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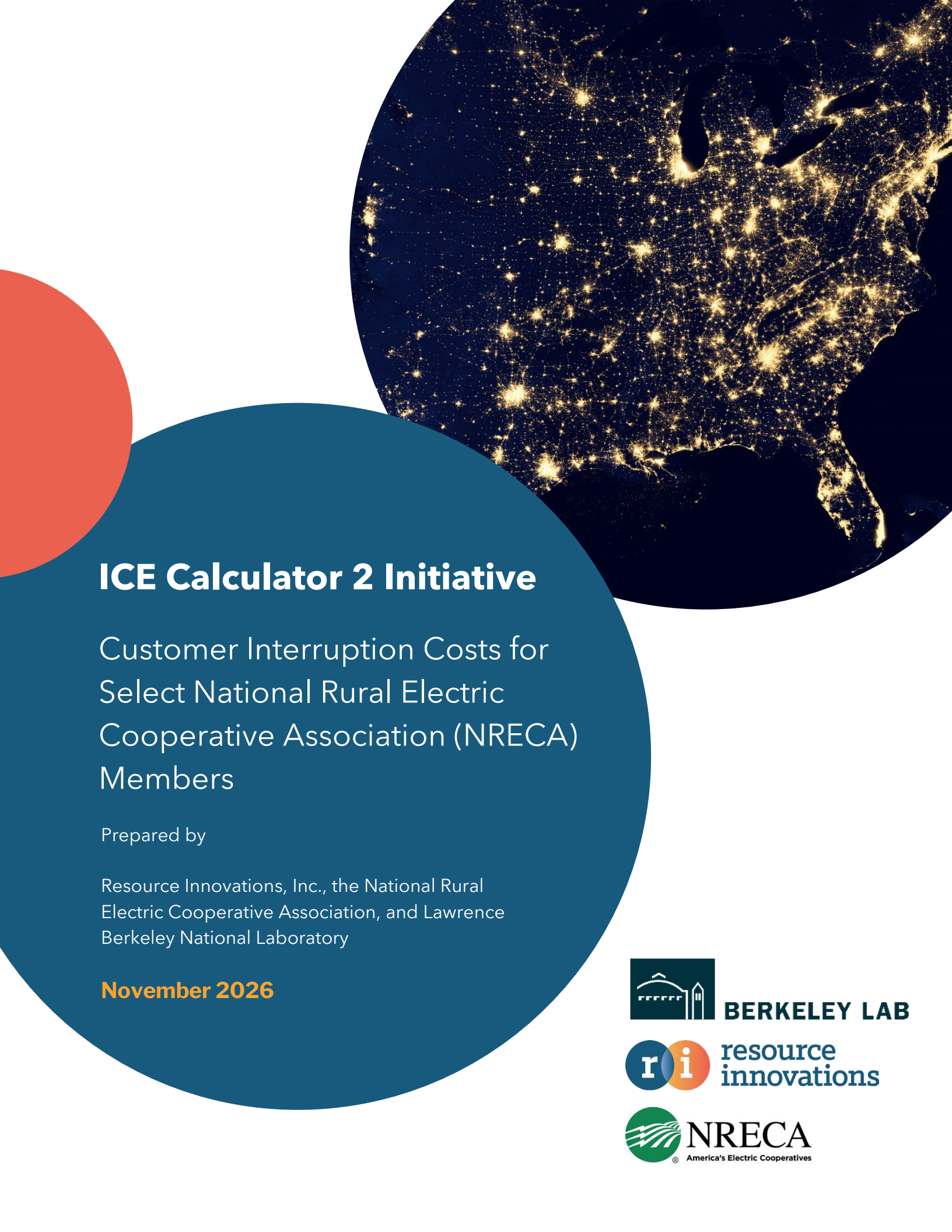
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ICE Calculator 2 Initiative

Customer Interruption Costs for Select National Rural Electric Cooperative Association (NRECA) Members

Prepared by

Resource Innovations, Inc., the National Rural
Electric Cooperative Association, and Lawrence
Berkeley National Laboratory

November 2026



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NRECA
America's Electric Cooperatives

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Executive Summary

The Interruption Cost Estimate (ICE) Calculator is a publicly-available, online tool that estimates the economic costs that electricity users experience due to power interruptions.¹ It was developed by Berkeley Lab and Resource Innovations (then Nexant) based on customer interruption cost surveys collected by U.S. electricity utilities between 1989 and 2012.² The tool has been used as a reference by utility planners and decision makers to estimate the economic benefits of grid reliability and resilience improvements.

In 2021, Berkeley Lab and Resource Innovations launched a national initiative, called ICE Calculator 2, to update the ICE Calculator based on modernized customer

¹ <https://icecalculator.com/home>

² Sullivan, M.J., M. Mercurio, and J. Schellenberg (2009). Estimated Value of Service Reliability for Electric Utility Customers in the United States. Lawrence Berkeley National Laboratory Report No. LBNL-2132E. <https://live-etabiblio.pantheonsite.io/sites/default/files/lbnl-2132e.pdf>

Sullivan, M.J., J. Schellenberg, and M. Blundell (2015). Updated Estimated Value of Service Reliability for Electric Utility Customers in the United States. Lawrence Berkeley National Laboratory Report No. LBNL-6941E. <https://live-etabiblio.pantheonsite.io/sites/default/files/lbnl-6941e.pdf>

Schellenberg, J. and P. Larsen (2018). Changes to the Underlying Econometric Models for the Interruption Cost Estimate (ICE)

Calculator. https://live-etabiblio.pantheonsite.io/sites/default/files/ice_calculator_recent_updates.pdf

interruption cost surveys and survey approaches administered consistently across the U.S.³

The ICE Calculator 2 initiative is a national study involving a significant number of utilities across the U.S. whose survey results collectively will improve the geographic representativeness of the tool. The initiative involves both direct sponsorship from utilities as well as from the Department of Energy (DOE) to administer customer interruption cost surveys in service territories across the U.S. Identical surveys and survey methods are being administered to ensure consistency.

The ICE Calculator 2 initiative is motivated by the following two concerns.

First, all of the customer interruption cost surveys used to develop the original ICE Calculator are over 10 years old, with a majority more than 25 years old. As electricity use has changed, in some instances significantly (e.g., work from home, digital controls for manufacturing processes), it is reasonable to expect that the value customers place on reliable electric service has also changed.

Second, the surveys underlying the original ICE Calculator were conducted primarily by utilities located on the West Coast and in the Southeastern portion of the U.S. In addition to the age of the surveys, challenges have been raised in state regulatory proceedings regarding the appropriateness of using the ICE Calculator to estimate the cost of power interruptions experienced by customers in other regions of the U.S.

The ICE Calculator 2 initiative is being conducted in multiple phases. Each phase involves the administration of interruption cost surveys to the customers of sponsoring utilities and the members of participating electric cooperatives followed by an update to the ICE Calculator based on the pooled, cumulative results from all completed phases of survey activities.

Phase I was sponsored by eight utilities: American Electric Power, Commonwealth Edison, Dominion Energy, Duke Energy, DTE Electric, Exelon, National Grid, and Puget Sound Energy. In Phase I, Berkeley Lab and Resource Innovations conducted 10 interruption cost surveys representing 23 distinct electricity distribution service territories in the eastern and midwestern regions of the U.S.

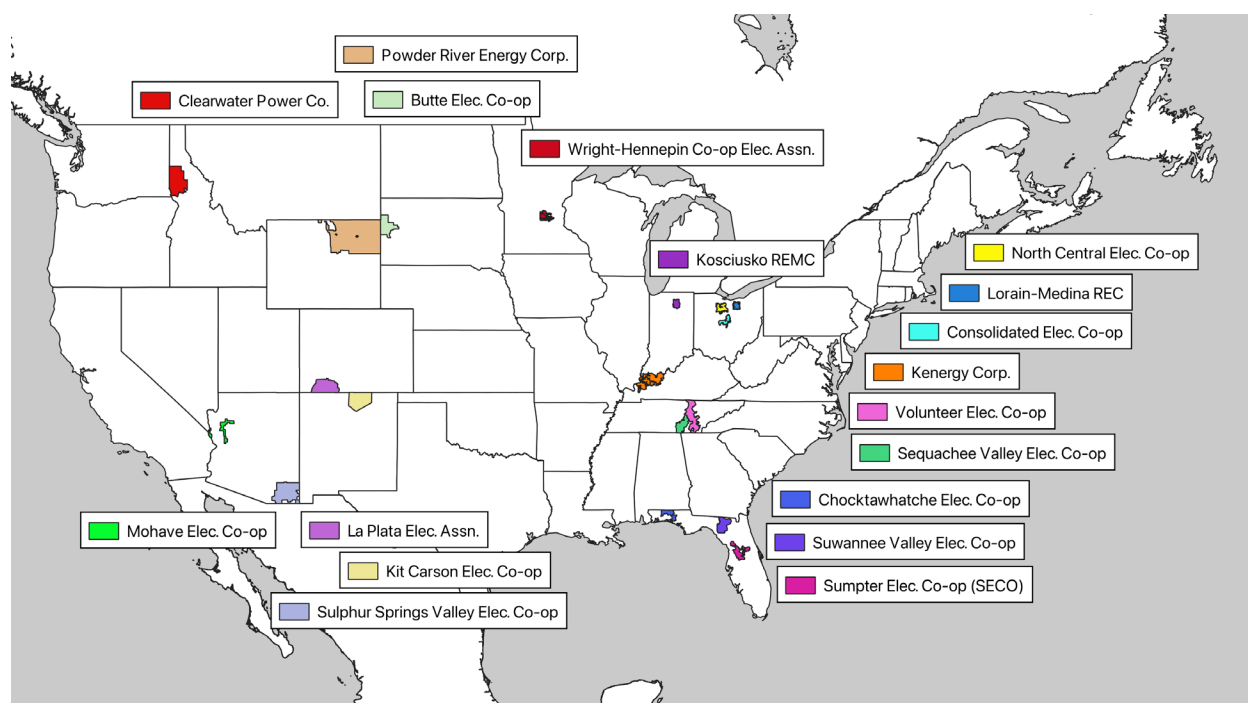
³ Sullivan et al. (2019). Elicitation of Electric Utility Customer Power Interruption Costs: A Roadmap for Conducting a National Survey. <https://icecalculator.com/assets/documents/National-Study-Roadmap.pdf>.

See also <https://icecalculator.com/assets/documents/ICE-2.0-Survey-Design-Memo.pdf>

Phase II was sponsored by six utilities: The Union Electric Company, Empire District Electric Company, Evergy Missouri, Pacific Gas & Electric, San Diego Gas & Electric, and Southern California Edison. In Phase II, Berkeley Lab and Resource Innovations conducted four interruption cost surveys.

The current phase of ICE Calculator 2, Phase III, will include survey data collected from 18 electric cooperative members of the National Rural Electric Cooperative Association (NRECA). The administration of and results from these surveys are the subject of this report. Recruitment is currently ongoing for additional utilities to participate in Phase III. Figure ES-1 presents a map showing the location of the participating cooperative members in Phase III.

Figure ES-1: Map of Participating NRECA Cooperatives



The sponsoring utilities for Phases I and II are all investor-owned utilities. NRECA was approached by Berkeley Lab to help recruit electric co-ops to participate in the ICE Calculator Initiative. This engagement was intended to include representation from electricity consumers (i.e., members of electric cooperatives) not served by investor-owned utilities, expand the geographic scope of participating utilities, better reflect the costs incurred by rural electricity consumers, and increase the overall number of surveys available to update the ICE Calculator.

The ICE Calculator 2 initiative is also supported through input provided by a Project Advisory Committee consisting of representatives from national organizations interested in the economic value of electricity reliability, including the U.S. Department of Energy, National Association of Regulatory Utility Commissioners, National Association of State Utility Consumer Advocates, National Association of State Energy Offices, Edison Electric Institute, American Public Power Association, National Rural Electric Cooperative Association, and Electric Power Research Institute.

This report summarizes the results from the interruption cost surveys administered to members of the eighteen participating electric cooperatives. The results presented in this study were derived from interruption cost surveys implemented from February to December 2025.

The methods used to estimate the interruption costs incorporate a number of methodological and analytical improvements over previous interruption cost surveys:

- Interruption costs borne by residential electricity consumers, which are more difficult to estimate than interruption costs borne by nonresidential electricity consumers, follow a state-of-the-art approach for eliciting willingness-to-pay for a hypothetical backup service;
- Interruption costs are estimated for four scenarios ranging from momentary power interruptions lasting up to 5 minutes to sustained interruptions lasting up to 24 hours - each taking place at different times of day and during different seasons of the year; and
- Specialized survey questions are included to better understand electric cooperative members' resilience to power interruptions, including the effect of advance notification in reducing interruption costs, the prevalence of member-owned backup generation, and the impacts and strategies they would take to cope with a three-day power interruption.

Interruption Cost Estimates

This report presents cost estimates for four interruption cost metrics: cost per interruption event, cost per average kW, cost per unserved kWh, and cost per minute interrupted. The first metric, cost per interruption event, is the average cost of an

interruption for each of four interruption durations. Cost estimates for the subsequent three interruption cost metrics are derived from cost per interruption event.⁴

Table ES-1 presents interruption costs per event. The results presented in this section are aggregated across all participating cooperatives. Residential interruption costs are based on willingness-to-pay to avoid a hypothetical power interruption. Non-residential interruption costs are based on estimates of the direct costs their organization would incur as a result of a hypothetical power interruption.⁵

For a momentary interruption (lasting up to 5 minutes), residential cooperative members reported a willingness-to-pay of \$1.90 and non-residential cooperative members reported a direct cost of \$1,283. As expected, these costs increase as the duration of an interruption increases. For a 24-hour interruption, residential members reported a willingness-to-pay of \$53.68 and non-residential members reported a direct cost of \$15,106.

Table ES-1: Average Interruption Cost by Duration and Type of Cooperative Member

Event Duration	Residential (\$/Event)	Non-Residential (\$/Event)
Momentary	\$1.90	\$1,283
2 hours	\$7.08	\$3,772
8 hours	\$29.42	\$7,898
24 hours	\$53.68	\$15,106

Figure ES-2 and Figure ES-3 present residential and non-residential interruption costs per event, respectively. The figures show the relationship between cost per interruption event and duration. The charts interpolate the cost reported for the four distinct interruption duration scenarios to all durations from momentary interruptions to 24 hours.

⁴ Section 4 provides additional information on the four interruption cost metrics.

⁵ Willingness-to-pay measurement techniques involve estimating the amount one would be willing to pay to avoid experiencing the interruption. Direct cost measurement techniques involve developing an estimate of the direct costs a firm or organization would incur during a service interruption. Refer to Section 2.3 for more details.

Figure ES-2: Residential Cost by Interruption Duration

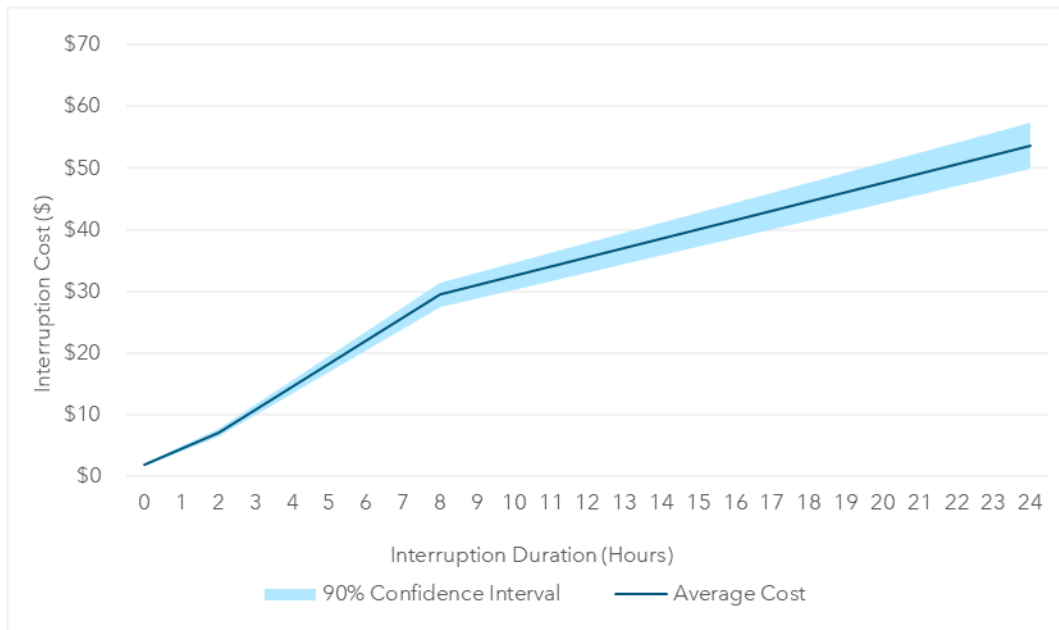


Figure ES-3: Non-Residential Cost by Interruption Duration

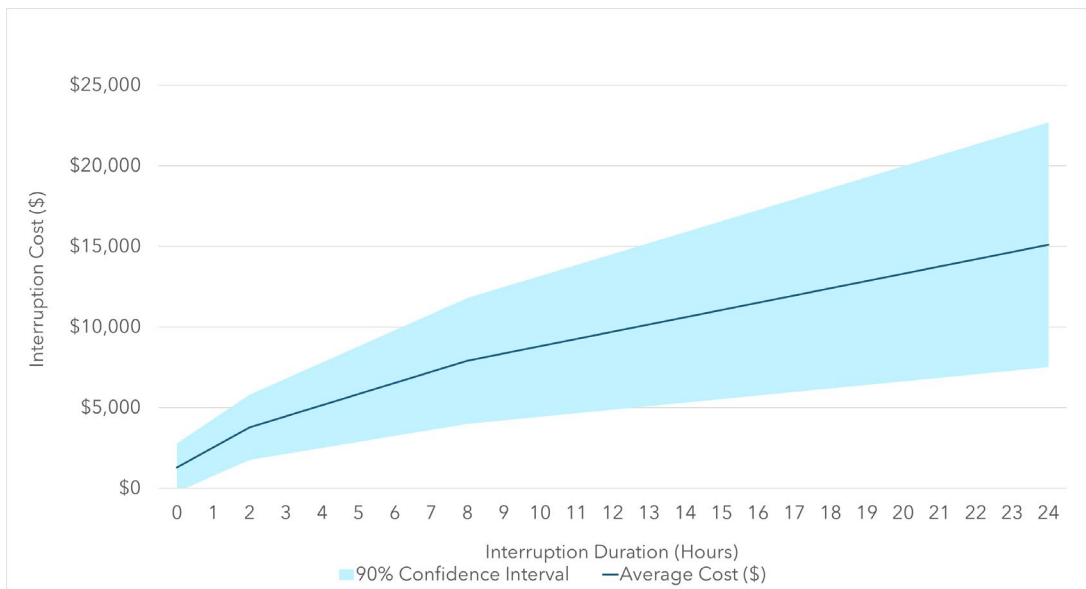


Table ES-2 presents interruption cost per kW. Interruption cost per kW is the interruption cost divided by average kW. This metric is useful for comparing interruption costs because costs are normalized by electricity use, as measured by demand.

For a momentary interruption, residential cooperative members reported a willingness-to-pay of \$1.66 per kW and non-residential cooperative members reported a direct cost of \$144 per kW. For both types of cooperative members, interruption cost per kW also increases as interruption event duration increases. For a 24-hour interruption, residential cooperative members report \$47.00 per kW and non-residential cooperative members report \$1,301 per kW.

Table ES-2: Average Cost per kW by Type of Cooperative Member

Event Duration	Residential (\$/kW)	Non-Residential (\$/kW)
Momentary	\$1.66	\$144
2 hours	\$6.20	\$288
8 hours	\$25.76	\$623
24 hours	\$47.00	\$1,301

Table ES-3 presents the interruption cost per unserved kWh. Interruption cost per unserved kWh is the interruption cost divided by the average amount of unserved electricity (i.e., electricity consumption foregone due to the interruption) of those surveyed. This metric is useful because it can be used directly in planning applications where the amount of unserved kWh is calculated.

For both types of cooperative members, the interruption cost per unserved kWh is highest for momentary interruptions because the amount of unserved kWh (the denominator of the equation) is small compared to longer-duration interruptions. The interruption cost per unserved kWh then decreases precipitously to a relatively stable value for longer interruption event durations (because, while unserved kWh increases linearly as interruption event duration increases, interruption costs increase more gradually).

Interruption cost per unserved kWh provides a direct “apples-to-apples” comparison of the value cooperative members place on electric service (as measured by the interruption costs they report) versus what they currently pay for electric service. Consistent with prior studies, we find that the value electricity consumers place on electric service greatly exceeds what they pay for electric service.

Table ES-3: Average Cost per Unserved kWh by Duration and Type of Cooperative Member

Event Duration	Residential (\$/kWh)	Non-Residential (\$/kWh)
Momentary	\$19.95	\$1,732
2 hours	\$3.10	\$144
8 hours	\$3.22	\$78
24 hours	\$1.96	\$54

Table ES-4 presents the interruption cost per customer minute interrupted (CMI). Interruption cost per CMI is the interruption cost divided by the duration of the interruption (expressed as minutes of interruption). Again, the interruption costs are largest for momentary interruptions, followed by a significant decrease that is relatively stable as interruption event durations increase.

Table ES-4: Cost per Customer Minutes Interrupted by Duration and Type of Cooperative Member

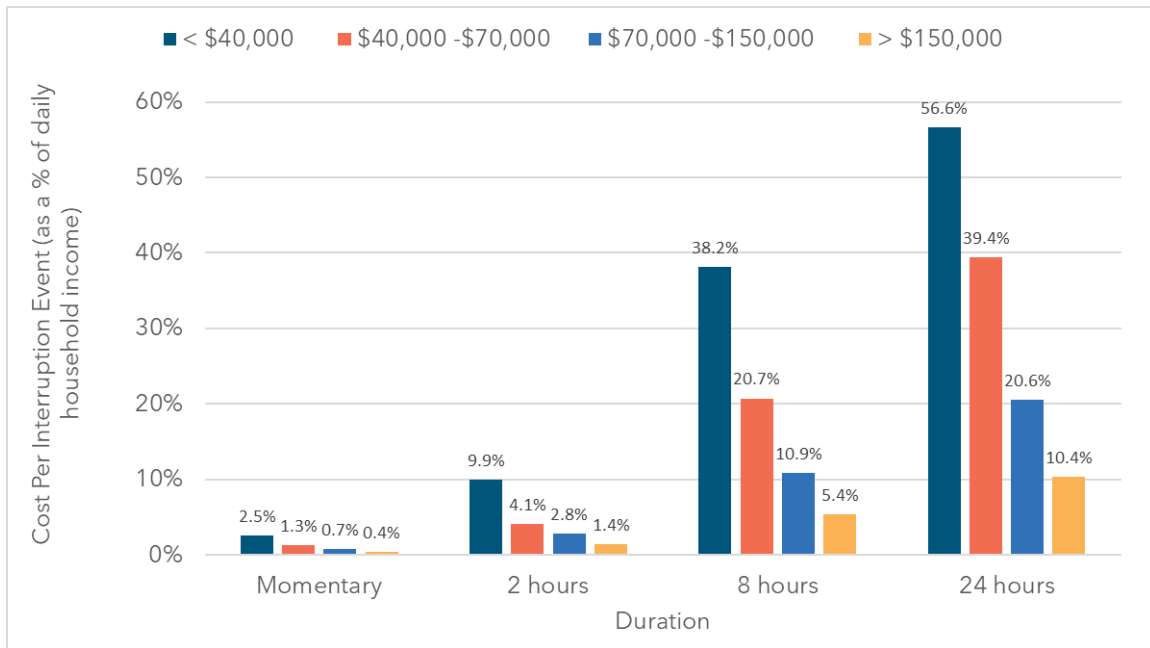
Event Duration	Residential (\$/CMI)	Non-Residential (\$/CMI)
Momentary	\$0.38	\$257
2 hours	\$0.06	\$31
8 hours	\$0.06	\$16
24 hours	\$0.04	\$10

Additional Findings

In addition to estimating interruption cost averages, costs were also examined for subgroups of residential and non-residential coop members.

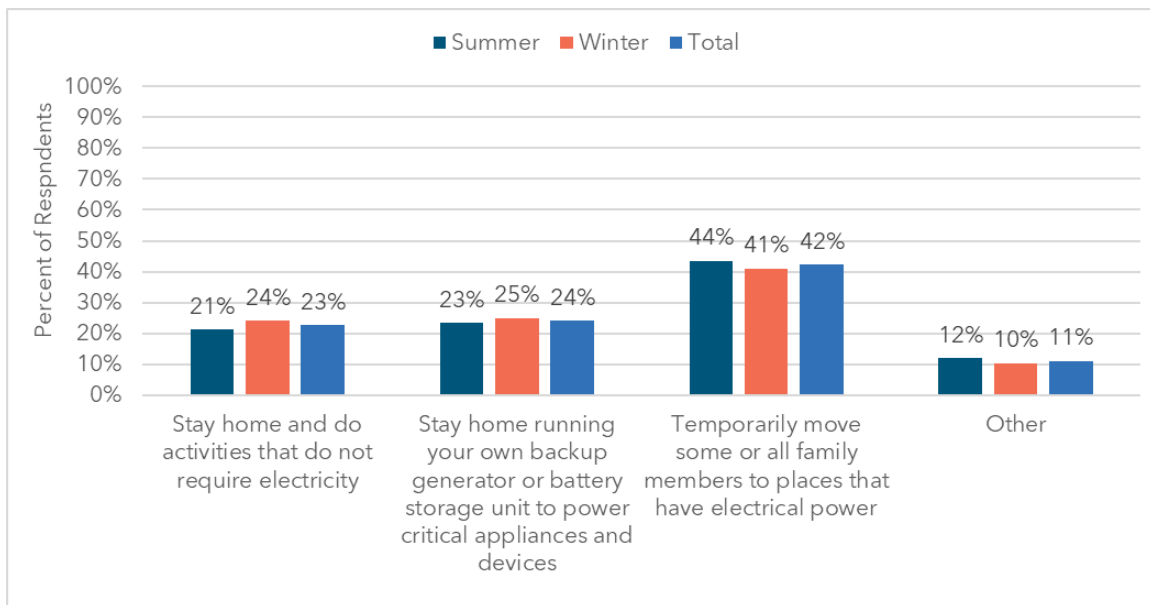
Figure ES-4 presents residential cost per interruption event as a percentage of daily household income for each income category. Overall, the two lowest income categories (household income under \$40,000 a year and income between \$40,000 and \$70,000 per year) had the highest interruption costs as a percentage of their daily income for all interruption durations.

Figure ES-4: Residential Cost Per Interruption as a Percentage of Daily Household Income



Survey respondents were also asked a brief series of non-cost-related questions regarding a long-duration interruption (one lasting three days or 72 hours). Respondents were presented with either a summer or winter long-duration scenario. Figure ES-5 presents residential responses to the two seasonal scenarios. Many residential respondents, 42%, stated that they would relocate some or all family members to a location with power. The responses were not statistically different between seasons ($p=0.10$).

Figure ES-5: Residential Responses to a Three-day Interruption



Residential respondents were also asked if their household income would be reduced during such a long-duration interruption. Overall, 6% stated they would lose all their household income, while 14% stated they would only lose some of their household income. The mean reported income lost was \$1,157.50 and the median income lost was \$625. Figure ES-6 shows the distribution of lost income for by season. Differences in income loss by season were not statistically significant.

Figure ES-6: Residential Income Lost Due to a Three-day Interruption by Season

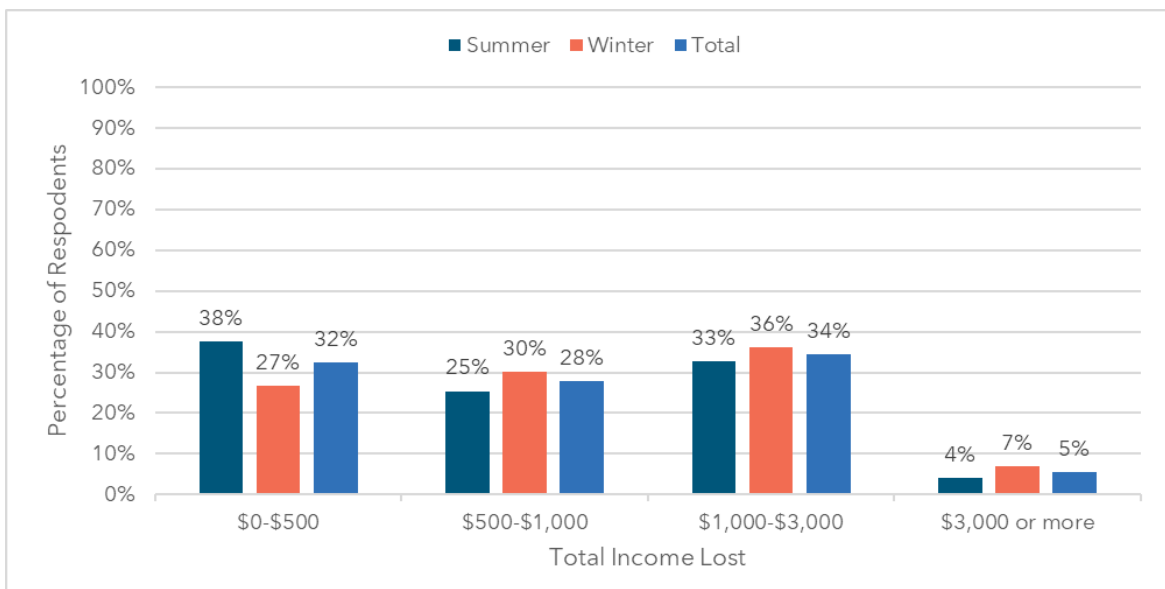
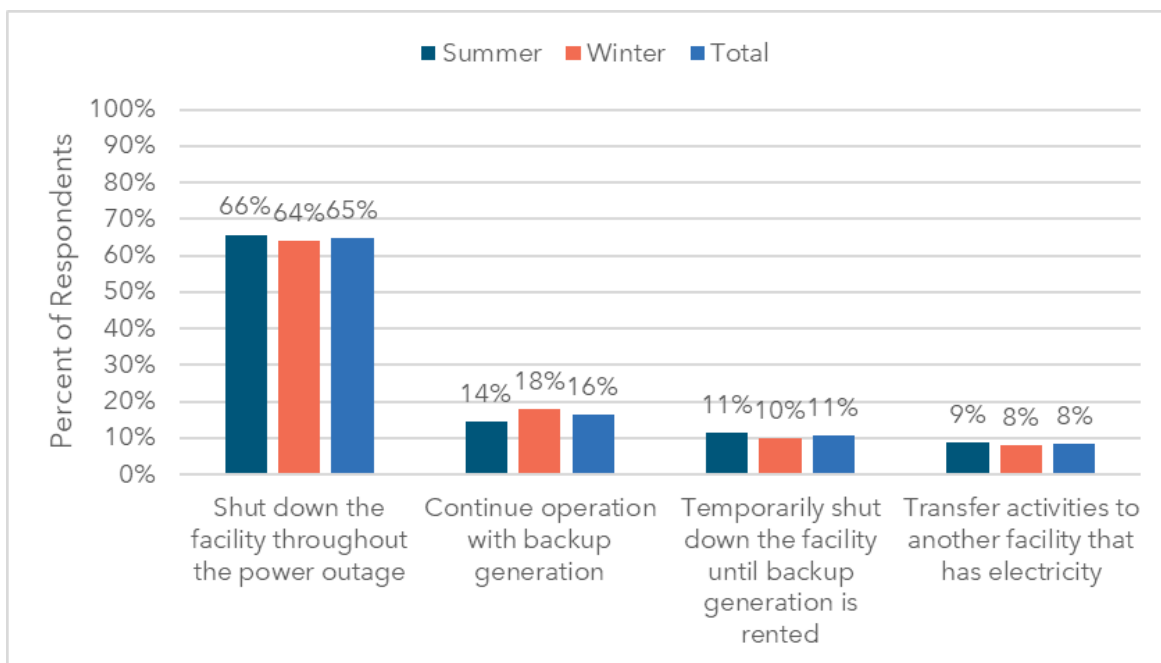


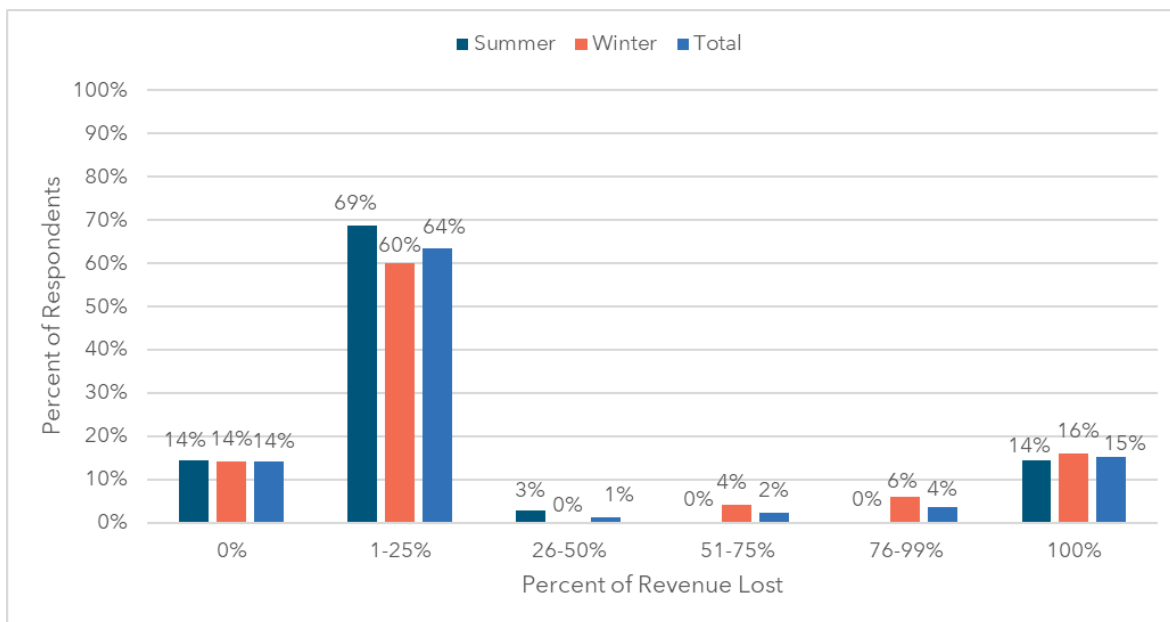
Figure ES-7 displays the non-residential responses to a three-day interruption by season. Overall, 65% stated they would shut down their facility for the duration of the interruption, while 16% stated they would continue business operations by using backup generation. The responses were not statistically different between seasons ($p=0.10$).

Figure ES-7: Non-Residential Responses to a Three-day Interruption



Finally, non-residential respondents were asked what percentage of their revenue would be lost during a three-day interruption. Approximately 15% stated they would lose all their revenue and 6% stated they would lose between 50% to 99% of their revenue. The average revenue loss was \$43,352 and the median revenue loss was \$10,000. Figure ES-8 shows the distribution of non-residential revenue lost by season. The responses were not statistically different between seasons ($p=0.10$).

Figure ES-8: Non-Residential Percent of Revenue Lost during a Three-Day Interruption by Season



Next Steps

The results presented in this report will be combined with those from the other utilities participating in the ICE Calculator 2 initiative to update the ICE Calculator. The first version of the ICE Calculator 2, which incorporated the surveys from the Phase I utilities, was released in early 2025 and the second version, which incorporated the surveys from both the Phase I and Phase II utilities was released in early 2026. Following the completion of each phase, we released a nationally focused report detailing the survey activities of the phase, along with the updated results from the combined survey activities of each phase.

The survey used to develop the results presented in this report will be used to update the ICE Calculator 2 in late 2026, early 2027.



1 Introduction

Lawrence Berkeley National Laboratory (Berkeley Lab) and Resource Innovations were retained by the Department of Energy to partner with the National Rural Electric Cooperative Association (NRECA) to conduct a customer interruption cost study – research to estimate the costs electric cooperative members incur during power interruptions – as part of a larger effort to update the Interruption Cost Estimate (ICE) Calculator.⁶

The ICE Calculator is a publicly-available, online tool that estimates the economic consequences of power interruptions. It was developed in 2009 by Berkeley Lab and Resource Innovations (then Nexant) using customer interruption cost survey results from 15 interruption cost studies conducted by 10 US utilities between 1989 and 2012.

The ICE Calculator is used routinely by utilities to support planning prioritization of grid reliability and resilience investments. The interruption cost estimates generated by the ICE Calculator can be used to assess the cost-effectiveness of investments in generation, transmission, and distribution systems, and to strategically compare alternative investments to determine which provides the most combined benefits to

⁶ <https://icecalculator.com/home>

the utility and its customers. This comprehensive approach to valuing reliability, commonly known as “value-based reliability planning,” has been a well-established practice in the utility industry for over 40 years.⁷ With the methodological improvements in this study, the results can be directly applied to many different types of utility investments at the generation-, transmission-, and distribution- levels. In other words, if *any* proposed investment in the power system may lead to an avoided interruption cost to an electricity consumer, then the results from this initiative can estimate a key benefit of that investment.

In order to support the ICE Calculator update, Berkeley Lab and Resource Innovations developed a completely new, updated set of survey instruments and then administered them consistently for each of the participating utilities. The updated surveys reflect current best practices for collecting information on the costs that electricity consumers incur due to power interruptions. For example, the survey employs a state-of-the-art econometric methodology to evaluate residential consumers' willingness-to-pay (WTP).

The overall goal of this effort is to update the ICE Calculator with new information collected from a nationwide, statistically-representative sample of U.S. electricity consumers on the economic costs they experience when electric service is interrupted. Further, it will provide relevant social science insights into the economic cost of power interruptions, allowing policymakers to understand the cost burden to households and businesses resulting from power interruptions.

This project is being conducted through a series of public -private partnerships with utilities, each supporting Berkeley Lab and Resource Innovations to administer a consistent set of updated surveys to their customers; aggregate and analyze survey information; and incorporate the combined findings from all surveys into an updated version of the ICE Calculator. The ICE Calculator update, referred to as ICE Calculator 2, will provide the most up-to-date, geographically-representative, and publicly available information on residential and non-residential interruption costs in existence.

The first phase of this effort was sponsored by eight utilities, including: American Electric Power, Commonwealth Edison, Dominion Energy, Duke Energy, DTE Electric, Exelon, National Grid, and Puget Sound Energy. The second phase of the effort was

⁷ Sullivan, M.J., M. Mercurio, and J. Schellenberg (2009). Estimated Value of Service Reliability for Electric Utility Customers in the United States. Lawrence Berkeley National Laboratory Report No. LBNL-2132E. <https://live-etabiblio.pantheonsite.io/sites/default/files/lbnl-2132e.pdf>

sponsored by six utilities, including: The Union Electric Company, Empire District Electric Company, Evergy Missouri, Pacific Gas & Electric, San Diego Gas & Electric, and Southern California Edison. The responses from the participating NRECA member cooperatives will be included in the Phase III update, which will take place in late 2026/early 2027.

Representatives from the sponsoring utilities participated in a Project Executive Committee (PEC), which was created to support the overall effort. The Committee provided suggestions and approvals throughout the ICE Calculator 2 project to ensure that the project would meet the needs of each utility and of the cohort as a whole. The PEC's contributions included a review of beta versions of the surveys, support for the recruitment of customers to participate in the surveys, and recommendations to enhance the functionalities of the updated ICE Calculator.

While many of the sponsoring utilities in Phases I and II are large investor-owned utilities, NRECA was approached by Berkeley Lab to help recruit cooperative utilities for the ICE Calculator 2 Initiative. This engagement was intended to include representation from electricity consumers (i.e., member of electric cooperatives) not served by investor-owned utilities, expand the geographic scope of participating utilities, better reflect the costs incurred by rural electricity consumers, and increase the overall number of surveys available to update the ICE Calculator.

To help meet these objectives, the 18 participating electric cooperatives were grouped into three distinct regions. The participating electric cooperatives in each region and state are listed in Table 1-1 below.

Table 1-1: Participating Electric Cooperatives by Region and State

Region	States Included	Participating Electric Cooperatives ⁸
Southeast	FL, TN, KY	• Suwannee Valley Electric Cooperative • SECO Energy • Sequachee Valley Electric Cooperative* • Kenergy • Choctawhatchee Electric Cooperative* • Volunteer Energy Association*
Great Plains/Upper Midwest	MN, OH, IN, SD	• Wright-Hennepin Cooperative Electric Association • Lorain-Medina Rural Electric Cooperative • North Central Electric Cooperative* • Kosciusko Rural Electric Membership Corporation* • Butte Electric Cooperative • Consolidated Electric Cooperative*
Intermountain West	WY, ID, AZ, CO, NM	• Powder River Energy Corporation* • Clearwater Power Company • Sulphur Springs Valley Electric Cooperative • La Plata Electric Association • Kit Carson Electric Cooperative • Mohave Electric Cooperative*

Each of the 18 studies involved the collection of detailed interruption cost information from a statistical sample of the cooperatives' members. Separate survey instruments were administered to for residential and non-residential cooperative members. In this report, the methodology used to recruit members and administer surveys to them, and the results from the surveys are summarized. The primary objectives of the overall study were to:

- Estimate costs for interruptions lasting less than 5 minutes up to 24 hours for (residential and non-residential cooperative members;
- Collect other useful information about cooperative members' preparation for and response to power interruptions; and
- Use the information collected to inform the broader effort to update the ICE Calculator.

⁸ Electric cooperatives marked with an asterisk surveyed only non-residential members.

The ICE Calculator 2 initiative will take place over a number of years. After each phase, the survey results from all participating utilities will be aggregated and used to update the customer damage functions (CDFs) relied on by the ICE Calculator. CDFs are econometric models that predict how interruption costs vary according to type of electricity consumer, interruption duration, and other interruption characteristics. For example, CDFs can relate how interruption costs vary by time of day and interruption duration for different types of electricity consumers. The survey data for the participating cooperatives will be included in the ICE Calculator update along with the survey data from all the Phase I and II utilities.

This report provides high-level results that are specific to the participating cooperative utilities. The results shown here represent a small fraction of the survey data that will be used to update the ICE Calculator, which as noted will aggregate results across all participating utilities. For this reason, the interruption cost estimates presented in this report are less precise (statistically speaking) than those that will be generated using the updated ICE Calculator. In addition, the smaller numbers of surveys collected for this report means that results are not included for some subgroups of the population (for example, by industry classification) for which the results would not be statistically meaningful.

This report is intended to be an informative summary of interruption costs reported by members of the participating electric coops. The ICE Calculator 2 update, in contrast, is based on a significantly larger body of customer interruption cost surveys representing all regions of the contiguous United States.

The remainder of this report is organized as follows:

- Section 1 – Introduction: The remainder of this section details the study methodology, discusses the history of value of service reliability studies, and the valuation methods used in this study.
- Section 2 – Survey Methodology: This section describes the survey methodology, including details on the survey implementation approach, survey instrument design, sample design, and data collection procedures.
- Section 3 – Interruption Cost Estimation Methodology: The results of this study focus on four key metrics – cost per interruption event, cost per average kW, cost per unserved kWh, and cost per customer minute interrupted. This section explains what each of these key metrics represent, how they are calculated from the survey data, and how they relate to each other.
- Section 4 – Residential Results: These sections present the interruption cost estimates for the residential cooperative members.

- Section 5 – Non-Residential Results: These sections present the interruption cost estimates for the non-residential cooperative members.
- Appendix A – Cooperative Communications: This appendix provides more details on the communications used to recruit the participating cooperatives.
- Appendix B – Invalid and Protest Responses: This section provides additional information on the removal of invalid survey responses.
- Appendix C – Results by Region: The interruption cost results in this section are presented separately for each of the three regions in the U.S.: Great Plains/Upper Midwest, Intermountain West, and Southeast.
- Appendix D – Residential Modeling: Additional information is provided about the model used to estimate residential results.
- Appendix E – Residential Income Normalization Procedure: In this appendix, details are given about the residential results by income class.
- Appendices F through H – Survey Instruments: These appendices contain the two survey instruments (residential and non-residential).

1.1 Study Methodology

The surveys and survey procedures used to estimate the costs electricity users experience due power interruptions have been developed and validated over the past 35 years.⁹

Noteworthy advances to these procedures in the ICE Calculator 2 effort include:

- **Building on lessons learned from ICE 1.0:** The initial ICE Calculator included some surveys dating back more than 25 years and did not include all regions of the country. Additionally, many of the surveys included in the ICE Calculator did not ask about interruptions up to 24 hours in duration. The ICE Calculator 2 effort addresses both issues by including results from each region of the contiguous U.S. and interruptions lasting up to 24 hours using a consistent set of survey questions across all utilities being surveyed.
- **Improved survey design:** The online survey was designed to produce an estimate of the average interruption cost across all time periods, as opposed to focusing on an individual interruption start time and duration. Data were collected to understand how interruption costs vary across different times of the day and week, for interruptions lasting up to 5 minutes to 24 hours. Additionally, the survey asked questions to gauge interruption cost variation

⁹ Sullivan, M. J., M. Collins, J. Schellenberg, and P. Larsen (2018). Estimating Power System Interruption Costs: A Guidebook for Electric Utilities.

based on season, the day of the week, and advanced interruption notice from the utility.

- **Cognitive testing of the residential survey:** The residential surveys went through extensive testing before they were used. The initial cognitive testing asked respondents to provide feedback about the clarity of the survey questions. These suggestions were used to improve survey functionality and helped refine question wording.
- **Advanced residential willingness-to-pay elicitation method:** The interruption costs for residential respondents were estimated using an advanced econometric approach called one-and-a-half bound discrete choice survey methodology. This type of estimation improves upon the methodology used in previous studies and produces more statistically reliable interruption costs.¹⁰
- **Institutional Review Board protocol:** This work is required by Berkeley Lab and the U.S. Department of Energy to follow an Institutional Review Board protocol, which details the research steps and all interactions involving human subjects (electric cooperative members). The Protocol ensures that comprehensive steps are taken to identify and mitigate potential risks stemming from interactions with surveyed individuals and firms.

1.2 Economic Value of Service Reliability¹¹

The purpose of interruption cost research is to measure the economic value of service reliability, using information regarding interruption costs as a proxy. Under the general theory of welfare economics, the economic value of service reliability is equal to the economic losses that electric consumers experience as a result of service interruptions. The estimation of interruption costs dates back several decades and has involved several approaches. These include:

- Scaled macro-economic indicators (e.g., gross domestic product, wages);

¹⁰ Sullivan et al. (2019). Elicitation of Electric Utility Customer Power Interruption Costs: A Roadmap for Conducting a National Survey. <https://icecalculator.com/assets/documents/National-Study-Roadmap.pdf>.

See also <https://icecalculator.com/assets/documents/ICE-2.0-Survey-Design-Memo.pdf>

¹¹ The information presented in this and the following sub-section was developed originally in support of surveys administered to customers of investor-owned utilities. It is fully understood that the consumers of electricity distributed by electric coop are not “customers;” they are members of the cooperative. Nevertheless, from the standpoint of estimating power interruption costs, the valuation concepts described in these sections apply equally with no loss of generality to members of electric cooperatives.

- Market-based indicators (e.g., incremental value of reliability derived from studies of price-elasticity of demand for service offered under non-firm rates); and
- Survey-based indicators (i.e., cost estimates obtained from surveys of representative samples of a utility's customers).

The most widely used approach to estimating customer interruption costs is through analysis of data collected via customer surveys. In a customer interruption cost survey, a representative sample of customers is asked to estimate the costs they would experience given several hypothetical interruption scenarios. In these scenarios, the key characteristics of the interruption are varied systematically to measure differential effects of service interruption events with various characteristics. A variety of statistical techniques are then used to identify and describe the relationships between customer economic losses and interruption attributes. Survey-based methods are generally preferred over the other measurement protocols because they can be used to obtain interruption costs for a wide variety of reliability conditions not observable using the other techniques.

1.3 Valuation Methods

Two basic valuation methods are used to measure interruption costs in the surveys: (1) direct cost measurement and (2) willingness-to-pay (WTP). Direct cost measurement techniques involve asking customers to estimate the direct costs they would incur during a service interruption. WTP measurement techniques involve estimating the amount customers would be willing to pay for a hypothetical backup service to avoid experiencing the interruption. In both approaches, the surveys ask respondents to provide these estimates for several interruption scenarios, which vary in terms of the characteristics of the event.

1.3.1 Direct Cost Measurement

For non-residential customers (small/medium and large), direct cost measurement was used in this study because their interruption costs are more tangible to estimate directly than residential customers. Generally speaking, the direct cost of an interruption is defined as follows in Equation 1-1:

Equation 1-1 Direct Cost Measurement

$$\text{Direct Cost} = \text{Value of Lost Production} + \text{Interruption Related Costs} \\ - \text{Interruption Related Savings}$$

The *Value of Lost Production* is the amount of revenue the customer's firm or business would have generated in the absence of the power interruption minus the amount of revenue it was able to generate given that the power interruption took place. That is, it represents the net loss in the economic value of production taking into account the possibility to make up for lost production.

Interruption Related Costs are additional production costs directly incurred because of the interruption. These costs include:

- 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 feedstocks;
- Costs of re-processing materials (if any); and
- Cost to operate backup generation equipment.

Interruption Related Savings are production cost savings resulting from the interruption. When production or sales cannot take place, there are economic savings resulting from the fact that inputs to the production or sales process cannot be used. For example, during the time electric power is interrupted, the enterprise cannot consume electricity and thus will experience savings on their electric bill. In many cases, savings resulting from interruptions are small and do not significantly affect interruption cost calculations. However, for manufacturing enterprises where energy and feedstock costs account for a significant fraction of production cost, these savings may be quite significant and should be subtracted from the other cost components to ensure interruption costs are not double counted. These savings include:

- 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; and
- Scrap value of any damaged materials.

In measuring interruption costs, only the incremental losses resulting from unreliability are included in the calculations. Incremental losses include only those costs described above and beyond the normal costs of production. If the customer can make up some percentage of their production loss at a later date (e.g., by running the production facility during times when it would normally be idle), the interruption cost does not include the full value of the production loss. Rather, it is calculated as the value of production not made up plus the cost of additional labor and materials required to make up the share of production eventually recovered.

To determine these costs, non-residential customers were asked to estimate a series of itemized costs, including lost revenue, restart costs, and damage to equipment, for the first interruption scenario they complete (an unexpected summer weekday “base” scenario at their first randomly assigned duration). Following this, respondents were presented with an estimated total cost based on their itemized costs, which they could confirm or adjust as needed. For all subsequent interruption scenarios, non-residential respondents were asked how their total cost would change relative to the first scenario. This format ensured that respondents were only required to answer questions relating to itemized costs once, saving time and increasing ease of taking the survey.

1.3.2 Willingness-to-Pay Approach

Cost estimates for the residential segment are based on a WTP question because residential customers do not experience many directly measurable costs during a shorter-duration interruption (less than 24 hours). WTP is a better representation of their underlying costs because most of the interruption cost for residential customers is a result of inconvenience.

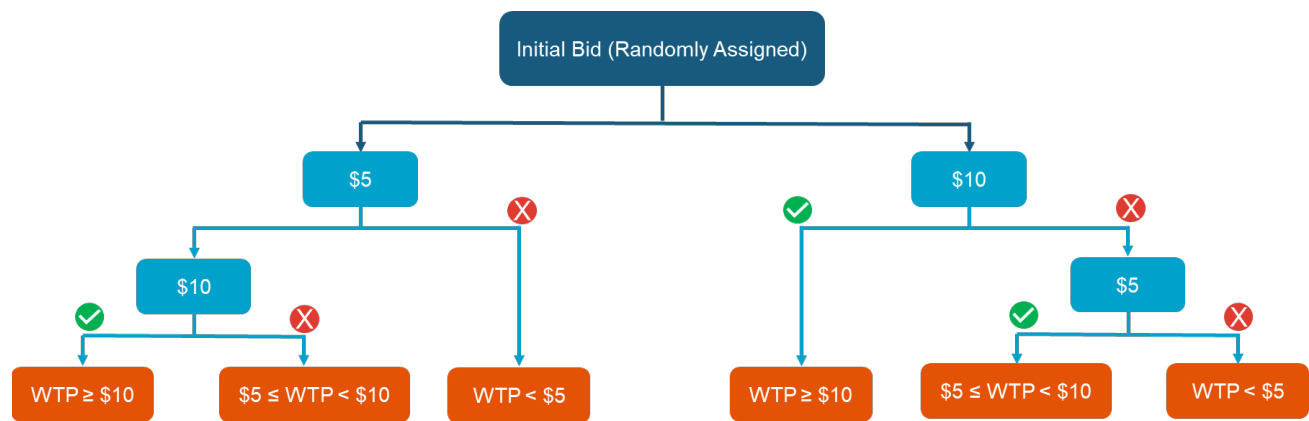
The WTP approach to interruption cost estimation is quite different from the direct cost measurement approach. Rather than asking what an interruption would cost the customer, the WTP approach asks how much the customer would pay for a hypothetical backup service to avoid its occurrence. This technique employs the concept of compensating valuation – customers are asked to estimate the economic value that would leave their welfare unchanged compared to a situation in which no interruption occurred. This approach is especially useful when intangible costs are present, which by their nature, are difficult to estimate using the direct cost measurement approach.

One-and-one-half-bound dichotomous choice contingent valuation (OHDC) is a type of choice experiment used to measure the value of a product or service.¹² This type of methodology is implemented when the market for a good, such as a market for perfectly reliable power, does not exist. The OHDC procedure is implemented in the survey by first describing a hypothetical, but plausible, backup service that can be purchased to avoid the interruption. Then, respondents are told the exact cost to purchase the service is unknown, but it is believed to be within a range of two discrete prices. Next, respondents are asked a series of questions based on their willingness to purchase the service at a pre-determined price.

¹² J. Cooper, M. Hanemann and G. Signorello (2002). One-and-One-Half-Bound Dichotomous Choice Contingent Valuation. *Review of Economics & Statistics* 84(4) 742-750.

Figure 1-1 illustrates the flow of questioning for an OHDC example scenario. For instance, the respondent is asked if they would purchase the service for \$5. If they respond positively, they are then asked if they would be willing to purchase the service for \$10. Alternatively, if they respond that they would not purchase the service for \$5, then they are not asked any other questions. A similar logic applies if the respondent is first asked if they would purchase the service for \$10. If they say they would purchase the service, there are no follow-up questions. If they respond “no”, they are asked if they would purchase the service for \$5. Appendix D – Residential Modeling describes the OHDC approach in more detail.

Figure 1-1: Survey Questioning using One-and-one-half-bound Contingent Valuation





2 Survey Methodology

This section describes the methodology used to survey coop members for this study. Section 2.1 discusses the design of the survey instrument and Section 2.2 covers survey administration.

2.1 Survey Instrument Design

This discussion of the survey instrument design focuses on the interruption scenarios, which were designed the same for respondents. The survey instruments are included in this report in Appendix F - Residential Survey Instrument, Appendix G - Small and Medium Non-Residential Survey Instrument (SMNR), and Appendix H - Large Non-Residential Survey Instrument (LNR).

Considering that most electricity consumers rarely experience sustained power interruptions, an interruption cost survey presents the respondent with hypothetical interruption scenarios that are specific to a certain time. Berkeley Lab and Resource Innovations developed survey instruments with a standard set of questions, one for each segment surveyed: residential, SMNR, and LNR. The survey instruments were designed and vetted to ensure respondents could easily estimate the financial impact power interruptions have on their household or business. Prior to fielding, the

residential survey underwent thorough cognitive testing with a random sample of more than 500 participants. This testing helped ensure the survey questions were easy to understand for the general population, the survey length was acceptable, and the respondents were able to provide valuable results. The survey instruments underwent an extensive review process involving both the participating Phase I utilities through the Project Executive Committee as well as feedback from well-known external stakeholders through the Project Advisory Committee.

Each of the three surveys included a series of introductory questions asking respondents about their household or organization's demographic or firmographic characteristics, their experience with prior power interruptions, and resilience measures they have in place (such as backup generators). Next, the survey presented each respondent with a set of scenarios varying in interruption duration. Each respondent was assigned three of the following four durations in random order:

1. Momentary (lasting up to 5 minutes)
2. 2 hours
3. 8 hours
4. 24 hours

For each of these durations, all respondents were initially introduced to the interruption as an unexpected summer weekday interruption – defined as the “base” scenario. However, following each base scenario at each duration, the respondent was also randomly presented with one (for residential and SMNR respondents) or two (for LNR respondents) randomly assigned “pivots” - each one a change in circumstances relative to the “base” scenario. These “pivot” conditions included:

1. The interruption still occurs during a summer weekday, but the respondent receives an advanced warning of the interruption prior to it occurring.
2. The interruption still occurs during a weekday without warning but occurs in the winter instead of the summer.
3. The interruption still occurs during the summer without warning but occurs on the weekend instead of during a weekday.

Each respondent was only presented with one “pivot” from the base scenario at a time, so all other circumstances of the new interruption scenario remained the same as the “base” scenario. For instance, if a respondent received the advanced warning “pivot”, their second interruption scenario would still occur in the summer and on a weekday. This was to ensure that respondents only had to focus on one change to their interruption circumstances at a time.

Residential and SMNR respondents received questions related to three unique short-duration interruption scenarios of varying duration, each with a base scenario and a pivot scenario, resulting in six total interruption scenarios presented to each respondent. LNR respondents also received three unique interruption durations, but each included one base scenario and two randomly assigned pivots. Respondents received the same pivot(s) for all three durations. For example, if they received the “advanced warning” pivot for the first duration presented to them, they would receive the “advanced warning” for the following two durations as well. Each of the three unique interruption scenarios occurred at the same onset time, either 9 AM, 2 PM, or 7 PM. Table 2-1 provides an example set of interruption scenarios.

Table 2-1: Example Set of Interruption Scenarios for an Individual Respondent

Scenario	Season	Time of Week	Onset Time	Advanced 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

Lastly, in addition to the primary short-duration scenario questions, each respondent was also presented with one hypothetical three-day interruption scenario at the end of the survey. This question was not intended to be used for interruption cost modeling. Instead, this scenario was included to give insight into how respondents would react to this longer-duration scenario and give a general sense of how adversely they would be affected. Respondents were randomly assigned either a summer or winter long-duration scenario for this question.

2.2 Survey Administration

Survey administration involved two steps. First, NRECA led recruitment of electric cooperatives to participate in the study. This included working with participating cooperatives to determine which of their members (residential and/or non-residential) would be involved in the study. Second, these cooperative members were then invited to complete the surveys. In a limited phase, financial incentives were paid to non-residential members in order to increase the number of surveys

completed. This sub-section concludes with summaries of the numbers of completed surveys.

2.2.1 NRECA Recruitment of Electric Cooperatives

Following discussions among NRECA, Berkeley Lab, and RI staff, recruitment of electric cooperatives to participate in the study was organized around targeting electric cooperatives in three geographic regions.

The geographic regions are defined as follows:

- Southeast Region: Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, and Tennessee.
- Great Plains/Upper Midwest Region: Iowa, Kansas, Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin. Due to recruiting difficulties for the non-residential samples, cooperatives from Indiana and Ohio were added to this region.
- Intermountain Region: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming.

Recruitment targets were set at 250 residential, 250 small and medium non-residential (SMNR), and 70 large non-residential (LNR) for each of the three regions.

In November 2024, NRECA's CEO sent an email to distribution cooperatives within each of these regions informing them of NRECA's participation in the project and encouraging them to participate in the survey effort. Following the initial communication, a second email was sent to the same list of electric cooperatives containing additional information about the survey process.

In support of the recruitment effort, NRECA staff developed a one-page overview to clearly communicate the purpose, scope, and value of the project. This document served as an essential resource for internal alignment and for introducing the project to distribution cooperatives in a concise and accessible format. In addition to the one-pager, the team created a streamlined project timeline to ensure that all milestones were achievable and that the project remained on track to meet its targets.

The initial recruitment efforts resulted in expressions of interest from 51 cooperatives with three ultimately participating.

In June 2025, a second recruitment effort was undertaken in which NRECA staff personally reached out to distribution cooperatives to encourage participation, with a specific emphasis on securing support for inviting more non-residential cooperative members to complete surveys. NRECA staff broadened their efforts by collaborating with another NRECA department to identify and engage cooperatives with large commercial and industrial members. This cross-departmental coordination helped refine outreach strategies and ensure that recruitment efforts were aligned with the project's evolving needs.

Throughout the process, NRECA staff held one-on-one calls with numerous cooperatives. These conversations provided opportunities to answer questions, address concerns, and emphasize the importance of the project to the broader cooperative network. This personalized engagement played a key role in building trust, clarifying expectations, and encouraging participation across the membership.

The targeted outreach effort resulted in participation from an additional 15 cooperatives, bringing total participation to 18 cooperatives. Ten of the 18 elected to participate in both the residential and non-residential surveys. Eight of the 18 elected to participate in only the non-residential surveys. See Table 1-1.

For reference, Appendix A – Cooperative Communications contains the cooperative recruitment materials.

2.2.2 Administration of the Surveys

Administration of the surveys took place between February and December 2025. In this sub-section, details of the administration of surveys for residential members are presented first, followed by those for non-residential members, including a discussion of the financial incentives paid to increase participation. A small number of potential respondents were deemed ineligible due to the ways their accounts were labeled, which suggested that they had not been classified properly in the records provided to the project team.

Residential Member Participation

Residential members were invited to complete surveys through an email from their cooperative informing them of their cooperative's participation in the study. The email message explained that they had been selected to receive the survey and a survey link would be sent in a follow up email. Data collection was initially open for two weeks. Members who did not complete the online survey received two email reminders during that time, one on Saturday of the first week and one on Wednesday of the second week.

For one cooperative (Kit Carson Electric Cooperative), data-collection was extended to three weeks due to the Thanksgiving holiday. In addition, some of the surveys were not closed on the originally communicated due date and so a small number of responses were received (and included) after this date.

Non-Residential Member Participation

All 18 cooperatives participated in the non-residential portion of the survey, including two that had been recruited specifically because they had non-residential members with higher-than-average electricity usage. For many participating cooperatives, the number of non-residential members was small and it was often difficult to obtain contacts beyond those identified as the billing contact.

Upon receiving member lists from the cooperatives, NRECA found that the pool of non-residential members to survey was much smaller than anticipated. Additionally, it was found that a number of non-residential members fell below the minimum usage of 0.25 kW/hour and that several participating cooperatives lacked usable contacts for non-residential members. These issues resulted in a lower-than-expected response rates for the small pool of available members surveyed. It led to subsequent cooperative recruitment efforts described above.

Non-residential members were invited to complete surveys by an email from their cooperative informing them of their cooperative's participation in the study. The email explained that they had been selected to participate and would receive an email with the survey link on the following Monday. Data collection was open for two weeks. Members who did not complete the online survey received two email reminders, one on Friday of the first week and another on the Wednesday of the second week. As with the residential survey, not all surveys were closed on the communicated due date and a small number of responses were received after this date. cooperatives.

It had originally been determined that no incentives would be offered to non-residential members for completion of surveys. However, after a low number of responses to the initial surveys, a decision was made to begin offering incentives of \$50 to SMNR and \$100 to LNR respondents who completed the survey. However, after further internal review, it was determined that the incentives were inconsistent with internal NRECA policy and therefore discontinued. Receipt of an incentive was voluntary.

Certain members were deemed ineligible for survey recruitment. Residential members with a calculated average demand of 10 kW or greater were excluded

under the assumption that the high-usage residential accounts are likely to be non-residential facilities that have been misclassified. Additionally, non-residential members with an average demand of less than 0.25 kW were excluded. Non-residential accounts with low usage are often associated with customers who are not actively managing energy consumption. These accounts tend to have much lower response rates to surveys and were thus excluded from the sample.

Both the residential and non-residential recruitment lists contained members without email addresses. These members were unable to be used for recruitment purposes. In general, all customers with a valid email that passed the initial recruitment screen were recruited to participate in the survey. Additionally, member lists were reviewed to remove duplicate emails, with the non-residential process focuses on keeping the highest demand account for sampling.

2.2.3 Survey Response Summary

The tables below present the total population, number of cooperative members invited to complete surveys, and the final number of completed surveys (and response rate) for both residential and non-residential segments. Each table further segments the survey responses according to ranges of electricity use (usage strata). Summaries are presented both for the total populations of residential and non-residential members and for each of three geographic regions (Southeast, Great Plains/Midwest, and Intermountain).

Overall and within each region, the residential response targets of 250 per region and 750 in total were met. By comparison, the non-residential response rate was much lower, for the reasons outlined previously. Across all regions, a total of 97 non-residential responses were collected.

Table 2-2: Residential Total Sample Design by Usage Category

Stratum	Usage Category (Average kW)	Population	Members Invited to Complete Surveys	Completed Surveys	Response Rate
1	0-0.5	62,049	8,465	218	2.6%
2	0.5-1	121,935	12,009	318	2.6%
3	1-2	179,097	15,040	417	2.8%
4	2-5	77,765	6,919	249	3.6%
5	5-10	4,303	1,048	33	3.2%
Total		445,139	43,481	1,235	2.8%

Table 2-3: Residential Southeast Region Sample Design by Usage Category

Stratum	Usage Category (Average kW)	Population	Members Invited	Completed Surveys	Response Rate
1	0-0.5	25,384	799	12	1.5%
2	0.5-1	71,359	1,885	45	2.4%
3	1-2	126,647	4,658	145	3.1%
4	2-5	52,097	2,049	52	2.5%
5	5-10	1,060	225	2	0.9%
Total		276,547	9,616	256	2.7%

Table 2-4: Residential Great Plains/Midwest Region Sample Design by Usage Category

Stratum	Usage Category (Average kW)	Population	Members Invited	Completed Surveys	Response Rate
1	0-0.5	8,892	984	33	3.4%
2	0.5-1	16,273	2,022	81	4.0%
3	1-2	21,345	3,234	128	4.0%
4	2-5	15,402	2,940	128	4.4%
5	5-10	2,964	751	29	3.9%
Total		64,876	9,931	399	4.0%

Table 2-5: Residential Intermountain Region Sample Design by Usage Category

Stratum	Usage Category (Average kW)	Population	Members Invited	Completed Surveys	Response Rate
1	0-0.5	27,773	6,682	173	2.6%
2	0.5-1	34,293	8,102	192	2.4%
3	1-2	31,105	7,148	144	2.0%
4	2-5	10,266	1,930	69	3.6%
5	5-10	279	72	2	2.8%
Total		103,716	23,934	580	2.4%

Table 2-6: Non-Residential Total Sample Design by Usage Category

Stratum	Usage Category (Average kW)	Population	Members Invited	Completed Surveys	Response Rate
1	0.25-2	9,469	4,630	44	1.0%
2	2-10	4,961	3,284	27	0.8%
3	10-50	2,070	1,409	17	1.2%
4	>50	755	573	9	1.6%
Total		17,255	9,896	97	1.0%

Table 2-7: Non-Residential Southeast Sample Design by Usage Category

Stratum	Usage Category (Average kW)	Population	Members Invited	Completed Surveys	Response Rate
1	0.25-2	4,538	1,720	19	1.1%
2	2-10	2,646	1,671	7	0.4%
3	10-50	1,275	834	10	1.2%
4	>50	506	365	4	1.1%
Total		8,965	4,590	40	0.9%

Table 2-8: Non-Residential Great Plains/Midwest Sample Design by Usage Category

Stratum	Usage Category (Average kW)	Population	Members Invited	Completed Surveys	Response Rate
1	0.25-2	564	299	3	1.0%
2	2-10	340	214	9	4.2%
3	10-50	282	182	1	0.6%
4	>50	130	103	1	1.0%
Total		1,316	798	14	1.7%

Table 2-9: Non-Residential Intermountain Sample Design by Usage Category

Stratum	Usage Category (Average kW)	Population	Members Invited	Completed Surveys	Response Rate
1	0.25-2	4,367	2,611	22	0.8%
2	2-10	1,975	1,399	11	0.8%
3	10-50	513	393	6	1.5%
4	>50	119	105	4	3.8%
Total		6,974	4,508	43	0.9%



3 Interruption Cost Estimation Methodology

This section summarizes how each interruption cost metric presented in the results section is developed.

3.1 Interruption Cost Metrics

The results presented for each customer class focus on the following four interruption cost metrics:

- Cost per Interruption Event;
- Cost per Average kW;
- Cost per Unserved kWh; and
- Cost per Customer Minute Interrupted (CMI).

Before presenting the results, it is important to understand how each metric was derived. This section begins with a description of the cost per interruption event estimate, which was calculated directly from the survey responses. Subsequently, the other three cost metrics are derived from the cost per interruption event.

Cost per Interruption Event: Cost per interruption event is the average cost for each interruption duration. For residential respondents, this was estimated by analyzing the responses to the one-and-one-half-bound dichotomous choice (OHDC) questions. By using a generalized linear model (GLM), it is possible to estimate the population's mean willingness-to-pay by analyzing the distribution of yes and no responses to each bid value. This regression was weighted to reflect population percentages of the strata (defined by average demand) used to create the survey sample. Appendix D – Residential Modeling contains additional information about the OHDC method and regression modeling.

The non-residential cost per interruption event was derived by calculating a weighted average of the values the respondents provided in the survey. Before calculating the weighted average of these estimates, interruption costs were checked for unrealistically high values. First, each respondent's interruption cost estimates were normalized by their average demand. Then, these values were then recalibrated to a log scale to account for the skewed distribution of costs. Interruption costs more than 1.5 times the demand-normalized logged interquartile range were identified as outliers and dropped. The rationale for dropping outliers is that the respondents provided unrealistically high estimates when taking an interruption cost survey due either to human error or misunderstanding of the question. This approach is in line with the previous value of lost load studies that have also dropped outliers using a similar methodology.¹³

After dropping outliers, the cost per interruption event was derived as an average of the remaining, valid responses, weighted by usage category for each segment in cooperatives' combined jurisdictions within each region. The interruption data is used to generate weights based on the interruption onset time, season, and day of the week. In general, the weights are implemented to ensure the results are representative of the population of cooperative members across all time periods that interruption could occur.

Cost per Average kW: Cost per average kW is the average cost per interruption event normalized by average demand. This metric is useful for comparing interruption costs across segments because it standardizes the cost per interruption event in terms of demand. Cost per average kW was derived by dividing the average cost per interruption event by the weighted average demand among respondents for each interruption duration by type of cooperative member. Therefore, for each interruption duration, the average cost per event was first calculated using the steps

¹³ Sullivan, M.J., M. Mercurio, and J. Schellenberg (2009). Estimated Value of Service Reliability for Electric Utility Customers in the United States. Lawrence Berkeley National Laboratory Report No. LBNL-2132E. <https://live-etabiblio.pantheon.io/sites/default/files/lbnl-2132e.pdf>

above and then divided by the average demand among respondents.¹⁴ The average demand for each respondent was calculated as the annual kWh usage divided by 8,760 hours in the year. The average cost per kW is then calculated by dividing the average cost by the average demand across the population as shown in the following equation:

Equation 3-1: Cost per Average kW

$$\text{Cost per Average kW} = \text{Average Cost per Event} \div \left(\frac{\text{Average Annual kWh Usage}}{8,760} \right)$$

As in the cost per interruption event average calculation, the average demand (the denominator of the ratio) was weighted by usage category for each segment.

Cost per Unserved kWh: Cost per unserved kWh is the cost per interruption event normalized by the expected amount of unserved kWh. This metric is useful because it can be readily used in planning applications, where the amount of unserved kWh resulting from an interruption is commonly available. For each duration, the average cost per event was first calculated using the steps above and then divided by the expected unserved kWh. The expected unserved kWh is the estimated quantity of electricity that would have been consumed if an interruption had not occurred and is calculated by multiplying the average kW demand by the interruption duration.

Equation 3-2: Cost per Unserved kWh

$$\text{Cost per Unserved kWh} = \text{Average Cost per Event} \div (\text{Average Demand} \times \text{Interruption Duration})$$

Cost per Customer Minute Interrupted: Cost per customer minute interrupted (CMI)¹⁵ is the average cost divided by the number of minutes of an interruption. This is calculated as the cost per interruption event divided by the number of minutes associated with the event. As the cost per interruption is already given, this is simply the cost per interruption divided by the number of minutes associated with the interruption. For instance, in the example of a two-hour interruption scenario, this

¹⁴ This method uses the ratio of averages instead of the average of the ratios. The ratio of averages treats each kW equally and answers, "What is the fraction of cost per kW?" The average of the ratios answers the question, "What is the average cost per kW for a random respondent?"

¹⁵ CMI is a metric developed by the IEEE Distribution Reliability Working Group. In this instance, it can be calculated and applied with no loss of generality equally to members of a cooperative with the understanding, noted previously, that cooperatives do not serve customers.

value would be equal to the average cost per interruption event divided by the duration of the interruption in minutes (i.e., 120 minutes).

Equation 3-3: Cost per Customer Minute Interrupted

$$\text{Cost per CMI} = \frac{\text{Cost per Interruption Event}}{\text{Duration of Interruption Event (in Minutes)}}$$

3.2 Confidence Intervals

For residential respondents, the confidence intervals shown in this report are calculated using a bootstrapping methodology to estimate the standard error associated with each mean value. Bootstrapping is a method that involves repeated sampling of a dataset and is commonly implemented for data where the population statistics are unknown. This bootstrapping process was accomplished by first randomly sampling a subset of the respondents (with replacement) and estimating the mean interruption cost within that sample. Then, another sample was taken and the mean interruption cost was estimated for that sample. This was repeated until the mean interruption costs from 100 distinct samples from the respondent population had been estimated, and a distribution of sample mean interruption cost values was formed. The distribution of these sample means was used to interruption the standard errors and corresponding confidence intervals for the population mean interruption cost estimates calculated using the entire set of survey respondents.

For non-residential respondents, the confidence intervals were calculated using the standard error estimated directly from the survey responses. The standard error of the weighted average interruption costs is clustered by respondent to account for serial correlation between responses from a given respondent, which would otherwise falsely increase the precision of the confidence intervals. Two-sided confidence intervals are then calculated from the standard error to represent the 90% confidence interval.



4 Residential Results

This section summarizes the results from surveying residential cooperative members. Section 4.1 presents summary statistics about the residential respondents to the survey, Section 4.2 displays the interruption cost metrics for residential cooperative members, and Section 4.3 describes results from the non-interruption cost-related questions in the survey. The results presented in this section represent cooperative members from all three geographic regions. The results by region are presented in Appendix C - Results by Region.

4.1 Residential Response to Survey

Table 4-1 summarizes the survey responses for residential cooperative members. With 1,235 total surveys completed, the number of responses exceeded the overall sample design target of 750. Overall, the survey had a 2.8% response rate.

Table 4-1: Interruption Cost Survey Response Summary - Residential

Demand Category (Average kW)	Population	Members Invited to Participate	Validated Responses	Response Rate
0-0.5	62,049	8,465	218	2.6%
0.5-1	121,935	12,009	318	2.6%
1-2	179,097	15,040	417	2.8%
2-5	77,765	6,919	249	3.6%
5-10	4,303	1,048	33	3.2%
Total	445,139	43,481	1,235	2.8%

Before developing interruption cost estimates, the surveys were screened to remove invalid responses and protest responses. See Appendix B - Invalid and Protest Responses for more details on and the results from the screening process.

4.2 Residential Interruption Cost Estimates

4.2.1 Residential Cost per Event

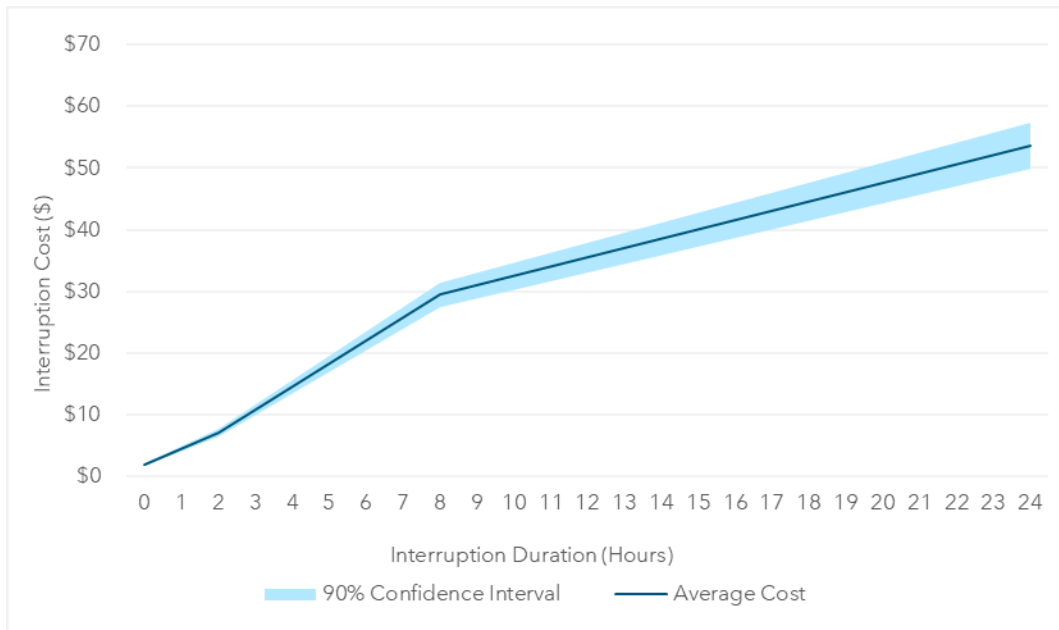
Table 4-2 presents the estimates for residential cost per interruption event as an average cost per residential cooperative member. For a momentary interruption, residential cooperative members report a cost of \$1.90 on average. Cost per interruption event increases to \$7.08 for 2 hours, \$29.42 for an 8-hour interruption, and finally \$53.68 for a 24-hour interruption. All the estimates are statistically significant since the lower bound of the 90% confidence interval is above \$0. Similarly, the differences between all the remaining point estimates presented in this section and \$0 are statistically significant.

Table 4-2: Residential Cost per Interruption Event

Interruption Duration	Respondents	Cost per Interruption Event	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	851	\$1.90	\$1.68	\$2.12
2 hours	833	\$7.08	\$6.49	\$7.67
8 hours	853	\$29.42	\$27.46	\$31.38
24 hours	880	\$53.68	\$49.98	\$57.38

Figure 4-1 shows the relationship between cost per interruption event and duration for residential cooperative members. This chart interpolates the cost reported by cooperative members for the four distinct interruption scenarios to all durations from momentary interruptions to 24 hours. The chart demonstrates how the relationship between duration and cost changes as duration increases. Additionally, the chart provides evidence that interruption costs increase rapidly, as interruption duration increases, for interruptions lasting less than eight hours. This can be seen in Figure 4-1 from the steepness of the curve for durations less than eight hours compared to durations greater than eight hours. The blue bands on the chart represent the lower and upper confidence intervals.

Figure 4-1: Residential Cost by Interruption Duration



4.2.2 Residential Cost per Average kW

Table 4-3 presents the residential cost per average kW for each duration scenario. For a momentary interruption, residential cooperative members experience a cost of 1.66 per kW. Cost per kW increases from \$6.20 for 2 hours to \$47.00 for a 24-hour interruption.

Table 4-3: Residential Cost per kW

Interruption Duration	Respondents	Cost per kW	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	851	\$1.66	\$1.47	\$1.86
2 hours	833	\$6.20	\$5.69	\$6.71
8 hours	853	\$25.76	\$24.04	\$27.48
24 hours	880	\$47.00	\$43.76	\$50.24

4.2.3 Residential Cost per Unserved kWh

Table 4-4 provides estimates for the residential cost per unserved kWh. Cost per unserved kWh is highest for momentary interruptions, as the amount of unserved energy is relatively small, and declines as interruption duration increases. In other words, total interruption cost increases as interruption duration increases, but the average cost per unserved kWh falls as the duration approaches 24 hours. For a momentary interruption, the cost estimate is \$19.95 because the expected amount of unserved kWh (the denominator of the equation) is very low for a short-duration interruption. The cost per unserved kWh for a 24-hour interruption is \$1.96.

Table 4-4: Residential Cost per Unserved kWh

Interruption Duration	Respondents	Cost per Unserved kWh	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	851	\$19.95	\$17.64	\$22.26
2 hours	833	\$3.10	\$2.84	\$3.36
8 hours	853	\$3.22	\$3.01	\$3.43
24 hours	880	\$1.96	\$1.82	\$2.09

4.2.4 Residential Cost per Customer Minute Interrupted

Table 4-5 presents residential cost per customer minute interrupted. Like cost per unserved kWh, this cost is highest for momentary interruptions and decreases as interruption duration increases. The total interruption cost increases as interruption duration increases, but the average cost per minute falls as the duration approaches 24 hours. This means that the cost per event increases, but at a decreasing rate, as interruption duration increases.

Table 4-5: Residential Cost per Customer Minute Interrupted

Interruption Duration	Respondents	Cost per CMI	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	851	\$0.38	\$0.34	\$0.42
2 hours	833	\$0.06	\$0.05	\$0.06
8 hours	853	\$0.06	\$0.06	\$0.07
24 hours	880	\$0.04	\$0.03	\$0.04

4.3 Other Findings

4.3.1 Residential Interruption Costs by Income Level

Interruption cost estimates can be segmented by annual earnings. Respondents were asked to give their total household income as one of nine possible categories. These categories were subsequently bucketed into four income classes. Figure 4-2 presents mean interruption cost per event for each of these four income categories. The costs were generally highest for residential cooperative members in the highest three income categories and generally lower for the under \$40,000 income category.

Figure 4-2: Residential Cost per Interruption Event by Household Income

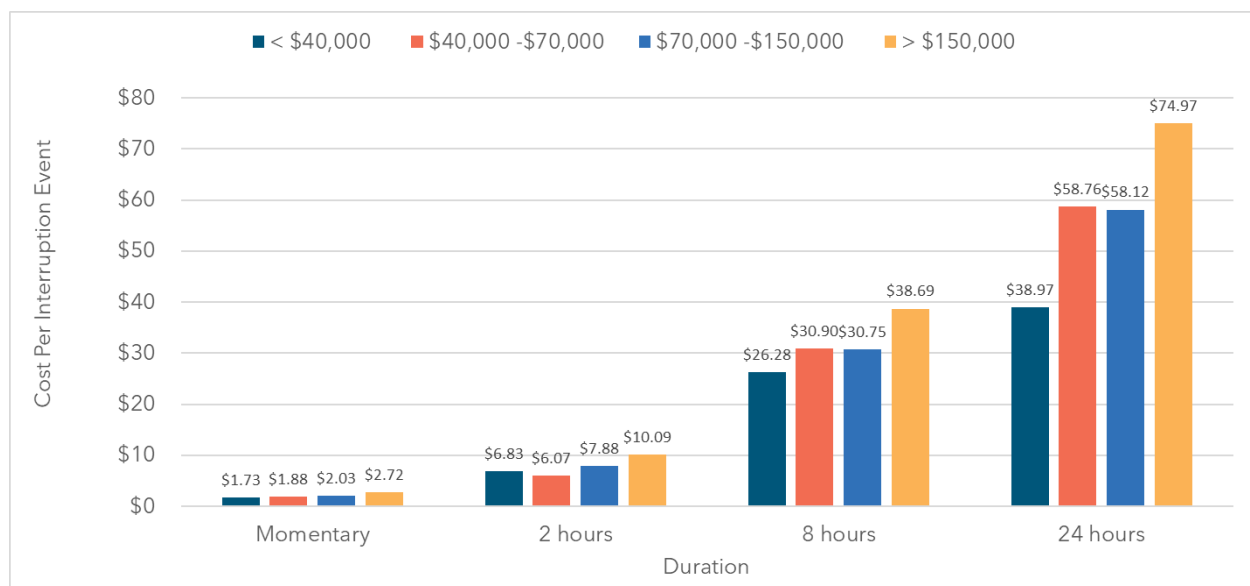
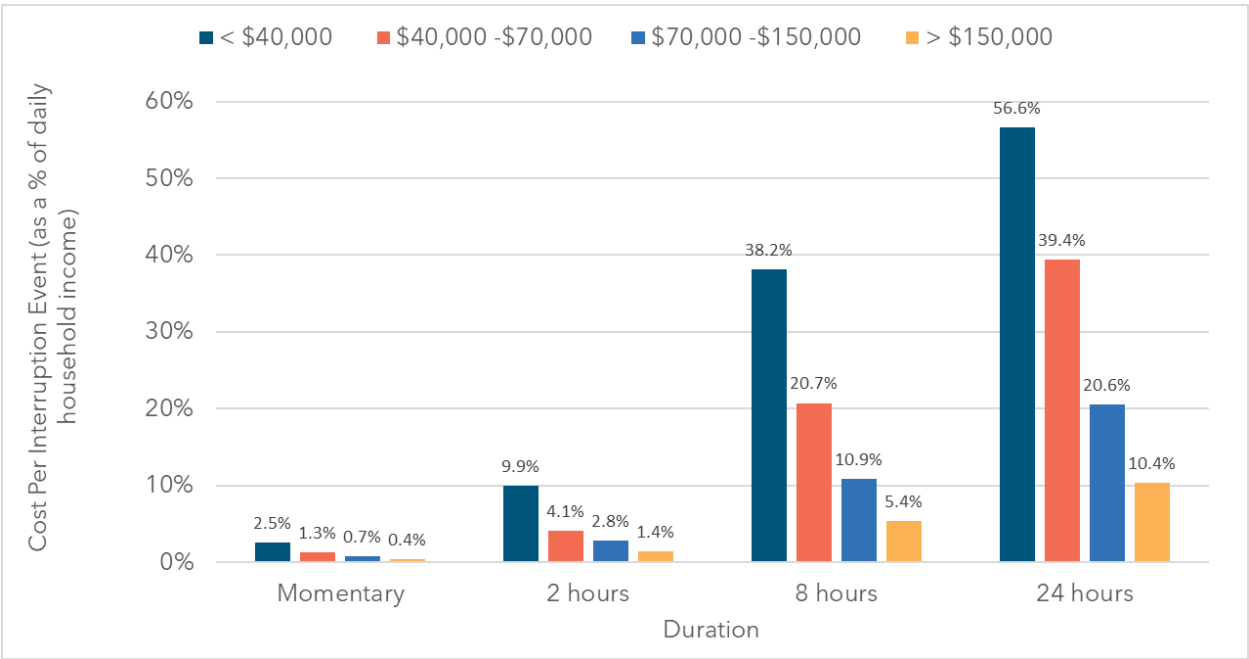


Figure 4-3 presents average costs per interruption event for residential respondents, normalized as a percentage of daily income. This calculation required making inferences about the mean and median income within each of the income buckets. Appendix E - Residential Income Normalization Procedure discusses the process for calculating the typical income within each income class. Cost as a percentage of daily income was generally highest for respondents in the lowest two income classes (<\$40,000 and \$40,000-\$70,000) and lowest for respondents in the highest income class (>\$150,000). This implies that as income increases, the interruption cost as a fraction of total income falls. For instance, the interruption costs for a 24-hour interruption account for 56.6% of the daily income for households making less than \$40,000 per year and 10.4% for households making greater than \$150,000 per year.

Figure 4-3: Residential Cost Per Interruption as a Percentage of Daily Household Income



4.3.2 Residential Backup Generation

Respondents were asked whether they had backup generation equipment that could be utilized during a power interruption. Table 4-6 presents results of this question by usage stratum. Respondents in the higher usage strata had a higher prevalence of backup generation equipment. The population average prevalence of backup generators was 30.9%.

Table 4-6: Percent of Residential Respondent with Backup Generation

Stratum	Usage Category (Average kW)	Respondents with Backup Generation	% of Population in Stratum
1	0-0.5	20.2%	13.9%
2	0.5-1	20.7%	27.4%
3	1-2	36.6%	40.2%
4	2-5	41.6%	17.5%
5	5-10	46.9%	1.0%
Total		30.9%	100.0%

4.3.3 Residential Advanced Warning Interruptions

Respondents were asked how much notice would be needed prior to the interruption to significantly reduce the costs they would incur due to the interruption. Figure 4-4 presents the percentage of respondents who selected each of the six options associated with this question. A plurality of residential cooperative members indicated that they would require at least 24 hours of advanced notice before an interruption, with 26% responding at least 24 hours and 13% responding at least 48 hours. Additionally, 18% of respondents stated that advanced warning would not reduce the costs caused by a power interruption.

Figure 4-4: Residential Advanced Warning Needed to Reduce Interruption Cost

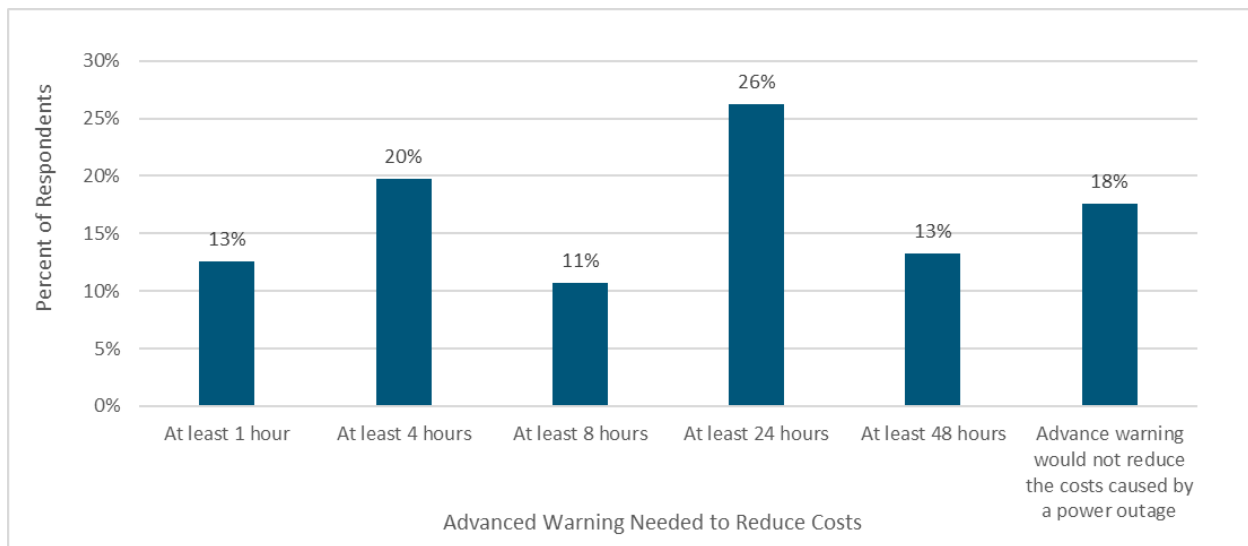


Table 4-7 displays the change in average cost per interruption if the cooperative member received notice in advance of the interruption. The amount of advance notice each respondent received was determined by how much prior warning they stated they would need, as noted above. For instance, respondents that stated they would need at least 24 hours of prior notice to significantly reduce the cost of the interruption were presented with an interruption scenario with 24 hours of advanced notice. Cooperative members that responded “advanced warning would not reduce the costs caused by a power outage” were not presented with an advanced warning interruption scenario.

When provided with advanced notice, the majority of residential respondents, 85%, did not change their willingness-to-pay responses compared to their responses without advanced notice. This finding is somewhat surprising because, as displayed in Figure 4-4, they reported that advance notice would reduce the costs they would experience. Furthermore, 10.9% reported that they would be willing to pay less to avoid the interruption and, again surprisingly, 3.8% reported they would pay more.

Table 4-7 shows the changes the average cost per interruption, for the above 14.7% of respondents that would either pay less or more with advanced warning for each duration. Residential cooperative members experience a 16.3% reduction in costs for a momentary interruption, 13.3% reduction in costs for 2-hour interruptions, a 9.3% reduction in costs for 8-hour interruptions, and a 6.7% reduction in costs for a 24-hour interruption. Given the methodology to calculate the advanced warning costs, we are unable to determine statistical significance between costs with and without advanced

warning. However, it is likely that the numerical values and percentages reported in Table 4-7 are not statistically significant.

Table 4-7: Change in Cost per Interruption with Advanced Warning - Residential¹⁶

Interruption Duration	Reduction in Cost	Percent Change
Momentary	-\$0.24	-16.3%
2 hours	-\$0.86	-13.3%
8 hours	-\$2.66	-9.3%
24 hours	-\$3.51	-6.7%

4.3.4 Residential Long-Duration Power Interruption

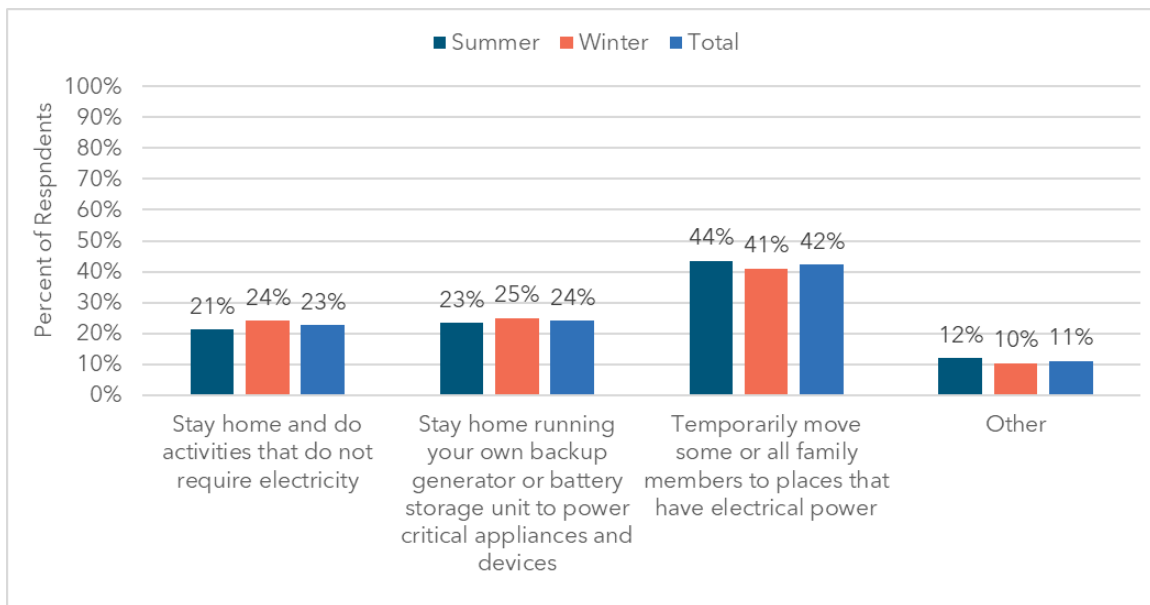
At the conclusion of the survey, residential respondents were asked how they would respond to a longer-duration interruption. The interruption was described as affecting a 20-mile radius around the respondent's home, and respondents were told to expect that it would last up to three days (72 hours). The interruption was presented as occurring in either the summer or the winter, with the season being randomly assigned to respondents. Respondents were asked how they would respond to this long-duration interruption, with possible choices including:

- Stay home and do activities that do not require electricity;
- Stay home running your own backup generator or battery storage unit to power critical appliances and devices;
- Temporarily move some or all family members to places that have electrical power (i.e., houses of family or friends outside the affected area, hotels, or emergency shelters outside the affected area)
- Other - Please explain: _____

Figure 4-5 presents responses to this question, separated by the season of the interruption. Responses were not significantly different by season.

¹⁶ Residential change in cost per interruption with advanced warning only compares summer weekday interruptions.

Figure 4-5: Residential Responses to a Long-Duration Interruption



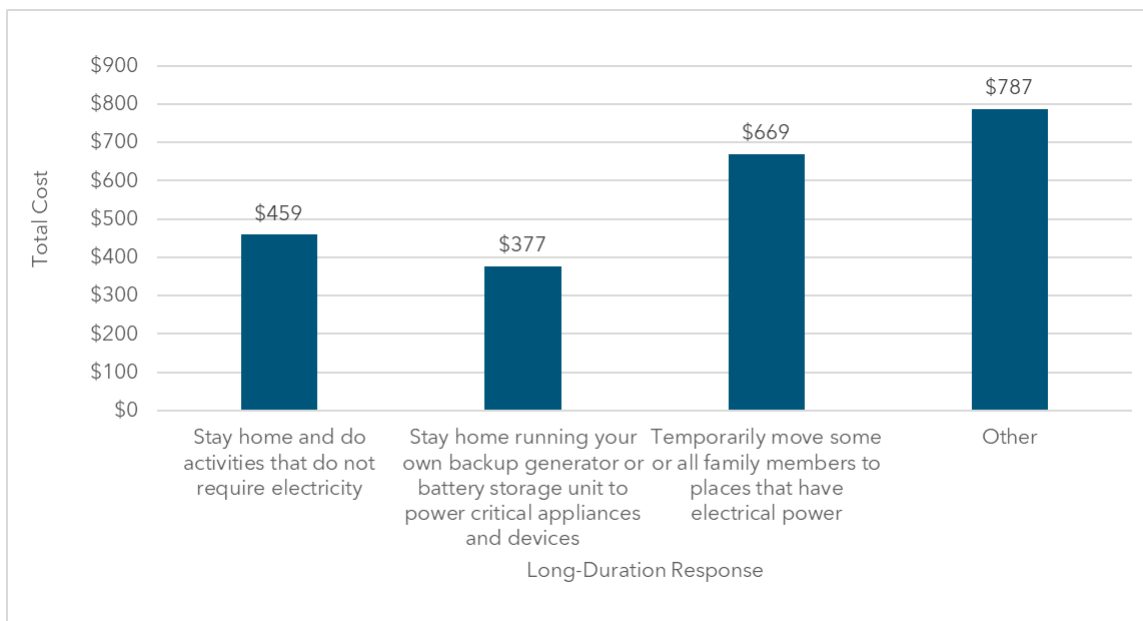
“Other” responses included purchasing ice to keep freezers and coolers cold, and using gas, oil, or wood stoves. Other respondents emphasized that they needed to remain home to tend to livestock.

Respondents were also asked how much these strategies for responding to a long-duration interruption would cost their household. Those who responded they would “stay home and do activities that do not require electricity” were asked to estimate the cost, in extra expenses, they would incur to adjust to the interruption. For example, extra costs include replacing spoiled food and transportation expenses. Those who responded they would “stay home running your own backup generator or battery storage unit to power critical appliances and devices” were asked to estimate the cost of purchasing, installing, and running their backup generator or battery storage equipment. Those who responded that they would “temporarily move some or all family members to places that have electrical power” were asked to estimate the cost of relocating their household, including food and lodging expenses. Finally, those who responded “other” were simply asked “what is the total cost to your household to account for other additional expenses associated with this three-day power outage?”

Figure 4-6 presents the average cost of a long-duration interruption for residential respondents for each of the four types of responses. Respondents who stated they would do “Other” reported the highest cost, whereas those who said they would

“Stay home running your own backup generator or battery storage unit to power critical appliances and devices” faced the lowest cost.¹⁷

Figure 4-6: Average Residential Cost of Long-Duration Interruption by Response



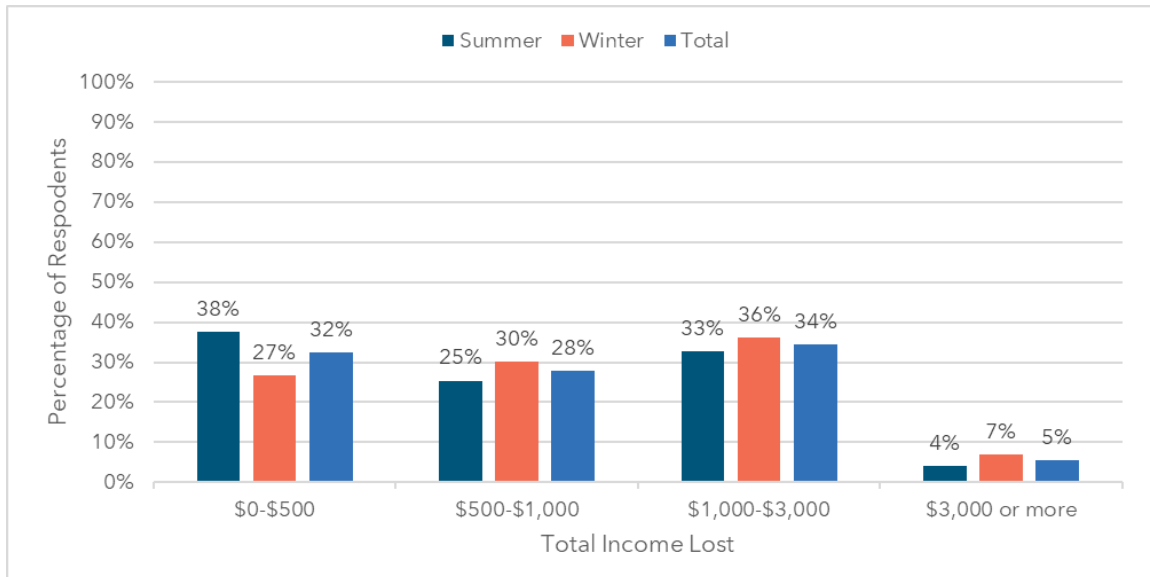
Respondents were also asked if their household income would be reduced during this interruption. Overall, 6.3% of respondents stated they would lose all their household income during a three-day interruption, whereas 14.7% of respondents stated they would lose some of their household income during the interruption.

Lastly, respondents who stated that they would lose some or all of their income were asked to estimate their total income lost due to this long-duration interruption. Of these respondents, the median total lost income due to a long-duration interruption was \$625, and the mean total lost income was \$1,157.50. Figure 4-7 shows the distribution of lost income for residential respondents by season in four distinct buckets. Approximately 5% of respondents indicated that they would lose more than

¹⁷ Respondents who selected “Other” frequently emphasized that they lived in remote areas and could not easily relocate. Many respondents noted their reliance on electricity for heat, water, and phone connectivity, and several also indicated that they were responsible for family members with health conditions, as well as livestock or other animals. These constraints limited their ability to relocate and likely contributed to the higher costs reported by respondents in this category.

\$3,000 in income due to a 3-day interruption. Differences in lost income were not statistically significant by season.

Figure 4-7: Lost Income Due to a Long-Duration Interruption by Season





5 Non-Residential Results

This section summarizes the results for non-residential cooperative members. As discussed in Section 2, non-residential cooperative members were segmented into two groups Small and Medium Non-residential (SMNR) and Large Non-residential (LNR) and each group was surveyed separately to ensure both groups were adequately represented in the results. In this section, results are pooled across both groups and across all three geographic regions in order to increase the statistical precision of the results. Results for each geographic region are presented in Appendix C – Results by Region.

Section 5.1 presents summary statistics on the non-residential cooperative members who took the survey, Section 5.2 displays the interruption cost metrics for non-residential cooperative members, and Section 5.3 describes results from non-interruption cost-related questions in the survey.

5.1 Non-Residential Response to Survey

Table 5-1 summarizes the survey response for non-residential cooperative members. With 97 total surveys completed, the cooperative member response fell well short of the overall non-residential response target of 960. Overall, the survey had a 0.97% response rate.

Table 5-1: Interruption Cost Survey Response Summary - Non-Residential

Stratum	Usage Category (Average kW)	Population	Members Invited to Participate	Validated Responses	Response Rate
1	0.25-2	9,469	4,630	44	1.0%
2	2-10	4,961	3,284	27	0.8%
3	10-50	2,070	1,409	17	1.2%
4	>50	755	573	9	1.6%
Total		17,255	9,896	97	1.0%

Before presenting the interruption cost estimates, survey responses were screened for invalid responses, protest responses, and extreme outliers as described in Section 3.1. See Appendix B - Invalid and Protest Responses for more details on and results from this screening process.

5.2 Non-Residential Interruption Cost Estimates

5.2.1 Non-Residential Cost per Event

Table 5-2 presents the average interruption cost per event for the non-residential respondents. For a momentary interruption, non-residential cooperative members reported a cost on average of \$1,283. The cost per interruption event increases to \$3,772 for 2 hours, \$7,898 for an 8-hour interruption, and finally \$15,106 for a 24-hour interruption. All the estimates other than the momentary interruption are statistically significant since the lower bound of each 90% confidence interval greater than \$0.

Table 5-2: Non-Residential Cost per Interruption Event

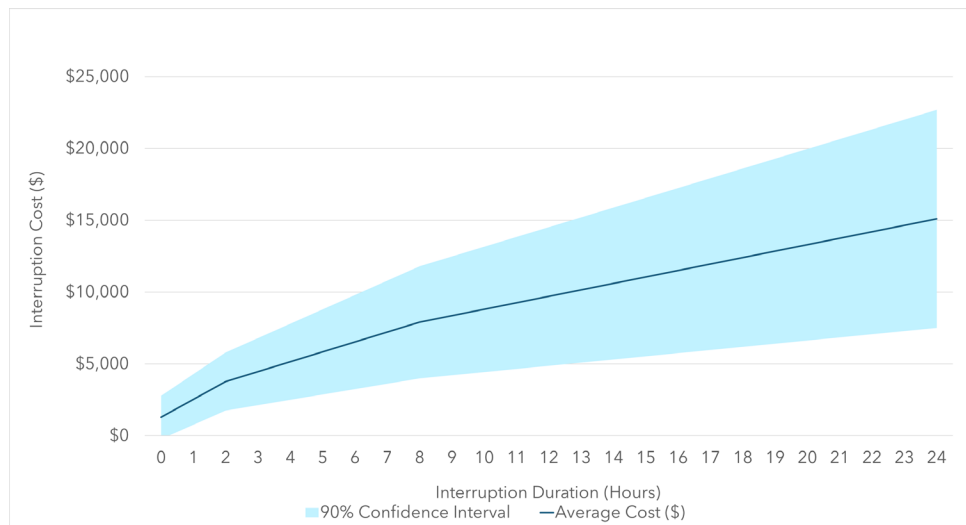
Interruption Duration	Respondents	Cost per Interruption Event	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	68	\$1,283	-\$227	\$2,792
2 hours	63	\$3,772	\$1,751	\$5,793
8 hours	63	\$7,898	\$3,986	\$11,809
24 hours	61	\$15,106	\$7,509	\$22,703

Figure 5-1 relationship between cost per interruption and interruption duration. The chart interpolates across the costs reported for the four surveyed interruption scenarios to all durations from momentary interruptions to 24 hours. The blue bands on the chart represent the lower and upper confidence intervals.¹⁸

As expected, the interruption costs increase as the duration increases. The rate of increase in interruption costs is the greatest for interruptions less than two hours. The rate of increase is relatively constant for interruptions lasting between two to 24 hours.

¹⁸ Note that these confidence intervals are wider than those estimated for the residential cooperative members (see Figure 5-1) due to lower response rates to the non-residential surveys.

Figure 5-1: Non-Residential Cost by Interruption Duration



5.2.2 Non-Residential Cost per Average kW

Table 5-3 presents non-residential cost per average kW for each interruption duration. Non-residential cooperative members reported the lowest cost per average kW for a momentary interruption, \$62 per kW. Cost per kW increases to \$163 for a 2-hour interruption, \$326 for an 8-hour interruption, and \$698 for a 24-hour interruption.

Table 5-3: Non-Residential Cost per kW

Interruption Duration	Respondents	Cost per kW	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	68	\$62	-\$20	\$144
2 hours	63	\$163	\$38	\$288
8 hours	63	\$326	\$29	\$623
24 hours	61	\$698	\$94	\$1,301

5.2.3 Non-Residential Cost per Unserved kWh

Table 5-4 presents the non-residential cost per unserved kWh for each interruption duration. Cost per unserved kWh is highest for momentary interruptions because the

amount of unserved energy is relatively small. For a momentary interruption, non-residential cooperative members experience a cost of \$746 per unserved kWh. Cost per unserved kWh decreases to \$29 for a 24-hour interruption.

Table 5-4: Non-Residential Cost per Unserved kWh

Interruption Duration	Respondents	Cost per kWh	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	68	\$746	-\$239	\$1,732
2 hours	63	\$82	\$19	\$144
8 hours	63	\$41	\$4	\$78
24 hours	61	\$29	\$4	\$54

5.2.4 Non-Residential Cost per Customer Minute Interrupted

Table 5-5 presents the average cost per customer minute interrupted for non-residential respondents. The cost is highest for momentary interruptions and decreases as interruption duration increases. In other words, total interruption cost increases as interruption duration increases, but the average cost per minute of interruption falls as the duration of an interruption approaches 24 hours.

Table 5-5: Non-Residential Cost Per Customer Minute Interrupted

Interruption Duration	Respondents	Cost per CMI	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	68	\$257	-\$45	\$558
2 hours	63	\$31	\$15	\$48
8 hours	63	\$16	\$8	\$25
24 hours	61	\$10	\$5	\$16

5.3 Other Findings

5.3.1 Non-Residential Responses by Industry

The survey asked respondents to confirm whether their industry was reported correctly in the file maintained by their cooperative association. If the type of industry was missing or incorrect, respondents were asked to indicate which North American Industry Classification System (NAICS) sector best describes their facility. Table 5-6 displays the percentage of valid responses by industry. The Accommodation and Food Services and Agriculture, Forestry, Fishing and Hunting sectors reflect the largest portion of respondents, at 20.0% and 16.5%, respectively.

Table 5-6: Non-Residential Responses by Industry

Industry	Percent
Accommodation and Food Services	20.0%
Agriculture, Forestry, Fishing and Hunting	16.5%
Public Administration	15.3%
Manufacturing	8.2%
Retail Trade	7.1%
Health Care and Social Assistance	5.9%
Administrative and Support Services	3.5%
Construction	3.5%
Educational Services	3.5%
Utilities	3.5%
Information	2.4%
Mining	2.4%
Warehousing and Storage	2.4%
Arts, Entertainment, and Recreation	1.2%
Finance and Insurance	1.2%
Professional, Scientific, and Technical Services	1.2%
Transportation	1.2%
Wholesale Trade	1.2%
Management of Companies and Enterprises	0.0%
Other Services (except Public Administration)	0.0%

5.3.2 Non-Residential Backup Generation

Non-residential respondents were asked if their facilities have some form of backup generation that would supply electricity to them during a power interruption. Overall, 21.2%, or 18, of non-residential respondents indicated that they have some form of backup generation on-site. To better reflect the percentage of non-residential cooperative members who have backup generation on-site, responses were weighted by the proportion of cooperative members in the population in each usage category. Table 5-7 displays the percentage of respondents with backup generation on-site by usage category. The table also describes the percentage of the non-residential population within each usage category. The weighted average percent of the non-residential population with backup generation is 19.5%.

Table 5-7: Non-Residential Respondents with Backup Generation by Usage Category

Stratum	Usage Category (Average kW)	Respondents with Backup Generation	Percent of Population in Strata
1	0.25-2	15.4%	54.9%
2	2-10	20.8%	28.8%
3	10-50	26.7%	12.0%
4	> 50	42.9%	4.4%
Total		19.5%	100.0%

Those who had backup generation were asked about the type of equipment they relied on. Table 5-8 lists the backup generation types for non-residential respondents. Of the respondents with backup generation, 60.9% had diesel or gasoline generators, 17.4% had battery storage, 13.0% had natural gas generators, and 8.7% had propane generators. It should be noted that some respondents had more than one type of backup generation equipment.

Table 5-8: Non-Residential Backup Generation Equipment Type

Back-Up Generation Type	Respondents	Percent
Diesel Or Gasoline Generator	14	60.9%
Battery Storage	4	17.4%
Natural Gas Generator	3	13.0%
Propane Generator	2	8.7%

5.3.3 Non-Residential Advanced Warning Interruptions

Non-residential respondents were asked if their electric utility notified their organization of an upcoming power interruption how much advanced warning would be needed to significantly reduce the cost and problems caused by the interruption. Figure 5-2 summarizes the non-residential responses. A majority of non-residential cooperative members reported that they would require at least 24 hours of advanced notice before an interruption, with 32% responding at least 24 hours and 25% responding at least 48 hours. Additionally, 18% of the non-residential respondents stated that advanced warning would not significantly reduce the costs caused by a power interruption.

Figure 5-2: Non-Residential Advanced Warning Needed to Reduce Interruption Cost

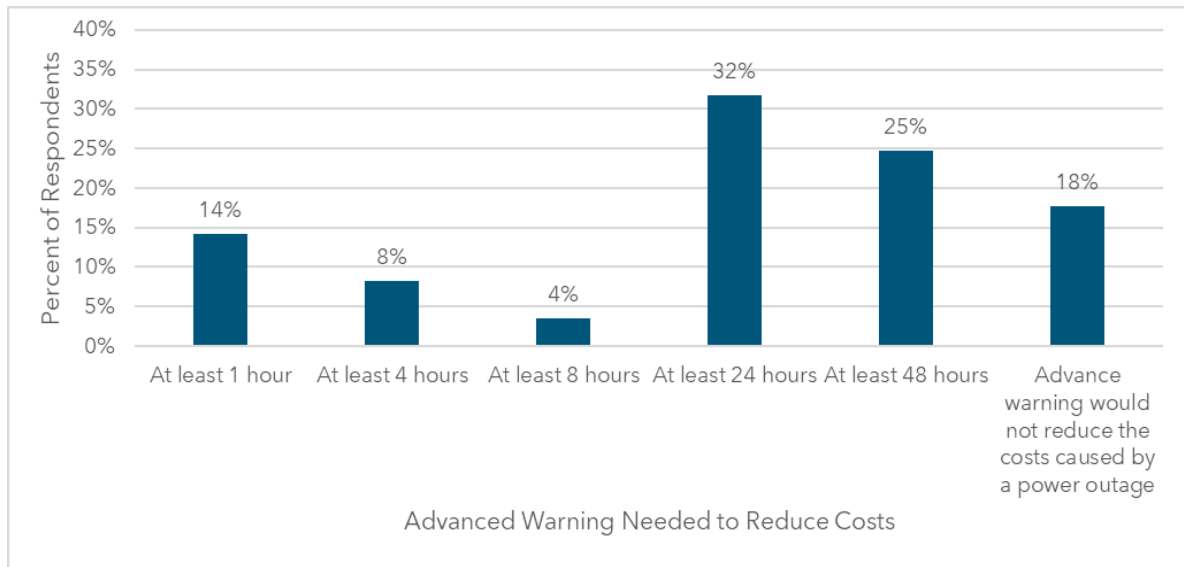


Table 5-9 presents the changes in average cost per interruption event if advanced notice of the interruption was provided. The amount of advanced notice was linked to how much prior warning the respondent had previously stated they would need, as noted above. For instance, if a respondent said they would need at least 24 hours of prior notice to significantly reduce the cost of the interruption, the advanced warning scenario would be an interruption with 24 hours of advanced warning.

When provided with advanced notice, 56% of non-residential respondents reported that it would reduce their interruption costs, 43% reported the costs would not change, and (surprisingly) 1% reported it would increase their costs. As noted in Table 5-9, the reduction in costs non-residential cooperative members experience ranges from a 26.7% reduction for a 2-hour interruption to a 59.0% reduction for a 8-hour interruption.

Table 5-9: Non-Residential Change in Cost per Interruption with Advanced Warning¹⁹

Interruption Duration	Reduction in Cost	Percent Change
Momentary	-\$49	-52.5%
2 hours	-\$508	-26.7%
8 hours	-\$4,126	-59.0%
24 hours	-\$3,946	-39.7%

5.3.4 Non-Residential Long-Duration Power Interruptions

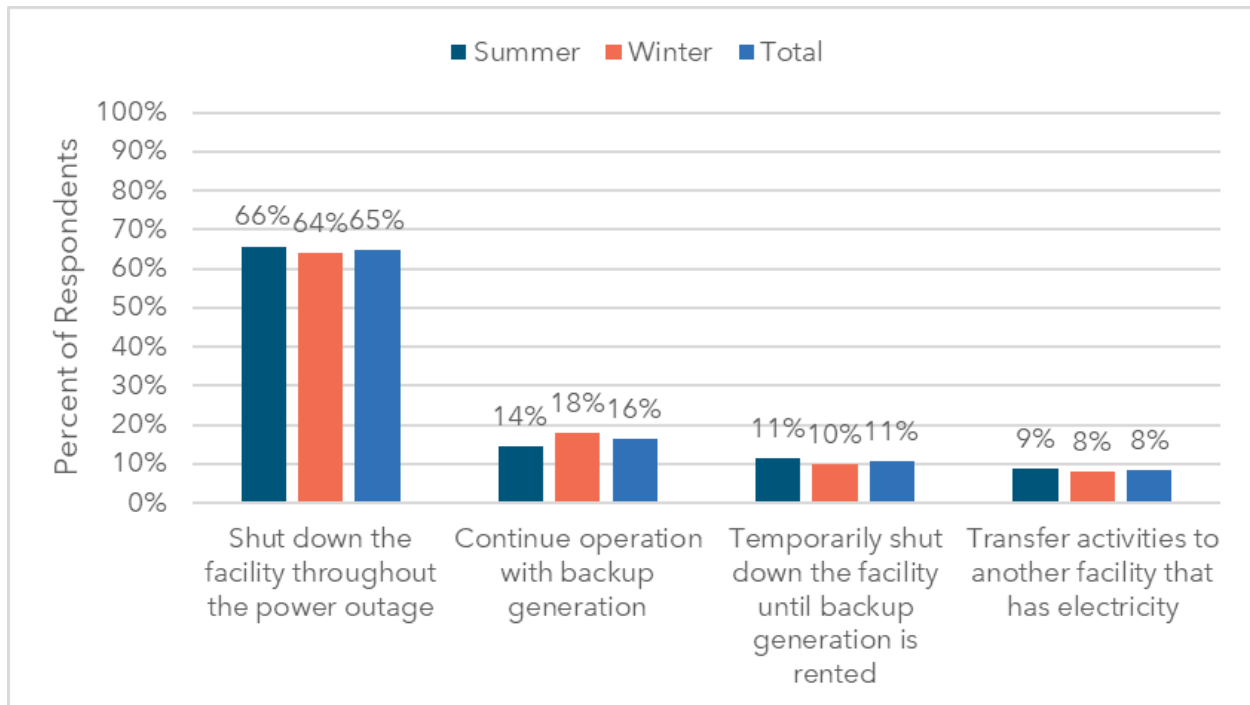
In addition to the interruption scenarios presented in Section 2.1, non-residential respondents were asked how they would respond to a long-duration interruption. The interruption was described as affecting a 20-mile radius around the respondent's facility, and respondents were told to expect that it would last up to three days (72 hours). The interruption was further described as resulting from extensive damage to power lines caused by an extreme summer or winter windstorm, with the season randomly assigned to respondents. Respondents were asked how they would respond given the following four options:

- Shut down the facility throughout the power interruption;
- Continue operation with backup generation;
- Temporarily shut down the facility until backup generation is rented; or
- Transfer activities to another facility that has electricity.

Figure 5-3 presents the percentage of non-residential respondents that would take each option. Overall, 65% of respondents would shut down their facility for the duration of the interruption, 16% would continue operation with backup generation, 11% would temporarily shut down their facility while seeking out backup generation for rent, and 8% would transfer activities to another facility that had electricity. More respondents stated that they would shut down their facility during the summer than in winter, at 66% and 64%, respectively. However, none of the responses were statistically different between seasons at the 90% confidence level.

¹⁹ Non-residential change in cost per interruption with advanced warning only compares summer weekday interruptions.

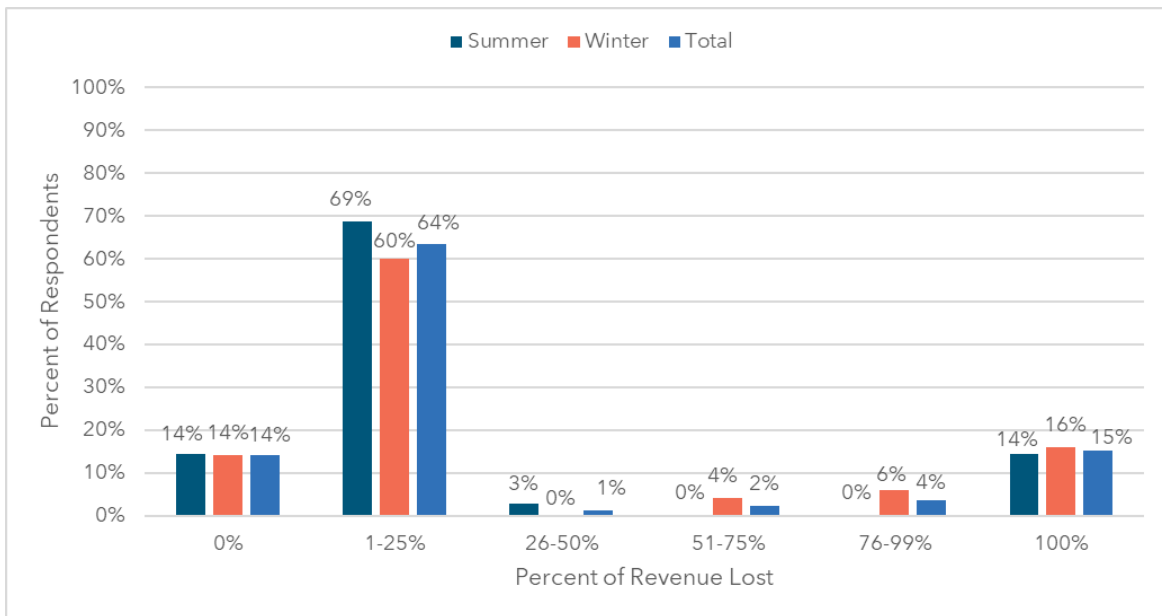
Figure 5-3: Non-Residential Responses to a Long-Duration Interruption



To get an insight into their financial scale, non-residential respondents were asked to provide information on their annual revenue or annual operating budget. On average, for-profit organizations had an annual revenue of \$2.2 million, whereas non-profit organizations had a \$7.0 million average annual operating budget. Non-residential respondents were also asked about the revenue that would be lost during the three-day interruption. On average, non-residential cooperative members reported a revenue loss of \$43,352 and a median loss of \$10,000.

Figure 5-4 presents the responses for the percentage of revenue lost by season. Overall, 15% of respondents said they would lose all of their revenue during a three-day interruption, 4% of respondents stated they would lose 76-99%, 2% stated they would lose 51-75%, 1% said they would lose 26-50%, 64% said they would lose 1-25%, and 14% stated they would not lose any of their revenue during the interruption. The percentage of revenue lost by non-residential cooperative members during a three-day interruption is not statistically different between the summer and winter seasons at the 90% confidence level.

Figure 5-4: Non-Residential Percent of Revenue Lost during a Three-Day Interruption by Season





6 Conclusion and Next Steps

The results presented in this report were developed based on detailed interruption cost information collected from members of eighteen electric cooperatives. The primary objectives of the study were to:

- Estimate costs to cooperative members for interruptions lasting from up to 5 minutes to 24 hours (both residential, non-residential);
- Collect other useful information about cooperative members' preparations for and responses to power interruptions; and
- Use the information collected to inform the broader effort to update the ICE Calculator

To meet each of the objectives above, interruption cost surveys were administered to members of the participating cooperatives and interruption cost metrics were estimated. The estimates can be used to assess the cost-effectiveness of investments in generation, transmission, and distribution systems. Moreover, the estimates can be utilized to strategically compare alternative investments to determine which provides the most combined benefits to the cooperative and its members. The results can be directly applied to many different types of investments at the generation,

transmission, and distribution levels. Alternatively, if any proposed investment in the power system leads to interruption costs that would be avoided by cooperative members, then the results from this initiative can be used to estimate a key benefit of these investments.

The ICE Calculator 2 initiative represents an unprecedented multi-year effort to quantify interruption costs experienced by electricity consumers across the country. Once updated, the ICE Calculator can be utilized to support planning and prioritization of grid reliability and resilience improvements. The broader collection of survey responses will be used to develop nationwide customer damage functions, relating interruption costs to a series of characteristics of both the interruption itself and the affected electricity consumers under a variety of scenarios.

In the coming months, Resource Innovations and Berkeley Lab will aggregate the data from all participating utilities to update the customer damage functions that form the basis of the ICE Calculator. These econometric models will predict how interruption costs vary across customers, interruption duration, and other characteristics. Given the large sample size of the aggregated data, the ICE Calculator will be able to estimate interruption costs for different regions in the country, including the region of each participating utility. Additionally, with the increased sample sizes, the ICE Calculator will be able to estimate results with greater statistical precision.

Appendix A - Cooperative Communications

Below are a series of communications sent to NRECA cooperative members as part of the recruitment effort of this study.

Email from Jim Matheson, NRECA CEO to Distribution Cooperative CEOs and General Managers

Subject: Upcoming Survey on Cost of Power Outages, sent November 7, 2024

NRECA Member CEO's/General Managers,

Providing reliable, affordable electricity to your members is a job that's not getting any easier. It's also never been more important. As our nation's dependence on electricity grows, so does the economic cost of power outages. With a deeper understanding of the economic cost of outages, we can better articulate the importance of a reliable, resilient power supply.

That's why NRECA is collaborating with Lawrence Berkeley National Laboratory to survey co-op members on the costs they incur when the electricity goes out. I am asking for your help in sharing the survey, which is being led by our Business and Technology Strategies team.

The results of this survey will help you, your statewide organizations and NRECA make the case for policies, incentives, investments, and technologies that will maintain a reliable power supply. The results of the survey could also help individual cooperatives as they evaluate their need for additional grid investments.

Soon you will receive an email from MarketResearch@NRECA.coop with more information on how your organization can take part in this important effort.

Thank you in advance for your participation and for all you do to keep the lights on.

Project Overview Provided to Interested Members

Thank you for your interest in participating in this project. I have attached copies of the surveys to help you gain a better understanding of what will be asked of your members. The surveys look much longer on paper than they are for the respondents,

but we have found that the residential survey takes about 10 to 15 minutes to complete and the non-residential is about 20 to 30 minutes.

Who is Surveyed:

We are collecting responses from three member groups: residential, small and medium non-residential, and large residential. Small and medium non-residential members are defined as having usage of 0.25 to 200 kilowatts per hour and large non-residential are those with usage of greater than 200 kilowatts per hour.

Member List:

To conduct the survey, the participating cooperatives will need to provide a member list to be used for sampling. We ask that the residential and non-residential lists be provided as two separate files. The member list should contain the following fields:

- Unique Member Number/Customer Number
- Member Name
- Service Address
- Service City
- Service State
- Service Zip
- Email address
- Average monthly usage

This member list will be used only for the purposes of sampling related to the survey and will not be used by NRECA for any other purposes. Your members' responses to the survey will be kept strictly confidential and no identifiable member information will be shared.

The member lists would be needed at least two weeks before data collection begins and NRECA will provide the co-op with a link to a secure OneDrive folder where the lists can be uploaded.

Co-op Logo: We ask that the co-op provide a JPEG image with their logo that will be used in the survey.

Data Collection:

Data collection will be conducted over the course of two weeks. We ask that the co-op send a survey pre-notification to members the week before data collection begins

to help encourage members to assist. For the non-residential members, we have found that it is beneficial for that message to come from the Key Account manager.

Pre-Survey Documents:

NRECA will provide a standard template which we ask be used by the co-op to notify members of the upcoming survey. Because this project is being conducted in conjunction with LBNL, this template should not be adjusted.

An FAQ will also be provided to the co-op that can be used by member services representatives should they receive any questions about the survey.

Survey Contact:

The survey will be conducted by NRECA Market Research. Mike Sassman, Director of Consumer Analytics and Market Research, will be the contact for any questions about the member list and data collection.

Appendix B - Invalid and Protest Responses

Residential

A small number of respondents were dropped from the final survey results due to invalid responses. Some respondents are confused by willingness-to-pay (WTP) questions or end up answering a question that is quite different from the one that is being asked. For example, residential electricity consumers sometimes react to questions about WTP by redefining the question so that it relates to their ability to pay, their satisfaction with service, or whether they think they are being fairly charged for the service they are receiving. Such responses do not accurately reflect the cost of an interruption, so they were removed from the analysis.

To identify these respondents, the survey included a follow-up question for respondents that asked if they were unwilling to pay any of the prices presented to them. If the respondent verified they were unwilling to pay because the prices presented exceeded the cost and inconvenience they experienced, their response was confirmed as valid and was included in the cost estimate calculations. However, if the respondent indicated there was some other reason that they were unwilling to pay the presented prices, their response was deemed invalid and not included in the cost estimate calculations.

Respondents were also dropped if the respondent expressed a higher WTP for a shorter duration scenario than a longer duration scenario, given the same interruption circumstances. For instance, if a respondent accepted a bid value for a 5-minute duration scenario but rejected an equal or lower bid value for a 2-hour duration scenario, all of their responses were dropped.

Due to the nature of the OHDC contingent valuation methodology, the results received from the residential segment consisted only of a series of responses to the price bids presented, instead of a distribution of actual costs as given in an open-ended cost survey. For this reason, the survey responses in the residential segment did not have “outliers” in the same sense that open-ended surveys do, so conducting an outlier analysis similar to that in the non-residential segment was not necessary or possible.

Table B-1 summarizes the prevalence of invalid responses by interruption duration in the residential survey.

Table B-1: Summary of Invalid Responses - Residential

Interruption Duration	Total Respondents	Invalid Respondents		Valid Respondents
		N	%	
Momentary	914	63	6.9%	851
2 hours	900	67	7.4%	833
8 hours	917	64	7.0%	853
24 hours	950	70	7.4%	880

Non-Residential

Non-residential survey responses were screened for any invalid responses. Responses were dropped for several reasons. First, responses were screened to identify any residential or rental properties that received the non-residential survey. Then, responses were screened to exclude any protest responses in which a respondent did not earnestly answer the survey questions. Survey responses were also screened for illogical responses. Illogical responses state a higher interruption cost for a shorter interruption duration than for a longer interruption during the same day type, season, and onset time.

After screening for and excluding invalid responses, interruption costs are screened for large outliers by duration. Outliers are identified by first normalizing interruption cost by average demand (kW) and calculating the log normalized interruption cost. Normalizing the costs by usage allows the team to avoid excluding primarily consumers with high-usage s with large interruption costs. Logging the normalized costs allows the interruption costs to form a normal distribution. Then, log normalized interruption costs outside of 1.5 times the interquartile range plus the 75th percentile for each duration are marked as outliers and dropped from the average interruption cost calculations.

Table B-2 summarizes the prevalence of invalid responses by interruption duration in the non-residential surveys. The percentage of responses deemed invalid varied from 9% for a momentary interruption to 14% for a 2-hour and 24-hour interruption. The majority of invalid responses were illogical responses.

Table B-2: Summary of Invalid Responses - Non-Residential

Interruption Duration	Total Respondents	Invalid Respondents		Valid Respondents	Outlier Respondents
		N	%		
Momentary	75	7	9%	68	0
2 hours	73	10	14%	63	0
8 hours	72	9	13%	63	0
24 hours	71	10	14%	61	0

Appendix C - Results by Region

The results displayed in this section are for each of the three major regions from which NRECA cooperatives are sampled (Great Plains/Upper Midwest, Intermountain West, and Southeast).

Table C-1: Participating Electric Cooperatives by Region and State

Region	States Included	Participating Cooperatives Surveyed ²⁰
Southeast	FL, TN, KY	• Suwannee Valley Electric Cooperative • SECO Energy • Sequachee Valley Electric Cooperative* • Kenergy • Choctawhatchee Electric Cooperative* • Volunteer Energy Association*
Great Plains/Upper Midwest	MN, OH, IN, SD	• Wright-Hennepin Cooperative Electric Association • Lorain-Medina Rural Electric Cooperative • North Central Electric Cooperative* • Kosciusko Rural Electric Membership Corporation* • Butte Electric Cooperative • Consolidated Electric Cooperative*
Intermountain West	WY, ID, AZ, CO, NM	• Powder River Energy Corporation* • Clearwater Power Company • Sulphur Springs Valley Electric Cooperative • La Plata Electric Association • Kit Carson Electric Cooperative • Mohave Electric Cooperative*

Residential Interruption Costs

As displayed in Table C-2, each of the three regions reached their response target of 250 residential members.

²⁰ Cooperatives marked with an asterisk surveyed only non-residential members.

Table C-2: Interruption Cost Survey Residential Response Summary by Usage Category and Region

Usage Category (Average kW)	Great Plains/Upper Midwest Responses	Intermountain West Responses	Southeast Responses
0-0.5	33	173	12
0.5-1	81	192	45
1-2	128	144	145
2-5	128	69	52
5-10	29	2	2
Total	399	580	256

Great Plains/Upper Midwest Region Interruption Cost Estimates

The results shown below are for residential respondents in the Great Plains/Upper Midwest region.

Table C-3: Residential Cost per Interruption Event - Great Plains/Upper Midwest Region

Interruption Duration	Respondents	Cost per Interruption Event	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	274	\$1.85	\$1.44	\$2.27
2 hours	271	\$7.15	\$6.10	\$8.19
8 hours	282	\$33.20	\$28.71	\$37.70
24 hours	283	\$62.20	\$54.99	\$69.42

Figure C-1: Residential Cost by Interruption Duration - Great Plains/Upper Midwest Region

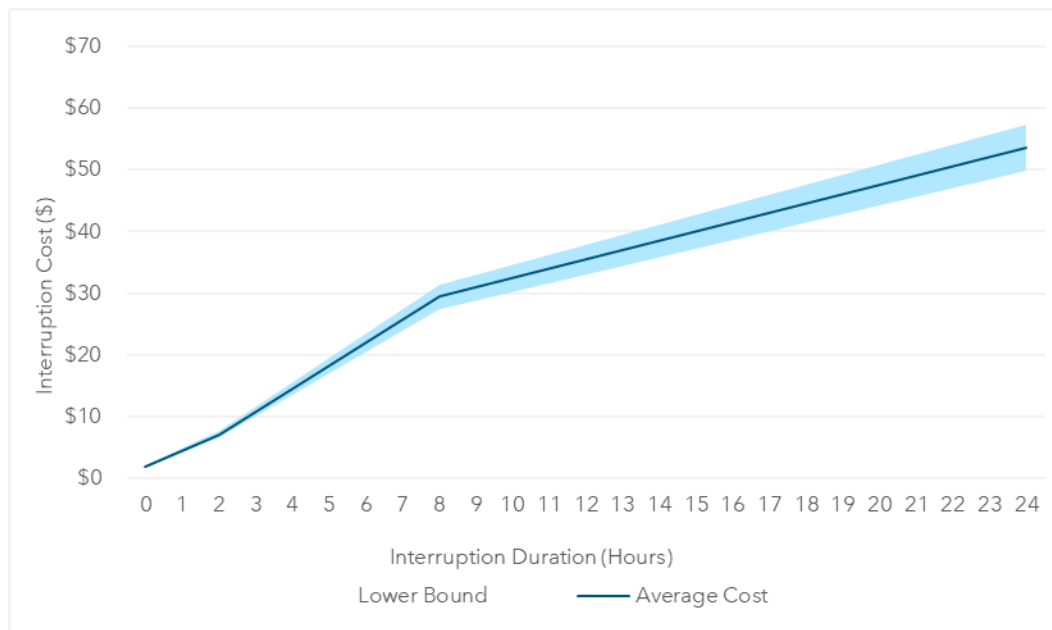


Table C-4: Residential Cost per kW - Great Plains/Upper Midwest Region

Interruption Duration	Respondents	Cost per kW	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	274	\$1.54	\$1.19	\$1.88
2 hours	271	\$5.94	\$5.07	\$6.81
8 hours	282	\$27.61	\$23.87	\$31.35
24 hours	283	\$51.72	\$45.73	\$57.73

Table C-5: Residential Cost per Unserved kWh - Great Plains/Upper Midwest Region

Interruption Duration	Respondents	Cost per Unserved kWh	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	274	\$18.47	\$14.34	\$22.61
2 hours	271	\$2.97	\$2.54	\$3.41
8 hours	282	\$3.45	\$2.98	\$3.92
24 hours	283	\$2.16	\$1.91	\$2.41

Table C-6: Residential Cost per Customer Minute Interrupted - Great Plains/Upper Midwest Region

Interruption Duration	Respondents	Cost per CMI	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	274	\$0.37	\$0.29	\$0.45
2 hours	271	\$0.06	\$0.05	\$0.07
8 hours	282	\$0.07	\$0.06	\$0.08
24 hours	283	\$0.04	\$0.04	\$0.05

Intermountain West Region Interruption Cost Estimates

The results shown below are for residential respondents in the Intermountain West region.

Table C-7: Residential Cost per Interruption Event - Intermountain West Region

Interruption Duration	Respondents	Cost per Interruption Event	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	409	\$1.95	\$1.63	\$2.27
2 hours	387	\$7.14	\$6.24	\$8.05
8 hours	389	\$27.73	\$25.28	\$30.17
24 hours	408	\$48.20	\$44.11	\$52.28

Figure C-2: Residential Cost by Interruption Duration - Intermountain West Region

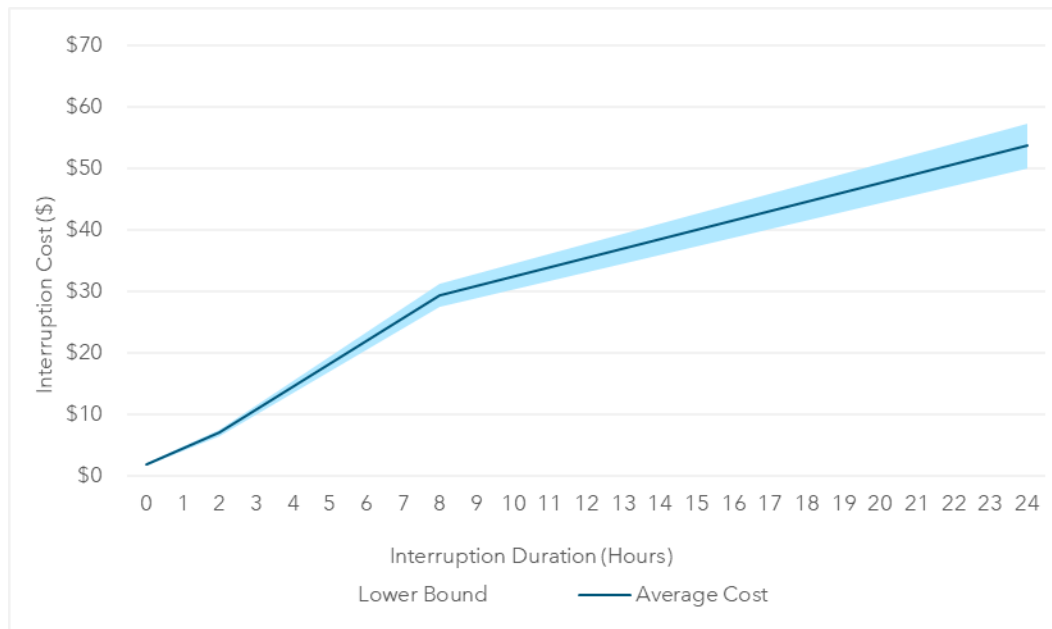


Table C-8: Residential Cost per kW - Intermountain West Region

Interruption Duration	Respondents	Cost per kW	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	409	\$1.74	\$1.45	\$2.03
2 hours	387	\$6.38	\$5.57	\$7.19
8 hours	389	\$24.77	\$22.58	\$26.95
24 hours	408	\$43.06	\$39.40	\$46.70

Table C-9: Residential Cost per Unserved kWh - Intermountain West Region

Interruption Duration	Respondents	Cost per Unserved kWh	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	409	\$20.89	\$17.43	\$24.35
2 hours	387	\$3.19	\$2.79	\$3.60
8 hours	389	\$3.10	\$2.82	\$3.37
24 hours	408	\$1.79	\$1.64	\$1.95

Table C-10: Residential Cost per Customer Minute Interrupted - Intermountain West Region

Interruption Duration	Respondents	Cost per CMI	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	409	\$0.39	\$0.33	\$0.45
2 hours	387	\$0.06	\$0.05	\$0.07
8 hours	389	\$0.06	\$0.05	\$0.06
24 hours	408	\$0.03	\$0.03	\$0.04

Southeast Region Interruption Cost Estimates

The results shown below are for residential respondents in the Southeast region.

Table C-11: Residential Cost per Interruption Event - Southeast Region

Interruption Duration	Respondents	Cost per Interruption Event	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	168	\$2.45	\$1.64	\$3.25
2 hours	175	\$7.83	\$5.24	\$10.42
8 hours	182	\$30.85	\$24.04	\$37.67
24 hours	189	\$57.61	\$46.39	\$68.84

Figure C-3: Residential Cost by Interruption Duration - Southeast Region

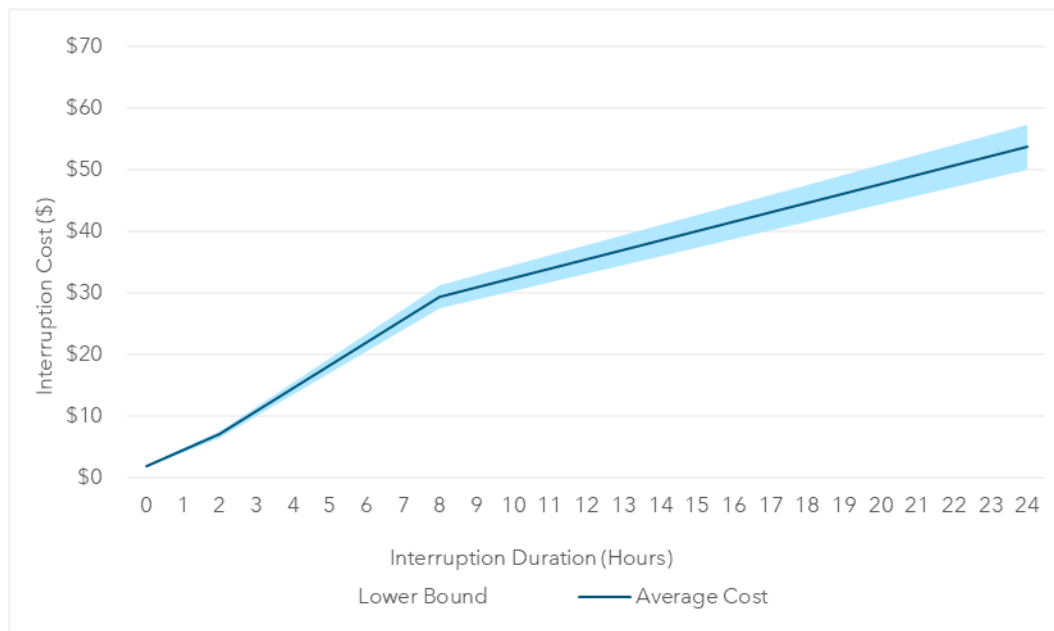


Table C-12: Residential Cost per kW - Southeast Region

Interruption Duration	Respondents	Cost per kW	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	168	\$2.32	\$1.56	\$3.08
2 hours	175	\$7.42	\$4.96	\$9.87
8 hours	182	\$29.21	\$22.76	\$35.66
24 hours	189	\$54.54	\$43.92	\$65.18

Table C-13: Residential Cost per Unserved kWh - Southeast Region

Interruption Duration	Respondents	Cost per Unserved kWh	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	168	\$27.80	\$18.67	\$36.94
2 hours	175	\$3.71	\$2.48	\$4.93
8 hours	182	\$3.65	\$2.85	\$4.46
24 hours	189	\$2.27	\$1.83	\$2.72

Table C-14: Residential Cost per Customer Minute Interrupted - Southeast Region

Interruption Duration	Respondents	Cost per CMI	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	168	\$0.49	\$0.33	\$0.65
2 hours	175	\$0.07	\$0.04	\$0.09
8 hours	182	\$0.06	\$0.05	\$0.08
24 hours	189	\$0.04	\$0.03	\$0.05

Non-Residential Interruption Costs

Since the number of non-residential responses was limited, many of the following results at the regional level are not significant at a 90% confidence level. Table C-15 shows the distribution of respondents with valid responses by usage category and region.

Table C-15: Interruption Cost Survey Non-Residential Response Summary by Usage Category and Region

Usage Category (Average kW)	Great Plains/Upper Midwest Responses	Intermountain West Responses	Southeast Responses
0.25-2	3	22	19
2-10	9	11	7
10-50	1	6	10
> 50	1	4	4
Total	14	43	40

Great Plains/Upper Midwest Region Interruption Cost Estimates

Table C-16: Non-Residential Cost per Interruption Event - Great Plains/Upper Midwest Region

Interruption Duration	Respondents	Cost per Interruption Event	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	11	\$210	-\$167	\$586
2 hours	12	\$6,550	\$2,246	\$10,854
8 hours	9	\$23,522	\$8,090	\$38,954
24 hours	4	\$34,301	\$22,052	\$46,549

Figure C-4: Non-Residential Cost per Interruption Event - Great Plains/Upper Midwest Region

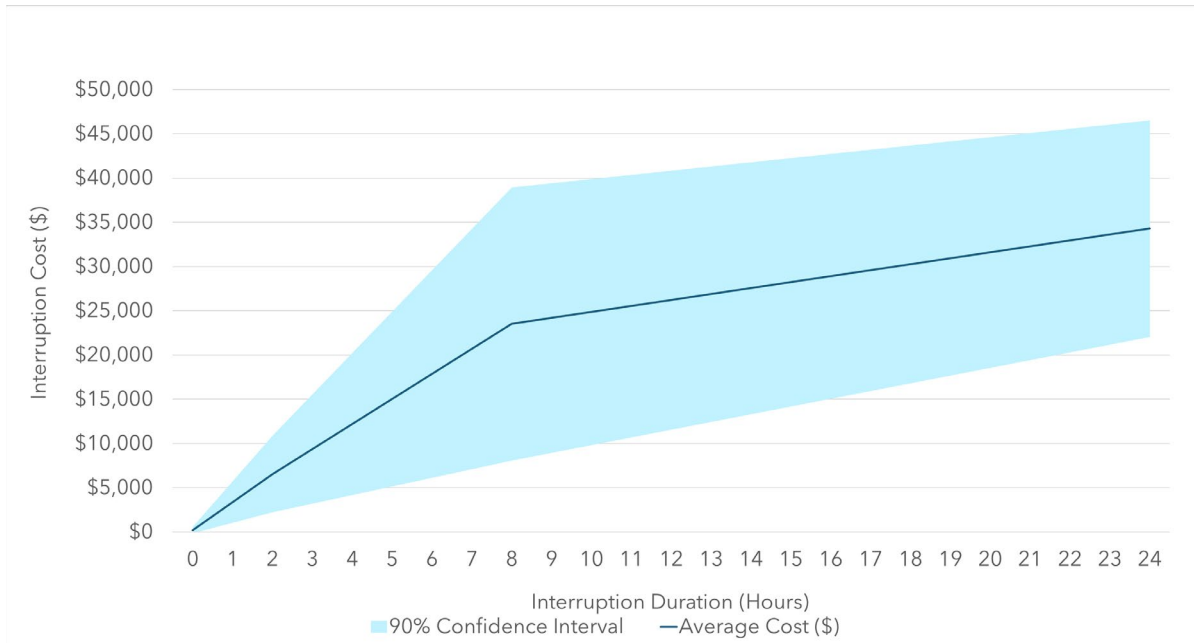


Table C-17: Non-Residential Cost per kW - Great Plains/Upper Midwest Region

Interruption Duration	Respondents	Cost per kW	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	11	\$19	-\$3	\$40
2 hours	12	\$684	-\$387	\$1,754
8 hours	9	\$2,209	-\$1,141	\$5,560
24 hours	4	\$12,903	\$1,452	\$24,353

Table C-18: Non-Residential Cost per Unserved kWh - Great Plains/Upper Midwest Region

Interruption Duration	Respondents	Cost per kWh	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	11	\$222	-\$32	\$477
2 hours	12	\$342	-\$193	\$877
8 hours	9	\$276	-\$143	\$695
24 hours	4	\$538	\$61	\$1,015

Table C-19: Non-Residential Cost Per CMI - Great Plains/Upper Midwest Region

Interruption Duration	Respondents	Cost per CMI	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	11	\$42	-\$33	\$117
2 hours	12	\$55	\$19	\$90
8 hours	9	\$49	\$17	\$81
24 hours	4	\$24	\$15	\$32

Intermountain West Region Interruption Cost Estimates

Table C-20: Non-Residential Cost per Interruption Event - Intermountain West Region

Interruption Duration	Respondents	Cost per Interruption Event	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	31	\$1,337	-\$606	\$3,280
2 hours	27	\$4,212	\$997	\$7,427
8 hours	28	\$6,377	\$2,134	\$10,620
24 hours	31	\$19,359	\$5,479	\$33,238

Figure C-5: Non-Residential Cost per Interruption Event - Intermountain West Region

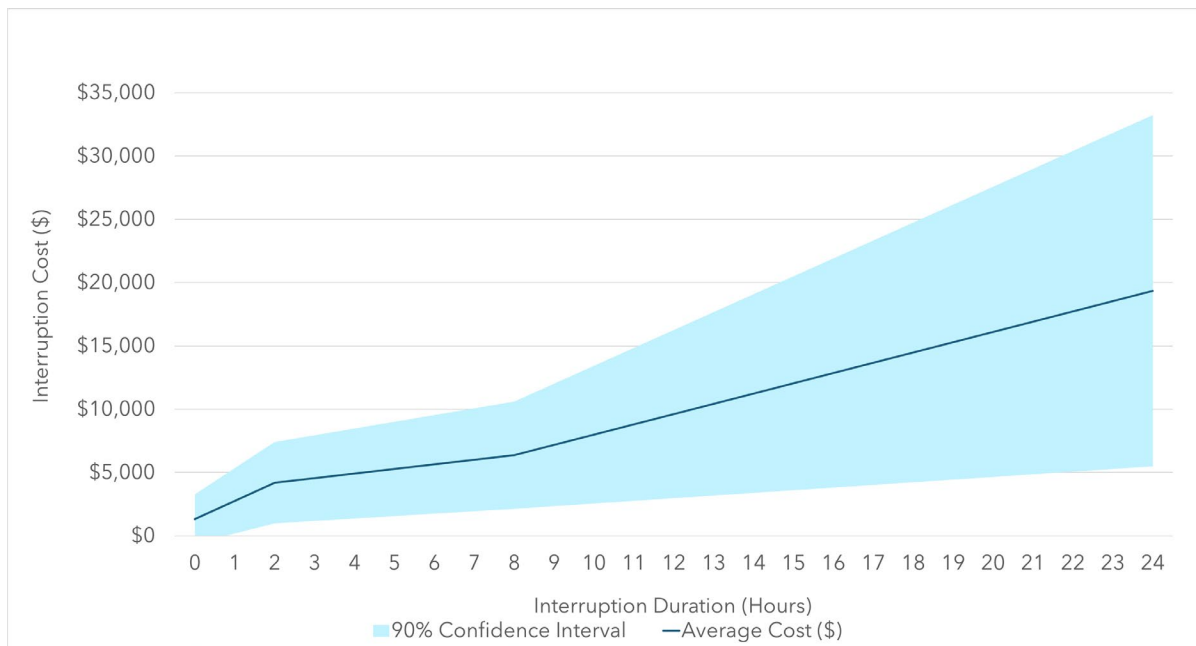


Table C-21: Non-Residential Cost per kW - Intermountain West Region

Interruption Duration	Respondents	Cost per kW	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	31	\$56	-\$34	\$146
2 hours	27	\$165	-\$1	\$332
8 hours	28	\$297	\$82	\$512
24 hours	31	\$865	-\$214	\$1,943

Table C-22: Non-Residential Cost per Unserved kWh - Intermountain West Region

Interruption Duration	Respondents	Cost per kWh	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	31	\$670	-\$411	\$1,751
2 hours	27	\$83	-\$1	\$166
8 hours	28	\$37	\$10	\$64
24 hours	31	\$36	-\$9	\$81

Table C-23: Non-Residential Cost Per CMI - Intermountain West Region

Interruption Duration	Respondents	Cost per CMI	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	31	\$267	-\$121	\$656
2 hours	27	\$35	\$8	\$62
8 hours	28	\$13	\$4	\$22
24 hours	31	\$13	\$4	\$23

Southeast Region Interruption Cost Estimates

Table C-24: Non-Residential Cost per Interruption Event - Southeast Region

Interruption Duration	Respondents	Cost per Interruption Event	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	26	\$1,144	-\$63	\$2,351
2 hours	24	\$3,168	\$468	\$5,869
8 hours	26	\$9,446	-\$1,203	\$20,095
24 hours	26	\$8,921	\$4,173	\$13,669

Figure C-6: Non-Residential Cost per Interruption Event - Southeast Region

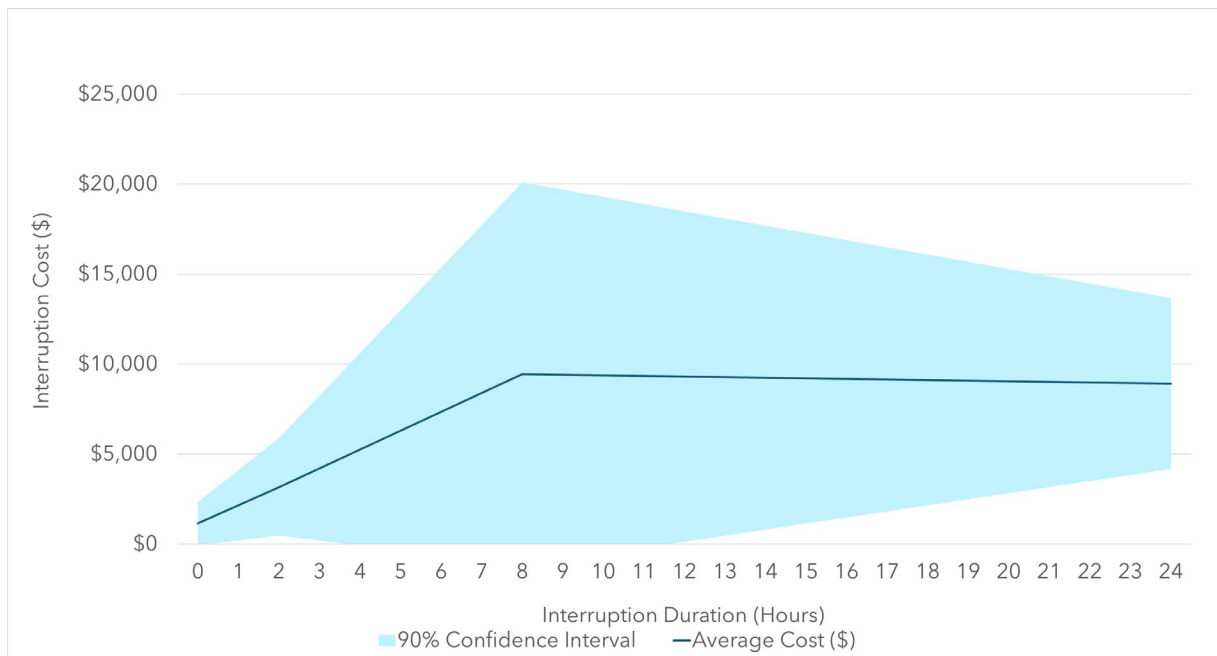


Table C-25: Non-Residential Cost per kW - Southeast Region

Interruption Duration	Respondents	Cost per kW	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	26	\$97	\$12	\$182
2 hours	24	\$147	-\$59	\$353
8 hours	26	\$284	-\$252	\$820
24 hours	26	\$434	-\$68	\$937

Table C-26: Non-Residential Cost per Unserved kWh - Southeast Region

Interruption Duration	Respondents	Cost per kWh	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	26	\$1,164	\$142	\$2,187
2 hours	24	\$73	-\$30	\$177
8 hours	26	\$35	-\$32	\$103
24 hours	26	\$18	-\$3	\$39

Table C-27: Non-Residential Cost Per CMI - Southeast Region

Interruption Duration	Respondents	Cost per CMI	90% Confidence Interval	
			Lower Bound	Upper Bound
Momentary	26	\$229	-\$13	\$470
2 hours	24	\$26	\$4	\$49
8 hours	26	\$20	-\$3	\$42
24 hours	26	\$6	\$3	\$9

Appendix D - Residential Modeling

Residential Price Value Selection

The interruption costs for residential respondents were estimated using a one-and-a-half bound discrete choice survey methodology (OHDC). As part of the analysis, respondents were shown a variety of prices, or bid values, regarding their willingness-to-pay to avoid the interruption. Following the standard procedure used in contingent valuation studies, the prices for ICE Calculator 2 were developed via an iterative testing process utilizing a pre-test study.²¹ Initially, a small number of preliminary prices were chosen based on the results of previous interruption cost studies. These prices were presented to respondents in the pre-test for the first utility enrolled in ICE Calculator 2 in Fall 2022. After administration of the pre-test, Resource Innovations closely examined the distribution of “yes” and “no” responses to these prices and adjusted them accordingly. Prices that were near-universally accepted (the vast majority of the respondents said “yes”) were increased, and prices that were near-universally rejected (the vast majority of the respondents said “no”) were lowered. Existing literature on OHDC bid design recommends, in the absence of knowing the true distribution of costs, selecting bids that are centered on the estimated median cost, but do not drift too far into the upper or lower tails.²¹ Following this recommendation, Resource Innovations’ goal was to select a series of lower bid values that on average yield between a 60/40 to 70/30 yes/no split, and a series of upper bid values that on average yield between a 30/70 to 40/60 no/yes split.

Table D-1 presents the current price values presented to respondents in the ICE Calculator 2 study. For ICE Calculator 2, Resource Innovations developed five “sets” of these prices that included a high and low price for each duration scenario. Each respondent was randomly assigned one of these sets and therefore received the corresponding price values for each duration. These sets were designed to be internally-consistent; within a given set, the high price for a longer duration would always be higher than the high price for a shorter duration, and the low price corresponding to a longer duration was higher than the low price corresponding to a shorter duration within the same set. This ensured that each respondent received a plausible set of prices where price increased with duration.

²¹ Hanemann, Michael, John Loomis, and Barbara Kanninen (1991). Statistical Efficiency of Double-Bounded Dichotomous Choice Contingent Valuation. *American Journal of Agricultural Economics*. 73(1991): 1255-1263.

Table D-1: Residential Price Values

Set	Duration							
	Momentary		2 hours		8 hours		24 hours	
	Low Price	High Price	Low Price	High Price	Low Price	High Price	Low Price	High Price
1	\$0.10	\$1.00	\$0.50	\$4.00	\$3.00	\$10.00	\$5.00	\$20.00
2	\$0.15	\$2.00	\$1.00	\$10.00	\$5.00	\$25.00	\$10.00	\$40.00
3	\$0.20	\$4.00	\$2.00	\$12.00	\$7.00	\$40.00	\$15.00	\$60.00
4	\$0.25	\$6.00	\$3.00	\$14.00	\$9.00	\$55.00	\$20.00	\$80.00
5	\$0.30	\$8.00	\$4.00	\$16.00	\$11.00	\$70.00	\$30.00	\$120.00

Residential Model Specification

Analysis of the responses to the OHDC question was conducted using regression analysis. The first step to estimating a regression formula is to translate the responses from the OHDC questions to a value for interruption cost, expressed in willingness-to-pay, to serve as the outcome variable to be estimated. Previous studies in the field of non-market valuation have shown that for a given duration scenario and bid value, the response (yes or no) to the OHDC question, divided by the probability density of the bid value the respondent received within the range of bid values shown for that duration constitutes a lower-bound estimate of willingness-to-pay (WTP).²² This lower-bound estimate of WTP is used as the outcome variable in the regression analysis.

In modeling interruption cost in a regression framework, the outcome variable is expressed as a function of a vector of explanatory variables, typically denoted as X' . Instead of using a typical ordinary least squares (OLS) regression, we instead employed the Poisson Quasi-Maximum Likelihood Estimator (QMLE). As opposed to OLS, where the outcome variable Y is modeled as a linear combination of a vector of covariates X' plus an error term and the vector of coefficients β is selected by minimizing the sum of squared errors, the Poisson QMLE instead models the *natural*

²² Watanabe, M. (2010). Nonparametric estimation of mean willingness-to-pay from discrete response valuation data. *American Journal of Agricultural Economics*, 92(4), 1114–1135. <https://doi.org/10.1093/ajae/aaq034>

$\log$ of Y as a function of X' . As a quasi-maximum likelihood model, this regression runs a series of iterations with different values of the vector of coefficients β and selects the coefficients β that maximizes the log-likelihood of generating the distribution of WTP observed in the sample. For this reason, the outcome variable is the expected value of Y (conditional on the covariates X'), and as a generalized linear model, the regression does not include an error term (as seen with OLS). Equation D-1 shows the general regression specification for the Poisson QMLE. This could also be expressed as estimating $E(Y|X')$ as a function of $e^{X_i'\beta}$.

Equation D-1: Regression Specification for Poisson Quasi-maximum Likelihood Estimator

$$\log(E(Y|X')) = X_i'\beta$$

This estimator has the advantage of yielding consistent estimates of the mean interruption cost without requiring the modeler to know the true distribution of interruption costs.²³ This estimator also ensures non-negative outcomes, which is appropriate for willingness-to-pay.

For the individual utility results, the only explanatory variable included in the regression model was duration. This was due to the relatively small sample size for individual utilities. As we did not want to assume the functional form of duration by specifying it as a continuous variable, mutually-exclusive binary variables were included for each duration length presented in the survey (momentary, 2 hours, 8 hours, and 24 hours). This is mathematically equivalent to including separate regressions for each individual duration but allows for greater statistical precision due to including the entire sample size in one regression. Therefore, the regression model for interruption cost for duration d , bid b , and respondent i can be expressed as follows in Equation D-2.

Equation D-2: Regression Specification for Poisson Quasi-maximum Likelihood Estimator

$$E(y|x')_{i,d,b} = e^{(\beta_1 * \text{Momentary}_{i,d} + \beta_2 * \text{2Hours}_{i,d} + \beta_3 * \text{8Hours}_{i,d} + \beta_4 * \text{24Hours}_{i,d})}$$

Where $y_{i,d}$ is the OHDC response (yes or no) from respondent i for bid b and duration d divided by the probability density of bid b in the distribution of possible bids for duration d .

This regression was weighted by sampling strata and interruption day type (weekend or weekday) and season to better reflect the respondents and interruptions observed

²³ Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data* (2nd ed.). MIT Press.

in the population. This was accomplished by comparing the prevalence of each sampling stratum in the sample responses to the population data provided by the utility. Also, the prevalence of interruption scenarios in each day type and season in the sample responses was compared to the utility's historical interruption data.

For each utility, after estimating the regression parameters using Equation D-2, we then used said parameters, combined with the weights discussed above, to estimate the population mean interruption cost at each duration level. This yielded the average interruption cost values reported for each duration.

Next, we utilized bootstrapping to estimate precision for these mean interruption cost estimates. This process was accomplished by first randomly sampling a subset of the respondents (with replacement) and estimating the mean interruption cost within that sample using the sample regression process as discussed above. Then, another sample was taken and the mean interruption cost was estimated for that sample. This was repeated until the mean interruption costs from 100 distinct samples from the respondent population had been estimated, and a distribution of sample mean interruption cost values was formed. The distribution of these sample means was used to estimate the standard errors and corresponding confidence intervals for the population mean interruption cost estimates calculated using the entire set of survey respondents.

Using the regression model and weighting processes discussed above, we can estimate the average interruption cost for residential electricity consumers, expressed in willingness-to-pay, for each duration level included in the survey instrument. Additionally, we can estimate the precision of these interruption cost values using the bootstrapping process described.

Appendix E - Residential Income Normalization Procedure

To calculate interruption cost values normalized by respondent income required making inferences about the distribution of income within each income class. This was performed by examining the distribution of respondents in each of the nine smaller income classes in the survey results. For each of the nine categories, the average income within each category was estimated using existing U.S. Census Bureau data that gives the mean income across the U.S. within granular income categories. Next, the typical income within each *larger* income bucket was calculated as the weighted average of all the mean income values for each of the smaller categories within the bucket, weighted by the share of respondents in each smaller category. Table E-1 depicts the calculation of typical daily household income by income category.

Table E-1: Household Typical Daily Income Calculation

Household Income (Survey Categories)	Count of Respondents	Category Typical Annual Income	Household Income (Final Buckets)	Bucket Typical Annual Income	Bucket Typical Daily Income
Under \$15,000	20	\$6,968	Under \$40,000	\$25,123	\$69
\$15,000 - \$29,999	87	\$22,271			
\$30,000 - \$39,999	66	\$34,384			
\$40,000 - \$49,999	66	\$44,459	\$40,000-\$70,000	\$54,417	\$149
\$50,000 - \$69,999	141	\$59,078			
\$70,000 - \$99,999	192	\$83,588	\$70,000-\$150,000	\$103,211	\$283
\$100,000 - \$149,999	207	\$121,412			
\$150,000 - \$199,999	86	\$171,212	\$150,000 or more	\$263,765	\$723
\$200,000 or more	95	\$347,549			

Appendix F - Residential Survey Instrument

To see if you qualify to participate in the study, we would like to gather some information on your household characteristics. This information will be used to understand how electrical power interruptions affect different households. Please answer for only your **primary residence**. If you live in an apartment building or duplex, answer only for the part of the building you live in. As a reminder, all your responses will remain confidential and anonymous.

Q0. Does your **primary residence** receive power from **Utility**?

- ☐ Yes
- ☐ No

Q1. Including yourself, how many people live in your household?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6 or more

Q2. Do you rent or own your **primary residence**?

- ☐ Rent
- ☐ Own
- ☐ Neither
- ☐ Don't know

Q3. What type of home best describes your **primary residence**?

- ☐ Single-family detached
- ☐ Townhome/townhouse (single-family attached to two or more houses)
- ☐ Duplex (two-family building)
- ☐ Condominium
- ☐ Small apartment building (3 to 4 units)
- ☐ Large apartment building (5 or more units)
- ☐ A mobile or manufactured home
- ☐ Other: _____

Q4. Which of the following categories best describes your total annual household income before taxes and other deductions? Please include all income to the household including social security, interest welfare payments, child support, etc.

- ☐ Under \$15,000
- ☐ \$15,000 - \$29,999
- ☐ \$30,000 - \$39,999
- ☐ \$40,000 - \$49,999
- ☐ \$50,000 - \$69,999
- ☐ \$70,000 - \$99,999
- ☐ \$100,000 - \$149,999
- ☐ \$150,000 - \$199,999
- ☐ \$200,000 or more
- ☐ Prefer not to answer

Q5. What is your age?

- ☐ 18 - 24 years
- ☐ 25 - 29 years
- ☐ 30 - 39 years
- ☐ 40 - 49 years
- ☐ 50 - 59 years
- ☐ 60 - 69 years
- ☐ 70 years or older
- ☐ Prefer not to answer

Internal note: We will screen respondents based on the answers to these demographic questions. If we reach the quota on certain demographics ("respondent does not qualify"), we will end the survey.

[Display if the respondent does not qualify] **Thank you for your time and interest in taking this survey. Unfortunately, we have already received enough responses from customers with similar household characteristics. You may now close the survey.**

Power interruptions can be caused by severe weather, traffic accidents, and equipment failures, among other things. When completing this survey, please note that a “power interruption” refers to a **complete** loss of electricity to your residence. If you share a building with other owners or tenants, please answer the questions for your residence only.

Q6. Over the past 12 months, have you experienced any power interruptions at your primary residence?

- ☐ Yes
- ☐ No
- ☐ Don't know



Q6A. [Display if Q6 = “Yes”] Over the past 12 months, have you experienced power interruptions at your home that lasted: (Select all that apply)

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 4 hours
- ☐ 4 hours to less than 24 hours
- ☐ 24 hours to less than 3 days
- ☐ 3 days or more

Q7. What is the longest power interruption you have experienced in the last **five years**?

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 4 hours
- ☐ 4 hours to less than 24 hours
- ☐ 24 hours to less than 3 days
- ☐ 3 days or more
- ☐ I've never experienced a power interruption
- ☐ Don't know

Q8. Do you or any of your household members earn an income working from home?

- ☐ Yes
- ☐ No



Q8A. [Display if Q8 = "Yes"] Which best describes your household members' "work from home" status? (Select all that apply)

- ☐ Self-employed
- ☐ Salaried employee
- ☐ Hourly employee
- ☐ Other - Please explain:

Q9. Does anyone in your household have any health conditions that could be worsened by a power interruption? For example, someone might need an oxygen machine powered by electricity or take medication that requires refrigeration.

- ☐ Yes
- ☐ No
- ☐ Don't know

Q10. Does your household have some form of backup electrical power, like a backup generator or battery storage system?

- ☐ Yes
- ☐ No
- ☐ Don't know



Q10A. [Display if Q10 = "Yes"] Which type of backup electrical power equipment do you have? (Select all that apply)

- ☐ Natural gas generator
- ☐ Diesel or gasoline generator
- ☐ Propane generator
- ☐ Solar PV
- ☐ Battery storage
- ☐ Other: _____
- ☐ Don't know

Q10B. [Display if Q10 = "Yes"] Given the size of your backup electrical system, what appliances would you power during an interruption? (Select all that apply)

- ☐ The backup electrical system provides power to the entire house
- ☐ Refrigerator
- ☐ Freezer
- ☐ Lights
- ☐ Air conditioning system
- ☐ Heating system
- ☐ Stove or cooktop
- ☐ Electronic devices (cell phone, computer, etc.)
- ☐ Clothes washer/dryer
- ☐ Home entertainment systems
- ☐ Electric vehicle charging station
- ☐ Swimming pool/spa
- ☐ Water pumps (well, sump, etc.)
- ☐ Other: _____

Q10C. [Display if Q10 = "Yes"] How long can your backup electrical system operate while the power is out? If the backup generator consumes fuel such as propane, consider how much is readily available at your home.

- ☐ Less than 1 hour
- ☐ 1 hour to less than 12 hours
- ☐ 12 hours to less than 24 hours
- ☐ 24 hours to less than 3 days
- ☐ 3 days or more (such as generators connected to a continuous fuel service)
- ☐ Don't know

Q11. Please estimate how long a power interruption can last at your home before the costs and inconvenience become significant. Some impacts to consider include the

loss of income or online education, inability to prepare meals at home, and replacing spoiled food.

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 2 hours
- ☐ 2 hours to less than 8 hours
- ☐ 8 hours to less than 24 hours
- ☐ 24 hours to less than 3 days
- ☐ 3 days or more
- ☐ Don't know

Q12. If your electric utility notified your household of an upcoming power interruption before it occurred, how much advance warning is needed to significantly reduce the costs and inconvenience caused by a power interruption? Please give your best estimate.

- ☐ At least 1 hour
- ☐ At least 4 hours
- ☐ At least 8 hours
- ☐ At least 24 hours
- ☐ At least 48 hours
- ☐ Advance warning would not reduce the costs caused by a power interruption

In the following sections, we present three possible future scenarios each involving a different electrical power interruption duration. For each scenario, we ask how your household would respond to the interruption and to estimate any extra expenses your household would experience due to the interruption. We will also ask you how much you would be willing to pay to avoid this interruption.

Following these three short-duration interruption scenarios, we will ask a very brief series of questions in a fourth scenario regarding how your household may respond to a hypothetical long-duration interruption scenario.

There are no right or wrong answers to these questions. Please respond based on your personal experience and current household circumstances. We simply want your best estimate.

You will estimate the additional costs your household could experience for each of the scenarios in the table below.

Scenario	Season	Day of Week	Start Time	End Time	Duration
A	Summer	Weekday	[AStart]	[AEnd]	[ADuration]
B	Summer	Weekday	[BStart]	[BEnd]	[BDuration]
C	Summer	Weekday	[CStart]	[CEnd]	[CDuration]
D	[DSeason]	-	-	-	3 days

[Display if (Q10A = "Solar PV" AND Q10A != "Battery storage") Note: If you have solar PV panels installed without a battery storage system, your household will still experience the power interruption and your solar PV system will not feed electricity into the grid.]

Scenario A

Season	Day of Week	Start Time	End Time	Duration
Summer	Weekday	[AStart]	[AEnd]	[ADuration]

A1. Without any warning, on a typical summer weekday, a complete power interruption occurs at **[AStart]**. You don't know how long it will last, but your household's electricity is fully restored in **[ADuration]**.

Since you would not know beforehand how long the power interruption would last, how would your household adjust during this **[ADuration_descriptor]** interruption? (Select all that apply)

[Display for all]

- ☐ Contact your utility to check the predicted interruption length
- ☐ Stay home and do activities that don't require electricity
- ☐ Stay home and run a backup power generator
- ☐ There's generally no one home at this time

[Display if ADuration != "5 minutes or less"]

- ☐ Find an alternative location to work (if someone from your household works from home)
- ☐ Do activities outside the house like going out to eat, shopping or visiting friends
- ☐ Relocate to an area with electricity
- ☐ Go to the store to buy supplies
- ☐ Find a different location to charge electric vehicle
- ☐ Use a propane/gas stove or grill for cooking

[Display for all]

- ☐ Other - Please describe:

A2. On a scale from 1 to 5, how disruptive would this **[ADuration_descriptor]** power interruption be to your household, with 1 meaning “Not disruptive” and 5 meaning “Very disruptive”?

- ☐ 1 – Not disruptive
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 – Very disruptive

A3. How much do you think it would cost your household in additional expenses that you would **otherwise not have to pay** to adjust to this **[ADuration_descriptor]** interruption? For example, lost wages, transportation or lodging to relocate, dining out, replacing spoiled food, or operating a backup generator.

- ☐ \$0
- ☐ \$1 to \$9
- ☐ \$10 to \$49
- ☐ \$50 to \$199
- ☐ \$200 to \$499
- ☐ \$500 to \$999
- ☐ \$1,000 or more
- ☐ Don't know

A4. Suppose a company that is not your electric utility developed a new service that can instantaneously deliver temporary backup power to your household during this **[ADuration_descriptor]** interruption. With the purchase of this backup service, you would not experience the interruption or need to take any additional actions. The cost of the service is a one-time fee that covers your household's normal electric usage during this single interruption.

The exact cost of providing the service for this **[ADuration_descriptor]** interruption is not yet known, but it is believed to be between **[\$ALow] to [\$AHigh]**. Would you purchase the backup service to avoid this single interruption for a one-time fee of **[\$ABid1]**?

- ☐ Yes
- ☐ No



A4A. [Display if (ABid1 = ALow & A4 = “Yes”) OR (ABid1 = AHigh & A4 = No)] Would you purchase the backup service to avoid this [ADuration_descriptor] interruption for a one-time fee of \$[ABid2]?

- ☐ Yes
- ☐ No

A4B. [Display if (ABid1 = ALow & A4 = “No”) OR (ABid1 = AHigh & A4A = “No”)] Which of the following reasons best describes why you would not pay \$[ALow] for this service to avoid the interruption?

- ☐ I would not experience enough cost or inconvenience to justify paying for the service
- ☐ The service is too expensive
- ☐ I can use my own backup generator to power my home during the interruption
- ☐ Other – Please explain: _____

A5. Display if Group = 1 OR (Group = 3 & Q12 = "Advance warning would not reduce the costs caused by a power interruption"), alter Scenario box to show Season as "Winter" instead of "Summer" and **bold** or **highlight** the change] Suppose the power interruption occurred in the winter rather than the summer. Think about how your circumstances might change, such as the ability to heat your home.

[Display if Group = 2, alter Scenario box to show Day of Week as "Weekend" instead of "Weekday" and **bold** or **highlight** the change] Suppose the power interruption occurred on a weekend rather than a weekday. Think about how your circumstances might change, such as being home and not working.

[Display if Group = 3 & Q12 != "Advance warning would not reduce the costs caused by a power interruption"] Suppose your utility notified your household of the power interruption [Q12] before it occurred. Think about how being able to prepare might change your circumstances.

[Display all] Would you purchase the backup service to avoid this single [ADuration_descriptor] interruption for a one-time fee of \$[ABid1]?

- ☐ Yes
- ☐ No

→ A5A. [Display if (ABid1 = ALow & A5 = "Yes") OR (ABid1 = AHigh & A5 = "No")]
Would you purchase the backup service to avoid this
[ADuration_descriptor] interruption for a one-time fee of \$[ABid2]?

- ☐ Yes
- ☐ No

A5B. [Display if (ABid1 = ALow & A5 = "No") OR (ABid1 = AHigh & A5A = "No")]
Which of the following reasons best describes why you would not pay
\$[ALow] for this service to avoid the interruption [Display if Group = 3 &
Q12 != "Advance warning would not reduce the costs caused by a power
interruption"] (for which you received advance warning)?

- ☐ I would not experience enough cost or inconvenience to justify paying for the service
- ☐ The service is too expensive
- ☐ I can use my own backup generator to power my home during the interruption
- ☐ Other - Please explain: _____

Scenario B

Season	Day of Week	Start Time	End Time	Duration
Summer	Weekday	[BStart]	[BEnd]	[BDuration]

B1. Without any warning, on a typical summer weekday, a complete power interruption occurs at **[BStart]**. You don't know how long it will last, but your household's electricity is fully restored in **[BDuration]**.

Since you would not know beforehand how long the power interruption would last, how would your household adjust during this **[BDuration_descriptor]** interruption? (Select all that apply)

[Display for all]

- ☐ Contact your utility to check the predicted interruption length
- ☐ Stay home and do activities that don't require electricity
- ☐ Stay home and run a backup power generator
- ☐ There's generally no one home at this time

[Display if BDuration != "5 minutes or less"]

- ☐ Find an alternative location to work (if someone from your household works from home)
- ☐ Do activities outside the house like going out to eat, shopping or visiting friends
- ☐ Relocate to an area with electricity
- ☐ Go to the store to buy supplies
- ☐ Find a different location to charge electric vehicle
- ☐ Use a propane/gas stove or grill for cooking

[Display for all]

- ☐ Other - Please describe:

B2. On a scale from 1 to 5, how disruptive would this **[BDuration_descriptor]** power interruption be to your household, with 1 meaning “Not disruptive” and 5 meaning “Very disruptive”?

- ☐ 1 – Not disruptive
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 – Very disruptive

B3. How much do you think it would cost your household in additional expenses that you would **otherwise not have to pay** to adjust to this **[BDuration_descriptor]** interruption? For example, lost wages, transportation or lodging to relocate, dining out, replacing spoiled food, or operating a backup generator.

- ☐ \$0
- ☐ \$1 to \$9
- ☐ \$10 to \$49
- ☐ \$50 to \$199
- ☐ \$200 to \$499
- ☐ \$500 to \$999
- ☐ \$1,000 or more
- ☐ Don't know

B4. As previously described, a company could immediately provide you with a temporary backup power service to handle all your household's electric needs during **this [BDuration_descriptor] interruption**.

The exact cost of providing the service for this **[BDuration_descriptor]** interruption is not yet known, but it is believed to be between **[\$BLow] to [\$BHigh]**. Would you purchase the backup service to avoid this **single interruption** for a **one-time fee** of **[\$BBid1]**?

- ☐ Yes
- ☐ No



B4A. [Display if (BBid1 = BLow & B4 = “Yes”) OR (BBid1 = BHigh & B4 = No)]

Would you purchase the backup service to avoid this **[BDuration_descriptor]** interruption for a **one-time fee** of **[\$BBid2]**?

- ☐ Yes
- ☐ No

B4B. *[Display if (BBid1 = BLow & B4 = "No") OR (BBid1 = BHigh & B4A = "No")]*
Which of the following reasons best describes why you would not pay
\$[BLow] for this service?

- ☐ I would not experience enough cost or inconvenience to justify paying for the service
- ☐ The service is too expensive
- ☐ I can use my own backup generator to power my home during the interruption
- ☐ Other - Please explain: _____

B5. [Display if Group = 1 OR (Group = 3 & Q12 = “Advance warning would not reduce the costs caused by a power interruption”), alter Scenario box to show Season as “Winter” instead of “Summer” and **bold** or **highlight** the change] Suppose the power interruption occurred in the winter rather than the summer. Think about how your circumstances might change, such as the ability to heat your home.

[Display if Group = 2, alter Scenario box to show Day of Week as “Weekend” instead of “Weekday” and **bold** or **highlight** the change] Suppose the power interruption occurred on a weekend rather than a weekday. Think about how your circumstances might change, such as being home and not working.

[Display if Group = 3 & Q12 != “Advance warning would not reduce the costs caused by a power interruption”] Suppose your utility notified your household of the power interruption [Q12] before it occurred. Think about how being able to prepare might change your circumstances.

[Display all] Would you purchase the backup service to avoid this single [BDuration_descriptor] interruption for a one-time fee of \$[BBid1]?

- ☐ Yes
- ☐ No



B5A. [Display if (BBid1 = BLow & B5 = “Yes”) OR (BBid1 = BHigh & B5 = “No”)]
Would you purchase the backup service to avoid this
[BDuration_descriptor] interruption for a one-time fee of \$[BBid2]?

- ☐ Yes
- ☐ No

B5B. [Display if (BBid1 = BLow & B5 = “No”) OR (BBid1 = BHigh & B5A = “No”)]
Which of the following reasons best describes why you would not pay
\$[BLow] for this service to avoid the interruption [Display if Group = 3 &
Q12 != “Advance warning would not reduce the costs caused by a power
interruption”] (for which you received advance warning)?

- ☐ I would not experience enough cost or inconvenience to justify paying for the service
- ☐ The service is too expensive
- ☐ I can use my own backup generator to power my home during the interruption
- ☐ Other - Please explain: _____

Scenario C

Season	Day of Week	Start Time	End Time	Duration
Summer	Weekday	[CStart]	[CEnd]	[CDuration]

C1. Without any warning, on a typical summer weekday, a complete power interruption occurs at **[CStart]**. You don't know how long it will last, but your household's electricity is fully restored in **[CDuration]**.

Since you would not know beforehand how long the power interruption would last, how would your household adjust during this **[CDuration_descriptor]** interruption? (Select all that apply)

[Display for all]

- ☐ Contact your utility to check the predicted interruption length
- ☐ Stay home and do activities that don't require electricity
- ☐ Stay home and run a backup power generator
- ☐ There's generally no one home at this time

[Display if CDuration != "5 minutes or less"]

- ☐ Find an alternative location to work (if someone from your household works from home)
- ☐ Do activities outside the house like going out to eat, shopping or visiting friends
- ☐ Relocate to an area with electricity
- ☐ Go to the store to buy supplies
- ☐ Find a different location to charge electric vehicle
- ☐ Use a propane/gas stove or grill for cooking

[Display for all]

- ☐ Other - Please describe:

C2. On a scale from 1 to 5, how disruptive would this **[CDuration_descriptor]** power interruption be to your household, with 1 meaning “Not disruptive” and 5 meaning “Very disruptive”?

- ☐ 1 – Not disruptive
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 – Very disruptive

C3. How much do you think it would cost your household in additional expenses that you would **otherwise not have to pay** to adjust to this **[CDuration_descriptor]** interruption? For example, lost wages, transportation or lodging to relocate, dining out, replacing spoiled food, or operating a backup generator.

- ☐ \$0
- ☐ \$1 to \$9
- ☐ \$10 to \$49
- ☐ \$50 to \$199
- ☐ \$200 to \$499
- ☐ \$500 to \$999
- ☐ \$1,000 or more
- ☐ Don't know

C4. As previously described, a company could immediately provide you with a temporary backup power service to handle all your household's electric needs during **this [CDuration_descriptor] interruption**.

The exact cost of providing the service for this **[CDuration_descriptor]** interruption is not yet known, but it is believed to be between **[\$CLow] to [\$CHigh]**. Would you purchase the backup service to avoid this **single interruption** for a **one-time fee** of **[\$CBid1]**?

- ☐ Yes
- ☐ No



C4A. [Display if (CBid1 = CLow & C4 = “Yes”) OR (CBid1 = CHigh & C4 = No)]
Would you purchase the backup service to avoid this **[CDuration_descriptor]** interruption for a **one-time fee** of **[\$CBid2]**?

- ☐ Yes
- ☐ No

C4B. *[Display if (CBid1 = CLow & C4 = "No") OR (CBid1 = CHigh & C4A = "No")]*
Which of the following reasons best describes why you would not pay
\$[CLow] for this service?

- ☐ I would not experience enough cost or inconvenience to justify paying for the service
- ☐ The service is too expensive
- ☐ I can use my own backup generator to power my home during the interruption
- ☐ Other - Please explain: _____

C5. [Display if Group = 1 OR (Group = 3 & Q12 = “Advance warning would not reduce the costs caused by a power interruption”), alter Scenario box to show Season as “Winter” instead of “Summer” and **bold** or **highlight** the change] Suppose the power interruption occurred in the winter rather than the summer. Think about how your circumstances might change, such as the ability to heat your home.

[Display if Group = 2, alter Scenario box to show Day of Week as “Weekend” instead of “Weekday” and **bold** or **highlight** the change] Suppose the power interruption occurred on a weekend rather than a weekday. Think about how your circumstances might change, such as being home and not working.

[Display if Group = 3 & Q12 != “Advance warning would not reduce the costs caused by a power interruption”] Suppose your utility notified your household of the power interruption [Q12] before it occurred. Think about how being able to prepare might change your circumstances.

[Display all] Would you purchase the backup service to avoid this single [CDuration_descriptor] interruption for a one-time fee of \$[CBid1]?

- ☐ Yes
- ☐ No



C5A. [Display if (CBid1 = CLow & C5 = “Yes”) OR (CBid1 = CHigh & C5 = “No”)] Would you purchase the backup service to avoid this [CDuration_descriptor] interruption for a one-time fee of \$[CBid2]?

- ☐ Yes
- ☐ No

C5B. [Display if (CBid1 = CLow & C5 = “No”) OR (CBid1 = CHigh & C5A = “No”)] Which of the following reasons best describes why you would not pay \$[CLow] for this service to avoid the interruption [Display if Group = 3 & Q12 != “Advance warning would not reduce the costs caused by a power interruption”] (for which you received advance warning)?

- ☐ I would not experience enough cost or inconvenience to justify paying for the service
- ☐ The service is too expensive
- ☐ I can use my own backup generator to power my home during the interruption
- ☐ Other - Please explain: _____

Scenario D

For the next few questions, you will be asked about what your household would do if there was a longer-lasting power interruption.

[Display if DSeason = "Summer"] Assume that a severe summer windstorm impacted your area. *[Display if DSeason = "Winter"]* Assume that a severe winter windstorm impacted your area. *[Display all]* As a result, a number of power lines were damaged, and the power is out in a 20-mile radius around your residence. Fortunately, you still have cellular service. Your electric utility has indicated that it will take up to three days (72 hours) to restore power.

D1. Please indicate how you might respond to this **3-day** power interruption.

- ☐ Stay home and do activities that do not require electricity
- ☐ Stay home running your own backup generator or battery storage unit to power critical appliances and devices
- ☐ Temporarily move some or all family members to places that have electrical power (i.e., houses of family or friends outside the affected area, hotels, or emergency shelters outside the affected area)
- ☐ Other - Please explain: _____

D2A. *[Display if D1 = "Stay home and do activities that do not require electricity"]* How much do you think it would cost your household in additional expenses to adjust to this three-day outage (e.g., replacing spoiled food, transportation expenses, dining out)?

\$_____

D2B_1. *[Display if D1 = "Stay home running your own backup generator or battery storage unit to power critical appliances and devices" & 10A = "Battery storage"]* How much did your battery storage approximately cost to purchase and install?

\$_____

D2B_2. *[Display if D1 = "Stay home running your own backup generator or battery storage unit to power critical appliances and devices" & 10A = "Other"]* How much

did your other backup source of electricity approximately cost to purchase and install?

\$_____

D2B_3. *[Display if D1 = “Stay home running your own backup generator or battery storage unit to power critical appliances and devices” & 10A = “Natural gas generator” or “Diesel or gasoline generator” or “Propane generator”]* What is the total cost of running your *[Insert response from question 10.A]* to power critical appliances and devices for three days?

\$_____

D2B_4. *[Display if D1 = “Stay home running your own backup generator or battery storage unit to power critical appliances and devices” & 10A = “Solar PV”]* How much did your solar PV system approximately cost to purchase and install?

\$_____

D2C. *[Display if D1 = “Temporarily move some or all family members to places that have electrical power (i.e., houses of family or friends outside the affected area, hotels, or emergency shelters outside the affected area”]* What is the total cost to your household to temporarily move some or all family members to places that have electrical power? Please include transportation, lodging, meals, and other expenses:

\$_____

D2D. *[Display if D1 = “Other”]* What is the total cost to your household to account for other additional expenses associated with this three-day power outage?

\$_____

D3. Would your household income be reduced during this **3-day** interruption?

- ☐ Yes, my household would **lose all income** during the 3-day interruption
- ☐ Yes, my household would **lose some income** during the 3-day interruption
- ☐ No, my household income would **stay the same** during the 3-day interruption
- ☐ Don't know

D4. *[Display if D3 = “Yes, my household would lose some income” or “Yes, my household would lose all income during the 3-day outage”]* How much income would your household lose because you could not work during this 3-day outage?

\$ _____

[Insert additional questions, if any, provided by the utility here]

Q13. Please share any additional comments:

Thank you for participating in this valuable study. Your responses will be used to better understand how electricity interruptions affect customers.

Appendix G - Small and Medium Non-Residential Survey Instrument

[If the respondent took the online introduction survey, skip to question Q5].

Please answer the following questions about your facility located at **[INSERT SERVICE ADDRESS]** only. Do not answer for other locations or facilities where your organization operates.

Q1. What is the approximate square footage of your organization's facility?

- _____ square feet
☐ Don't know

Q2. How many of each type of employee are currently employed at this location?

- _____ Number of **year-round salaried** employees
_____ Number of **year-round hourly** employees
_____ Number of **seasonal hourly** employees

Q3. *[If NAICS was included in customer data]* We have your business type as **[INSERT BUSINESS TYPE]**. Is that correct?

- ☐ Yes
☐ No



Q3A. *[Display if Q3 = "No" or if NAICS was not included in customer data]* Which of the following categories best describes your facility? *[If a phone interview, only read the list if necessary]*

- ☐ Accommodation and Food Services
- ☐ Administrative and Support Services
- ☐ Agriculture, Forestry, Fishing and Hunting
- ☐ Arts, Entertainment, and Recreation
- ☐ Construction
- ☐ Educational Services
- ☐ Finance and Insurance
- ☐ Health Care and Social Assistance
- ☐ Information, Data, and Telecommunications
- ☐ Management of Companies
- ☐ Manufacturing
- ☐ Mining

- ☐ Professional, Scientific, and Technical Services
- ☐ Public Administration/Government
- ☐ Real Estate
- ☐ Rental and Leasing Services
- ☐ Retail Trade
- ☐ Transportation
- ☐ Utilities
- ☐ Warehousing and Storage
- ☐ Waste Management and Remediation Services
- ☐ Wholesale Trade
- ☐ Other (please specify):_____

Q4. Is your business a primarily minority- or women-owned business?

- ☐ Yes
- ☐ No
- ☐ Don't know

[Display if the respondent took the online introduction survey] Please answer the following questions about your facility located at **[INSERT SERVICE ADDRESS]** only. Do not answer for other locations or facilities where your organization operates.

Power outages can be caused by severe weather, traffic accidents, and equipment failures, among other things. When completing this survey, please note that a “power outage” refers to a **complete** loss of electricity to your organization’s workspace. If your organization shares a building with other owners or tenants, please answer the questions for your organization only.

Q5. Over the past 12 months, have you experienced any power outages at your facility?

- ☐ Yes
- ☐ No



Q5A. *[Display if Q5 = “Yes”]* Over the past 12 months, have you experienced power outages at your facility that lasted: (Select all that apply)

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 4 hours
- ☐ 4 hours to less than 24 hours
- ☐ 24 hours to less than 3 days
- ☐ 3 days or more

Q6. What is the longest power outage you have experienced at your facility in the last five years?

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 4 hours
- ☐ 4 hours to less than 24 hours
- ☐ 24 hours to less than 3 days
- ☐ 3 days or more
- ☐ Have never experienced an outage at this facility
- ☐ Don’t know

Q7. Has your organization or business ever sent employees home during a power outage?

- ☐ Yes
- ☐ No

Q8. Please estimate how long a power outage can last at your facility before it has a substantial impact on your operations.

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 2 hours
- ☐ 2 hours to less than 8 hours
- ☐ 8 hours to less than 24 hours
- ☐ 24 hours to less than 3 days
- ☐ 3 days or more
- ☐ Don't know

Q9. If your electric utility notified your organization of an upcoming power outage, how much advance warning is needed to significantly reduce the cost and problems caused by a power outage? Please give your best estimate.

- ☐ At least 1 hour
- ☐ At least 4 hours
- ☐ At least 8 hours
- ☐ At least 24 hours
- ☐ At least 48 hours
- ☐ Advance warning would not reduce the costs caused by a power outage

Q11. Does your facility have some form of **backup** generation that can supply electricity to the facility during a power outage?

- ☐ Yes
- ☐ No



Q11A. *[Display if Q11 = "Yes"]* What type of **backup** generation equipment do you have? (Select all that apply)

- ☐ Natural gas generator
- ☐ Diesel or gasoline generator
- ☐ Propane generator
- ☐ Solar PV
- ☐ Battery storage
- ☐ Wind turbine
- ☐ Other _____
- ☐ Don't know

Q11B. *[Display if Q11A = "Natural gas generator"]* What is the total rated capacity of all **backup** natural gas generators? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q11C. *[Display if Q11A = "Diesel or gasoline generator"]* What is the total rated capacity of all **backup** diesel or gasoline generators? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q11D. *[Display if Q11A = "Propane gas generator"]* What is the total rated capacity of all **backup** propane gas generators? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q11E. *[Display if Q11A = "Solar PV"]* What is the total rated capacity of all **backup** solar PV systems? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Other _____
 - ☐ Don't know

Q11F. *[Display if Q11A = "Battery storage"]* What is the total rated capacity of all **backup** battery storage systems? (Please include units)

- _____
- ☐ Kilowatt-hours (kWh)
 - ☐ Megawatt-hours (MWh)
 - ☐ Other _____
 - ☐ Don't know

Q11G. *[Display if Q11A = "Wind turbine"]* What is the total rated capacity of all **backup** wind turbines? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Other _____
 - ☐ Don't know

Q11H. *[Display if Q11A = "Other"]* What is the total rated capacity of all **backup** *[Display Q11A Other]?* (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q11I. *[Display if Q11 = "Yes"]* What percentage of your electrical demand could be supplied by your backup generation equipment? Please provide your best estimate.

- ☐ 0%
- ☐ 1-25%
- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-99%
- ☐ 100%

Q11J. *[Display if Q11 = "Yes"]* What percentage of your employees are currently able to work when your facility is operating on **backup** power? Please provide your best estimate.

- ☐ 0%
- ☐ 1-25%
- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-99%
- ☐ 100%

Q11K. *[Display if Q11 = "Yes"]* How long can your **backup** electrical system operate while the power is out? If the backup generator consumes fuel such as diesel or propane, consider how much is readily available at your facility.

- ☐ Less than 1 hour
- ☐ 1 hour to less than 12 hours
- ☐ 12 hours to less than 24 hours
- ☐ 24 hours to less than 3 days
- ☐ 3 days or more (such as generators connected to a continuous fuel service)
- ☐ Don't know

Q12. **Other than backup power during outages**, does your facility use equipment (such as rooftop solar) to generate electricity?

- ☐ Yes
- ☐ No



Q12A. *[Display if Q12 = "Yes"]* What type of **non-backup** generation equipment do you have? (Select all that apply)

- ☐ Natural gas generator
- ☐ Diesel or gasoline generator
- ☐ Propane generator
- ☐ Solar PV
- ☐ Battery storage
- ☐ Wind turbine
- ☐ Other _____
- ☐ Don't know

Q12B. *[Display if Q12A = "Natural gas generator"]* What is the total rated capacity of all **non-backup** natural gas generators? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q12C. *[Display if Q12A = "Diesel or gasoline generator"]* What is the total rated capacity of all **non-backup** diesel or gasoline generators? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q12D. *[Display if Q12A = "Propane gas generator"]* What is the total rated capacity of all **non-backup** propane gas generators? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q12E. *[Display if Q12A = "Solar PV"]* What is the total rated capacity of all **non-backup** solar PV systems? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Other _____
 - ☐ Don't know

Q12F. *[Display if Q12A = "Battery storage"]* What is the total rated capacity of all **non-backup** battery storage systems? (Please include units)

- _____
- ☐ Kilowatt-hours (kWh)
 - ☐ Megawatt-hours (MWh)
 - ☐ Other _____
 - ☐ Don't know

Q12G. *[Display if Q12A = "Wind turbine"]* What is the total rated capacity of all **non-backup** wind turbines? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Other _____
 - ☐ Don't know

Q12H. *[Display if Q12A = "Other"]* What is the total rated capacity of all **non-backup** *[Display Q12A Other]*? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q12I. *[Display if Q12 = "Yes"]* What percentage of your facility's total electrical demand could be supplied by your **non-backup** generation equipment? Please provide your best estimate.

- ☐ 0%
- ☐ 1-25%
- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-99%
- ☐ 100%

Q13. What percentage of your employees currently work remotely?

- ☐ 0%
- ☐ 1-25%
- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-99%
- ☐ 100%

Q13A. Does your organization own, rent, or operate any additional facilities besides the location at **[INSERT SERVICE ADDRESS]**?

- ☐ Yes
- ☐ No



Q14. *[Display if Q13 != 100% & Q13A = "Yes"]* Could employees who typically work at **[INSERT SERVICE ADDRESS]** relocate to one of these facilities to substitute for this location?

- ☐ Yes
- ☐ No



Q14A. *[Display if Q14 = "Yes"]* How far away (in miles) is the closest of these locations? Please provide your best estimate.

_____ miles



Q14B. *[Display if Q14 = "Yes"]* If your current location were suddenly inoperable, what percentage of employees could relocate to these locations?

- ☐ 0%
- ☐ 1-25%
- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-99%
- ☐ 100%

Q16. *[Display if Q13A = "Yes"]* Assume the outage only causes the facility at **[INSERT SERVICE ADDRESS]** to lose power. Would an outage at this

location financially impact other sites or facilities owned by your organization (for example, other components of your firm's supply chain)?

- ☐ Yes
- ☐ No



Q16A. *[Display if Q16 = "Yes"]* How long could an outage last at **[INSERT SERVICE ADDRESS]** before it begins to financially impact other your organization's other facilities?

- ☐ Less than 5 minutes
- ☐ 5 minutes to less than 2 hours
- ☐ 2 hours to less than 8 hours
- ☐ 8 hours to less than 24 hours
- ☐ 24 hours to less than 3 days
- ☐ 3 days or more
- ☐ Other _____

In the following sections, we present three different possible future scenarios involving electrical power outages lasting 24 hours or less. Assume that for these scenarios the power outages are:

- Local to your facility at **[INSERT SERVICE ADDRESS]**
- *[Display if Q13 != 0%]* Do not impact your employees' ability to work remotely
- *[Display if Q13A = "Yes"]* Do not impact the other locations mentioned previously.

For each scenario, we first ask how your facility would respond to the outage. Second, we ask you to estimate any financial impact your facility would experience due to the outage. Following these three short-duration outage scenarios, we will ask a brief series of questions in a fourth scenario regarding how your organization may respond to a hypothetical long-duration outage scenario.

There are no right or wrong answers to these questions. Please respond based on your personal experience and the current circumstances facing your organization. We simply want your best estimate.

You will estimate the additional costs your organization would experience for each of the scenarios in the table below. Please answer all questions about the potential impact of these power outage scenarios at your facility only *[Display if Q14 = "Yes" OR Q16 = "Yes"]* (not other locations or facilities where your organization operates).

Scenario	Season	Time of Week	Start Time	End Time	Duration
A	Summer	Weekday	<i>[AStart]</i>	<i>[AEnd]</i>	<i>[ADuration]</i>
B	Summer	Weekday	<i>[BStart]</i>	<i>[BEnd]</i>	<i>[BDuration]</i>
C	Summer	Weekday	<i>[CStart]</i>	<i>[CEnd]</i>	<i>[CDuration]</i>
D	<i>[DSeason]</i>	-	-	-	3 days

[Display if (Q11A = "Solar PV" OR Q12A = "Solar PV") AND (Q11A != "Battery storage" AND Q12A != "Battery storage")] **Note: If you have solar PV panels installed**

without a battery storage system, your organization will still experience the power outage and your solar PV system will not feed electricity into the grid.

Scenario A

Season	Day of Week	Start Time	End Time	Duration
Summer	Weekday	[AStart]	[AEnd]	[ADuration]

A1. Without any warning, on a typical summer weekday, a complete power outage occurs at **[AStart]**. Assume that this outage is:

Appendix A. Local to your facility at **[INSERT SERVICE ADDRESS]**

Appendix B. *[Display if Q13 != 0%]* Does not impact your employees' ability to work remotely

Appendix C. *[Display if Q13A = "Yes"]* Does not impact any other facilities owned by your company.

[Display all] You don't know how long it will last, but your facility's electricity is fully restored in **[ADuration]**.

On a scale from 1 to 5, how disruptive would this **[ADuration]** power outage be to your organization, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

- ☐ 1 - Not disruptive
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 - Very disruptive

A2. Would your operations or services typically stop or slow down as a result of this power outage?

- ☐ Yes
- ☐ No

→ A2A. *[Display if A2 = "Yes"]* Please estimate how long operations or services would stop or slow down resulting from a power outage of this length (include time during and after the power outage).

[Display if ADuration = "5 minutes or less" OR Q11 = "Yes"]

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 2 hours

[Display if ADuration = "5 minutes or less" or "2 hours" OR Q11 = "Yes"]

- ☐ 2 hours to less than 8 hours

[Display if ADuration = "5 minutes or less", "2 hours", or "8 hours" OR Q11 = "Yes"]

- ☐ 8 hours to less than 24 hours

[Display all]

- ☐ 24 hours to less than 3 days
- ☐ 3 days or more
- ☐ Other _____

A3. What is the approximate dollar value of the operations or services that typically would be lost, at least temporarily, during the power outage and any slow period after the power outage? Please make your best estimate.

\$ _____ value of lost work or services

[Display if A3 NOT = 0]

A4. What percentage of the operations or services lost would typically be made up, either at this facility at **[INSERT SERVICE ADDRESS]** after the power outage, or by another facility operated by your organization?

- ☐ 0%
- ☐ 1-25%
- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-99%
- ☐ 100%

[Assign A4 value as the midpoint of the selected range: If the respondent chooses "1-25%" then A4 = 13%; "26-50%" = 38%, etc. If A4 = 0% or 100%, store that direct value.]

A5. Would there be any **incremental or additional labor costs** associated with this power outage such as salaries and wages for staff needed to deal with any **outage-related issues** or overtime pay to make up for operations or services?

☐ Yes

☐ No

→ A5A. [Display if A5 = "Yes"] Please estimate the value for each of the following.

\$ _____ overtime/extra shifts to make up lost output [A5A1]

\$ _____ extra labor costs to restart activities [A5A2]

\$ _____ other labor-related costs [A5A3]

A6. Would there be any **damage costs** associated with this power outage such as damage to equipment, materials, or cost to dispose of hazardous materials?

☐ Yes

☐ No

→ A6A. [Display if A6 = "Yes"] Please estimate the value for each of the following.

\$ _____ damage to equipment [A6A1]

\$ _____ damage/spoilage to materials [A6A2]

\$ _____ cost of disposing hazardous materials [A6A3]

A7. Would there be any other **material or fuel costs** associated with this power outage (such as fuel to run a backup generator)?

☐ Yes

☐ No

→ A7A. [Display if A7 = "Yes"] Please estimate any other materials or fuel costs.

\$ _____ other materials [A7A1]

\$ _____ fuel to run a backup generator [A7A2]

A8. Would there be **any other tangible costs** associated with this power outage (such as extra restart costs)?

- ☐ Yes
☐ No

→ A8A. [Display if A8 = "Yes"] Please estimate the other costs associated with this power outage.

\$ _____ other tangible costs

A10. In addition to the costs discussed above, some organizations may avoid expenses because of electrical outages. Some examples include a lower electricity bill, lower material outlays, and lower personnel costs. Would you experience any **savings** associated with this power outage?

- ☐ Yes
☐ No

→ A10A. [Display if A10 = "Yes"] Please estimate the savings you would accrue resulting from this outage.

\$ _____ savings [A10A1]

Instructions for the interviewer: The table below summarizes the respondent's responses to the previous questions and sums the costs into a total value. If this is a phone interview and the respondent cannot see, recap each item in this table to the interviewee and allow them to change their answers if they wish to do so.

Here is a recap of the costs associated with this [ADuration] outage:

Category	Costs Due to Outage
Operations and Services Lost (minus revenue made up afterwards)	\$ [Display A3 * (1-A4)]
Overtime/Extra Shifts to Make Up for Lost Time	\$ [Display A5A1]

Extra Labor Costs to Restart Activities	\$ [Display A5A2]
Other Labor-Related Costs	\$ [Display A5A3]
Damage to Equipment	\$ [Display A6A1]
Damage/Spoilage to Materials	\$ [Display A6A2]
Cost of Disposing Hazardous Materials	\$ [Display A6A3]
Additional Materials	\$ [Display A7A1]
Fuel Cost to Run Backup Generator	\$ [Display A7A2]
Other Tangible Costs	\$ [Display A8A]
Subtotal:	\$ [Display Subtotal] [ASUB]
Savings due to the outage	\$ [Display A10A1]
TOTAL:	\$ [Display TOTAL] [ATOTAL]

A11. Based on your responses to the prior questions, we estimate that your most likely total for this **[ADuration]** outage is **[ATOTAL]**. Does this sound correct?

- ☐ Yes
☐ No


A11A. [Display if A11 = "No"] What do you think your most likely total cost is?

\$ _____ total cost [Replace ATOTAL]

A12. Keeping this most likely total in mind for a **[ADuration]** outage, please estimate the total costs you would incur for a **best-case** (lowest-cost) scenario and the costs for a **worst-case** (highest-cost) scenario.

\$ _____ [A12A]	\$ [Display ATOTAL]	\$ _____ [A12B]
Lowest Total Outage Cost	Most Likely Total Outage Cost	Highest Total Outage Cost

A13. *[Display if Group = 1 or (Group = 3 & Q9 = “Advance warning would not reduce the costs caused by a power outage”), alter Scenario box to show Season as “Winter” instead of “Summer” and **bold** or **highlight** the change]* Suppose the power outage occurred in the winter rather than the summer. Think about how circumstances might change at your facility. If your total cost for a **[ADuration]** power outage in the summer is approximately **[ATOTAL]**, what do you think your total cost would be for a **[ADuration]** outage in the winter?

*[Display if Group = 2, alter Scenario box to show Day of Week as “Weekend” instead of “Weekday” and **bold** or **highlight** the change]* Suppose the power outage occurred on a weekend rather than a weekday. Think about how circumstances might change at your facility. If your total cost for a **[ADuration]** power outage on a weekday is approximately **[ATOTAL]**, what do you think your total cost would be for a **[ADuration]** outage on the weekend?

[Display if Group = 3 & Q9 != “Advance warning would not reduce the costs caused by a power outage”] Suppose your utility notified your organization of the power outage [Q9] before it occurred. Think about how being able to prepare might change circumstances at your facility. If your total cost for a **[ADuration]** power outage is approximately **[ATOTAL]**, what do you think your total cost would be for a **[ADuration]** outage if you received advance notice?

\$ _____ total cost

Scenario B

Day of Week	Start Time	End Time	Duration
Weekday	[BStart]	[BEnd]	[BDuration]

B1. Without any warning, on a typical summer weekday, a complete power outage occurs at **[BStart]**. Assume that this outage is:

Appendix D. Local to your facility at [INSERT SERVICE ADDRESS]

Appendix E. [Display if Q13 != 0%] Does not impact your employees' ability to work remotely

Appendix F. [Display if Q13A = "Yes] Does not impact any other facilities owned by your company.

[Display all] You don't know how long it will last, but your facility's electricity is fully restored in **[BDuration]**.

On a scale from 1 to 5, how disruptive would this **[BDuration]** power outage be to your organization, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

- ☐ 1 - Not disruptive
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 - Very disruptive

B2. Would your operations or services typically stop or slow down as a result of this power outage?

- ☐ Yes
- ☐ No

→ B2A. *[Display if B2 = "Yes"]* Please estimate the number of hours that operations or services would stop or slow down resulting from a power outage of this length (include time during and after the power outage).

[Display if BDuration = "5 minutes or less" OR Q11 = "Yes"]

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 2 hours

[Display if BDuration = "5 minutes or less" or "2 hours" OR Q11 = "Yes"]

- ☐ 2 hours to less than 8 hours

[Display if BDuration = "5 minutes or less", "2 hours", or "8 hours" OR Q11 = "Yes"]

- ☐ 8 hours to less than 24 hours

[Display all]

- ☐ 24 hours to less than 3 days
- ☐ 3 days or more
- ☐ Other _____

Instructions for the interviewer: The table below summarizes the respondent's total cost estimates to the previous scenarios. Recap each scenario's total cost so they can use it as a reference point when answering the following questions.

Here is a recap of the outage costs you have estimated so far. If applicable, use these estimates as a reference when answering the following questions.

Scenario	Season	Time of Week	Start Time	Duration	Outage Cost
A	Summer	Weekday	[AStart]	[ADuration]	\$(ATOTAL)

B3. What do you think your most likely total cost would be for a **[BDuration]** outage occurring on a summer weekday?

\$ _____ total cost

B4. Keeping this most likely total in mind for a **[BDuration]** outage, please estimate the total costs you would incur for a **best-case** (lowest-cost) scenario and the costs for a **worst-case** (highest-cost) scenario.

\$ _____ [B4A]	\$ [Display B3]	\$ _____ [B4B]
Lowest Total Outage Cost	Most Likely Total Outage Cost	Highest Total Outage Cost

B5. *[Display if Group = 1 OR (Group = 3 & Q9 = “Advance warning would not reduce the costs caused by a power outage”), alter Scenario box to show Season as “Winter” instead of “Summer” and **bold** or **highlight** the change]* Suppose the power outage occurred in the winter rather than the summer. Think about how circumstances might change at your facility. If your total cost for a **[BDuration]** power outage in the summer is approximately **[B3]**, what do you think your total cost would be for a **[BDuration]** outage in the winter?

*[Display if Group = 2, alter Scenario box to show Day of Week as “Weekend” instead of “Weekday” and **bold** or **highlight** the change]* Suppose the power outage occurred on a weekend rather than a weekday. Think about how circumstances might change at your facility. If your total cost for a **[BDuration]** power outage on a weekday is approximately **[B3]**, what do you think your total cost would be for a **[BDuration]** outage on the weekend?

[Display if Group = 3 & Q9 != “Advance warning would not reduce the costs caused by a power outage”] Suppose your utility notified your organization of the power outage [Q9] before it occurred. Think about how being able to prepare might change circumstances at your facility. If your total cost for a **[BDuration]** power outage is approximately **[B3]**, what do you think your total cost would be for a **[BDuration]** outage if you received advance notice?

\$ _____ total cost

Scenario C

Season	Day of Week	Start Time	End Time	Duration
Summer	Weekday	[CStart]	[CEnd]	[CDuration]

C1. Without any warning, on a typical summer weekday, a complete power outage occurs at **[CStart]**. Assume that this outage is:

Appendix G. Local to your facility at [INSERT SERVICE ADDRESS]

Appendix H. [Display if Q13 != 0%] Does not impact your employees' ability to work remotely

Appendix I. [Display if Q13A = "Yes] Does not impact any other facilities owned by your company.

[Display all] You don't know how long it will last, but your facility's electricity is fully restored in **[CDuration]**.

On a scale from 1 to 5, how disruptive would this **[CDuration]** power outage be to your organization, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

- ☐ 1 - Not disruptive
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 - Very disruptive

C2. Would your operations or services typically stop or slow down as a result of this power outage?

- ☐ Yes
- ☐ No

→ C2A. *[Display if C2 = "Yes"]* Please estimate the number of hours that operations or services would stop or slow down resulting from a power outage of this length (include time during and after the power outage).

[Display if CDuration = "5 minutes or less" OR Q11 = "Yes"]]

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 2 hours

[Display if CDuration = "5 minutes or less" or "2 hours" OR Q11 = "Yes"]]

- ☐ 2 hours to less than 8 hours

[Display if CDuration = "5 minutes or less", "2 hours", or "8 hours" OR Q11 = "Yes"]]

- ☐ 8 hours to less than 24 hours

[Display all]

- ☐ 24 hours to less than 3 days
- ☐ 3 days or more
- ☐ Other _____

Instructions for the interviewer: The table below summarizes the respondent's total cost estimates to the previous scenarios. Recap each scenario's total cost so they can use it as a reference point when answering the following questions.

Here is a recap of the outage costs you have estimated so far. If applicable, use these estimates as a reference when answering the following questions.

Scenario	Season	Time of Week	Start Time	Duration	Outage Cost
A	Summer	Weekday	[AStart]	[ADuration]	\$(ATOTAL)
B	Summer	Weekday	[BStart]	[BDuration]	\$(B3)

C3. What do you think your most likely total cost would be for a **[CDuration]** outage occurring on a summer weekday?

\$ _____ total cost

C4. Keeping this most likely total in mind for a **[CDuration]** outage, please estimate the total costs you would incur for a **best-case** (lowest-cost) scenario and the costs for a **worst-case** (highest-cost) scenario.

\$ _____ [C4A]	\$ [Display C3]	\$ _____ [C4B]
Lowest Total Outage Cost	Most Likely Total Outage Cost	Highest Total Outage Cost

C5. *[Display if Group = 1 OR (Group = 3 & Q9 = "Advance warning would not reduce the costs caused by a power outage")]*, alter Scenario box to show Season as "Winter" instead of "Summer" and **bold** or **highlight** the change] Suppose the power outage occurred in the winter rather than the summer. Think about how circumstances might change at your facility. If your total cost for a **[CDuration]** power outage in the summer is approximately **[C3]**, what do you think your total cost would be for a **[CDuration]** outage in the winter?

*[Display if Group = 2, alter Scenario box to show Day of Week as "Weekend" instead of "Weekday" and **bold** or **highlight** the change]* Suppose the power outage occurred on a weekend rather than a weekday. Think about how circumstances might change at your facility. If your total cost for a **[CDuration]** power outage on a weekday is approximately **[C3]**, what do you think your total cost would be for a **[CDuration]** outage on the weekend?

[Display if Group = 3 & Q9 != "Advance warning would not reduce the costs caused by a power outage"] Suppose your utility notified your organization of the power outage **[Q9] before it occurred**. Think about how being able to prepare might change circumstances at your facility. If your total cost for a **[CDuration]** power outage is approximately **[C3]**, what do you think your total cost would be for a **[CDuration]** outage if you received **advance notice**?

\$ _____ total cost

Scenario D

For the next series of questions, we would like to ask what your organization would do if there was a longer-lasting power outage.

[Display if DSeason = "Summer"] Assume that a severe summer windstorm impacted your area. *[Display if DSeason = "Winter"]* Assume that a severe winter windstorm impacted your area. *[Display all]* As a result, a number of power lines were damaged and the power is out in a 20-mile radius around your facility. Fortunately, you still have cellular service. Your electric utility has indicated that it might take up to three days (72 hours) to restore power.

D1. How might you respond to this **3-day** power outage?

- ☐ Shut down the facility throughout the power outage
- ☐ Continue operation with backup generation
- ☐ Temporarily shut down the facility until backup generation is rented
- ☐ Transfer activities to another facility that has electricity

D2. If you are a for-profit organization, what is your approximate annual revenue?

- \$_____
- ☐ Not applicable

If you are a **non-profit** or government organization, what is your approximate annual operating budget?

- \$_____
- ☐ Not applicable

D3. Please think about the revenue or business value of the operations or services that typically would be over an average three-day period during the *[DSeason]*. What percentage of this revenue would you lose during this three-day power outage?

- ☐ 0%
- ☐ 1-25%
- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-99%
- ☐ 100%

D4. *[Display if D2 = "For profit"]* You indicated that a *[max of ADuration, BDuration, or CDuration]* long power outage would most likely cost *[max of ATotal, B3, or C3]*.

If you are a for-profit organization, besides lost revenue, how much do you estimate that a three-day (72 hour) power outage would cost your organization (e.g., overtime labor, cost to restore operations to normal, lost inventory, backup generator fuel costs)?

72-hour outage cost: \$_____

☐ Not applicable

[Insert additional questions, if any, provided by the utility here]

Q17. Please share any additional comments:

Thank you for participating in this valuable study. Your responses will be used to better understand how electricity outages affect customers.

Appendix H - Large Non-Residential Survey Instrument

[If the respondent took the online introduction survey, skip to question Q5].

Please answer the following questions about your facility located at **[INSERT SERVICE ADDRESS]** only. Do not answer for other locations or facilities where your organization operates.

Q1. What is the approximate square footage of your organization's facility?

- _____ square feet
☐ Don't know

Q2. How many of each type of employee are currently employed at this location?

- _____ Number of **year-round salaried** employees
_____ Number of **year-round hourly** employees
_____ Number of **seasonal hourly** employees

Q3. *[If NAICS was included in customer data]* We have your business type as **[INSERT BUSINESS TYPE]**. Is that correct?

- ☐ Yes
☐ No



Q3A. *[Display if Q3 = "No" or if NAICS was not included in customer data]* Which of the following categories best describes your facility? *[If a phone interview, only read the list if necessary]*

- ☐ Accommodation and Food Services
- ☐ Administrative and Support Services
- ☐ Agriculture, Forestry, Fishing and Hunting
- ☐ Arts, Entertainment, and Recreation
- ☐ Construction
- ☐ Educational Services
- ☐ Finance and Insurance
- ☐ Health Care and Social Assistance
- ☐ Information, Data, and Telecommunications
- ☐ Management of Companies
- ☐ Manufacturing
- ☐ Mining

- ☐ Professional, Scientific, and Technical Services
- ☐ Public Administration/Government
- ☐ Real Estate
- ☐ Rental and Leasing Services
- ☐ Retail Trade
- ☐ Transportation
- ☐ Utilities
- ☐ Warehousing and Storage
- ☐ Waste Management and Remediation Services
- ☐ Wholesale Trade
- ☐ Other (please specify):_____

Q4. Is your business a primarily minority- or women-owned business?

- ☐ Yes
- ☐ No
- ☐ Don't know

[Display if the respondent took the online introduction survey] Please answer the following questions about your facility located at **[INSERT SERVICE ADDRESS]** only. Do not answer for other locations or facilities where your organization operates.

Power outages can be caused by severe weather, traffic accidents, and equipment failures, among other things. When completing this survey, please note that a “power outage” refers to a **complete** loss of electricity to your organization’s workspace. If your organization shares a building with other owners or tenants, please answer the questions for your organization only.

Q5. Over the past 12 months, have you experienced any power outages at your facility?

- ☐ Yes
- ☐ No



Q5A. *[Display if Q5 = “Yes”]* Over the past 12 months, have you experienced power outages at your facility that lasted: (Select all that apply)

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 4 hours
- ☐ 4 hours to less than 24 hours
- ☐ 24 hours to less than 3 days
- ☐ 3 days or more

Q6. What is the longest power outage you have experienced at your facility in the last five years?

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 4 hours
- ☐ 4 hours to less than 24 hours
- ☐ 24 hours to less than 3 days
- ☐ 3 days or more
- ☐ Have never experienced an outage at this facility
- ☐ Don’t know

Q7. Has your organization or business ever sent employees home during a power outage?

- ☐ Yes
- ☐ No

Q8. Please estimate how long a power outage can last at your facility before it has a substantial impact on your operations.

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 2 hours
- ☐ 2 hours to less than 8 hours
- ☐ 8 hours to less than 24 hours
- ☐ 24 hours to less than 3 days
- ☐ 3 days or more
- ☐ Don't know

Q9. If your electric utility notified your organization of an upcoming power outage, how much advance warning is needed to significantly reduce the cost and problems caused by a power outage? Please give your best estimate.

- ☐ At least 1 hour
- ☐ At least 4 hours
- ☐ At least 8 hours
- ☐ At least 24 hours
- ☐ At least 48 hours
- ☐ Advance warning would not reduce the costs caused by a power outage

Q10. What normally happens to your facility's operations when a power outage lasting more than **one minute** occurs? (What major equipment is affected, what are the worst effects on operations, etc.)?

Q11. Does your facility have some form of **backup** generation that can supply electricity to the facility during a power outage?

- ☐ Yes
- ☐ No



Q11A. *[Display if Q11 = "Yes"]* What type of **backup** generation equipment do you have? (Select all that apply)

- ☐ Natural gas generator
- ☐ Diesel or gasoline generator
- ☐ Propane generator
- ☐ Solar PV
- ☐ Battery storage
- ☐ Wind turbine
- ☐ Other _____
- ☐ Don't know

Q11B. *[Display if Q11A = "Natural gas generator"]* What is the total rated capacity of all **backup** natural gas generators? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q11C. *[Display if Q11A = "Diesel or gasoline generator"]* What is the total rated capacity of all **backup** diesel or gasoline generators? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q11D. *[Display if Q11A = "Propane gas generator"]* What is the total rated capacity of all **backup** propane gas generators? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q11E. *[Display if Q11A = "Solar PV"]* What is the total rated capacity of all **backup** solar PV systems? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Other _____
 - ☐ Don't know

Q11F. *[Display if Q11A = "Battery storage"]* What is the total rated capacity of all **backup** battery storage systems? (Please include units)

- _____
- ☐ Kilowatt-hours (kWh)
 - ☐ Megawatt-hours (MWh)
 - ☐ Other _____
 - ☐ Don't know

Q11G. *[Display if Q11A = "Wind turbine"]* What is the total rated capacity of all **backup** wind turbines? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Other _____
 - ☐ Don't know

Q11H. *[Display if Q11A = "Other"]* What is the total rated capacity of all **backup** *[Display Q11A Other]?* (Please include units)

- ☐ Kilowatts (kW)
- ☐ Megawatts (MW)
- ☐ Horsepower (hp)
- ☐ Other _____
- ☐ Don't know

Q11I. *[Display if Q11 = "Yes"]* What percentage of your electrical demand could be supplied by your backup generation equipment? Please provide your best estimate.

- ☐ 0%
- ☐ 1-25%
- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-99%
- ☐ 100%

Q11J. *[Display if Q11 = "Yes"]* What percentage of your employees are currently able to work when your facility is operating on **backup** power? Please provide your best estimate.

- ☐ 0%
- ☐ 1-25%
- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-99%
- ☐ 100%

Q11K. *[Display if Q11 = "Yes"]* How long can your **backup** electrical system operate while the power is out? If the backup generator consumes fuel such as diesel or propane, consider how much is readily available at your facility.

- ☐ Less than 1 hour
- ☐ 1 hour to less than 12 hours
- ☐ 12 hours to less than 24 hours
- ☐ 24 hours to less than 3 days
- ☐ 3 days or more (such as generators connected to a continuous fuel service)
- ☐ Don't know

Q12. **Other than backup power during outages**, does your facility use equipment (such as rooftop solar) to generate electricity?

- ☐ Yes
- ☐ No



Q12A. *[Display if Q12 = "Yes"]* What type of **non-backup** generation equipment do you have? (Select all that apply)

- ☐ Natural gas generator
- ☐ Diesel or gasoline generator
- ☐ Propane generator
- ☐ Solar PV
- ☐ Battery storage
- ☐ Wind turbine
- ☐ Other _____
- ☐ Don't know

Q12B. *[Display if Q12A = "Natural gas generator"]* What is the total rated capacity of all **non-backup** natural gas generators? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q12C. *[Display if Q12A = "Diesel or gasoline generator"]* What is the total rated capacity of all **non-backup** diesel or gasoline generators? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q12D. [Display if Q12A = "Propane gas generator"] What is the total rated capacity of all **non-backup** propane gas generators? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Horsepower (hp)
 - ☐ Other _____
 - ☐ Don't know

Q12E. [Display if Q12A = "Solar PV"] What is the total rated capacity of all **non-backup** solar PV systems? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Other _____
 - ☐ Don't know

Q12F. [Display if Q12A = "Battery storage"] What is the total rated capacity of all **non-backup** battery storage systems? (Please include units)

- _____
- ☐ Kilowatt-hours (kWh)
 - ☐ Megawatt-hours (MWh)
 - ☐ Other _____
 - ☐ Don't know

Q12G. [Display if Q12A = "Wind turbine"] What is the total rated capacity of all **non-backup** wind turbines? (Please include units)

- _____
- ☐ Kilowatts (kW)
 - ☐ Megawatts (MW)
 - ☐ Other _____
 - ☐ Don't know

Q12H. *[Display if Q12A = "Other"]* What is the total rated capacity of all **non-backup** *[Display Q12A Other]*? (Please include units)

- ☐ Kilowatts (kW)
- ☐ Megawatts (MW)
- ☐ Horsepower (hp)
- ☐ Other _____
- ☐ Don't know

Q12I. *[Display if Q12 = "Yes"]* What percentage of your facility's total electrical demand could be supplied by your **non-backup** generation equipment? Please provide your best estimate.

- ☐ 0%
- ☐ 1-25%
- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-99%
- ☐ 100%

Q13. What percentage of your employees currently work remotely?

- ☐ 0%
- ☐ 1-25%
- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-99%
- ☐ 100%

Q13A. Does your organization own, rent, or operate any additional facilities besides the location at **[INSERT SERVICE ADDRESS]**?

- ☐ Yes
- ☐ No



Q14. *[Display if Q13 != 100% & Q13A = "Yes"]* Could employees who typically work at **[INSERT SERVICE ADDRESS]** relocate to one of these facilities to substitute for this location?

- ☐ Yes
- ☐ No

→ **Q14A.** *[Display if Q14 = "Yes"]* How far away (in miles) is the closest of these locations? Please provide your best estimate.

_____ miles

→ **Q14B.** *[Display if Q14 = "Yes"]* If your current location were suddenly inoperable, what percentage of employees could relocate to these locations?

- ☐ 0%
- ☐ 1-25%
- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-99%
- ☐ 100%

Q15. During an outage that lasts multiple days or weeks, would you physically relocate your infrastructure, equipment, parts, supplies, or inventory to ensure the continuity of your operations?

- ☐ Yes
- ☐ No

→ **Q15A.** *[Display if Q15 = "Yes"]* How long (in days and hours) would it take to physically relocate?

- ☐ _____ days
- ☐ _____ hours

Q15B. *[Display if Q15 = "Yes"]* How much would it cost to physically relocate?
Please provide your best estimate.

\$ _____

Q16. *[Display if Q13A = "Yes"]* Assume the outage only causes the facility at **[INSERT SERVICE ADDRESS]** to lose power. Would an outage at this location financially impact other sites or facilities owned by your organization (for example, other components of your firm's supply chain)?

☐ Yes

☐ No



Q16A. *[Display if Q16 = "Yes"]* How long could an outage last at **[INSERT SERVICE ADDRESS]** before it begins to financially impact other your organization's other facilities?

☐ 5 minutes or less

☐ Greater than 5 minutes to less than 2 hours

☐ 2 hours to less than 8 hours

☐ 8 hours to less than 24 hours

☐ 24 hours to less than 3 days

☐ 3 days or more

☐ Other _____

Q16B. *[Display if Q16 = "Yes"]* Describe how an outage at this facility would financially affect these other locations.

In the following sections, we present three different possible future scenarios involving electrical power outages lasting 24 hours or less. Assume that for these scenarios the power outages are:

- Local to your facility at **[INSERT SERVICE ADDRESS]**
- *[Display if Q13 != 0%]* Do not impact your employees' ability to work remotely
- *[Display if Q13A = "Yes"]* Do not impact the other locations mentioned previously.

For each scenario, we first ask how your facility would respond to the outage. Second, we ask you to estimate any financial impact your facility would experience due to the outage. Following these three short-duration outage scenarios, we will ask a brief series of questions in a fourth scenario regarding how your organization may respond to a hypothetical long-duration outage scenario.

There are no right or wrong answers to these questions. Please respond based on your personal experience and the current circumstances facing your organization. We simply want your best estimate.

You will estimate the additional costs your organization would experience for each of the scenarios in the table below. Please answer all questions about the potential impact of these power outage scenarios at your facility only *[Display if Q14 = "Yes" OR Q16 = "Yes"]* (not other locations or facilities where your organization operates).

Scenario	Season	Time of Week	Start Time	End Time	Duration
A	Summer	Weekday	<i>[AStart]</i>	<i>[AEnd]</i>	<i>[ADuration]</i>
B	Summer	Weekday	<i>[BStart]</i>	<i>[BEnd]</i>	<i>[BDuration]</i>
C	Summer	Weekday	<i>[CStart]</i>	<i>[CEnd]</i>	<i>[CDuration]</i>
D	<i>[DSeason]</i>	-	-	-	3 days

[Display if (Q11A = "Solar PV" OR Q12A = "Solar PV") AND (Q11A != "Battery storage" AND Q12A != "Battery storage")] **Note: If you have solar PV panels installed**

without a battery storage system, your organization will still experience the power outage and your solar PV system will not feed electricity into the grid.

Scenario A

Season	Day of Week	Start Time	End Time	Duration
Summer	Weekday	[AStart]	[AEnd]	[ADuration]

A1. Without any warning, on a typical summer weekday, a complete power outage occurs at **[AStart]**. Assume that this outage is:

Appendix J. Local to your facility at **[INSERT SERVICE ADDRESS]**

Appendix K. *[Display if Q13 != 0%]* Does not impact your employees' ability to work remotely

Appendix L. *[Display if Q13A = "Yes"]* Does not impact any other facilities owned by your company.

[Display all] You don't know how long it will last, but your facility's electricity is fully restored in **[ADuration]**.

On a scale from 1 to 5, how disruptive would this **[ADuration]** power outage be to your organization, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

- ☐ 1 - Not disruptive
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 - Very disruptive

A2. Would your operations or services typically stop or slow down as a result of this power outage?

- ☐ Yes
- ☐ No

→ A2A. *[Display if A2 = "Yes"]* Please estimate how long operations or services would stop or slow down resulting from a power outage of this length (include time during and after the power outage).

[Display if ADuration = "5 minutes or less" OR Q11 = "Yes"]

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 2 hours

[Display if ADuration = "5 minutes or less" or "2 hours" OR Q11 = "Yes"]

- ☐ 2 hours to less than 8 hours

[Display if ADuration = "5 minutes or less", "2 hours", or "8 hours" OR Q11 = "Yes"]

- ☐ 8 hours to less than 24 hours

[Display all]

- ☐ 24 hours to less than 3 days
- ☐ 3 days or more
- ☐ Other _____

A3. What is the approximate dollar value of the operations or services that typically would be lost, at least temporarily, during the power outage and any slow period after the power outage? Please make your best estimate.

\$ _____ value of lost work or services

[Display if A3 NOT = 0]

A4. What percentage of the operations or services lost would typically be made up, either at this facility at **[INSERT SERVICE ADDRESS]** after the power outage, or by another facility operated by your organization?

- ☐ 0%
- ☐ 1-25%
- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-99%
- ☐ 100%

[Assign A4 value as the midpoint of the selected range: If the respondent chooses "1-25%" then $A4 = 13\%$; "26-50%" = 38%, etc. If $A4 = 0\%$ or 100%, store that direct value.]

A5. Would there be any **incremental or additional labor costs** associated with this power outage such as salaries and wages for staff needed to deal with any **outage-related issues** or overtime pay to make up for operations or services?

☐ Yes

☐ No

→ A5A. [Display if A5 = "Yes"] Please estimate the value for each of the following.

\$ _____ overtime/extra shifts to make up lost output [A5A1]

\$ _____ extra labor costs to restart activities [A5A2]

\$ _____ other labor-related costs [A5A3]

A6. Would there be any **damage costs** associated with this power outage such as damage to equipment, materials, or cost to dispose of hazardous materials?

☐ Yes

☐ No

→ A6A. [Display if A6 = "Yes"] Please estimate the value for each of the following.

\$ _____ damage to equipment [A6A1]

\$ _____ damage/spoilage to materials [A6A2]

\$ _____ cost of disposing hazardous materials [A6A3]

A7. Would there be any other **material or fuel costs** associated with this power outage (such as fuel to run a backup generator)?

☐ Yes

☐ No

→ A7A. [Display if A7 = "Yes"] Please estimate any other materials or fuel costs.

\$ _____ other materials [A7A1]

\$ _____ fuel to run a backup generator [A7A2]

A8. Would there be other **any other tangible costs** associated with this power outage (such as extra restart costs)?

- ☐ Yes
- ☐ No

└─→ A8A. [Display if A8 = "Yes"] Please estimate the other costs associated with this power outage.

\$ _____ other tangible costs

A9. [Display if A9 = "Yes"] Would you be able to **recoup any costs** by scrapping the damaged products or materials?

- ☐ Yes
- ☐ No

└─→ A9A. [Display if A9 = "Yes"] Please estimate the value recouped.

\$ _____ scrap value of damaged products or inputs

A10. In addition to the costs discussed above, some organizations may avoid expenses because of electrical outages. Some examples include a lower electricity bill, lower material outlays, and lower personnel costs. Would you experience any **savings** associated with this power outage?

- ☐ Yes
- ☐ No

└─→ A10A. [Display if A10 = "Yes"] Please estimate the savings for each of the following.

\$ _____ savings from wages that were not paid [A10A2]

\$ _____ savings from unused raw and intermediate materials (except fuel) [A10A3]

\$ _____ savings on your firm's fuel or electricity bill [A10A4]

Instructions for the interviewer: The table below summarizes the respondent's responses to the previous questions and sums the costs into a total value. If this is a

phone interview and the respondent cannot see, recap each item in this table to the interviewee and allow them to change their answers if they wish to do so.

Here is a recap of the costs associated with this [ADuration] outage:

Category	Costs Due to Outage
Operations and Services Lost (minus revenue made up afterwards)	\$ <i>[Display A3 * (1-A4)]</i>
Overtime/Extra Shifts to Make Up for Lost Time	\$ <i>[Display A5A1]</i>
Extra Labor Costs to Restart Activities	\$ <i>[Display A5A2]</i>
Other Labor-Related Costs	\$ <i>[Display A5A3]</i>
Damage to Equipment	\$ <i>[Display A6A1]</i>
Damage/Spoilage to Materials	\$ <i>[Display A6A2]</i>
Cost of Disposing Hazardous Materials	\$ <i>[Display A6A3]</i>
Additional Materials	\$ <i>[Display A7A1]</i>
Fuel Cost to Run Backup Generator	\$ <i>[Display A7A2]</i>
Other Tangible Costs	\$ <i>[Display A8A]</i>
Subtotal:	\$ <i>[Display Subtotal]</i> [ASUB]
Scrap Value of Damaged Products or Input	\$ <i>[Display A9A]</i>
Savings on Wages	\$ <i>[Display A10A2]</i>
Savings from Unused Materials (Except Fuel)	\$ <i>[Display A10A3]</i>

Savings on Fuel/Electricity	\$ [Display A10A4]
TOTAL:	\$ [Display TOTAL] [ATOTAL]

A11. Based on your responses to the prior questions, we estimate that your most likely total for this **[ADuration]** outage is **[ATOTAL]**. Does this sound correct?

- ☐ Yes
☐ No

→ A11A. [Display if A11 = "No"] What do you think your most likely total cost is?

\$ _____ total cost [Replace ATOTAL]

A12. Keeping this most likely total in mind for a **[ADuration]** outage, please estimate the total costs you would incur for a **best-case** (lowest-cost) scenario and the costs for a **worst-case** (highest-cost) scenario.

\$ _____ [A12A]	\$ [Display ATOTAL]	\$ _____ [A12B]
Lowest Total Outage Cost	Most Likely Total Outage Cost	Highest Total Outage Cost

A13. [Display if Group = 1 OR Group = 3, alter Scenario box to show Season as "Winter" instead of "Summer" and **bold** or **highlight** the change] Suppose the power outage occurred in the winter rather than the summer. Think about how circumstances might change at your facility. If your total cost for a **[ADuration]** power outage in the summer is approximately **[ATOTAL]**, what do you think your total cost would be for a **[ADuration]** outage in the winter?

[Display if Group = 2, alter Scenario box to show Day of Week as "Weekend" instead of "Weekday" and **bold** or **highlight** the change] Suppose the power outage occurred on a weekend rather than a weekday. Think about how circumstances might change at your facility. If your total cost for a **[ADuration]** power outage on a weekday is approximately **[ATOTAL]**, what do you think your total cost would be for a **[ADuration]** outage on the weekend?

\$ _____ total cost

A14. *[Display if Group = 2 & Q9 = “Advance warning would not reduce the costs caused by a power outage”, alter Scenario box to show Season as “Winter” instead of “Summer” and **bold** or **highlight** the change]* Suppose the power outage occurred on a winter weekday rather than in the summer. Think about how circumstances might change at your facility. If your total cost for a **[ADuration]** power outage in the summer is approximately **[ATOTAL]**, what do you think your total cost would be for a **[ADuration]** outage in the winter?

*[Display if Group = 1 OR (Group = 3 & Q9 = “Advance warning would not reduce the costs caused by a power outage”), alter Scenario box to show Day of Week as “Weekend” instead of “Weekday” and **bold** or **highlight** the change]* Suppose the power outage occurred on a summer weekend rather than a weekday. Think about how circumstances might change at your facility. If your total cost for a **[ADuration]** power outage on a weekday is approximately **[ATOTAL]**, what do you think your total cost would be for a **[ADuration]** outage on the weekend?

[Display if (Group = 2 OR Group = 3) & Q9 != “Advance warning would not reduce the costs caused by a power outage”] Suppose your utility notified your organization of the power outage [Q9] before it occurred on a summer weekday. Think about how being able to prepare might change circumstances at your facility. If your total cost for a **[ADuration]** power outage is approximately **[ATOTAL]**, what do you think your total cost would be for a **[ADuration]** outage if you received advance notice?

\$ _____ total cost

Scenario B

Season	Day of Week	Start Time	End Time	Duration
Summer	Weekday	[BStart]	[BEnd]	[BDuration]

B1. Without any warning, on a typical summer weekday, a complete power outage occurs at **[BStart]**. Assume that this outage is:

Appendix M. Local to your facility at [INSERT SERVICE ADDRESS]

Appendix N. [Display if Q13 != 0%] Does not impact your employees' ability to work remotely

Appendix O. [Display if Q13A = "Yes] Does not impact any other facilities owned by your company.

[Display all] You don't know how long it will last, but your facility's electricity is fully restored in **[BDuration]**.

On a scale from 1 to 5, how disruptive would this **[BDuration]** power outage be to your organization, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

- ☐ 1 - Not disruptive
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 - Very disruptive

B2. Would your operations or services typically stop or slow down as a result of this power outage?

- ☐ Yes
- ☐ No

→ B2A. *[Display if B2 = "Yes"]* Please estimate the number of hours that operations or services would stop or slow down resulting from a power outage of this length (include time during and after the power outage).

[Display if BDuration = "5 minutes or less" OR Q11 = "Yes"]]

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 2 hours

[Display if BDuration = "5 minutes or less" or "2 hours" OR Q11 = "Yes"]]

- ☐ 2 hours to less than 8 hours

[Display if BDuration = "5 minutes or less", "2 hours", or "8 hours" OR Q11 = "Yes"]]

- ☐ 8 hours to less than 24 hours

[Display all]

- ☐ 24 hours to less than 3 days
- ☐ 3 days or more
- ☐ Other _____

Instructions for the interviewer: The table below summarizes the respondent's total cost estimates for the previous scenarios. Recap each scenario's total cost so they can use it as a reference point when answering the following questions.

Here is a recap of the outage costs you have estimated so far. If applicable, use these estimates as a reference when answering the following questions.

Scenario	Season	Time of Week	Start Time	Duration	Outage Cost
A	Summer	Weekday	[AStart]	[ADuration]	\$(ATOTAL)

B3. What do you think your most likely total cost would be for a **[BDuration]** outage occurring on a summer weekday?

\$ _____ total cost

B4. Keeping this most likely total in mind for a **[BDuration]** outage, please estimate the total costs you would incur for a **best-case** (lowest-cost) scenario and the costs for a **worst-case** (highest-cost) scenario.

\$ _____ [B4A]	\$ [Display B3]	\$ _____ [B4B]
Lowest Total Outage Cost	Most Likely Total Outage Cost	Highest Total Outage Cost

B5. *[Display if Group = 1 OR Group = 3, alter Scenario box to show Season as “Winter” instead of “Summer” and **bold** or **highlight** the change]* Suppose the power outage occurred in the winter rather than the summer. Think about how circumstances might change at your facility. If your total cost for a **[BDuration]** power outage in the summer is approximately **[B3]**, what do you think your total cost would be for a **[BDuration]** outage in the winter?

*[Display if Group = 2, alter Scenario box to show Day of Week as “Weekend” instead of “Weekday” and **bold** or **highlight** the change]* Suppose the power outage occurred on a weekend rather than a weekday. Think about how circumstances might change at your facility. If your total cost for a **[BDuration]** power outage on a weekday is approximately **[B3]**, what do you think your total cost would be for a **[BDuration]** outage on the weekend?

\$ _____ total cost

B6. *[Display if Group = 2 & Q9 = “Advance warning would not reduce the costs caused by a power outage”, alter Scenario box to show Season as “Winter” instead of “Summer” and **bold** or **highlight** the change]* Suppose the power outage occurred on a winter weekday rather than in the summer. Think about how circumstances might change at your facility. If your total cost for a **[BDuration]** power outage in the summer is approximately **[B3]**, what do you think your total cost would be for a **[BDuration]** outage in the winter?

*[Display if Group = 1 OR (Group = 3 & Q9 = “Advance warning would not reduce the costs caused by a power outage”), alter Scenario box to show Day of Week as “Weekend” instead of “Weekday” and **bold** or **highlight** the change]* Suppose the power outage occurred on a summer weekend rather than a weekday. Think about how circumstances might change at your facility. If your total cost for a **[BDuration]** power outage on a weekday is approximately **[B3]**, what do you think your total cost would be for a **[BDuration]** outage on the weekend?

[Display if (Group = 2 OR Group = 3) & Q9 != “Advance warning would not reduce the costs caused by a power outage”] Suppose your utility notified your organization of the power outage **[Q9] before it occurred on a summer weekday**. Think about how being able to prepare might change circumstances at your facility. If your total cost for a **[BDuration]** power outage is approximately **[B3]**, what do you think your total cost would be for a **[BDuration]** outage if you received **advance notice**?

\$ _____ total cost

Scenario C

Day of Week	Start Time	End Time	Duration
Weekday	[CStart]	[CEnd]	[CDuration]

C1. Without any warning, on a typical summer weekday, a complete power outage occurs at **[CStart]**. Assume that this outage is:

Appendix P. Local to your facility at [INSERT SERVICE ADDRESS]

Appendix Q. [Display if Q13 != 0%] Does not impact your employees' ability to work remotely

Appendix R. [Display if Q13A = "Yes] Does not impact any other facilities owned by your company.

[Display all] You don't know how long it will last, but your facility's electricity is fully restored in **[CDuration]**.

On a scale from 1 to 5, how disruptive would this **[CDuration]** power outage be to your organization, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

- ☐ 1 - Not disruptive
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 - Very disruptive

C2. Would your operations or services typically stop or slow down as a result of this power outage?

- ☐ Yes
- ☐ No

→ C2A. *[Display if C2 = "Yes"]* Please estimate the number of hours that operations or services would stop or slow down resulting from a power outage of this length (include time during and after the power outage).

[Display if CDuration = "5 minutes or less" OR Q11 = "Yes"]]

- ☐ 5 minutes or less
- ☐ Greater than 5 minutes to less than 2 hours

[Display if CDuration = "5 minutes or less" or "2 hours" OR Q11 = "Yes"]]

- ☐ 2 hours to less than 8 hours

[Display if CDuration = "5 minutes or less", "2 hours", or "8 hours" OR Q11 = "Yes"]]

- ☐ 8 hours to less than 24 hours

[Display all]

- ☐ 24 hours to less than 3 days
- ☐ 3 days or more
- ☐ Other _____

Instructions for the interviewer: The table below summarizes the respondent's total cost estimates for the previous scenarios. Recap each scenario's total cost so they can use it as a reference point when answering the following questions.

Here is a recap of the outage costs you have estimated so far. If applicable, use these estimates as a reference when answering the following questions.

Scenario	Season	Time of Week	Start Time	Duration	Outage Cost
A	Summer	Weekday	[AStart]	[ADuration]	\$(ATOTAL)
B	Summer	Weekday	[BStart]	[BDuration]	\$(B3)

C3. What do you think your most likely total cost would be for a **[CDuration]** outage occurring on a summer weekday?

\$ _____ total cost

C4. Keeping this most likely total in mind for a **[CDuration]** outage, please estimate the total costs you would incur for a **best-case** (lowest-cost) scenario and the costs for a **worst-case** (highest-cost) scenario.

\$ _____ [C4A]	\$ [Display C3]	\$ _____ [C4B]
Lowest Total Outage Cost	Most Likely Total Outage Cost	Highest Total Outage Cost

C5. *[Display if Group = 1 OR Group = 3, alter Scenario box to show Season as “Winter” instead of “Summer” and **bold** or **highlight** the change]* Suppose the power outage occurred in the winter rather than the summer. Think about how circumstances might change at your facility. If your total cost for a **[CDuration]** power outage in the summer is approximately **[C3]**, what do you think your total cost would be for a **[CDuration]** outage in the winter?

*[Display if Group = 2, alter Scenario box to show Day of Week as “Weekend” instead of “Weekday” and **bold** or **highlight** the change]* Suppose the power outage occurred on a weekend rather than a weekday. Think about how circumstances might change at your facility. If your total cost for a **[CDuration]** power outage on a weekday is approximately **[C3]**, what do you think your total cost would be for a **[CDuration]** outage on the weekend?

\$ _____ total cost

C6. *[Display if Group = 2 & Q9 = “Advance warning would not reduce the costs caused by a power outage”, alter Scenario box to show Season as “Winter” instead of “Summer” and **bold or highlight** the change]* Suppose the power outage occurred on a winter weekday rather than in the summer. Think about how circumstances might change at your facility. If your total cost for a **[CDuration]** power outage in the summer is approximately **[C3]**, what do you think your total cost would be for a **[CDuration]** outage in the winter?

*[Display if Group = 1 OR (Group = 3 & Q9 = “Advance warning would not reduce the costs caused by a power outage”), alter Scenario box to show Day of Week as “Weekend” instead of “Weekday” and **bold or highlight** the change]* Suppose the power outage occurred on a summer weekend rather than a weekday. Think about how circumstances might change at your facility. If your total cost for a **[CDuration]** power outage on a weekday is approximately **[C3]**, what do you think your total cost would be for a **[CDuration]** outage on the weekend?

[Display if (Group = 2 OR Group = 3) & Q9 != “Advance warning would not reduce the costs caused by a power outage”] Suppose your utility notified your organization of the power outage [Q9] before it occurred on a summer weekday. Think about how being able to prepare might change circumstances at your facility. If your total cost for a **[CDuration]** power outage is approximately **[C3]**, what do you think your total cost would be for a **[CDuration]** outage if you received advance notice?

\$ _____ total cost

Scenario D

For the next series of questions, we would like to ask what your organization would do if there was a longer-lasting power outage.

[Display if DSeason = "Summer"] Assume that a severe summer windstorm impacted your area. *[Display if DSeason = "Winter"]* Assume that a severe winter windstorm impacted your area. *[Display all]* As a result, a number of power lines were damaged and the power is out in a 20-mile radius around your facility. Fortunately, you still have cellular service. Your electric utility has indicated that it might take up to three days (72 hours) to restore power.

D2. If you are a for-profit organization, what is your approximate annual revenue?

\$ _____

☐ Not applicable

If you are a **non-profit** or government organization, what is your approximate annual operating budget?

\$ _____

☐ Not applicable

D3. Please think about the revenue or business value of the operations or services that typically would be over an average three-day period during the *[DSeason]*. What percentage of this revenue would you lose during this three-day power outage?

☐ 0%

☐ 1-25%

☐ 26-50%

☐ 51-75%

☐ 76-99%

☐ 100%

D4. *[Display if D2 = "For profit"]* You indicated that a *[max of ADuration, BDuration, or CDuration]* long power outage would most likely cost *[max of ATotal, B3, or C3]*.

If you are a for-profit organization, besides lost revenue, how much do you estimate that a three-day (72 hour) power outage would cost your organization (e.g., overtime

labor, cost to restore operations to normal, lost inventory, backup generator fuel costs)?

72-hour outage cost: \$_____

☐ Not applicable

[Insert additional questions, if any, provided by the utility here]

Q17. Please share any additional comments:

Thank you for participating in this valuable study. Your responses will be used to better understand how electricity outages affect customers.



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