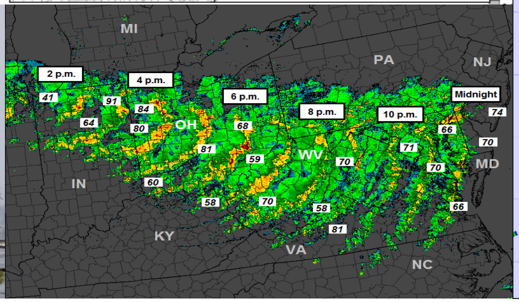
Approach and Scope

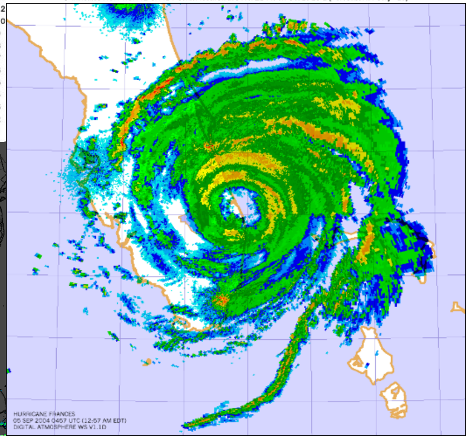
- We conducted case studies of investor-owned utilities and regulatory processes in six jurisdictions—selected for geographic, regulatory, utility-practice, and extreme event-type variation.











Research Method

Availability of information on categories of economic impacts summarized in tables…	
Symbol	Key
●	Extensive publicly-available documentation
◒	Moderate amount of publicly-available documentation
○	Little/no publicly-available documentation

- Economic information related to cost recovery including:
  1. Transmission system costs
  2. Distribution system costs
  3. Generation system costs
  4. Increased customer service costs
  5. Other costs

- Economic information related to mitigating future impacts including:
  1. Avoided customer interruption costs
  2. Avoided regional economic impacts
  3. Other avoided societal impacts
  4. Other
  5. Cost-effectiveness or cost-benefit analysis conducted?

Summary of Available Information:
Cost Recovery

- **Utilities have a long history of assessing the damage (costs) to their systems in the immediate aftermath of a natural disaster....**

Availability of economic information related to cost recovery…

Utility	**Precipitating Event**	**Trans. System Costs**	**Dist. System Costs**	**Gen. System Costs**	**Increased Customer Service Costs**	**Other Costs**
Florida Power & Light (FL)	Hurricanes of 2004-2005	●	●	●	●	●
Consolidated Edison (NY)	Tropical Storm Sandy	●	●	●	●	●
AEP Texas (TX)	Hurricanes of 2005, 2008, and 2017	●	●	N/A	◒	●
San Diego Gas and Electric (CA)	2007 Southern California wildfires	○	○	○	○	○
Unitil Energy Systems (NH)	Severe fall and winter storms	N/A	●	N/A	○	○
Baltimore Gas & Electric (MD)	June 2012 Derecho	●	●	●	○	○

Summary of Available Information:
Mitigating Future Impacts

Availability of economic information related to mitigating future customer and regional impacts…							
Organization	**Precipitating Event**	**Avoided Customer Interruption Costs**	**Avoided Regional Economic Impacts**	**Other Avoided Societal Impacts**	**Other**	**Cost-Effectiveness Analysis?**	**Cost-Benefit Analysis?**
Florida Power & Light (FL)	Hurricanes of 2004-2005	○	○	○	○	Yes	No
Consolidated Edison (NY)	Tropical Storm Sandy	●	○	○	○	Yes	Yes
City of New York (NY)	Tropical Storm Sandy	○	◒	○	○	Yes	Yes
CenterPoint Energy (TX)	Hurricanes of 2005, 2008, and 2017	◒	○	○	○	Yes	Yes
San Diego Gas and Electric (CA)	2007 Southern California wildfires	◒	○	○	○	Yes	No
Unitil Energy Systems (NH)	Severe fall and winter storms	○	○	○	○	Yes	No
Grid Resiliency Task Force (MD)	June 2012 Derecho	●	○	○	○	Yes	Yes

…but utilities and other stakeholders struggle to justify preventative investments, because they *do not* know the value of those investments (e.g., avoided economic impact or social burden)

Summary of Key Findings

1. ***How do utilities assess the costs of system damage caused by extreme weather and the costs of recovering from this damage?***
   - Utilities conduct detailed physical and engineering assessments of damages
   - They estimate costs of replacement and repair as well as response and recovery operations
2. ***How do utilities estimate customer costs of past power interruptions?***
   - **Utilities often report statistics, including the counts, locations, and durations of customers without power, but generally did not monetize these customer impacts**
3. ***How do utilities or others estimate the costs and benefits of investments to reduce power system vulnerabilities to future extreme weather events?***
   - **Costs of preventive investments can be estimated with reasonable accuracy, but the economic benefits are very uncertain**; Cost-effectiveness analysis is the most common method
   - Berkeley Lab's ICE Calculator was used, but there was no evidence of avoided cost information being developed specifically for LDWI applications
   - **No utility or regulator used regional economic modeling to estimate either direct or indirect costs of power interruptions**

Summary of Key Findings (cont.)

4. ***How do utilities and regulators use the concept of resilience in economic assessments of extreme weather impacts and the value of preventive investments?***
   - Utilities and regulators referred to "resilience" extensively in two of the case studies, a moderate amount in two others, and very little in the remaining two
   - **"Resilience investments" were typically related to traditional storm hardening, for example, but at greater scale and cost**
   - **Challenge is not what "resilience metrics" should be used, but rather how to value proposed investments using these metrics within a cost-benefit framework**
5. ***How do regulatory processes influence utilities' economic analysis related to power interruptions?***
   - Laws, regulations, and regulatory practices can significantly influence utilities' preparation for, and response to, long-duration widespread power interruptions
   - **New economic tools and methods are usually developed and/or adopted through collective decision-making involving utilities as well as other stakeholders, rather than unilaterally by utilities**

Key Policy Recommendations

1. Mandate the consistent and comprehensive collection of information on past extreme events

2. **Support economic analysis of avoided costs associated with preventing long-duration, widespread power interruptions**

3. Support research that identifies barriers and solutions to ensure that economic information is used in long-term planning and procurement for reliability/resilience

How to Estimate Economic Impact of Widespread, Long Duration Power Interruptions?

The Challenge:

- Existing survey-based information detailing customer costs is dated, not statistically representative of the US, as a whole, and *not well-suited for long duration/widespread interruptions*.
- Regional economic models, which can estimate direct and indirect impacts of longer duration power outages, are often difficult to interpret, do not fully consider customer behavior, and/or do not always produce results that are used in planning.
- Regulators and utilities need simple and accessible tools to assess the value of investments to avoid short (long), local (widespread) power interruptions…

…Develop a Power Outage Economics Tool (POET)

One Solution:

- Conduct *hybrid* resilience valuation approach that integrates:
  1. Survey-based techniques to identify mitigating/adaptive behaviors that residential, commercial, industrial, and public sector customers may take to reduce risk before, during, or after a power interruption occurs
  2. Regional economic models that have been calibrated—using survey responses—to assess the full range of economic impacts from power interruptions
- Develop a Power Outage Economics Tool (“POET”) that allows users to estimate direct and indirect impacts of power interruptions under a wide range of scenarios

Customer Surveys

- How much were your overall costs reduced by shifting the time or location of your production?
- By how much were your overall costs reduced by having backup generation?
- ***Direct costs of interruptions < 24 hours***

CALIBRATION

Regional Economic Model(s)

- ***% and $ change in sales revenue***
- ***% change in producer (consumer) prices***
- ***% and $ change in net economic output***
- ***% change in labor supply (demand)***

Results by business sector and region for outages > 24 hours

POET Field Demonstration

- **We are collaborating with Commonwealth Edison (ComED) to develop a simple-to-use online version of POET that estimates direct and indirect impacts of both short- and long-duration power interruptions under a wide range of scenarios**
- During the field demonstration, we will explore some critical issues (e.g., complexity of regional economic models and their data intensity, the costs of survey design and implementation, differences in results between direct elicitation and model output)

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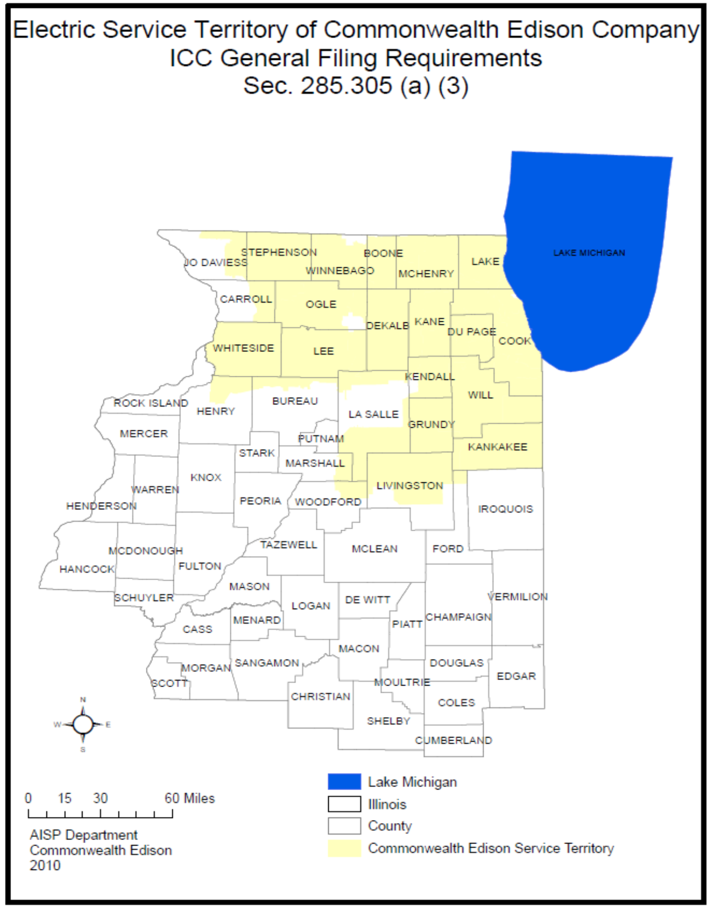

POET Outcomes

Metric	Category	Description of Economic Impact Metric
1	Welfare	% change in welfare—i.e., economic well-being (as measured by an approximation of personal income)—due to the outage in each of the nine household income classes for the 14 model regions
2	Gross output	% and $ change in gross output (i.e., sales revenue) in each of the 34 sectors x 14 model regions
3	Producer prices	% change in producer sale prices of each of the 34 commodities x 14 model regions
4	Uses of intermediate inputs	% change in region-specific quantities of goods and services that are used to produce other goods and services (e.g., raw materials, processed goods and components, electricity) , in each of the 34 commodities x 14 model regions
5	Consumer prices	% change in region-specific consumer prices of each of the 34 commodities x 14 model regions
6	Value added (~ gross regional product)	% and $ change in net economic output for each of the 34 commodities x 14 model regions
7	Employment	% change in labor demand/supply for the 14 model regions; this represents total labor demand (supply) in each region divided by the benchmark labor demand (supply) for that region; Note: This is not jobs, but hours worked multiplied by wage rates.

Outage Duration (days to weeks)

Outage Extent (county-level to service territory-level)

✖ **14 Regions** ✖ **34 Economic Sectors** =

Key Outcome:

State-of-the-art information on the economic impacts of long duration, widespread power interruptions will allow ComEd to estimate the avoided impact (*or benefit*) from proposed investments in resilience.

Interested in learning more about participating in ICE Calculator 2.0?

Email me:
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Interested in learning more about our research?

Link:
https://emp.lbl.gov/

Contact Information

Peter Larsen, Staff Scientist/Department Head

Peter conducts research and analysis on electricity reliability and resiliency, energy efficiency, and regional electric system planning including: Energy Services Company Industry and Market Trends; Utility Resource Planning Practices and Trends; Western Electricity and Natural Gas Markets; Societal Impacts from Abnormal Weather; and the Reliability of the U.S. Power System. Peter holds a Ph.D. in Management Science and Engineering from Stanford University; M.S. degrees from Stanford University (Management Science and Engineering) and Cornell University (Natural Resource Economics); and a B.A. in Economics from the University of Montana at Missoula.

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