ICE Calculator 2.0: Quantifying the Cost of Power Outages

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ICE Calculator 2.0 Overview

What? The ICE Calculator 2.0 is being updated by this multiple year project

Who? Users can apply the calculator to determine the costs customers incur during outages

Why? The old calculator, ICE 1.0, is dated

How? Utilities across the USA are working with Resource Innovations and Berkeley Lab

Imagine this…

❑ It's 7:00 p.m. in your home and the power goes out.

❑ Dinner is half-cooked in the oven, the house is sweltering, and your kids are trying to finish homework by flashlight. The air conditioner is silent. Your phone battery is draining fast. You're stressed and inconvenienced.

How much would you be willing to pay to avoid the outage?

ICE Calculator Purpose

❏ Resource Innovations and Berkeley Lab's Interruption Cost Estimate (I.C.E.) Calculator is the leading and only publicly-available tool for estimating the customer cost of power interruptions (icecalculator.com)

❏ Why does the ICE Calculator matter?
- Supports internal utility reliability planning activities
- Provides a basis for discussing utility reliability investments with regulators
- Assesses the economic impact of past power outages

Motivation for Updating the ICE Calculator

❑ The original ICE Calculator, ICE 1.0, is based on utility-sponsored customer surveys

❑ Challenges with ICE 1.0 surveys:

- Dated–many of the surveys are 25+ years old

- Not statistically representative of all regions of the U.S.

- Limited survey data available for estimating the cost of interruptions over 12 hours

Summary of ICE 1.0 Surveys

Utility Company	Survey Year	Number of Observations			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

ICE 2.0 Participating Utilities: Phase 1
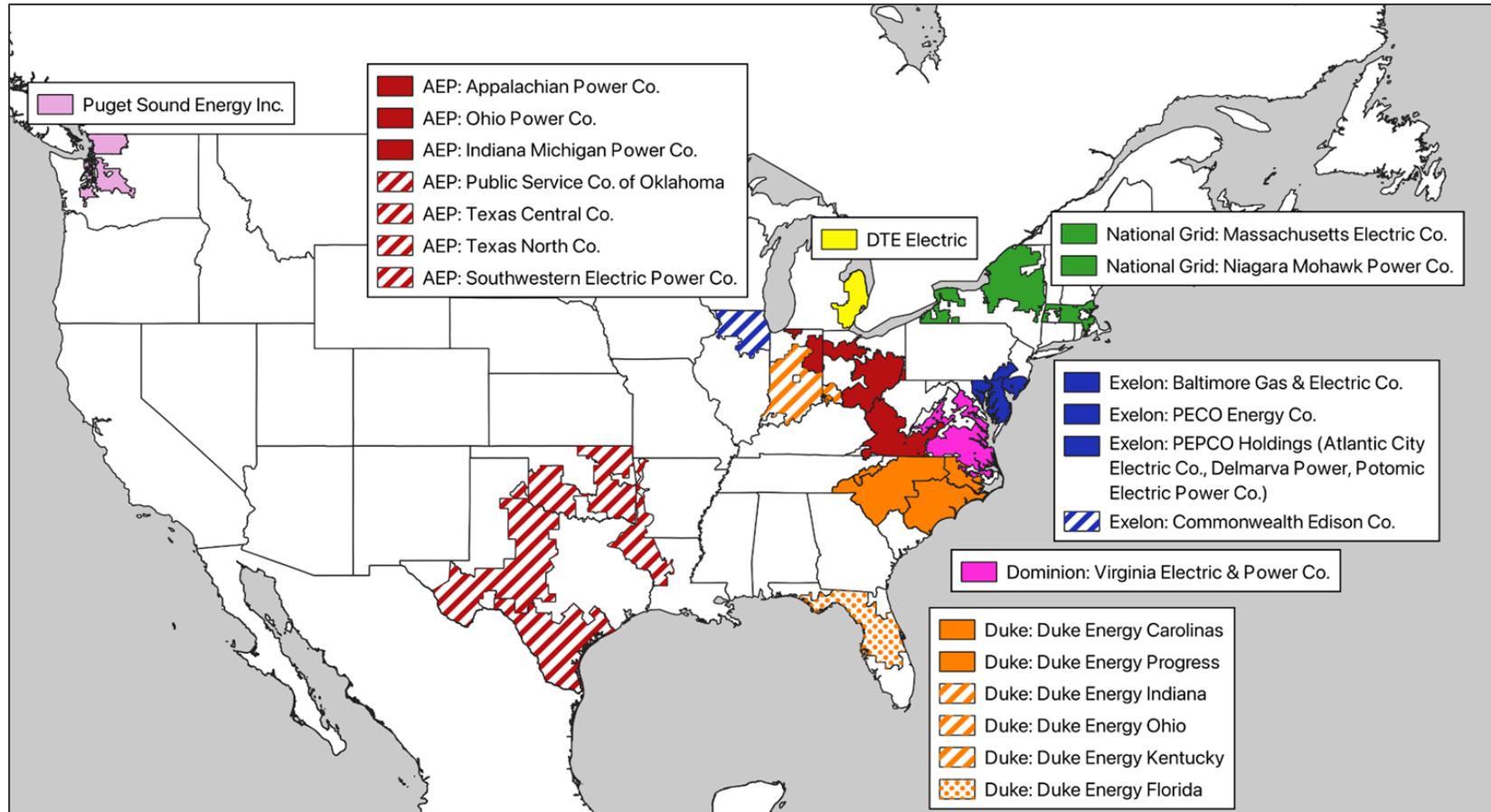
❑ Surveys were launched for each sponsoring utility

❑ 11 distinct survey activities

❑ 24 investor-owned utility distribution service territories represented

ICE 2.0 Participating Utilities: Phase 1 and 2
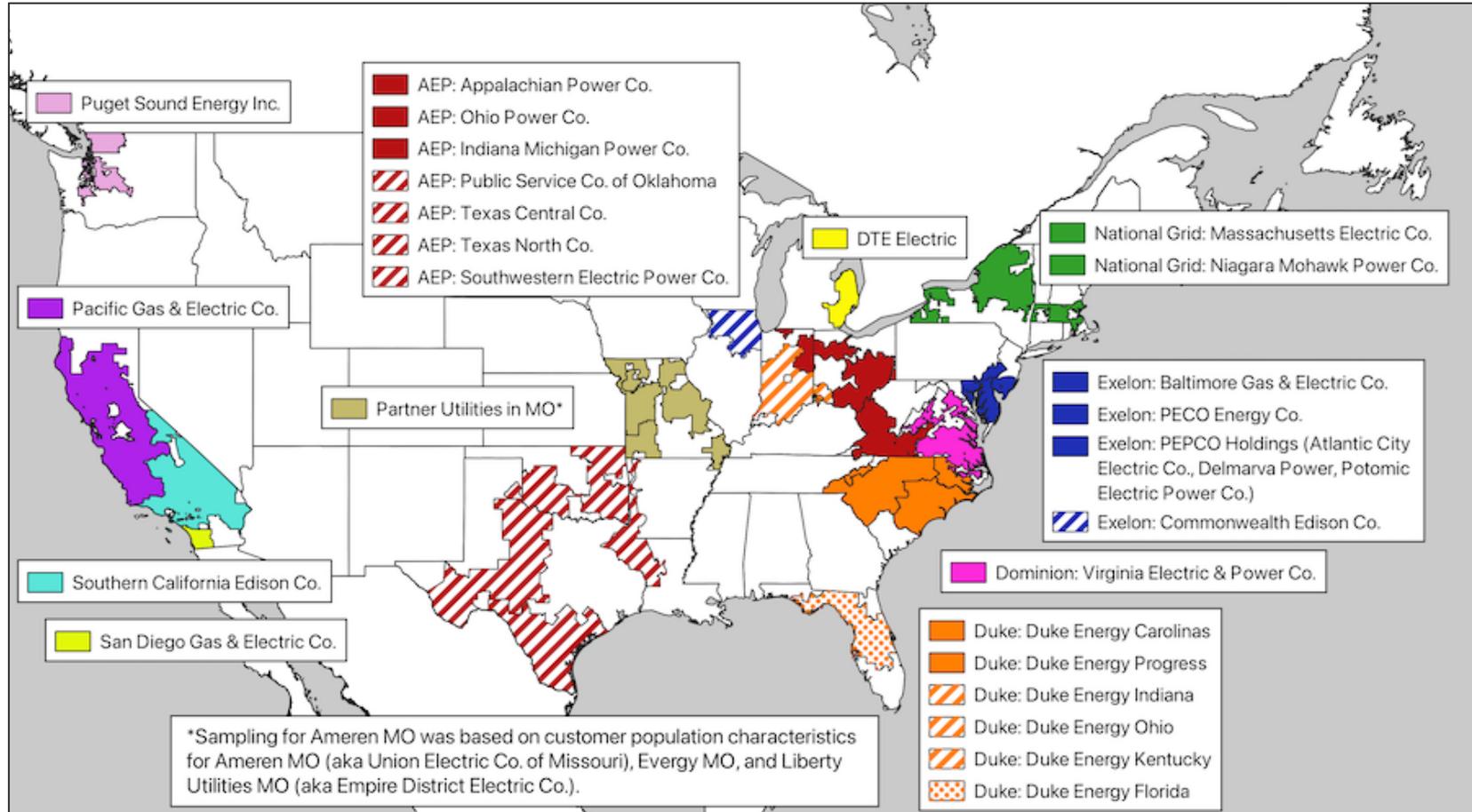
❏ The ICE Calculator will incorporate data from Phase 2 this year

Upcoming Phase 3:

❏ We received support from U.S. DOE to partner with NRECA to survey select rural cooperatives across the U.S.

❏ One utility in the West

❏ Recruiting ongoing

Steps to Develop ICE Calculator 2.0

Step 1 — A representative sample of residential and non-residential customers is selected to be surveyed

Step 2 — The ICE 2.0 surveys are administered to this sample of respondents

Step 3 — The survey responses are analyzed and average interruption costs are estimated

Step 4 — The results of these surveys are incorporated to update the ICE calculator
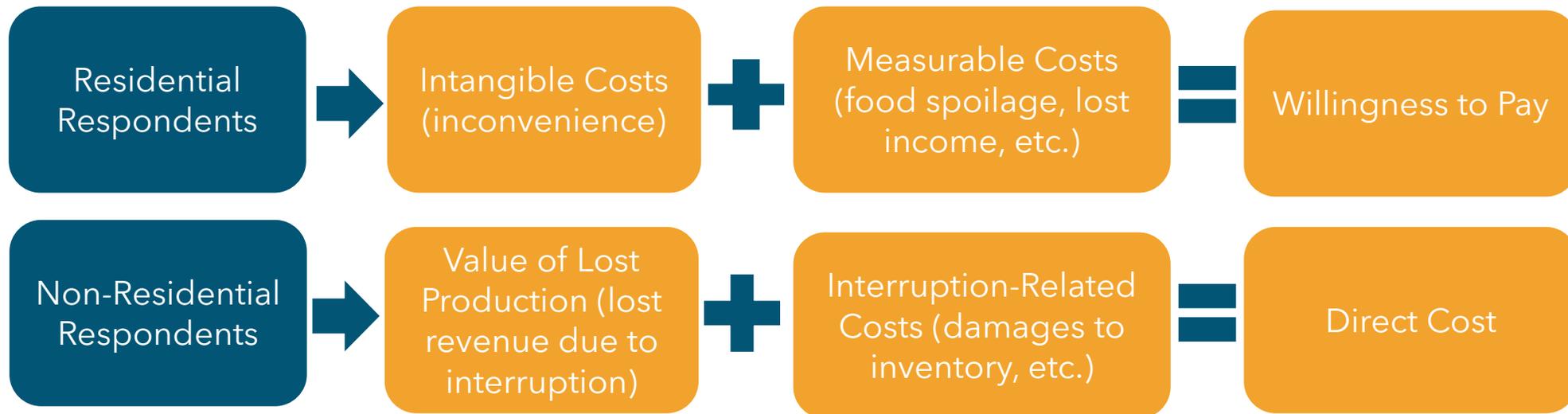
Surveying Summary

❏ Three different online customer surveys: residential, small/medium non-residential (SMNR), and large non-residential (LNR)

❏ Stratified sample of customers in each class based on usage

❏ Four interruption durations: momentary (up to 5 min), 2 hours, 8 hours, and 24 hours

❏ Four interruption scenarios: season, day of week, time of day, and advanced warning

Summary of Phase 1 ICE 2.0 Surveys

| Utility	Survey Responses		
	Residential	SMNR	LNR
Study 1	300	330	91
Study 2	289	307	56
Study 3	300	350	74
Study 4	332	300	100
Study 5	301	300	73
Study 6	295	300	72
Study 7	300	330	113
Study 8	300	401	33
Study 9	300	350	110
Study 10	300	402	26
Study 11	305	336	125
Total	**3,322**	**3,706**	**873**

Valuation Approach

❑ Residential respondents surveyed based on a willingness-to-pay (WTP) approach

❑ Non-residential customers surveyed based on a direct cost approach

| Residential Respondents | → | Intangible Costs (inconvenience) | + | Measurable Costs (food spoilage, lost income, etc.) | = | Willingness to Pay |
| Non-Residential Respondents | → | Value of Lost Production (lost revenue due to interruption) | + | Interruption-Related Costs (damages to inventory, etc.) | = | Direct Cost |

How ICE Models Function

❑ Processed survey responses were used develop customer damage functions (CDFs)

❑ These equations correlate interruption costs to a range of explanatory variables

- Duration, electricity consumption, income, industry types, and more

❑ The customer damage functions allow users to estimate interruption costs for specific customer populations
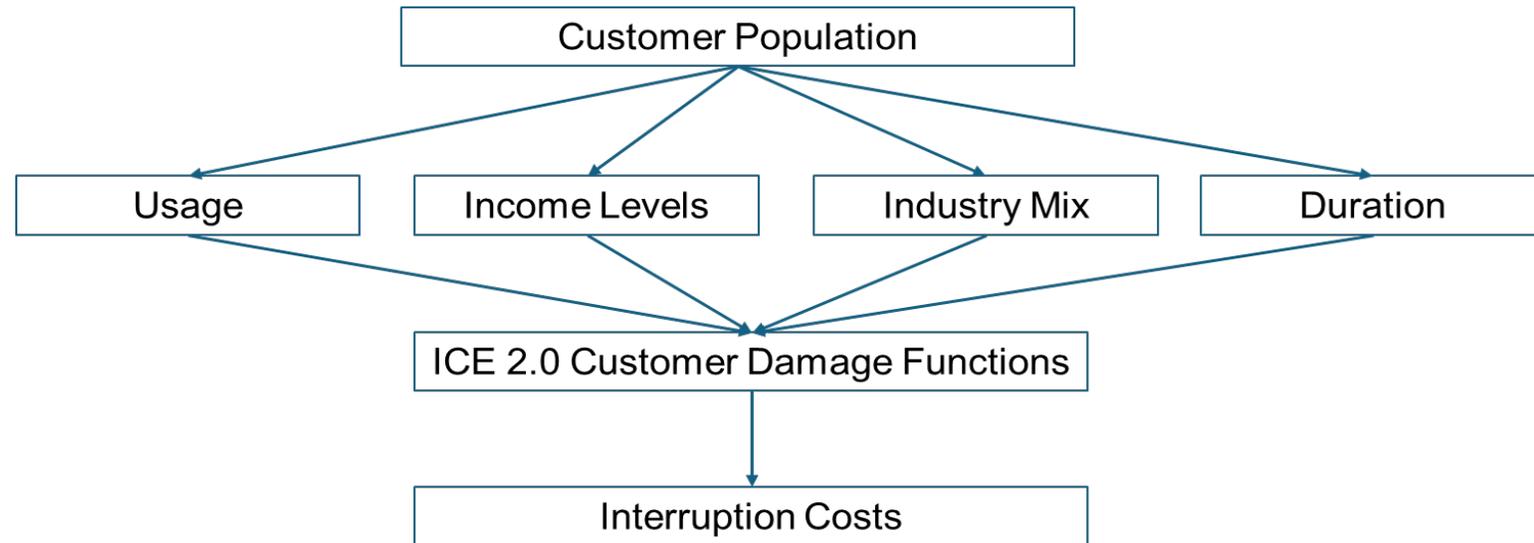
Residential Model Selection

Potential Model Variables

Continuous Variables	
Interruption Duration (in minutes)	
Annual Electric Usage (in kWh)	
GDP per KWH (collected at the state level)	

Categorical Variables	
Interruption Specific	**Demographics**
Interruption Onset Time	Persons in Household
Season	Ownership of Backup Generation
Day of Week	Work from Home
Advance Warning	Age of Respondent
Previous Interruption in Last 12 Months	Total Household Income
	Housing Type

Model Selection →

Final Residential Model

Continuous Variables
Interruption duration (in minutes)
Annual electricity usage (in kWh)

Categorical Variables
Season

- Summer
- Winter

Ownership of Backup Generation
- Yes
- No

Work from Home Status
- Yes
- No

Total Household Income
- Under $50,000 per year
- $50,000-$100,000 per year
- $100,000-$150,000 per year
- Over $150,000 per year

Non-Residential Model Selection

Potential Model Variables

Continuous Variables	
Interruption Duration (in minutes)	
Annual Electric Usage (in kWh)	
GDP per KWH (collected at the state level)	

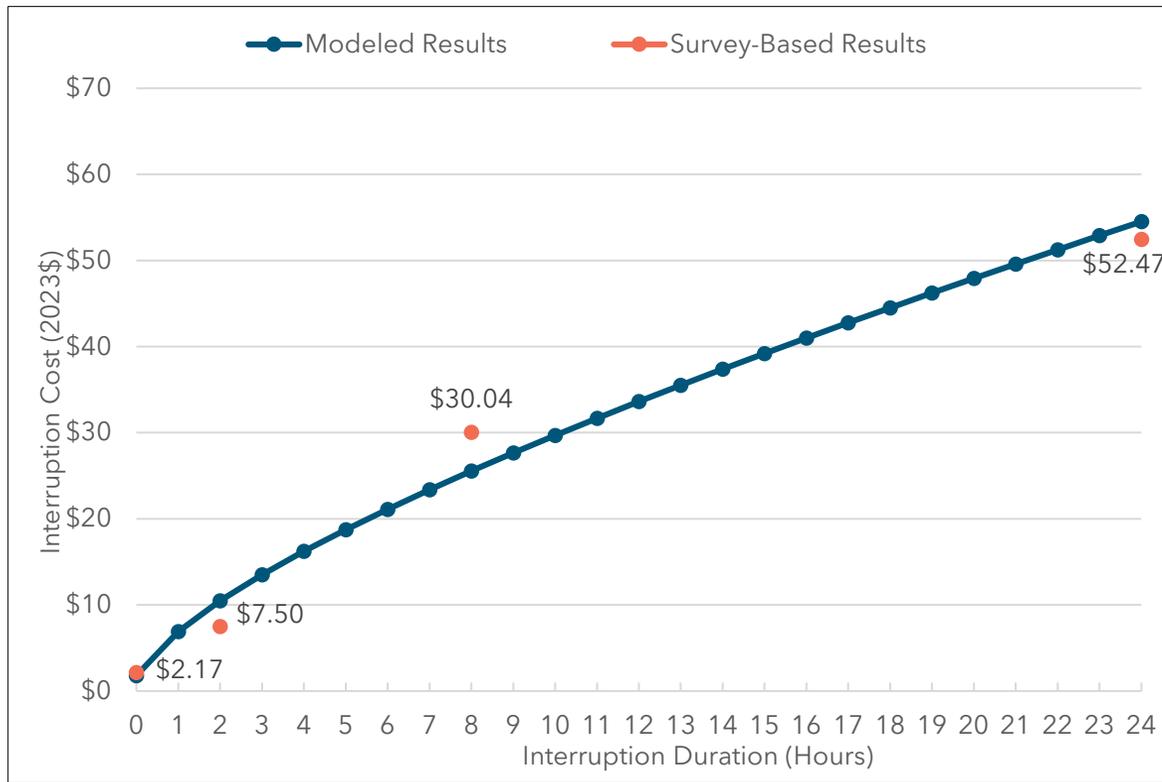| Categorical Variables	
Interruption Specific	**Demographics**
Interruption Onset Time	Ownership of Backup Generation
Season	Industry
Day of Week	
Advance Warning	
Previous Interruption in Last 12 Months	

Model Selection →

Final Residential Model

Continuous Variables
Interruption duration (in minutes)
Annual electricity usage (in kWh)

Categorical Variables
Advance Warning
• Yes
• No
Day of Week
• Weekday
• Weekend
Industry
• Health Care and Social Assistance
• Manufacturing
• All other industries

ICE 2.0 Phase I Modeled Results

Residential

Modeled Results — Survey-Based Results

Interruption Cost (2023$) vs. Interruption Duration (Hours)

$2.17
$7.50
$30.04
$52.47

Non-Residential

Modeled Results — Survey-Based Results

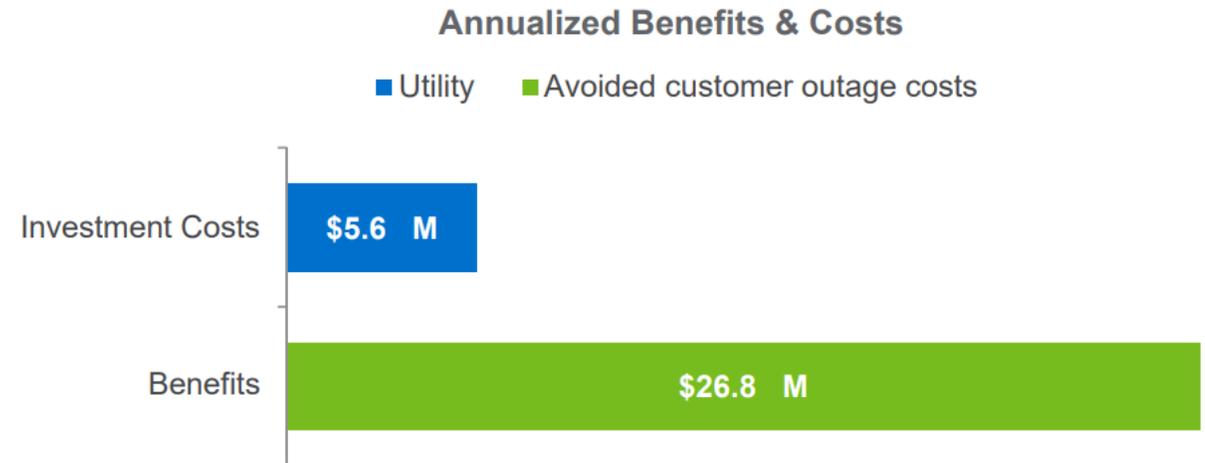Interruption Cost (2023$) vs. Interruption Duration (Hours)

$772
$2,771
$6,568
$11,677
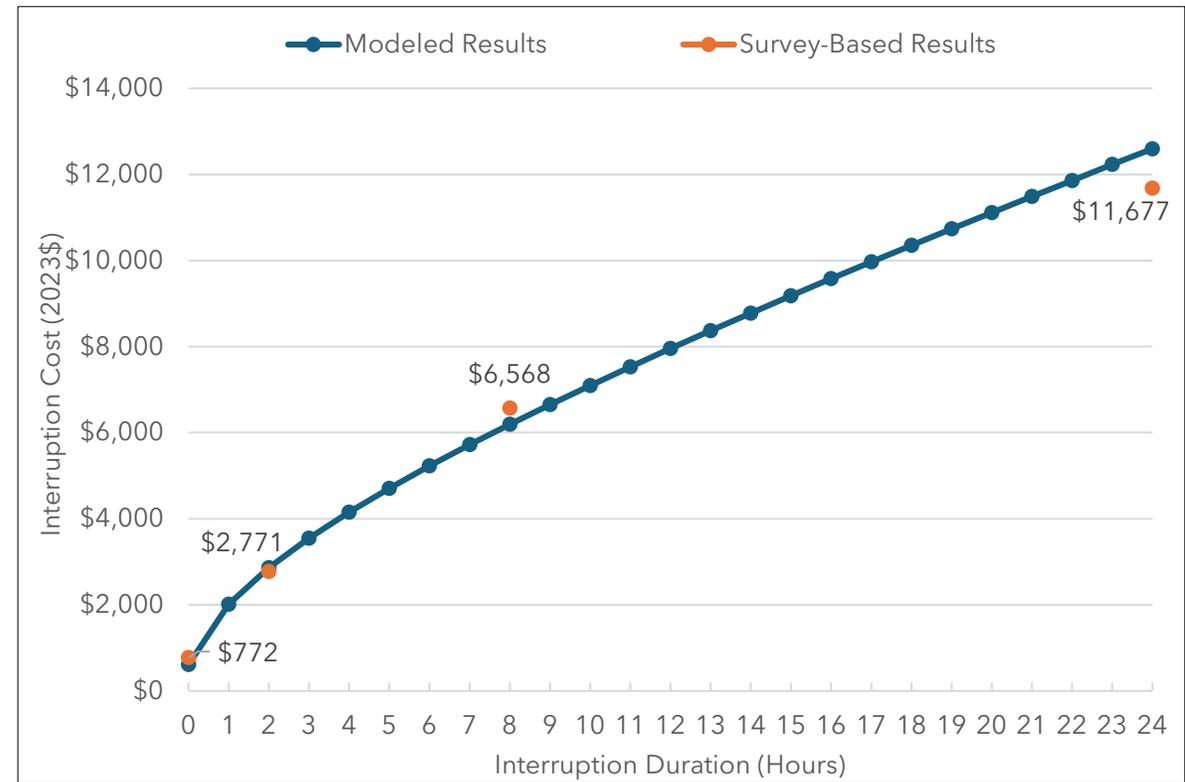
Case Study: How the ICE Calculator is Used

❑ Utility:
- EPB of Chattanooga

❑ Investment:
- 1,200 automated circuit switches and sensors on 171 circuits

❑ Reliability Improvement:
- Interruption Duration: ↓45% (from 112 to 62 minutes/year)
- Interruption Frequency: ↓51% (from 1.4 to 0.7 interruptions/year)

Annualized Benefits & Costs

■ Utility   ■ Avoided customer outage costs

Investment Costs $5.6 M

Benefits $26.8 M

Lifetime of Benefit Calculated: $26.8M per year (2014$). Benefit shown for non-severe weather events only.

Lifetime of Cost Calculated: $5.6M per year ($48.4M annualized over an assumed useful life of 20 years).

ICE Calculator Next Steps

❑ The Phase 2 data will be incorporated into the calculator this winter

❑ For more information about the free online tool, including a comprehensive report and case studies that utilize the calculator, visit icecalculator.com