



ICE Calculator 2.0: Assisting Consumer Advocates, Utilities, and Regulators Estimate the Costs of Power Outages

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Agenda

- ❑ Motivation for updating the ICE Calculator
- ❑ ICE Calculator is being updated in at least three phases
- ❑ Surveying approach and results
- ❑ Modeling approach and results
- ❑ ICE Calculator website and API
- ❑ Simple comparison of ICE 2.0 to 1.0
- ❑ Upcoming milestones

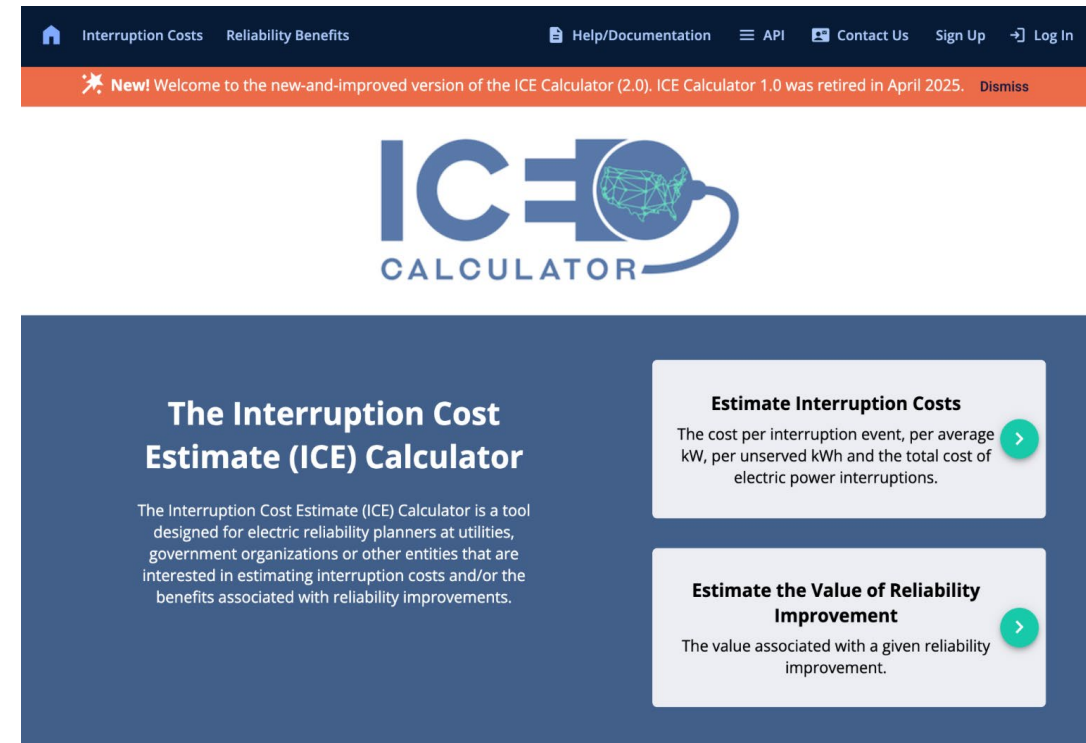


Motivation for updating the ICE Calculator



ICE Calculator estimates customer costs of shorter duration interruptions

- ❑ 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
- ❑ Development of the ICE Calculator was sponsored by the U.S. Department of Energy Office of Electricity
- ❑ ICE Calculator is being used to:
 - ❑ Support internal utility reliability planning activities
 - ❑ Provide a basis for discussing utility reliability investments with regulators
 - ❑ Assess 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
- ❑ Reliance on ICE 1.0 has been challenged because the surveys are:
 - ❑ 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			0.25	8
Northwest-2	1999	7,091			0	12



Updating and upgrading the ICE Calculator

Berkeley Lab and Resource Innovations have:

- ❑ Created a Project Executive Committee (PEC) made up of the sponsoring utilities
- ❑ Created a Project Advisory Committee (PAC) made up of well-known external stakeholders, including NASUCA
- ❑ Received key feedback and/or approvals from PEC and PAC throughout the Initiative
- ❑ Developed a consistent set of short duration (up to 24 hours) customer interruption cost surveys
- ❑ Coordinated consistent administration of surveys
- ❑ Developed new short duration customer damage function (CDF) equations with new survey information
- ❑ Updated the ICE Calculator website including new enhancements



ICE Calculator is being updated in phases

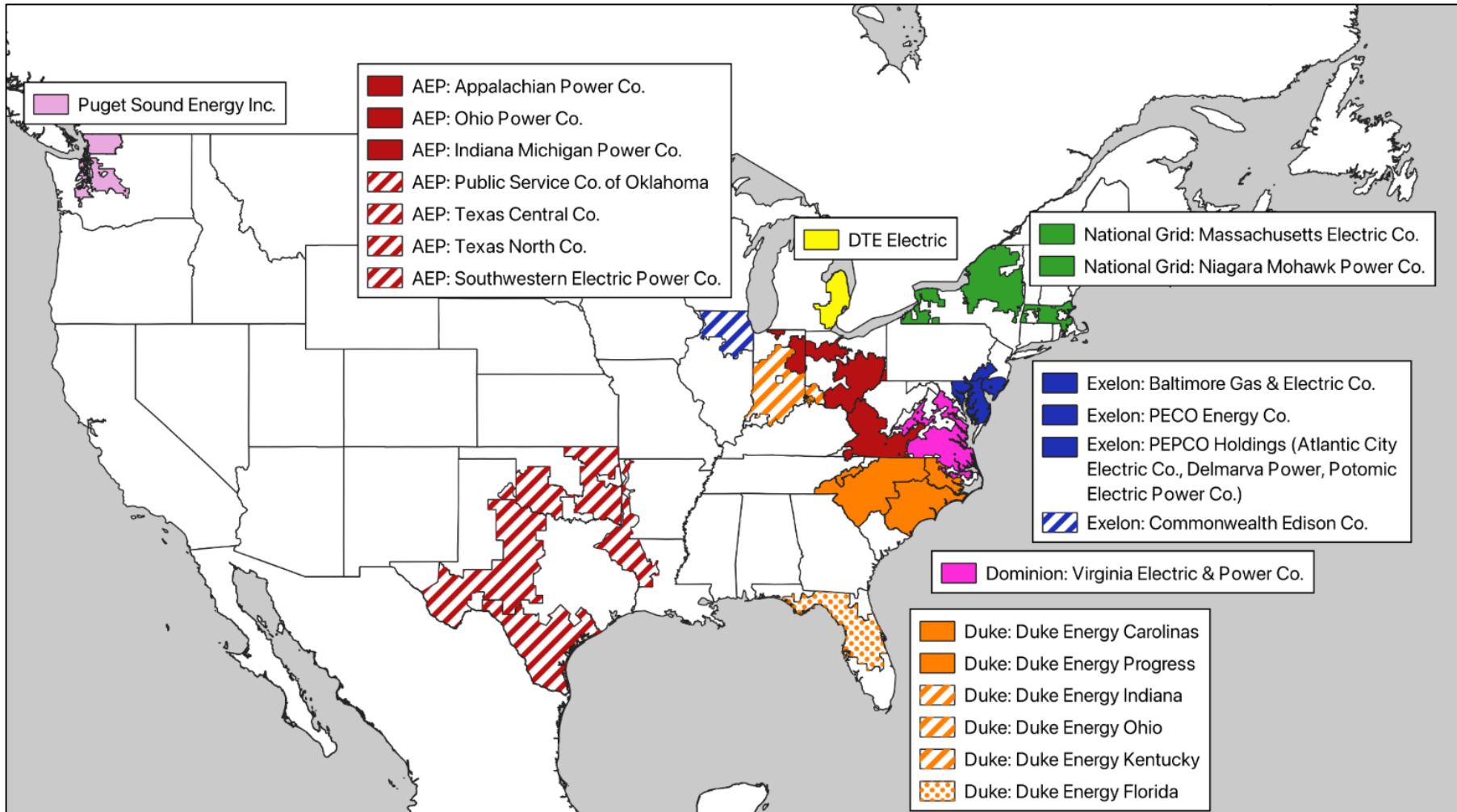


Update of ICE Calculator happening in phases

- ❑ Phase 1 (complete)
 - ❑ Based on 11 surveys conducted in Eastern and Midwestern U.S., with one utility in the Pacific Northwest
 - ❑ ICE 2.0 version of ICE Calculator released April 28, 2025
 - ❑ Updated customer damage functions
 - ❑ Upgraded web interface with enhanced capabilities
- ❑ Phase 2 (nearing completion)
 - ❑ Surveying recently completed for California investor-owned utilities and Missouri utilities
 - ❑ Another ICE Calculator update expected late 2025/early 2026
- ❑ Phase 3 (in process)
 - ❑ Surveying in process with select utility cooperatives in the U.S.
 - ❑ Surveying early next year with another Western utility
 - ❑ Continue to seek additional utility partners, especially in New England, Upper Great Plains, Rockies, and Desert Southwest



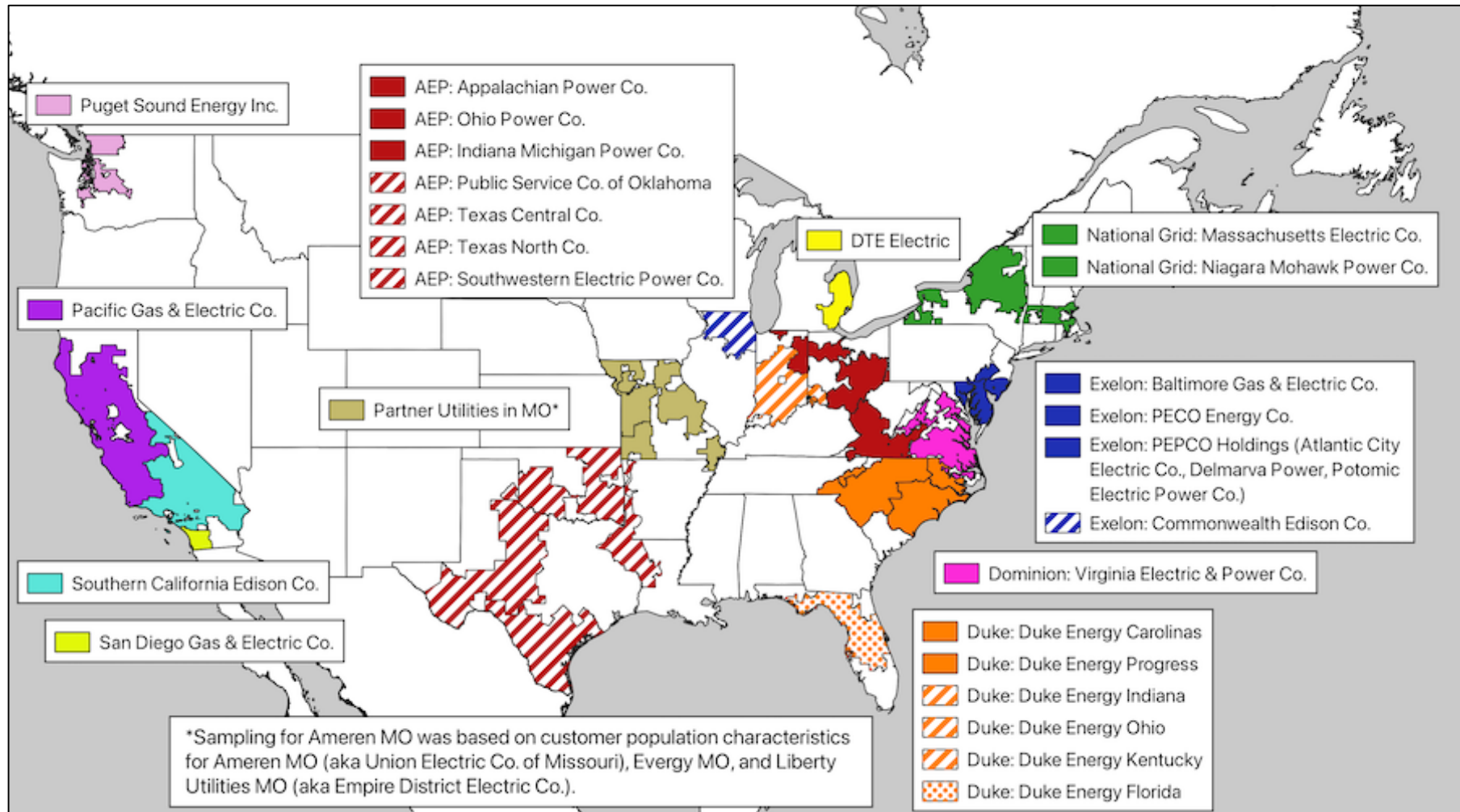
Participating utilities: Phase 1



- ❑ 8 sponsors
- ❑ 11 distinct survey activities
- ❑ 24 investor-owned utility distribution service territories represented



Participating utilities: Phase 1 and 2



- ☐ 12 sponsors
- ☐ 15 distinct survey activities
- ☐ 30 investor-owned utility distribution service territories represented

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



Surveying approach and results



Valuation approach

Residential Customers	Non-residential Customers
Willingness-to-pay for hypothetical backup service*	Direct cost = value of lost production + interruption related costs – interruption related savings
<p>Residential costs are often related to inconvenience.</p> <p>However, potential tangible costs include:</p> <ul style="list-style-type: none"> • Relocation costs • Buying supplies • Going out to eat • Inability to work 	<p>Interruption-related costs:</p> <ul style="list-style-type: none"> • Labor costs to make up any lost production (which can be made up) • Labor costs to restart the production process • Material costs to restart the production process • Costs resulting from damage to input feed stocks • Costs of re-processing materials (if any) • Cost to operate backup generation equipment <p>Interruption-related savings:</p> <ul style="list-style-type: none"> • Savings from unpaid wages during the interruption (if any) • Savings from the cost of raw materials not used because of the interruption • Savings from the cost of fuel not used • Scrap value of any damaged materials

*One-and-one-half-bound dichotomous choice contingent valuation (Cooper, Hanemann, and Signorello 2002)



Survey overview

- ❑ Three different customer surveys: residential, small/medium non-residential (SMNR), and large non-residential (LNR)
- ❑ 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
- ❑ One longer duration (3 days) scenario question (not used to update the ICE Calculator)
- ❑ Target responses per survey: 250 residential, 250 SMNR, and 67 LNR
- ❑ Stratified sample of customers in each class based on usage

Example set of interruption scenarios for a respondent

Scenario	Season	Time of Week	Onset Time	Advance Warning	Duration	Pivot
A	Summer	Weekday	2:00 PM	No	5 minutes or less	Weekend
B	Summer	Weekday	2:00 PM	No	2 hours	Weekend
C	Summer	Weekday	2:00 PM	No	24 hours	Weekend



Survey responses: All customers

Segment	Customer Sampling Population	Customers Sampled	Response Target	Total Responses	Overall Response Rate	Validated Responses	Validated Response Rate
Residential	22,276,695	35,743	2,750	3,316	9.3%	3,026	8.5%
Non-residential	2,141,558	90,464	3,487	4,579	5.1%	3,874	4.3%

*Initial responses were screened for invalid, illogical, or outlier responses



Validated survey responses

Utility	Validated Residential Responses	Validated Non-residential Responses
AEP East	314	342
AEP West	263	301
ComEd	259	369
Duke Energy Carolinas	270	404
Duke Energy Florida	267	367
Duke Energy Midwest	280	384
DTE Electric	271	351
Dominion Energy	281	288
Exelon	270	294
National Grid	275	350
PSE	276	424
Total	3,026	3,874

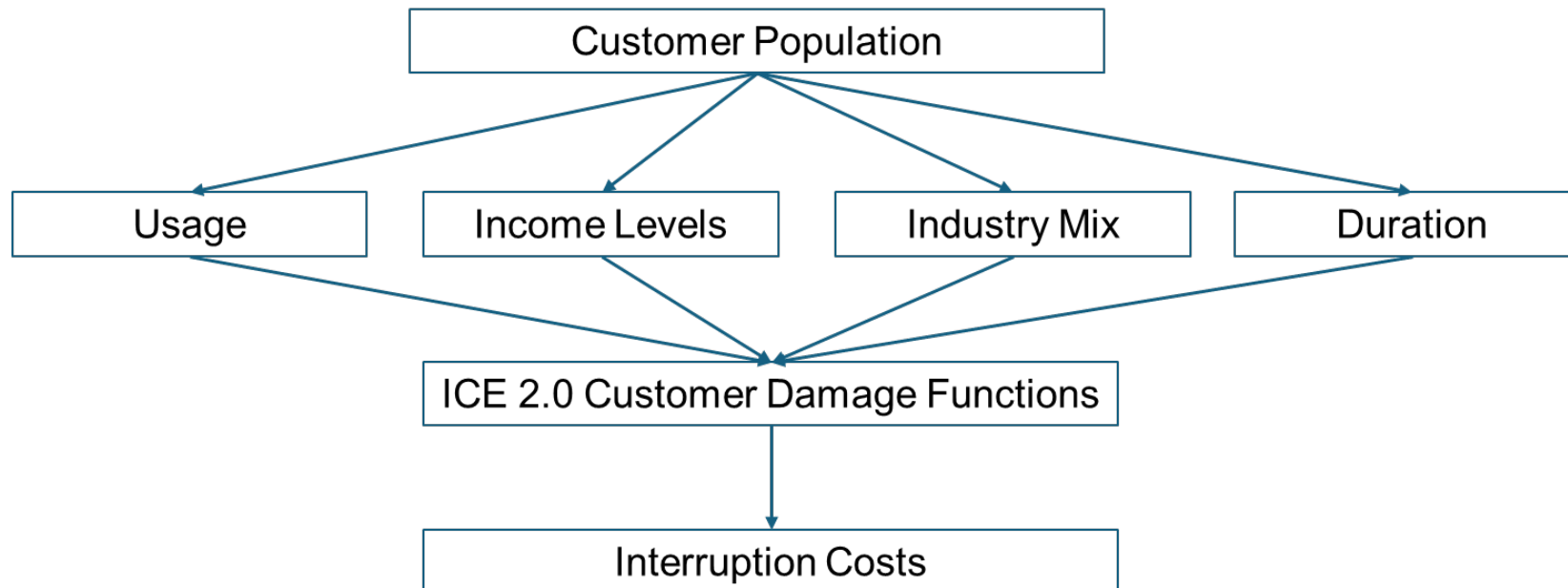


Modeling approach and results



Goal: Develop “customer damage functions” (CDF)

- ❑ LBNL/RI processed the survey responses and developed customer damage functions
- ❑ 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
 - For example, costs could be estimated at the circuit level if the characteristics of the customers served on that specific circuit are known



Residential model selection: Potential and selected explanatory variables

Potential Model

Continuous Variables

- Interruption duration (in minutes)
- Annual electricity usage (in kWh)
- GDP per kWh (collected at the state level)

Categorical Variables

Interruption Onset Time

- Morning
- Midday
- Evening

Season

- Summer
- Winter

Day of Week

- Weekday
- Weekend

Advance Warning

- Yes
- No

Previous Interruption in Last 12 Months

- Yes
- No

Persons in Household

- 1-2 people
- 3+ people

Ownership of Backup Generation

- Yes
- No

Work from Home

- Yes
- No

Age of Respondent

- Under 40 years
- 40-70 years
- 70+ years

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

Housing Type

- Apartment/Condominium
- Attached Single-Family
- Detached Single-Family
- Mobile Home
- Unknown/Other

Final 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

Model
Selection



Non-Residential model selection: Potential and selected explanatory variables

Potential Model	
Continuous Variables	
<ul style="list-style-type: none">• Interruption duration (in minutes)• Annual electricity usage (in kWh)• GDP per kWh (collected at the state level)	
Categorical Variables	
Interruption Onset Time <ul style="list-style-type: none">• Morning• Midday• Evening	Ownership of Backup Generation <ul style="list-style-type: none">• Yes• No
Season <ul style="list-style-type: none">• Summer• Winter	Industry <ul style="list-style-type: none">• Accommodation and Food Services• Administrative and Support and Waste Management and Remediation Service• Agriculture, Forestry, Fishing and Hunting• Arts, Entertainment, and Recreation• Construction• Educational Services• Finance and Insurance• Health Care and Social Assistance• Information (e.g., Data Centers)• Management of Companies and Enterprises• Manufacturing• Mining, Quarrying, and Oil and Gas Extraction• Other Services• Professional, Scientific, and Technical Services• Public Administration• Real Estate and Rental and Leasing• Retail Trade• Transportation and Warehousing• Utilities• Wholesale Trade
Day of Week <ul style="list-style-type: none">• Weekday• Weekend	
Advance Warning <ul style="list-style-type: none">• Yes• No	
Previous Interruption in Last 12 Months <ul style="list-style-type: none">• Yes• No	

Model
Selection

Final Model	
Continuous Variables	
<ul style="list-style-type: none">• Interruption duration (in minutes)• Annual electricity usage (in kWh)	
Categorical Variables	
Advance Warning <ul style="list-style-type: none">• Yes• No	
Day of Week (Probit Only) <ul style="list-style-type: none">• Weekday• Weekend	
Industry (GLM Model Only) <ul style="list-style-type: none">• Health Care and Social Assistance• Manufacturing• All other industries	

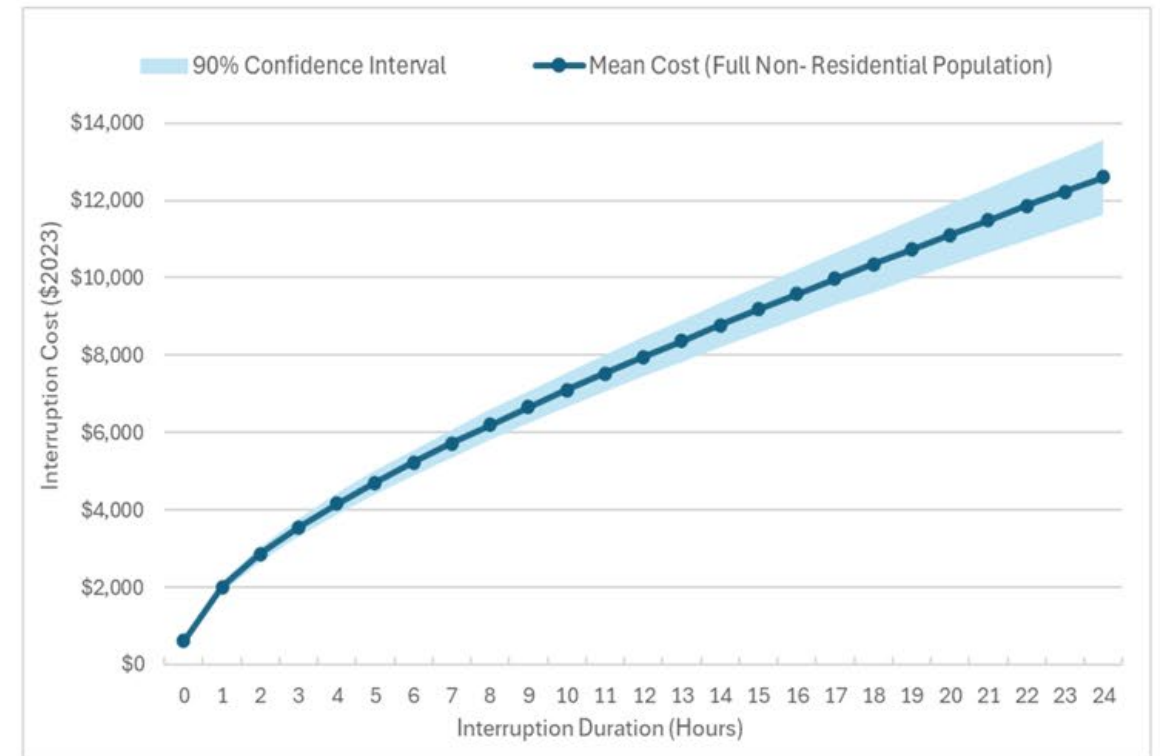
- ☐ For modeling purposes, the SMNR and LNR responses were combined into one non-res segment
- ☐ The single non-res model can estimate costs for all customer segmentations, regardless of size
- ☐ Users can input usage values into the tool that align with their jurisdictions definition of “small”, “medium”, or “large” customers

Predicted interruption costs by duration (default values; 90% confidence)

Residential



Non- Residential



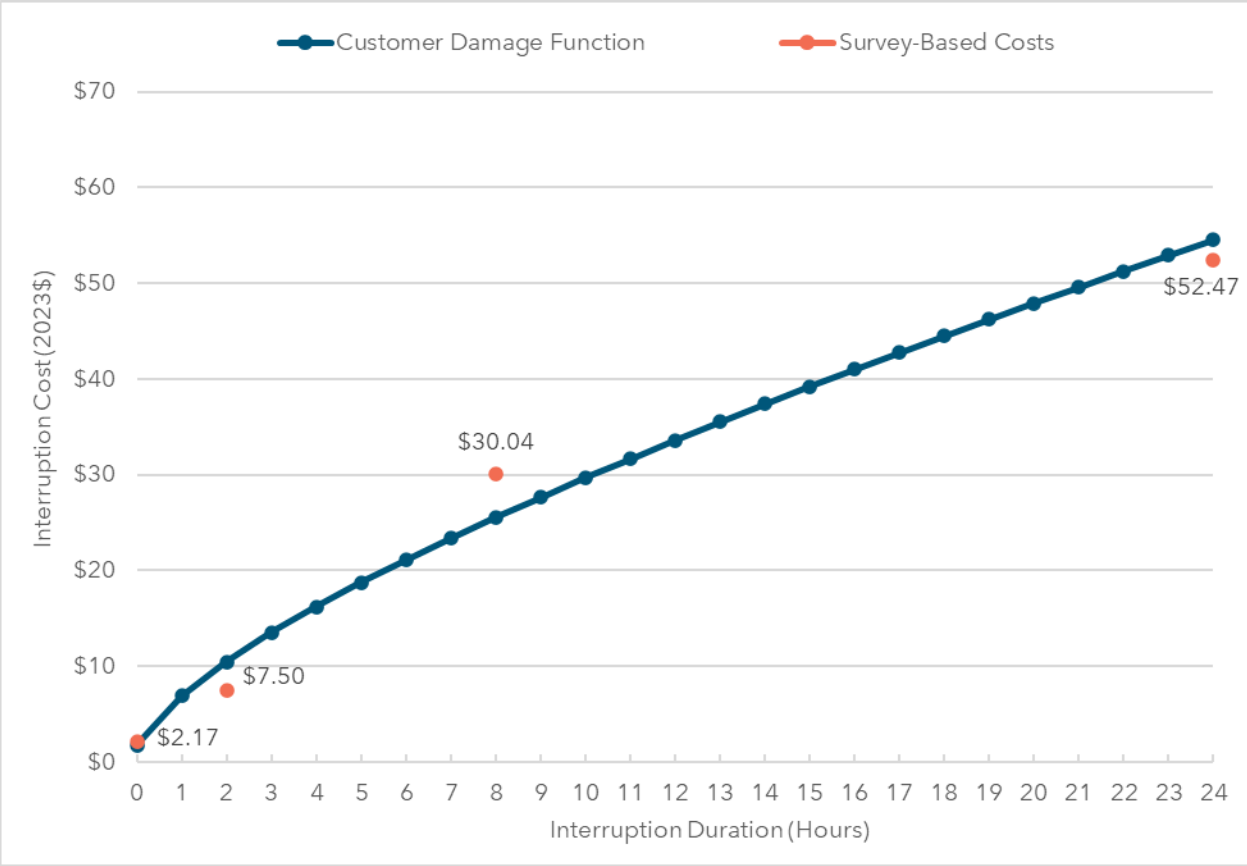
Modeled results (2023\$)

Duration of Power Interruption Event	Cost per Event	Cost per kW	Cost per Unserved kWh	Cost per CMI
Residential				
Momentary	\$1.80	\$1.50	\$18.03	\$0.36
2 Hours	\$10.49	\$8.62	\$4.31	\$0.09
8 Hours	\$25.55	\$21.21	\$2.65	\$0.05
24 Hours	\$54.52	\$44.76	\$1.86	\$0.04
Non-residential				
Momentary	\$609	\$43	\$521	\$122
2 Hours	\$2,839	\$202	\$101	\$24
8 Hours	\$6,172	\$440	\$55	\$13
24 Hours	\$12,646	\$902	\$38	\$9

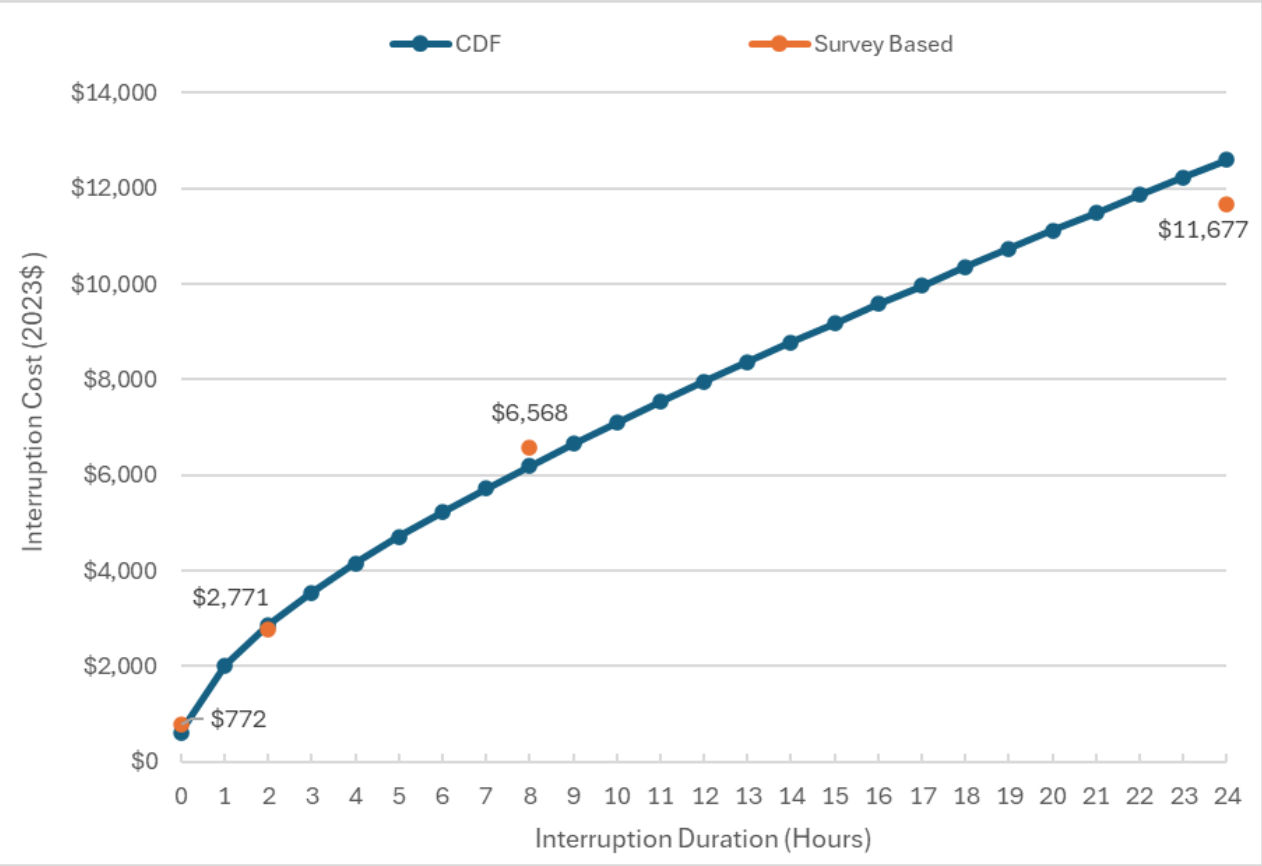


CDF vs. survey-based interruption costs

Residential



Non- Residential



ICE Calculator website and API



ICE 2.0 website: <https://icecalculator.com/>



The Interruption Cost Estimate (ICE) Calculator

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.

Estimate Interruption Costs

The cost per interruption event, per average kW, per unserved kWh and the total cost of electric power interruptions.



Estimate the Value of Reliability Improvement

The value associated with a given reliability improvement.



About the ICE Calculator 2.0

A reliability planning tool designed for electric utilities, government organizations, and other entities interested in estimating interruption costs and/or the benefits associated with reliability improvements in the United States. The tool was developed by ...

See All 

ICE Calculator API

Access the ICE Calculator's functionality programmatically through our REST API. Generate interruption cost estimates and reliability improvement valuations directly from your applications. Get started by creating an API key and exploring our comprehensive API documentation.

Get Started 

Documentation

The ICE Calculator documentation provides comprehensive guides and resources to help you understand and utilize the calculator effectively. Browse through our organized sections to find the information you need.

See All 



Help/Documentation page

[Interruption Costs](#)[Reliability Benefits](#)[Help/Documentation](#)[API](#)[Contact Us](#)[Sign Up](#)[Log In](#)

ICE Calculator Documentation

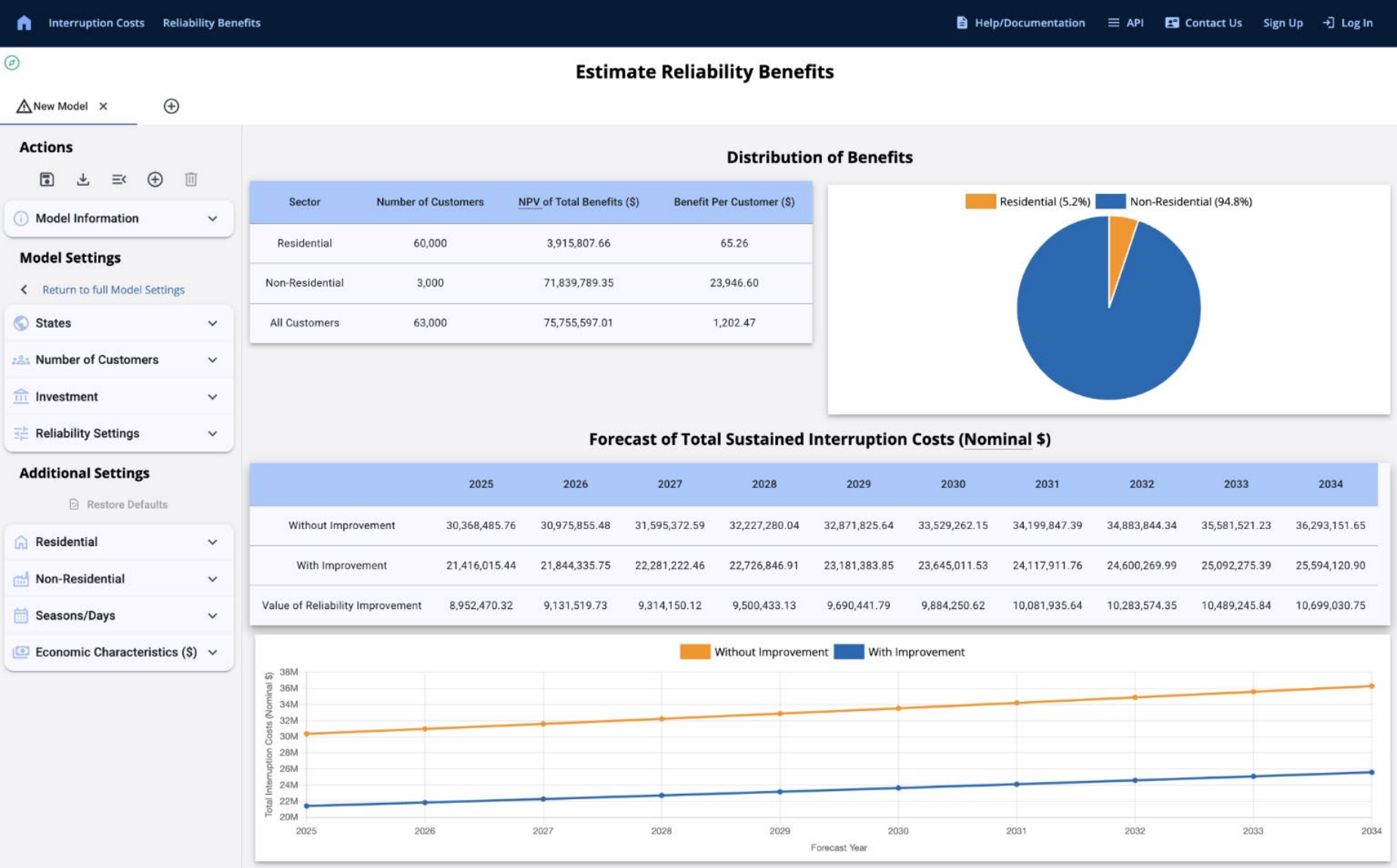
Welcome to the ICE Calculator documentation. Here you'll find user guides, technical documentation, and additional resources organized by topic. Click on each section below to explore the available documents.

[About the ICE Calculator](#)[Technical Support](#)[Video Tutorials](#)[Interruption Cost Estimate Calculator 2.0 \(Current\)](#)[Participating Utilities](#)[Use Cases and Applications of ICE](#)[Interruption Cost Estimate Calculator 1.0 \(Pre 2025\)](#)[Value of Lost Load Survey Methods](#)[ENERGY TECHNOLOGIES AREA](#)[ENERGY ANALYSIS DIVISION](#)[ENERGY MARKETS & PLANNING](#)

Estimate interruption costs



Estimate reliability benefits



Application programming interface (API)

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API Documentation

Introduction

Getting Started

API Explorer

Interruption Cost

Inputs/Outputs

Examples

Reliability Benefits

Inputs/Outputs

Examples

Lookup Table

Inputs/Outputs

Examples

Override Model Defaults

Override Model Defaults


ICE Calculator API

What is an API?

An API (Application Programming Interface) is a way for different applications to communicate with each other. Think of it like a waiter in a restaurant:


- You (the application) place an order (make a request)
- The waiter (API) takes your order to the kitchen (server)
- The kitchen prepares your meal (processes the request)
- The waiter brings back your food (returns the data)

Benefits of Using Our API




Automation

Automate tasks and integrate services directly into your workflow




Efficiency

Save time by accessing data and services programmatically



Integration

Easily connect our services with your existing systems

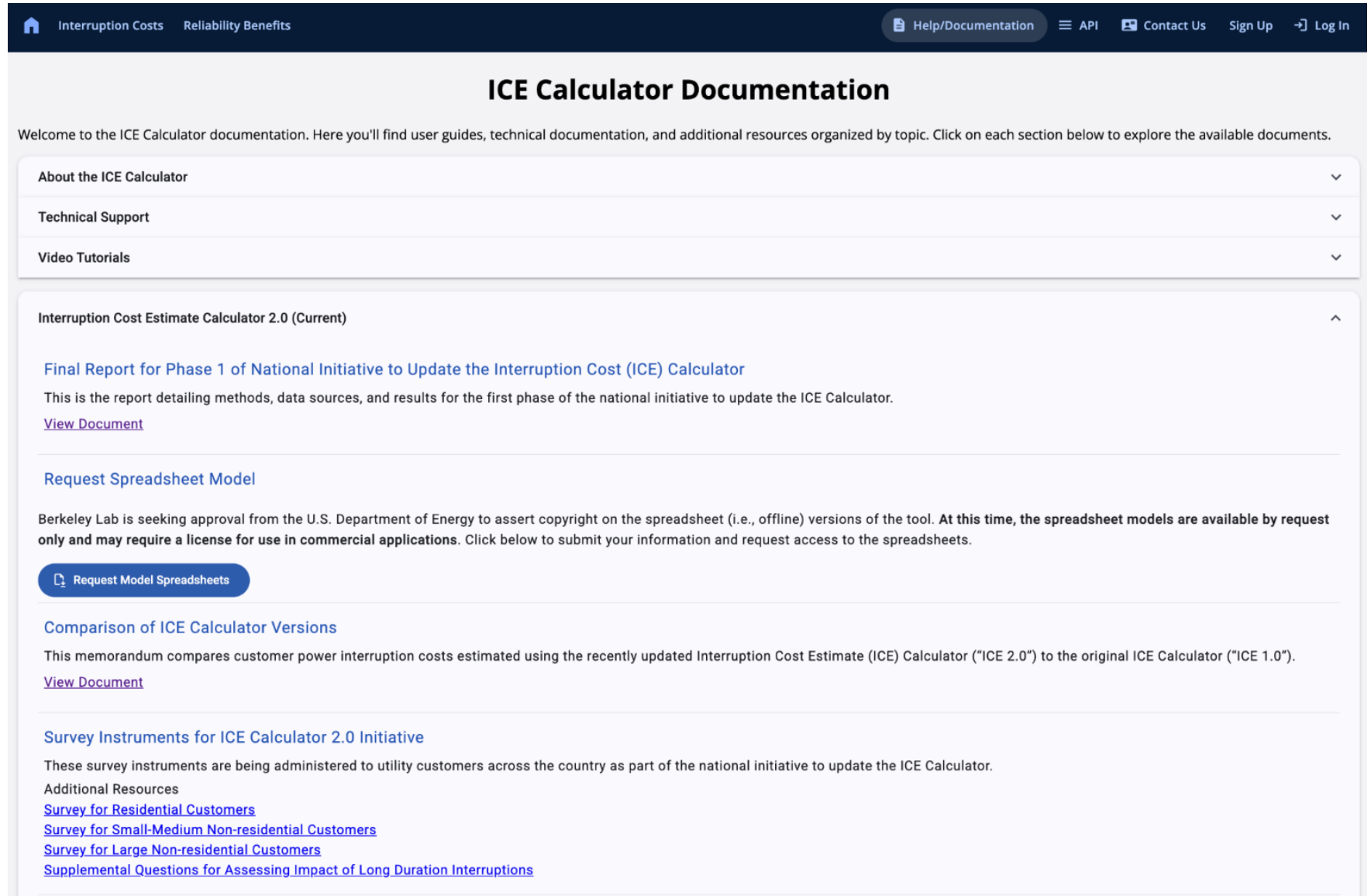


Real-time Access

Get immediate access to the latest data and functionality

Request spreadsheet model (non-commercial use only)

- ❑ Users can request spreadsheet-based version of ICE 2.0
- ❑ We are sharing these on a case-by-case basis
- ❑ Spreadsheets will be made available if not shared outside of organization and not used for commercial purposes
- ❑ ICE 1.0 spreadsheet is available on website



The screenshot shows the 'ICE Calculator Documentation' website. The header includes navigation links for 'Interruption Costs', 'Reliability Benefits', 'Help/Documentation', 'API', 'Contact Us', 'Sign Up', and 'Log In'. The main content area is titled 'ICE Calculator Documentation' and includes a welcome message. Below this, there are expandable sections for 'About the ICE Calculator', 'Technical Support', and 'Video Tutorials'. The 'Interruption Cost Estimate Calculator 2.0 (Current)' section is expanded, showing links to the 'Final Report for Phase 1 of National Initiative to Update the Interruption Cost (ICE) Calculator', a 'Request Spreadsheet Model' button, and a 'Comparison of ICE Calculator Versions' section. The 'Request Spreadsheet Model' section states that Berkeley Lab is seeking approval from the U.S. Department of Energy to assert copyright on the spreadsheet (i.e., offline) versions of the tool. At this time, the spreadsheet models are available by request only and may require a license for use in commercial applications. Click below to submit your information and request access to the spreadsheets. The 'Comparison of ICE Calculator Versions' section states that this memorandum compares customer power interruption costs estimated using the recently updated Interruption Cost Estimate (ICE) Calculator ("ICE 2.0") to the original ICE Calculator ("ICE 1.0"). The 'Survey Instruments for ICE Calculator 2.0 Initiative' section states that these survey instruments are being administered to utility customers across the country as part of the national initiative to update the ICE Calculator. Additional Resources are listed: Survey for Residential Customers, Survey for Small-Medium Non-residential Customers, Survey for Large Non-residential Customers, and Supplemental Questions for Assessing Impact of Long Duration Interruptions.

Interruption Costs Reliability Benefits Help/Documentation API Contact Us Sign Up Log In

ICE Calculator Documentation

Welcome to the ICE Calculator documentation. Here you'll find user guides, technical documentation, and additional resources organized by topic. Click on each section below to explore the available documents.

- About the ICE Calculator
- Technical Support
- Video Tutorials

Interruption Cost Estimate Calculator 2.0 (Current)

Final Report for Phase 1 of National Initiative to Update the Interruption Cost (ICE) Calculator

This is the report detailing methods, data sources, and results for the first phase of the national initiative to update the ICE Calculator.

[View Document](#)

Request Spreadsheet Model

Berkeley Lab is seeking approval from the U.S. Department of Energy to assert copyright on the spreadsheet (i.e., offline) versions of the tool. **At this time, the spreadsheet models are available by request only and may require a license for use in commercial applications.** Click below to submit your information and request access to the spreadsheets.

[Request Model Spreadsheets](#)

Comparison of ICE Calculator Versions

This memorandum compares customer power interruption costs estimated using the recently updated Interruption Cost Estimate (ICE) Calculator ("ICE 2.0") to the original ICE Calculator ("ICE 1.0").

[View Document](#)

Survey Instruments for ICE Calculator 2.0 Initiative

These survey instruments are being administered to utility customers across the country as part of the national initiative to update the ICE Calculator.

Additional Resources

- [Survey for Residential Customers](#)
- [Survey for Small-Medium Non-residential Customers](#)
- [Survey for Large Non-residential Customers](#)
- [Supplemental Questions for Assessing Impact of Long Duration Interruptions](#)



Comparison of ICE 2.0 to 1.0



Summary of differences between ICE 1.0 and 2.0

	ICE 1.0	ICE 2.0
Surveys Conducted (Years)	<ul style="list-style-type: none"> • 1989-2012 	<ul style="list-style-type: none"> • 2022-2024 (Phase 1)
Survey Approach	<ul style="list-style-type: none"> • Administered independently • Information on sample designs and recruitment procedures not available • Different surveys with different questions 	<ul style="list-style-type: none"> • LBNL/Resource Innovations (RI) administered in a fully coordinated manner • Consistent sample designs and recruitment procedures • Identical set of survey questions • One-and-one-half-bound dichotomous choice contingent valuation (residential)
Geographic Coverage	<ul style="list-style-type: none"> • 15 distinct surveying efforts conducted across 10 utility service territories • Mostly conducted in western and southeastern U.S. 	<ul style="list-style-type: none"> • 11 distinct survey activities conducted across 24 utility service territories • Eastern and midwestern U.S. as well as the pacific northwest (future phases will include additional regional representation)
Interruption Durations Considered	<ul style="list-style-type: none"> • Varied and generally limited to 12 hrs or less 	<ul style="list-style-type: none"> • Momentary (lasting up to 5 min), 2 hrs, 8 hrs, and 24 hrs
Customer Damage Functions	<ul style="list-style-type: none"> • Residential • Small non-residential • Medium/large non-residential 	<ul style="list-style-type: none"> • Residential • Non-residential



Upcoming milestones



Upcoming milestones

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Estimate Interruption Costs

New Model

Model Settings

Select States

Set Parameters

Select States

A default set of inputs are calculated based on the selected states.

Selection Rules: You can select multiple mainland US states, Alaska, and Hawaii together. Puerto Rico and Guam must be selected individually and cannot be combined with other locations.

Search for a State...

Alaska

Hawaii

United States

Puerto Rico

Guam

Next

Run Model

Feature	Comments
Mobile-friendly version	<ul style="list-style-type: none">Just released
Inclusion of Guam and Puerto Rico	<ul style="list-style-type: none">Release expected later this yearData collected via separate projectsICE Calculator can estimate costs for up to 30 day power outage (Guam and Puerto Rico)
Confidence intervals around cost estimates	<ul style="list-style-type: none">Release expected later this year
Phase II update of ICE Calculator customer damage functions	<ul style="list-style-type: none">Release expected later this year or early next year



Interested in Joining Initiative?



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Berkeley Lab
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(510) 486-5015



ICE 2.0: Technical Support ([link](#))

ICE 2.0: National Report Documenting Phase 1 ([link](#))

Comparison of ICE 2.0 to 1.0 ([link](#))



Explanatory variables included in the CDFs

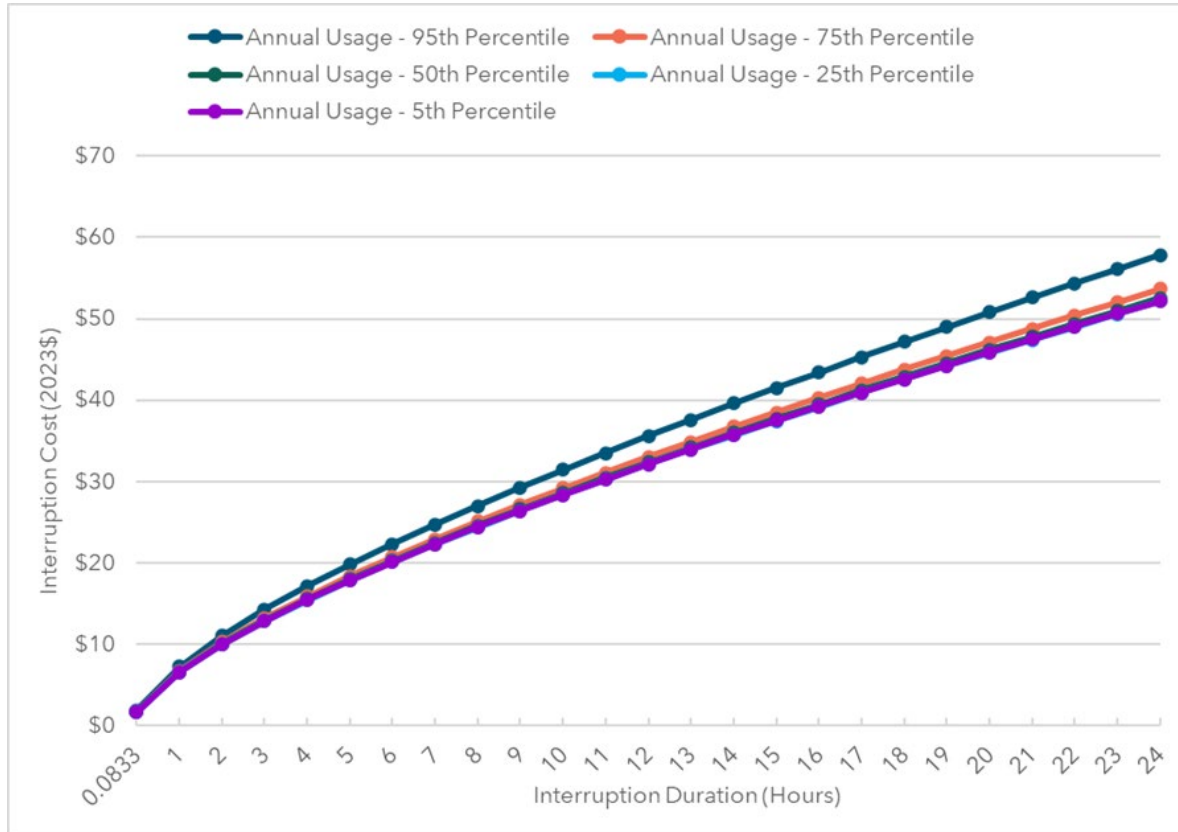
Residential	Non-residential	
	Probit	GLM
Duration of Interruption**	Duration of Interruption**	Duration of Interruption**
Annual kWh Usage**	Annual kWh Usage**	Annual kWh Usage**
Season**	Day of Week**	Percentage of Customers Given Advance Warning**
Percentage of Customers with Backup Generators**	Percentage of Customers Given Advance Warning**	Percentage of Customers in the Manufacturing Industry**
Percentage of Customers Working From Home*	-	Percentage of Customers in the Health Care Industry**
Annual Household Income**	-	-

* significant at $p < 0.05$

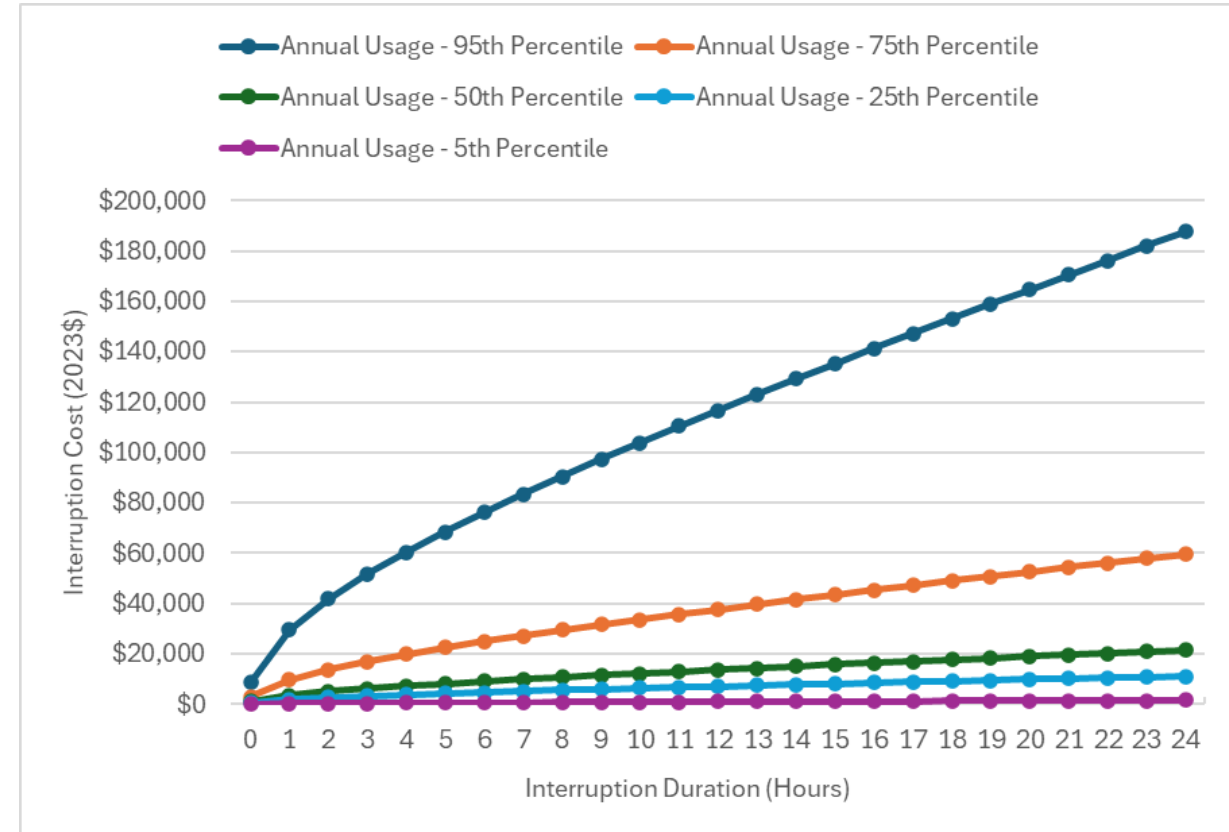
** significant at $p < 0.01$

Interruption costs by annual usage (consumption)

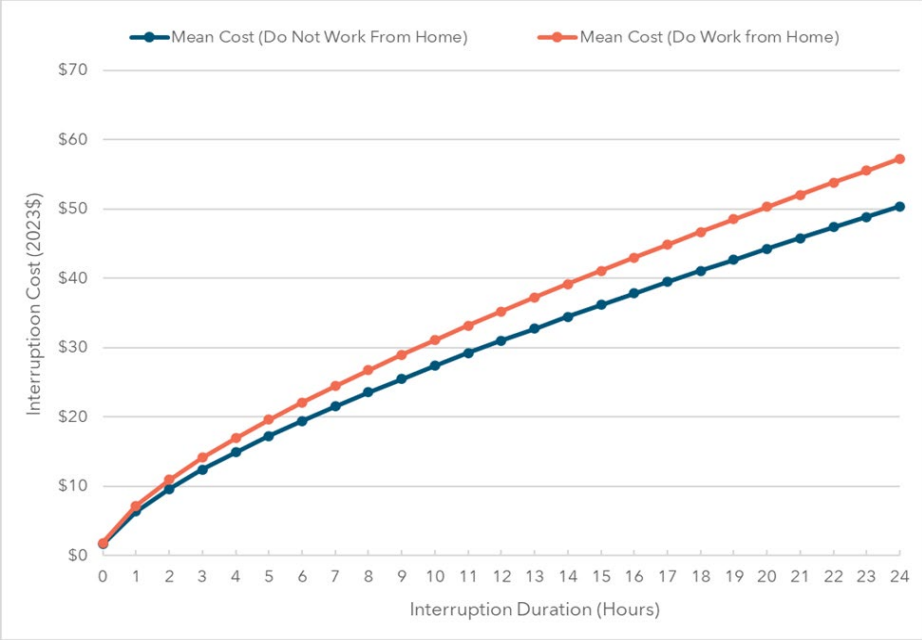
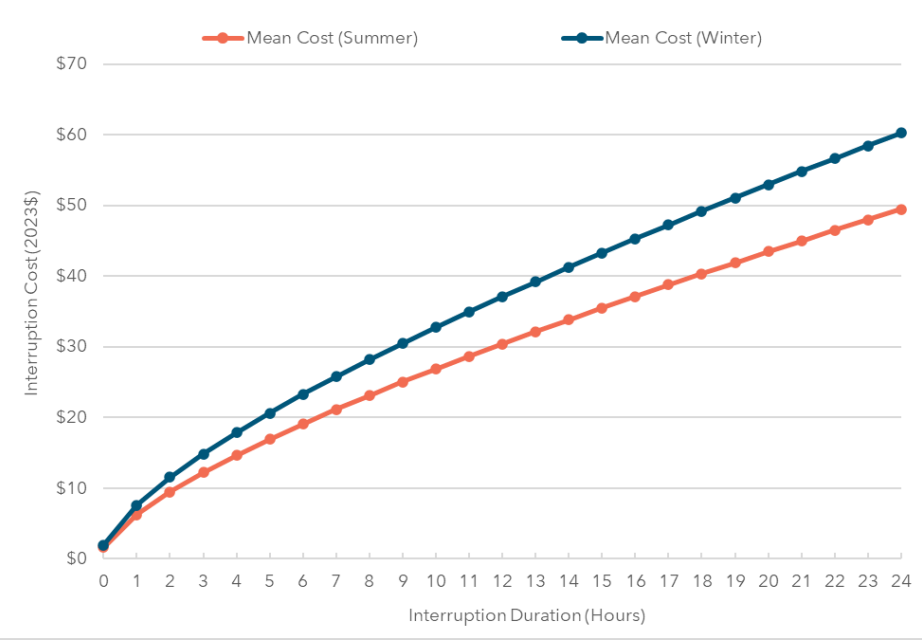
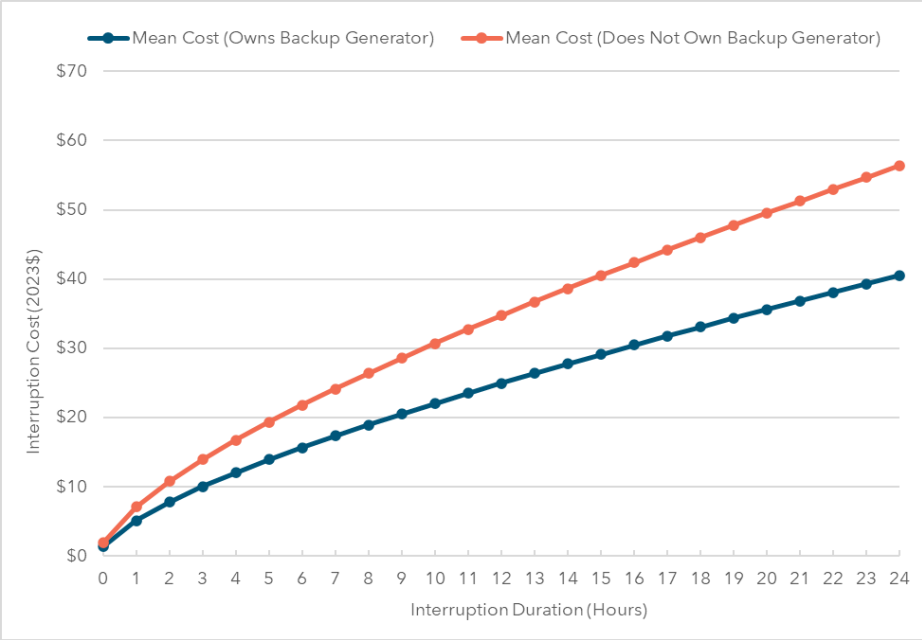
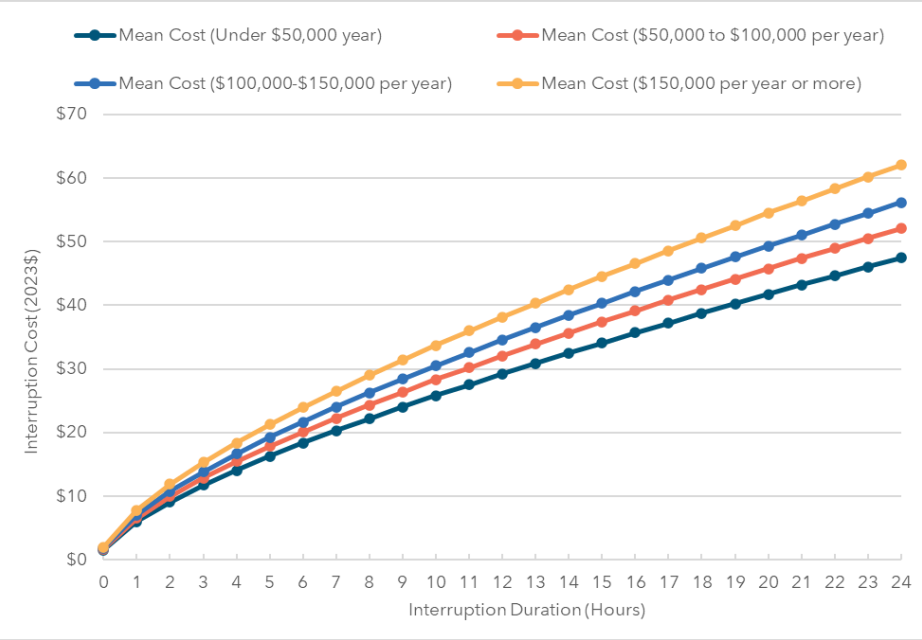
Residential



Non- Residential



Residential cost by income, backup generator, season, and work from home



Non-residential costs by day of week, industry, and advanced warning

