Elicitation of Electric Utility Customer Power Interruption Costs

A Roadmap for Conducting a National Survey

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Acronyms and Abbreviations

C&I	Commercial & Industrial
CDF	Customer Damage Function
CE	Choice Experiment
CGE	Computable General Equilibrium
CIC	Customer Interruption Cost
CV	Contingent Valuation
DBDC	Double Bounded Discrete Choice
DCE	Discrete Choice Experiment
DOE	Department of Energy
EIA	Energy Information Administration
GLM	Generalized Linear Model
ICE	Interruption Cost Estimation
I-O	Input-Output
IRC	Interruption-Related Costs
IRS	Interruption-Related Savings
LBNL	Lawrence Berkeley National Laboratory
LDW	Long-Duration, Widespread
LNR	Large Non-Residential
MBDC	Multiple Bounded Discrete Choice
MLE	Maximum Likelihood Estimation
MTurk	Amazon Mechanical Turk
NOAA	National Oceanic and Atmospheric Administration
OHDC	One-and-a-Half Bound Discrete Choice
OLS	Ordinary Least Squares
PCM	Payment Card Method
PEV	Plug-in Electric Vehicle
REM	Regional Economic Model
SBDC	Single Bound Discrete Choice
SMNR	Small and Medium Non-Residential
SPC	Stochastic Payment Card
USPS	United States Postal Service
VLP	Value of Lost Production
VOS	Value of Service
WTP	Willingness to Pay

Executive Summary

This document provides a "Roadmap" for conducting a national study of electricity customer interruption costs (CICs). Utilities use CICs to identify economically efficient strategies for which the cost of improving reliability (resilience) is less than or equal to the benefit customers receive from the improvement. One option for utilities to obtain CICs is to use the online Interruption Cost Estimate Calculator ("ICE Calculator") to estimate them. The ICE Calculator is a free, web-based tool which draws from the results of 34 previous interruption cost studies to provide CICs for reliability planning. However, the ICE Calculator relies on older studies and has geographical gaps where no interruption cost studies have been conducted. The ICE Calculator is also limited in that it can only estimate economic impacts for interruptions lasting sixteen hours or less. The proposed national study is intended to fill the existing gaps in the ICE Calculator meta-database by obtaining CICs for regions that are not well represented in the existing database, including the Northeastern U.S., and updating CIC estimates for all regions. It is also intended to advance the field of interruption cost estimation by refining and further developing methods—on a national scale—to:

- Elicit residential customer willingness to pay (WTP) to avoid both short- and long-duration outages
- Measure direct costs of residential and non-residential customers for long-duration outages
- Improve regional economic models of long-duration power outages by using surveys to collect model parameters from non-residential customers.

This Roadmap describes the work that will be necessary to undertake a national interruption cost study for each of four customer market segments—residential customers, small and medium non-residential customers, large commercial and industrial customers, and commercial occupants of high rise buildings. Each study will comprise a set of pre-tests followed by a full-scale national study. The pre-tests are designed to refine survey instruments and ensure that implementation protocols will yield acceptable response rates and reduce the potential for bias for each customer segment.

Table ES-1 summarizes the sample designs for each phase of the study. The residential study has an extensive set of pre-tests, testing elicitation methods using both WTP and direct cost. The pre-tests will include cognitive testing as well as small-scale tests designed to ensure validity and reliability of outage descriptions and survey questions. The full-scale residential study will include completed interviews for 4,500 households from a curated national survey panel. The small and medium non-residential study (SMNR) phase will also include cognitive and other small-scale tests, but will focus primarily on ensuring that an adequate response rate is obtained from this customer segment. The full-scale SMNR study consists of 5,000 customer responses sampled from utilities who agree to participate in the study via a partnership arrangement. The large, non-residential (LNR) phase utilizes in-person interviewers and will have a scaled-down pre-test, as many of the issues with the survey instrument would likely be identified in the SMNR pre-test and could be revised and refined prior to the LNR study. The full-scale LNR study will use a sample of 1,000 customer facilities sampled from participating utilities. The final phase of the study is for master-metered customers and would utilize data from customers identified as having a master meter in the SMNR and LNR phases of the study. Sample size and design for this phase would be determined after master-metered customers were identified.

Table ES-1. Study Design Summary

Customer Class	Test Description	Test Type	Purpose	Scale
Residential	Outage scenario and solution descriptions	Cognitive testing	Understand scenario descriptions	Several rounds of 10-15 interviews
		Small-scale testing	Determine important contextual factors	270 in region-specific blocks of 30
			Understand scenarios	120 short duration; blocks of 30
				120 long duration; blocks of 30
				120 combination of short and long; blocks of 30
			Understand solutions	Three rounds of 10-15 interviews
				120 - blocks of 30
	Assessing customer actions in response to outages and their direct costs	Cognitive testing	Understand questions	Three rounds of 10-15 interviews
		Usability testing	Easily estimate outage costs	120 in three waves
	Eliciting WTP	SBDC exercise	Set WTP range for full-scale study	200
	Formal pre-test	Final pre-test of instrument	Completed in less than 30 minutes and no sequence effects	Three waves of 120
	Full-scale study			**4,500**
Small/medium non-residential	Outage scenario descriptions	Cognitive testing	Understand scenario descriptions	Several rounds of 10-15
		Small-scale testing	Understand scenarios	120 for short duration direct cost
				120 for long duration direct cost
				120 for combo of short duration direct cost and long duration elasticities
	Elicitation questions	Small-scale testing	Understand survey questions	120 - blocks of 30
	Response rate	Cognitive testing	Reason for not completing survey	Several rounds of 10-15 interviews
		Small-scale testing	Ensure adequate response rate	120 for survey length (60 shorter surveys / 60 standard length surveys)
				120 for delivery method (60 via telephone / 60 via email link)
				300 for incentive level (100 each at $75, $150, $200)

Customer Class	Test Description	Test Type	Purpose	Scale
	Formal pre-test	Final pre-test of instrument	Response rate and implementation protocols	200
	Full-scale study			**5,000**
Large non-residential	Outage scenario descriptions	Cognitive testing	Understand questions	50
	Formal pre-test	Final pre-test of instrument	Response rate and implementation protocols	25
	Full-scale study			1,000
Master-metered	Pre-test	Final pre-test of instrument	Response rate and implementation protocols	TBD
	Full-scale study			**TBD**

This Roadmap proposes to solicit utilities in each region to join a 'National Study Partnership' to implement the non-residential components of the study. Participating utilities would assist with various components of the study including cost-sharing, access to data, branding, and leveraging customer relationships. This assistance would help the study team with sample design and customer recruitment. In return for their assistance, participating utilities would receive a report describing the results of the survey for their customers as well as the interruption cost estimates provided by their customers who completed the survey.

A typical VOS study for one utility service territory could cost a utility between $750,000 and $1 million[1]. A budget for a national study would have to be determined during an actual study scoping process. The costs should cover the expenses for study management (including sample design, survey instrument design, analysis, and reporting), as well as survey implementation and incentives for customers who complete the survey. The output from the study will include a number of metrics to characterize interruption costs for each customer class as well as system-wide values weighted by the proportion of each customer class in each region. The metrics will cover outage durations ranging from five minutes to two weeks and will include cost per event, cost per average kW, cost per unserved kWh, and cost per customer minute interrupted. The output will also include results of customer damage function modeling, which will relate certain characteristics of the customers, interruptions, and the environment to the cost of the interruption. These models will be incorporated into the online ICE Calculator, which is a free, online tool for utility planners, or a separate tool as determined by the study team. Upon completion of the study, utility planners and researchers will have access to region-specific CIC estimates for the entire U.S. for both short and long-duration interruptions.

[1] Range comes from the authors' experience conducting CIC studies and judgement regarding costs for a typical study.

1. Introduction

Utilities must balance the economic costs of their investments against the economic value that customers receive from those investments—i.e., the value of service (VOS) created. If spending on reliability and/or resilience exceeds the economic impacts that are avoided by these investments, the cost (and price) of electricity will increase unnecessarily. Conversely, if utilities invest too little on reliability and/or resilience, customers will experience expensive and unnecessary interruption costs and inconvenience that could have been avoided. Achieving an appropriate balance between investment cost and customer interruption costs (CICs) is becoming an increasingly important challenge for utilities and their customers as the population grows increasingly dependent on electricity, increasing threats to reliability and resilience (e.g., extreme weather events, cybersecurity vulnerabilities) are emerging and distributed energy resources are becoming more available. For this reason, the need for valid and reliable measurements of customer VOS has increased dramatically.

VOS is the economic value that customers receive from reliability or resilience. It is expressed in a variety of ways, such as $/unserved kWh or $/customer-minute interrupted. These types of VOS measures are often expressed as averages or sums across all customers in a given utility. Underlying these aggregate values are the VOS quantities for each customer. The value that customers place on service varies considerably by customer type, as certain customers have higher VOS than others. For example, a residential customer may not incur significant costs or be inconvenienced by frequent, short duration interruptions, while a large industrial customer may incur substantial costs from loss of production from even a single momentary outage. VOS also varies among customers even within the same customer class. A stay-at-home parent may have a very different VOS than a day trader operating out of his/her home. These examples could all be located on the same circuit within a utility's service territory—and there is a wide variation in VOS across circuits. Utilities thus have significant opportunities to optimize investments by targeting high-value circuits, or circuits with high costs of unreliability.

Utilities have been conducting CIC[2] studies for decades to measure their customers' VOS and obtain data for performing value-based reliability planning exercises. The U.S. Department of Energy (DOE), Lawrence Berkeley National Laboratory (LBNL), and Nexant[3] have been working together for over fifteen years to help utilities determine CICs for planning purposes. Part of this effort has focused on analyzing data from existing CIC studies and organizing the results into a usable format and meta-database for utilities and other stakeholders seeking to develop outage cost estimates. This meta-database became the basis for the ICE[4] Calculator in 2011, which is a free, web-based, interactive tool for estimating interruption costs[5]. The meta-analysis was updated in 2015 with data from several more recent studies and the team made subsequent improvements to the ICE Calculator. It now contains CIC

[2] The term "customer interruption cost" is used interchangeably with "value of service"
[3] Formerly Freeman, Sullivan & Co.
[4] Interruption Cost Estimate
[5] See https://icecalculator.com/home

data from 34 studies (total of 105,000 customer surveys) completed by 10 utilities between 1989 and 2012.

The ICE Calculator is a useful tool, but it has certain limitations. The Northeast U.S. is not well represented in the underlying meta-database, because no utilities in that region have undertaken recent outage cost studies. In addition, the outage cost surveys in the underlying meta-database were conducted sporadically across different utility service territories over a 20-year period, so it is impossible to separate the impacts of time and geography on interruption costs. Because many of the outage cost surveys in the database are over 20 years old, it is likely that many of the outage cost estimates are out of date. The ICE Calculator is also limited in that it can only estimate economic impacts for interruptions lasting sixteen hours or less. As described in Section 3.1.1 of this Roadmap, CICs are believed to fundamentally change for longer-duration outages. For this reason, attempts to extrapolate short-duration CICs to long-duration CICs is not advised by the LBNL/Nexant team.

Despite these limitations, there is a significant need for interruption cost estimates in utility planning and utilities are increasingly using CIC data to estimate interruption costs. Utilities are also increasingly interested in obtaining interruption cost estimates for longer-duration outages for purposes of evaluating proposed investments in resilient infrastructure. This interest is spurred by an increasing awareness of the frequency and cost of catastrophic events in recent years (e.g., wind, fire, flooding, terrorism), which can cause damage to utility infrastructure and result in outages that can last for days or weeks. These events can cause widespread economic damage across multiple sectors of the economy, including significant indirect costs that extend to areas not directly affected by the outage. According to the National Oceanic and Atmospheric Administration (NOAA), the U.S. experienced sixteen extreme weather events in 2017 with damages each exceeding $1 billion. The combined cost of these sixteen events was over $300 billion (NCEI, 2018).[6] Furthermore, these events are not confined to a specific geographic area or type of disaster (see Figure 1-1), resulting in the resilience of the electric system becoming a significant policy issue throughout the country.

[6] Most of the costs were due to Hurricanes Harvey, Irma, and Maria.

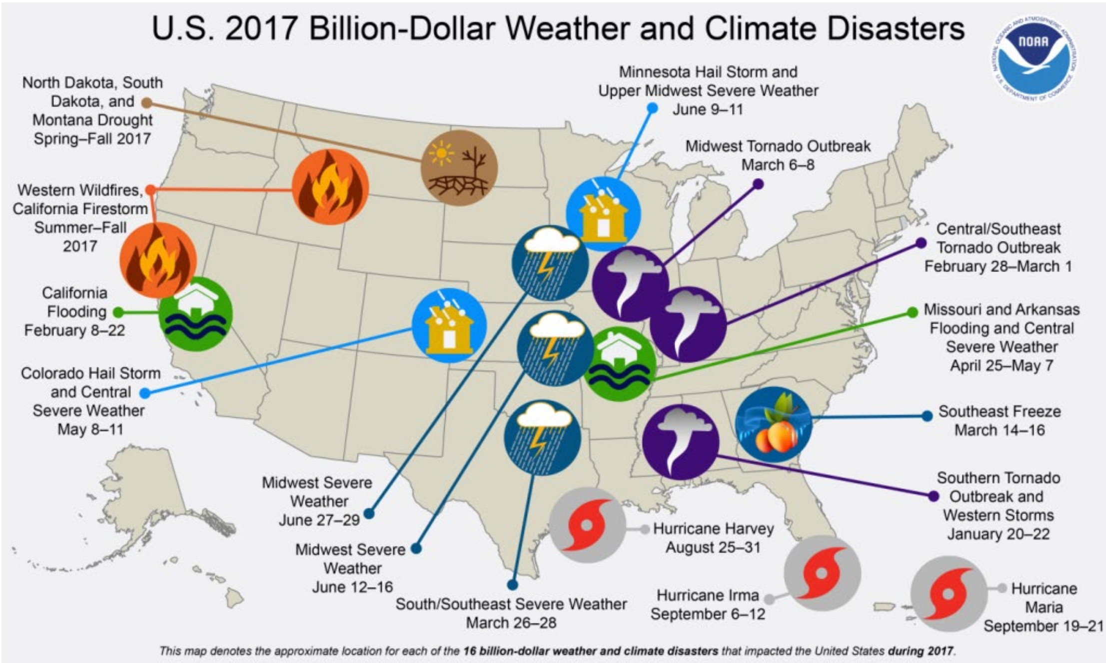

Figure 1-1. U.S. 2017 Billion-Dollar Weather and Climate Disasters (from NCEI, 2018)

This study is intended to fill the existing gaps in the ICE Calculator meta-database by obtaining CICs for regions that are not well represented in the existing database, including the Northeastern U.S., and by bringing CIC estimates for all regions up to date. It is also intended to advance the field of interruption cost estimation by refining and further developing methods on a national scale to:

- Elicit residential customer willingness to pay (WTP) to avoid both short- and long-duration outages
- Measure direct costs of residential and non-residential customers for long-duration outages
- Improve regional economic models of long-duration power outages by using surveys to collect model parameters from non-residential customers.

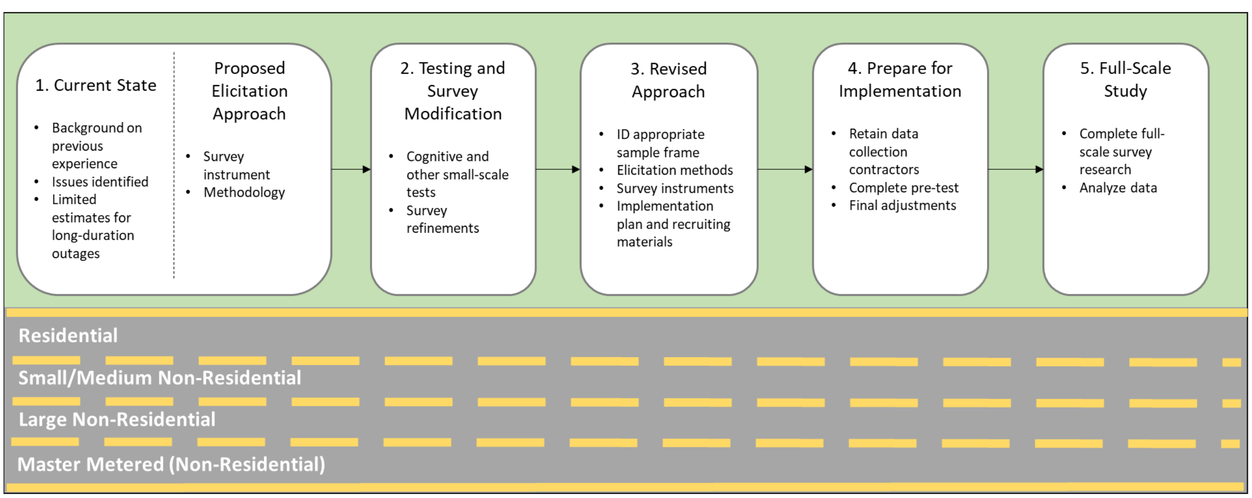

Figure 1-2. Flow Diagram of National Interruption Cost Study

This Roadmap details a plan for undertaking a national study of CICs. It proposes to complete the study for four types of customers, which could be done sequentially or concurrently. Figure 1-2 illustrates the overall plan for the study. It shows an overview of the steps required to go from the current state to an end state where we have obtained CICs from a successful study. The four customer market segments—residential, small/medium non-residential, large non-residential, and master-metered—are shown in lanes at the bottom of the figure. For each customer class, the first point on the Roadmap is an explanation of the current state of the CIC estimation, including any key gaps related to data or methodology. It also proposes an elicitation approach with which to begin a rigorous testing and refinement process. Survey instruments from previous studies have been modified, and can be tested and further refined. This testing and modification process is reflected in the second numbered point in the figure.

The third point in the Roadmap for each lane, as shown in Figure 1-2, is the completed development of the "Revised Approach." This includes completion of all survey design work including: identification of an appropriate sampling frame, exact specification of the elicitation method(s) to be used in surveying, exact specification of the materials to be used in recruiting respondents to the survey, and identification of statistical and econometric procedures to be used in analyzing the survey data. To reach this milestone, sufficient small scale testing must be completed to identify a single survey design that is judged to produce reliable and valid measurements of CICs for customers in each geographical region of the U.S. (described later). The survey designs will likely be completed by one or more contractors qualified to complete the design work for each market segment. The contractors will identify survey and sampling protocols in sufficient detail to allow procurement of survey administration services to be delivered by qualified survey companies. Based on the current state of the art in design in each of the market segments, it is expected that the commercial and industrial customer surveys will reach this point on the Roadmap relatively quickly, while it may take some time to more thoroughly test the proposed elicitation method of the residential market segment. For this reason, it is likely that delivery of the results from the residential lane will lag delivery of results from the other market segments by as much as a year.

The fourth point on the Roadmap starts the process of preparing for survey implementation. It covers the steps that the study team, survey administrators, utilities, and interviewers take to prepare for the launch of the study. To complete this step, it will be necessary to identify and contract with one or more qualified data collection contractors, complete final pre-tests of the survey instruments and other materials to be used in studying the market and make any necessary adjustments to forms and protocols the survey administration contractor views as necessary to complete the project. To reach the fifth and final milestone, the survey administration contractor(s) will complete full scale survey research and analyze the data. The full-scale study for each customer class includes a pre-test, which would be a full implementation test on a sample of 200 as a final test of protocols and readiness and to identify any potential pitfalls in the implementation process.

Sections 2 through 5 of this Roadmap cover the elements of the national study for each customer class: residential (Section 2), small/medium non-residential (SMNR) (Section 3), large non-residential (LNR)

(Section 4) and master-metered (Section 5). The Roadmap calls for implementing the residential phase first, followed by SMNR second, LNR third, and master-metered customers fourth. This ordering reflects the initial availability of study funds as discussed preliminarily with DOE—and the preference to undertake the least expensive component of the study first. The residential segment would be the least expensive to survey using the procedure outlined herein. The non-residential segments involve working with utilities and using more hands-on methods for recruiting customers and administering the survey (particularly for large customers). These segments will be more expensive to implement. Ordering of the study phases can easily be modified to reflect changes in priorities or available funding.

Throughout this Roadmap, the authors use several terms to describe four distinct entities which would be working to implement this study:

- Study team: led by third party study managers and consisting of stakeholders from DOE, LBNL, subject matter experts, and representatives from participating utilities. The study team will have the responsibility of coordinating the activities of the study and making decisions related to design and implementation. The core study team (study managers and LBNL) will engage other parts of the broader team when needed for specific advice, assistance, and decision-making.
- Survey panel administrators: the curators of the nation-wide survey panel, which the study team would engage for the residential phase of the study.
- Survey administrators: third party survey labs—separate from the study managers—with the additional capabilities of hosting on-line surveys, printing, mailing, and emailing in bulk. They would print and mail letters, survey packages, and incentive checks, email recruitment materials, call non-residential customers to recruit them for the study, staff an incoming phone line to receive calls regarding the survey instrument or study in general, program the survey instrument into a web-based tool, receive completed surveys in the mail and enter data, and provide survey data files in electronic format to the study team for analysis.
- Interviewers: Individuals who will be conducting the in-person interviews with large, non-residential customers. They could each have separate contracts for the study, or they could be a group of employees/contractors from the same company—where the company contracts to perform the work. The interviewers typically have experience and/or education in industrial engineering, facilities management, or business administration. The ideal interviewer has experience with the issues that large commercial and industrial electricity customers face as a result of reliability and power quality issues. In past studies, retired utility business account representatives have proven to be the best interviewers for collecting outage cost information from large, non-residential customers

This Roadmap is intended to provide a detailed procedure for the survey administrators to use during the course of conducting the study—both in preparing to implement the study and in implementing the pre-test and full-scale study. Table 1-1 shows the sections in the Roadmap that are relevant for the survey administrators, who should be able to use these sections of the Roadmap as a step-by-step guide for their components of the study.

Table 1-1. Sections Relevant for Survey Administrators

Chapter	Customer Class	Section Containing Procedure for Survey Administrators
2	Residential	-
3	Non-Residential: Small and Medium	3.3.3: Prepare for Implementation 3.3.4: Survey Implementation
4	Non-Residential: Large	4.3.4: Prepare for Implementation 4.3.5: Survey Implementation
5	Non-Residential: Master-metered	5.3: Prepare for Implementation 5.4: Conduct Pretest 5.5: Survey Implementation

The output from the study will include a number of metrics to characterize interruption costs for each customer class as well as system-wide values weighted by the proportion of each customer class in region or service territory. The interruption cost metrics will include:

- Cost per Outage Event: average cost of each outage duration for each customer class.
- Cost per Average kW: average cost per outage event normalized by average customer demand. This metric is useful for comparing outage costs across segments because it is normalized by customer demand.
- Cost per unserved kWh: cost per outage event normalized by the expected amount of unserved kWh. This metric is useful because it can be readily used in planning applications, for which the amount of unserved kWh as a result of a given outage is commonly available.
- Cost per Customer Minute Interrupted (CMI): average cost per outage event divided by the number of customer minutes interrupted for each outage duration and customer class.
- Duration Costs: cost per outage event minus the cost for a momentary interruption. The duration cost for a momentary interruption is thus always $0. The other two duration cost metrics—duration cost per average kW and duration cost per unserved kWh—are calculated as described above, but with the adjusted event cost.

The output will also include results of customer damage function modeling. These regression models will relate certain characteristics of the customers, interruptions, and the environment to the cost of the interruption. The models will enable utilities to estimate the differences in interruption cost between different types of customers, interruptions that occur at different times of day, and how season and temperature impact interruption costs. The information will be incorporated into the ICE Calculator (or a subsequent tool) to produce results that are based on up-to-date, region-specific information for interruptions lasting between 5 minutes and 14 days.

The Roadmap contains a number of instances where the study team will have to determine the appropriate course of action for designing the sample and/or the survey instrument. The study team will need to assess proposals for sample size and stratification scheme as the details and/or constraints of the study become clearer over time. The team will also need to develop and revise certain specifics of the survey instruments based on the results of small-scale testing. If this national study is undertaken following the protocols outlined herein, it could help to advance research methods while obtaining important data for utilities to use for long-term reliability and resilience planning.

2. Residential Customers

This section outlines a proposal for conducting a national study of residential customers to estimate CICs for both short-duration and long-duration power interruptions. For short-duration interruptions, the results can be incorporated in the ICE Calculator to give up-to-date and geographically complete information on outage costs for residential customers by geographical region. In preparation for the national study, survey questions and measurement protocols will be tested and revised. These revisions will be designed to allow measurements of outage costs for both short and long duration outages to be collected using the same survey instruments and procedures. The revisions to the survey design will be carried out in a process that systematically ensures the new outage scenario descriptions are well understood by respondents and that outage cost estimation elicitation methods are valid and reliable. The effort to improve the survey design will leverage the expertise of leading researchers in the field. As there is no clear consensus among experts on the best way to estimate costs for long-duration interruptions from residential customers, this study will push the frontiers of research in that field.

The residential portion of the national study will be conducted in two phases. The first phase will focus on developing and validating a new survey design intended to be fielded online applying the latest survey techniques to develop scenario descriptions, new survey forms designed to collect more detailed information about the direct worth of losses that residential customers experience, and a new willingness to pay elicitation method. Once the first phase of the study is completed, the full-scale study will be completed as the second phase of the investigation. The results of the first phase will provide the complete details of the survey design to be used in the full-scale study. The study team will use these results to prepare detailed specifications for competitively procuring the data collection services for the full scale study.

The national study will utilize a national online panel curated by a third party research firm for the full-scale study phase selected based on its representativeness of the U.S. population. The panel should represent people who would not normally have access to or routinely use the internet and should provide a sufficient sample within the nine US Census Regions to allow precise estimation of customer outage costs at the regional level. The benefits of using an online panel selected in this manner—as opposed to working through utilities to identify and recruit participants—include:

- Representativeness of the survey sample by region
- Avoiding a painstaking process of assembling a representative sample of residential customers from utilities
- Ability to field the survey of households entirely over the internet, which allows for more advanced and adaptive survey instrument designs
- Providing a sample frame that includes occupants of multi-family master-metered customers that generally cannot be directly identified in a utility sampling frame
- Availability of background demographic data on panel participants
- Avoiding bias that may be introduced if the customers know that their utility is conducting the study

The principal downside of a national panel is the lack of data on electricity demand and consumption for sample design and interruption cost modeling purposes. Electricity consumption is correlated with interruption costs and historically has been used as an effective basis for sample pre-stratification. That will not be possible with the national panel because the panel managers do not have this information. However, because residential usage and outage costs do not vary dramatically from customer to customer, this problem can be overcome by increasing the sample sizes within regions. In calibrating per-event outage cost estimates obtained from the survey to annual and hourly energy consumption, it is possible to use reported energy bills (along with information about utility rates) for summer and winter as a proxy for energy consumption in the analysis phase of the proposed research.

Section 2.1 provides background on the use of customer surveys for estimating interruption costs for residential customers. It explains the difference between short-duration and long-duration interruptions, the importance of the distinction, and the implications for designing the national study. It also reviews elicitation methods and survey instrument designs. Section 2.2 outlines a path forward for testing alternative designs, with the objective of informing the design of the full-scale study. Section 2.3 details the full-scale study design, implementation, and analysis of results.

2.1 Background

Customer surveys have been used for more than two decades to estimate the economic costs consumers and businesses experience as a result of electric and natural gas service interruptions (Woo & Pupp, 1992) (Billinton, Tollefson, & Wacker, 1993) (Sullivan & Keane, Outage Cost Estimation Guidebook, 1995) (Lawton, Sullivan, Van Liere, Katz, & Eto, 2003) (Sullivan, Schellenberg, & Blundell, 2015). Most of the interruption cost studies carried out since the early 1990s in North America have used a common survey measurement framework comprising sample designs, survey forms, customer contact protocols and analysis procedures. A recent report titled *Estimating Power System Interruption Costs* describes this framework in detail (Sullivan, Collins, Schellenberg, & Larsen, 2018). These surveys have been carried out for representative samples of utility customers by large electric utilities located on the West Coast, Southwest, Southeast and Midwest. In general, the approach involved in developing and carrying out the national study will be to improve the survey research methods that have been used historically, update the data, conduct surveys in under-represented areas, and determine the costs for long duration and geographically widespread outages.

Unlike the proposed national study, nearly all of the survey designs used in past studies have been designed to estimate outage costs for short duration interruptions (i.e., those lasting 24 hours or less). The only work that has been done to estimate the costs of long duration outages for residential customers was reported by Baik et al. (2018) studying residential WTP to avoid long-duration, widespread (LDW) interruptions in the Pittsburgh area. Extension of the survey framework used in prior studies to the national study involves a number of challenges discussed below.

2.1.1 Challenges in Estimating Costs for Long-Duration Interruptions

CIC estimation for short and long duration outages entail very different measurement challenges and different outage cost measurement techniques may be necessary to estimate costs for them. As indicated above, until very recently, outage cost surveys have focused on outages lasting less than 24 hours. This is because these measurements have been used primarily to estimate the economic value of reliability in the context of planning for generation, transmission and distribution investments designed to serve what might be thought of as "normal" operating circumstances. Normal operating circumstances do not include major storms, earthquakes, wildfire, cyber-attacks, and other catastrophic events that are very rare but potentially very costly. In the past 10 years, as catastrophic weather events have become increasingly common and concerns about cyber security have increased, utility planners and policy makers have become concerned about designing electricity supply systems that are resilient to these threats. Thus, the need to obtain reliable CIC estimates associated with long duration and geographically widespread outages has increased.

In short duration interruptions, customers incur "direct costs," which arise from the interruption of power to their homes. Direct costs include tangible costs required to survive and recover from outages (e.g., cost of candles or going out to eat when kitchen facilities are not available) and intangible costs (e.g., inconvenience or lost leisure time due to unavailability of appliances). It is believed that most of the costs incurred by residential customers in short duration outages are intangible.

During long-duration and geographically widespread interruptions, customers can experience different and much larger economic costs. Depending on the duration and geographical scope of the interruption, customers may be required to take actions that impose costs which are not produced by short term interruptions. For example, as a result of LDW interruptions, residential customers may lose the value of the contents of their refrigerators and freezers, be required to travel long distances to obtain basic necessities, and may even be required to relocate some or all family members to locations outside of the affected area. These actions and their attendant costs are quite tangible and significant and they are not addressed in the survey instruments that have been designed to-date to measure the costs of short duration outages.

2.1.2 Measuring Residential Outage Costs

When a market exists for a particular good, researchers can observe purchasing behavior and use what are called revealed preferences to determine the good's economic value to consumers. In other words, one can examine what people have paid for the good in the past to establish its value to them. When a market for a good does not exist—such as a market for perfectly reliable power—researchers often rely on stated preferences to determine the value of the good. In a study of stated preferences, consumers indicate what they would pay for a good if it were available in a hypothetical market. This method has been used to value non-market environmental resources, such as conservation of natural habitat and open space (Kopp, Pommerehne, & Schwarz, 1997) and to establish customer interest in and willingness to pay for products that have not yet reached the market. For example, stated preference studies have been used to assess consumer interest in new vehicles, alternative electric rates and a wide range of other applications where a market has not yet developed (or will never develop) for products and services.

A stated preferences survey design is useful in quantifying the economic loss that consumers experience during power outages because measured WTP theoretically contains both the tangible and intangible losses that customers experience as a result of power interruptions. That is, it includes both the direct worth of their losses and the significant fraction of the interruption costs that comes from the inconvenience and lost consumer surplus resulting from the power interruption.

A common method for eliciting CICs through stated preferences is WTP. The WTP approach to CIC estimation does not provide a measurement of the direct worth of the interruption in terms of net lost utility, but rather how much the customer would be willing to pay to avoid the lost utility. This technique employs the concept of compensating variation. In economics, compensating variation refers to the amount of additional money an agent would need to receive to reach their initial utility after a change in prices, a change in product quality, or the introduction of new products (Hicks, 1939). In a WTP measurement, customers estimate the economic value that would leave their welfare unchanged in the event of a power outage compared to a situation in which no power interruption occurred.

There are a number of ways to elicit WTP and some of these have been used in past interruption cost studies. Over the decades, a two-stage WTP cost estimation strategy has been developed and was used widely in estimating the costs of short duration outages. In the first stage, customers are asked to consider how a particular power interruption would affect their household and to estimate their out-of-pocket and inconvenience costs. The purpose of the questions posed in this stage is to get respondents to think concretely about how a described outage would affect their household and what it might cost. Then, in the second stage, respondents are presented with a payment card (containing a range of possible payment amounts) and asked to identify the maximum amount they would be willing to pay for a service that would prevent the outage (Sullivan, Collins, Schellenberg, & Larsen, 2018). The process is repeated to estimate the costs for 5-6 hypothetical outages (with variations in onset time randomly assigned).

In developing the Roadmap for the national study, experts in surveying and outage cost estimation reviewed the proposed survey protocols. They raised several concerns about the proposed survey design for residential outage cost measurement – particularly when applied to the estimation of long duration outage costs. The concerns included:

- the validity and reliability of WTP measurements derived from payment card responses
- the validity of WTP measurements obtained from repeated presentation of outage scenarios to the same respondent
- the difficulty consumers may have in formulating answers to questions about their WTP to avoid long duration, widespread outages
- the need to allow respondents to express uncertainty about their WTP responses

Before indicating how the above concerns should be addressed, it is useful to consider the history of the development and application of the various techniques that can be used to elicit WTP.

2.1.3 Alternative Strategies for Measuring Willingness to Pay

Studies of stated preferences began to be used in the early 1960s and since that time a number of alternative strategies have been employed to measure the economic value of non-market goods. The basic techniques include:

- *Asking open ended questions*: e.g., what is the most you would be willing to pay for a given good
- *Payment cards*: asking respondents to select the maximum amount they would be willing to pay from a range presented on a card
- *Bidding games*: iteratively asking whether respondents would be willing to pay an amount adjusted upward or downward based on the respondent's prior answers
- *Bounded discrete choice experiments*: asking respondents whether they would be willing to pay a given amount or amounts selected at random by the researcher from a distribution of possible payments
- *Choice exercises*: asking respondents to select from two to three alternatives (defined by price and other attributes) in repeated exercises

2.1.4 Discussion of Techniques for Measuring Stated Preferences

Open Ended WTP

The first stated preference valuation survey was conducted in 1961 by Davis (1963). Influenced by Davis, Ridker (1967) used open-ended WTP questions to ask respondents in two cities how much they would be willing to pay to avoid air pollution. The open ended WTP question has come in and out of popularity several times since the study of stated preferences began. With widespread adoption of forms of discrete-choice format elicitation, open-ended WTP has ceased to be the most common format, but it is still used today. Despite its continuing popularity, there is reason to reject it as an approach to measuring CICs. The reason is that there are several lines of evidence which show that the response to an open-ended valuation question does not reflect the *maximum* WTP: it is only *an* amount that the respondent would be willing to pay. That is, open-ended WTP elicitation is generally likely to understate true WTP, and open-ended elicitation of willingness to accept (WTA) to overstate true WTA. For this reason, the open ended measurement strategy should not be used to estimate WTP in the national study.

Bidding Games

In 1972, Randall et al. (1974) used a survey format similar to Davis (1963) to value the abatement of environmental damages associated with the Four Corners Power Plant. However, instead of posing an open ended WTP question, respondents were asked a series of questions designed to cause the respondent to iterate to a solution to the answer. The interviewer began with some specific dollar amount and asked: "Would you be willing to pay amount X?" If the respondents said "yes," the interviewer raised the dollar amount and repeated the question. This continued until a "no" answer was reached. Conversely, if the initial amount elicited a response of "no", the interviewer would lower the dollar amount and repeat the question, continuing until a "yes" answer was reached. The dollar amount that elicited the highest "yes" answer was taken as the amount of the respondent's WTP. This approach to WTP measurement was called "the bidding game".

The bidding game was adopted by a number of researchers until it was discovered that the final WTP amount observed using this technique was related systematically to the initial bid amount. Using a higher initial bid yielded a higher final estimate of WTP, while using a lower initial bid led to a lower final WTP – a phenomenon that became known as "*starting point bias*." A likely explanation is that respondents tired of the iterations: after saying "no" four, five or six times, the respondents may have grown tired or bored and said "yes" just to halt the game. Because the bidding game is subject to starting point bias, it should not be used to measure WTP in the national study.

Payment Card Method

The bidding game format fell into disuse during the 1980s for the reasons cited above; and was replaced by the Payment Card Method (PCM). This method (used in the current residential CIC survey) was introduced by Mitchell & Carson (1981), (1984) as an alternative to the bidding game that would avoid starting point bias.[7] In PCM, respondents are given a card with a range of possible cost/price choices. The range on the card is from 0 to some positive number believed to contain the complete range of values that consumers would be willing to pay. They are asked to select the maximum amount they would be willing to pay for the good. It is thought that the provision of the range on the card stimulates respondents to make a choice and relieves the need for tiresome questioning to find the WTP amount (as in the bidding game). It is also the case that the data resulting from the payment card exercise allows for relatively precise estimation of CICs compared with the results obtained from bounded discrete choice experiments discussed below. This is because the choice of a given price is bounded on the lower end by the amount of the price category immediately below it. For example, imagine a payment card whose values range from $0 to $100 by intervals of $10. Imagine further that the respondent selects $50 as the maximum amount they are willing to pay. By virtue of the structure of the exercise, we know that the maximum amount they are willing to pay must be above $40 – the actual amount the respondent is willing to pay is between $40 and $60. As will be seen below, this is a much narrower range than can be achieved with the bounded discrete choice procedures.

Unfortunately, there is evidence that the results obtained from the PCM may be sensitive to the range of values presented to respondents on the card. The wider the range of values presented, the higher the WTP. In essence, the PCM may be subject to what is called anchoring bias. Anchoring bias occurs when respondents rely too heavily on an initial item of information (considered to be the "anchor") when selecting a WTP response – regardless of whether that item was somehow relevant to the decision. The impact of anchoring bias on prior measurements of residential outage costs does not appear to have been significant. The evidence for this conclusion is that results from prior applications of the payment card to outage cost estimation surveys show that responses exhibit a bi-modal

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[7] The first dollar amount in the payment card was set at zero. Also, it was thought that the visual aid of a payment card offered some benefit to stimulate respondents and eliminate tiresome questioning.

distribution with relatively large numbers of observations at $0 and a cluster of non-zero answers below the center of the range offered on the payment card. However, considering the importance of these measurements for policy making and their likely use in regulatory proceedings, it is probably appropriate to use an alternate elicitation method for the national study based on concerns about anchoring bias.

Bounded Discrete Choice Experiments

In 1978, Bishop and Heberlein (1979) introduced a new elicitation format, which subsequently became known as *Single-Bound Discrete Choice (SBDC)*. This was essentially the first valuation question posed in the bidding game format, but with no further iterations. That is, respondents were confronted with a single dollar amount (which was represented as the cost of the program) and were asked: "Would you be willing to pay amount X?" Different respondents received different randomly selected dollar amounts, but each received only one amount. A fuller and utility-theoretic interpretation of this format was provided in Hanemann (1984), and the approach gained popularity. The key insight in this approach was that the yes/no (i.e., discrete) response provided *a bound* on the value of respondent WTP: if they said "yes" when confronted with a cost of $65, the inference was that their WTP was some amount equal to or larger than $65, but if they said "no," their WTP must be less than $65. Either way, the survey response generated a value interval for WTP – either [0, 65) or (65, ∞). In statistical terminology, WTP was measured as a censored variable. A statistical model of responses could be estimated from this interval data using maximum likelihood regression. The SBDC format was employed by the State of Alaska's research team following the *Exxon Valdez* oil spill in 1989 (Carson R. T., Hanemann, Kopp, & Ruud, 1992), and was subsequently endorsed by the NOAA Blue Ribbon Panel on Contingent Valuation (CV) (Arrow, et al., 1993). The SBDC measurement of WTP is unbiased provided the range of offers presented to respondents contains the mean WTP. ***This method can be used to estimate WTP in the national study.***

While the SBDC method produces unbiased estimates of WTP it produces a relatively imprecise estimate—owing to the fact that the range above and below the "offer" is necessarily wide. To improve the precision of the WTP estimate a variant of the design was proposed by Hanemann (1985) and first applied by Carson, Hanemann and Mitchell (1986) and Hanemann, Loomis and Kanninen (1991), known as *Double-Bounded Discrete Choice (DBDC)*. The DBDC format starts out just like the SBDC version, presenting the respondent with a given price/cost amount and asking whether they would buy the item or support the program (depending on the context) at that cost. However, instead of stopping at that point, it adds a single follow-up question, conditioned on the response to the initial question. If the respondent says "yes" to the initial amount, the follow-up involved a higher amount and the question would read something like: "Suppose the cost were actually Z instead of X – would you still support the program?" If the respondent had said "no" to the initial amount, the follow-up would involve a lower amount and read something like: "Suppose the cost were actually Y instead of X – would you then support the program?" Here, $Y<X<Z$. The possible responses were "no, no" or "no, yes" or "yes, no" or "yes, yes." The implied intervals of WTP value were, respectively, [0, Y), [Y, X), [X, Z), or [Z, ∞).

Compared to SBDC, the responses in the DBDC format generate much more statistical information –

more tightly bounded intervals for the WTP value. The result is a more efficient estimation of the respondent WTP distribution. The empirical application by Hanemann, Loomis and Kanninen (1991) found a substantial gain in efficiency – the confidence interval for the estimate of mean respondent WTP using DBDC was much smaller than that using SBDC. In effect, the bid values used for the first valuation question were not well designed, and the second valuation question greatly corrected for this. A general finding was that DBDC provides insurance against failings in the bid design for SBDC. While the confidence interval for the estimate of mean WTP was tighter with DBDC than SBDC, the mean value of WTP was lower. Since the mean WTP from the SBDC is known to be unbiased, the implication is that the DBDC exercise produces a biased (and lower) estimate of the WTP. In fact, it turned out that the utility model underlying the responses to the first and second valuation questions for the DBDC were similar but not identical. This led researchers to question the validity of the DBDC format.

Researchers now believe that the difference arises from the surprise introduction of a new cost estimate for the second valuation question (Cooper, Hanemann, & Signorello, 2002). Respondents were told what the cost would be when receiving the first valuation question. Now, without warning, this information is being changed with the introduction of the second valuation question. The change has an adverse effect on the respondent. He may think that a different product is being offered, since it is cheaper; or he may conclude that the cost is really uncertain and he should not trust the second cost estimate either; or he may feel he is being taken advantage of (this is becoming a bargaining exercise). All of these considerations are reasons for the respondent to become more negative towards the item in the second valuation question. For this reason, the DBDC experiment is not appropriate for use in eliciting WTP in the national study.

The remedy, proposed in Cooper, Hanemann and Signorello (2002) modified the elicitation format to remove the element of surprise from the elicitation procedure. In the revised procedure, the respondent is told upfront that the exact cost is unknown, but it is believed to lie in the range from X to Y. He is then asked if he would buy/support the item at one of those two amounts (determined at random) – say at a cost of X. If he says "no," there is no follow-up question; if he says "yes," he is then asked if he would buy/support it at Y. The process is similar if the initial question starts with Y. This provides less information; the potential interval values for WTP are [0, X), [X, Y), and [Y,∞). It was given the name of *One-and-a-half Bound Discrete Choice (OHDC)*. This procedure generates consistent answers to the two valuation questions and provides a significant gain in statistical efficiency. That is, it does not suffer from the potential bias present in the DBDC experiment. ***Since this method appears to produce unbiased results, it is a good candidate for use in the national study and a better candidate than the SBDC because it is more precise.***

Choice Experiments

Choice experiments (CE) were introduced into non-market valuation by Louviere, Swait and collaborators and became very popular starting around the mid-1990s. Like SBDC, DBDC and OHDC, they elicit a form of discrete response from respondents. However, instead of offering a single choice to be evaluated, whether at a single price or multiple prices, in CE respondents are offered several packages (combinations of price and product attributes) and asked which they prefer. In a study of outage costs, the respondent might be shown two service levels involving different amounts they would have to pay along with different combinations of service reliability attributes (e.g., a given frequency of outages, of given durations, occurring in a given season and perhaps time of day). They would be asked to select the combination of price and attributes that they prefer.

CE is typically repeated so that respondents are presented with multiple sets (e.g., 10) of choices and asked which they prefer in each choice. The reason for the repetitions is the desire to observe the valuation of the individual components (attributes) that collectively constitute the packages being evaluated. Whereas SBDC etc. holistically evaluate a single package, CE (also known as attribute-based valuation) deconstructs what is being valued into its separate components and seeks to elicit their individual values.

By construction, CE therefore generates more information than the discrete choice experiments. It generates a valuation that is disaggregated into the separate components (attributes). Whereas the discrete choice experiments generate a valuation of just one thing – the particular program/package being offered to respondents -- CE provides a general valuation function that can be applied to other packages (other combinations of attributes) than the particular ones included in the valuation survey. This design is very attractive because it provides the ability to simultaneously estimate the impacts of different service attributes on WTP. In particular, it provides that ability to estimate the different effects of duration, frequency, season, and onset time on outage cost – allowing for a much richer definition of the ultimate customer damage function.

The drawback to this approach is that it is very sensitive to the specification of the utility function that relates prices to service attributes. Researchers often assume a simple structure (e.g. additively linear). But, for individual respondents, there could be significant interactions, such as attribute X mattering only if attribute Y is present, etc. Moreover, there is the possibility of lexicographic preferences with respect to some attributes.

An additional concern is that the implementation of CE through a set of repeated choices can be problematic if respondents become tired or bored. Behavioral phenomena such as attribute elimination may occur, as respondents proceed through successive experiments and start simplifying their choices by focusing on a smaller subset of the attributes on which to base their selection. The result is that later choices may elicit different preferences than do earlier ones. In short, as a valuation method, CE may be quite frail in practice. For this reason, this very interesting approach is probably not appropriate for use in an environment where results are likely to be challenged on the basis of econometric assumptions used in estimation. Further work in applying this technique to outage cost estimation is warranted, but it is probably a mistake to put the solution to the many challenges it entails on the critical path to fielding a national study.

2.1.5 Additional Design Considerations

In addition to identifying an appropriate WTP elicitation methodology, it is important to ensure that two other important design elements are taken into consideration in developing the survey instruments used in the national study. The current version of the residential outage cost survey estimates the costs of outages with varying characteristics by presenting a series of six scenario descriptions that vary the duration, season and other attributes of the outage. It is unknown whether the order of the presentation of these scenarios affects the results of outage cost measurements, but evidence suggests that this is a possibility. It is also possible that respondents are uncertain about the costs they will experience and the amount they are willing to pay to avoid it—and that this uncertainty matters in assessing their outage costs. These problems and possible solutions are discussed below.

Avoiding Sequence Effects in Valuing Multiple Items

As indicated above, it is necessary to collect outage costs for a number of outage scenarios involving different durations, onset times, seasons and other factors. This can be done by using a large sample and randomly assigning different scenarios to different members of the sample. It is also possible to use a single sample and have each respondent conduct more than one valuation exercise (an internal test). In some prior outage cost surveys, these approaches have been combined so that some outage scenarios are presented to all sample respondents and some receive other scenarios that are only received in that subset of the sample.

In some past studies, order effects have been observed when multiple scenarios are presented to the same respondent. For example, Payne et al. (2000) conducted an internal valuation of five different environmental programs, using an open-ended WTP question, in which they randomly varied the order in which the five programs were valued. They found a strong sequence effect: regardless of what the program was, WTP was larger for the first program than for the subsequent ones. Also, total WTP for the bundle of five programs depended on which program was valued first – the more highly valued the first program, the higher the total WTP for the bundle. Thus, it is possible that order effects arise when multiple outage scenarios are presented to respondents in sequence.

Placing the scenarios in random order and showing respondents a summary of the scenarios before the choice exercises begin should eliminate the order effects. The survey forms in the national study will employ this technique.

Incorporating Uncertainty into Outage Cost Measurements

An issue raised by Opaluch and Segerson (1989) and others was: Can we be sure that the people responding to WTP elicitation surveys *really* know their preferences? Instead of being fully informed, “rational” consumers, perhaps respondents are uncertain or ambivalent about their own preferences. Various approaches were developed to deal with the possibility of respondent uncertainty or ambivalence. Most of these approaches used the SBDC format and tweaked it to incorporate respondent uncertainty. For example, Svento (1993) allowed the respondent in a SBDC survey to answer “don’t know” as an alternative to “yes” or “no.” The presence of “don’t know” responses was handled with a statistical model that represented “thick” indifference curves containing a zone of ambivalence or indifference represented by a specific parameter that could be estimated.

Hanemann et al. (1995) developed an alternative statistical model where SBDC was used with only yes/no responses but the parametrization of the model incorporated a parameter representing respondent preference uncertainty. This model was found to discriminate very effectively between real and hypothetical SBDC survey responses, with the latter reflecting a larger degree of respondent uncertainty. Li and Mattsson (1995) used SBDC with the standard yes/no response alternatives, but then followed up with "How certain were you of your answer to the previous question?" with the reply on a scale from 0% to 100%. Both responses were combined in a statistical model of WTP distribution. Whether or not these models measure uncertainty in terms of an expressed probability, what they have in common is a statistical model of respondent WTP that has been modified in some manner to account for respondent uncertainty.

Another portion of the literature supplements the yes-no response options to the closed-ended SBDC responses, slices the data into different subsets based on the responses to the supplementary question, and then applies standard SBDC estimation to particular subsets of the data. In Johansson et al. (1993), the respondent faced one specified payment amount but was offered as alternative responses "definitely yes" or "probably yes" or "probably no" or definitely no," along with "don't know." In Ready, Whitehead and Blomquist (1995), the response categories were "definitely yes," "probably yes," "maybe yes," "maybe no," "probably no," and "definitely no." In these studies, the data analysis employed the standard SBDC statistical model, but the model was applied to *different subsets* of the response data. For example, the SBDC model was estimated using only responses involving "definitely yes" or "definitely no." Or, the responses were divided into "definitely yes" versus everything else (i.e., treating all the other responses as equivalent to "no"). By slicing up the data in different ways, one obtained different estimates of the mean of the respondent WTP distribution. The researcher then must decide which estimate (which subsample of responses) to report.

Welsh and Poe (1998) introduced a variant of this approach which blends the survey format used by Ready, Whitehead and Blomquist (1995) with the payment card format. This is known as the Multiple Bounded Discrete Choice (MBDC) format. This approach is used by Baik et al. (2018) in their long duration outage cost study. It resembles the payment card format because there is iterative questioning of the respondent using a sequence of bid values like the monetary amounts listed in a payment card. For each bid amount, the response options are essentially those of Johansson et al.: "definitely no," "probably no," "not sure," "probably yes," and "definitely yes." From the responses, Welsh and Poe (1998) extracted a single value interval containing the respondent's WTP. That value interval depended on the degree of certainty specified by the researcher. For example, it could be the interval specified by the highest dollar amount receiving a "definitely yes" versus the next bid amount receiving a less positive response than "definitely yes." Slicing up each respondent's responses differently generated different estimates of mean WTP value. Subsequently, Alberini et al. (2003) extended the Welsh and Poe (1998) methodology by utilizing the respondent's answer to every bid amount in the payment schedule. They found, however, that MBDC was subject to an *order effect*: it made a difference to the resulting estimate of mean WTP if the bid amounts were arranged in ascending versus descending order. It is also likely that the MBDC method using the modified payment card has the same potential for anchoring bias as the payment card method.

Bid Design for Discrete Response Elicitation

Whenever one estimates a statistical model from data, the resulting coefficient estimates are dependent on the particular data used in the estimation. If one employs a different data set, the coefficient estimates will be different. If the researcher has the ability to design the data used in the estimation – for example, by running an experiment from which the data emerge – while it remains true that the resulting coefficient estimates will be dependent on the data generated by the researcher, those coefficient estimates can have some desirable (optimal) properties (such as maximizing the determinant of the information matrix associated with the coefficient estimates). In fact, there is a body of literature on how to design experiments in various branches of science so as to obtain data that will generate coefficient estimates with optimal properties.

This literature on experimental design has implications for discrete response CV, and it has in fact been applied in that valuation literature. SBDC, for example, is conceptually analogous to a dose-response experiment in biology where an organism is exposed to a certain agent—different subjects receive different levels of the agent—in order to trace out an empirical response function. The bid (cost) presented to respondents in a SBDC study is the analog of the dose in a dose-response experiment, and the response is “yes” or “no,” as opposed to the death or survival of the organism. The WTP distribution being estimated in the CV study corresponds to the tolerance distribution being estimated in a biological dose-response experiment.

The statistical methods for the design of doses in a dose-response experiment have been applied in SBDC studies, and they have been extended to the case of DBDC and OHDC (for details, see Kanninen, (1993a) (1993b)). In general, the researcher needs to have some prior idea (estimate) of the WTP probability distribution that is to be estimated with the data generated by the discrete response experiment. The researcher should select the bids (doses) corresponding to certain particular quantiles of that distribution. If there is flexibility to adjust the bids during the course of the experiment, this should be exploited. Thus, at intervals during the data collection, the researcher should employ the data generated by the experiment thus far to estimate a WTP distribution (perhaps combining it with the prior estimate in a Bayesian manner, or perhaps not), and then use the new estimate of the WTP distribution to update the bids used in the next part of the data collection.

While optimal design techniques are available for SBDC, OHDC or DBDC valuation, there is no analog in terms of optimal design for the values offered in a payment card or an MBDC elicitation format, as these measurement strategies do not rely on choice experiments.

2.2 Survey Modifications and Testing

The national study provides an opportunity (and requirement) to improve the reliability and validity of survey procedures used to measure residential customer outage costs. These improvements are necessary in part because the current measurement procedures contain certain technical weaknesses that should be corrected going forward and in part because the scope of the survey measurements has been expanded to the measurement of outage costs for long duration outages. Several important modifications have been made to the residential survey design in Sullivan et al., (2018). A first draft of the modified survey instrument for residential customers is in Appendix A. Further refinements should be made using small scale empirical tests, outlined herein, designed to perfect alternative scenario descriptions and elicitation formats.

As explained above, most prior studies of residential outage costs have asked customers how much they would be willing to pay to avoid outages of different durations under varying conditions. The most widely used approach involves a two-stage process in which an electricity outage is described in terms of its onset time (i.e., season, day of week, and time of day) and duration. Customers are asked:

- How their household would be affected by the described outage (and what it would cost to respond to it); and
- How much they would be willing to pay for a backup service designed to avoid it

The pre-test will assess survey design alternatives in preparation for the national study. It should be designed to improve the following three elements of the elicitation design described above: outage scenario and solution development, assessing customer actions in response to outages and their direct costs, and eliciting the amount customers are willing to pay.

1) Outage Scenario and Solution Development

In prior outage cost studies, respondents were asked to estimate their outage costs for relatively short duration outages (i.e., from 5 minutes to 16 hours). For example, a customer might be told: "On a summer day, a complete power outage occurs at 3:00 PM without any warning. You do not know how long the outage will last, but after 4 hours the power is restored." This is a relatively simple scenario that most customers have experienced so there is little reason to be concerned that they understand the circumstances. The impacts of such outages on customers and their likely responses are also relatively easy for customers to imagine.

In the proposed national study, outage costs will be estimated for long-duration outages of 1 day, 7 days, and 14 days, affecting the entire community and possibly others. These durations were selected to align with existing planning efforts for long-duration outages by the Department of Defense (Army, 2017). Most customers have not experienced such lengthy outages in the past and may have difficulty imagining how these outages might affect them – much less what it might cost. To obtain valid measurements of customer costs and WTP for such outages, it is necessary to "educate" the respondents about the likely impacts of such outages so that they can provide reasonable answers about how these outages will affect them and what it might cost their household if they occur. It is important to take account of the uncertainty respondents may have about outage costs they will experience and their willingness to pay to avoid them.

Another important consideration for long duration interruptions is that customers may have different interruption costs depending on the context of the outage. CICs may vary depending on the answers to several contextual questions defining the long duration interruption:

- *What is the weather and/or outside temperature?* The health risks for long periods without electricity could be much different depending on whether it is very hot or very cold. In addition, customers may face increased damage to property as the interruption continues, including frozen pipes and any resulting damage.
- *Has other infrastructure or have other services been disrupted at the same time as the interruption?* Customers may place a different value on electricity depending on whether all the normal infrastructure is still in place or whether a natural disaster has damaged or destroyed it.
- *In what ways might other infrastructure (e.g., sewage or water treatment plants) fail, and what value would customers place on resilient electric supply to those facilities?*
- *Does the initiating event matter?* Customers may estimate interruption costs differently depending on what caused the interruption. Customers' valuations may change between a two-week outage caused by a hurricane versus a terrorist event (though results from studies thus far suggest they do not (see Baik, et al., 2019)).

One set of pre-tests should explore which contextual factors are relevant for each region. Each region will have its own possibilities for contextual factors, as regions experience different types of extreme weather events and natural disasters, and there are region-specific interdependencies between the electricity system and other infrastructure. The testing should explore whether the contextual factors are associated with different CICs so that the study team knows which factors to include in the full-scale study.

Long-duration outage scenarios within the survey instruments should be customized for each region of the U.S. once the contextual factors are understood. This will reduce confusion and increase the chance that respondents understand the scenarios and are able to better project how they would react in those situations. The scenarios should be constructed around the most likely types of natural disasters for each region that could severely damage electrical infrastructure while not having customer dwellings incur damage. For example, in California, the LDW outage could be caused by a major earthquake, which leaves homes intact but damages a generating station and/or transmission and distribution infrastructure badly enough that it would take 1-2 weeks to repair. In the Great Plains and Midwest, the disaster could be one or more tornadoes; in other parts of the country, a powerful wind and rain event or ice storm might be the precipitating factor.

It is possible to imagine a wide range of approaches to communicating the circumstances of different kinds of outages to respondents. For example, with an online survey, it is possible to use short (i.e., 1-3 minute) video clips to educate respondents concerning the kinds of impacts they might experience during the various kinds of outages in the survey. Alternatively, one might develop written descriptions of the outages that are designed to carefully describe the circumstances that might arise during each outage.

Regardless of the content of the descriptions that are developed, it will be important to ensure that respondents understand the outage circumstances described in the survey and can imagine how the described circumstances might affect their household. Correspondingly, the outage scenarios to be employed in the survey (both short and long duration) should be subjected to:

- Cognitive testing to ensure that respondents understand the scenario descriptions and are not confused by the presentation of multiple outage descriptions. Cognitive testing of the outage descriptions should be conducted until the stimulus is demonstrated to be well understood by potential respondents. Based on experience, this should require several rounds (allowing for making changes to the stimulus) of 10-15 cognitive interviews.
- Small scale online tests of contextual factors of long-duration interruptions. This would include 30 respondents in each of the 9 regions, for a total of 270 observations.
- Small scale online tests of respondents' ability to understand scenarios:
    - 120 respondents for short duration outages
    - 120 respondents for long duration outages
    - 120 respondents testing combinations of 6 short and long duration outages

The tests should be conducted in blocks of 30 designed to be used to iteratively "tune up" the stimuli to ensure that members of the target samples can recall the details of the outages that are being described, can describe how these outages might affect them, and that respondents can successfully transition from one outage description to another when multiple outage scenarios are presented in sequence. The sample size of 30 was set to produce a sample that is relatively stable, yet is not so large that it would use an excessive amount of budget or number of potential observations. A block size of 30 should be able to balance these objectives.

The same design and testing process should be used to ensure respondents understand the "solutions" that will be provided to avoid the outage (e.g. provision of backup electricity generator sufficient to meet their household electricity demand). They should believe the solutions could be applied to their circumstances and also believe that it is a legitimate product for third parties to be offering into the market. The small scale tests should include:

- Cognitive testing to ensure that the respondents are convinced by the solution description, i.e. that the solution can avoid the outage, that it is safe, that it can be delivered to their home in time to avoid significant cost, and that it is technically reliable. As in the case of the outage descriptions, cognitive tests should be conducted until it is demonstrated that respondents understand the purported solutions and believe they could avoid the outages that are described (i.e. three rounds of 10-15 interviews).
- Small scale tests of the ability of respondents to understand and accept the solutions finalized in the cognitive testing—120 respondents—to be completed in blocks of 30 to iteratively

improve the solution description to correct for any respondent uncertainties or misunderstandings.

2) Assessing Customer Actions in Response to Outages and their Direct Costs

In prior outage cost studies of residential customers, questions concerning actions homeowners might take in response to outages and the resulting direct costs have been used to help the respondents forecast the consequences of the outage for their household. The direct cost estimates used in the present survey are not very detailed and are not usually relied upon as estimates of customer costs. This is a reasonable strategy for short duration outages because most of the costs for short duration outages are intangible (e.g., lost leisure time activities or inconvenience associated with being unable to use desired electrical appliances). This may not be a reasonable measurement strategy for long duration outages and certainly the direct cost categories used in prior surveys for short duration outages fall short of what is necessary to describe the potentially very significant direct costs of long duration outages.

For these reasons there is a need to develop an appropriate methodology for estimating the direct costs of long duration outages for households. The components of direct cost that customers might experience in a long duration/widespread outage include the:

- Value of perishable food stored in refrigerator(s) and freezer(s)
- Damages that result from failure to supply power to other household functions that require continuous power (e.g., fish tanks, food dryers)
- Cost to relocate some or all family members during the outage (when the conditions require it)
- Cost of meals outside the home (when conditions require it)
- Cost to run backup generation if they have it (if they don't have backup generation they should be told to assume it will not be available in nearby stores)
- Cost of transportation to alternate location (if necessary)
- Cost to hire private security (if they choose to do so)
- Other costs not easily imagined

The costs customers might experience as a result of an LDW outage will depend on the conditions under which the outage occurs (e.g., severity of weather) and the actions the customer takes in response to them. For example, if a customer has a backup generator, they can decide to run it and not take any other unusual actions. Their cost would be comprised primarily of the cost to run their backup generation and the inconvenience of starting and servicing it. If they do not have backup generation, food stored in their refrigerator(s) and freezer(s) will probably spoil and they may have to relocate some or all of the household residents to lodging outside the affected area – experiencing the cost of transportation to and from the location as well as lodging and meals for the duration of the outage.

There are a number of cost elements involved in estimating the direct cost of actions residents might take in response to an outage and it would be difficult for any respondent to make an accurate and reliable estimate of their likely costs without assistance. So, to obtain an accurate and reliable estimate of the cost of a long duration outage it will be necessary to guide the respondent through a structured process that takes account of the actions they are likely to take and the resulting costs. Fortunately, it is possible to develop an easy to use cost estimation framework to be used by respondents to estimate their direct cost – something similar to the approach that is used to estimate direct cost for small commercial and industrial customers.

As in the case of the survey questions used to estimate the direct worth of outages for SMB customers, it should be assumed that consumers will have some uncertainty about their direct costs depending on the unique conditions that may arise in any particular long duration outage. To allow them to express their uncertainty concerning these costs, they should be asked to state a lowest and highest range around the estimate of the outage cost automatically calculated by the survey instrument.

A first draft of a survey instrument is in Appendix A. The scenario and solution descriptions were based on survey instruments in Baik et al. (2018) and Sullivan et al. (2018). The wording on the survey form should be developed and tested to ensure that respondents can easily use it to project their costs. The testing should involve cognitive testing to ensure they understand the questions that they are being asked during the elicitation process.[8] This will involve:

- Cognitive testing to ensure that all of the questions posed on the survey are properly understood; and
- Usability testing to refine the survey questions to ensure that respondents can easily estimate their outage costs

It is expected that roughly 30 cognitive tests will be required to refine the survey questions so that users have a common and useful understanding of the questions. The usability testing should be carried out with approximately 120 homeowners tested in three waves – allowing for changes between waves to perfect the instrument. Once this testing has been completed, the direct cost estimation module should be installed in the main survey instrument.

3) *Eliciting Amount Customers Are Willing to Pay*

While a number of WTP elicitation methods have been employed in the second stage of prior residential outage cost studies (i.e., open-ended questions, payment cards, various kinds of choice exercises such as single bounded discrete choice exercises, double bounded discrete choice exercises, and choice experiments), most of the recent surveys have employed a payment card methodology because of its simplicity. There has been no effort to systematically compare the results from these

[8] The survey instrument also contains a WTP question for the LDW outage scenario. The question is structured similar to the WTP question for the short-duration outage (explained below). Including this question will allow the study team to compare WTP and direct cost elicitation results for LDW outages. The study design could also vary the order of the WTP question—placing it prior to the direct cost questions for some surveys and after the direct cost questions for others—to test whether working through the direct cost questions has any impact on respondents' WTP.

different elicitation methods.

As explained above, there is evidence that the payment card method is subject to anchoring bias, which occurs when respondents use the center point of the range provided on the payment card as an anchoring point to select their WTP response. Going forward with the national study, this possible source of bias should be eliminated and the payment card technique used in the second stage of the WTP measurement should be replaced with a question series that does not suffer from this flaw. Based on the performance of the other WTP elicitation measures in other settings, we believe the payment card method should be replaced with OHDC. In an OHDC exercise, respondents are told that the cost of supplying the service needed to avoid the outage is believed to be between X (on the lower end) and Y (on the upper end). The ranges (X,Y) are randomly assigned to customers. Each customer is then asked whether they would be willing to pay X (or Y) for the described outage avoidance service. If they say no (yes), the choice exercise terminates. If they say yes (no), they are then asked whether they would be willing to pay Y (or X). Regardless of their answer to this second question, the choice exercise terminates at this point. The survey instrument in Appendix A reflects this approach. Censored regression techniques are then used to estimate the average WTP over the sample controlling for variation in season, onset time and duration.

This approach is not subject to anchoring bias and is relatively simple for respondents to answer. However, in order to apply this technique, it is necessary to design the bid price offers (X,Y) making reasonable assumptions about the probability distribution for WTP in the population of interest and to select the bid ranges for the choice exercises based on the quantiles of that distribution. This should be done using a Bayesian sampling design approach in which samples of potential respondents are supplied with plausible bid ranges that can be used to identify the likely probability distribution of WTP.

The approach would use an SBDC choice exercise iteratively with samples of customers in Amazon Mechanical Turk (MTurk) to identify the probability distribution of WTP for outages of different durations. It would start with a wide range, e.g. from $1 to $1,000, divide the range into 10 intervals and then offer 10 bids from each interval to a sample of residential customers. The study team would inspect the response distribution and decrease and increase the lower and upper limits of the bid distribution to eliminate intervals for which the response probability was zero. The resulting probability distribution would be used to generate bid ranges for the national study. This would likely need to be completed for the short duration and long duration outages separately.

Once the above design work has been completed, a final set of tests should be conducted. These tests will be designed to assess the combined performance of the changes that have been made to the survey instrument. This should be a formal pre-test of the survey instrument carried out with three waves of 120 observations. Care should be taken at this stage of the design work to ensure that the survey instrument can be completed in under 30 minutes by the average respondent. This may require restructuring the sample design so that different respondents receive different (and shorter) versions of the survey. Table 2-1 summarizes the pre-testing for the residential study.

Table 2-1. Summary of Residential Study

Customer Class	Test Description	Test Type	Purpose	Scale
Residential	Outage scenario and solution descriptions	Cognitive testing	Understand scenario descriptions	Several rounds of 10-15 interviews
		Small-scale testing	Determine important contextual factors	270 in region-specific blocks of 30
			Understand scenarios	120 short duration; blocks of 30
				120 long duration; blocks of 30
				120 combination of short and long; blocks of 30
			Understand solutions	3 rounds of 10-15 interviews
				120 - blocks of 30
	Assessing customer actions in response to outages and their direct costs	Cognitive testing	Understand questions	3 rounds of 10-15 interviews
		Usability testing	Easily estimate outage costs	120 in 3 waves
	Eliciting WTP	SBDC exercise	Set WTP range for full-scale study	200
	Formal pre-test	Final pre-test of instrument	Completed in less than 30 minutes and no sequence effects	3 waves of 120
	Full-Scale Study			**4,500**

2.3 Full-Scale Study

2.3.1 Study Design

2.3.1.1 Sample size

The first objective of a sample design is to ensure that CICs estimated from the sample are representative of the interruption costs of the entire population. Random sampling—where each study subject has a predetermined, non-zero probability of being selected for observation—can achieve this first objective assuming reasonably high response rates are obtained during survey administration. The second objective of sample design is to identify the number of interruption cost observations in the sample required to ensure an acceptable level of statistical precision (i.e., the number of observations required to achieve a given sampling error rate in estimating the population parameters from the sample parameters). In outage cost surveys, stratification is usually employed to enhance sampling precision.

2.3.1.2 Stratification

Sample stratification is useful when significant variation is present within subgroups of a population of interest. This is the case with interruption costs—which vary widely both between and within utility customer classes. Stratifying a sample serves two purposes. First, it improves the precision of the estimates. Second, it helps researchers obtain estimates for population parameters of interest which define the strata.

Prior surveying experience tells us that probability distributions of CICs are bimodal with long tails skewed to the right (i.e., a large fraction of customers report zero outage costs while a small but significant number of customers report extremely high costs). Customers with high interruption costs have a relatively low probability of being selected in a simple random sample. Consequently, outage cost distributions have unusually large variation and correspondingly require relatively large sample sizes to achieve reasonable sampling precision.

It is possible to reduce required sample sizes by stratifying the sample on a proxy variable that is known to be correlated with interruption costs. For example, in prior residential interruption cost surveys, samples have been stratified by annual usage, since annual usage has been shown in prior research to be correlated with residential customer outage costs. In these sample designs, customers with higher usage (and larger outage costs) are oversampled, thereby achieving higher levels of precision than can be achieved using a simple random sample of the entire population (Sullivan & Keane, 1995). This occurs because within-stratum variation is significantly smaller than the overall variation of a random, non-stratified sample of the entire population. The study team will not have information on annual usage, as it is utilizing a survey panel and not utility data for stratification purposes. However, survey panels generally have information on geographic location, dwelling type, household income and household size, which are correlated with consumption and outage costs. Some combination of these factors should be used in place of the commonly used energy consumption stratification variable to improve sampling precision.

In addition to increasing the precision of the estimates, stratifying a sample can reveal how certain population parameters impact interruption costs. For example, interruption costs may vary by geographical areas (e.g., urban vs. rural), type of dwelling unit (e.g., single family detached vs. multi-family), and for customers with different kinds of technologies like backup generation, rooftop solar or natural gas service. Stratifying the sample along these lines will not only increase precision (if the variation is significant), but allow the study team to describe how these different factors affect interruption costs on average.

Stratification Scheme

For residential customers, there is good reason to suspect that different regions of the country have different interruption costs. Different geographic regions can have different climates, which mean different heating, cooling, water heating, and other loads. Appliance and end use characteristics also vary by region. For example, electric heating is more common in the Southeast than in the West, where most households use natural gas. Table 2-2 shows the variation in average 1-hour interruption costs by region for customers represented in the ICE Calculator meta-database. Average costs vary from $3 to $9 for three different regions.

Table 2-2. Average 1-Hour Interruption Costs by Region from ICE Calculator Meta-Database: Residential Customers ($2019)

Region	Mean	Standard Deviation	Percentiles				
			5%	25%	50%	75%	95%
Northwest	$3.30	$6.60	$0	$0	$0	$3	$18.69
Southeast	$8.80	$13.19	$0	$0	$3.30	$11.00	$29.69
West	$6.60	$19.79	$0	$0	$1.10	$6.60	$31.89

This Roadmap proposes to stratify residential customers by geographic region for the full-scale study. As described earlier, the long-duration outage scenarios will be specific to each region. Thus, each stratum will have a different survey instrument. The study team can determine the best way to segment the U.S. for stratification based on the level of geographical data available from the survey panel. This Roadmap recommends using U.S. Census Regions and Divisions if possible, which the Energy Information Administration (EIA) uses to group state information. Figure 2-1 shows the U.S. divided into its four Census Regions and nine Census Divisions. This breakout should be able to capture the geographical differences in interruption costs from the factors outlined above. An additional benefit is that the results by Region or Division could be used in conjunction with data from EIA, which is reported at the same level.

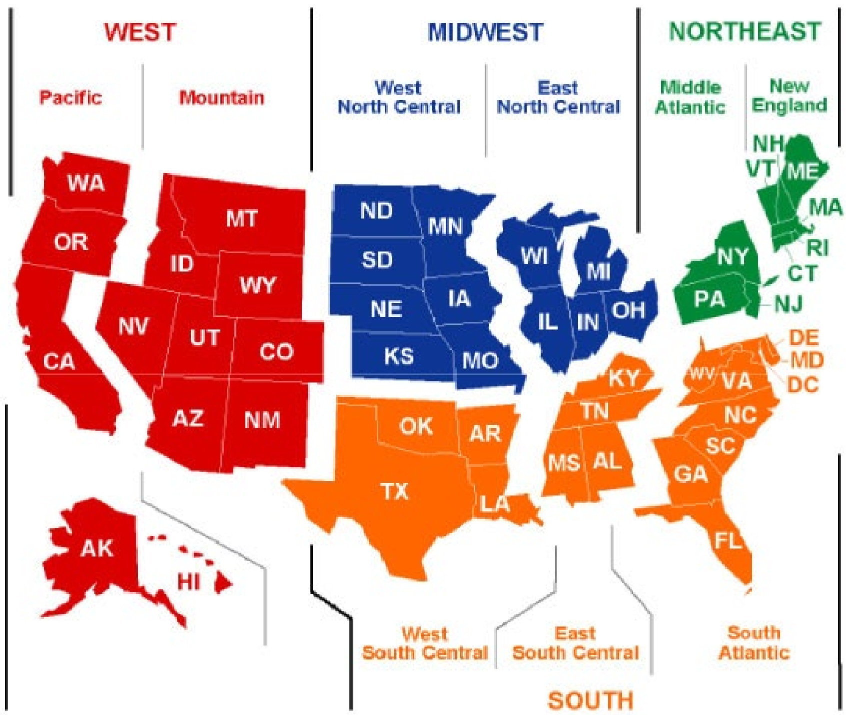

Figure 2-1. Census Divisions, as Used by EIA[9]

2.3.2 Implementation

Past CIC studies have been funded by utilities and supported by them during implementation. The implementation process generally involves preparing and sending recruitment material to sampled customers, fielding phone inquiries, arranging incentives, and trouble-shooting miscellaneous issues that arise throughout the course of the study. For a nationally curated survey panel managed by a single firm, the implementation phase will not involve utilities and will be under the control of the panel vendor. Nevertheless, it will be important for the panel vendor to align its sample management and survey contact protocols with the specific requirements of the national study.

2.3.2.1 Prepare for Implementation

Develop Recruitment Materials

The purpose of recruitment materials for CIC studies is to drive customers to the survey instrument and obtain a high response rate. The proposed design calls for using an existing nationwide survey panel. The recruitment strategy—including the initial introduction to the study and reminders for completing the survey—should comport with the established practices of the survey panel administrators.

At the beginning of the study, an introductory letter or email (depending on the survey panel practices) should be sent to potential respondents. The letter should contain information to accomplish the following objectives:

[9] https://www.eia.gov/consumption/residential/reports/2009/16-states.php

- Explain the purpose of the study, why it is important, and how the results will be used
- Inform the respondent who is conducting and sponsoring the study
- Reassure potential respondents that their responses will be kept confidential and not associated with their personal information
- Remind customers to complete the study

The study team will submit the survey instrument to the survey panel administrator to program into its online survey tool. When the programming has been completed, the study team should carefully review the online tool, making sure that the questions have been properly installed and that the skip logic and flying computations are correct. The online instrument should require responses to the hypothetical WTP questions and not allow respondents to skip through them to complete the survey faster.

2.3.2.2 Conduct Formal Pre-test and Full-Scale Study

The study team can authorize the release of the survey to the panel once the online instrument has been thoroughly reviewed and tested. Members of the panel should be sent the introductory communication when the study goes live and they are asked to take the survey. The pre-test can confirm the effectiveness of the communications materials and protocols. It will also test how long it takes respondents to complete the survey and thus allow the study team to remove questions if needed prior to the full-scale study.

2.3.3 Analysis of Survey Results

The survey yields a set of outage cost estimates with specific interruption start times and durations. To be able to apply the results to other customers and for interruptions with different characteristics, it is necessary to develop customer damage functions. Customer damage functions relate interruption costs to a set of variables describing the interruption attributes, customer characteristics and environmental attributes. Results from OHDC survey questions are analyzed using maximum likelihood estimation (MLE) for interval-censored data (Cooper, Hanemann, & Signorello, 2002).

The open-ended direct cost results will use a two-step approach, which has proven to be effective for estimating customer damage functions (Sullivan, Mercurio, & Schellenberg, 2009). The first step involves estimating the latent probability that customers experience a non-zero interruption cost using a probit model, based on a set of independent predictor variables related to the interruption, the customer, and the environment. The model estimates and retains these probabilities. In the second part of the approach, a Generalized Linear Model (GLM) relates outage costs to a set of independent variables only for those customers who reported interruption costs greater than zero in part one.[10] The second step involves estimating interruption costs for all customers—even those customers who

[10] A GLM model specification, which uses maximum likelihood estimation, is more appropriate than ordinary least square (OLS) for specifying the customer damage function due to the nature of the interruption cost data. GLM does not assume a linear relationship between interruption cost and the independent variables, but it does assume linear relationship between the transformed interruption cost in terms of the link function and the explanatory variables. The link function for the customer damage function (CDF) is a log link function, due to the zero-value bound to the left and the long tail to the right.

reported zero cost values. Finally, multiplying the probabilities from step one by the interruption cost estimates generated during step two produces the final interruption cost estimates.

The MLE (for WTP), probit and GLM models each use a set of independent variables which describe the characteristics of the customers and outage scenarios. The study team will have to determine the actual sets of variables for each model. Out-of-sample testing is a useful procedure for selecting and validating the best econometric model for each customer segment. Using out-of-sample testing, the CIC study team should experiment with different model specifications and estimate each model while withholding 25% of the data from the regression. To select the final model, the team should compare the out-of-sample predicted interruption costs from each model with the reported interruption costs to see which performs best. Sullivan et al. (2009) and Sullivan et al. (2012) report potential explanatory variables including, but not limited to:

- *Interruption attributes*: interruption duration, season, time of day, and day of the week during which the interruption occurs.
- *Customer characteristics:* customer type, customer size, business hours, industry group, multifamily (residential)/multi-tenant (C&I) facility, household family structure, presence of interruption-sensitive equipment, presence of back-up equipment, experienced interruption in last 12 months.
- *Environmental attributes:* temperature, humidity, storm frequency and other external/climate conditions.

The analysis will yield interruption costs and a customer damage function for both the WTP and direct cost results. The interruption costs can be expressed in terms of the metrics described in Section 1 and the damage functions will provide insight into the association between interruption costs and the interruption, customer, and environmental factors listed above. The results will also indicate the relative magnitude of WTP and direct costs across different interruption durations. The hypothesis is that the WTP results will be larger than the direct cost results for short-duration outages and that direct cost results will be larger than WTP for long-duration outages. Short-duration interruptions may be inconvenient, but inconvenience does not always lead to households needing to incur direct costs to cope with the loss of power. Long-duration interruptions can cause households to suffer more tangible losses (e.g. losing the content of their refrigerators) and also compel them to incur costs for adapting to the loss of power (e.g. relocating family members), as discussed in Section 2.1.1. The results of the study will provide information into the relationship between these two types of costs.

3. Non-Residential: Small and Medium Customers

This section outlines a proposal for conducting a national study of CICs for small and medium non-residential customers, defined as utility customers whose peak demand is less than 500kW. The study will use customer surveys addressing both short- and long-duration interruptions. The results of the short-duration component will fill in the geographical data gap in the current version of the ICE Calculator. The long-duration component will 1) generate CIC estimates of direct costs and 2) generate information to help researchers inform regional economic models (REMs), which are necessary for capturing indirect costs (i.e. the connections between businesses and industries and the cascading economic effects of power outages). The surveys will ask questions that modelers may find useful for parameterizing the REMs to make them more accurate.

Section 3.1 covers the background of the current state of the methodology and survey issues. Section 3.2 details the proposed survey modification and testing. Section 3.3 describes the framework of the full-scale study and the analysis of results.

3.1 Background and Proposed Sample Frame

Non-residential customers' interruption costs, unlike those of residential customers, are measured only with a direct cost methodology. Their costs are not elicited via CV, as the magnitude of direct costs they incur from tangible factors such as loss of revenue far exceed any intangible costs. This section covers the current state of the methodology for measuring direct costs for both short-duration and long-duration outages. The biggest issues for this customer class are ensuring an adequate response rate and that respondents understand the questions. This section discusses those issues and Section 3.2 discusses potential tests to address them.

3.1.1 Direct Cost Survey Methodology

Section 2.1.1 detailed the differences between short-duration and long-duration interruptions[11]—along with the implications for measuring interruption costs. The SMNR survey instruments will measure direct costs of both short-duration and long-duration interruptions. Researchers determine the direct economic cost of interruptions to non-residential customers (*i*) by asking about specific costs incurred and savings realized related to a set of hypothetical power interruption scenarios (*s*)—then summing them over all *n* customers to find the total direct cost under each scenario (*s*). Equation 3-1 depicts this relationship.

[11] To reiterate, short-duration interruptions are assumed to be 24 hours or less, while long-duration interruptions are greater than 24 hours.

Equation 3-1. Direct Cost of Interruptions for Non-Residential Customers

$$\boldsymbol{Direct\ Cost_s} = \sum_{i=1}^{n} (\boldsymbol{VLP_{is}} + \boldsymbol{IRC_{is}} - \boldsymbol{IRS_{is}})$$

where:

- VLP is the value of lost production
- IRC is the set of interruption-related costs
- IRS is the set of interruption-related savings.

The following paragraphs discuss each component of the direct cost equation separately, focusing on information typically collected from businesses.

Value of Lost Production (VLP)

Value of lost production is the amount of revenue the surveyed business would have generated in the absence of the interruption minus the amount of revenue it is able to generate given that the interruption occurred. In short, VLP is a business' net loss in the economic value of production after accounting for its ability to make up for lost production. VLP includes the entire cost of making or selling the product as well as any profit it could have made from the production.

Certain types of non-residential customers do not generate revenue and thus the method for quantifying the value of lost production must be modified. Government institutions and schools are the two main types of customers in this category. These entities operate on budgets funded by taxpayers and "produce" public services for which they do not collect revenue (or at least not at the level of the full cost of the good or service). To measure the cost of the interruption, the methodology for this specific type of customer would use the operating budget of the entity as a proxy for the value of lost production.

Annual budgets for government agencies (specific to a particular facility) are generally easily accessible and sometimes publicly available. The value of lost production should be the portion of the annual budget corresponding to the amount of time of that the facility is impacted by the interruption. Equation 3-2 shows the calculation for VLP for governments and schools (and other public entities that do not generate revenue).

Equation 3-2. Value of Lost Production for Government Facilities and Schools

$$Value\ of\ Lost\ Production = Annual\ Budget\left(\frac{\$}{year}\right) \div OH\frac{hours}{year} \times Hours\ Affected$$

where:

- OH is the number of operating hours per year

For example, consider a facility with operating hours from 9am to 5pm on weekdays and a $5 million annual budget. Assume this facility experienced a three-hour interruption, but the facility would cease to operate for a total of four hours because it would take one hour to recover. The VLP would be:

$5 million/year ÷ 2080 operating hours/year x 4 hours = $9,615

Interruption-Related Costs (IRC)

Interruption-related costs are additional production costs directly incurred because of the interruption. Interruption-related costs typically include:

- Damage to equipment
- Labor to make up any lost production
- Labor to restart the production process
- Material to restart the production process
- Costs resulting from damage to input feed stocks
- Costs of re-processing materials (if any); and
- Costs to operate backup generation equipment

Interruption-Related Savings (IRS)

Interruption-related savings are production cost savings resulting from the interruption. Businesses see savings from unused inputs when production or sales cannot occur. For example, if a soft drink bottling company experienced an interruption, the company may use less water during the interruption and thus save money on its water 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 study teams must measure them and subtract them from the other cost components to ensure they do not double count interruption costs. Savings include:

- Unpaid wages during the interruption (if any)
- Cost of raw materials not used because of the interruption
- Cost of fuel not used; and
- Scrap value of any damaged materials

Interruption cost calculations only include incremental losses resulting from unreliability, which are costs beyond the normal costs of production. If the customer is able to make up some percentage of its production loss at a later date (e.g., by running the production facility during times when it would normally be idle), the CIC estimate does not include the full value of the production loss. Rather, it is 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.

3.1.2 Indirect Cost Methodology for Long-Duration, Widespread Interruptions

Customer surveys are inadequate for estimating indirect costs related to all of the cascading impacts in a regional economy from a LDW interruption. For this reason, the authors believe it is more appropriate to use a combination of customer surveys and regional economic models to estimate interruption costs over longer durations. Regional economic models forecast changes in the output of economic sectors for a given geographical region from changes in inputs to sector level production functions defined either theoretically or empirically for the sectors in the model. These models project the output of economic sectors—not the output of individual firms or other entities that comprise them. While there are certain theoretical and technical drawbacks to using regional economic models to forecast interruption costs for regions (particularly small ones), these models are capable of projecting the direct and indirect costs of electric service interruptions.

There are several different types of REMs, including input-output (I-O) models, computable general equilibrium (CGE) models, and macro-economic models (see Sanstad (2016) for a thorough review of regional economic models). I-O models represent relationships, or flows, between industries. A system of linear equations represents how certain industries' outputs are the inputs for other industries, while other outputs become consumer goods. CGE models represent "all supplies and demands in an economy and both their direct and indirect market interactions" (Sanstad, 2016). Macro-economic models are systems of statistical forecasting equations based on historical time-series data (Sanstad, 2016).

Regional economic models can estimate how an economy reacts to external shocks, such as policies, technological change, and disruptions to energy supply (Larsen et al., 2018). They have been used to estimate the economic costs of catastrophic events such as earthquakes and hurricanes (Rose & Guha, Computable General Equilibrium Modeling of electric utility lifeline losses from earthquakes, 2004) (Rose, Benavides, Chang, Szczesniak, & Lim, 1997) (Mantell, Seneca, Lahr, & Irving, 2013). However, a recognized weakness in such models is that they are heavily assumption driven (Sanstad, 2016). Model results have been shown to be particularly sensitive to two classes of assumptions -- those regarding substitution elasticities, and those regarding actions firms can take to reschedule production or revise production practices to mitigate damages. These assumptions about the resilience of firms to economic shocks can make a large difference in the estimated cost of a catastrophic loss of electricity supply (Rose, Liao, & Oladosu, 2007).

This Roadmap proposes to use customer surveys to 1) estimate direct costs from long-duration interruptions and 2) collect information to calculate statistically defensible estimates of substitution elasticities. The direct cost estimates can be compared to the results of the REMs and could potentially be used to calibrate them. The surveys can also provide more concrete information regarding the ability of firms in different industries to sustain operations and recover from interruptions. Sanstad (2016) noted that integrating CIC survey data with economic data for regional economic models would facilitate model improvements. Sullivan et al. (2018) recommends advancing collaboration between researchers who use survey-based methods and those who develop regional economic models. This national survey of commercial and industrial customers provides a good opportunity for doing so.

For CGE models, Sue Wing (2018) suggested undertaking analytical work to transform the answers a researcher might receive in a national survey into elasticities of substitution capable of being slotted into an economic model. He developed a CGE model, which modeled firm behavior, including firms' ability to substitute alternative sources of power. Rose (2018) has focused research on firms who have experienced an actual LDW interruption and thus have actual data to share on their activities related to repair, restoration, and reconstruction. This study will explore whether a survey with hypothetical scenarios can capture valid information on these activities among firms that have not experienced a recent LDW interruption. Given that no future LDW interruption scenario will impact the same population in the same manner as any prior interruption, the ability to capture valid information for hypothetical LDW interruption scenarios would be a significant improvement in that it would allow for application of the results to any set of customers and conditions for which utilities expect to have a LDW interruption in the future.

3.1.3 Proposed Survey Instrument

This Roadmap proposes to use four separate survey instruments for SMNR customers:

- Survey 1: SMNR commercial and industrial customers
    - Direct cost elicitation for short-duration interruptions
    - Substitution elasticity questions for long-duration interruptions
- Survey 2: SMNR commercial and industrial customers
    - Direct cost elicitation for long-duration interruptions
    - Substitution elasticity questions for long-duration interruptions
- Survey 3: SMNR government and educational facilities
    - Direct cost elicitation for short-duration interruptions
    - Substitution elasticity questions for long-duration interruptions
- Survey 4: SMNR government and educational facilities
    - Direct cost elicitation for long-duration interruptions
    - Substitution elasticity questions for long-duration interruptions

Each respondent would receive only one of the instruments to complete, as including direct cost elicitation questions for both short- and long-duration interruptions in one survey instrument would be a large burden for the respondent and could cause survey fatigue and lower completion rates.

The sections of the SMNR surveys are similar to those of the residential survey, but the specific elicitation questions are different. Survey 1 (direct cost of short duration interruptions) (Appendix B) begins with an introductory section to ground respondents to previous interruption experiences. The second section of the survey introduces the interruption scenarios. It should contain no more than 4 or 5 hypothetical scenarios to elicit costs. After describing each scenario, the survey instrument asks a series of questions in order to obtain cost estimates for the different elements of the business' cost equation: labor costs, direct damage costs, other tangible costs, etc. The survey instrument then asks the respondent to estimate the overall interruption cost—under each scenario—using a range of possibilities: best case, typical case, and worst case. It should be noted that the survey only asks the SMNR customers to provide their best, typical, and worst case estimates for the total cost—not for each cost element. Asking the customers to provide detailed interruption cost information for only the first scenario significantly reduces the burden of the survey exercise, leads to higher completion rates, and customers staying focused on the estimation scenarios. The study team should analyze the survey results using the 'typical case' scenario. The best and worst case scenarios still provide a purpose by giving respondents the opportunity to express the uncertainty associated with their individual CIC estimate. Researchers believe that this process produces improves estimates for the 'typical case' response.

The third section contains questions intended to help developers of regional economic models. These questions inquire about the ability of the business to adapt to a LDW outage. They focus on whether the facility generates any of its own electricity, the presence of backup generation, the ability to work remotely, and the ability to relocate work. This section ends with two hypothetical LDW outage scenarios. For these scenarios, the survey does not ask the respondent to estimate costs from the outage, but instead asks several questions related to substitution elasticity and adaptability: whether the company would close as a result of the outage, whether it would relocate temporarily, the impact to labor, and the impact to revenue.

Survey 2 (direct cost of long-duration interruptions) (Appendix C) does not ground customers to past outage experiences as intently as Survey 1. The reason for this is that most customers have not experienced interruptions lasting longer than one day. Instead, this section contains demographic questions along with the adaptation questions intended to help developers of regional economic models. Asking these questions before the long-duration elicitation scenarios should help respondents get in the right mindset and improve the accuracy of their responses.

The next section of the survey elicits direct costs for three hypothetical long-duration interruptions. They follow a similar format as the short-duration interruptions. Given the range of durations (24 hours, 1 week, and 2 weeks), the instrument asks respondents to itemize costs for each scenario.

Surveys 3 and 4 (Appendices D and E) are similar to Surveys 1 and 2 but are designed for government and educational facilities. As such, they do not ask questions about lost revenue. Instead, they ask about the operating budget in order to estimate the value of lost production using the budget as a proxy.

3.1.4 Proposed Sample Frame: National Study Partnership

This Roadmap proposes to solicit utilities in each region to join a 'national study Partnership' (henceforth "Partnership"). Utilities who join the Partnership would agree to:

- Allow the study team to solicit their customers to take the survey
- Allow the use of their branding to give legitimacy to the study and boost response rates
- Provide customer data needed to design the sample and recruit respondents
- Provide partial funding for the study
- Leverage utility account representative relationships with customers (if applicable)
- Pre-approve a set of draft customer communications.

In return for performing the actions above, Partnership utilities will receive a report describing the results of the survey for their participating customers as well as the interruption cost estimates provided by their customers who completed the survey. Utilities will be asked to provide only minimal funding needed to support field data collection efforts and in return will receive valuable information for describing the economic impacts of their investments in reliability/resilience.

The benefits to the study team of having utility data are substantial. Interruption costs are correlated with electricity consumption and both of these values are highly variable for non-residential customers (Sullivan et al., 2018). Without electricity consumption data, the study team would not have a good variable to use for stratifying the sample. In addition, utilities have a dataset of businesses that includes customer contact information. The availability of electricity consumption data for each respondent also significantly improves modeling of interruption cost survey data for the purposes of updating the underlying econometric models in the ICE Calculator and other utility planning tools. Without accurate electricity consumption data for non-residential utility customers, the broader applicability of utility planning tools that rely on modeling of interruption cost survey responses is limited.

In past utility-funded CIC studies, the utility and the third-party study team work together to draft a set of customer communications that the utility is comfortable sending to its customers. Given the number of utilities that will be involved in a national study Partnership, coordinating utility revisions and approvals would be very time consuming and challenging. Instead, while the customer communications will use utility branding and logos, Partnership utilities will be required to pre-approve the content of customer contact collateral as a condition of participation in the Partnership.

The study will benefit from the Partnership arrangement for the recruitment process as well. The Partnership utilities will send an introductory letter and email explaining that they are participating in an important study of CICs sponsored by the U.S. Department of Energy. It will ask the customer to take the survey and answer questions regarding the costs they experience as a result of interruptions. After sending a letter and email, recruitment will be completed via telephone by the survey administrator (not the utility) so that the best person for taking the study (i.e. has the highest knowledge base) is identified and recruited. Businesses are more likely to answer survey questions that are about them and their immediate community than they are for a national study with no connection to the utility.

3.1.5 Issues with Current Methodology

The current SMNR survey methodology faces several challenges. The key challenge is obtaining an adequate response rate while balancing the other considerations of the study, including representativeness, survey length, and response validity and reliability.

The general approach to surveying SMNR customers has changed very little over the last two decades. It is a multi-mode survey protocol in which the sampled business is first contacted by telephone to identify an appropriate person at the business to answer the survey. In a second step, the survey form containing the survey questions (or more recently an internet URL) is sent by mail (or more recently by email) to the business manager. This two-step process is necessary because the survey requests information that can only be reliably supplied by a person who is knowledgeable about the operating costs and revenues associated with the facility of interest.

Over the past two decades, response rates to all survey modes (i.e., telephone, mail and in-person) have declined substantially. With the emergence of automated attendants and voicemail, it is increasingly difficult to directly reach targeted respondents at businesses to recruit them. When VOS surveys of SMNR customers began in earnest in the early 1990s it was possible to contact and recruit about 80% of business managers to undertake a VOS survey. In recent surveys, fewer than 25% of business managers can be recruited in this manner.

Response rates to the second step mail or internet survey have also declined significantly over the period. In the 1990s, more than 70% of business managers who agreed to answer the survey questions about interruption costs returned their surveys. Today, fewer than 25% of survey forms provided to business managers are returned after repeated reminders and including a $50 contingent incentive.[12]

Declining response rates to both survey modes has led to a significant increase in survey cost and raises significant concerns about the representativeness of survey responses that are eventually obtained with the current methodology. For these reasons, it is appropriate and necessary to identify adjustments to the survey methodology to improve response rates to the survey. It is probably impossible to significantly improve the response rate to the first step in the process (i.e., initial contact with the business manager) because modern business communications systems are designed to protect business managers from outside distractions such as surveyors or sales personnel. However, it may be possible to significantly improve the response rate to the second step (completion of the survey form) by increasing economic incentives for completing the survey and improving the usability of the survey form to reduce the difficulty involved in completing it.

3.2 Survey Modification and Testing

The pre-test will test survey design and delivery alternatives in preparation for the national study. It should test that respondents understand the outage circumstances, similar to the residential pre-test. It should also be designed to improve response rates while maintaining representativeness of the sample and collecting as much information as is reasonable and feasible.

1) Outage Scenario Descriptions

As was the case with the Residential Study, cognitive testing should be completed to ensure that SMNR customers understand the scenario descriptions and are not confused by the presentation of multiple outage descriptions—particularly given the presence of both short and long-duration outage scenarios. Cognitive testing of the outage descriptions should be conducted until the stimulus is demonstrated to be well understood by potential respondents. Based on experience, this should require several rounds

[12] Based on authors' experience conducting VOS studies.

(allowing for making changes to the stimulus) of 10-15 cognitive interviews.

After the cognitive interviews, small scale on-line tests of respondents' ability to understand scenarios should include:

- 120 respondents for direct costs of short duration outages;
- 120 respondents for direct costs of long duration outages;
- 120 respondents testing combinations of direct cost for short duration outages and elasticities for long duration outages.

Small scale online tests of respondents' ability to understand survey questions should include:

- 120 respondents for components of direct cost. Should pay particular attention to non-residential customers whose business is not producing or selling widgets, e.g. government facilities and organizations.

Similar to the residential test, the SMNR tests should be conducted in blocks of 30 designed to tune the stimuli, ensuring recollection of scenario details, ability of respondents to describe impacts, and ease of transition from one outage description to another when multiple outage scenarios are presented in sequence. The sample size of 120 would allow four blocks of 30 subjects each.

2) Response Rates

As indicated above, the effort to improve response rates to the survey should focus on improving the response to the mail/internet component of the survey. A beginning point to improving the response to this element of the survey should be cognitive testing designed to identify why respondents are deciding not to complete the survey form. Are respondents concerned about revealing proprietary information? Are the questions that are being posed too difficult to answer? Is the survey form too boring or too repetitive? The answers to these questions will lead to potentially significant changes in the design of the survey form that should be refined in the cognitive testing process. Based on experience, this should require several rounds (allowing for making changes to the stimulus) of 10-15 cognitive interviews.

Once the surveys have been revised according to the results of the cognitive testing process, the survey team should optimize the response rate to the survey by testing the impacts of three key factors on response rates. These factors are survey length, delivery method and financial incentives:

- Survey length: the SMNR survey instrument in Sullivan et al. (2018) was designed to measure short-duration interruption costs using six hypothetical scenarios. The survey also contains questions about firm demographics, experience with outages, and satisfaction. It can sometimes take 25 minutes for the respondent to complete when outages have impacts to multiple components of the production cycle and must be carefully considered. It thus can place a significant burden on respondents. The survey instrument for the national study will include not only hypothetical short-duration scenarios but also questions relevant to long-duration outages. It will thus be critical to streamline the survey and determine how many outage scenarios respondents can reasonably answer after removing any questions that are not essential to the analysis.

- Delivery method: the survey team has several options for how to deliver the survey. Current protocols (described further in Section 3.3) call for the survey administrators to identify by telephone the appropriate person to complete the survey. Once the appropriate person is reached, there are several options for delivering the survey, including emailing a link to an online survey instrument, mailing a paper survey, and walking the respondent through the survey over the phone. The online instrument has several advantages over the conventional paper and telephone interviewing protocol arising from the fact that significant online computational aids can be provided in an online version and survey forms can be customized "on the fly" to target different kinds of businesses that have different cost structures (i.e., different outage cost questions for retail stores, restaurants, schools and other service establishments).
- Incentives: increasing the incentives offered to business managers to deliver the survey will undoubtedly increase response rates. The question is: how much must incentives be raised (from their current level of $50) in order to substantially increase response rates?

The study team should complete small-scale testing of survey length, delivery method, and incentive amount to measure impact on response rates. It should test two different survey lengths (varying the number of scenarios), two delivery methods (completion over the phone and emailing the survey link), and three incentive amounts ($75, $150, $200). The study should use an orthogonal design over the three parameters to determine the impact of each parameter on response rate.

- 120 respondents for survey length
    - 60 shorter surveys (10-15 minutes)
    - 60 regular length surveys (20-25 minutes)
- 120 respondents for delivery method
    - 60 encouraged to complete over telephone
    - 60 completion via emailing link
- 300 respondents at 3 increasing levels of incentives
    - 100 regular length surveys at $75
    - 100 regular length surveys at $150
    - 100 regular length surveys at $200

Table 3-1 summarizes the pre-tests for the SMNR phase of the study. These tests will also serve to help the study team understand the quality of the utilities' customer contact information. If response rates are too low using customer contact information obtained from utilities in the national study Partnership, the study team could consider alternative sample frames, such as working with industry groups and chambers of commerce to conduct the study.

Table 3-1. Study Summary for SMNR

Customer Class	Test Description	Test Type	Purpose	Scale
Small/medium non-residential	Outage scenario descriptions	Cognitive Testing	Understand scenario descriptions	Several rounds of 10-15 interviews
		Small-Scale Testing	Understand scenarios	120 for short duration direct cost
				120 for long duration direct cost
				120 for combo of short duration direct cost and long duration elasticities
	Elicitation questions	Small-Scale Testing	Understand survey questions	120 - blocks of 30
	Response rate	Cognitive Testing	Reason for not completing survey	Several rounds of 10-15 interviews
		Small-Scale Testing	Ensure adequate response rate	120 for survey length (60 shorter surveys / 60 standard length surveys)
				120 for delivery method (60 via telephone / 60 via email link)
				300 for incentive level (100 each at $75, $150, $200)
	Formal pre-test	Final pre-test of instrument	Response rate and implementation protocols	200
	Full-Scale Study			**5,000**

3.3 Full-Scale Study / Study Details

This sections describes the communications plan and contacting protocols for the full-scale study. These protocols have been used in previous interruption cost studies conducted at single utilities. They should be modified as needed based on the results of the small-scale testing. In addition, once the study team and survey administrators are ready, the survey should be formally pre-tested with a sample of 200 as a final preparation for the full-scale study.

3.3.1 Prepare Standardized Communications Content and Survey Instrument

The study team will prepare drafts of all of the recruitment materials, as well as the survey instrument itself, prior to soliciting utilities to join the national study Partnership. A condition of joining the Partnership will be an approval of the communications content and strategy—and an understanding that any changes to the communications they request will be minimal.

Table 3-2 contains a list of the draft materials that the study team will need to prepare. The objective of the recruitment material is to leverage the utility brands as much as possible, in order to add credibility to the study (in the eyes of the customers) and thus boost the response rate. The table indicates the mode of each customer communication in the “Type” column: paper mail, email, or phone script. The “Detail” column gives information on what is contained in the communication item. The “Letterhead/Logo” column indicates whether the communication contains the logo and brand of the utility or the implementer. Most materials contain the utility logos, with the exception of the email sent directly to the contact at the customer's organization who is identified as the appropriate person to complete the survey. The "Signed" column shows whose signature will appear at the bottom of the communication, even though each item will be sent by the implementer and not the utility itself. For the initial drafts of the materials, the main objective is to develop the proper content and messaging that the utility will be comfortable with. The study team can use placeholders for anything needed from the utility, such as logos, signature names, and signature images. The signature name and image should be that of a manager at the utility who has some involvement with the study and who could be available to field infrequent calls from concerned customers. Having the signature from an actual manager adds credibility to the study, but, from past experience, it is rare to have customers call the number and ask to speak to the manager.

The "Approximate Timing" column shows when during the implementation process the communication would be sent. The study team can either decide to send all introductory letters out at once, then follow-up with an intensive phone recruitment process, or stagger the introductory communications in waves, with a series of lower-volume phone recruitment efforts. The "Need from the Utility" column indicates what information or files are needed from the utility to finalize the communication.

The itemized explanations below give more detail about each piece of communication in Table 3-2:

1: Introduction to the study	• One version is a paper letter (for all customers) and one version is an email (for customers with email addresses on file at the utility). It explains the purpose of the study and its importance, and notifies customers that a third party research firm will be contacting them about taking a survey. It requests customers' participation, informs them of the incentive ($75 or more), gives them the phone number of the survey administrator to obtain a copy of the survey, and also provides them a phone number at the utility to call and verify the legitimacy of the study.
2: Initial recruitment call script	• The survey administrator will use this script when calling customers to identify the proper person to take the survey and to recruit them to do so. Part of the script should be designed to help the phone rep determine whether the premise is master-metered and should thus be excluded from this phase of the study.
3: First email with link	• The phone rep sends this email to the customer after speaking with them on the phone, confirming they are the appropriate person to take the survey, and obtaining their email address. The email contains a direct link to the specific version of the survey for that customer.
4: Paper survey package	• The survey package is sent to customers who specifically request a paper copy of the survey to complete. It includes the survey instrument and a return envelope addressed to the survey administrator—either stamped or labeled with "No Postage Necessary."
5: Reminder email	• The survey administrator sends this email to the customer one week after sending the first email if the customer has not completed the survey. The email contains a direct link to the specific version of the survey for that customer.
6: Reminder call script	• This item is a short phone script for the survey administrator to use to remind customers to complete the survey. The survey administrators should call the customer one week after sending the reminder email and ten days after sending the paper survey if they still have not completed it. They are can also choose to make reminder phone calls as needed after this point to try to boost response rates.
7: Incentive	• One letter would be addressed to the customer and thank them for their participation. The second version of the letter would be addressed to the charity that the customer chooses and would explain why they are receiving a check. The incentive check will have the branding of the survey administrator. The envelope should have the utility logo.

Table 3-2. Customer Communications Materials for Small/Medium Non-Residential

Item	Item No.	Type	Detail	Letterhead/ Logo	Signed	Approximate Timing	Need from Utility	Utility Decisions
1	1a	Paper Mail	One-page letter introducing study and providing phone number	Utility	Utility manager	Day 1	• Format • Font • Logo or letterhead • Signature image	Manager for signature and phone number
	1b	Envelope	#10 White envelope	Utility	-		• Either printed envelopes or format, font, and logo specs	-
	1c	Email	Email explaining study and providing phone number	Utility			• Format • Font • Logo or letterhead • Signature image	Manager for signature and phone number
2	2	Phone	Initial recruitment call script	N/A	-	Within 2 weeks of sending letter	-	-
3	3	Email	1st Email with Link	Implementer (or no logo)	Implementer	Upon contacting customer	-	-
4	4a	Paper Mail	Paper Survey (if requested)	Utility	Utility manager	Upon contacting customer (if customer requests paper survey via mail)	• Logo • Signature image	Manager for signature and phone number (same manager as Item 1)
	4b	Envelope	#10 White envelope	Utility	-		• Either printed envelopes or format, font, and logo specs	-
	4c	Return Envelope	#9 White envelope addressed to implementer	-	-		-	-
5	5	Email	Reminder email	Implementer "on behalf of utility"	Implementer	1 week after 1st email	-	-
6	6	Phone	Reminder call(s)	N/A	-	1 week after 2nd email (and afterwards as needed)	-	-
7	7a	Paper mail	Thank-you letter to customer accompanying incentive check	Utility	Utility manager	Upon completion of survey	• Logo • Signature image	Manager for signature
	7b	Paper Mail	Letter to charity accompanying incentive check	Utility	Utility manager		• Logo • Signature image	Manager for signature
	7c	Check	Incentive check	Implementer (or none)	Implementer		-	-
	7d	Envelope	#10 White envelope	Utility	-		• Envelopes, or: • Format, font, logo	

3.3.2 Sample Design

3.3.2.1 Sample Size and Stratification

This roadmap proposes using a sample size of 5,000 for the full-scale study. The study team will need to revisit this target with stakeholders (e.g., Partnership utilities) upon commencing the study to make sure the final target is adequate for the sample design and expected precision. As with residential customers (see Section 2), different regions of the country likely have different interruption costs. They also have different inherent factors of what could potentially cause a LDW outage and what the experience of residents would be for such an outage. This Roadmap proposes to stratify SMNR customers first by geographic region and next by estimated interruption costs. The study team should use the same geographical strata—the nine U.S. Census Divisions—as it used for residential customers. Table 3-3 shows the variation in average 1-hour interruption costs by region for customers represented in the ICE Calculator meta-database. The sample size target for each region would be roughly 550 for the full-scale study.

Estimated interruption costs will form the basis for the second stratification. Sullivan et al. (2018) notes that three to five strata has been shown from past analyses to keep the standard deviation of estimate interruption costs low while mitigating the added complexity to study implementation of increasing the number of strata. This Roadmap recommends four strata for each geographical region. The study team will have consumption data from the utilities participating in the Partnership, which it can use for sample design. It can use the underlying econometric models from the ICE Calculator to generate individual CIC estimates—and use these estimates to stratify the customers within each region in the sample. The econometric models use consumption to estimate interruption costs.

The authors recommend that the study team employ a two-step process to achieve an optimal stratification scheme. In the first step, the team identifies optimal stratum boundaries using the Dalenius-Hodges method. The Dalenius-Hodges method determines the optimal endpoints for the strata given a predefined number of strata (1959). Next, the team should use the Neyman allocation, which uses these strata boundaries to establish the optimal number of customers to sample from the final population in each stratum (Neyman, 1934). In the Neyman allocation, the sample is drawn proportionally to the estimated variation in interruption costs across strata. This two-step approach is particularly useful for measuring skewed populations and will maximize survey precision for a given sample size and number of strata (Sullivan et al., 2018).

Table 3-3. Average 1-Hour Interruption Costs by Region from ICE Calculator Meta-Database: Small Commercial & Industrial Customers ($2019)

Region	Mean	Standard Deviation	Percentiles				
			5%	25%	50%	75%	95%
Midwest	$853	$2,463	$0	$0	$129	$689	$3,445
Northwest	$427	$1,627	$0	$0	$0	$292	$1,756
Southeast	$865	$2,908	$0	$0	$0	$559	$4,052
Southwest	$1,016	$3,021	$0	$0	$71	$716	$4,830
West	$820	$2,377	$0	$0	$128	$637	$3,822

Response rates for SMNR customers will depend on the quality of the contact information obtained from the utilities and the ability of the survey implementers to recruit customers to take the survey. The study team should assume a response rate of 10 percent for the pre-test and pull a sample of 2,000 customers (10 percent of 2,000 yields 200 completes). If the study team finds that the response rate for SMNR is higher than 10 percent, it can adjust accordingly for the full-scale study to save costs on recruitment materials and data handling. The study team may find that certain regions of the country have different response rates than others. It can adjust response rate assumptions by region for the full-scale study. If the 10 percent estimate holds true during the pre-test, the study team will need to pull a sample of 50,000 (10x) for the full-scale study.

The study team should look to exclude master-metered buildings from the sample design process. Interruption costs for these customers will be estimated in a separate phase of the study, as described in Section 5. There are two main types of master-metered buildings. First, master-metered buildings could be managed by a SMNR customer but have residential tenants. For these customers, interruption costs can be estimated using the results from the residential study. Second, master-metered buildings may have non-residential tenants. These will be estimated using the method described in Section 5. Master-metered buildings can be identified in several different ways.

- Some utilities have data that indicates whether a premise is master-metered.
- Utility data with NAICS or SIC codes indicating that the company is a property manager—and for which there are no similar service addresses.
- During study implementation, phone script contains language to identify property managers who pay the entire cost of electricity for the building to the utility

3.3.2.2 Aggregating Customer Site-Level Data

Each utility has its own system for identifying customers, accounts and premises using identification numbers. Data from the utility will thus include several customer identification numbers. The study team will have the objective during the sample design process of creating an identification system that uniquely identifies a particular premise and which allows customers to understand the premise for which the survey is eliciting responses. Aggregating usage for each unique combination of customer + service address allows both of these objectives to be met. The study team should create a unique identification number of each customer + service address combination.

The premise could consist of multiple service points with each service point on a different rate. This is the case particularly with larger, non-residential customers. For example, a manufacturing plant may have several service points, including a standard voltage line to front offices, standard voltage—but higher usage—lines to a warehouse, and one or more higher voltage lines to the processing area. Each service point at this particular service address could be on a different rate. The customer will be familiar with the service address and should be able to answer questions related to economic impacts from interruptions to the entire service address. Customers are less likely to know the identification numbers corresponding to each service point at that address.

Utilities often have a premise or site number that indicates the physical location of the service and remains constant when the facility owner or occupant changes. It is not uncommon for one service address to have multiple premise identifiers. This unfortunately can lead to confusion for a survey respondent: they would likely be unable to give estimates for a premise number and if the survey asked for estimates for the corresponding service address, the usage associated with the response would be incomplete (another premise number would be associated with additional usage for the service address).

The aggregation process is not straightforward in all cases and the study team will need to be prepared for potential issues. For example, in some cases, a property manager may be leasing to tenants who each pay the utility for electricity. The property manager may also have a service account for the building common area (for which it pays the bill) along with other service points, which may or may not be classified as separate service addresses. For example, a property manager or home owners association could be paying the bill for the common area of the service address '123 Main Street,' along with a vacant unit (e.g. 123 Main Street #5), and separate common area with pool pumps (e.g. 123 Main Street Pumps). If it received a survey for '123 Main Street,' it may assume that it should include the vacant unit and pool pumps in its response. The study team should do its best to ensure that the aggregation process maintains the integrity of customer + service address level combinations while allowing the customer to understand which facilities and/or service points to include in its survey responses.

The study team should drop certain customers from the sample before drawing the sample. Low response rates can be an issue with SMNR customers and the study team should do everything it can to increase the probability that it is sampling accounts where there are individuals who could potentially engage with the study team on behalf of the sampled entity. First, the study team should drop any inactive accounts and accounts without proper numerical identification numbers. This indicates bad data and likely bad contact information as well. Second, it should drop any customers if there is any indication (e.g., rate) that it is an account for street or outdoor lighting. Third, it should drop customers with zero consumption over the previous 12 months and any other level of consumption low enough to indicate a low probability of response. The study team should examine the distribution of interruption costs to make the determination of what this threshold should be. Previous studies have found that 0.25 kW average hourly usage is a reasonable threshold for small/medium non-residential customers.

3.3.2.3 Data Requests from Partnership Utilities

The study team will need to submit at least two data requests to Partnership utilities for sample design and implementation. The first data request will be to obtain customer data for designing the sample. This request will include the variables necessary for estimating interruption costs using the ICE Calculator equations, including one year of consumption and industry type—usually as a NAICS or SIC code. It should also include maximum demand so that the study team can verify that the customer is indeed considered small/medium (i.e., peak demand is less than 500 kW). The study team should also request that Partnership utilities include all customer identification numbers. Utilities have different systems for identifying customers and different names for variables, so the study team should request all identification associated with the customer, such as the account number, service point, premise, customer number, etc. The data request should also include whether a building is master-metered if this is an option for the utility.

The second data request will include the contact information from sampled customers for the purposes of recruitment. Recruitment will occur through mail, email and telephone, so the study team should request this information, along with any contact information specific to individuals at the SMNR business or organization who interact with the utility regarding the account. If the utility has any type of account coverage for the customers, it should also be included in the data request, as well as any other data fields that the utility believes could assist the study team with the recruitment process.

3.3.3 Prepare for Implementation

This section describes the steps that the study team and survey administrators will take to recruit Partnership utility customers and administer the survey. The steps apply to preparation for both the pre-test and full-scale study.

3.3.3.1 Finalize Communications Material and Obtain Approvals from Utilities

The general content of the draft materials will have already been approved by the utilities as a condition of joining the Partnership. To finalize the materials, the study team will need to obtain the files indicated in the “Need from Utility” column. The study team should coordinate preparation of the final drafts of the material, which would include putting the pre-approved content into the appropriate font and format, and adding utility artwork and/or letterhead where necessary. The study team will prepare a proof of each communications item and submit to each Partnership utility for approval.

The Partnership utilities will approve a final version of the recruitment materials and survey instrument. These documents will have mail merge fields as placeholders for customer-specific information (e.g. name, address, etc.) on the letters and for customer-specific survey info on the surveys (e.g. onset time, season, etc.). The introduction letters can be merged with the customer data to prepare to send. The emails can also be prepared—either by the survey administrator or the utility (depending on the arrangement)—and queued for sending when the study team is ready. Each customer will have an online version of the survey available for them to complete, but the survey administrators will only send the paper survey to customers who specifically request it. The SMNR surveys should thus only be printed on an as-needed basis. The study team should have discretion to determine the exact format for the paper survey. In the past, a booklet composed of 11x17-sized pages folded in half has worked well.

The study team has discretion to determine the appropriate mailing method for the survey. In previous studies, the survey administrator has used a #10 white envelope with a smaller #9 return envelope inside for the respondent to use to return the completed survey. It should have the logo of the utility and the return address should be for the survey implementer (with the permission of the utility). The return envelope could be stamped, or the survey administrator could use business reply mail, which is a service of the U.S. Postal Service (USPS) where it pays at a lower rate only for the surveys that respondents mail back.

3.3.3.2 Survey Administrator Preparations

There are several preparations the survey administrator will undertake apart from finalizing the recruitment and communications materials. The administrator should open and fund the incentive account and order check stock. Partnership utilities will likely help fund the study—including the incentives—but they will not cut the incentive checks themselves. Therefore, while the thank-you letter will likely be signed by the utility manager and branded with utility logos, the check itself (whether on a separate page or perforated on the same page) will not contain the utility brand and should thus be as non-descript as possible to avoid having another company's brand prominently displayed in a way that might confuse the respondent. The survey administrator should budget several weeks for this process to complete.

The survey administrator will program the survey instrument into an online format under a domain name that indicates it is a survey related to either the research team or a specific utility. The online survey's skip logic should require answers for the upfront questions and the interruption scenarios. Back-end questions about the data for the facility can be allowed to be skipped. After the survey administrator programs the survey instrument into the online format, the study team should test it for quality control. Partnership utilities can check the online instrument after any revisions by the study team.

The survey administrator will establish a toll-free help-line that respondents can call to obtain help in completing the survey. Incoming calls will include customers returning voicemails, customers who opened the survey and are asking technical questions, and customers who need someone to walk them through the entire survey.

3.3.3.3 Utility Preparations

Utilities can take a number of different steps to prepare its personnel and customers for the study, which can boost response rates. At a minimum, utilities should inform their customer contact center representatives when the study will occur, along with giving them high-level details about the purpose of the study, the presence of the third party survey administrator in conducting the study, and a number they can reach (either the utility manager or a member of the study team) where they can find more information about the study. Fully-informed contact center representatives will allow customers to quickly verify the legitimacy of the study. Other actions the Partnership utilities can take involve proactively informing customers about the study and encouraging anyone who is contacted to participate. In previous studies, utilities have posted a notice on the utility's website that they are conducting a study with a random sample of customers in case a customer is contacted by the survey administrator to take the survey. Utilities have also used regular newsletters to non-residential customers to inform them of the study.

Some utilities may have business account coverage models that have account representatives ("reps") assigned to some of the customers considered to be in the SMNR customer class. Generally, the large non-residential customers are much more likely to have an account representative, but some utilities have dedicated reps for smaller customers and some have a "lighter touch" coverage model where there may be a team of reps that handle inquiries from a larger group of customers. Whatever the model, if the Partnership utilities have a way to contact customers and speak with them about the study, they should use this connection to encourage them to participate.

3.3.3.4 Prepare Contact Protocols

The study team will need to finalize the customer contact protocols now that it has the contact information from the utility for the sampled customers. In particular, the study team should look for necessary exceptions to the general processes it established for survey recruitment. As discussed earlier, the study team should look to leverage the account coverage relationships that the Partnership utilities have with any SMNR customers in the sample. These customers should be recruited for the study by using these contacts.

A number of customers may have multiple sampled premises—i.e. the customers' contact information from the utility is identical for several different service address + customer combinations. The study team should carefully review the customer contact information to make sure that any duplicate contact names, addresses and phone numbers are identified and develop a strategy for recruiting these customers. Generally, the appropriate individual for completing the survey will be physically located at the service address. A centralized contact for multiple sites for the business or organization can sometimes refer the study team to a different individual at each facility who would be familiar with the economic impacts of an interruption at that specific facility. The survey implementer and study team do not want to be calling the same contact for multiple sites, as it will make the survey implementation process seem uncoordinated and could frustrate utility customers (and, subsequently, the Partnership utility). In some cases, the single point of contact for multiple facilities may in fact be the appropriate person for providing estimates for all of the sampled facilities. For this national study, the study team should also check whether one company or organization has multiple facilities in the sample across multiple utility service territories and not just within each service territory.

Another issue that the study team should try to identify is whether the contact information that utilities provide may be for a third party and not for the customer. Some businesses and organizations use third party energy managers or bill payers and the contact information the utility provides may be for the third party (as the billing contact). The study team should flag these observations and come up with a strategy for contacting the customers. It could begin with probing the third party for facility-specific contact information from the customers. It could also search manually for the general contact information online, or hire a vendor to undertake the process for all such cases identified in the sample. Once the recruitment exceptions are identified and protocols developed for dealing with them, the survey administrator can load the customer phone numbers into its calling software for auto-dialing and phone rep assignment.

3.3.4 Survey Implementation

Prior to administering the survey on the full sample of 5,000 customers, the survey implementation and data collection procedures should be tested on a sample of 200. For the pre-test, the study team will be testing whether the protocols are effective and working out any problems with the recruitment and survey delivery processes. If it finds that any of the steps described in this or previous sections do not work well in one or more regions, it can modify the main part of the study accordingly.

3.3.4.1 Recruitment

Recruitment for the SMNR customers begins with an introductory letter and email (if email address is available) to all sampled customers. These communications will be very similar to one another and will function to take advantage of both modes of communication in order to reach as many customers as possible in a customer class that can be more difficult to recruit. The introductory letter and email will explain the purpose of the study, request participation in the study, and state the incentive amount for the customer to take the survey. It will give a toll-free number for the survey administrator so that the customer can call the number and speak with a representative about obtaining either a link to the online survey or a paper survey in the mail. The introductory letter and email will not contain a link or printed URL for customers to go directly to the survey instrument, as it is important for the survey administrator to first verify that the correct person is identified to take the survey. The survey administrator—and overall study team—wants to avoid the situation where a person who is not familiar with the company or organization’s cost structure is merely trying to take the survey quickly in order to get the incentive.

The second part of recruitment is to contact sampled businesses by telephone to identify the appropriate individuals (usually a business or facilities manager) for answering questions related to energy and outage issues at that company. The survey administrator’s phone representative will explain the purpose of the survey and inform the individual that an incentive payment will be paid—upon completion of the survey—as a token of appreciation for participating. In some cases, business representatives will refuse monetary incentives, because their internal policies prohibit receiving such compensation. In these cases, the implementation team should give the respondent the option of identifying a charity that will receive a donation in their name. This can lead to participation by businesses which were initially unable to participate because they could not accept monetary compensation.

The survey administrator phone rep will attempt to secure a verbal agreement from the contacted individual to complete the survey. They will encourage the individuals who agree to participate to receive a link to the survey via email and complete it online, but will also give them the option of receiving the survey in the mail if the customer is hesitant to complete it online or specifically requests a paper copy. If the individual agrees to complete the survey online, the phone representative will obtain their email address and the survey administration team will send an email containing an individualized survey link. If the individual agrees to complete the survey via mail, the survey administration team will send a survey package containing the following:

- Survey booklet. The cover of booklet should contain the following:
  - Explanation for the purpose for the research
  - Simple instructions for completing the survey questions
  - Toll-free telephone number to call if they have questions about the research (or wish to verify its authenticity)
- Return envelope with pre-arranged postage. If the postage is pre-paid, the survey administration team should make sure that the postage covers cost to send the envelope and the completed survey booklet.

One week after emailing the survey link, the survey implementation team should call respondents to remind them to complete the survey. Customers who request regular mail should receive the first reminder calls two weeks following the mailing. About 10 days after the email participants' reminder calls, the team should resend the email to anyone who did not complete it. If a respondent does not complete the survey within 10 days, then the team should (1) assume that the customer will not complete the survey and (2) not contact them again. The implementation team should mail incentives to customers as soon as possible upon receipt of their completed surveys, depending on batching requirements (e.g. if it is not cost effective to print and mail incentives on a rolling basis).

3.3.4.2 Mitigating Low Response Rates

The 10 percent estimated response rate is a relatively safe assumption for conducting a survey among SMNR utility customers. It is nonetheless possible that the study team finds itself in a situation where the response rates are lower than it planned to reach the minimum targeted number of completed surveys. The study team should conduct regular and frequent check-ins with the survey administrator to monitor the number of contacted customers, the number of successful recruits (email or paper survey sent), the number of surveys started, and the number of surveys completed. The survey administrator can provide each of these figures and they will give the two teams insight into whether any recruitment practices—or other activity—need to be examined or adjusted. For example, surveys started but not completed could indicate a problem with the website or just with the length of the survey. A high rate of success in contacting customers but a low rate of successful recruitment (sending the survey instrument) could indicate that the call scripts should be adjusted to convince the customers that the survey is worth their time.

If the number of completed surveys remains below the rates planned for in the study design (which currently is 10 percent), the study team could take additional measures to boost recruitment. It could expand the study design and release more sample to the survey administrators, thus accepting the lower response rate and working with it to reach the desired number of completed surveys. The study team could also test offering larger incentives, alter the recruitment protocols to send an additional reminder email or have the survey administrators make additional recruitment calls.

3.4 Analysis of Results

The analysis methodology for estimating CICs for short-duration interruptions will follow that of residential customers for direct cost. The model is the two-step probit/GLM described in Section 2.3. The study team should use the value for the typical case to perform the CIC calculations. Data on parameters estimated for regional economic models will be shared with the appropriate stakeholders.

4. Non-Residential: Large Customers

This section outlines a proposal for conducting a national study of CICs for large non-residential customers (LNR), defined as utility customers whose demand is greater than 500kw. The study will use customer surveys addressing both short- and long-duration interruptions. The results of the short-duration component will fill in the geographical data gap in the current version of the ICE Calculator. The long-duration component will 1) generate CIC estimates of direct costs and 2) generate information to help researchers inform REMs, which are necessary for capturing indirect costs (i.e. the connections between businesses and industries and the cascading economic effects of power outages). The approach for LDW outages will mirror the SMNR portion of the study, with the surveys containing questions that modelers may find useful for parameterizing the REMs to make them more accurate. As with the residential and SMNR customer classes, we propose to undertake the non-residential portion of the study in two parts. The first part will be the pre-tests, in which the study team tests its customer recruitment protocols and survey instrument. The full-scale study (part 2) will use the results of the pre-test to maximize response rate and ensure the study team is using an efficient and well-understood survey instrument that minimizes bias.

4.1 Background

For the purposes of this study, large non-residential customers as having peak demand greater than 500kW. The strategy for conducting the study of CICs for LNR customers is similar to that for small and medium non-residential customers in that DOE will solicit utilities to join a “National Study Partnership” (“Partnership”). The arrangement is described in Section 3.1. Each utility that agreed to join the Partnership would do the following:

- Allow the study team to solicit their customers to take the survey
- Allow the use of its brand to give legitimacy to study and boost response rates
- Provide customer data that the study team could use to design the sample and recruit respondents
- Potentially help to fund the study
- Leverage utility account relationship with customers
- Pre-approve a set of draft customer communications

As with the SMNR portion of the study, Partnership utilities would receive certain benefits from their participation in and funding of the study. They would receive the interruption cost estimates for customers in their service territories who completed the survey. The study team would benefit from having utility data on electricity usage and would also be able to leverage the relationship of the utility account representatives to help recruit customers for in-person interviews.

Estimating interruption costs for LNR customers involves conducting an in-person interview with someone at the business or organization to walk through all of the implications of a power interruption and the economic implications for the firm. Sample sizes are generally smaller than for SMNR customers and the in-person interviews generally take 1-1.5 hours, as opposed to the 20-30 minutes required for the SMNR survey. The in-person interviews are necessary because the interruption costs for LNR customers can be quite high and it is important that the survey subjects thoroughly understand the survey questions and are providing accurate information.

Section 2.1.1 detailed the differences between short-duration and long-duration interruptions—along with the implications for measuring interruption costs. This LNR survey will measure direct costs of both short-duration and long-duration interruptions. Researchers determine the direct economic cost of interruptions to non-residential customers (*i*) by asking about specific costs incurred and savings realized related to a set of hypothetical power interruption scenarios (*s*)—then summing them over all *n* customers to find the total direct cost under each scenario (*s*). Equation 4-1 (same as Equation 3-1) depicts this relationship.

Equation 4-1. Direct Cost of Interruptions for Non-Residential Customers

$$\mathbf{Direct\ Cost_s} = \sum_{\mathbf{i=1}}^{\mathbf{n}} (\mathbf{VLP_{is}} + \mathbf{IRC_{is}} - \mathbf{IRS_{is}})$$

where:

- VLP is the value of lost production
- IRC is the set of interruption-related costs
- IRS is the set of interruption-related savings.

The in-person interviewer will address each component of Equation 4-1 systematically with each customer for each hypothetical interruption. For any non-C&I customers, such as government and educational facilities, interviewers can use the organization's budget as a proxy for the value of lost production (as explained for the SMNR customers, which have a separate survey instrument for that purpose).

For LDW interruptions, this Roadmap proposes following the same procedure as with the SMNR customers, where each survey instrument would include additional questions for the respondent to obtain information for regional economic modelers.

4.2 Survey Modification and Testing

As with SMNR customers, small-scale tests and a more formal pre-test will help prepare for the full-scale study. It should test that respondents understand the outage circumstances, similar to the residential pre-test. The short-duration outage questions have been used extensively, so cognitive testing should focus on the long-duration outage scenarios. Cognitive testing of the outage descriptions should be conducted until the stimulus is demonstrated to be well understood by potential respondents. Based on past experience, at least 50 cognitive interviews are required. The long-duration outage scenarios should be region-specific, so the testing should cover each type of scenario. Results from the SMNR pre-test can be leveraged for the large customers to reduce the required pre-testing.

Interviewers can collect feedback from their subjects to help hone the region-specific long-duration scenarios. Table 4-1 summarizes the LNR pre-testing.

Table 4-1. LNR Study Summary

Customer Class	Test Description	Test Type	Purpose	Scale
Large non-residential	Outage scenario descriptions	Cognitive testing	Understand questions	50
	Formal pre-test	Final pre-test of instrument	Response rate and implementation protocols	25
	Full-Scale Study			1,000

4.3 Full-Scale Study / Study Details

4.3.1 Prepare Standardized Communications Content and Survey Instrument

The study team will prepare drafts of all of the recruitment and study coordination materials, as well as the survey instrument itself, prior to soliciting utilities to join the national study Partnership. A condition of joining the Partnership will be an approval of the communications content and strategy—and an understanding that any changes to the communications they request will be minimal. Appendices F and G contain templates for the LNR survey instruments. Table 4-2 contains a list of the draft materials that the study team will need to prepare. The account reps of Partnership utilities will be helping to recruit study participants by leveraging their relationships with the large customers. Thus, the utility logo and brand is less important in the study materials listed in the table than it is for SMNR customers. The table indicates the mode of each customer communication in the “Type” column: paper mail, email, or phone script. The “Detail” column gives information on what is contained in the communication item. The “Letterhead/Logo” column indicates whether the communication contains the logo and brand of the utility or the implementer. For LNR customers, only the thank-you letter with the incentive check—sent after the interview—has the utility letterhead. The email with the study explanation (item #3) can be signed by the survey administrator, as the utility account rep will inform the LNR customer in advance that a third party will help to administer the survey.

The “Signed” column shows whose signature will appear at the bottom of the communication, even though each item will be sent by the implementer and not the utility itself. For the initial drafts of the materials, the main objective is to develop the proper content and messaging that utilities would be comfortable with. The study team can use placeholders for anything needed from utility, such as logos, signature names, or signature images. The signature name and image should be that of a manager at the utility who has some involvement with the study and who could be available to field infrequent calls from concerned customers. If the utility was part of the Partnership for the SMNR study, the manager should be the same. The “Approximate Timing” column shows when during the implementation process the communication would be sent. The “Need from the Utility” column indicates what information or files are needed from the utility to finalize the communication and the “Utility Decisions” column lists the decisions that the utility will have to make to finalize the communication. These two columns only apply to Item 6, which is the incentive check and related material. This material is the same as that for the SMNR study, so if the utility was part of the SMNR Partnership, the study team does not need to recreate separate draft materials.

The itemized explanations below give more detail about each piece of communication in Table 4-2:

1: Account rep contact

- A short set of bullet points that account reps can use to learn about the purpose of the CIC study, communicate that purpose to their customer contacts, and request the customers' participation in the study. It should be no more than one page. Account reps can use the summary as talking points when on a phone call with their customer contacts.

2: Email

- This is an email template that account reps can use to construct emails to send to customers. It gives a general purpose for the study and informs customers that someone from a third party survey administrator will call them to schedule an interview, unless they do not want to participate.

3: Initial recruitment call script

- The survey administrator will use this script when calling LNR customers to schedule the interviews. It assumes that the customer has already been informed of the study and asked to participate. Part of the script should be designed to help the phone rep determine whether the premise is master-metered and should thus be excluded from this phase of the study.

4: Study confirmation email

- The phone rep sends this email to the customer (and cc's the account rep) after scheduling the interview. The email includes the general topics that the survey interview will cover to ensure that the customer contact brings the appropriate additional personnel, if needed. It should also include the date and time of the interview.

5: Paper survey

- LNR customers will not be given a copy of the survey; the interviewers will record all answers themselves on the paper survey. It should thus be functional and include room for notes, but does not need any utility branding.

6: Incentive

- This item includes two draft letters. One letter would be addressed to the customer and thank them for their participation. The second version of the letter would be addressed to the charity that the customer chooses and would explain why they are receiving a check. The incentive check will have branding of the survey administrator. The envelope should have the utility logo. If the utility already participated in the SMNR study, this incentive package would be the same. (The incentive package is Item 7 in the SMNR version of this table: Table 3-2).

Table 4-2. Customer Communications Material for Large Non-Residential

Item	Item No.	Type	Detail	Letterhead/ Logo	Signed	Sent By	Approximate Timing	Need from Utility	Utility Decisions
1	1	Account rep contact	Summary of study for utility account reps to use when contacting customers	-	-	-	Prior to Day 1	-	-
2	2	Email	Account reps can use to inform customers about study	-	Account rep	Account rep	Prior to Day 1	-	-
3	3	Phone	Initial recruitment call script	Implementer "on behalf of utility"	-	Implementer	Day 1	-	-
4	4	Email	Confirmation with study explanation and interview scheduling details	Implementer (or no logo)	Implementer	Implementer	Upon contacting customer via phone	-	-
5	5a	Paper survey	Paper Survey (for interviewers to use during in-person interview)	-	-	-	At scheduled time		
6	6a	Paper mail	Thank-you letter to customer accompanying incentive check	Utility	Utility manager	Implementer	Upon completion of survey	• Logo • Signature image	Manager for signature
	6b	Paper Mail	Letter to charity accompanying incentive check					• Logo • Signature image	Manager for signature
	6c	Check	Incentive check	Implementer (or none)	Implementer			-	-
	6d	Envelope	#10 White envelope	Utility	-			• Either printed envelopes or format, font, and logo specs	

4.3.2 Sample Design

4.3.2.1 Sample Size and Stratification

The number of LNR customers is generally much smaller than the number of SMNR customers for a particular utility. However, given the high consumption of LNR customers, the total load for the segment can be similar to residential and SMNR. This Roadmap proposes a target of completed surveys of 25 completed surveys for the pre-test and 1,000 for the full-scale study. The study team will need to revisit this target with stakeholders after commencing the study to make sure the final target is adequate for the sample design and expected precision.

The LNR sample design will use the two-part stratification scheme, similar to SMNR. For the first stratification, the study team will use the nine Census Divisions described in Section 2.3.1. Table 4-3 shows the variation in average 1-hour interruption costs by region for customers represented in the ICE Calculator meta-database for medium and large C&I customers. Given the low number of LNR customers suggested for the pre-test and the logistical challenges of in-person interviews, this Roadmap recommends limiting the pre-test to two utility service territories in geographical regions with limited existing data (e.g., Northeastern U.S.). This will allow the study team to test the survey instrument and interview protocols without excessively dedicating project budget to travel expenses.

Table 4-3. Average 1-Hour Interruption Costs by Region from ICE Calculator Meta-Database: Medium/Large Commercial & Industrial Customers ($2019)

Region	Mean	Standard Deviation	Percentiles				
			5%	25%	50%	75%	95%
Midwest	$14,406	$86,498	$0	$0	$688	$4,578	$43,971
Northwest	$4,153	$19,651	$0	$0	$218	$1,463	$16,971
Southeast	$18,742	$108,921	$0	$0	$770	$4,929	$61,735
Southwest	$6,947	$59,735	$0	$0	$161	$1,657	$17,059
West	$25,209	$136,362	$0	$112	$1,116	$7,440	$87,262

Interviewing a large number of LNR customers for the full-scale study can present a logistical challenge for the study team. Sending interviewers throughout each region of the country—without imposing any geographical limits to the sample—would add significant costs to the budget in terms of travel time and expenses. To reduce the required cost of the study, this Roadmap proposes to select 2-3 large metropolitan areas within each region from which to sample LNR customers. The benefits of mitigating the burden on budget and logistics should outweigh any loss of variation from excluding certain areas within each region.

As with the SMNR sample, estimated interruption costs will form the basis for the second stratification. This Roadmap recommends three strata for each geographical region (two regions for the pre-test and nine regions for the full-scale study). The study team will have consumption data from the utilities participating in the Partnership, which it can use for sample design. It can use the underlying econometric models from the ICE Calculator to generate individual CIC estimates—and use these estimates to stratify the customers within each region in the sample. The econometric models use consumption—along with industry type—to estimate interruption costs. The study team should use the Dalenius-Hodges method to find the optimal strata boundaries and the Neyman allocation to determine the sample size (i.e. number of completes) for each stratum.

Response rates for LNR customers will depend on the ability of the study team to leverage utility account reps to help recruit customers to participate. This approach has tended to yield the highest response rates of any customer class for CIC studies. The study team should assume a response rate of 33 percent for the pre-test and pull a sample of 300 customers. Some utilities are more effective than others at cultivating relationships with large non-residential customers and it would not be surprising to find different response rates by utility. The study team may also find that certain regions of the country have different response rates than others. It can adjust response rate assumptions by region for the full-scale study. If the 33 percent estimate holds true during the pre-test, the study team will need to pull a sample of 3,000 (3x) for the full-scale study.

As with the SMNR customer class, the study team should look to exclude master-metered buildings from the sample design process. Interruption costs for these customers will be estimated in a separate phase of the study, as described in Section 5. The number of master-metered customers in the sample should, however, be recorded and tracked. It is not always obvious from utility data which of its customers are master-metered. To properly calculate CICs for the entire customer population, CICs for master-metered customers will have to be accounted for after they are estimated during that phase of the study. The study team should track the proportion of master-metered customers in the sample to estimate the proportion in the general LNR population. Master-metered buildings can be identified in several different ways.

- Some utilities have data that indicates whether a premise is master-metered
- Utility data with NAICS or SIC codes indicating that the company is a property manager—and for which there are no similar service addresses
- Utility account reps can identify customers as master-metered
- During study implementation, phone script contains language to identify property managers of master-metered buildings

The customer site-level aggregation process for LNR customers is the same as that for SMNR customers, detailed in Section 3.3.2.2. The main difference between large and small/medium non-residential customers is that large customers generally average more service points within the same service address, so there is more to aggregate for each sample point. The study team should follow a similar data cleaning process to SMNR customers prior to drawing the sample. It should drop inactive accounts, those with missing or suspect identification numbers, and aggregated accounts with consumption below a reasonable threshold that would indicate a customer who was active and could respond to study recruitment efforts.

4.3.2.2 Data Requests from Partnership Utilities

The study team will follow a similar procedure for requesting data for LNR customers as described in Section 3.3.2.3 for SMNR customers. The first data request will be to obtain customer data for designing the sample and will request the same variables as described previously. The second data request will include the contact information from sampled customers for the purposes of recruitment. The study team will work with the Partnership utilities to coordinate a recruitment effort with the account reps.

4.3.3 Survey Instrument Design

Interviewers conduct CIC surveys in-person for large C&I customers. This practice ameliorates the difficulties that survey respondents have with estimating large C&I interruption costs quickly and accurately. Qualified interviewers typically have experience and/or education in industrial engineering, facilities management or business administration. The ideal interviewer has experience with the issues that large commercial and industrial electricity customers face as a result of reliability and power quality issues. In past studies, retired utility business account representatives have proven to be the best interviewers for collecting interruption cost information from large C&I customers.

Just as with SMNR customers, this Roadmap proposes to use two separate survey instruments for LNR customers:

- Survey 1:
    - Direct cost elicitation for short-duration interruptions
    - Substitution elasticity questions for long-duration interruptions
- Survey 2:
    - Direct cost elicitation for long-duration interruptions
    - Substitution elasticity questions for long-duration interruptions

Each respondent would only be administered one version of the survey, as including direct cost elicitation questions for both short- and long-duration interruptions in one survey instrument would be a large burden for the respondent and could cause survey fatigue and lower completion rates.

The two survey instruments for large non-residential customers follows the same general format as those of SMNR customers. Appendices F and G contain instruments for measuring direct costs for LNR customers for interruptions of less than 24 hours (Appendix F) and 24 hours or more (Appendix G). Similar to the SMNR instrument, the survey asks the subject about the various components of the direct cost equation. However, the questions ask about each component in more detail than the survey instrument for SMNR customers. Larger C&I facilities tend to track more detailed information and this allows interviewers to collect this additional level of detail about costs. It is important to ensure the accuracy of this information given the large magnitude of interruption costs typical to this class of customers. Survey instruments for large C&I customers often elicit information about production schedules and processes, which is information not usually requested from SMNR customers.

Certain types of facilities will have very different responses to an interruption than others—some responses may be quite unique given the nature of the facility and industry. For example, most hospitals have a robust backup power system, but they still are not able to perform non-emergency surgeries during the interruption. The hospital's economic losses from halting non-emergency surgeries can be very significant. It is important for interviewers to know about common issues with these types of customers, so that they may effectively probe the customer about their past experiences during the onsite interview.

4.3.4 Prepare for Implementation

This section describes the steps that the study team will take to prepare for recruiting Partnership utility customers and administering the survey. The steps apply to preparation for both the pre-test and full-scale study and include a training session prior to the pre-test.

4.3.4.1 Finalize Draft Materials

The general content of the draft materials described in Table 4-2 will have already been approved by the utilities as a condition of joining the Partnership. To finalize the materials, the study team will need to obtain the files indicated in the "Need from Utility" column. The study team should coordinate preparation of the final drafts of the material, which would include putting the pre-approved content into the appropriate font and format, and adding artwork and/or letterhead where necessary. The study team will prepare a proof of each communications item and submit to each Partnership utility for final approval.

4.3.4.2 Utility and Survey Administrator Preparations

The survey administrator and utilities will need to complete a number of tasks to finalize preparations for implementing the survey. Similar to the SMNR study, the administrator should open and fund the incentive account and order check stock. Partnership utilities will likely help fund the study—including the incentives—but they will not cut the incentive checks themselves. Therefore, while the thank-you letter will likely be signed by the utility manager and branded with utility logos, the check itself (whether on a separate page or perforated on the same page) will not contain the utility brand and should thus be as non-descript as possible to avoid having another company's brand prominently displayed in a way that might confuse the respondent. The survey administrator should budget several weeks to complete this process.

Utilities should inform their business account reps that the study is occurring and explain the purpose and procedure. Once customers are selected for the study, these account reps will already know the process for contacting customers and will be able to begin the recruitment protocols more efficiently.

4.3.4.3 Prepare Communications Protocols

The study team and survey administrators will need to establish a standardized process for scheduling and confirming interviews. The in-person interviewers may be employees of a separate third party vendor than either the study team or the survey administrators, so coordination between all parties will be important. The process for scheduling interviews and notifying relevant parties is covered in the

Survey Implementation section (Section 4.3.5), but the protocols should be determined and agreed upon during the preparation phase. The study team should also establish the scheduling protocols for interviewers, such as which interviewers will be scheduled during what times, interviewer prioritization, availability, and any other details that the survey administrator should know for scheduling interviews.

4.3.4.4 Arrange Training for Interviewers

The study team will utilize interviewers for the large, non-residential customers to conduct the survey on-site for each sampled customer. Interviewers will require training from someone experienced in conducting CIC interviews. The study team should organize the training, which includes both classroom and on-the-job interview practice. The classroom training generally takes 1-2 days. After the classroom training, the group of interviewers can observe the trainer conducting practice interviews at the sites of actual customers. Generally, two days with two interviews on each day is an adequate amount of observation for trainees.

The practice interviews will need to be arranged in advance. Once the sample has been pulled, the study team can try to identify customers who are good candidates for scheduling practice interviews. The study team should leverage the utility's account representatives to help arrange the practice interviews.

4.3.4.5 Understand Sampled Customers

The study team should review the utility's customer data to understand the types of customers in the sample. Different businesses, institutions, and organizations have different cost structures—and having an idea of what those cost structures may be can be beneficial for engaging and recruiting customers. For some customers, knowing their company name and/or industry type is enough to have a high-level understanding of the nature of the business or organization. For other customers, a cursory level of research can help prepare interviewers for speaking to the customer and conducting the interview. The study team also may be able to identify master-metered customers in this manner.

Below are some examples of different types of facilities, their general differences in cost structure, and the implications for interruption costs. The examples are taken from recent experiences of the authors in conducting interruption cost studies for utilities.

Manufacturing

Manufacturers with heating or cooling in their production processes (such as pharmaceuticals, injection molding/extrusions, food production), or manufacturers with a high speed component in their process (such as pulp and paper products) tend to be very sensitive to power interruptions, or power quality issues as they can lose large amounts of throughput with little to no salvage value, high cost of disposal, and then endure a long restart time. In such cases, the interviewee is generally enthusiastic to share their experience with power interruptions or voltage sags and have good data about the loss of output and additional costs, as they feel they are getting their voices heard by the utility. Typical costs include damage/spoilage to raw or intermediate materials and disposal, damage to equipment, backup generation, and extra labor.

Complex manufacturing processes, such as aircraft production, involve many different production departments, and periods of time much longer than the CIC outage scope. This poses a difficult task in trying to quantify revenue loss as facility managers are not as cognizant of the impact of power interruptions, and many managers would be involved in quantifying the costs.

Public Institutions (Certain Universities & Hospitals)

In the case of public health and education facilities, the direct costs tend to be the cost of emergency generation, damage to equipment, and spoilage of food. For Universities, there is not a substantial loss of revenue except in the case of a long duration interruption when courses may get refunded if they cannot be delivered. It was noted that shorter term extension classes or professional development course may be refunded on a per-day/class basis, and revenue from food sales would be lost. For these customers, budgets can function as a proxy for the value of lost production.

One of the potentially large costs that can arise, but is difficult for interviewees to quantify, is the potential cost of lost research/materials due to a power outage at either a university or hospital with a research wing. These costs could be due to temperature sensitive experiments or samples, or computationally intensive work being performed that could be lost in the case of an interruption. While it would be infeasible to attempt to survey every academic or medical research department, it would be reasonable to assume that a sensitive department's average case scenario could proxy for the rest and scaled by square footage.

Public Services

Public services such as wastewater treatment do not have any direct loss of revenue or quantifiable output. For these customers, the budget can function as a proxy for the value of lost production. Nonetheless, during interviews at these facilities, it is important to communicate to the contacts that the study is only considering direct costs as the customers may feel that the methodology is undervaluing the value of the service that they produce. Interruption costs tend to be the typical costs of generation, damage to equipment, extra staff, and potential regulatory fines.

Telecommunications and Broadcasting

Telecommunications and broadcasting companies tend to have 100 percent power backup capabilities onsite. The costs due to power interruptions thus tend to be damage to equipment, the cost of backup generation, and additional labor.

Event Venues

Venues such as arenas or stadiums typically do not experience any loss of revenue due to a power interruption. The building management still retains tenant revenue in the event of an interruption as delivery of electricity is not guaranteed in lease agreements. It is usually the case that the building or venue will actually save money from avoiding electricity expense, but the tenants can experience large costs and must be surveyed separately for a cost estimate.

Rail Transportation

Subway or light rail services experience losses of revenue that are difficult to quantify. In the event of an interruption at a subway station, the track is not electrified and train service ceases at that location. Busses may be brought in to make up the deficiency for riders. Costs include extra labor, costs of busses and back up generation if applicable.

4.3.4.6 Initial Customer Contact through Account Reps

The CIC survey implementation team will work closely with the utility's business customer account representatives to engage with LNR customers during the recruitment phase. The recruitment process begins with the list of sampled LNR customers, which the study team provides to the utility and its account representatives. The utility representatives should make the first contact with each sampled customer to identify the best individual at each business to participate in the survey. The account rep should use their study summary sheet (see Item 1 in Table 4-2) to communicate the purpose of the study and the type of information the interviewer will request. Each account rep should record five pieces of information for each customer they are asked to reach out to:

- Name of contact
- Position of contact (e.g. plant manager, etc.)
- Contact information for contact
- Whether individual agreed to participate in study
- Any additional notes that could help study team schedule an interview (planned vacation, general availability, best time to reach over the phone, etc.)

A study coordinator at the utility should collect all of the responses from all of the account reps and provide the spreadsheet (henceforth the "Point of Contact List") back to the study team. The study team should make no further attempts to recruit LNR customers who indicated that they are not interested in participating in the study.

4.3.5 Survey Implementation

The survey implementation process for the pre-test will be identical to the full-scale study process. Any differences in process or protocol will be due to adjustments made after the pre-test to improve study coordination or response rates.

4.3.5.1 Scheduling the In-Person Interviews

The general process for recruiting customers proceeds as follows:

- A phone rep on the survey administration team will use the Point of Contact List to call the designated person at each of the sampled premises. The target respondent will usually be a plant manager or plant engineering manager—or someone else who is very familiar with the cost structure of the enterprise
- The phone rep will set up an appointment with one of the survey administration team's executive interviewers. The survey administration team will offer a financial incentive of $150 for completing the interview—to be paid by mail after the interview
- Once the appointment is scheduled, the team should email the customer a confirmation along with a written description of the study and an explanation of the information that they will be asked to provide. This allows the respondent to assemble any required records or request that other parties (e.g., plant engineering staff) attend the interview. The interview should be

scheduled at the convenience of the customer. The phone rep should copy the utility account rep and the in-person interviewer on the email

- The phone rep should send a calendar invitation to the customer, account rep, and interviewer and copy a member of the study team for tracking purposes
- One day before the interview, the interviewer should make a follow-up call to confirm the appointment
- On the agreed upon date, the executive interviewer should visit the sampled business and conduct the in-person interview. The utility's account representative can also attend the interview if they choose
    - At the conclusion of the interview, the interviewer edits and codes the completed interview
    - As each interview is completed, the completed survey materials will be returned to the study team via a web-based tool. The materials include:
        - Completed surveys
        - Additional notes from each interview

4.3.5.2 Interview Process

The on-site interview should take approximately 1-1.5 hours to complete. The executive interview from the survey administration team will ask the company's representative(s) a series of questions about actual interruptions experiences, the processes affected by electrical interruptions and the likely impacts of hypothetical power outages. In most cases, the respondents will know the relevant information or have immediate access to it. In the event that they do not know an answer to a question, the question should be skipped until the end of the interview. If the respondent cannot answer the question by the conclusion of the interview, the interviewer will request that the respondent contact the person in their organization who is most likely to be in possession of the desired information and obtain it from them. Most of the time, this can be accomplished while the interviewer is at the facility. However, in some cases, call-backs, emails, or return visits may be necessary. If accurate or reliable data cannot be obtained, the answer to the question should be coded "Don't know" -- indicating missing data.

The questions are designed to guide the respondent(s) through a series of factors that affect interruption costs before posing the hypothetical scenarios. To ensure that comparable answers are obtained from the different interviewers in the study, interviewers should adhere to the following procedures:

- Ask all questions exactly as worded; do not add or leave out anything
- Ask questions in the order they are numbered in the questionnaire
- Ask every question and do not assume any answers
- Ask questions in a relaxed manner. Do not make it sound like a test or cross-examination; on the other hand, show confidence in the study and do not apologize for asking the questions
- Do not attempt to explain or define questions unless you have been provided with a specific definition

- Be sure to enter the answers clearly and thoroughly. Illegible or ambiguous responses cannot be used
- Never make changes in procedures
- At the interview, prepare a draft version that will be kept for records. Upon completion of the interview, assemble a separate final version to be delivered to the study managers via the web-based tool
- Remember that this study and its contents—including the survey responses from the customers—are completely confidential

4.3.5.3 Discussion of Survey Questions and Instructions for Interviewers

This section reviews portions of the LNR survey instrument for the outage cases in detail and the instructions for the interviewers. The remaining questions on the survey are relatively straightforward, but the outage scenarios—for which the interviewer is determining a direct outage cost—merit special attention. This section also covers questions related to substitution elasticity—related both to outages that occurred in the past and hypothetical outages that have not occurred. The complete survey instruments are in Appendices F and G. Note below that the question appears in blue and the explanation/instructions appear in black.

CASE SCENARIOS

Go through each outage case completely before moving on to the next outage case. Ask questions C1-C21 about Case #1, then ask questions C1 through C21 about Case #2. Describe each scenario in detail to the Respondent.

Outage Cost Measurements

Q.C1 How long would activities stop or slow down as a result of this outage?
(if zero, skip to Q.C6)

This value represents the entire time the plant's operations are stopped or slowed down due to the interruption in service. In most cases, the amount of time the plant will shut down as a result of an outage will be in excess of the total duration of service interruption.

Q.C2 By what percentage would activities stop or slow down?

This question refers to the percentage of the plant's production process that would stop or slow down as result of the conditions described in the outage scenario. The percentages to be recorded under Q.C.2 are to be calculated in the following manner. If a single percentage is given by the respondent that number is to be used. If the respondent said the plant production stops for four hours (i.e. Case #1) and then is at 50 percent production for two hours and then 75 percent for three more hours before returning to normal operations, the value entered is the average percentage for the entire time the plant is affected:

[(4 hrs*100%)+(2 hrs*50%)+(3 hrs*25%)]/9hrs=63.9%

Note that the times are multiplied by 100, 50 and 25 percent respectively not 0, 50 and 75 percent because the questions asks for the percentage activities would be stopped or slowed down -- not the production level.

Q.C3 What's the value of output (cost plus profit) that would be lost (at least temporarily) while activities are stopped or slowed down due to the outage?

This value is generally given directly by the respondent. It is usually expressed as the total economic value of plant production (including all cost and profits) for a given length of time. Often it must be converted by the surveyor to reflect the actual number of hours the plant will be down as a result of the conditions described in the outage scenario. In these circumstances this value was multiplied by the answers to Q.C1 and Q.C2 to get Q.C3.

Q.C4 What percent of this lost output is likely to be made up?

This is a key question for determining the total outage costs. If production cannot be made up, the loss sustained by the facility will include the total value of Q.C.3. However, if production can be made up, the facility's economic loss must be adjusted to reduce the loss in Q.C.3 according to the amount that will be made up and increase the overall cost according to the additional labor and resources that will be used in the makeup process. This also determines if there would be any savings from this outage. If the plant makes up all the lost production then any savings they might have on raw materials or electricity will go right back into the production costs for the makeup.

Q.C5 I'd estimate that the amount that your firm's revenue or budget would change as a result of the outage would be [insert estimate]. Is that correct?

This is the value of lost production after taking into account any work that could be made up. This is determined by taking the value of lost production (Q.C3) and subtracting the value of made up production (Q.C3 times Q.C4). Thus if they made up 100 percent of their lost production in Q.C3 then Q.C5 equals zero. If they made up zero percent the value of Q.C5 is the same as Q.C3.

Extra Materials Costs

Q.C6 Damage/spoilage to raw or intermediate materials

This question is designed to measure the cost of damage to materials or input feed stocks that results from the conditions described in the outage scenario.

Q.C7 Cost of disposing of hazardous materials

This question includes both the incremental cost of disposing of any hazardous waste that may result from the conditions described in the outage and any fines that may be levied by authorities for uncontrolled discharges of hazardous substances. An example of this would be a sewage treatment plant that is unable to treat the waste adequately without power and so disposes of it in an unsanitary manner. Refineries, chemical plants and other entities that must treat their waste streams are subject to such fines which can range as high as $1,000,000 per occurrence.

Q.C8 Damage to your organization's plant or equipment

This question includes the cost of damage to machinery and equipment arising from the conditions described in the outage. Machining equipment may damage a tool if it is in the process of cutting when an interruption occurs. Motor starters and printed circuit boards also may sustain damage during interruptions depending on the conditions. Really significant economic damages arise from instances where a mix, furnace or kiln stops working or cools down unexpectedly. This can result in damage to very large and expensive pieces of equipment.

Q.C9 Costs to run backup generation or equipment

This question includes the operating cost for backup generation equipment. Do not include cost to purchase or maintain backup generation equipment in answering this question.

Q.C10 Additional materials and other fuel costs to restart facilities

This question includes incremental material and fuel costs that may be required to restart production.

Savings on Materials Cost

Q.C11 Savings from unused raw and intermediate materials (except fuel)

This question includes the value of the input feed stocks (not fuels) that would not be used during the production that is lost as a result of the outage. Often respondents will not have this figure at hand. It must be estimated from budgets for raw materials and calibrated to operating hours. This way an hourly cost of production materials can be calculated. From this you can multiply by Q.C1 (duration of slowed production) and by Q.C2 (percentage of slowed production) to get the value of the raw materials saved with no make-up in production. Then this value must be multiplied by 100 percent minus Q.C4 (the percentage of made-up production) to get the actual savings from the outage from unused raw materials. Note if there is 100 percent make-up there are no savings on input materials.

Q.C12 Savings on your firm's fuel (electricity) bill

This question includes the economic value of fuels that would not be used as a result of the interruption. This value is determined in the same manner as Q.C12. Fuel bills for an average month are usually available and can be used to obtain an hourly fuel cost based on their operating hours. This figure can be multiplied by the duration of slowed production and extent of slowed production to obtain fuel savings. Note as in the case of Q.C12, if there is 100 percent make-up there are no savings.

Q.C13 Scrap value of damaged products or inputs

This question includes the value of scrap that may result from the outage. Scrap values are only calculated if there is damage to raw or intermediate materials. Most of the time, the respondents will be able to estimate the scrap value as a percent of the original value of the material. In these circumstances Q.C6 can be multiplied by the percentage given to get the scrap value.

Labor Costs

Q.C14 How would the lost output most likely be made up? *Check all that apply.*

This question is only asked of respondents who state that some of the lost production will be made up. More than one answer may be given by the respondent. Record all answers that are given.

Q.C15 Labor costs to make-up lost output

This question includes the economic value of labor costs associated with making up for lost production. Do not record costs in this question if the respondent states that production will not be made up. These costs may be calculated based on average hourly wages, duration needed to make-up lost work, number of employees and any time-and-a-half or bonuses if applicable.

Q.C16 Extra labor costs to restart activities

The question includes the economic value of labor required to restart production. These costs have nothing to do with whether there is make-up work or not. Re-start costs generally occur when maintenance crews are scheduled into overtime to restart the facility. This is fairly common since normally facilities only keep a skeleton crew of one or two maintenance people on for swing or graveyard shifts, and they have to call in extras for restarting the plant.

Q.C17 Savings from wages that were not paid

Savings on labor can occur if employees are sent home during an outage. This is a very rare occurrence which should not be observed given the outage durations involved in this study (i.e., under 8 hours).

Q.C18-19 18) Other costs

19) Other savings

These questions are designed to record any other costs or savings the respondent mentions during the interview.

Q.C20 Total costs

(ASK ONLY IF RESPONDENT REFUSES TO PROVIDE DETAILED INFORMATION) Sometimes respondents refuse to provide detailed interruption cost estimates for security reasons but will agree to provide an overall estimate of the cost they will experience as a result of a given outage. If this occurs Q.C20 is to be used to record the result.

Q12 Now that we have discussed the *direct* costs associated with these outages, would you experience any *intangible* costs such as loss of good will, potential liability, or loss of future customers?

This is not a dollar value answer. If the respondent answers yes then he asked to explain what intangible costs he/she is referring. A common response was missed shipments to customers. The only respondents that said they could have liability were hospitals and other similar service organizations.

Substitution Elasticity - Long-Duration Interruptions that Occurred in the Past

The set of four questions below is intended to obtain information about how utility customers adapted to actual long-duration interruptions they experienced in the past. These questions are important for regional economic modelers, as the results would be used to get the model to reflect adaptive customer behavior.

Q.L1 Has your business/organization ever experienced an outage lasting longer than 24 hours? (Choose one.)

○ No
○ Yes—How long did the outage last? ____

Determine whether respondent has experienced one or more long-duration interruptions. If not, respondent can skip the remaining 3 questions (a, b, c).

Q.L1a What major tactics did you use to cope with the electricity disruption?

Gain information on the actions that the customer took to cope with the long-duration interruption(s). Tactics could include using backup generators, using distributed generation, conserving electricity, and relocating operations—either temporarily or permanently.

Q.L1b What was the cost of implementing each tactic in (a)?

For each tactic the respondent listed in 1a, obtain estimates of what the costs were for implementing them.

Q.L1c What was the benefit to your firm of the tactics in (a) in terms of the prevention of business interruption (lost revenues or profits)?

Obtain the benefits of the coping tactics from 1a. It may be difficult or impossible for the respondent to estimate the benefit from each tactic separately. If this is the case, have them estimate the benefit for full set of tactics for each long-duration interruption.

Substitution Elasticity – Hypothetical Long-Duration Interruptions

The set of questions below asks respondents about how they would cope with a hypothetical long-duration interruption. The questions are relatively straightforward and do not merit individual explanation. They can obtain information on hypothetical adaptive behavior without presenting a significant cognitive burden, as respondents will still need to answer the detailed scenario questions.

Q.H1 Would this [long-duration] outage cause you to go out of business?

- ○ No
- ○ Yes

Q.H2 Would this [long-duration] outage cause you to go out of business?

- ○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
- ○ The organization would resume partial operation during the outage (please specify what operations would continue)____
- ○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
- ○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
- ○ Other please describe____

Q.H3 Would you your employees receive their full typical pay during this period?

- ○ No
- ○ Yes

Q.H3a. If 'No,' what percent of typical pay would each type of employee receive?

Full-time employees: ________%

Part-time year-round employees: _______%
Contractors/project-based/temporary employees: _______%

Q.H4 What would be your approximate revenue loss from this [long-duration] outage?

$____________

Final Notes

After the interview is completed, the interviewers are to provide a written summary of their observations during the interview. These comments range from explanations of unusual situations at the site, to warnings in the event of customers who are very unhappy with the utility's services.

Most of the survey questions are best answered by plant engineers, maintenance supervisors, or manufacturing engineers. However, often times the interruption cost measurement questions are most accurately answered by plant controllers or operations engineers. If it looks like the initial respondent is unable to answer these questions, the interviewer must identify the proper person to answer these questions and obtain access to them. This must be done tactfully and the original respondent should always be asked to remain in the room for his or her input once the appropriate respondent has been identified.

Respondents will all view interruption costs differently. It is the interviewer's job to help the respondent understand the study team's measurement system and then allow them to produce the data the study team is trying to collect. The key to observing interruption cost measurements is to find the *incremental* costs experienced by the facility as a result of an interruption.

4.3.5.4 Potential Issues with Interviews

Managers may be apprehensive to divulge information regarding profit margins or cost of output as they may deem the information to be competitively sensitive. The interviewer should remind the respondent of the confidentiality of the study. Even with this assurance, some participants will likely be unwilling to give the information necessary to complete a full and complete cost estimate.
Problems will arise if the survey administration phone rep does not schedule the interview with the correct person. If they schedule the interview with a facilities manager, they should confirm that the individual will have information on revenue, such as the value of lost output, or value for the delivery of the service provided by the company. Incomplete interviews can involve extensive follow up to complete the data collection, which takes study personnel time and budget.

4.4 Analysis of Results

The analysis methodology for estimating CICs will be identical to that of the SMNR customers. One note, however, is that any outliers for LNR customers should be examined very thoroughly and only dropped after careful examination. The data is collected in a supervised environment, with an interviewer essentially performing a quality check on customer responses along the way. The variation in interruption costs for LNR customers—and the possibility of large customers experiencing significant impacts—could mean that the study team does not remove any outliers from the dataset. An additional difference between the LNR and SMNR survey data is the set of questions related to the business or organization. This data will not affect the CIC values, but does provide a slightly different set of variables to examine if the study team or utilities wish to relate interruption costs to certain characteristics of the customers or their facilities.

5. Master-Metered Buildings

This section details a proposed fourth phase of the study, in which the study team will obtain CIC estimates for master-metered buildings. Master-metered buildings are those which have one utility meter that is shared by multiple tenants. The building owner may or may not have the building sub-metered by a third party in order to track tenants' consumption. The building owner is the utility's customer, but interruptions will have greater impacts on tenants, who occupy the majority of the building and consume the electricity. This phase of the study will use a smaller sample of the master-metered customers included in the main sample and will administer the SMNR survey to a subset of businesses within each master-metered facility.

5.1 Scope and Methods

The non-residential customer samples from the utilities will almost certainly include some multi-tenant office or residential buildings (e.g., high rise buildings). In these situations, it is often the case that building management pays the entire electricity bill for tenants. The landlord will generally incorporate the cost of the utility bill in the fixed monthly lease amount. The customer that the utility would identify for the sample is the landlord that pays the bill for the premise, but it is the tenants who experience the losses from a power interruption. The study team must estimate the costs for the tenants within master-metered buildings to properly estimate interruption costs for the entire premise.

This Roadmap proposes accounting for master-metered building tenants after drawing the samples for SMNR and LNR. To carry out this approach, the study team must identify tenant-occupied master-metered premises during the process of surveying non-residential customers. The initial telephone recruitment process for SMNR—and account rep recruitment process for LNR—provide good opportunities to inquire about whether the premise is master-metered. The executive interviewer can confirm the arrangement at the interview and, if the premise is master-metered, determine the amount of tenant occupied space served by the master meter as well as the total number of tenants occupying space in the premise. After surveying the customer with the master meter, the study team should identify a sample of the premise's tenants for the purpose of eliciting their interruption costs. It is unlikely that the building owner will divulge contact information for the tenants, so the study team must either obtain a list of tenants using the building directory or perform a "reverse lookup" of building occupants using an online source.

The protocols and survey instrument for master-metered tenants are the same as those for SMNR customers. The survey will collect data on the floor area that each tenant occupies. This information is used to scale up the interruption costs from the sample of tenants to the entire premise. For example, the team could obtain interruption costs from businesses accounting for 100,000 square feet of building space comprising 500,000 square feet of total rentable space. The total interruption cost can then be scaled up by multiplying the sampled interruption costs by a factor of five.

5.2 Sample Design and Survey Instrument

5.2.1 Sample Size and Stratification

The study team will use data from the SMNR and LNR phases of the study to select a sample for the master-metered phase of the study. It is impractical to propose a sample size given that the study team does not know in advance the proportion of master-metered customers in the general population, nor the different types of master-metered buildings. The facilities could be large high-rise office buildings in the downtown area of a large metropolis, or smaller multi-unit buildings in a suburban area.

Throughout the SMNR and LNR phases, the study team will be recording which of the sampled customers from Partnership utilities are master-metered. The study team proposes to draw a smaller sample from this group of customers and stratify it based on consumption, region, and proximity to a major metropolitan downtown area. It is likely that most of these buildings are offices. The utility data available to the study team will not contain information on square footage, so consumption should be a reasonable indication of the square footage of the office building.

Part of the study implementation process is to use a reverse lookup service, which takes the address of the master-metered building and provides as output all of the tenant businesses at the premise and their phone numbers. The question of how many tenants to survey in each building presents a problem. The utility—and thus the study team—does not have access to electricity consumption data from the tenants, as its customer is the building landlord. Without consumption data, the study team is missing crucial information for designing a sample for each building. Previous studies have attempted to complete interruption cost surveys with 5 to 10 tenant businesses occupying the master-metered premise (Sullivan, et al., 2012). In the absence of empirical studies showing better ways to design the tenant sample, this Roadmap recommends surveying at least 5 to 10 tenants per master-metered premise. How to account for interruption costs of master-metered buildings was identified as an opportunity for further research in Sullivan et al. (2018). With data from across the U.S. identifying master-metered buildings—along with information from the reverse phone lookup service—the study team can examine the characteristics of the sampled buildings and determine an appropriate sample and stratification scheme.

5.2.2 Survey Instrument

The master-metered customers will use the same survey instruments as the SMNR customers, so there is no need to design separate instruments. The only modification related to the survey is in which version of the survey instrument the tenant will receive and in how the responses will be tracked. For the SMNR and LNR customers, the outage onset time on the survey varied by customer + service address combination. For master-metered customers, the tenants in each building should receive surveys with the same onset time for the hypothetical outages. This will allow all tenants within the same building to estimate economic impacts of the same hypothetical outages. The survey identification numbering scheme should be structured such that one could determine from the numbers that two tenant surveys were in the same master-metered building.

5.3 Prepare for Implementation

Recruitment efforts will take place only over the telephone and not via mail or email, as the tenants are not utility customers. The study team can obtain phone numbers using a vendor that specializes in the reverse lookup service, where the vendor enters an address and can obtain a list of businesses and organizations at that address. Apart from this difference, implementation preparations will progress similar to the SMNR study. The survey instruments should be programmed into the web-based tool, with a method for identifying tenants occupying the same master-metered facility. The survey administrator should establish and fund the incentive accounts and set up the toll-free survey help line.

5.4 Conduct Pre-test

The pre-test will largely be a test of the effectiveness of recruitment procedures and determining ways to adjust them to boost response rates. One issue will be that tenants did not receive a notice about the study and may therefore be more hesitant to participate. This issue may be exacerbated by the fact that the business or organization does not have a customer relationship with the utility. The quality of the contact information will be another key factor to assess. The survey administrator should track the accuracy of the phone numbers provided by the reverse lookup service to make sure the information is not outdated or otherwise of low quality. Another issue will be that the phone numbers will be for the “main line” of the business and not a specific individual identified as being the point of contact for handling issues with the electricity account. The study team will be receiving the names and phone numbers of points of contact for the SMNR phase of the study, but it will not have a way of identifying specific contacts in advance for the master-metered tenants. Survey administrator phone reps will have to adjust their approach when calling.

5.5 Survey Implementation

The pre-test will provide useful information for determining how to implement the full-scale study. The study team will work with stakeholders to determine an appropriate sample size and can adjust recruitment scripts and protocols as needed. It will also be able to test the 5-10 customer threshold for scaling up usage—and determine if the threshold should be adjusted for better representativeness within the building.

5.6 Analysis of Results

The analysis methodology for estimating CICs will be identical to that of the SMNR customers, except that the study team will first need to scale the results up to the premise level. The surveys associated with a particular address should be consolidated and the CIC data summed, such that the study team has an estimate of the total interruption cost for a particular event for a known portion of the overall building (as measured in square feet). The CIC for the building can be estimated by scaling interruption costs up to the full square footage.

6. Conclusion

This Roadmap proposes to undertake a national interruption cost study for each of four customer classes, with each customer class having a set of pre-tests followed by a full-scale study. The pre-tests are designed to refine survey instruments and ensure that implementation protocols will yield acceptable response rates. Table 6-1 summarizes the sample designs of each phase of the study. The residential study has an extensive set of pre-tests, as the elicitation methods for this customer class would include both WTP and direct cost. The full-scale residential study would use 4,500 households from a curated national survey panel. The SMNR phase would also have cognitive and other small-scale tests, but would focus more on response rate. The full-scale SMNR study would consist of 5,000 customer premises from the customer data of Partnership utilities. The LNR phase utilizes in-person interviewers and would have a scaled-down pre-test, as many of the issues with the survey instrument would likely be identified in the SMNR pre-test and could be revised and refined prior to the LNR study. The full-scale LNR study would use a sample of 1,000 customer facilities. The final phase of the study is for master-metered customers and would utilize data from customers identified having a master meter in the SMNR and LNR phases of the study. Sample size and design for this phase would be determined after master-metered customers were identified.

Table 6-1. Study Design Summary

Customer Class	Test Description	Test Type	Purpose	Scale
Residential	Outage scenario and solution descriptions	Cognitive testing	Understand scenario descriptions	Several rounds of 10-15 interviews
		Small-scale testing	Determine important contextual factors	270 in region-specific blocks of 30
			Understand scenarios	120 short duration; blocks of 30
				120 long duration; blocks of 30
				120 combination of short and long; blocks of 30
			Understand solutions	Three rounds of 10-15 interviews
				120 - blocks of 30
	Assessing customer actions in response to outages and their direct costs	Cognitive testing	Understand questions	Three rounds of 10-15 interviews
		Usability testing	Easily estimate outage costs	120 in three waves
	Eliciting WTP	SBDC exercise	Set WTP range for full-scale study	200
	Formal pre-test	Final pre-test of instrument	Completed in less than 30 minutes and no sequence effects	Three waves of 120
	Full-scale study			**4,500**
Small/medium non-residential	Outage scenario descriptions	Cognitive testing	Understand scenario descriptions	Several rounds of 10-15
		Small-scale testing	Understand scenarios	120 for short duration direct cost
				120 for long duration direct cost
				120 for combo of short duration direct cost and long duration elasticities
	Elicitation questions	Small-scale testing	Understand survey questions	120 - blocks of 30
	Response rate	Cognitive testing	Reason for not completing survey	Several rounds of 10-15 interviews
		Small-scale testing	Ensure adequate response rate	120 for survey length (60 shorter surveys / 60 standard length surveys)
				120 for delivery method (60 via telephone / 60 via email link)
				300 for incentive level (100 each at $75, $150, $200)
	Formal pre-test	Final pre-test of instrument	Response rate and implementation protocols	200
	Full-scale study			**5,000**
Large non-residential	Outage scenario descriptions	Cognitive testing	Understand questions	50
	Formal pre-test	Final pre-test of instrument	Response rate and implementation protocols	25
	Full-scale study			1,000
Master-metered	Pre-test	Final pre-test of instrument	Response rate and implementation protocols	TBD
	Full-scale study			**TBD**

This Roadmap contains a number of instances where specific details are unknown and the study team will have to determine the appropriate course of action as the study progresses. Unforeseen issues inevitably arise in studies of this size and complexity, so careful analysis, coordination and communication between the study team and stakeholders will be necessary to ensure a successful outcome. A typical VOS study for one utility service territory could cost between $750,000 and $1 million[13]. A budget for a national study would have to be determined during an actual study scoping process.

Logical next steps for conducting a national study include building support for a public-private partnership that could fund the effort, managing the study, and ensuring that the output is in a useful, accessible format for utility planners and researchers across the U.S. (and abroad). This team could include an initial set of 'Partnership' utilities (as described in this document), which would help co-fund and implement the study in return for results specific to their service territories. Other members of the team could be leading academics and researchers in the fields of short and long-duration interruption cost economics. The public sector could also play a large role in funding, managing, administering and/or disseminating the study results. This public-private partnership would form the basis of the study team as described in the report and would lay the foundation for undertaking a successful study.

Additional applications of the study results could include exploring whether CICs have changed significantly over time. Results of the national study could be compared with the ICE Calculator meta-database to evaluate factors that may explain differences in CICs over time. However, this analysis may not lead to conclusive results regarding the change in outage costs over time, given that the sampling frame would be substantially different. The Roadmap builds off of the lessons learned from decades of CIC studies to use what has worked and to refine areas where possible. Alternatively, successful completion of the first national study, including identifying lessons learned, could serve as a foundation for measuring future changes to interruption costs. National and/or regional studies with similar sampling frames and survey instruments could be conducted in subsequent years—perhaps every two to three years—to more definitively identify changes in outage costs over time.

The national study described in this Roadmap would provide an opportunity to fill the existing gaps in publicly available interruption cost data by obtaining CICs for regions with little to no data and by bringing CIC estimates for all regions up to date. Upon completion of the study, utility planners and researchers would have access to region-specific CIC estimates for the entire U.S. for both short and long-duration interruptions. This study would also provide an opportunity to advance the field of interruption cost estimation by revising elicitation methods used for residential customers and beginning to address the challenges posed by estimating costs for LDW interruptions.

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[13] This range comes from the authors' experience conducting CIC studies and judgement regarding costs for a typical study.

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Appendix A. Residential Survey Instrument

This appendix contains a first draft of a modified residential survey instrument, which elicits interruption cost estimates for short and long-duration interruptions. This survey instrument is a guide and the study team can modify questions or descriptions at its discretion through the testing process.

Customer Interruption Cost Survey

Residential Customers

[Introduction message]

When completing this survey, please note that a "power outage" refers to a complete loss of electricity to your residence. Power outages can be caused by many factors such as bad weather, traffic accidents, or equipment failures. If you share a building with other owners or tenants, please answer the questions only about your residence.

1. **Over the past 12 months, about how many outages of the durations listed below have you experienced at your home? Please enter the number of outages in the blanks below. (If none, use "0".)**

   ________ Short duration (5 minutes or less)
   ________ Longer than 5 minutes and up to 1/2 hour
   ________ Longer than 1/2 hour and up to 1 hour
   ________ Longer than 1 hour and up to 4 hours
   ________ Longer than 4 hours and up to 24 hours
   ________ Over 24 hours

2. **Have you ever experienced an outage lasting longer than 24 hours? (Choose one.)**
   ○ No
   ○ Yes—How long did the outage last? ____

3. **Do you feel that the number of power outages your residence experiences is (Choose one.):**

   ○ Very low
   ○ Low
   ○ Moderate
   ○ High
   ○ Very high

4. **In general, how long can an outage last at your home before the costs become significant? Please estimate that time length.**

   ______ days ______ hours and ______ minutes

5. **Do you or any of your household members work at home most of the time? (Choose one.)**

   ○ No
   ○ Yes—What kind of business is it? ____

   a. **If you answered "Yes" in question 5, how are you compensated for the work you perform at home? (Choose one.)**

      ○ Self-employed
      ○ Salary from employer
      ○ Hourly wage from employer
      ○ Other – Please explain: ____

6. **Do you or does anyone in your household have any health conditions for whom a power outage could be a problem? (Choose one.)**

○ No
○ Yes – Please explain: ____

7. **Does your household have some form of backup electrical power (like a backup generator)?**

○ No
○ Yes

a. **If you answered "Yes" in question 7, approximately what percent of your household's electrical demand could be supplied by your backup generation equipment?**
___________ %

In the following sections, we will ask you about 3 different hypothetical scenarios involving electrical power outages. For each scenario, we would first like to know how you and your household would adjust to the outage. Second, we will ask you to estimate the extra expenses that your household would experience as a result of the outage as well as an estimated cost associated with any inconvenience or hassle.

Because every person may have different expenses and may feel differently about the amount of inconvenience or hassle, there are no right or wrong answers to these questions. We simply want your honest opinion.

IMPORTANT

As you answer questions about the hypothetical scenarios, please remember these two definitions:

Extra expenses
This category covers additional expenses you experience as a direct result of the power outage. This section may include, but is not necessarily limited to:

- Food spoilage
- Dining out (if you are unable to cook at home)
- The cost of fuel used to power a generator
- Lost wages for lost work time due to outages

Please do **not** include expenses that your household would have incurred whether or not the power outage happened. For example, if you decided to dine out during the outage **instead of** going out another night, the cost of the dinner should **not** be considered as an extra expense because it is simply shifted from another night. However, if you had to dine out during the outage **in addition to** another night, the cost of the dinner should be considered an extra expense.

Inconvenience or hassle costs
Although inconveniences or hassles do not have a monetary price associated with them, this category includes the value that you place on, for example:

- Having to use flashlights, batteries, and/or candles
- Having to leave your residence
- Being unable to charge your computer or mobile phone
- Not being able to watch television
- Having limited or no internet access
- Being unable to use solar photovoltaic (PV) equipment or charge your electric vehicle

Note: If you have solar PV panels installed, your household will still experience the power outage and your solar PV system will not feed electricity into the grid.

Case A

Suppose that on a «SEASON» weekday, a complete power outage occurs at «ONSET» without any warning. You don't know how long it will last, but after **«HOUR1» hours** your household's electricity is fully restored. (Note that **all** of the remaining cases occur at **«ONSET»**.)

SUMMARY:

Conditions:	«SEASON» weekday	**Start time:**	«ONSET»
Duration:	«HOUR1» hours	**End time:**	«END1»

A1. Since you would not know beforehand when the outage would occur or how long it would last, how would your household adjust during and after this outage? (Check all that apply.)

☐ There's generally no one home at this time
☐ Stay home and do activities that don't require electricity
☐ Find an alternative location to work (if someone from your household works from home)
☐ Go out to eat, shop or visit friends
☐ Run a backup power generator
☐ Find a different location to charge electric vehicle
☐ Use a propane/gas stove or grill for cooking
☐ Reset clocks and appliances after outage
☐ Other (please describe) ____

A2. How much do you think it would cost your household in extra expenses <u>and</u> in inconvenience or hassle to adjust to this outage? If necessary, please refer to the definitions on page 3.

$ ___________ extra expenses **<u>and</u>** inconvenience costs

A3. Of the above amount, how much of it would be just for the extra expenses?

$ ___________ extra expenses **<u>only</u>**

A4. Suppose a company (<u>other than your utility</u>) could immediately provide you with a temporary backup power service to handle all of your household's electricity needs during <u>this particular outage</u>. With this backup service, you would not experience the outage and would not have to make any adjustments.

The exact cost of providing this service is unknown, but it is believed to lie in the range from $X to $Y. Would you purchase the backup service for this particular outage for $X ($Y)?

○ No
○ Yes

→ **[If "Yes" ("No")]: Would you purchase the backup service for this particular outage for $Y ($X)?**

○ No
○ Yes

Case B

Without any warning, on a «SEASON» weekday, a complete power outage occurs at «ONSET». You don't know how long it will last, but in this case your household's electricity is fully restored after **1 hour**.

Summary

Conditions:	«SEASON» weekday	**Start time:**	«ONSET»
Duration:	1 hour	**End time:**	«END2»

B1. Since you would not know beforehand when the outage would occur or how long it would last, how would your household adjust during and after this outage? (Check all that apply.)

☐ There's generally no one home at this time
☐ Stay home and do activities that don't require electricity
☐ Find an alternative location to work (if someone from your household works from home)
☐ Go out to eat, shop or visit friends
☐ Run a backup power generator
☐ Find a different location to charge electric vehicle
☐ Use a propane/gas stove or grill for cooking
☐ Reset clocks and appliances after outage
☐ Other (please describe) ____

B2. How much do you think it would cost your household in extra expenses <u>and</u> in inconvenience or hassle to adjust to this outage? If necessary, please refer to the definitions on page 3.

$ ___________ extra expenses **<u>and</u>** inconvenience costs

B3. Of the above amount, how much of it would be just for the extra expenses?

$ ___________ extra expenses **<u>only</u>**

B4. Suppose a company (<u>other than your utility</u>) could immediately provide you with a temporary backup power service to handle all of your household's electricity needs during <u>this particular outage</u>. With this backup service, you would not experience the outage and would not have to make any adjustments.

The exact cost of providing this service is unknown, but it is believed to lie in the range from $X to $Y. Would you purchase the backup service for this particular outage for $X ($Y)?

○ No
○ Yes

→ a. **[If "Yes" ("No")]: Would you purchase the backup service for this particular outage for $Y ($X)?**
○ No
○ Yes

Scenario Description:
In this section, I would like you to imagine the following situation: it is a [hot/cold] [summer/winter] [weekday/weekend]. At sunrise, you wake up to your dwelling shaking and realize an earthquake is occurring. The power goes out. Assume that you can find a battery operated radio. It tells you that the power outage is not local, but instead extends across a large region.

The radio says that a high-magnitude earthquake struck your region, causing damage to big power lines and major electricity generating stations. This caused a blackout that spread to a large portion of [region]. It also tells you that the earthquake did <u>not</u> cause extensive damage to nearby buildings and roads. Your utility estimates that it will take about one week to restore power.

A number of appliances in your home and services in your community will not work during this time period. These include:

<u>Home</u>

- Electrical appliances that cannot run on a battery (refrigerator, television, desktop computers, washing machine, dryer, etc.)
- Telephones that plug into a power outlet
- Internet
- Cable
- Solar PV panels

<u>Community</u>

- Traffic signals
- Street lights
- Banks and ATMs
- Most gas stations
- Grocery stores
- Most restaurants and retail stores
- Airports (major delays)

Suppose a company (<u>other than your utility</u>) could immediately provide you with a temporary backup power service to handle all of your household's electricity needs during <u>this particular outage</u>. With this backup service, you would not experience the outage and would not have to make any adjustments.

The exact cost of providing this service is unknown, but it is believed to lie in the range from $X to $Y. Would you purchase the backup service for this particular outage for $X ($Y)?

○ No
○ Yes

→ **a. [If "Yes" ("No")]: Would you purchase the backup service for this particular outage for $Y ($X)?**

○ No
○ Yes

Please list the approximate dollar value of the following items if they apply. If the cost does not apply to you for this particular scenario, leave the answer blank. If you're not sure of the dollar amount, please make your best guess.

C1. What's the approximate dollar value of the perishable food stored in any refrigerators and freezers that would go bad? (Note: a refrigerator without power will keep food safe for up to 4 hours.)

$ ____________

C2. What's the approximate dollar value of damages from lack of power to household appliances that require continuous power (e.g. aquariums, food dryers, etc.)?

$ ____________

C3. What's the approximate cost to run backup generation, if you already have it? (If you not already have it, assume it will no longer be available in stores.)

$ ____________

C4. What's the approximate cost to relocate some or all family members during the outage, including finding alternative care for sick or elderly relatives?

$ ____________

C5. What's the approximate cost to relocate your home-based business?

$ ____________

C6. Are there other costs you would incur that were not already listed?

$ ____________

C7. Would you save any money from not having power, apart from the savings on your electricity bill?

$ ____________

Fill in the following table using your answers above, summing the costs to find a subtotal, and then subtracting the savings to find your total costs due to the outage.

Category	**Costs Due to Outage**
C1. Perishable food that would go bad	$
C2. Damages from lack of power to appliances	$
C3. Cost to run backup generation	$
C4. Relocate family members / sick and elderly care	$
C5. Relocate home-based business	$
C6. Other costs	$
Subtotal:	**$**
C7. Savings due to the outage (subtract from subtotal)	$
TOTAL:	**$**

C8. Considering all of the costs you might experience as a result of this 1-week outage, please estimate the total costs for an assumed "Best Case" scenario, the cost for a "Typical Case" scenario and the cost for a "Worst Case" scenario. Please enter zero if there are no costs.

$______________________	$______________________	$______________________
Lowest Total Outage Cost **(Best Case)**	Most Likely Total Outage Cost **(Typical Case)**	Highest Total Outage Cost **(Worst Case)**

To better understand how electrical power outages affect your household, we would like to gather some information on your household characteristics. Please answer the following questions to the best of your ability. If you live in an apartment building or duplex, answer only for the part of the building you actually live in.

8. **What is the size of your residence?**

   ________square feet

9. **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. (Choose one.)**

   ○ Under $25,000
   ○ $25,000 - $49,999
   ○ $50,000 - $74,999
   ○ $75,000 - $99,999
   ○ $100,000 - $124,999
   ○ $125,000 - $149,999
   ○ $150,000 - $174,999
   ○ $175,000 - $199,999
   ○ $200,000 - $250,000
   ○ Above $250,000

Please share any additional comments:

____

____

____

____

Appendix B. Small & Medium C&I Survey Instrument: Direct Costs for Short-Duration Interruptions

This appendix contains a first draft of a modified small and medium C&I survey instrument, which elicits direct costs for short-duration interruptions. This survey instrument is a guide and the study team can modify questions or descriptions at its discretion through the testing process.

Customer Interruption Cost Survey

Commercial & Industrial Customers

Thank you for agreeing to participate in this important study. We ask that you complete this survey thinking **only** about the facilities that your organization occupies **at this location**:

«SERVICE_ADDRESS», «SERVICE_CITY»

If your organization shares a building with other businesses or you're the property manager at the above address(es), please answer the questions only for the space **your organization** occupies at this location and the activities **your organization** undertakes.

All your answers will be kept confidential. Your name and your organization's name and address will be kept anonymous and will not be associated with the information you provide.

Please return your completed survey in the enclosed return envelope to receive your $XX check. If you have any concerns, please contact [Utility] at [phone number]. For specific questions about the survey, please contact [Survey Administrator] at [phone number] Monday through Friday between the hours of 9:00 AM and 5:00 PM.

Sincerely,

Manager

This survey is also available online at: [website]
Your survey ID is [Survey ID]

When completing this survey, please note that a "power outage" refers to a complete loss of electricity to your facility. Power outages can be caused by many factors, such as bad weather, traffic accidents and equipment failures.

1. **In the past 3 months, how many brief interruptions of five minutes or less have you experienced at your business location?**

   ________ Brief interruptions (5 minutes or less)

2. **In the past 3 months, how many lengthy outages of more than five minutes have you experienced at your business location?**

   ________ Lengthy outages (more than 5 minutes)

3. **What type(s) or duration(s) of outages at this location have financial effects on other sites owned by your company?**

   ____

   ____

   ____

4. **Has your organization ever sent employees home during a power outage? (Choose one.)**

   ○ No
   ○ Yes

5. **In general, how long can an outage last at your facility before it has a substantial impact on your operations? Please estimate that time length.**

   ______ hours and ______ minutes

6. **How much advance warning of a power outage does your organization need to significantly reduce the problems caused by a power outage? (Choose one.)**

   ○ Advance notice would not reduce problem(s)
   ○ At least 1 hour
   ○ At least 4 hours
   ○ At least 8 hours
   ○ At least 24 hours

7. **What's the approximate square footage of this facility?**

   __________ Square feet

8. Which of the following categories best describes your organization? (Choose one.)

- ○ Agriculture/Agricultural Processing
- ○ Assembly/Light Industry
- ○ Chemicals/Paper/Refining
- ○ Food Processing
- ○ Government
- ○ Grocery Store/Restaurant
- ○ Hospital
- ○ Lodging (hotel, dormitory, prison, etc.)
- ○ Lumber/Mining/Plastics
- ○ Office
- ○ Oil/Gas Extraction
- ○ Retail
- ○ School/University
- ○ Stone/Glass/Clay/Cement
- ○ Technology
- ○ Transportation
- ○ Utility
- ○ Other (please specify):________________

9. How many of each type of employee is currently employed by your organization at this location?

___________ Full-time, year-round with ANNUAL SALARY

___________ Full-time, year-round with HOURLY WAGE

___________ Part-time, year-round

___________ Contractor/project-based/temporary

The next section describes four different power outage scenarios. We'd like to know the costs to your business of adjusting to each of these power outages.

The costs of a power outage depend upon the particular situation, and may vary from day to day depending upon business conditions. So for each outage scenario, you'll be given the opportunity to report the range of outage costs that your business might face (from low to high), as well as to estimate the cost that you would most likely have under typical circumstances.

It's important to try to answer all of the questions. If a question is difficult for you to answer, please give us an estimate and feel free to write down any comments about your answer.

Case A

On a «SEASON» weekday, a complete power outage occurs at «ONSET» without any warning. You don't know how long it will last, but after **«HOUR1» hours** your organization's electricity is fully restored. Note that **all** of the remaining cases occur at **«ONSET».**

SUMMARY:
Conditions: «SEASON» weekday
Duration: «HOUR1» hours
Start time: «ONSET»
End time: «END1»

A1. How disruptive would this power outage be to your organization? (Choose one.)

○	○	○	○	○	○	○
1 Not disruptive at all	2	3	4	5	6	7 Very disruptive

A2. Would your operations or services typically stop or slow down as a result of this power outage? (If yes, please state the number of hours.) (Choose one.)

○ No
○ Yes

a. **If you answered "Yes" in question A2, please enter the number of hours that operations or services would stop or slow down (include time <u>during and after</u> the power outage?**

___________ hours

A3. What's 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? (If you're not sure please make your best guess.)

$ ___________ value of lost work or services

[Add to this table and sum at the end]

Category	Costs Due to Outage
A3. Operations and Services Lost	$

A4. What percent of the operations or services typically would be made up after the power outage? (Choose one.)

○	○	○	○	○	○	○	○	○	○	○
0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

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

○ No
○ Yes

a. **If you answered "Yes" in question A5, please state the cost for lost labor as well as the cost for overtime labor to make up for lost work.**

$ ____________ incremental labor costs to deal with outage related issues
$ ____________ labor costs in overtime/extra shifts to make up for lost work

[Add to this table and sum at the end]

Category	Costs Due to Outage
A5-1. Incremental Labor Costs to Deal with the Outage	$
A5-2. Overtime/Extra Shifts to Make Up for Lost Time	$

A6. Would there be any damage costs associated with this power outage such as damage to equipment, materials, etc.? (Choose one.)

○ No
○ Yes

a. **If you answered "Yes" in question A6, please state how much the damage cost for equipment would be and how much the damage cost to materials would be.**

$ ____________ damage to equipment
$ ____________ damage to materials

[Add to this table and sum at the end]

Category	Costs Due to Outage
A6-1. Damage to Equipment	$
A6-2. Damage to Materials	

A7. Would there be additional tangible costs associated with this power outage (such as extra restart costs, and costs to run and/or rent backup equipment)? (Choose one.)

○ No
○ Yes

a. **If you answered "Yes" in question A7, please state the additional costs.**

$ ___________ additional tangible costs

[Add to this table and sum at the end]

Category	Costs Due to Outage
A7. Other Tangible Costs	$

A8. Would there be <u>intangible costs</u> due to this power outage (such as inconvenience, potential liability, or loss of customers)? (Choose one.)

○ No
○ Yes

a. **If you answered "Yes" in question A8, please estimate the intangible costs.**

$ ___________ intangible costs

A9. In addition to the costs discussed above, some organizations may avoid expenses because of electrical outages. Some examples include a lower electrical bill, lower material outlays, and lower personnel costs. Would you experience any savings associated with this power outage? (Choose one.)

○ No
○ Yes

a. **If you answered "Yes" in question A7, please state the savings.**

$ ___________ savings

[Add to this table and sum at the end]

Category	Savings Due to Outage
A9. Savings Due to the Outage	$

Fill in the following table using your answers above, summing the costs to find a subtotal, and then subtracting the savings to find your total costs due to the outage.

Category	Costs Due to Outage
A3. Operations and Services Lost	$
A5-1. Incremental Labor Costs to Deal with the Outage	$
A5-2. Overtime/Extra Shifts to Make Up for Lost Time	$
A6-1. Damage to Equipment	$
A6-2. Damage to Materials	$
A7. Other Tangible Costs	$
Subtotal:	**$**
A9. Savings Due to the Outage (Subtract from Subtotal)	$
TOTAL:	**$**

A10. Considering all of the costs you might experience as a result of this «HOUR1»-hour «SEASON» weekday outage beginning at «ONSET», please estimate the total costs for an assumed "Best Case" scenario, the cost for a "Typical Case" scenario and the cost for a "Worst Case" scenario. Please enter zero if there are no costs.

$______________________	$______________________	$______________________
Lowest Total Outage Cost **(Best Case)**	Most Likely Total Outage Cost **(Typical Case)**	Highest Total Outage Cost **(Worst Case)**

Case B

Without any warning, on a «SEASON» weekday, a complete power outage occurs at «ONSET». You don't know how long it will last, but **after 1 hour** your organization's electricity is fully restored.

SUMMARY:

Conditions:	«SEASON» weekday	**Start time:**	«ONSET»
Duration:	1 hour	**End time:**	«END2»

B1. Considering all of the costs you might experience as a result of this <u>1-hour «SEASON» weekday outage beginning at «ONSET»</u>, please estimate the total costs for an assumed "Best Case" scenario, the cost for a "Typical Case" scenario and the cost for a "Worst Case" scenario. Please enter zero if there are no costs.

$______________________	**$**______________________	**$**______________________
Lowest Total Outage Cost **(Best Case)**	Most Likely Total Outage Cost **(Typical Case)**	Highest Total Outage Cost **(Worst Case)**

Case C

Without any warning, on a «SEASON» weekday, a complete power outage occurs at «ONSET». You don't know how long it will last, but after **5 minutes** your organization's electricity is fully restored.

SUMMARY

Conditions:	«SEASON» weekday	**Start time:**	«ONSET»
Duration:	5 minutes	**End time:**	«END3»

C1. Considering all of the costs you might experience as a result of this <u>5-minute «SEASON» weekday outage beginning at «ONSET»</u>, please estimate the total costs for an assumed "Best Case" scenario, the cost for a "Typical Case" scenario and the cost for a "Worst Case" scenario. Please enter zero if there are no costs.

$______________________	**$**______________________	**$**______________________
Lowest Total Outage Cost **(Best Case)**	Most Likely Total Outage Cost **(Typical Case)**	Highest Total Outage Cost **(Worst Case)**

Longer Outages

Under extremely rare circumstances, it is possible for an outage to last multiple days or weeks. Although it is unlikely that your business has experienced such a long duration outage, we would like to know about various aspects of your business that would affect your company's response to an outage that lasts multiple days or weeks.

It's important to try to answer all of the questions. If a question is difficult for you to answer, please give us an estimate and feel free to write down any comments about your answer.

10. Does your organization have a plan for what to do during a long power outage that could last anywhere from several days to several weeks?

○ No
○ Yes

Please describe the plan:

____
____
____
____

11. Has your organization ever experienced an outage lasting longer than 24 hours? (Choose one.)

○ No
○ Yes—How long did the outage last? ____

a. **What major tactics did you use to cope with the electricity disruption?**

____
____
____
____

b. **What was the cost of implementing each tactic in (a)?**

____
____
____
____

c. What was the benefit to your firm of the tactics in (a) in terms of the prevention of business interruption (lost revenues or profits)?

____
____
____
____

12. Does your facility generate any of its own electricity (separate from backup power)?

O No
O Yes

a. What is the rated capacity of your generation equipment?

____

O kW
O MW
O Horsepower
O Don't know

b. What percent of your electrical demand is supplied by your generation equipment?

___________ %

c. What is the fuel source for the generation equipment?

O Natural gas
O Solar PV
O Diesel
O Battery
O Other__________

13. Does your facility have some form of backup electrical power?

O No
O Yes

a. What is the rated capacity of your backup generation equipment?

____

O kW
O MW
O Horsepower
O Don't know

b. What percent of your electrical demand could be supplied by your backup generation equipment?

___________ %

c. What percent of your employees are currently able to work while the facility is on backup power?

___________ %

d. With the fuel stored onsite, how long can this backup operate?

___________ days

14. What percent of your employees are currently able to work remotely?

___________ %

15. **Do you have other offices or facilities similar to this location outside of the region?**
   - ○ No
   - ○ Yes

     If yes: Where are they?

     ____

16. **If your current location were suddenly inoperable, what percent of employees could relocate to your other locations?**

   ___________ %

17. **During an outage that lasts multiple days or weeks, could you physically relocate your equipment or infrastructure to ensure continuity of your operations?**
   - ○ No
   - ○ Yes

     If yes: How long would it take to do so?

     ___________ days

     If yes: How much would it cost to do so?

     $ ___________

18. **What expenses would you experience in relocating operations temporarily, i.e. more than one day?**

   $ ___________

The next section describes two hypothetical power outages that could last anywhere between one day and two weeks. For each outage scenario, you will be asked to estimate the cost that you would most likely experience under typical circumstances. The costs of a power outage depend upon the particular situation, and may vary from day to day depending upon conditions. Consequences of the outage could include, but not be limited to:

- **People may be unable to work because:**
  1. **they could not perform their job (i.e., computers not working)**
  2. **the temperature in their work space was too hot or cold *or***
  3. **their workspace became too hazardous.**
- **The public may not be able to access the facility because of safety concerns**
- **Sensitive equipment and/or facilities may become damaged by extended deprivation of electric power**

It's important to try to answer all of the questions. If a question is difficult for you to answer, please give us an estimate and feel free to write down any comments about your answer.

Case D

An earthquake in **«SEASON»** causes widespread damage to the region, including severe damage to electricity generation and distribution infrastructure. Your organization does not experience any damages from the natural disaster, but the power outage persists and you do not know how long it will last. After a few days, your utility announces that the outage will last for **one week**.

D1. Would this 1-week outage cause you to go out of business?
○ No
○ Yes

D2. Which of the following best describes how your organization would react to an outage of this duration?
○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
○ The organization would resume partial operation during the outage (please specify what operations would continue) ____
○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
○ Other please describe ____

D3. Would your employees receive their full typical pay during this period?
○ No
○ Yes

D3a. If 'No,' what percent of typical pay would each type of employee receive?

Full-time employees:	_______%
Part-time year-round employees:	_______%
Contractors/project-based/temporary employees:	_______%

D4. What would be your approximate revenue loss from this 1-week outage?
$ ___________

Case E

A similar situation occurs as Case D, where an earthquake in **«SEASON»** causes widespread damage to the region, including severe damage to electricity generation and distribution infrastructure. Your business and employees do not experience any damages from the natural disaster, but the power outage persists and you do not know how long it will last. In this case, your utility announces after a few days that the outage will last for **two weeks**.

E1. Would this 2 week outage cause you to go out of business?
○ No
○ Yes

E2. Which of the following best describes how your organization would react to an outage of this duration?
○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
○ The organization would resume partial operation during the outage (please specify what operations would continue) ____
○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
○ Other please describe ____

E3. Would you your employees receive their full typical pay during this period?

○ No

○ Yes

E3a. If 'No,' what percent of typical pay would each type of employee receive?

Full-time employees:	_______%
Part-time year-round employees:	_______%
Contractors/project-based/temporary employees:	_______%

E4. What would be your approximate revenue loss from this 2 week outage?

$ ___________

Please share any additional comments:

____

____

____

Thank you for your help

Appendix C. Small & Medium C&I Survey Instrument: Direct Costs for Long-Duration Interruptions

This appendix contains a first draft of a modified small and medium C&I survey instrument, which elicits direct costs for long-duration interruptions. This survey instrument is a guide and the study team can modify questions or descriptions at its discretion through the testing process.

Customer Interruption Cost Survey

Commercial & Industrial Customers

Thank you for agreeing to participate in this important study. We ask that you complete this survey thinking **only** about the facilities that your organization occupies **at this location**:

«SERVICE_ADDRESS», «SERVICE_CITY»

If your organization shares a building with other businesses or you're the property manager at the above address(es), please answer the questions only for the space **your organization** occupies at this location and the activities **your organization** undertakes.

All your answers will be kept confidential. Your name and your organization's name and address will be kept anonymous and will not be associated with the information you provide.

Please return your completed survey in the enclosed return envelope to receive your $XX check. If you have any concerns, please contact [Utility] at [phone number]. For specific questions about the survey, please contact [Survey Administrator] at [phone number] Monday through Friday between the hours of 9:00 AM and 5:00 PM.

Sincerely,

Manager

This survey is also available online at: [website]
Your survey ID is [Survey ID]

When completing this survey, please note that a "power outage" refers to a complete loss of electricity to your facility. Power outages can be caused by many factors, such as bad weather, traffic accidents and equipment failures.

1. **Which of the following categories best describes your organization? (Choose one.)**

   ○ Agriculture/Agricultural Processing
   ○ Assembly/Light Industry
   ○ Chemicals/Paper/Refining
   ○ Food Processing
   ○ Government
   ○ Grocery Store/Restaurant
   ○ Hospital
   ○ Lodging (hotel, dormitory, prison, etc.)
   ○ Lumber/Mining/Plastics
   ○ Office
   ○ Oil/Gas Extraction
   ○ Retail
   ○ School/University
   ○ Stone/Glass/Clay/Cement
   ○ Technology
   ○ Transportation
   ○ Utility
   ○ Other (please specify):________________

2. **Does your organization have a plan for what to do during a long power outage that could last anywhere from several days to several weeks?**
   ○ No
   ○ Yes

   Please describe the plan:
   ____
   ____
   ____
   ____

3. **Has your organization ever experienced an outage lasting longer than 24 hours? (Choose one.)**
   ○ No
   ○ Yes—How long did the outage last? ____

   a. **What major tactics did you use to cope with the electricity disruption?**
   ____
   ____
   ____
   ____

   b. **What was the cost of implementing each tactic in (a)?**
   ____
   ____
   ____
   ____

   c. **What was the benefit to your firm of the tactics in (a) in terms of the prevention of business interruption (lost revenues or profits)?**
   ____
   ____
   ____
   ____

4. **How many of each type of employee is currently employed by your organization at this location?**

   __________ Full-time, year-round with ANNUAL SALARY

   __________ Full-time, year-round with HOURLY WAGE

   __________ Part-time, year-round

   __________ Contractor/project-based/temporary

5. **What is your organization's approximate total annual payroll at this location?**

   $__________per year

6. **What percent of your organization's payroll is for employees whose jobs are primarily related to facility safety, security and operations/maintenance?**
   ○ 0-5%
   ○ 6-10%
   ○ 11-15%
   ○ 16-20%
   ○ More than 20%

7. **Does your facility generate any of its own electricity (separate from backup power)?**
   ○ No
   ○ Yes

   a. What is the rated capacity of your generation equipment?

   ____
   ○ kW
   ○ MW
   ○ Horsepower
   ○ Don't know

   b. What percent of your electrical demand is supplied by your generation equipment?
   ___________ %

   c. What is the fuel source for the generation equipment?
   ○ Natural gas
   ○ Solar PV
   ○ Diesel
   ○ Battery
   ○ Other__________

8. **Does your facility have some form of backup electrical power?**
   ○ No
   ○ Yes

a. What is the rated capacity of your backup generation equipment?

____

O kW
O MW
O Horsepower
O Don't know

b. What percent of your electrical demand could be supplied by your backup generation equipment?
___________ %

c. What percent of your employees are currently able to work while the facility is on backup power?
___________ %

d. With the fuel stored onsite, how long can this backup operate?
___________ days

9. **What percent of your employees are currently able to work remotely?**

   ___________ %

10. **Do you have other offices or facilities similar to this location outside of the region?**
    O No
    O Yes
    If yes: Where are they?
    ____

11. **If your current location were suddenly inoperable, what percent of employees could relocate to your other locations?**
    ___________ %

12. **During an outage that lasts multiple days or weeks, could you physically relocate your equipment or infrastructure to ensure continuity of your operations?**
    O No
    O Yes
    If yes: How long would it take to do so?
    ___________ days

    If yes: How much would it cost to do so?
    $ ___________

13. **What expenses would you experience in relocating operations temporarily, i.e. more than one day?**

    $ ___________

14. **What type(s) or duration(s) of outages at this location have effects on other sites operated by your organization?**

____

____

____

15. **In general, how long can an outage last at your facility before it has a substantial impact on your operations? Please estimate that time length.**

    ______ hours and ______ minutes

16. **How much advance warning of a power outage does your organization need to significantly reduce the problems caused by a power outage? (Choose one.)**

    ○ Advance notice would not reduce problem(s)
    ○ At least 1 hour
    ○ At least 4 hours
    ○ At least 8 hours
    ○ At least 24 hours

17. **What is the approximate square footage of this facility?**

    __________ Square feet

Under extremely rare circumstances, it is possible for an outage to last multiple days or weeks. Although it is unlikely that your business has experienced such a long duration outage, we would like to know about various aspects of your business that would affect your company's response to an outage that lasts multiple days or weeks.

The next section describes two hypothetical power outages that last between one day and two weeks. The costs of a power outage depend upon the particular situation, and may vary from day to day depending upon business conditions. So for each outage scenario, you'll be given the opportunity to report the range of outage costs that your business might face (from low to high), as well as to estimate the cost that you would most likely have under typical circumstances.

It's important to try to answer all of the questions. If a question is difficult for you to answer, please give us an estimate and feel free to write down any comments about your answer.

Case A

An earthquake in **«SEASON»** causes widespread damage to the region, including severe damage to electricity generation and distribution infrastructure. Your organization does not experience any damages from the natural disaster, but the power outage persists and you do not know how long it will last. After a few days, your utility announces that the outage will last for **one week**.

A1. Would this one-week outage cause you to go out of business?
○ No
○ Yes

A2. Which of the following best describes how your organization would react to an outage of this duration?
○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
○ The organization would resume partial operation during the outage (please specify what operations would continue) ____
○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
○ Other please describe ____

A3. Would any employees likely be instructed to not come to work as you waited for the power to be restored?
○ No (SKIP TO A4)
○ Yes

If "Yes": What fraction of employees likely be instructed not to come to work as you waited for the power to be restored?

__________ %

A4. During this interruption, would you continue to pay…

Full-time employees? (Choose one.)

○ Yes, all ○ Yes, some (what %?) ___ ○ No ○ Not applicable

Part-time employees? (Choose one.)

○ Yes, all ○ Yes, some (what %?) ___ ○ No ○ Not applicable

Contractors/project-based/temporary employees? (Choose one.)

○ Yes, all ○ Yes, some (what %?) ___ ○ No ○ Not applicable

A5. What's the most likely 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? (If you're not sure please make your best guess.)

$ ___________ most likely value of lost work or services

In addition, please provide your lowest and highest estimates of dollar value of operations or service lost for this hypothetical outage.

$ ___________ lowest value of lost work or services

$ ___________ highest value of lost work or services

[Add to this table and sum at the end]

Category	Costs Due to Outage
A5. Operations and Services Lost	$

A6. What percent of the operations or services typically would be made up after the power outage? (Choose one.)

○ 0% ○ 10% ○ 20% ○ 30% ○ 40% ○ 50% ○ 60% ○ 70% ○ 80% ○ 90% ○ 100%

A7. Would there be any <u>incremental</u> labor costs associated with this power outage such as salaries and wages for staff <u>to deal with any outage-related issues</u> or overtime pay to make up for operations or services? (Choose one.)

○ No
○ Yes

If you answered "Yes" in question A5, please state the cost for lost labor as well as the cost for overtime labor to make up for lost work.

$ ___________ incremental labor costs to deal with outage related issues
$ ___________ labor costs in overtime/extra shifts to make up for lost work

[Add to this table and sum at the end]

Category	Costs Due to Outage
A7-1. Incremental Labor Costs to Deal with the Outage	$
A7-2. Overtime/Extra Shifts to Make Up for Lost Time	$

A8. Would there be any damage costs associated with this power outage such as damage to equipment, materials, etc.? (Choose one.)

○ No
○ Yes

If you answered "Yes" in question A6, please state how much the damage cost for equipment would be and how much the damage cost to materials would be.

$ ____________ damage to equipment
$ ____________ damage to materials

[Add to this table and sum at the end]

Category	Costs Due to Outage
A8-1. Damage to Equipment	$
A8-2. Damage to Materials	

A9. Would there be additional tangible costs associated with this power outage (such as extra restart costs, and costs to run and/or rent backup equipment)? (Choose one.)

○ No
○ Yes

If you answered "Yes" in question A7, please state the additional costs.

$ ____________ additional tangible costs

[Add to this table and sum at the end]

Category	Costs Due to Outage
A9. Other Tangible Costs	$

A10. Would there be <u>intangible costs</u> due to this power outage (such as inconvenience, potential liability, or loss of customers)? (Choose one.)

○ No
○ Yes

If you answered "Yes" in question A8, please estimate the intangible costs.

$ ____________ intangible costs

A11. In addition to the costs discussed above, some organizations may avoid expenses because of electrical outages. Some examples include a lower electrical bill, lower material outlays, and lower personnel costs. Would you experience any savings associated with this power outage? (Choose one.)

○ No
○ Yes

If you answered "Yes" in question A7, please state the savings.

$ ____________ savings

[Add to this table and sum at the end]

Category	Savings Due to Outage
A11. Savings Due to the Outage	$

Fill in the following table using your answers above, summing the costs to find a subtotal, and then subtracting the savings to find your total costs due to the outage.

Category	Costs Due to Outage
A5. Operations and Services Lost	$
A7-1. Incremental Labor Costs to Deal with the Outage	$
A7-2. Overtime/Extra Shifts to Make Up for Lost Time	$
A8-1. Damage to Equipment	$
A8-2. Damage to Materials	$
A9. Other Tangible Costs (Restart Costs, Backup Generation, etc.)	$
Subtotal:	**$**
A11. Savings Due to the Outage (Subtract from Subtotal)	$
TOTAL:	**$**

A12. Considering all of the costs you might experience as a result of this <u>1-week «SEASON» weekday outage beginning at «ONSET»</u>, please estimate the total costs for an assumed "Best Case" scenario, the cost for a "Typical Case" scenario and the cost for a "Worst Case" scenario. Please enter zero if there are no costs.

$______________________	$______________________	$______________________
Lowest Total Outage Cost **(Best Case)**	Most Likely Total Outage Cost **(Typical Case)**	Highest Total Outage Cost **(Worst Case)**

Case B

An earthquake in **«SEASON»** causes widespread damage to the region, including severe damage to electricity generation and distribution infrastructure. Your business and employees do not experience any damages from the natural disaster, but the power outage persists and you do not know how long it will last. After a few days, your utility announces that the outage will last for **<u>two weeks</u>**.

B1. Would this two-week outage cause you to go out of business?
○ No
○ Yes

B2. Which of the following best describes how your organization would react to an outage of this duration?
○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
○ The organization would resume partial operation during the outage (please specify what operations would continue) ____
○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
○ Other please describe ____

B3. Would any employees likely be instructed to not come to work as you waited for the power to be restored?
○ No (SKIP TO B4)
○ Yes

> **If "Yes": What fraction of employees likely be instructed not to come to work as you waited for the power to be restored?**
>
> **__________ %**

B4. During this interruption, would you continue to pay…

Full-time employees? (Choose one.)

O Yes, all   O Yes, some (what %?) ___   O No   O Not applicable

Part-time employees? (Choose one.)

O Yes, all   O Yes, some (what %?) ___   O No   O Not applicable

Contractors/project-based/temporary employees? (Choose one.)

O Yes, all   O Yes, some (what %?) ___   O No   O Not applicable

B5. Please estimate the most likely cost of the following expenses.

Category	Costs Due to Outage
Operations and Services Lost	$
Incremental Labor Costs to Deal with the Outage	$
Overtime/Extra Shifts to Make Up for Lost Time	$
Damage to Equipment	$
Damage to Materials	$
Other Tangible Costs (Restart Costs, Backup Generation, etc.)	$
Subtotal:	**$**
Savings Due to the Outage (Subtract from Subtotal)	$
TOTAL:	**$**

B6. Considering all of the costs you might experience as a result of this <u>2-week «SEASON» outage</u>, please estimate the total costs for an assumed "Best Case" scenario, the cost for a "Typical Case" scenario and the cost for a "Worst Case" scenario. Please enter zero if there are no costs.

$______________________	$______________________	$______________________
Lowest Total Outage Cost **(Best Case)**	Most Likely Total Outage Cost **(Typical Case)**	Highest Total Outage Cost **(Worst Case)**

Case C

An earthquake in **«SEASON»** causes widespread damage to the region, including severe damage to electricity generation and distribution infrastructure. Your business and employees do not experience any damages from the natural disaster, but the power outage persists and you do not know how long it will last. After **24 hours**, the power is restored.

C1. Which of the following best describes how your organization would react to an outage of this duration?

○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
○ The organization would resume partial operation during the outage (please specify what operations would continue) ____
○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
○ Other please describe ____

C2. Would any employees likely be instructed to not come to work as you waited for the power to be restored?

○ No (SKIP TO C3)
○ Yes

If "Yes": What fraction of employees likely be instructed not to come to work as you waited for the power to be restored?

__________ %

C3. During this interruption, would you continue to pay…

Full-time employees? (Choose one.)

○ Yes, all ○ Yes, some (what %?) ___ ○ No ○ Not applicable

Part-time employees? (Choose one.)

○ Yes, all ○ Yes, some (what %?) ___ ○ No ○ Not applicable

Contractors/project-based/temporary employees? (Choose one.)

○ Yes, all ○ Yes, some (what %?) ___ ○ No ○ Not applicable

C4. Please estimate the most likely cost of the following expenses.

Category	Costs Due to Outage
Operations and Services Lost	$
Incremental Labor Costs to Deal with the Outage	$
Overtime/Extra Shifts to Make Up for Lost Time	$
Damage to Equipment	$
Damage to Materials	$
Other Tangible Costs (Restart Costs, Backup Generation, etc.)	$
Subtotal:	**$**
Savings Due to the Outage (Subtract from Subtotal)	$
TOTAL:	**$**

C5. Considering all of the costs you might experience as a result of this 24-hour «SEASON» outage, please estimate the total costs for an assumed "Best Case" scenario, the cost for a "Typical Case" scenario and the cost for a "Worst Case" scenario. Please enter zero if there are no costs.

$______________________	$______________________	$______________________
Lowest Total Outage Cost **(Best Case)**	Most Likely Total Outage Cost **(Typical Case)**	Highest Total Outage Cost **(Worst Case)**

Please share any additional comments:

____

____

____

____

Thank you for your help

Appendix D. Government & Educational Facilities Survey Instrument: Direct Costs for Short-Duration Interruptions

This appendix contains a first draft of a government and education facilities survey instrument, which elicits direct costs for short-duration interruptions. This survey instrument is a guide and the study team can modify questions or descriptions at its discretion through the testing process.

Customer Interruption Cost Survey

Government and Education Facilities

Thank you for agreeing to participate in this important study. We ask that you complete this survey thinking **only** about the facilities that your organization occupies **at this location**:

«SERVICE_ADDRESS», «SERVICE_CITY»

If your organization shares a building with other businesses or you're the property manager at the above address(es), please answer the questions only for the space **your organization** occupies at this location and the activities **your organization** undertakes.

All your answers will be kept confidential. Your name and your organization's name and address will be kept anonymous and will not be associated with the information you provide.

Please return your completed survey in the enclosed return envelope to receive your $XX check. If you have any concerns, please contact [Utility] at [phone number]. For specific questions about the survey, please contact [Survey Administrator] at [phone number] Monday through Friday between the hours of 9:00 AM and 5:00 PM.

Sincerely,

Manager

This survey is also available online at: [website]
Your survey ID is [Survey ID]

When completing this survey, please note that a "power outage" refers to a complete loss of electricity to your facility. Power outages can be caused by many factors, such as bad weather, traffic accidents and equipment failures.

1. **In the past 3 months, how many brief interruptions of five minutes or less have you experienced at your location?**

   ________ Brief interruptions (5 minutes or less)

2. **In the past 3 months, how many lengthy outages of more than five minutes have you experienced at your location?**

   ________ Lengthy outages (more than 5 minutes)

3. **What type(s) or duration(s) of outages at this location have financial effects on other sites owned by your organization?**

   ____

   ____

   ____

4. **Has your organization ever sent employees home during a power outage? (Choose one.)**

   ○ No
   ○ Yes

5. **In general, how long can an outage last at your facility before it has a substantial impact on your operations? Please estimate that time length.**

   ______ hours and ______ minutes

6. **How much advance warning of a power outage does your organization need to significantly reduce the problems caused by a power outage? (Choose one.)**

   ○ Advance notice would not reduce problem(s)
   ○ At least 1 hour
   ○ At least 4 hours
   ○ At least 8 hours
   ○ At least 24 hours

7. **What's the approximate square footage of this facility?**

   __________ Square feet

8. Which of the following categories best describes your organization? (Choose one.)

○ Government - Federal
○ Government - State
○ Government - Local
○ School – Primary
○ School – Secondary
○ School – College or University
○ Other – Please Describe____________________

9. How many of each type of employee is currently employed by your organization at this location?

__________ Full-time, year-round with ANNUAL SALARY

__________ Full-time, year-round with HOURLY WAGE

__________ Part-time, year-round

__________ Contractor/project-based/temporary

10. What is your organization's annual budget for this location?

$__________per year

The next section describes four different power outage scenarios. We'd like to know the costs to your organization of adjusting to each of these power outages.

The costs of a power outage depend upon the particular situation, and may vary from day to day depending upon operating conditions. So for each outage scenario, you'll be given the opportunity to report the range of outage costs that your organization might face (from low to high), as well as to estimate the cost that you would most likely have under typical circumstances.

It's important to try to answer all of the questions. If a question is difficult for you to answer, please give us an estimate and feel free to write down any comments about your answer.

Case A

On a «SEASON» weekday, a complete power outage occurs at «ONSET» without any warning. You don't know how long it will last, but after **«HOUR1» hours** your organization's electricity is fully restored. Note that **all** of the remaining cases occur at **«ONSET».**

SUMMARY:

Conditions:	«SEASON» weekday	**Start time:**	«ONSET»
Duration:	1 hour	**End time:**	«END2»

A1. How disruptive would this power outage be to your organization? (Choose one.)

○	○	○	○	○	○	○
1 Not disruptive at all	2	3	4	5	6	7 Very disruptive

A2. Would your operations or services typically stop or slow down as a result of this power outage? (If yes, please state the number of hours.) (Choose one.)

○ No
○ Yes

If you answered "Yes" in question A2, please enter the number of hours that operations or services would stop or slow down (include time <u>during and after</u> the power outage?

____________ hours

A3. What's 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? You can estimate this amount based on the following calculation:

$$\textit{Value of Lost Operations or Services} = \textit{Annual Budget (Question 10)} \div \textit{Facility Operating Hours per Year} \times \textit{Outage Duration (in hours)}$$

$ ____________ value of lost work or services

[Add to this table and sum at the end]

Category	Costs Due to Outage
A3. Operations and Services Lost	$

A4. What percent of the operations or services typically would be made up after the power outage? (Choose one.)

○ 0% ○ 10% ○ 20% ○ 30% ○ 40% ○ 50% ○ 60% ○ 70% ○ 80% ○ 90% ○ 100%

A5. Would there be any <u>incremental</u> labor costs associated with this power outage such as salaries and wages for staff <u>to deal with any outage-related issues</u> or overtime pay to make up for operations or services? (Choose one.)

○ No
○ Yes

If you answered "Yes" in question A5, please state the cost for lost labor as well as the cost for overtime labor to make up for lost work.

$ ____________ incremental labor costs to deal with outage related issues
$ ____________ labor costs in overtime/extra shifts to make up for lost work

[Add to this table and sum at the end]

Category	Costs Due to Outage
A5-1. Incremental Labor Costs to Deal with the Outage	$
A5-2. Overtime/Extra Shifts to Make Up for Lost Time	$

A6. Would there be any damage costs associated with this power outage such as damage to equipment, materials, etc.? (Choose one.)

○ No
○ Yes

If you answered "Yes" in question A6, please state how much the damage cost for equipment would be and how much the damage cost to materials would be.

$ ____________ damage to equipment
$ ____________ damage to materials

[Add to this table and sum at the end]

Category	Costs Due to Outage
A6-1. Damage to Equipment	$
A6-2. Damage to Materials	

A7. Would there be additional tangible costs associated with this power outage (such as extra restart costs, and costs to run and/or rent backup equipment)? (Choose one.)

○ No
○ Yes

If you answered "Yes" in question A7, please state the additional costs.

$ ____________ additional tangible costs

[Add to this table and sum at the end]

Category	Costs Due to Outage
A7. Other Tangible Costs	$

A8. Would there be intangible costs due to this power outage (such as inconvenience, potential liability, or loss of customers)? (Choose one.)

○ No
○ Yes

If you answered "Yes" in question A8, please estimate the intangible costs.

$ ____________ intangible costs

A9. In addition to the costs discussed above, some organizations may avoid expenses because of electrical outages. Some examples include a lower electrical bill, lower material outlays, and lower personnel costs. Would you experience any savings associated with this power outage? (Choose one.)

○ No
○ Yes

If you answered "Yes" in question A9, please state the savings.

$ ____________ savings

[Add to this table and sum at the end]

Category	Savings Due to Outage
A9. Savings Due to the Outage	$

Fill in the following table using your answers above, summing the costs to find a subtotal, and then subtracting the savings to find your total costs due to the outage.

Category	Costs Due to Outage
A3. Operations and Services Lost	$
A5-1. Incremental Labor Costs to Deal with the Outage	$
A5-2. Overtime/Extra Shifts to Make Up for Lost Time	$
A6-1. Damage to Equipment	$
A6-2. Damage to Materials	$
A7. Other Tangible Costs	$
Subtotal:	**$**
A9. Savings Due to the Outage (Subtract from Subtotal)	$
TOTAL:	**$**

A10. Considering all of the costs you might experience as a result of this «HOUR1»-hour «SEASON» weekday outage beginning at «ONSET», please estimate the total costs for an assumed "Best Case" scenario, the cost for a "Typical Case" scenario and the cost for a "Worst Case" scenario. Please enter zero if there are no costs.

$______________________	$______________________	$______________________
Lowest Total Outage Cost **(Best Case)**	Most Likely Total Outage Cost **(Typical Case)**	Highest Total Outage Cost **(Worst Case)**

Case B

Without any warning, on a «SEASON» weekday, a complete power outage occurs at «ONSET». You don't know how long it will last, but **after 1 hour** your organization's electricity is fully restored.

SUMMARY:

Conditions:	«SEASON» weekday	**Start time:**	«ONSET»
Duration:	1 hour	**End time:**	«END2»

B1. Considering all of the costs you might experience as a result of this <u>1-hour «SEASON» weekday outage beginning at «ONSET»</u>, please estimate the total costs for an assumed "Best Case" scenario, the cost for a "Typical Case" scenario and the cost for a "Worst Case" scenario. Please enter zero if there are no costs.

$______________________	**$**______________________	**$**______________________
Lowest Total Outage Cost **(Best Case)**	Most Likely Total Outage Cost **(Typical Case)**	Highest Total Outage Cost **(Worst Case)**

Case C

Without any warning, on a «SEASON» weekday, a complete power outage occurs at «ONSET». You don't know how long it will last, but after **5 minutes** your organization's electricity is fully restored.

SUMMARY:

Conditions:	«SEASON» weekday	**Start time:**	«ONSET»
Duration:	5 minutes	**End time:**	«END3»

C1. Considering all of the costs you might experience as a result of this <u>5-minute «SEASON» weekday outage beginning at «ONSET»</u>, please estimate the total costs for an assumed "Best Case" scenario, the cost for a "Typical Case" scenario and the cost for a "Worst Case" scenario. Please enter zero if there are no costs.

$______________________	**$**______________________	**$**______________________
Lowest Total Outage Cost **(Best Case)**	Most Likely Total Outage Cost **(Typical Case)**	Highest Total Outage Cost **(Worst Case)**

Longer Outages

Under extremely rare circumstances, it is possible for an outage to last multiple days or weeks. Although it is unlikely that your business has experienced such a long duration outage, we would like to know about various aspects of your business that would affect your company's response to an outage that lasts multiple days or weeks.

It's important to try to answer all of the questions. If a question is difficult for you to answer, please give us an estimate and feel free to write down any comments about your answer.

11. Does your organization have a plan for what to do during a long power outage that could last anywhere from several days to several weeks?

○ No
○ Yes

Please describe the plan:

____
____
____
____
____

12. Has your organization ever experienced an outage lasting longer than 24 hours? (Choose one.)

○ No
○ Yes—How long did the outage last?

____

a. **What major tactics did you use to cope with the electricity disruption?**

____
____
____
____

b. **What was the cost of implementing each tactic in (a)?**

____
____
____
____

c. What was the benefit to your firm of the tactics in (a) in terms of the prevention of business interruption (lost revenues or profits)?

____
____
____
____

13. Does your facility generate any of its own electricity (separate from backup power)?

○ No
○ Yes

a. What is the rated capacity of your generation equipment?

____

○ kW
○ MW
○ Horsepower
○ Don't know

b. What percent of your electrical demand is supplied by your generation equipment?

___________ %

c. What is the fuel source for the generation equipment?

○ Natural gas
○ Solar PV
○ Diesel
○ Battery
○ Other__________

14. Does your facility have some form of backup electrical power?

○ No
○ Yes

a. What is the rated capacity of your backup generation equipment?

____

○ kW
○ MW
○ Horsepower
○ Don't know

b. What percent of your electrical demand could be supplied by your backup generation equipment?

___________ %

c. What percent of your employees are currently able to work while the facility is on backup power?

___________ %

d. With the fuel stored onsite, how long can this backup operate?

___________ days

15. What percent of your employees are currently able to work remotely?

___________ %

16. **Do you have other offices or facilities similar to this location outside of the region?**
    ○ No
    ○ Yes
        If yes: Where are they?
        ____

17. **If your current location were suddenly inoperable, what percent of employees could relocate to your other locations?**
    ___________ %

18. **During an outage that lasts multiple days or weeks, could you physically relocate your equipment or infrastructure to ensure continuity of your operations?**
    ○ No
    ○ Yes
        If yes: How long would it take to do so?
        ___________ days

        If yes: How much would it cost to do so?
        $ ___________

19. **What expenses could you experience in relocating operations temporarily, i.e. more than one day?**

    $ ___________

The next section describes two hypothetical power outages that could last anywhere between one day and two weeks. For each outage scenario, you will be asked to estimate the cost that you would most likely experience under typical circumstances. The costs of a power outage depend upon the particular situation, and may vary from day to day depending upon conditions. Consequences of the outage could include, but not be limited to:

- **People may be unable to work because:**
    1. **they could not perform their job (i.e., computers not working)**
    2. **the temperature in their work space was too hot or cold *or***
    3. **their workspace became too hazardous.**
- **The public may not be able to access the facility because of safety concerns**
- **Sensitive equipment and/or facilities may become damaged by extended deprivation of electric power.**

It's important to try to answer all of the questions. If a question is difficult for you to answer, please give us an estimate and feel free to write down any comments about your answer.

Case D

An earthquake in **«SEASON»** causes widespread damage to the region, including severe damage to electricity generation and distribution infrastructure. Your organization does not experience any damages from the natural disaster, but the power outage persists and you do not know how long it will last. After a few days, your utility announces that the outage will last for **one week**.

D1. Would this 1-week outage cause you to go out of business?

○ No
○ Yes

D2. Which of the following best describes how your organization would react to an outage of this duration?

○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
○ The organization would resume partial operation during the outage (please specify what operations would continue) ____
○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
○ Other please describe ____

D3. Would you your employees receive their full typical pay during this period?

○ No
○ Yes

D3a. If 'No,' what percent of typical pay would each type of employee receive?

Full-time employees:	_______%
Part-time year-round employees:	_______%
Contractors/project-based/temporary employees:	_______%

Case E

A similar situation occurs as Case D, where an earthquake in **«SEASON»** causes widespread damage to the region, including severe damage to electricity generation and distribution infrastructure. Your business and employees do not experience any damages from the natural disaster, but the power outage persists and you do not know how long it will last. In this case, your utility announces after a few days that the outage will last for **two weeks**.

E1. Would this 2 week outage cause you to go out of business?

○ No
○ Yes

E2. Which of the following best describes how your organization would react to an outage of this duration?
○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
○ The organization would resume partial operation during the outage (please specify what operations would continue) ____
○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
○ Other please describe ____

E3. Would you your employees receive their full typical pay during this period?
○ No
○ Yes

E3a. If 'No,' what percent of typical pay would each type of employee receive?

Full-time employees: _______%
Part-time year-round employees: _______%
Contractors/project-based/temporary employees: _______%

Please share any additional comments:

____

____

____

____

Thank you for your help

Appendix E. Government & Educational Facilities Survey Instrument: Direct Costs for Long-Duration Interruptions

This appendix contains a first draft of a survey instrument for government and education facilities, which elicits direct costs for long-duration interruptions. This survey instrument is a guide and the study team can modify questions or descriptions at its discretion through the testing process.

Customer Interruption Cost Survey

Government and Educational Facilities

Thank you for agreeing to participate in this important study. We ask that you complete this survey thinking **only** about the facilities that your organization occupies **at this location**:

«SERVICE_ADDRESS», «SERVICE_CITY»

If your organization shares a building with other organizations or businesses, please answer the questions only for the space **your organization** occupies at this location and the activities **your organization** undertakes.

All your answers will be kept confidential. Your name and your organization's name and address will be kept anonymous and will not be associated with the information you provide.

Please return your completed survey in the enclosed return envelope to receive your $XX check. If you have any concerns, please contact [Utility] at [phone number]. For specific questions about the survey, please contact [Survey Administrator] at [phone number] Monday through Friday between the hours of 9:00 AM and 5:00 PM.

Sincerely,

Manager

This survey is also available online at: [website]
Your survey ID is [Survey ID]

Background

When completing this survey, please note that a "power outage" refers to a <u>complete</u> loss of electricity to your facility. Power outages can be caused by many factors, such as bad weather, traffic accidents and equipment failures.

1. **Which of the following categories best describes your organization? (Choose one.)**

   ○ Government - Federal
   ○ Government - State
   ○ Government - Local
   ○ School – Primary
   ○ School – Secondary
   ○ School – College or University
   ○ Other – Please Describe____________________

2. **Does your organization have a plan for what to do during a long power outage (for example one that could last anywhere from several days to several weeks)?**
   ○ No
   ○ Yes

   Please describe the plan:
   ____
   ____
   ____
   ____

3. **Has your organization ever experienced an outage lasting longer than 24 hours? (Choose one.)**
   ○ No
   ○ Yes—How long did the outage last? ____

   a. **What major tactics did you use to cope with the electricity disruption?**
   ____
   ____
   ____
   ____

   b. **What was the cost of implementing each tactic in (a)?**
   ____
   ____
   ____
   ____

   c. **What was the benefit to your firm of the tactics in (a) in terms of the prevention of business interruption (lost revenues or profits)?**
   ____
   ____
   ____
   ____

4. How many of each type of employee is currently employed by your organization at this location?

__________ Full-time, year-round with ANNUAL SALARY

__________ Full-time, year-round with HOURLY WAGE

__________ Part-time, year-round

__________ Contractor/project-based/temporary

5. What is your organization's approximate total annual payroll (including contract employees) at this location?

$__________per year

6. What percent of your organization's payroll is for employees whose jobs are primarily related to facility safety, security and operations/maintenance?

○ 0-5%
○ 6-10%
○ 11-15%
○ 16-20%
○ More than 20%

7. What is your organization's annual budget for this location?

$__________per year

8. Does your facility generate any of its own electricity (separate from backup power)?

○ No
○ Yes

a. What is the rated capacity of your generation equipment?

____

○ kW
○ MW
○ Horsepower
○ Don't know

b. What percent of your electrical demand is supplied by your generation equipment?

___________ %

c. What is the fuel source for the generation equipment?

○ Natural gas
○ Solar PV
○ Diesel
○ Battery
○ Other__________

9. **Does your facility have some form of backup electrical power?**
   ○ No
   ○ Yes

   a. What is the rated capacity of your backup generation equipment?
   ____
   ○ kW
   ○ MW
   ○ Horsepower
   ○ Don't know

   b. What percent of your electrical demand could be supplied by your backup generation equipment?
   ___________ %

   c. What percent of your employees are currently able to work while the facility is on backup power?
   ___________ %

   d. With the fuel stored onsite, how long can this backup operate?
   ___________ days

10. **What percent of your employees are currently able to work remotely?**

   ___________ %

11. **Do you have other offices or facilities similar to this location outside of the region?**
   ○ No
   ○ Yes
   If yes: Where are they?
   ____

12. **If your current location were suddenly inoperable, what percent of employees could relocate to your other locations?**
   ___________ %

13. **During an outage that lasts multiple days or weeks, could you physically relocate your equipment or infrastructure to ensure continuity of your operations?**
   ○ No
   ○ Yes
   If yes: How long would it take to do so?
   ___________ days

   If yes: How much would it cost to do so?
   $ ___________

14. **What expenses would you experience in relocating operations temporarily, i.e. more than one day?**

   $ ___________

15. **What type(s) or duration(s) of outages at this location have effects on other sites operated by your organization?**

____

____

____

16. **In general, how long can an outage last at your facility before it has a substantial impact on your operations? Please estimate that time length.**

______ hours and ______ minutes

17. **How much advance warning of a power outage does your organization need to significantly reduce the problems caused by a power outage? (Choose one.)**

○ Advance notice would not reduce problem(s)
○ At least 1 hour
○ At least 4 hours
○ At least 8 hours
○ At least 24 hours

18. **What is the approximate square footage of this facility?**

__________ Square feet

Under extremely rare circumstances, it is possible for an outage to last multiple days or weeks. Although it is unlikely that your organization has experienced such a long duration outage, we would like to know about various aspects of your organization that would affect its response to an outage that lasts multiple days or weeks.

The next section describes two hypothetical power outages that could last anywhere between one day and two weeks. For each outage scenario, you will be asked to estimate the cost that you would most likely experience under typical circumstances. The costs of a power outage depend upon the particular situation, and may vary from day to day depending upon conditions. Consequences of the outage could include, but not be limited to:

- **People may be unable to work because:**
  1. **they could not perform their job (i.e., computers not working)**
  2. **the temperature in their work space was too hot or cold *or***
  3. **their workspace became too hazardous.**
- **The public may not be able to access the facility because of safety concerns**
- **Sensitive equipment and/or facilities may become damaged by extended deprivation of electric power.**

It's important to try to answer all of the questions. If a question is difficult for you to answer, please give us an estimate and feel free to write down any comments about your answer.

Case A

An earthquake in **«SEASON»** causes widespread damage to the region, including severe damage to electricity generation and distribution infrastructure. Your organization does not experience any damages from the natural disaster, but the power outage persists and you do not know how long it will last. After a few days, your utility announces that the outage will last for **one week**.

A1. Which of the following best describes how your organization would react to an outage of this duration?

○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
○ The organization would resume partial operation during the outage (please specify what operations would continue) ____

○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
○ Other please describe ____

A2. Would any employees likely be instructed to not come to work as you waited for the power to be restored?

○ No (SKIP TO A3)
○ Yes

If "Yes": What fraction of employees likely be instructed not to come to work as you waited for the power to be restored?

__________ %

A3. During this interruption, would you continue to pay…

Full-time employees? (Choose one.)

○ Yes, all ○ Yes, some (what %?) ___ ○ No ○ Not applicable

Part-time employees? (Choose one.)

○ Yes, all ○ Yes, some (what %?) ___ ○ No ○ Not applicable

Contractors/project-based/temporary employees? (Choose one.)

○ Yes, all ○ Yes, some (what %?) ___ ○ No ○ Not applicable

A4. Would there be labor costs beyond the level of normal operations ensure safety and security; to make up for the backlog of work and/or repair of compromised facilities after this outage? (Choose one.)

○ No
○ Yes

If "Yes" - please estimate the amount of labor costs.

$ ___________ labor costs to make up for the backlog of work and/or repair compromised facilities

Sudden power outages may cause damage to equipment. Outages may also damage materials in the facility—particularly for longer outages (for example, items requiring refrigeration or freezing). In very cold weather, other damage may be caused by pipes freezing as a result of the outage. Please estimate the cost of damage to equipment and materials.

[Include pictures to remind respondents of possible damages, e.g. robotic lab equipment, refrigerated products, frozen pipes]

A5.1 EQUIPMENT: Would there be any damage costs from this extended outage such as damage to sensitive electrical or mechanical equipment? (Choose one.)

○ No
○ Yes

If "Yes" - please state how much the damage cost for equipment would be.

$ ___________ damage to equipment

A5.2 MATERIALS: Would there be any damage to materials from the outage? (Choose one.)

○ No
○ Yes

If "Yes" - please state how much the damage cost for equipment would be.

$ ___________ damage to materials

A6. Would there be additional tangible costs associated with this power outage (such as extra restart costs, and costs to run and/or rent backup equipment)? (Choose one.)

○ No
○ Yes

If "Yes" - please state the additional costs.

$ ___________ additional tangible costs

A7. Would there be <u>intangible costs</u> due to this power outage (such as inconvenience, potential liability, or loss of customers)? (Choose one.)

○ No
○ Yes

If "Yes" - please estimate the intangible costs.

$ ___________ intangible costs

A8. In addition to the costs discussed above, some organizations may avoid expenses because of electrical outages. (For example, a lower electrical bill.) Apart from any labor-related savings (which you explained in an earlier question), would you experience any savings associated with this power outage? (Choose one.)

○ No
○ Yes

If "Yes" - please state the savings.

$ ___________ savings

Case B

An earthquake in **«SEASON»** causes widespread damage to the region, including severe damage to electricity generation and distribution infrastructure. Your organization does not experience any damages from the natural disaster, but the power outage persists and you do not know how long it will last. After a few days, your utility announces that the outage will last for **<u>two weeks</u>**.

B1. Which of the following best describes how your organization would react to an outage of this duration?

○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
○ The organization would resume partial operation during the outage (please specify what operations would continue) ____

○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
○ Other please describe ____

B2. Would any employees likely be instructed to not come to work as you waited for the power to be restored?

○ No (SKIP TO B3)
○ Yes

If "Yes": What fraction of employees likely be instructed not to come to work as you waited for the power to be restored?
__________ %

B3. During this interruption, would you continue to pay…

Full-time employees? (Choose one.)

O Yes, all   O Yes, some (what %?) ___   O No   O Not applicable

Part-time employees? (Choose one.)

O Yes, all   O Yes, some (what %?) ___   O No   O Not applicable

Contractors/project-based/temporary employees? (Choose one.)

O Yes, all   O Yes, some (what %?) ___   O No   O Not applicable

B4. Would there be labor costs beyond the level of normal operations ensure safety and security; to make up for the backlog of work and/or repair of compromised facilities after this outage? (Choose one.)

O No
O Yes

If "Yes" - please estimate the amount of labor costs.

$ ___________ labor costs to make up for the backlog of work and/or repair compromised facilities

Sudden power outages may cause damage to equipment. Outages may also damage materials in the facility—particularly for longer outages (for example, items requiring refrigeration or freezing). In very cold weather, other damage may be caused by pipes freezing as a result of the outage. Please estimate the cost of damage to equipment and materials.

[Include pictures to remind respondents of possible damages, e.g. robotic lab equipment, refrigerated products, frozen pipes]

B5.1 EQUIPMENT: Would there be any damage costs from this extended outage such as damage to sensitive electrical or mechanical equipment? (Choose one.)

O No
O Yes

If "Yes" - please state how much the damage cost for equipment would be.

$ ___________ damage to equipment

B5.2 MATERIALS: Would there be any damage to materials from the outage? (Choose one.)
○ No
○ Yes

If "Yes" - please state how much the damage cost for equipment would be.

$ ___________ damage to materials

B6. Would there be additional tangible costs associated with this power outage (such as extra restart costs, and costs to run and/or rent backup equipment)? (Choose one.)

○ No
○ Yes

If "Yes" - please state the additional costs.

$ ___________ additional tangible costs

B7. Would there be <u>intangible costs</u> due to this power outage (such as inconvenience, potential liability, or loss of customers)? (Choose one.)

○ No
○ Yes

If "Yes" - please estimate the intangible costs.

$ ___________ intangible costs

B8. In addition to the costs discussed above, some organizations may avoid expenses because of electrical outages. (For example, a lower electrical bill.) Apart from any labor-related savings (which you explained in an earlier question), would you experience any savings associated with this power outage? (Choose one.)
○ No
○ Yes

If "Yes" - please state the savings.

$ ___________ savings

Please share any additional comments:

____

____

____

Thank you for your help

Appendix F. Large Non-Residential Survey Instrument: Direct Costs for Short Duration Interruptions

This appendix contains a first draft of a modified large non-residential survey instrument, which elicits direct costs for short-duration interruptions. This survey instrument is a guide and the study team can modify questions or descriptions at its discretion through the testing process.

Associated Delivery Numbers (Acct #)

ID #: «ID»

Date of Interview: ___________________

Interviewer Name: ___________________

Interview Start Time: _________________

Interview End Time: _________________

Name:	Title:
Name:	Title:
Name:	Title:

I would like to talk to you about the costs of power outages for:
(Describe the part of the site served by the selected deliveries.)

Company Name:

Service Address:

If delivery serves only part of the site, describe location served:

OUTAGE SCENARIOS

Case	Season	Day	Start Time	End Time	Duration
1	«SEASON1»	Weekday	«ONSET»	«END1»	4 hours
2	«SEASON1»	Weekday	«ONSET»	«END2»	1 minute
3	«SEASON1»	Weekday	«ONSET»	«END3»	1 hour
4	«SEASON1»				1 week
5	«SEASON1»				2 weeks

What are the operating hours of this facility?

Use military time. If open 24 hours, use 00:00 to 00:00.

Weekday

	Open	Close
Shift 1		
Shift 2		
Shift 3		

Saturday

	Open	Close
Shift 1		
Shift 2		
Shift 3		

Sunday

	Open	Close
Shift 1		
Shift 2		
Shift 3		

PRODUCT AND PROCESS DESCRIPTION

1) What products do you make and/or what services do you provide at this facility?

____

____

____

____

____

2) What processes do you use to make these products and/or generate these services?

____

____

____

____

____

OUTAGE EXPERIENCE

In the past 12 months, about how many outages of the durations listed below have you had at this business location? Write a number in each blank. *(Use 0 if none.)*

3.1)	Short duration or momentary (five minutes or less)	_______
3.2)	Longer than five minutes and up to ½ hour	_______
3.3)	Longer than ½ hour and up to 1 hour	_______
3.4)	Longer than 1 hour and up to 4 hours	_______
3.5)	Longer than 4 hours and up to 24 hours	_______
3.6)	Over 24 hours	_______

MOST RECENT OUTAGE EVENTS

Please describe your three most recent power outages:

	Outage Date *Mo/Yr*	Duration *Hrs/Mins/Secs*	Time *Military*	Weather Conditions *Clear/Stormy*	Description of Impacts
3.7)	_______	_________	______	________	____
3.8)	_______	_________	______	________	____
3.9)	_______	_________	______	________	____

4) What normally happens to your facility's operations when a prolonged power outage (lasting more than one minute) occurs?

(Prompt for major equipment affected, worst effects on operations, etc.)

____

____

____

5.1) Does an outage at this location have financial effects on other sites owned by your company?

- ○ No
- ○ Yes

(if No, skip to Q5.4)

5.2) What type(s) or duration(s) of outages at this location have financial effects on other sites owned by your company?

(Probe for interdependencies of the production network.)

____

____

____

5.3) What are the specific financial effects?

____

____

5.4) Does an outage at this location have financial effects at your customers' sites?

○ No
○ Yes

6) Does your facility generate any of its own electricity (separate from backup power)?

○ No
○ Yes

6a) What percent of your electrical demand is supplied by your generation equipment?

___________ %

6b) What is the rated capacity of your generation equipment? ___________

○ kW
○ MW
○ Horsepower
○ Don't know

6c) What is the fuel source for the generation equipment?

○ Natural gas
○ Solar PV
○ Diesel
○ Battery
○ Other__________

7) Does your facility have some form of backup electrical power?

○ No
○ Yes

7a) What percent of your electrical demand could be supplied by your backup generation equipment? ___________ %

7b) What is the rated capacity of your backup generation equipment? ___________

○ kW
○ MW
○ Horsepower
○ Don't know

8) What percent of your employees are currently able to work remotely?

___________ %

9) During an outage that lasts multiple days or weeks, could you physically relocate your equipment or infrastructure to ensure continuity of your business operations?

○ No
○ Yes

9a) How long would it take to do so?

___________ days

9b) How much would it cost to do so?

$ ___________

10) Do you have other offices or facilities similar to this location outside of the region?

○ No
○ Yes

10a) Where are they? ____

11) If your current location were suddenly inoperable, what percent of employees could relocate to your other locations?

___________ %

12) What expenses would you experience in relocating operations temporarily, i.e. more than one day?

$ ___________

13) Has your business/organization ever experienced an outage lasting longer than 24 hours? (Choose one.)

○ No

○ Yes—How long did the outage last? ____

13a) What major tactics did you use to cope with the electricity disruption?

____
____
____
____

13b) What was the cost of implementing each tactic in (a)?

____
____
____
____

13c) What was the benefit to your firm of the tactics in (a) in terms of the prevention of business interruption (lost revenues or profits)?

____
____
____
____

14) Which one of the following categories best describes your business?

○ Agriculture/Agricultural Processing
○ Assembly/Light Industry
○ Chemicals/Paper/Refining
○ Food Processing
○ Grocery Store/Restaurant
○ Lodging (hotel, health care facility, dormitory, prison, etc.)
○ High Tech
○ Lumber/Mining/Plastics
○ Office
○ Oil/Gas Extraction
○ Retail
○ Stone/Glass/Clay/Cement
○ Transportation
○ Utility
○ Other *(please specify)*: ______________________________

15) What is the approximate square footage of the facility?

__________ Square feet

16) How many <u>full-time</u> (30+ hours per week) employees are employed by your business at this location?

__________ Full-time employees

17) List the number of people employed by your business at this location in each of the following categories:

__________ # of part-time year-round employees

__________ # of full-time seasonal employees

__________ # of part-time seasonal employees

18) What is the approximate value of your business's annual operations or services (income)?

$_____________ per year

19) What is the approximate value of your business's total annual expenses (including labor, rent, materials, and other overhead expenses)?

$_____________ per year

20) Approximately what percentage of your business's annual operating budget is spent on electricity? __________ %

The next section describes 5 different power outages. We would like to know the impacts to your business of adjusting to each of these power outages. **Assume that all of the described outages arise from issues associated with [Utility's] infrastructure and occur <u>without advance warning</u>, which means that you do not initially know how long each outage will last.**

For many businesses, the costs of a power outage depend upon the particular situation, and may vary from day to day depending upon business conditions. For each outage type, please estimate the costs that you would be most likely to have under average circumstances.

Since some businesses have more than one building at one location, and others have multiple buildings in several locations, please remember to fill out these questions thinking <u>only</u> about the building(s) that your business occupies at the location specified for this survey.

It is important to try to answer all of the questions. If a question is difficult for you to answer, please give us an estimate and feel free to provide any comments about your answer.

Case	Season	Day	Start Time	End Time	Duration
1	«SEASON1»	Weekday	«ONSET»	«END1»	4 hours

1C1) How long would activities stop or slow down as a result of this outage? ___hr ___min
(if zero, skip to Q.1C6)

1C2) By what percentage would activities stop or slow down? __________ %
1C3) What is the value of output (cost plus profit) that would be lost (at least temporarily) while activities are stopped or slowed down due to the outage? __________ $

1C4) What percent of this lost output is likely to be made up? __________ %
1C5) I would estimate that the amount that your firm's revenue or budget would change as a result of the outage would be… IS THAT RIGHT? __________ $

EXTRA MATERIALS COST
1C6) Damage/spoilage to raw or intermediate materials __________ $

1C7) Cost of disposing of hazardous materials __________ $

1C8) Damage to your firm's plant or equipment __________ $

1C9) Costs to run backup generation or equipment __________ $

1C10) Additional materials and other fuel costs to restart facilities __________ $

SAVINGS ON MATERIAL COST (NET OF ANY MAKE-UP PRODUCTION)
1C11) Savings from unused raw and intermediate materials (except fuel) __________ $

1C12) Savings on your firm's fuel (electricity) bill __________ $

1C13) Scrap value of damaged products or inputs __________ $

LABOR COST
1C14) How would the lost output most likely be made up? *Check all that apply.*

____ a) Overtime

____ b) Extra shifts

____ c) Work more intensely

____ d) Reschedule work

____ e) Other (specify: ____)

1C15) Labor costs to make-up lost output __________ $

1C16) Extra labor costs to restart activities __________ $

1C17) Savings from wages that were not paid __________ $

1C18) Other costs __________ $

1C19) Other savings __________ $

1C20) **Total costs** *(Ask only if respondent will not provide component costs)* __________ $

Case	Season	Day	Start Time	End Time	Duration
2	«SEASON1»	Weekday	«ONSET»	«END2»	1 minute

2C1) How long would activities stop or slow down as a result of this outage? ___hr ___min
(if zero, skip to Q.2C6)

2C2) By what percentage would activities stop or slow down? __________ %
2C3) What is the value of output (cost plus profit) that would be lost (at least temporarily) while activities are stopped or slowed down due to the outage? __________ $

2C4) What percent of this lost output is likely to be made up? __________ %
2C5) I would estimate that the amount that your firm's revenue or budget would change as a result of the outage would be… IS THAT RIGHT? __________ $

EXTRA MATERIALS COST
2C6) Damage/spoilage to raw or intermediate materials __________ $

2C7) Cost of disposing of hazardous materials __________ $

2C8) Damage to your firm's plant or equipment __________ $

2C9) Costs to run backup generation or equipment __________ $

2C10) Additional materials and other fuel costs to restart facilities __________ $

SAVINGS ON MATERIAL COST (NET OF ANY MAKE-UP PRODUCTION)
2C11) Savings from unused raw and intermediate materials (except fuel) __________ $

2C12) Savings on your firm's fuel (electricity) bill __________ $

2C13) Scrap value of damaged products or inputs __________ $

LABOR COST
2C14) How would the lost output most likely be made up? *Check all that apply.*

____ a) Overtime

____ b) Extra shifts

____ c) Work more intensely

____ d) Reschedule work

____ e) Other (specify: ____)

2C15) Labor costs to make-up lost output __________ $

2C16) Extra labor costs to restart activities __________ $

2C17) Savings from wages that were not paid __________ $

2C18) Other costs __________ $

2C19) Other savings __________ $

2C20) **Total costs** *(Ask only if respondent will not provide component costs)* __________ $

Case	Season	Day	Start Time	End Time	Duration
3	«SEASON1»	Weekday	«ONSET»	«END3»	1 hour

3C1) How long would activities stop or slow down as a result of this outage? ___hr ___min
(if zero, skip to Q.3C6)

3C2) By what percentage would activities stop or slow down? __________ %
3C3) What is the value of output (cost plus profit) that would be lost (at least temporarily) while activities are stopped or slowed down due to the outage? __________ $

3C4) What percent of this lost output is likely to be made up? __________ %
3C5) I would estimate that the amount that your firm's revenue or budget would change as a result of the outage would be… IS THAT RIGHT? __________ $

EXTRA MATERIALS COST
3C6) Damage/spoilage to raw or intermediate materials __________ $

3C7) Cost of disposing of hazardous materials __________ $

3C8) Damage to your firm's plant or equipment __________ $

3C9) Costs to run backup generation or equipment __________ $

3C10) Additional materials and other fuel costs to restart facilities __________ $

SAVINGS ON MATERIAL COST (NET OF ANY MAKE-UP PRODUCTION)
3C11) Savings from unused raw and intermediate materials (except fuel) __________ $

3C12) Savings on your firm's fuel (electricity) bill __________ $

3C13) Scrap value of damaged products or inputs __________ $

LABOR COST
3C14) How would the lost output most likely be made up? *Check all that apply.*

____ a) Overtime

____ b) Extra shifts

____ c) Work more intensely

____ d) Reschedule work

____ e) Other (specify: ____)

3C15) Labor costs to make-up lost output __________ $

3C16) Extra labor costs to restart activities __________ $

3C17) Savings from wages that were not paid __________ $

3C18) Other costs __________ $

3C19) Other savings __________ $

3C20) **Total costs** *(Ask only if respondent will not provide component costs)* **__________ $**

Longer-Duration Outages

Under extremely rare circumstances, it is possible for an outage to last multiple days or weeks. Although it is unlikely that your business has experienced such a long duration outage, we would like to know about various aspects of your business that would affect your company's response to an outage that lasts multiple days or weeks.

CASE 4

An earthquake in **«SEASON»** causes widespread damage to the region, including severe damage to electricity generation and distribution infrastructure. Your organization does not experience any damages from the natural disaster, but the power outage persists and you do not know how long it will last. After a few days, your utility announces that the outage will last for **one week**.

4.1. Would this 1-week outage cause you to go out of business?
○ No
○ Yes

4.2. Which of the following best describes how your organization would react to an outage of this duration?
○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
○ The organization would resume partial operation during the outage (please specify what operations would continue) ____
○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
○ Other please describe ____

4.3. Would you your employees receive their full typical pay during this period?
○ No
○ Yes

4.3a. If 'No,' what percent of typical pay would each type of employee receive?

Full-time employees:	_______%
Part-time year-round employees:	_______%
Contractors/project-based/temporary employees:	_______%

4.4. What would be your approximate revenue loss from this 1-week outage?
$ ___________

CASE 5

An earthquake in **«SEASON»** causes widespread damage to the region, including severe damage to electricity generation and distribution infrastructure. Your organization does not experience any damages from the natural disaster, but the power outage persists and you do not know how long it will last. After a few days, your utility announces that the outage will last for **two weeks**.

5.1. Would this 2-week outage cause you to go out of business?

○ No
○ Yes

5.2. Which of the following best describes how your organization would react to an outage of this duration?

○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
○ The organization would resume partial operation during the outage (please specify what operations would continue) ____
○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
○ Other please describe ____

5.3. Would you your employees receive their full typical pay during this period?

○ No
○ Yes

5.3a. If 'No,' what percent of typical pay would each type of employee receive?

Full-time employees:	_______%
Part-time year-round employees:	_______%
Contractors/project-based/temporary employees:	_______%

5.4. What would be your approximate revenue loss from this 1-week outage?

$ ____________

That concludes our interview today. Thank you very much for your time.

FOR INTERNAL USE ONLY:

Based on your observations of this facility, give a brief summary of the facility, any unusual occurrences with their power supply, and the critical factors that minimize and/or exacerbate outage costs.

____

____

____

Appendix G. Large Non-Residential Survey Instrument: Direct Costs for Long Duration Interruptions

This appendix contains a first draft of a modified large non-residential survey instrument, which elicits direct costs for long-duration interruptions. This survey instrument is a guide and the study team can modify questions or descriptions at its discretion through the testing process.

Associated Delivery Numbers (Acct #)

ID #: «ID»

Date of Interview: ___________________

Interviewer Name: ___________________

Interview Start Time: _________________

Interview End Time: _________________

Name:	Title:
Name:	Title:
Name:	Title:

I would like to talk to you about the costs of power outages for:
(Describe the part of the site served by the selected deliveries.)

Company Name:
Service Address:

If delivery serves only part of the site, describe location served:

____

____

____

What are the operating hours of this facility?

Use military time. If open 24 hours, use 00:00 to 00:00.

	Weekday Open	Weekday Close		Saturday Open	Saturday Close		Sunday Open	Sunday Close
Shift 1			Shift 1			Shift 1		
Shift 2			Shift 2			Shift 2		
Shift 3			Shift 3			Shift 3		

PRODUCT AND PROCESS DESCRIPTION

1) What products do you make and/or what services do you provide at this facility?

____

____

____

____

____

2) What processes do you use to make these products and/or generate these services?

____

____

____

____

____

OUTAGE EXPERIENCE

3) What normally happens to your facility's operations when a prolonged power outage (lasting more than one minute) occurs?

(Prompt for major equipment affected, worst effects on operations, etc.)

____

____

____

3.1) Does an outage at this location have financial effects on other sites owned by your company?

- ○ No
- ○ Yes

(if No, skip to Q3.4)

3.2) What type(s) or duration(s) of outages at this location have financial effects on other sites owned by your company?

(Probe for interdependencies of the production network.)

____

____

____

3.3) What are the specific financial effects?

____

____

3.4) Does an outage at this location have financial effects at your customers' sites?

- ○ No
- ○ Yes

4) Does your facility generate any of its own electricity (separate from backup power)?

- ○ No
- ○ Yes

4a) What percent of your electrical demand is supplied by your generation equipment?

___________ %

4b) What is the rated capacity of your generation equipment? ___________

- ○ kW
- ○ MW

○ Horsepower
○ Don't know

4c) What is the fuel source for the generation equipment?
○ Natural gas
○ Solar PV
○ Diesel
○ Battery
○ Other__________

5) Does your facility have some form of backup electrical power?
○ No
○ Yes

7a) What percent of your electrical demand could be supplied by your backup generation equipment? ___________ %

7b) What is the rated capacity of your backup generation equipment? ___________
○ kW
○ MW
○ Horsepower
○ Don't know

6) What percent of your employees are currently able to work remotely?
___________ %

7) During an outage that lasts multiple days or weeks, could you physically relocate your equipment or infrastructure to ensure continuity of your business operations?
○ No
○ Yes

9a) How long would it take to do so?
___________ days

9b) How much would it cost to do so?
$ ___________

8) Do you have other offices or facilities similar to this location outside of the region?
○ No
○ Yes

8a) Where are they? ____

9) If your current location were suddenly inoperable, what percent of employees could relocate to your other locations?

___________ %

10) What expenses would you experience in relocating operations temporarily, i.e. more than one day?

$ ___________

11) Has your business/organization ever experienced an outage lasting longer than 24 hours? (Choose one.)

○ No

○ Yes—How long did the outage last? ____

11a) What major tactics did you use to cope with the electricity disruption?

____

____

____

____

11b) What was the cost of implementing each tactic in (a)?

____

____

____

____

11c) What was the benefit to your firm of the tactics in (a) in terms of the prevention of business interruption (lost revenues or profits)?

____

____

____

____

12) Which one of the following categories best describes your business?

- ○ Agriculture/Agricultural Processing
- ○ Assembly/Light Industry
- ○ Chemicals/Paper/Refining
- ○ Food Processing
- ○ Grocery Store/Restaurant
- ○ Lodging (hotel, health care facility, dormitory, prison, etc.)
- ○ High Tech
- ○ Lumber/Mining/Plastics
- ○ Office
- ○ Oil/Gas Extraction
- ○ Retail
- ○ Stone/Glass/Clay/Cement
- ○ Transportation
- ○ Utility
- ○ Other *(please specify)*: ______________________________

13) What is the approximate square footage of the facility?

__________ Square feet

14) How many <u>full-time</u> (30+ hours per week) employees are employed by your business at this location?

__________ Full-time employees

15) List the number of people employed by your business at this location in each of the following categories:

__________ # of part-time year-round employees

__________ # of full-time seasonal employees

__________ # of part-time seasonal employees

16) What is the approximate value of your business's annual operations or services (income)?

$_____________ per year

17) What is the approximate value of your business's <u>total</u> annual expenses (including labor, rent, materials, and other overhead expenses)?

$_____________ per year

18) Approximately what percentage of your business's annual operating budget is spent on electricity? __________ %

Under extremely rare circumstances, it is possible for an outage to last multiple days or weeks. Although it is unlikely that your business has experienced such a long duration outage, we would like to know about various aspects of your business that would affect your company's response to an outage that lasts multiple days or weeks.

The next section describes three hypothetical power outages that last between one day and two weeks. The costs of a power outage depend upon the particular situation, and may vary from day to day depending upon business conditions. So for each outage scenario, you'll be given the opportunity to report the range of outage costs that your business might face (from low to high), as well as to estimate the cost that you would most likely have under typical circumstances.

Since some businesses have more than one building at one location, and others have multiple buildings in several locations, please remember to answer these questions thinking only about the building(s) that your business occupies at the location specified for this survey.

It is important to try to answer all of the questions. If a question is difficult for you to answer, please give us an estimate and feel free to provide any comments about your answer.

CASE 1

On a «SEASON» weekday, a complete power outage occurs at «ONSET» without any warning. You don't know how long it will last, but after **24 hours** your organization's electricity is fully restored.

1C1) How long would activities stop or slow down as a result of this outage? ___hr ___min
(if zero, skip to Q.1C6)

1C2) By what percentage would activities stop or slow down? _________ %
1C3) What is the value of output (cost plus profit) that would be lost (at least temporarily) while activities are stopped or slowed down due to the outage? _________ $

1C4) What percent of this lost output is likely to be made up? _________ %
1C5) I would estimate that the amount that your firm's revenue or budget would change as a result of the outage would be… IS THAT RIGHT? _________ $

EXTRA MATERIALS COST
1C6) Damage/spoilage to raw or intermediate materials _________ $

1C7) Cost of disposing of hazardous materials _________ $

1C8) Damage to your firm's plant or equipment _________ $

1C9) Costs to run backup generation or equipment _________ $

1C10) Additional materials and other fuel costs to restart facilities _________ $

SAVINGS ON MATERIAL COST (NET OF ANY MAKE-UP PRODUCTION)
1C11) Savings from unused raw and intermediate materials (except fuel) _________ $

1C12) Savings on your firm's fuel (electricity) bill _________ $

1C13) Scrap value of damaged products or inputs _________ $

LABOR COST
1C14) How would the lost output most likely be made up? *Check all that apply.*
____ a) Overtime
____ b) Extra shifts
____ c) Work more intensely
____ d) Reschedule work
____ e) Other (specify: ____)

1C15) Labor costs to make-up lost output _________ $

1C16) Extra labor costs to restart activities _________ $

1C17) Savings from wages that were not paid _________ $

1C18) Other costs _________ $

1C19) Other savings _________ $

1C20) **Total costs** *(Ask only if respondent will not provide component costs)* _________ $

CASE 2

An earthquake in «SEASON» causes widespread damage to the region, including severe damage to electricity generation and distribution infrastructure. Your business and employees do not experience any damages from the natural disaster, but the power outage persists and you do not know how long it will last. After a few days, your utility announces that the outage will last for **one week**.

2.1. Would this 1-week outage cause you to go out of business?
○ No
○ Yes

2.2. Which of the following best describes how your organization would react to an outage of this duration?
○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
○ The organization would resume partial operation during the outage (please specify what operations would continue) ____
○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
○ Other please describe ____

2.3. Would you your employees receive their full typical pay during this period?
○ No
○ Yes

2.3a. If 'No,' what percent of typical pay would each type of employee receive?

Full-time employees: _______%
Part-time year-round employees: _______%
Contractors/project-based/temporary employees: _______%

2.4. What would be your approximate revenue loss from this 1-week outage?
$ ___________

2C1) How long would activities stop or slow down as a result of this outage? ___hr ___min
(if zero, skip to Q.2C6)

2C2) By what percentage would activities stop or slow down? __________ %

2C3) What is the value of output (cost plus profit) that would be lost (at least temporarily) while activities are stopped or slowed down due to the outage? __________ $

2C4) What percent of this lost output is likely to be made up? __________ %

2C5) I would estimate that the amount that your firm's revenue or budget would change as a result of the outage would be… IS THAT RIGHT? __________ $

EXTRA MATERIALS COST

2C6) Damage/spoilage to raw or intermediate materials __________ $

2C7) Cost of disposing of hazardous materials __________ $

2C8) Damage to your firm's plant or equipment __________ $

2C9) Costs to run backup generation or equipment __________ $

2C10) Additional materials and other fuel costs to restart facilities __________ $

SAVINGS ON MATERIAL COST (NET OF ANY MAKE-UP PRODUCTION)

2C11) Savings from unused raw and intermediate materials (except fuel) __________ $

2C12) Savings on your firm's fuel (electricity) bill __________ $

2C13) Scrap value of damaged products or inputs __________ $

LABOR COST

2C14) How would the lost output most likely be made up? *Check all that apply.*

____ a) Overtime

____ b) Extra shifts

____ c) Work more intensely

____ d) Reschedule work

____ e) Other (specify: ____)

2C15) Labor costs to make-up lost output __________ $

2C16) Extra labor costs to restart activities __________ $

2C17) Savings from wages that were not paid __________ $

2C18) Other costs __________ $

2C19) Other savings __________ $

2C20) **Total costs** *(Ask only if respondent will not provide component costs)* __________ $

CASE 3

An earthquake in «SEASON» causes widespread damage to the region, including severe damage to electricity generation and distribution infrastructure. Your business and employees do not experience any damages from the natural disaster, but the power outage persists and you do not know how long it will last. After a few days, your utility announces that the outage will last for **two weeks.**

3.1. Would this 2-week outage cause you to go out of business?
○ No
○ Yes

3.2. Which of the following best describes how your organization would react to an outage of this duration?
○ The facility would shut down most or all operations and maintain only a skeleton crew of maintenance and security personnel
○ The organization would resume partial operation during the outage (please specify what operations would continue) ____
○ The organization would temporarily transfer work (and workers) to another location outside of the affected region
○ The organization would maintain full or almost full operations during the outage using self-generation or backup power
○ Other please describe ____

3.3. Would you your employees receive their full typical pay during this period?
○ No
○ Yes

3.3a. If 'No,' what percent of typical pay would each type of employee receive?

Full-time employees:	_______%
Part-time year-round employees:	_______%
Contractors/project-based/temporary employees:	_______%

3.4. What would be your approximate revenue loss from this 2-week outage?
$ ___________

3C1) How long would activities stop or slow down as a result of this outage? ___hr ___min
(if zero, skip to Q.3C6)

3C2) By what percentage would activities stop or slow down? __________ %

3C3) What is the value of output (cost plus profit) that would be lost (at least temporarily) while activities are stopped or slowed down due to the outage? __________ $

3C4) What percent of this lost output is likely to be made up? __________ %

3C5) I would estimate that the amount that your firm's revenue or budget would change as a result of the outage would be… IS THAT RIGHT? __________ $

EXTRA MATERIALS COST

3C6) Damage/spoilage to raw or intermediate materials __________ $

3C7) Cost of disposing of hazardous materials __________ $

3C8) Damage to your firm's plant or equipment __________ $

3C9) Costs to run backup generation or equipment __________ $

3C10) Additional materials and other fuel costs to restart facilities __________ $

SAVINGS ON MATERIAL COST (NET OF ANY MAKE-UP PRODUCTION)

3C11) Savings from unused raw and intermediate materials (except fuel) __________ $

3C12) Savings on your firm's fuel (electricity) bill __________ $

3C13) Scrap value of damaged products or inputs __________ $

LABOR COST

3C14) How would the lost output most likely be made up? *Check all that apply.*

____ a) Overtime

____ b) Extra shifts

____ c) Work more intensely

____ d) Reschedule work

____ e) Other (specify: ____)

3C15) Labor costs to make-up lost output __________ $

3C16) Extra labor costs to restart activities __________ $

3C17) Savings from wages that were not paid __________ $

3C18) Other costs __________ $

3C19) Other savings __________ $

3C20) **Total costs** *(Ask only if respondent will not provide component costs)* **__________ $**

That concludes our interview today. Thank you very much for your time.

FOR INTERNAL USE ONLY:

Based on your observations of this facility, give a brief summary of the facility, any unusual occurrences with their power supply, and the critical factors that minimize and/or exacerbate outage costs.

____

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