PROJECT NO. 55837

REVIEW OF VALUE OF LOST LOAD	**§**	**PUBLIC UTILITY COMMISSION**
	§	
IN THE ERCOT MARKET	**§**	**OF TEXAS**

VALUE OF LOST LOAD STUDY FINAL REPORT

The Brattle Group (Brattle) has completed its analysis of the Value of Lost Load (VOLL) survey results and included its findings in the attached *VOLL Study Final Report* (**Attachment A**). Electric Reliability Council of Texas, Inc. (ERCOT) recommends that the one-hour ERCOT-wide value identified by the survey of ~$35,000[1] per megawatt hour (MWh) be adopted for use in planning activities, including the reliability standard.

I. BACKGROUND

At the February 16, 2023 Open Meeting, the Public Utility Commission of Texas (Commission) discussed the need for a VOLL study in order to support the development of a reliability standard for the ERCOT Region.[2] VOLL represents a proxy for the costs and impacts experienced by customers due to an outage and is an important input to inform the benefits of future investments to improve reliable electric supply. As far back as 2013, the Commission had considered a survey to estimate VOLL and the consultant at that time, London Economics International, LLC, recommended that "arriving at an accurate VOLL estimate for the purposes identified by ERCOT will require a comprehensive customer survey process."[3] The present VOLL Study achieves that objective and provides the first comprehensive survey of VOLL for the ERCOT Region.

Following the Commission's request, ERCOT engaged Brattle and its survey administration subcontractor, PlanBeyond, to conduct the VOLL Study, including a customer survey. The *VOLL Study Final Report* presents the results and conclusions of the VOLL Study

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[1] The one-hour, system-wide VOLL for the ERCOT Region yielded by the VOLL survey is $35,685 per MWh.

[2] *See also*, *Review of Wholesale Electric Market Design*, Project No. 52373, Commissioner McAdam's Memorandum (Feb. 15, 2023) (recommending a review of VOLL).

[3] *Commission Proceeding to Ensure Resource Adequacy in Texas*, Project No. 40000, Value of Lost Load Literature Review and Macroeconomic Analysis Prepared for ERCOT by London Economics International, LLC at bates 3 (June 18, 2013).

performed by Brattle. Part 1 of the VOLL Study entailed a review of 11 VOLL studies conducted in recent years in North America, the United Kingdom, and Germany and identified six key takeaways that informed development and analysis of the customer survey.[4] Under Part 1, Brattle also applied Lawrence Berkeley National Laboratory's (LBNL) econometric model to publicly-available, ERCOT-specific outage and customer data in order to provide options to use as an interim VOLL during the pendency of the VOLL Study.[5] The Commission adopted Commission Staff's recommendation to use $25,000 per MWh as an interim VOLL for planning purposes.[6]

Part 2 of the VOLL Study entailed a survey of retail customers throughout the ERCOT Region. Brattle adapted LBNL's Interruption Cost Estimate (ICE) 2.0 customer surveys for use as the VOLL survey for the ERCOT Region. This resulted in two adapted survey instruments: one for residential customers and one for commercial customers.[7] Brattle's subcontractor, PlanBeyond, utilized the Customer Billing Contact Information (CBCI) submitted by Retail Electric Providers (REPs) to ERCOT in March 2024 to email an individualized survey link to retail customers in competitive areas of the ERCOT Region beginning on March 26, 2024. ERCOT also partnered with five Non-Opt-In Entities (NOIEs) to facilitate distribution of the VOLL survey by those NOIEs to their respective retail customers.[8] The survey concluded on May 31, 2024. As further explained in the *VOLL Study Final Report*, customer completions of the VOLL survey significantly exceeded targets, representing a robust and statistically significant level of customer response. Brattle then developed population-weighted models of customers' willingness-to-pay (WTP), in the case of residential customers, and outage-related cost estimates, in the case of commercial customers, to develop VOLL estimates by length of outage duration and by customer class. These two separate models were necessary based on the differing methodology used for residential and commercial VOLL survey instruments.

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[4] VOLL Study Literature Review and Interim VOLL (Dec. 21, 2023).

[5] Note that the interim VOLL was only used for planning purposes, including ERCOT's Reliability Standard Study, and was not considered for wholesale market pricing.

[6] *See* Commission Staff Recommendation Memorandum on Interim VOLL (Jan. 25, 2024) (selecting a value between Options 2a and 2b presented by Brattle).

[7] The survey instruments were previously filed with the Commission and are also included as Appendix A to the *VOLL Study Final Report*. *See* VOLL Study Update at 18-50 (Mar. 14, 2024).

[8] As previously identified, the five NOIEs that chose to partner with ERCOT for performance of the VOLL Study included Bandera Electric Cooperative, CPS Energy, Garland Power & Light, Guadalupe Valley Electric Cooperative, and Pedernales Electric Cooperative, Inc.

II. VOLL RECOMMENDATION

The *VOLL Study Final Report* includes four main sections: (1) a description of VOLL use cases and Brattle's literature review from Part 1 of the VOLL Study, (2) an explanation of the survey design and administration of the survey, (3) a description of the methodology to estimate VOLL based on the survey responses, and (4) Brattle's conclusions. Table ES.1 from the *Report* presents the topline results of the VOLL survey with VOLL per unserved MWh presented by customer class and by length of outage duration:[9]

Table ES.1: VOLL per Unserved MWh by Customer Class and Duration[10]

	Residential	Commercial & Industrial: Small	Commercial & Industrial: Medium/Large	**ERCOT-Wide**
1 hour	$3,964	$666,907	$22,721	**$35,685**
2 hours	$3,303	$407,229	$12,783	**$21,326**
4 hours	$2,039	$253,454	$8,064	**$13,340**
8 hours	$1,407	$195,591	$6,507	**$10,435**
16 hours	$1,091	$239,280	$9,463	**$13,581**

These values represent estimates for an outage occurring on a weekday afternoon with no advance notice and are applicable to both the summer and winter seasons. As further explained in the *Report*, this was determined to be the most representative example based on customer survey responses. For further context on the values yielded by the survey, Brattle explains:

> "Based on the literature reviewed in Part I of this study, ERCOT residential VOLLs are on the lower side of the distribution, whereas ERCOT medium/large C&I estimates are comparable to those from other VOLL studies. ERCOT small C&I VOLL estimates, however, are very large and at the high end of the estimates from other studies. The latter is mainly driven by moderate levels of VOLLs per event

[9] In Section IV(D) of the *VOLL Study Final Report*, Brattle notes that transmission-interconnected customers do not typically experience the same level of load shed as distribution-interconnected customers and accordingly presents alternative VOLLs that exclude transmission-interconnected customers. This would result in a one-hour ERCOT-wide VOLL of $61,394 per MWh. While a noteworthy observation, this does not appear to align with any practice identified in other regions or studies and raises questions beyond the scope of the instruction to develop VOLLs for each customer class and a system-wide VOLL. ERCOT recommends proceeding with the $35,000 per MWh VOLL identified in the main body of the report.

[10] Amounts are presented in 2024 dollars.

> estimated for the small C&I class, resulting in a very large VOLL per unserved MWh given the small average usage of the customers in this class."[11]

The ERCOT-wide VOLL established in this Study is higher than the interim VOLL. However, this is also a more accurate estimation as the data informing this number are reflective of actual survey responses from customers in the ERCOT Region (as opposed to estimates using other studies and data) and is supported by well-established best practices and econometric techniques aligned with those used by LBNL in their ICE Calculator. As Brattle noted, this represents a reasonable value that is within the range identified by the literature review and during the development of the interim VOLL. Furthermore, such a VOLL is in the approximate range utilized for resource adequacy and transmission planning purposes in neighboring regions.[12]

Based on Brattle's *VOLL Study Final Report*, ERCOT recommends that the Commission adopt the ERCOT-wide value for a one-hour outage duration of ~$35,000 per MWh as a VOLL estimation to use for planning purposes, including in the reliability standard and for the cost and market effects analysis to be performed by ERCOT and the Independent Market Monitor (IMM) for the Performance Credit Mechanism (PCM).

III. Data Exchange and Confidentiality

In order to conduct the VOLL Study, several data exchanges occurred. ERCOT provided CBCI and historical customer usage information to Brattle and PlanBeyond. The CBCI was used to send the VOLL survey to customers and the historical customer usage information was used to weight the selection of the pool of customers to receive the VOLL survey. Brattle and PlanBeyond also received anonymized customer information from CPS Energy and Guadalupe Valley Electric Cooperative (GVEC) in order to assist with selection of customers to receive the survey in their respective service areas.[13] Brattle received anonymized ICE 2.0 survey responses from LBNL and Resource Innovations for those ICE 2.0 surveys conducted in AEP Texas, Inc.'s service area. Because the VOLL survey instruments were based on the ICE 2.0 survey instruments, these ICE

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[11] VOLL Study Final Report at 3.

[12] *See*, *e.g.*, Southwest Power Pool (SPP), *Market Working Group*, 08 Calculating VOLL for Resource Adequacy and Transmission Planning (Apr. 23, 2024), available at: https://www.spp.org/Documents/71477/MWG%20Meeting%20Materials%2020240423-24.zip (indicating on Slide 8 an SPP Region-wide VOLL of $32,503 per MWh for a one-hour outage).

[13] The other three NOIE partners independently selected the sample of customers to receive the survey, so no customer information was sent to Brattle or PlanBeyond.

2.0 survey responses were used to supplement the VOLL survey responses, particularly for large commercial and industrial customers. Furthermore, in order to incorporate the VOLL survey results into LBNL's ICE Calculator, Brattle provided the anonymized VOLL survey responses to LBNL and to LBNL's ICE 2.0 survey administration contractor, Resource Innovations.

Maintaining the confidentiality of Protected Information throughout this VOLL Study has been and continues to be a priority for ERCOT. Unless anonymized such that the customer cannot be identified, CBCI and customer-specific historical electricity usage data is Proprietary Customer Information[14] under the Commission's rules and accordingly constitutes confidential Protected Information under ERCOT Nodal Protocol § 1.3.1.1(1)(r). As noted in prior filings,[15] ERCOT is permitted under ERCOT Nodal Protocol § 1.3.6(1)(h) to share confidential Protected Information with a vendor so long as the vendor is not an ERCOT Market Participant, other than an Independent Market Information System Registered Entity (IMRE), and is subject to a confidentiality agreement with requirements at least as restrictive as those established by ERCOT Nodal Protocol § 1.3. Brattle is registered as an IMRE and executed ERCOT's Professional Services Agreement, which contains sufficient confidentiality requirements in § 7.[16] PlanBeyond is not a Market Participant and, as a subcontractor to Brattle, is subject to the terms of the Professional Services Agreement, including its confidentiality provisions.[17] Nevertheless, out of an abundance of caution, ERCOT also executed a Non-Disclosure Agreement with PlanBeyond separately requiring them to abide by the same confidentiality provisions. Note that the customer information shared by CPS Energy and GVEC was not confidential Proprietary Customer Information because it was anonymized. Since the completion of the VOLL survey, PlanBeyond has purged all customer information from its system. At this time, Brattle continues to hold the CBCI, historic electricity usage information, and VOLL survey responses. ERCOT intends to direct Brattle to

[14] 16 Tex. Admin. Code § 25.5(89) (defining Proprietary Customer Information).

[15] *See* VOLL Survey Work Plan at 2 (Dec. 7, 2023) (Footnote 2 provides the legal basis for data sharing).

[16] *See* ERCOT.com, Procurement, Professional Services Agreement (last accessed on Aug. 20, 2024), available at: https://www.ercot.com/about/procurement.

[17] *See id.* at § 3.3(C) (binding subcontractors to the terms of the Professional Services Agreement).

purge this data at an appropriate time after the Commission's consideration of the *VOLL Study Final Report*.

In regard to the VOLL survey responses shared with LBNL and Resource Innovations, although those were anonymized and therefore did not contain Proprietary Customer Information, ERCOT nevertheless designated the VOLL survey responses as confidential Protected Information pursuant to ERCOT Nodal Protocol § 1.3.1.1(1)(q). Accordingly, ERCOT entered into a Non-Disclosure Agreement with LBNL and Resource Innovations in order for those entities to be bound to maintain the confidentiality of the VOLL survey responses.

IV. CONCLUSION

ERCOT appreciates the opportunity to present the findings of the VOLL Study as reflected in Brattle's *VOLL Study Final Report* and recommends that the one-hour ERCOT-wide value identified by the survey of ~$35,000 per MWh be adopted for use in planning activities. ERCOT personnel will be available at the August 29, 2024 Open Meeting to answer any questions and receive any feedback.

Dated: August 22, 2024

Respectfully submitted,

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Attachment A

Value of Lost Load Study for the ERCOT Region

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Electric Reliability Council of Texas, Inc. (ERCOT)

WITH SUPPORT FROM

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AUGUST 19, 2024

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NOTICE

- This report was prepared for ERCOT, in accordance with The Brattle Group's engagement terms, and is intended to be read and used as a whole and not in parts.
- The report reflects the analyses and opinions of the authors and does not necessarily reflect those of The Brattle Group's clients or other consultants.
- There are no third-party beneficiaries with respect to this report, and The Brattle Group does not accept any liability to any third party in respect of the contents of this report or any actions taken or decisions made as a consequence of the information set forth herein.

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Appendix A: Survey Instruments

Appendix B: Technical Appendix

Executive Summary

The Electric Reliability Council of Texas, Inc. ("ERCOT") undertakes this Value of Lost Load ("VOLL") study on behalf of the Public Utility Commission of Texas ("Commission") to determine the estimated value of electric reliability in the ERCOT Region. VOLL represents a proxy for the economic costs that customers incur due to a power outage. Knowledge of the VOLL can help inform cost-benefit decisions with respect to generation and transmission investments and can be an important input for resource adequacy decisions.

The Brattle Group ("Brattle") and our survey administration subcontractor, PlanBeyond (collectively "Brattle team"), conducted this study on behalf of ERCOT by surveying residential, commercial, and industrial customers in the ERCOT Region to determine ERCOT-specific VOLL values for use in system planning efforts. While separate VOLL values are estimated for each customer class, the Brattle team also calculated a load-weighted average of the customer class VOLLs to be used for ongoing Commission market design initiatives, particularly the development of a reliability standard for the ERCOT Region.

Survey Instrument. The Brattle team was asked to develop a VOLL survey study that is consistent with the methodology employed by Lawrence Berkeley National Laboratory ("LBNL") so the data may be used to update LBNL's Interruption Cost Estimate ("ICE") Calculator in the future. Therefore, we began with survey instruments provided by LBNL and streamlined the survey instruments to best fit the needs of this study. The core of the survey asks each respondent to consider several outage scenarios. We characterized outage scenarios using the same dimensions considered in the LBNL survey, including season, start time, day type (weekend or weekday), duration, and whether an advance warning was provided or not. Respondents were asked to consider eight scenarios based on a combination of these different dimensions. Different strategies were used to elicit residential and commercial & industrial ("C&I") customers' valuation of uninterrupted electricity service. Appendix A presents the survey instrument previously filed with the Commission.

Survey Participant Selection. Undertaking this study required surveying a large and diverse set of customers in the ERCOT Region to understand the value that they place on reliable electric service. This raises unique challenges in the context of an Independent System Operator ("ISO")-arranged survey because ERCOT does not have a direct relationship with retail customers or own and operate the infrastructure that enables electric service. Through a careful review of options, and based on input from the Commission, our team developed a survey administration approach that involved recruiting respondents from areas open to competition using Customer Billing Contact Information ("CBCI") data provided to ERCOT by competitive retail electric providers ("REPs") and, for customers in a Non Opt-In Entity ("NOIE") service territory, relying on partnerships with five NOIEs to perform recruitment in their respective service areas.

Survey Administration. PlanBeyond, a full-service market research firm, created the survey interface and administered it. All participants were invited via email; no offline invitations were issued. The email invitation offered a brief background on the project goals and sponsoring parties, as well as a link to a frequently asked questions page on the Commission website to enhance the credibility of the outreach and to address anticipated questions. Each email included a unique, single-use link to ensure that respondents took the survey only once and to prevent the sharing of links with other parties. Data collection began on March 26, 2024 and ended on May 31, 2024.

Completion rates for residential customers were 3% for customers in competitive areas and nearly 7% from NOIE customers. C&I customers responded at a rate of 1.2%. This corresponds to 2,991 residential completes and 1,711 C&I completes. Only 36 of the C&I responses were from large customers, however; for this reason, we supplement our collection with analogous data collected data in American Electric Power ("AEP") Texas service territory by LBNL.

VOLL Estimates. We estimated VOLLs by customer class using well-established econometric techniques. Once we obtained estimates using our survey samples, we reweighted them to match the ERCOT-wide population and business characteristics. For the residential class, we accounted for the following characteristics using data from the US Census Bureau: (a) whether the customer's use is above or below that of the median residential customer; (b) whether the customer's income is above or below the statewide median; (c) whether the customer lives in an urban area; (d) whether someone in the respondent's household has health needs that require access to power; and (e) whether they work from home daily. For the C&I class, we accounted for industry, facility level of employment, and rural/urban location using County Business Pattern data from the US Census Bureau. Appendix B presents technical details of our analysis.

Using data from all survey respondents, we estimated population-weighted VOLLs expressed in terms of dollars *per outage event* ($). We also expressed these VOLLs in terms of dollars *per unserved MWh*, using the average hourly MWh values for the residential, small C&I, and medium and large C&I classes based on the ERCOT-provided customer usage data. While we surveyed customers to elicit the differences in their VOLLs in summer versus winter seasons, as well as morning, afternoon, and evening times, we did not identify substantive differences in their VOLLs along these dimensions. We found that advance warning lowered customers' VOLLs for all classes. As a representative example, estimates presented in the report are for a weekday afternoon outage without advance warning, which are applicable for both summer and winter seasons.

Table ES.1 presents these values by customer class as well as on an ERCOT Region-wide basis, calculated using the class load shares.

TABLE ES.1: VOLL PER UNSERVED MWH BY CUSTOMER CLASS AND DURATION (2024$/MWH)

		Commercial & Industrial		**ERCOT-**
	Residential	Small	Medium/Large	**Wide**
1 hour	$3,964	$666,907	$22,721	**$35,685**
2 hours	$3,303	$407,229	$12,783	**$21,326**
4 hours	$2,039	$253,454	$8,064	**$13,340**
8 hours	$1,407	$195,591	$6,507	**$10,435**
16 hours	$1,091	$239,280	$9,463	**$13,581**

Source: Residential population-weighted WTP model and C&I population-weighted cost model. Estimates shown for a weekday afternoon outage without warning.

Based on the literature reviewed in Part I of this study,[1] ERCOT residential VOLLs are on the lower side of the distribution, whereas ERCOT medium/large C&I estimates are comparable to those from other VOLL studies. ERCOT small C&I VOLL estimates, however, are very large and at the high end of the estimates from other studies. The latter is mainly driven by moderate levels of VOLLs per event estimated for the small C&I class, resulting in a very large VOLL per unserved MWh given the small average usage of the customers in this class.

In comparison to the interim VOLL estimates developed for ERCOT during Part I of the study, the ERCOT Region-wide estimate developed in this report is higher than the interim VOLL. Table ES.2 presents the interim VOLL calculations and the two options that were presented to the Commission at that time representing an ERCOT-wide **one-hour outage**. As can be seen from comparing Tables ES.1 and ES.2, the 1-hour VOLL estimate in dollars per unserved MWh from the present study is larger than the interim VOLL estimate by approximately $10,000. As shown later in the report, however, the interim VOLL estimate is within the 95% confidence interval of the present study (ranging from approximately $25,000 to $53,000).

Comparison of the customer class specific estimates from this study to the interim estimates reveal that, while residential values are generally comparable, C&I values are drastically different.

1 See *Review of Value of Lost Load in the ERCOT Market*, PUCT Project No. 55837, VOLL Study Literature Review and Interim VOLL (Dec. 21, 2023) ("Brattle Part I Study").

There are several potential reasons for this. First of all, the interim estimate was still fundamentally driven by the underlying response function from the US metadata from the LBNL study, even though we made adjustments to reflect ERCOT usage characteristics. Second, VOLLs per unserved MWh are very sensitive to the assumptions about the level of unserved load for a given outage duration. This study relied on the CBCI data to develop the average unserved load assumptions, whereas the interim VOLL estimates relied upon more generic EIA 861 consumption estimates for Texas and on customer class definitions that may not align perfectly with those used in this study.

TABLE ES.2: BRATTLE STUDY PART I ERCOT-WIDE INTERIM VOLL ESTIMATES (2023$/MWH)

Cost per Unserved Megawatt Hour (MWh)	30 Minute Outage	1 Hour Outage	8 Hour Outage
Residential	$9,283	$5,122	$1,817
Small C&I	$167,315	$102,490	$81,172
Medium / Large C&I	$130,797	$78,824	$53,954
Region-wide Option 1	$99,052	$60,093	$44,321
Region-wide Option 2a (cap using all studies)		$24,693	
Region-wide Option 2b (cap using all US studies)		$26,245	
Region-wide Option 2c (cap using all US that test a 1-hour duration outage)		$52,259	

Source: ERCOT PUC filing, December 21, 2023.

Other considerations. The primary case we have analyzed in this report and presented in Table ES.1 includes all customer classes, per the instructions of the Commission. In Section IV.D of this report, we also present an alternative case that excludes large C&I customers that are interconnected directly to the transmission system. Those customers could be subject to load shed, but in practice are generally not shed during system shortages, even during long and deep shortages. This is because the transmission service provider ("TSP") load shedding practices focus on distribution-connected customers. Our alternative calculation presented later in the report reflects the average VOLL solely of distribution-interconnected customers and is almost twice as high as our primary calculation. As long as load-shedding practices remain the same, this correspondingly higher VOLL may be more relevant when evaluating the benefits of adding generation or transmission that reduce the risks of shortages and load shedding.

Our survey respondents also include critical load customers, for whom the suspension of electric service would create dangerous or life-threatening conditions. Many of these customers may be on feeders that the TSPs protect from load shedding, but we do not exclude them from the sample since their critical load status is self-reported and we were not able to independently verify their status or prevalence in the overall ERCOT Region. While we did not develop a sensitivity that excludes critical load customers in a similar fashion to the transmission-interconnected customers, we investigate their VOLLs separately in Section IV.B of this report.

While this study estimated VOLLs for 1-day and 3-day outage durations, there is considerable uncertainty associated with those VOLLs. For long duration outages, the nature of costs changes and other indirect effects to the communities and economy should be considered.[2] A recent report from LBNL indicates that few survey-based studies have elicited preferences regarding longer-duration outages, in part because responses may be less informed by experience with such outage durations.[3] Therefore, these longer duration VOLLs should not be directly used for resiliency planning.

Lastly, it is important to bear in mind the inherent limitations in the use of surveys to evaluate customer behavior. The applicability of the results depends upon the reliability of the responses received. Residential customers are asked to state whether they would purchase protection to avoid an outage, but stated intentions may not match actual behavior. For C&I customers, they are asked to provide estimates of the expected costs associated with an outage, but the impact of an actual outage on a business is complex and may be difficult to evaluate in the context of hypothetical survey scenarios. To mitigate some of these issues, we removed response patterns that seemed unreasonable and used statistical methods capable of incorporating a variety of customer behavior.

2 Michael J. Sullivan, Josh Schellenberg, and Marshall Blundell, "Updated Value of Service Reliability Estimates for Electric Utility Customers in the United States," January 2015, Lawrence Berkeley National Laboratory.

3 Madeline Macmillan, Kyle Wilson, Sunhee Baik, Juan Pablo Carvallo, Anamika Dubey, and Christine A. Holland, "Shedding light on the economic costs of long-duration power outages: A review of resilience assessment methods and strategies," May 2023, Lawrence Berkeley National Laboratory.

I. Introduction

The Electric Reliability Council of Texas, Inc. ("ERCOT") has commissioned this Value of Lost Load ("VOLL") study on behalf of the Public Utility Commission of Texas ("Commission") to determine the estimated value of electric reliability in the ERCOT Region. Subsequently, ERCOT issued a Request for Proposal for a contractor to perform the VOLL study and has selected The Brattle Group ("Brattle") and their survey administration subcontractor, PlanBeyond (collectively "Brattle team"), to conduct the study by surveying residential, commercial, and industrial customers in the ERCOT Region to determine ERCOT-specific VOLL values for use in system planning efforts.

VOLL is an important metric for electric markets. It represents a proxy for the economic costs that customers incur due to a power outage. Alternatively, it can be considered an average customer's willingness to pay to avoid an outage. Given that electricity use-cases differ across customer classes, the costs incurred from an outage can vary widely based on the customer class under consideration and the characteristics of a potential outage event. For an industrial customer, this may involve a variety of labor- and production-related costs, while for the typical residential customer, it may primarily involve disruptions associated with not having power. Knowledge of the VOLL can prove useful for both planning and operations management. With respect to planning, it can help inform cost-benefit decisions with respect to generation and transmission investment and can drive resource adequacy and resiliency policy on the operations side.

The Brattle team initiated their work by undertaking a comprehensive literature review of VOLL studies in the United States and elsewhere.[4] Deriving VOLL values from the literature, even after adjusting them for ERCOT-specific circumstances, may fail to capture important aspects of valuations of uninterrupted power for customers in the ERCOT Region. The literature review also demonstrated that a survey is generally the most comprehensive means to determine how customers in an area value reliability. Therefore, the Brattle team undertook a customer survey in the ERCOT Region and estimated resulting VOLL values using well-established econometric techniques. While separate VOLL values are estimated for each customer class, the Brattle team also calculated a load-weighted average of the customer class VOLLs to be used for ongoing Commission market design initiatives, particularly the development of a reliability standard for the ERCOT Region.

[4] See Brattle Part I Study.

This report is organized as follows: Section II reviews VOLL estimation methods and use cases and provides a recap of the literature review of prior VOLL studies. Section III details the survey design and administration. Section IV describes the VOLL estimation approach and presents the resulting VOLL estimates for each customer class. Section V presents the Brattle team's conclusions.

II. VOLL Use Cases and Literature Review

Use of VOLL is essential for making informed decisions regarding energy market design, including incentivizing infrastructure investments, establishing system reliability, and setting appropriate pricing and policy frameworks. In Part I of this study, we reviewed the literature of VOLL studies, summarized the methodologies used, selected ones that could be mapped to the ERCOT Region, and developed preliminary VOLL values to inform ongoing discussions. In this section, we provide an overview of our findings from Part I and discuss how they informed our approach to Part II of the study. We also highlight how the VOLL can be used in decision-making.

A. Description of VOLL and Use Cases

VOLL is an economic measure used in the electric industry to quantify the economic impact of power outages or interruptions on customers. It reflects the monetary cost, opportunity cost, or loss experienced by individuals, businesses, or the economy more broadly as a result of not having access to electricity or other critical associated services during an outage. For residential customers, it is typically expressed as the willingness to pay to avoid a particular outage scenario, while for non-residential customers, it is the measure of estimated economic losses (net of benefits) resulting from a given outage scenario. It is typically expressed in terms of dollars per outage event ($) or dollars per unserved energy ($/MWh).

There are several factors that influence VOLL:

- **Customer type**: Residential, commercial, and industrial users may experience different levels of inconvenience and impacts from outages resulting in different VOLL values.
- **Sector-specific impacts**: Different sectors within commercial and industrial classes have varying degrees of sensitivity to outages due to the nature of their business (*e.g.*, manufacturing versus healthcare).

- **Timing, duration, and frequency of outages**: Longer or more frequent outages generally increase the VOLL.
- **Existence of backup power supply**: Existence of backup power may reduce the inconvenience experienced during the outages and generally decreases the VOLL.
- **Advance warning**: Advance notification of an impending outage generally decreases the VOLL.

VOLL is often used by utilities, market stakeholders, and policymakers to assess the cost-benefit trade-off of reliability improvements, determine infrastructure investment priorities, and develop strategies to minimize the impact of power disruptions. It helps in decision-making processes related to balancing the costs of maintaining and upgrading power systems with the costs of potential outages. Without this information, utilities and market stakeholders could make uneconomic reliability decisions.

The economically efficient level of reliability is determined when the marginal cost of improved reliability is equal to the marginal benefit of reducing outages. It is generally straightforward to determine the marginal cost of improved reliability through standard engineering cost estimation methods. The marginal benefit of reducing outages is the economic value customers place on reliability and is quantified through VOLL studies.[5] These studies are used as inputs to various planning functions, such as the determination of resource adequacy standards or reserve margin and transmission and distribution planning studies to determine the cost-effectiveness of proposed investments.[6]

B. Overview of VOLL Literature Review

As indicated earlier, the Brattle team initiated Part I of this VOLL study with a comprehensive review of the existing VOLL literature that was filed with the Commission on December 21, 2023.[7] Our literature review identified four main modeling approaches that are used in the literature to estimate VOLL:

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5 Michael Sullivan, Myles T. Collins, Josh Schellenberg, and Peter H. Larsen, *Estimating Power System Interruption Costs: A Guidebook for Electric Utilities*, 2018, Lawrence Berkeley National Laboratory (“LBNL Guidebook”).

6 For additional potential uses of VOLL, see: “Estimated Value of Service Reliability for Electric Utility Customers in the United States,” Lawrence Berkeley National Laboratory, June 2009.

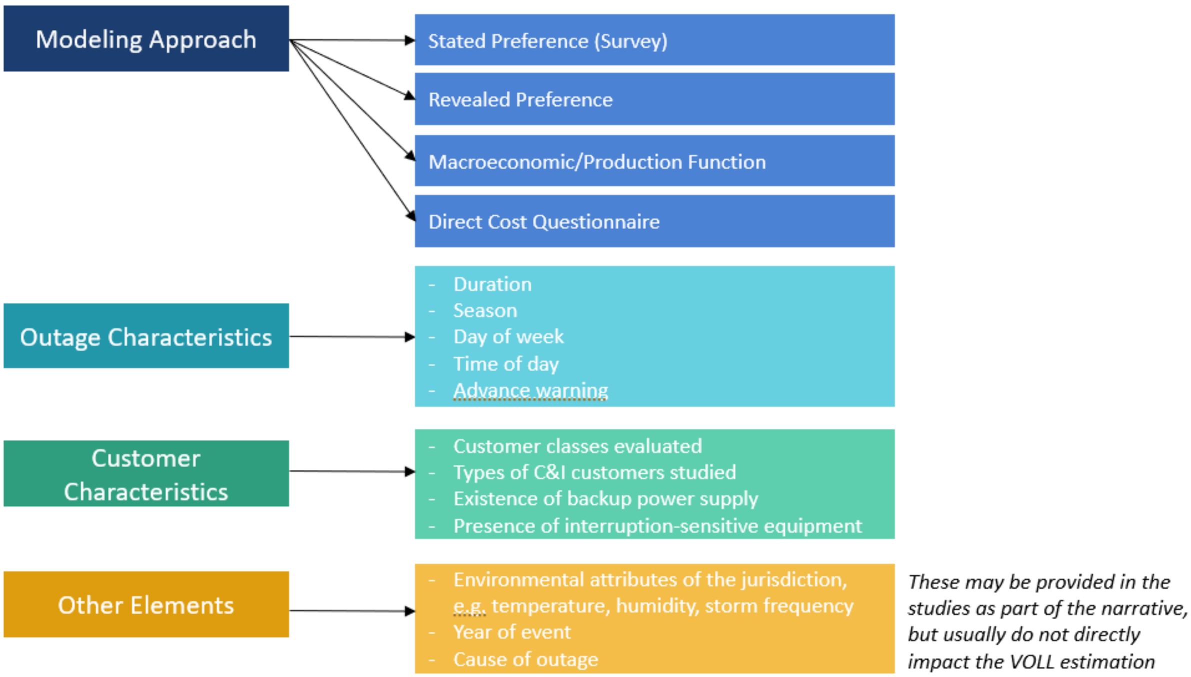
7 See Brattle Part I Study.

- **Stated Preference Survey** approach relies on responses provided by customers surveyed about their perceptions of outage scenarios, *e.g.*, their willingness-to-pay ("WTP") to avoid an outage.
- **Revealed Preference** approach relies on measures of actual behavior, *e.g.*, investing in backup power to avoid outages.
- **Macroeconomic/Production Function** approach uses macroeconomic data and observable expenditure data (*e.g.*, gross domestic product, energy consumption, or value of leisure time) to estimate a VOLL
- **Direct Cost Questionnaire** approach is generally similar to surveys but relies on data arising from actual outages.

The direct, **survey-based approach** ("Stated Preferences") is often the most comprehensive approach for deriving a customer's willingness to pay to avoid an outage or to be guaranteed a higher level of reliability. However, time, budget, and data limitations may preclude researchers' ability to carry out full-scale surveys of customers in a region, leading to the use of other methods. On the other hand, this approach is based on what customers say they would do, not actual behavior. Furthermore, customers may not be able to accurately calculate or forecast costs associated with various outage types.

The Brattle team tabulated the key modeling approaches and characteristics used in the 11 studies included in our literature review. Figure 1 presents key decision variables and dimensions commonly observed in these studies.

FIGURE 1: KEY DECISION VARIABLES AND DIMENSIONS FOR VOLL ESTIMATION



Source: Brattle Part I Study

Our review of the literature generated several key takeaways that informed our subsequent survey design and modeling choices and provided a benchmark as we examined the results from our VOLL survey. These takeaways include:

1. **"Stated Preference" surveys are the most comprehensive way to measure customer WTP, but some combination of stated and revealed preference also seems to be common in existing studies.** To measure "stated preferences," conjoint surveys are the preferred survey method. In a conjoint analysis, respondents are asked to choose among alternative scenarios of energy service, each with different characteristics including reliability at various price points. This type of question is thought to reduce customer response bias over other methods like contingent valuation, which either directly asks consumers how much they value reliability or asks whether they would be willing to pay a certain amount to attain reliability.[8]

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[8] Stated preference surveys are generally limited because they rely on what consumers say they would do, not what they actually do. Furthermore, focusing the respondent on one specific aspect of a product (*e.g.,* the potential for a utility to have an outage) can lead the respondent to over-value that feature; indeed, the LBNL Guidebook notes that this approach is subject to response biases (LBNL Guidebook, p. 58–60). To reduce these biases, the LBNL Guidebook recommends considering an alternative methodology based on discrete choice experiments (DCE), alternatively known as conjoint surveys, stating: "DCE surveys could mitigate anchoring bias and would present respondents with choice sets that better resemble an actual choice they would make in purchasing improved reliability…[T]he authors [of the LBNL Guidebook] believe that the development of a standard DCE-based survey design could yield improvements over the existing methodology—eliminating

Continued on next page

2. **Residential VOLL is typically lower than commercial and industrial ("C&I") customer VOLL.** Residential customers are more likely to prepare for operational risks such as outages. Residential customers are also likely to report $0 interruption costs for short-term (less than one hour) outages. Testing multiple outage durations is crucial to capture the nonlinearity in preferences.
3. **Socioeconomic status plays a key role in a household's WTP for electric reliability.** VOLL is likely a function of income levels; lower WTP values may be driven by lower ability to pay. This is consistent with a growing literature that demonstrates that households in lower income regions are less likely to adopt emerging energy technologies, such as batteries, that could help mitigate the impacts of outages.
4. **There is heterogeneity in and across end-user groups, especially C&I customers.** The service sector usually has the lowest VOLL, while manufacturing and mining have the highest VOLL. Small C&I customers are generally less likely to prepare for outages by purchasing backup generation than large C&I customers, leading to generally higher VOLLs.
5. **Consideration of indirect costs as well as cost reduction measures may affect the VOLL for C&I customers; however, some of these may be difficult to capture.** These include supply chain disruptions and cascading effects on other businesses and customers; cost reductions through adaptive responses like a temporary switch to less electricity-dependent activities; or making up decreased production after power has been restored.
6. **VOLL results are highly sensitive to the methodology used.** Different estimation methods introduce different types of biases that can skew the results. More specifically, the macroeconomic production function approach might underestimate the VOLL for C&I customers in the short run but might overestimate it in the long run as improvements in conservation and energy efficiency occur. Stated or revealed preference survey results can be influenced by the respondent's location and the relative prevalence of outages in that location. For instance, in a highly reliable region with infrequent outages, the cost of backup generation may be higher than the benefits of ever using such backup generation.

As part of our literature review, we collected VOLL estimates by customer class from each of the studies reviewed. While these results may not be directly comparable to the results estimated for the ERCOT Region due to the variation in the geographies, climates, existing reliability levels, and modeling approaches represented in the studies, they still provide a useful benchmark for

uncertainty about important sources of bias. We recommend that a survey development project be undertaken to design and test alternative survey designs based on DCE" (LBNL Guidebook, p. 64-65). For an example of this alternative approach, see David A. Hensher, Nina Shore and Kenneth Train, 2014, "Willingness to pay for residential and electricity supply quality and reliability," *Journal of Applied Energy*, 115: 280–292.

the VOLL values estimated for the ERCOT Region in this study. These values are presented in Section V, as part of our conclusions.

III. Survey Design and Administration

We were asked to develop a VOLL survey study that is consistent with the methodology employed by Lawrence Berkeley National Lab's ("LBNL") so the data collected here may also be used to update LBNL's Interruption Cost Estimate ("ICE") Calculator. LBNL has been supporting and analyzing studies that underlie the ICE Calculator since 2005 and developed a guidebook that offers advice to practitioners looking to conduct their own studies.[9] We were asked to ensure that the output of our study could serve as an input to the ICE Calculator to improve the ICE Calculator's coverage and representativeness; for this reason, we were limited in our ability to deviate from LBNL's approach. In this section, we discuss how respondents were selected for the survey, how the survey was administered, and the overall design of the survey. Specifically, we discuss changes that we made to the survey form used by LBNL, which otherwise was used as a starting point for our own instrument.

A. Survey Participant Selection

Undertaking this study requires surveying a large and diverse set of customers in the ERCOT Region to understand the value they place on reliable electricity service. This raises unique challenges in the context of an independent system operator ("ISO")-arranged survey because ERCOT does not have a direct relationship with retail customers or own and operate the infrastructure that enables electric service. Through a careful review of options, and based on input from the Commission, our team developed a survey administration approach that involved recruiting respondents from areas open to competition using Customer Billing Contact Information ("CBCI") data provided to ERCOT by competitive retail electric providers ("REPs") and, for customers in a Non Opt-in Entity ("NOIE") service territory, relying on partnerships with NOIEs to perform recruitment in their respective service areas.[10] Below, we discuss the details of survey participant selection for areas open to competition and NOIE areas respectively.

9 LBNL Guidebook.

10 See the VOLL Work Plan for more background on these deliberations. *Review of Value of Lost Load in the ERCOT Market*, PUCT Project No. 55837, VOLL Survey Work Plan (Dec. 7, 2023)

Areas open to competition. REPs are required to regularly submit customer contact information to ERCOT to allow for the expeditious transfer of retail customers from a REP exiting the market to a Provider of Last Resort in the event of a mass transition. This data is referred to as Customer Billing Contact Information ("CBCI") data. While REPs are required to include customer mailing addresses in their CBCI submissions to ERCOT, inclusion of email addresses is not mandatory. Because our outreach was done entirely via email (see Section III.C below), we would not be able to contact any of a REP's customers if they chose not to include email addresses.[11] Accordingly, ERCOT and the Commission encouraged REPs that had customer email addresses in their possession to include those in their February and March 2024 CBCI submissions, if they were not doing so already. We understand that this succeeded in significantly bolstering the amount of email addresses included in those CBCI submission cycles than in prior submission cycles. Overall, 120 out of 144 REPs submitted CBCI to ERCOT that included customer email addresses; of these, 87% of residential customers and 64% of C&I customers included valid email addresses.[12]

ERCOT provided a portion of the March 2024 CBCI submission data to the Brattle team, which was represented to include all C&I customers and a 10% sample of residential customers. To these contact lists, ERCOT added information about each customer's electricity usage, including monthly kilowatt-hour ("kWh") use, peak demand, and days active. The Brattle team understands that CBCI is confidential Protected Information under the ERCOT Nodal Protocols and Commission rules, and that the Protocols permit sharing of Protected Information with a vendor so long as the vendor is subject to confidentiality requirements at least as restrictive as those of Protocols § 1.3 and that the vendor is not a registered ERCOT Market Participant.[13] Because Brattle is ERCOT's vendor and PlanBeyond is a subvendor to Brattle and both are bound by the confidentiality provisions of ERCOT's Professional Services Agreement,[14] ERCOT was permitted to share CBCI data with the Brattle team and the Brattle team is obligated to maintain the confidentiality of that data. After completing the survey distribution, PlanBeyond purged this data from its systems. ERCOT has instructed Brattle to maintain this data for now but may direct Brattle to destroy the data at an appropriate time.

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11 Even for those REPs that include email addresses from their CBCI submissions, not every customer provides an email address to their REP.

12 Here, a "valid" email address is one in an appropriate format (*i.e.,* begins with letters or numbers, followed by an "@", followed by a domain, including a top-level domain (*e.g.*, "gmail.com"). Without attempting delivery, we were not able to determine whether an address was active.

13 *See* ERCOT Nodal Protocol § 1.3.6(1)(h). Note that the vendor is permitted to be an Independent Market Information System Registered Entity, a type of ERCOT Market Participant, which The Brattle Group is.

14 *See* ERCOT Professional Services Agreement § 7 (containing confidentiality provisions for vendors), available on the ERCOT website at: https://www.ercot.com/files/docs/2022/05/04/Professional-Services-Agreement-Rev-09-22-2023.pdf.

To select contacts from these lists, they were first filtered to ESI IDs associated with valid email addresses provided, then grouped by customer class (residential, small C&I, medium C&I, and large C&I).[15] Within these groups, unique email addresses were selected for outreach. For each selected email address, one facility associated with that email was chosen as the basis for the survey questions. In other words, if there were multiple ESI IDs at a single customer facility but all used the same contact email address, then only one of those ESI IDs was contacted. Filtering was also performed with the goal of each company taking at most one survey covering its facilities, rather than a single company taking multiple surveys covering multiple of that company's locations.

For the soft launch on March 26, 2024, 20,000 residential and 10,000 small/medium C&I customers were selected for outreach. Based on response rates observed during the soft launch (approximately 3% and 1% respectively), an additional 61,565 residential and 132,857 small/medium C&I customers were selected for outreach to attain target sample sizes of 2,500 and 1,500 respectively. All unique emails associated with large C&I customers were selected for the full launch (862 customers).

NOIEs. NOIEs are not required to provide CBCI data to ERCOT, hence a different approach was required. ERCOT staff reached out to NOIEs to solicit their participation in the study. Five NOIEs partnered with ERCOT to support the VOLL survey: Bandera Electric Cooperative ("BEC"), CPS Energy, Garland Power & Light ("GPL"), Guadalupe Valley Electric Cooperative ("GVEC"), and Pedernales Electric Cooperative, Inc. ("PECI").

Of these five NOIE partners, CPS and GVEC provided complete anonymized customer lists from which the Brattle team selected a sample to invite to participate in the survey, while BEC, GPL, and PECI selected samples of customers that they then provided in anonymized form to the Brattle team. For CPS and GVEC, we sampled residential and C&I customers in the same proportion as we did using the CBCI list: roughly 13 per 1,000 residential customers and 89 per 1,000 small/medium C&I customers, plus a representative for each large C&I customer.

[15] Prior to the selection process, the CBCI data were reviewed for quality and consistency. In particular, we removed customers active for less than 350 days, customers with log annual usage less than 3 standard deviations from the average usage within their class and residential customers with log usage more than 3 standard deviations greater than average. The CBCI data indicate whether a customer is residential, non-residential, or large non-residential, which were used in this process.

B. Survey Administration

PlanBeyond, a full-service market research firm, created the survey interface and administered it using the Qualtrics platform.[16] All participants were invited via email; no offline invitations were issued.[17] The email invitation offered a brief background on the project goals and sponsoring parties, as well as a link to a frequently asked questions page on the Commission website to enhance the credibility of the outreach and to address anticipated questions. Each email included a unique, single-use link to ensure that respondents took the survey only once and to prevent the sharing of links with other parties. After discussing with Commission Staff, it was determined that financial incentives for survey completion would not be used. Data collection began on March 26, 2024 and ended on May 31, 2024. The survey process took place across four distinct phases:

- **Phase I: Soft Launch.** Using the CBCI data provided by ERCOT, an initial round of surveys was sent to residential and small/medium C&I customers. The goal of the soft launch was to test the entire survey administration process before undertaking the widespread outreach. Participants received an initial email on March 26, 2024 with a follow-up reminder email sent on April 1, 2024 to individuals who had yet to complete the survey.
- **Phase II: Main Launch, Customers in Areas Open to Competition.** For customers in areas open to competition (*i.e.,* those for whom we received contact information from ERCOT), the main outreach began on April 9, 2024, with a follow-up reminder email sent on April 16, 2024 to any recipient who had not completed the survey.
- **Phase III: NOIE Outreach.** Survey invitations were distributed by NOIE partners to their own customers. We provided each NOIE with individual links for each customer for whom outreach was to be undertaken. NOIE outreach took place on or around April 16, 2024, with a reminder email sent around April 23, 2024.
- **Phase IV: Trade Organization and REP Direct Outreach.** To improve coverage of large C&I customers, unique survey invitation links were produced for trade organizations and REPs whose customers or members expressed interest in participating in the survey. This was performed on an as-requested basis.

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[16] While paper-based survey distribution by mail was considered, the outage scenario randomization approach used made a static, paper-based medium not viable.

[17] Due to the short data collection window, offline methods such as direct mail would have been too slow to be effective. Further, because the survey had to be distributed digitally, offline outreach methods would likely not have improved participation among respondents with little-to-no access to computers, smartphones, or internet connections.

As discussed further in the next subsection, separate surveys were used for residential and C&I customer classes. Both surveys included a short qualification section. To qualify to participate in the survey, residential customers: (i) had to be responsible for paying electricity bills; (ii) unaffiliated with the Commission, ERCOT, and transmission and distribution utilities; and (iii) have lived in their residence for at least one year. For C&I customers to qualify, respondents: (i) had to have responsibility in their organization for monitoring electricity bills and usage and (ii) the customers must have been in business for at least one year. Additionally, respondents had to confirm that the address on file for them corresponded to a residence if they were tagged as residential customers or as a business if they were tagged as C&I customers. This was to ensure that the respondent was receiving a survey that matched their customer class. Respondents not meeting these qualification criteria were prevented from completing the survey.

Table 1 below shows the number of outreach emails sent and the resulting number of surveys completed along with the completion rate. Completion rates were higher for residential customers—3% for customers in areas open to competition and nearly 7% for residential NOIE customers. C&I customers responded at a rate of 1.2%. Our outreach was sufficient to exceed our target number of completions. We anticipated these targets to be sufficient to attain reasonable statistical precision in our analysis.

However, only 36 of the C&I responses were from large customers. For this reason, we supplemented our collection with analogous data collected by American Electric Power Texas ("AEP Texas") in its service territory in coordination with LBNL. In total, 26 survey responses from large C&I customers were provided by AEP Texas to supplement the 36 VOLL survey responses. AEP Texas and LBNL agreed to share this anonymized data with the Brattle team under the same confidentiality requirements discussed above.

TABLE 1: OUTREACH AND COMPLETION STATISTICS

	Outreach	Completion	Target	Completion Rate
Residential				
Areas open to competition	81,565	2,507		3.1%
NOIE partners	7,102	484		6.8%
Total	**88,667**	**2,991**	**2,500**	**3.4%**
Small C&I				
Areas open to competition	114,413	1,194		1.0%
NOIE partners	3,333	25		0.8%
Total	**117,746**	**1,219**		**1.0%**
Medium C&I				
Areas open to competition	28,444	435		1.5%
NOIE partners	1,430	21		1.5%
Total	**29,874**	**456**		**1.5%**
Large C&I				
Areas open to competition	928	33		3.6%
NOIE partners	181	3		1.7%
Total	**1,109**	**36**		**3.2%**
Total C&I				
Areas open to competition	143,785	1,662		1.2%
NOIE partners	4,944	49		1.0%
Total	**148,729**	**1,711**	**1,500**	**1.2%**

C. Survey Design

The Brattle team designed and administered a stated preference survey to elicit customers' valuation of uninterrupted electricity service to be consistent with existing data collection efforts by LBNL. This was to ensure that our data could be used in the ICE Calculator and that the data collected for LBNL's initiative in AEP Texas' service area could be incorporated into the ERCOT VOLL study as appropriate. The complete survey instruments were filed with the Commission on March 14, 2024 and also included in Appendix A for ease of reference.[18]

[18] *See Review of Value of Lost Load in the ERCOT Market*, Project No. 55837, Value of Lost Load Study Update (Mar. 14, 2024).

1. Adjustments Made to the LBNL Survey Instruments

Consistent with our assignment, we began with survey instruments provided by LBNL for residential, small and medium C&I, and large C&I customers. From this starting point, we harmonized the two commercial versions into a single instrument to simplify the data collection process. We streamlined or eliminated some of the background questions in both the commercial and residential instruments that were not necessary to our analysis and adjusted the language to enhance clarity.

The core of the survey asks the respondent to consider four outage scenarios. Under the LBNL design, three scenarios were less than a day long while the fourth was a 3-day outage. For that fourth extended-duration outage scenario in the LBNL survey instrument, the questions were limited and respondents were not asked to provide information that could be used to estimate VOLLs. To maximize the information elicited from respondents, we chose to ask the same set of questions under each scenario, including the extended-duration outage scenario. Due to their higher frequency, shorter duration scenarios were of greater interest and not all respondents were asked to consider a 3-day outage.

After finalizing our survey instruments in English, they were translated into Spanish to ensure that Spanish-speaking populations could participate in the survey.

2. Characteristics of Scenarios

We characterized each outage scenario using the same dimensions considered in the LBNL survey. These include season, start time, day type (weekend or weekday), duration, and whether an advance warning was provided or not. Respondents were asked to consider eight scenarios that were selected using the following protocol and depicted in Figure 2 below:

1. A respondent was shown either a **winter outage or a summer outage scenario** first, selected at random.
2. A **start time and day type for that season** were selected at random following the probabilities in Table 2 below. These were held fixed within a season to reduce respondent fatigue.
3. For the resulting season + start time + day type combination, **two different duration bins** (listed in Table 2) were selected.
    a. A specific duration time from each bin was then selected at random. Possible durations include 5 minutes, each whole hour from 1 to 16 hours, 1 day, or 3 days.

b. If the difference between the two selected durations was less than 3 hours (*e.g.*, 7 hours and 9 hours), then one of the durations (chosen at random) was changed to another duration in the same duration bin that is at least 3 hours from the unaltered duration.[19]

This approach ensures that respondents see sufficiently varied durations to avoid perceiving that they were being asked essentially the same question more than once.

4. For each season + start time + day type + duration combination, respondents were asked questions related to an outage **without warning**, then they were asked to evaluate **the same outage but this time having received an advance warning**.
5. Steps 2–4 were repeated for the second season.

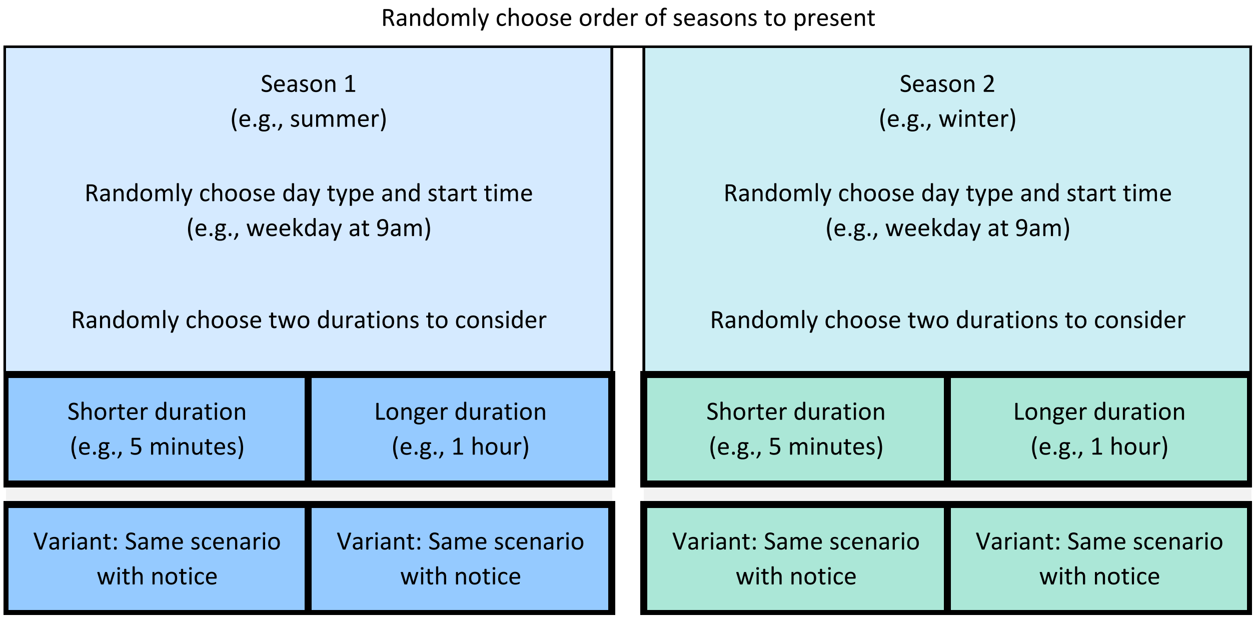
Steps 1 and 2, when repeated in Step 5, provides two season + start time + day type combinations for the respondent to consider. For each of these combinations, Step 3 yields two durations to consider. Lastly, Step 4 provides two variants for each duration. Taken together, this implies 2 × 2 × 2 = 8 scenarios presented to the respondent.

Each respondent was guaranteed to see both a winter and a summer scenario.[20] Because start time and day type were chosen randomly, the respondent may have seen the same start time or same day type in both seasons.

[19] Because a momentary outage cannot be shortened, if that duration was in conflict with another selected duration (*i.e.*, a 1-, 2-, or 3-hour duration), then the latter was lengthened to resolve the conflict (*i.e.*, to 4 hours).

[20] To evaluate whether a shorter survey would lead to higher completion rates, during the soft launch phase, half of respondents were only shown one season and its associated scenarios. We found that completion rates were similar for respondents who were only shown one season as those who were shown both, leading us to use the full-length survey as our final instrument.

FIGURE 2: SCEMATIC OF SCENARIO CREATION FOR A RESPONDENT



Notes: Bold-bordered boxes represent unique choice scenarios.

The likelihood of each start time and duration bin were chosen based on discussions with ERCOT and a review of preliminary results of simulations performed by ERCOT that indicate the potential frequency of outages of different durations during different times of day and different seasons. These simulations revealed that long outages are unlikely in the summer; hence those were only considered for winter scenarios. Furthermore, outages were more likely in the evening during the summer, whereas they were more likely in the morning during the winter months.

TABLE 2: SELECTION PROBABILITIES OF SCENARIO CHARACTERISTICS

	Probability of Selection	
	Summer	Winter
Start time		
7 a.m.	35%	50%
2 p.m.	15%	15%
7 p.m.	50%	35%
Day type		
Weekday	50%	50%
Weekend	50%	50%
Duration bin		
5 minutes	10%	5%
1-4 hours	45%	30%
5-8 hours	45%	20%
9-16 hours	0%	30%
1 or 3 days	0%	15%

Notes: Each characteristic was chosen independently of the rest, other than season as shown. The probability of selecting a given duration bin are approximate; actual probabilities are somewhat different due to the elimination of durations that are less than 3 hours apart (see Step 3 above).

3. VOLL Elicitation Strategy

To ensure consistency with recent LBNL surveys and data, we follow the same methodology to elicit customers' valuation of uninterrupted electricity service as used in its surveys. The questions used to elicit these values are different for residential and C&I respondents. Emphasis in quotations below is as shown in the survey instrument.

C&I customers. For C&I customers, LBNL takes a relatively direct approach. After providing a description of the outage scenario, the respondent is asked: "*What do you think your most likely total cost would be for this outage?*" Respondents are also asked to provide their estimates of the best- and worst-case costs they associate with the outage.

To help guide their thinking in developing this estimate, the first time that the respondent is presented with an outage scenario, they are asked to estimate costs related to specific categories of impact, such as costs associated with lost operations and services or damage or spoilage of materials. After collecting costs related to each category, a summary table and total are shown to the respondent, who is asked to verify that the total seems reasonable.

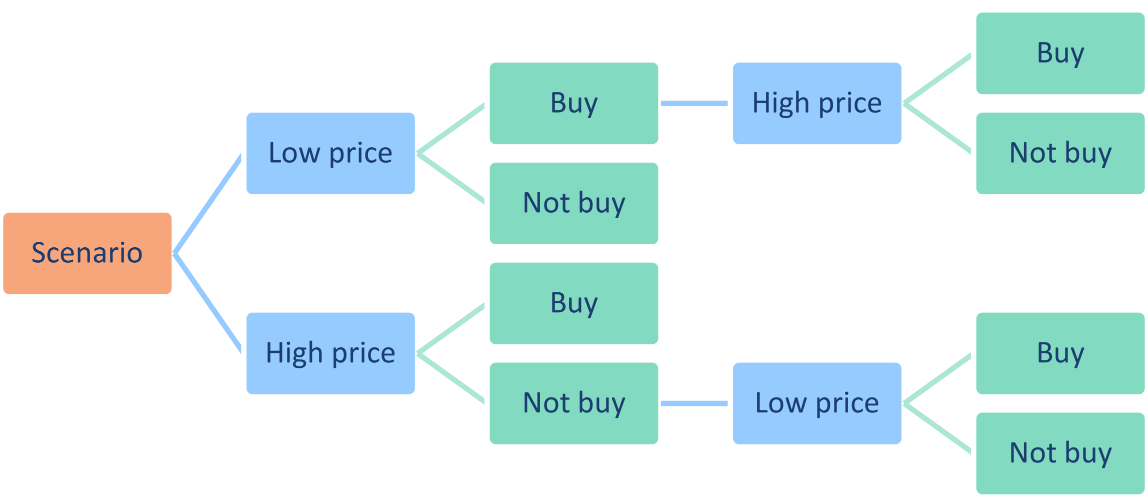
Residential customers. The approach for residential customers is more indirect. The respondent is presented with the following hypothetical:

> *Suppose that a company that is <u>not</u> your retail electric provider developed a new service that can instantaneously deliver temporary backup power to your household during this outage. With the purchase of this backup service, you would not experience the outage or need to take any additional actions. The cost of the service is a <u>one-time fee</u> that covers your household's normal electric usage during this <u>single outage</u>.*

Then, the customer is asked: "Would your household purchase the backup service to avoid this **<u>single outage</u>** for a **<u>one-time fee</u>** of $[X]?"

Two potential proposed fees are selected randomly for each respondent: a low fee and a high fee. The respondent is then shown either the high or low value. If the respondent saw the low value and agreed to purchase the service, they were then asked: "Would your household purchase the backup service to avoid this outage for a one-time fee equal to $[high value]?" Alternatively, if they saw the high value first and rejected it, they were asked whether they would pay the low value. This design is depicted in the schematic of Figure 3 below.

FIGURE 3: SCHEMATIC OF PRICE OFFERS MADE BASED ON RESPONSES GIVEN



Notes: Respondent choices are in green; survey design is shown in blue. The initial offer price is selected randomly for each scenario.

To determine the prices proposed to the respondent, respondents were classified into one of four usage bins. Based on this usage level and the duration of the outage, we determined an expected WTP value based on the literature review conducted in Part I of this study and informed by the LBNL ICE Study.[21] The low price was selected to be lower than the expected value and the high value above the expected value.[22] The expected price does not need to be perfectly accurate. The survey provides the most information when roughly half of respondents decline the offer and half accept (which would be expected if the values were reasonably accurate). So long as some portion agreed to purchase the service and some portion declined the service, no matter how skewed these portions are, the responses would provide useable results, but would engender larger statistical uncertainty.

Further questions. Both C&I and residential respondents were also asked to rate the disruptiveness of the outage on a scale from 1 to 5. After evaluating the primary scenario, the respondent was asked to consider how receiving advance warning of the outage would change their response. C&I customers were asked for the total cost for this variant and residential customers were asked an analogous sequence of purchase questions as discussed above and depicted in Figure 3.

IV. VOLL Methodology and Estimates

As discussed in Section III.C above, different approaches were used to elicit VOLLs from residential and C&I customers. While residential customers were asked a yes-or-no choice of whether to purchase protection against an outage, C&I customers were asked for the cost associated with experiencing an outage. Because these quantities are different (notably, one is binary and the other can be any non-negative number), the modeling strategy must be different. We discuss the approach for each in this section and provide estimates of the VOLLs by customer class. Additional technical details related to our methodologies are provided in Appendix B. We also provide an estimate of a single ERCOT-wide VOLL across all customer classes. We discuss the overall results further in Section V and contrast them to the interim values calculated in Part I of the present study.

21 Brattle Part I Study.

22 In particular, to get the low price offer, the expected estimate was reduced by a random percentage from 0% to 50%; to get the high fee offer, the expected estimate was increased by a random percentage from 0% to 50%. If the two fees were less than \$0.25 apart, the high fee was increased by \$0.25. Lastly, each fee was rounded to the nearest quarter to ensure that the respondent found the proposed price credible. For the warning scenarios, the no-warning low fee was randomly reduced by 0 to 25%, then this low fee was scaled up by up to a factor of 2 to get the warning high fee. These values were also ensured to be at least \$0.25 apart and rounded.

Table 3 below compares the total number of responses that we received to the number of observations used in our analysis. For both residential and C&I customers, we removed respondents who finished the survey much faster than the rest; for C&I customers, we also performed additional checks as described in Appendix B.2.a. Approximately 10% of small C&I and large C&I responses were removed for quality reasons; medium C&I responses were removed at a marginally lower rate. Less than 1% of residential respondents were removed.

TABLE 3: COMPARISON OF RESPONSE COUNTS AND OBSERVATION COUNTS IN THE DATASET USED IN OUR ANALYSIS

	Completed	Final Dataset
Residential		
Areas open to competition	2,507	2,494
NOIE partners	484	481
Total	**2,991**	**2,975**
Small C&I		
Areas open to competition	1,194	1075
NOIE partners	25	23
Total	**1,219**	**1,098**
Medium C&I		
Areas open to competition	435	406
NOIE partners	21	20
Total	**456**	**426**
Large C&I		
Areas open to competition	33	27
NOIE partners	3	3
AEP	26	26
Total	**62**	**56**
Total C&I		
Areas open to competition	1,662	1,508
NOIE partners	49	46
AEP	26	26
Total	**1,737**	**1,580**

Notes: Respondents were removed for completing the survey too quickly or for quality issues described in Appendix B.2.a. Some scenarios pairs were removed from the remaining respondents as described in that discussion.

For each customer class, we discuss how we reweight responses to account for potential non-response bias that can arise in three ways: (a) customers may live in areas served by non-participating NOIEs or in areas open to competition where REPs did not provide email addresses in the CBCI data; (b) customers may not have provided email addresses to their REP or the email address provided may have been incorrect; or (c) customers may have been selected to participate in the study, but they did not complete the survey. At a high level, we estimate VOLL values that depend upon customer characteristics, then weight by the prevalence of those characteristics in the ERCOT Region according to data from the US Census Bureau.[23] This approach is known as *post-stratification*.[24]

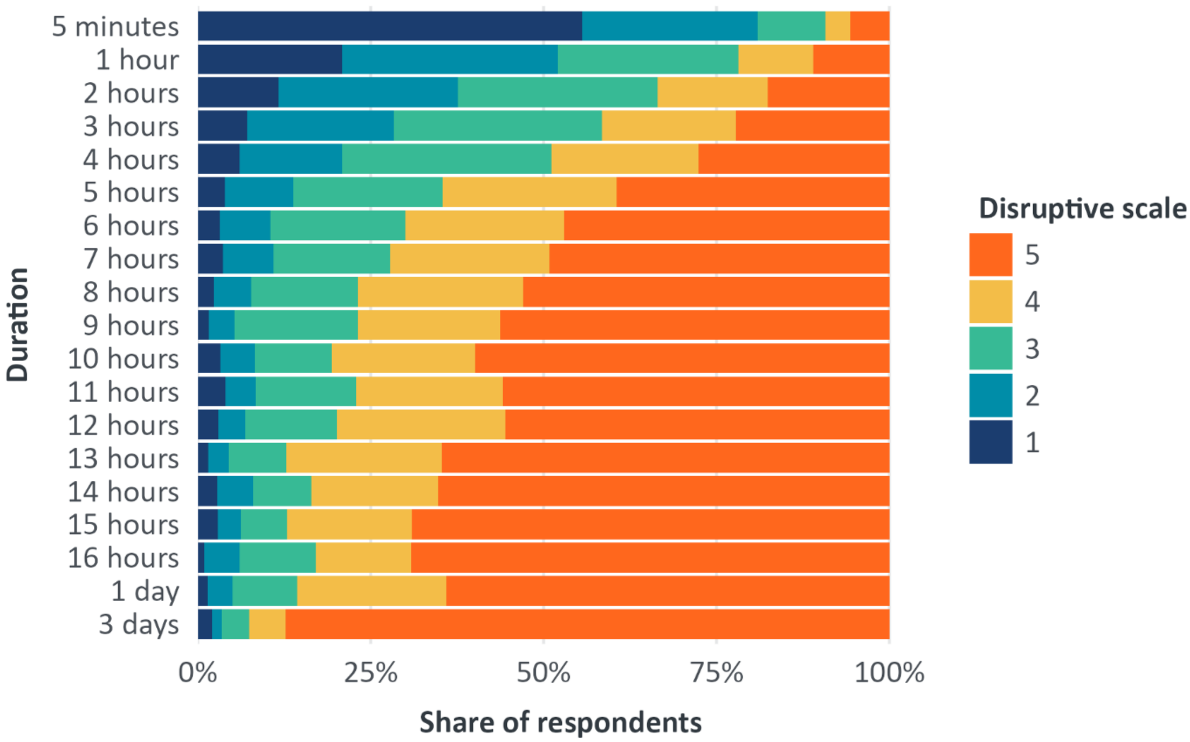
A. Residential Customers

For each outage scenario, respondents were asked to rate its disruptiveness on a scale from 1 (not disruptive) to 5 (very disruptive). To provide context for our modeling and results, we reviewed these disruptiveness ratings and depict them by duration in Figure 4 below. More than half of respondents give one of the two highest disruption scores to durations of 4 hours or longer; nearly 10% of respondents declare that even a 5-minute outage merits one of the two highest scores.

[23] Demographic data was obtained from "IPUMS USA Data Extract," IPUMS, April 23, 2024, retrieved from https://usa.ipums.org/usa/. Weights for the commercial responses rely on the County Business Pattern data obtained from "All Sectors: County Business Patterns, including ZIP Code Business Patterns, by Legal Form of Organization and Employment Size Class for the U.S., States, and Selected Geographies: 2021," United States Census Bureau, retrieved from https://www.census.gov/programs-surveys/cbp/data/tables.All.List_1592946817.html#list-tab-List_1592946817.

[24] Our approach uses hierarchical Bayesian models with post-stratification weighting. "Hierarchical" means that each respondent has their own preferences that depend upon the demographic group they belong to. See, for example, Andrew Gelman and Jennifer Hill, 2006, *Data Analysis Using Regression and Multilevel/Hierarchical Models, Cambridge University Press*.

FIGURE 4: DISTRIBUTION OF DISRUPTIVENESS RATINGS BY DURATION FOR RESIDENTIAL RESPONDENTS



Source: Residential customer response data.

Broadly speaking, residential customers were asked whether they would be willing to pay a certain amount to avoid a single outage with specified characteristics. In economics research, this is known as a "**stated preference discrete choice experiment**." The choice is discrete in that consumers can indicate either that they would buy the product or not; it is stated because we are eliciting what the consumer says what they would do, rather than observing their actual choice behavior.

Economists have developed statistical models to analyze discrete choice data. Daniel McFadden connected the "logit" model to economic theory; in particular, he showed that the parameters of a logit model can be used to determine how much consumers would pay for attributes of a product. Along with Kenneth Train, he further showed that, by allowing the parameters to vary across consumers, this model could approximate any set of consumer preferences arbitrarily well.[25] For this reason, these models have become standard when analyzing consumer responses to discrete choice surveys.[26] This approach has been adjusted to accommodate the elicitation

[25] Daniel McFadden and Kenneth Train, 2000, "Mixed MNL Models for Discrete Response," *Journal of Applied Econometrics*, 15: 447–470. Dr. McFadden's research on discrete choice models earned him a Nobel Prize in 2000.

[26] Greg M. Allenby and Peter E. Rossi, 2006, "Hierarchical Bayes Models," in *Handbook of Marketing Research: Uses, Misuses, and Future Advances*, Rajiv Grover and Marco Vriens (eds.), SAGE Publications.

strategy used by LBNL—namely, potentially following up an initial offer with a higher or lower price to gain additional information from the respondent.[27]

As discussed in the preamble to this section, we evaluate whether our results may be biased due to non-response and adjust our results based on customer characteristics that influence the customer's VOLL. For residential customers, the factors that we find to influence the VOLL include: (a) whether the customer's use is above or below that of the median residential customer; (b) whether the customer's income is above or below the statewide median; (c) whether the customer lives in an urban area; (d) whether someone in the respondent's household has health needs that require access to power; and (e) whether they work from home.[28]

Table 4 below shows two sets of model results. In the "unweighted" version of the model, preferences are allowed to vary across respondents, but not systematically based on demographics and accordingly are not reweighted to reflect the demographics of the ERCOT Region. The "population-weighted" approach is adjusted for the factors listed above to account for potential non-response bias. We see that the unweighted and population-weighted models yield similar results, suggesting that any non-response to the survey did not substantially bias the results. This is at least in part because residential respondents in aggregate are reasonably similar to the ERCOT population based on the demographics that we consider.

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[27] This question design is known as one-and-on-half bounded; *See* Joseph C. Cooper, Michael Haneman and Giovanni Signorello, 2002, "One-and-One-Half-Bound Dichotomous Choice Contingent Valuation," *The Review of Economics and Statistics*, 84(4): 742–750.

[28] Median usage is approximately 13,600 kWh per year; median annual income is approximately $75,000.

TABLE 4: RESIDENTIAL CLASS UNWEIGHTED AND POPULATION-WEIGHTED ESTIMATED INTERRUPTION COST PER EVENT (2024$)

	Unweighted	Population Weighted
Momentary	$0.24	$0.49
1 hour	$7.08	$7.03
2 hours	$11.74	$11.72
Each additional hour (up to 16)	$1.48	$1.38
1 day	$28.83	$30.83
3 days	$40.60	$43.60
Advance warning	-$1.62	-$1.65

Source: Residential customer WTP models. The unweighted model is a random coefficient model and the population-weighted model is a hierarchical model adjusted for region demographics. See the Technical Appendix for additional discussion.

Using the population-weighted results, we show the relationship between duration and WTP in Figure 5. Our results indicate no statistically detectable WTP to avoid a momentary (5 minute) outage. Customers on average have a WTP of $7.03 to avoid a one-hour outage, which increases to $11.72 to avoid a two-hour outage, an increase of over $4.50. From there, WTP increases by $1.38 per hour up to 16 hours. The shaded area surrounding the curve in this figure provides a 95% confidence interval for the average WTP; we see that this band is relatively narrow, indicating reliable statistical precision in our results.

The WTP to avoid a day-long outage is only marginally higher than that for 16 hours; increasing the duration to three days increases the WTP by $13 (about 40%). The 95% confidence intervals for these values are wider, reflecting less statistical precision in these estimates since fewer respondents were asked to evaluate these extended durations. A report from LBNL indicates that few survey-based studies have elicited preferences regarding longer-duration outages, in part because responses may be less informed on these outage durations.[29]

We also assessed whether these WTP values varied by season, time of day, and day type. We did not find any systematic differences along these characteristics. We compare the results presented here to a model that accounts for timing-related factors in the Technical Appendix.

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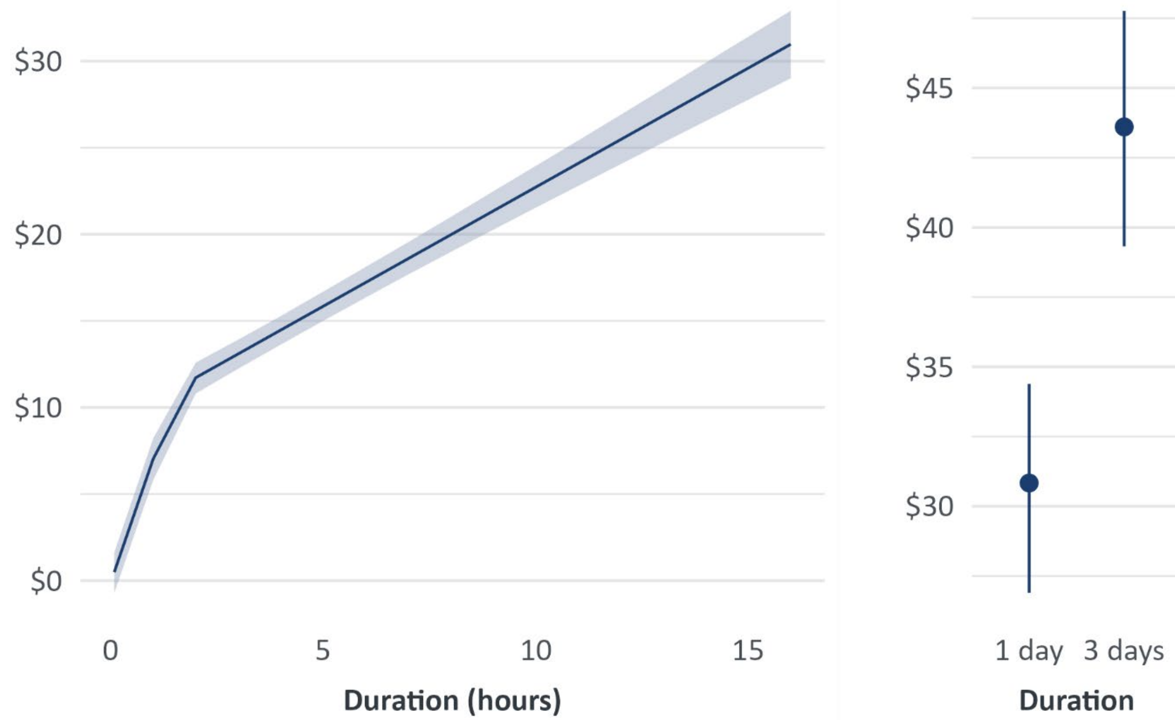
[29] Madeline Macmillan, Kyle Wilson, Sunhee Baik, Juan Pablo Carvallo, Anamika Dubey, and Christine A. Holland, "Shedding light on the economic costs of long-duration power outages: A review of resilience assessment methods and strategies," May 2023, Lawrence Berkeley National Laboratory.

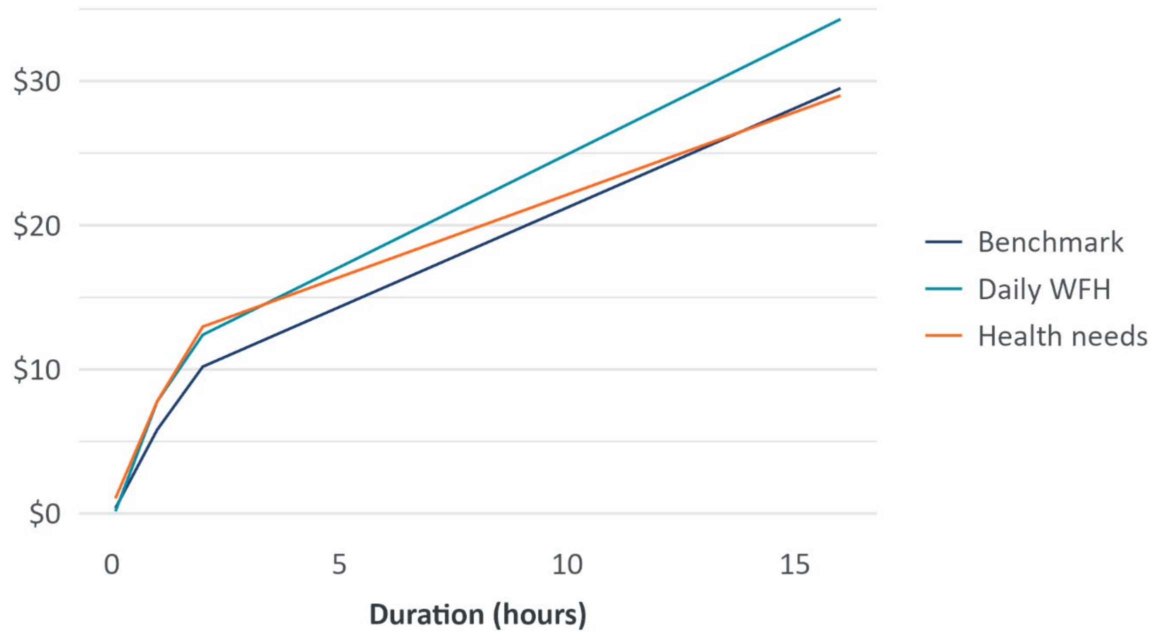
FIGURE 5: AVERAGE RESIDENTIAL INTERRUPTION COSTS PER EVENT AND 95% CONFIDENCE BOUNDS (2024$)



Source: Residential customer population-weighted WTP model.

Figure 6 shows the estimates from a benchmark population model along with those for people whose households have health needs that require access to power and for people who work from home every day. Both groups have higher WTP values for shorter durations than the benchmark group that does not meet either criterion. The WTP values for those with health needs converge with those for the benchmark population, while the WTP values for those who regularly work from home remain shifted to a higher level across durations. To the extent that a larger share of the population works from home on a daily basis, this will tend to increase the residential VOLL. Note, however, that this may lead to a concomitant decline in the C&I VOLL.

FIGURE 6: AVERAGE RESIDENTIAL INTERRUPTION COSTS PER EVENT FOR SELECTED DEMOGRAPHIC GROUPS (2024$)



Source: Residential customer hierarchical WTP model. The benchmark, daily work-from-home ("WFH"), and health needs populations have regionwide average values for income, usage, and share living in urban areas. The benchmark population does not have health needs or work from home daily; the daily WFH group only works from home daily; and the health needs group only has health needs.

Table 4 indicates that respondents' WTP to avoid an outage is $1.65 lower across durations when they would receive advance warning of the outage. When asked about their willingness to pay to avoid an outage that was accompanied by advance warning, respondents were not told how far in advance the warning would be given. However, respondents were separately asked how much warning would be necessary to "significantly reduce the costs and inconvenience" from an outage. Table 5 below shows that 20% of respondents declare that advance warning would not impact their costs; at least 8 hours of notice would be required to assist half of those that would find warnings useful.

TABLE 5: AMOUNT OF WARNING REQUIRED AS REPORTED BY RESIDENTIAL RESPONDENTS

	Share
At least 1 hour	11%
At least 4 hours	21%
At least 8 hours	10%
At least 24 hours	25%
At least 48 hours	13%
Not beneficial	20%

Source: Residential customer response data.

B. C&I Customers

Whereas the VOLL for residential customers was inferred based upon their stated choices, the VOLL for C&I customers is based on those respondents' direct assessments of their costs arising from outages. This difference in approach requires a different methodology for analysis as well as additional data validation steps.

Customer Classification. We classify C&I customers as small, medium, or large. In the CBCI data, large customers are identified directly; for NOIE data that do not directly identify large customers, we define this category as C&I customers with annual usage above 4.5 million kWh. To separate the small and medium categories, we use a threshold of 50,000 kWh per year consistent with LBNL's classification of these customers in their analysis. All three categories complete the same survey instrument. Due to the relatively small number of responses by large customers, we combine the medium and large customer classes in our analysis. Results presented separately for the large C&I class would have a high degree of statistical uncertainty. As we will see, combining the medium and large customer classes and reweighting to reflect the overall population leads to results with reasonable statistical precision.

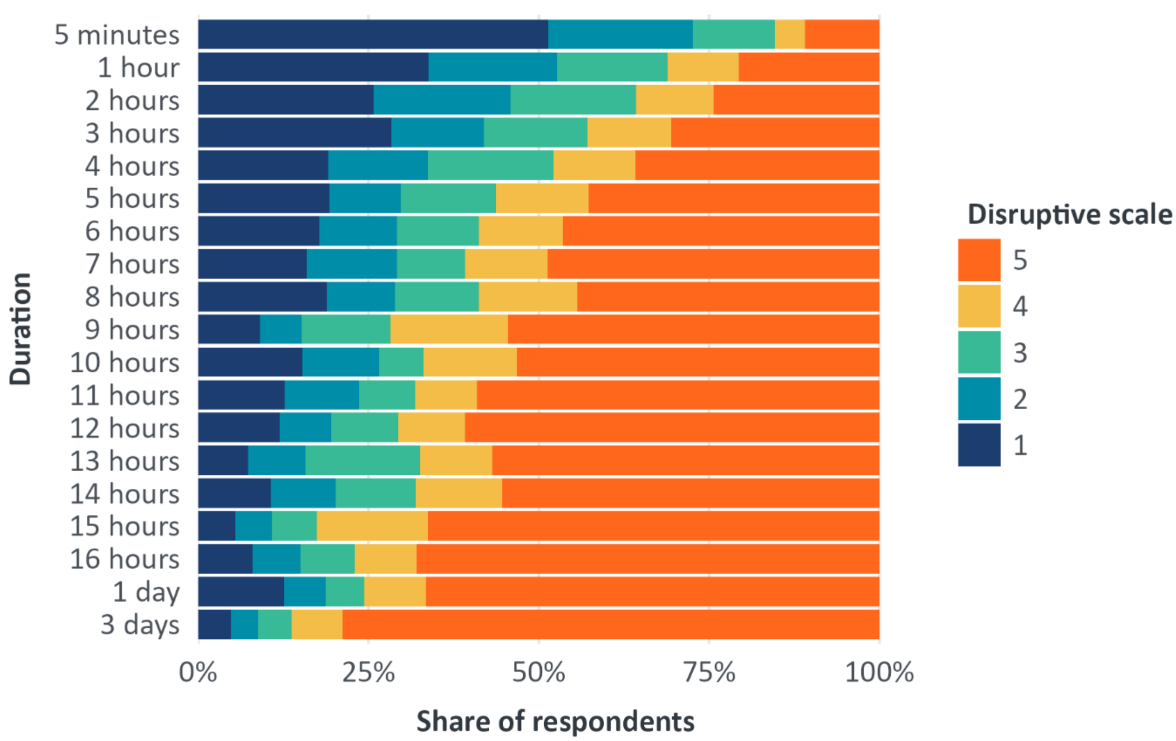
Data validation. The accuracy of our analysis depends on the validity of the data used. Accordingly, we reviewed the costs reported by respondents to assess their reliability. We specifically looked for two patterns that could indicate unreliable responses.

First, we determined whether the respondent gave the same value for all outage scenarios. Absence of a relationship between outage characteristics and costs may indicate that the respondent was not carefully evaluating each scenario. There are some cases where this pattern may be reasonable, however; for example, if the respondent was only presented with weekend scenarios and their business is closed on the weekend. We implemented a set of rules to separate potentially reliable responses from ones less likely to be reliable and discuss these further in the Technical Appendix.

Second, we reviewed respondents who provided seemingly irrational responses—specifically that longer outages had lower costs. We concluded that these response pairs are likely unreliable and we removed them from our data. We provide additional detail in the Technical Appendix.

Sensitivity to duration. As context for our analysis, Figure 7 below shows the distribution of disruptiveness scores from C&I respondents by duration. Similar to residential respondents, after four hours, half or more of C&I respondents indicate that the outage would score one of the two highest disruptiveness levels. C&I respondents rate shorter outages to be somewhat more disruptive than do residential respondents, including 15% that indicate that even a momentary outage would merit one of the top two disruptiveness ratings. Compared to the residential class, the change in disruptiveness is less dramatic with increasing outage duration.

FIGURE 7: DISTRIBUTION OF DISRUPTIVENESS RATINGS BY DURATION FOR C&I RESPONDENTS

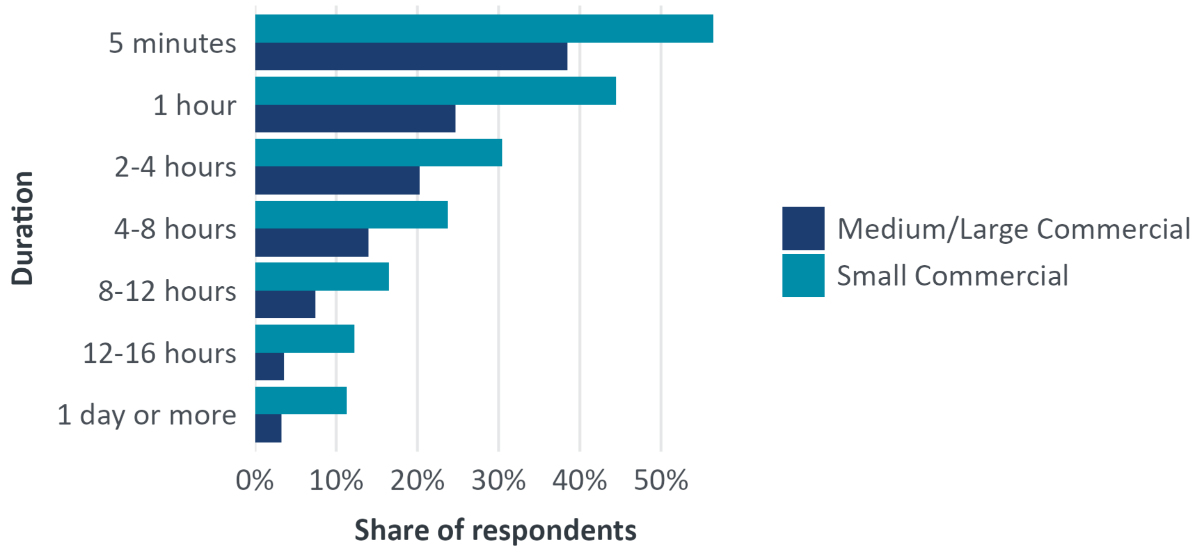


Source: C&I customer response data.

Another way to evaluate the disruptiveness of outages is to examine the share of respondents who indicate that there would be no costs associated with the outage. Figure 8 below shows the share of respondents who indicate no costs by duration length. Small C&I respondents are more likely to respond that they would not experience any costs for an outage with a given duration than medium/large C&I respondents do, though the shares for both classes are non-trivial for up to four-hour outages.

While respondents were not asked to explain or justify their values, the intuition for these responses is likely that there is some degree of inconvenience a C&I customer may be capable of absorbing without leading to substantial costs; beyond a threshold level of disruption, however, costs begin to accumulate.

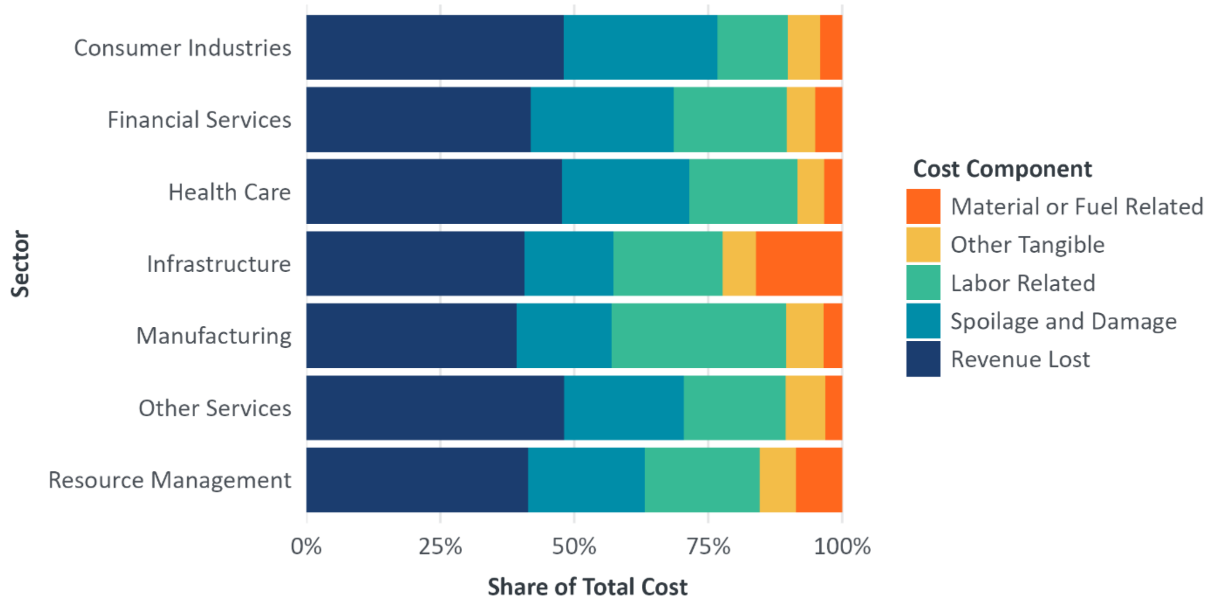
FIGURE 8: SHARE OF SCENARIOS WITH NO REPORTED COSTS BY DURATION AND CUSTOMER CLASS



Source: C&I customer response data.

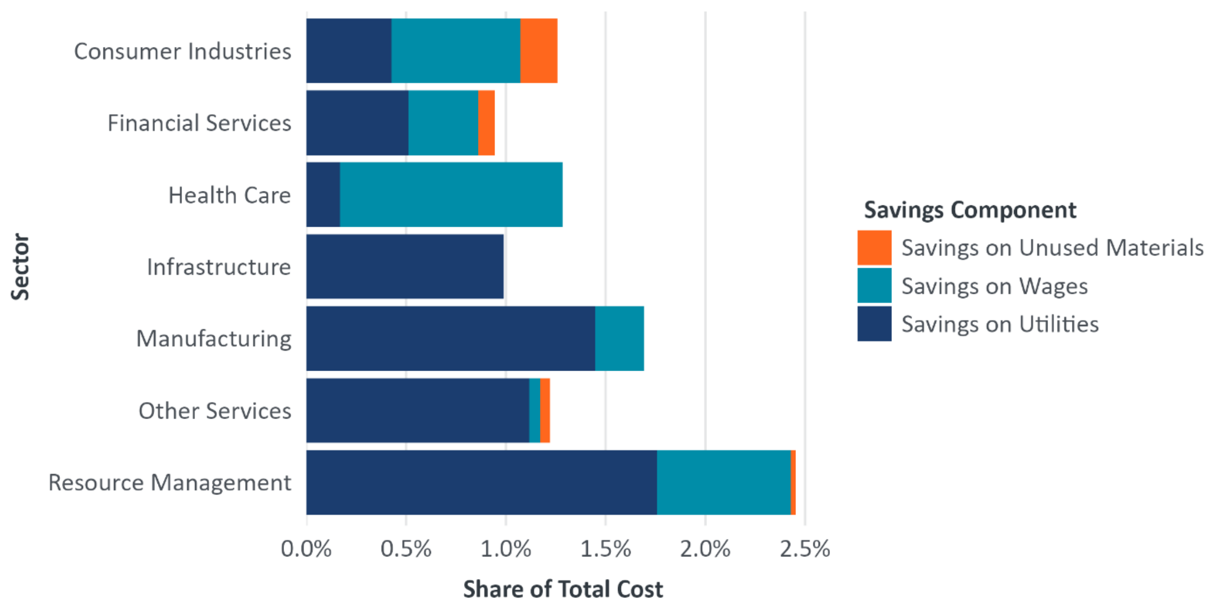
Source of costs. When considering the first outage scenario, each C&I respondent was asked to provide costs attributable to specific cost categories. This extensive questioning serves two purposes. First, it helps the respondent consider the full range of costs (and potential offsets) that may be experienced from the outage. The goal is for this buildup to generate a more comprehensive, thoughtful, and reliable total. Second, it allows us to assess the primary sources of costs when confronting an outage. Figure 9 below shows the share of total costs attributable to each category by sector and Figure 10 shows the share of savings arising from different categories. Lost revenue generates the highest share of costs for all sectors, with spoilage and damage and labor-related costs being similar in share. Cost savings are negligible at 2.5% of total costs or less. While we do not statistically model each cost category separately, these breakdowns provide helpful context for the source of total costs and potential offsets.

FIGURE 9: ALLOCATION OF TOTAL COST ACROSS CATEGORIES BY SECTOR



Source: C&I customer response data.

FIGURE 10: ALLOCATION OF COST SAVINGS RELATIVE TO TOTAL COST ACROSS CATEGORIES BY SECTOR



Source: C&I customer response data.

Statistical model. Figure 8 indicates a key feature of C&I customer responses that need to be captured by our statistical analysis: a non-trivial share of respondents report not expecting costs for an outage and this share depends upon the characteristics of the outage (*e.g.*, duration) and the customer (*e.g.*, customer class). A statistical model that permits some responses to be 0 while the rest can take on a range of positive values is called a *hurdle model*. This type of model allows

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some fraction of responses to be 0, with a continuous range of possible responses above 0. We estimate the likelihood that respondents perceive no costs from the outage along with the costs that arise if the disruption threshold is exceeded.

Within this framework, we adopt analogous features to those used in our analysis for the residential class. In particular, we allow each respondent to have their own sensitivity to outage characteristics (*i.e.,* parameters in the model) and determine how those sensitivities relate to characteristics of customers. We find that costs arising from outages vary systematically based on: (a) customer class; (b) sector; (c) status as a critical load customer; (d) whether the customer is transmission connected; (e) availability of backup power; (f) rural or urban location; and (g) employee count.

We find that the duration of the outage influences both whether the customer experiences costs and how large those costs are, but the timing of the outage only impacts whether the customer experiences any costs. Because of this limited channel for generating differences, the timing of the outage has a limited impact on average costs. *For this reason, we use results for weekday afternoons as a benchmark for our figures and tables below*. As with the residential class, we did not detect differences in costs between the two seasons.

Table 6 shows average costs by customer class without accounting for population characteristics and after reweighting to match the sample to the overall ERCOT C&I population. The basis for this reweighting is County Business Pattern data from the US Census Bureau. We use these data to align our results based on industry, facility employment, and rural/urban location. This reweighting has very little impact for the small C&I class. For the medium/large class, other than for momentary outages, reweighting reduces average costs by 20–25%.

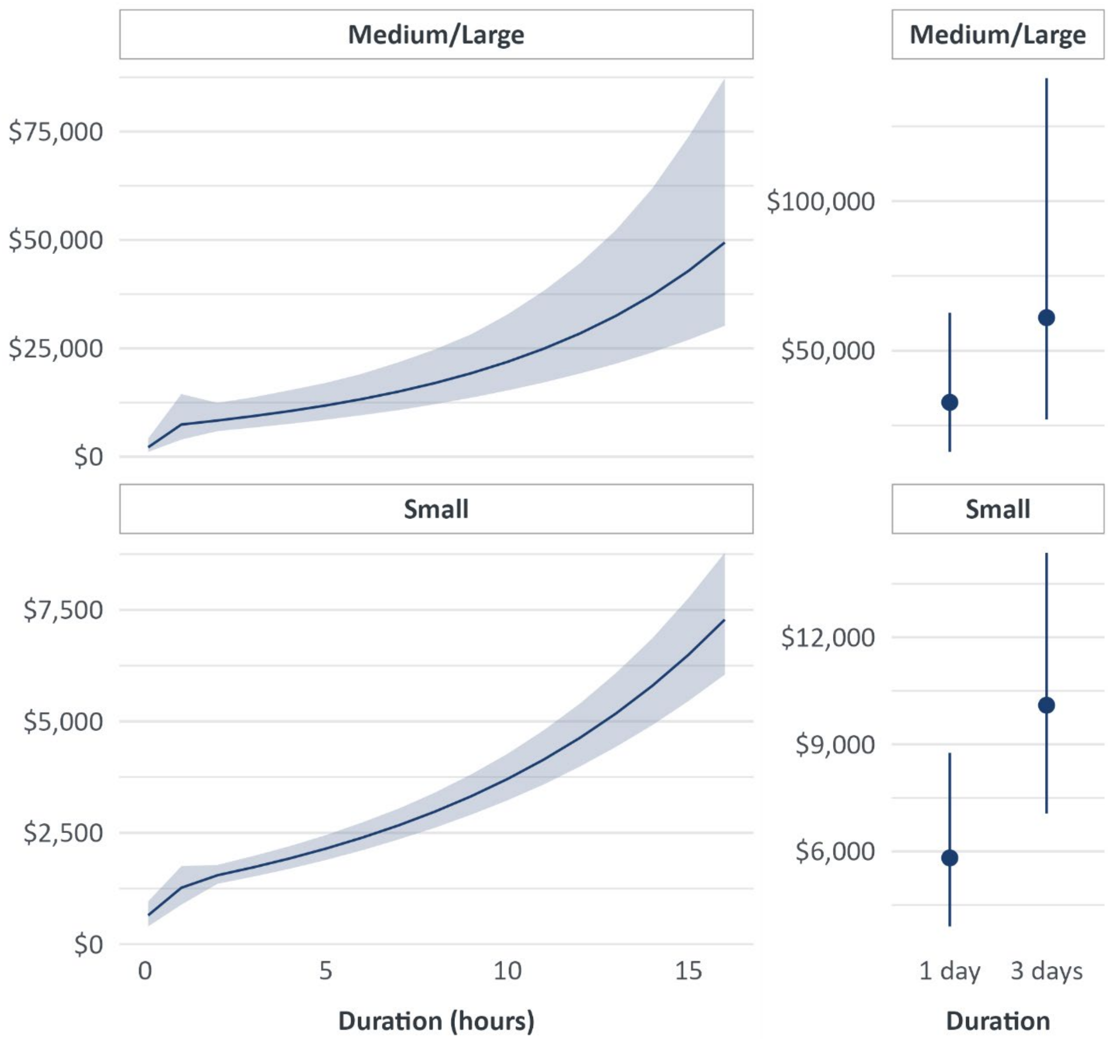
TABLE 6: C&I CLASS ESTIMATED INTERRUPTION COST PER EVENT FOR SELECTED DURATIONS (2024$)

	Small		Medium/Large	
Duration	Unweighted	Population Weighted	Unweighted	Population Weighted
Momentary	$612	$650	$1,764	$2,162
1 hour	$1,307	$1,268	$10,828	$7,413
2 hours	$1,564	$1,549	$11,797	$8,342
4 hours	$1,943	$1,928	$14,764	$10,524
8 hours	$2,992	$2,976	$23,316	$16,985

Source: C&I cost model without and with reweighting to match regionwide characteristics. Estimates shown for a weekday afternoon outage without warning.

Figure 11 shows population-weighted average costs by C&I customer class across durations. The curves showing relationships for shorter durations are surrounded by 95% confidence intervals; vertical segments relay the same information in the panels depicting costs for longer durations. Unlike for the residential class, C&I customers have statistically detectible, though small, costs associated with momentary outages. Average costs are nearly an order of magnitude larger for medium/large customers than for small customers. Similar to residential customers, we find little change in costs going from 16 to 24 hours and a proportionally smaller change in costs when increasing outage duration from 1 to 3 days. There is notable statistical uncertainty associated with these longer durations, however.

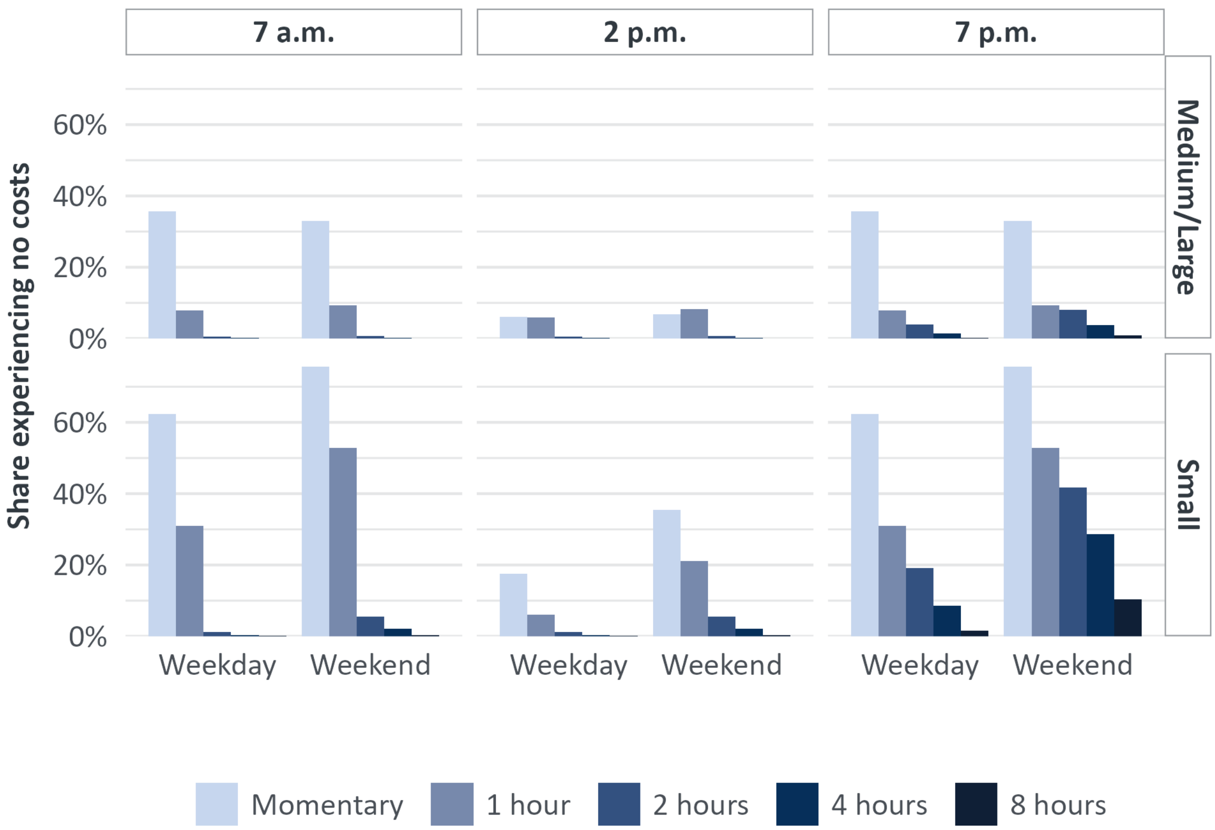
FIGURE 11: AVERAGE C&I CLASS INTERRUPTION COSTS PER EVENT AND 95% CONFIDENCE BOUNDS (2024$)



Source: C&I customer population-weighted cost model. Estimates shown for a weekday afternoon outage without warning.

As mentioned above, the timing of the outage influences whether a C&I customer experiences any costs during the outage, but not the magnitude of costs if they do experience them. Figure 12 below shows how the share of customers experiencing no costs changes with customer class, day type, start time, and duration. As expected, the share of customers that do not experience any costs decreases with duration and is lower for the medium/large customer class than the small C&I class. For both classes, no costs are much more likely in the morning and in the evening than during standard business hours. Also unsurprisingly, C&I customers are more capable of absorbing longer duration outages in the evening than when the day is beginning or underway. Customers are more likely to experience costs on a weekday than on the weekend.

FIGURE 12: SHARE OF CUSTOMERS EXPERIENCING NO COSTS



Source: C&I customer population-weighted cost model. Estimates shown for a weekday afternoon outage without warning.

Table 7 below shows average interruption costs per event by sector. Costs are substantially largest in the infrastructure sector, which includes refineries and data centers; these average costs are more than five times those for the next highest sector (manufacturing), which itself is more than double costs in the remaining sectors. Similarly, Table 8 shows average costs for critical load customers. Industrial critical loads (customers where the suspension of electric service would create dangerous and/or life-threatening conditions on premise) have average costs that are four times larger than those reported by other critical loads. Public safety customers (*e.g.*, hospitals, police stations, fire stations, critical water or wastewater facilities) are double those of customers without a critical load designation.

TABLE 7: AVERAGE INTERRUPTION COST PER EVENT BY SECTOR (2024$)

	Average cost
Infrastructure	$50,180
Manufacturing	$8,574
Health Care and Social Assistance	$3,589
Consumer Industries	$2,466
Resource Management	$2,176
Finance, Technology, and Professional Services	$1,561
Other Services	$1,152

Source: C&I customer population-weighted cost model. Estimates shown for a weekday afternoon outage without warning.

TABLE 8: AVERAGE INTERRUPTION COST PER EVENT BY CRITICAL LOAD STATUS (2024$)

	Average cost
Industrial customer	$23,509
Other critical load	$6,006
Electric generation or co-generation	$5,517
Public safety customer	$3,680
None of the above	$1,719

Source: C&I customer population-weighted cost model. Estimates shown for a weekday afternoon outage without warning.

Advance warning of outages is more effective at reducing costs for small C&I customers than larger customers. Table 9 below shows that costs experienced by medium/large customers fall by approximately 20% when warning is provided and costs to small customers fall by 35% or more. Asked separately from the specific scenario questions, Table 10 shows that small C&I respondents are more likely to report that advance warning would be useful compared to medium/large C&I respondents; both of these shares are lower than the corresponding share for residential respondents (80%; see Table 5). Given that advance warning would be useful, approximately half of respondents across classes require notice to be given 8 hours or more in advance for it to be useful.

TABLE 9: AVERAGE INTERRUPTION COST PER EVENT ESTIMATES FOR C&I CUSTOMERS WITH AND WITHOUT ADVANCE WARNING (2024$)

Duration	Small		Medium/Large	
	No Warning	Advance Warning	No Warning	Advance Warning
Momentary	$650	$317	$2,162	$1,343
1 hour	$1,268	$703	$7,413	$5,347
2 hours	$1,549	$956	$8,342	$6,036
4 hours	$1,928	$1,228	$10,524	$7,692
8 hours	$2,976	$1,923	$16,985	$12,315

Source: C&I customer population-weighted cost model. Estimates shown for a weekday afternoon outage.

TABLE 10: AMOUNT OF WARNING REQUIRED AS REPORTED BY C&I RESPONDENTS

	Small	Medium/Large
At least 1 hour	13%	9%
At least 4 hours	15%	14%
At least 8 hours	8%	6%
At least 24 hours	24%	23%
At least 48 hours	15%	13%
Not beneficial	25%	35%

Source: C&I customer response data.

C. ERCOT-wide VOLL Estimates

While the prior two sections focused on VOLL values *per event* by customer class (reproduced in Table 11 below), in this section we summarize these results on a *per unserved MWh* basis and calculate an ERCOT-wide VOLL estimate. To do this, we normalize the per customer-event values based on average use for that customer class for outages with different durations. This is to calculate the "unserved load" during an outage of a given duration. Then, we calculate a weighted average based on the share of use for each customer class to arrive at the ERCOT-wide VOLL per unserved MWh. Table 11 below presents these components.

TABLE 11: VOLL PER EVENT BY CUSTOMER CLASS AND DURATION (2024$)

	Residential	Commercial & Industrial	
		Small	Medium/Large
1 hour	$7	$1,268	$7,413
2 hours	$12	$1,549	$8,342
4 hours	$14	$1,928	$10,524
8 hours	$20	$2,976	$16,985
16 hours	$31	$7,281	$49,404

Source: Residential population-weighted WTP model and C&I population-weighted cost model. Estimates shown for a weekday afternoon outage without warning.

TABLE 12: AVERAGE HOURLY USE AND SHARE OF ANNUAL TOTAL USAGE BY CUSTOMER CLASS

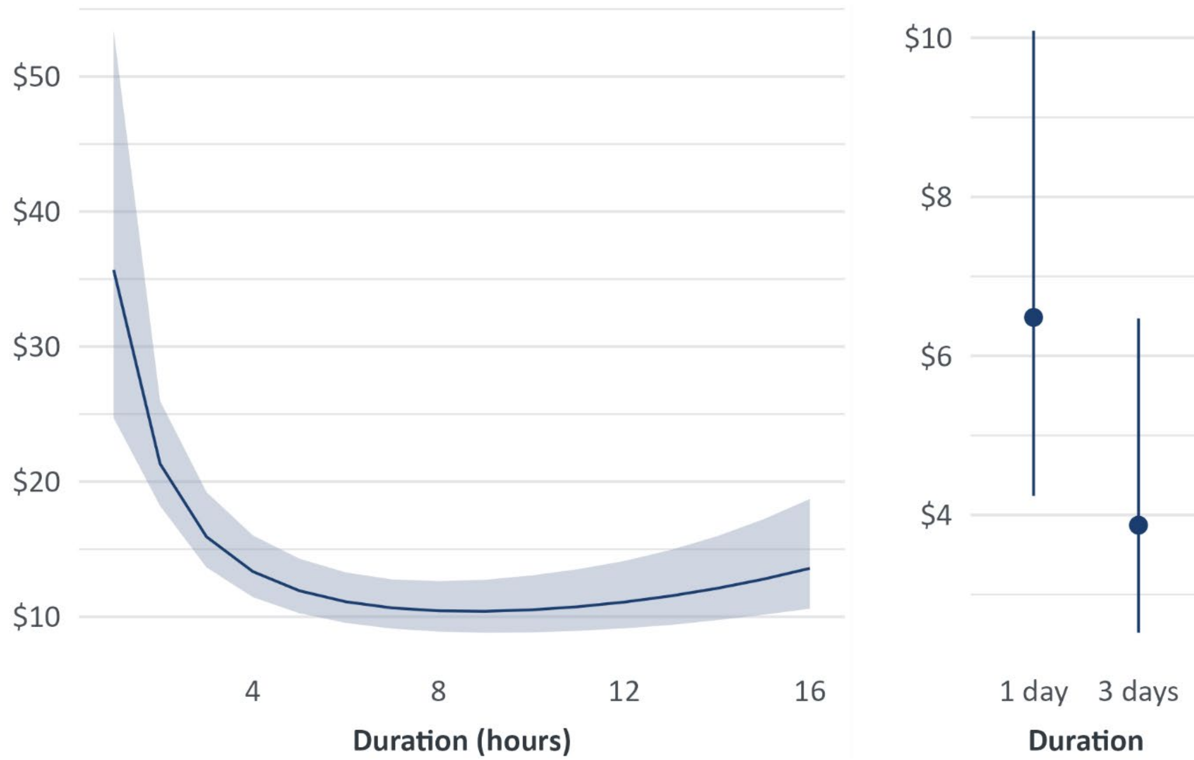
Class	Average Usage (kW per hour)	Usage Share
Residential	1.8	30%
Small C&I	1.9	3%
Medium/Large C&I	326.3	67%

Source: Average usage is a population-weighted average of use among respondents calculated as total annual usage in kWh divided by hours in the year. Usage share is calculated using the ERCOT-provided usage data due to its comprehensive nature.

Figure 13 below shows the resulting ERCOT-wide VOLLs per unserved MWh. VOLL values are higher for 1-hour outages than other durations (excluding momentary outages, which are not shown in the figure). VOLL values fall until durations of approximately four hours, then level off; they are lower still for the extended durations considered. It is worth noting that VOLL values generally decline as the outage duration increases. This is due to the spreading of the cost per event on a larger volume of unserved MWh as the outage duration increases. However, sometimes this relationship is not entirely monotonic as observed going from 8 hour duration to 16 hour duration in the figure.

Table 13 provides the ERCOT-wide value for select durations along with the values for individual customer classes. The class-specific values are lowest for residential customers; values for medium/large C&I customers are approximately four-to-six times those of residential customers. Small C&I customers have substantially higher reported costs per unserved MWh. For all classes, the value falls as the duration of the outage increases.

FIGURE 13: ERCOT-WIDE VOLL PER UNSERVED MWH BY DURATION (2024$, THOUSANDS)



Source: Residential population-weighted WTP model and C&I population-weighted cost model. Estimates shown for a weekday afternoon outage without warning.

TABLE 13: ERCOT-WIDE VOLL PER UNSERVED MWH AND 95% CONFIDENCE BOUNDS FOR SELECTED DURATIONS (2024$)

	By Class			ERCOT-Wide	Confidence Bounds	
Duration	Res.	Small C&I	M/L C&I	Average	Lower	Upper
1 hour	$3,964	$666,907	$22,721	$35,685	$24,721	$53,384
2 hours	$3,303	$407,229	$12,783	$21,326	$18,207	$25,977
4 hours	$2,039	$253,454	$8,064	$13,340	$11,447	$16,016
8 hours	$1,407	$195,591	$6,507	$10,435	$8,895	$12,630
16 hours	$1,091	$239,280	$9,463	$13,581	$10,597	$18,716

Source: Residential population-weighted WTP model and C&I population-weighted cost model. Estimates shown for a weekday afternoon outage without warning.

D. Impact of Excluding Customers Interconnected at the Transmission Level

As discussed earlier, the primary case we have analyzed includes all customer classes, per the instructions of the Commission. Below, we present an alternative case that excludes large C&I

customers that are interconnected directly to the transmission system, which account for approximately 10% of large C&I customers and 58% of large C&I annual load.[30] Those customers can be included in a load shed event, but in practice are generally not curtailed during system shortages, even during long and deep shortages. This is because the transmission service provider ("TSP") load shedding practices focus on distribution-connected customers and our alternative calculation reflects their average VOLL.

Table 14 presents the VOLL per event values excluding transmission-interconnected customers. This table shows that limiting the analysis to the distribution-interconnected customers lowers the VOLL per event for these customers relative to that for the full sample of medium/large C&I customers presented in Table 11.

TABLE 14: VOLL PER EVENT BY CUSTOMER CLASS EXCLUDING TRANSMISSION-INTERCONNECTED CUSTOMERS (2024$)

		Commercial & Industrial	
	Residential	Small	Medium/Large
1 hour	$7	$1,268	$4,946
2 hours	$12	$1,549	$6,219
4 hours	$14	$1,928	$7,914
8 hours	$20	$2,976	$12,972
16 hours	$31	$7,281	$37,981

Source: Residential population-weighted WTP model and C&I population-weighted cost model, the latter excluding transmission-interconnected customers. Estimates shown for a weekday afternoon outage without warning.

Table 15 presents the population-weighted average usage after excluding transmission-connected customers. This information, along with the VOLL per event estimates from Table 14, is used to estimate the VOLL per unserved MWh after excluding transmission-interconnected customers.

[30] This corresponds to about 37% of the load of medium/large C&I customers.

TABLE 15: AVERAGE HOURLY USE AND SHARE OF ANNUAL TOTAL USAGE BY CUSTOMER CLASS EXCLUDING TRANSMISSION-INTERCONNECTED CUSTOMERS

Class	Average Usage (kW per hour)	Usage Share
Residential	1.8	40%
Small C&I	1.9	4%
Medium/Large C&I	81.1	56%

Source: Average usage is a population-weighted average of use among respondents excluding those that are transmission-interconnected calculated as total annual usage in kWh divided by hours in the year. Usage share is calculated using the ERCOT-provided customer usage data excluding transmission-interconnected customers.

TABLE 16: ERCOT-WIDE VOLL PER UNSERVED MWH EXCLUDING TRANSMISSION-INTERCONNECTED CUSTOMERS AND 95% CONFIDENCE BOUNDS FOR SELECTED DURATIONS (2024$)

	By Class			ERCOT-Wide	Confidence Bounds	
Duration	Res.	Small C&I	M/L C&I	Average	Lower	Upper
1 hour	$3,964	$666,907	$60,974	$61,394	$43,873	$88,214
2 hours	$3,303	$407,229	$38,339	$38,463	$32,875	$45,425
4 hours	$2,039	$253,454	$24,394	$24,230	$20,775	$28,527
8 hours	$1,407	$195,591	$19,991	$19,285	$16,324	$22,991
16 hours	$1,091	$239,280	$29,267	$26,033	$19,922	$35,668

Source: Residential population-weighted WTP model and C&I population-weighted cost model, the latter excluding transmission-interconnected customers. Estimates shown for a weekday afternoon outage without warning.

These tables show that, when transmission-interconnected customers are excluded, VOLL per event decreases for the remaining medium/large C&I customers. However, because this is accompanied by a reduction in the average usage for the medium/large C&I group, the resulting VOLL per unserved MWh estimate ends up higher than that for the full sample of medium/large C&I customers. Overall, the ERCOT-wide VOLL per unserved MWh for a 1-hour duration is $60,974, approximately $26,000 higher than the primary case presented in this report. As long as load-shedding practices remain the same, this correspondingly higher VOLL may be more relevant when evaluating the benefits of adding generation or transmission that reduce the risks of shortages and load shedding.[31]

[31] The literature review completed as part of the Brattle Part I study did not identify any analyses that considered the impact of transmission-interconnected customers.

V. Conclusions

We estimated VOLLs for residential small C&I, and medium/large C&I customer classes in the ERCOT Region using well-established econometric techniques. Once we obtained estimates using our survey samples, we reweighted them to match the ERCOT-wide population and firm characteristics. For the residential class, we accounted for the following characteristics using data from the US Census: (a) whether the customer's use is above or below that of the median residential customer; (b) whether the customer's income is above or below the statewide median; (c) whether the customer lives in an urban area; (d) whether someone in the respondent's household has health needs that require access to power; and (e) whether they work from home daily. For C&I class, we accounted for industry, facility employment, and rural/urban location using County Business Pattern data from the US Census Bureau.

We estimated population-weighted VOLLs expressed in terms of dollars per outage event ($). We also expressed these VOLLs in terms of dollars per unserved MWh, using the average hourly MWh values for the residential, small C&I, and medium and large C&I classes according to the CBCI data. Key takeaways from the study include the following:

1. While we surveyed customers to elicit the differences in their VOLLs in summer versus winter seasons, as well as morning, afternoon, and evening times, we did not identify substantive differences in their VOLLs along these dimensions.
2. We found that advance warning lowered customers' VOLLs for all classes.
3. Representative estimates presented in the report are for a weekday afternoon outage without advance warning, irrespective of the season. Table 17 presents these values by customer class as well as on an ERCOT Region-wide basis, calculated using the class load shares. For an outage with one-hour duration, the ERCOT-wide value is estimated to be $35,685.

TABLE 17: VOLL PER UNSERVED MWH BY CUSTOMER CLASS AND DURATION (2024$/MWH)

		Commercial & Industrial		**ERCOT-**
	Residential	Small	Medium/Large	**Wide**
1 hour	$3,964	$666,907	$22,721	**$35,685**
2 hours	$3,303	$407,229	$12,783	**$21,326**
4 hours	$2,039	$253,454	$8,064	**$13,340**
8 hours	$1,407	$195,591	$6,507	**$10,435**
16 hours	$1,091	$239,280	$9,463	**$13,581**

Source: Residential population-weighted WTP model and C&I population-weighted cost model. Estimates shown for a weekday afternoon outage without warning.

4. In comparison to the interim VOLL estimates developed for ERCOT during Part I of the study, the ERCOT-wide estimate developed in this study is higher. For ease of reference, Table 18 presents the interim VOLL calculations and the two options that were previously presented to the Commission representing an ERCOT-wide **one-hour outage**. Comparing Tables 17 and 18 shows that the 1-hour VOLL estimate in dollars per unserved MWh from the present study is larger than the interim VOLL estimate by approximately $10,000 ($35,685 versus $24,693). However, the interim VOLL estimate is within the 95% confidence interval of the present study (ranging from approximately $25,000 to $53,000).

TABLE 18: BRATTLE STUDY PART I ERCOT-WIDE INTERIM VOLL ESTIMATES

Cost per Unserved Megawatt Hour (MWh)	30 Minute Outage	1 Hour Outage	8 Hour Outage
Residential	$9,283	$5,122	$1,817
Small C&I	$167,315	$102,490	$81,172
Medium / Large C&I	$130,797	$78,824	$53,954
Region-wide Option 1	$99,052	$60,093	$44,321
Region-wide Option 2a (cap using all studies)		$24,693	
Region-wide Option 2b (cap using all US studies)		$26,245	
Region-wide Option 2c (cap using all US that test a 1-hour duration outage)		$52,259	

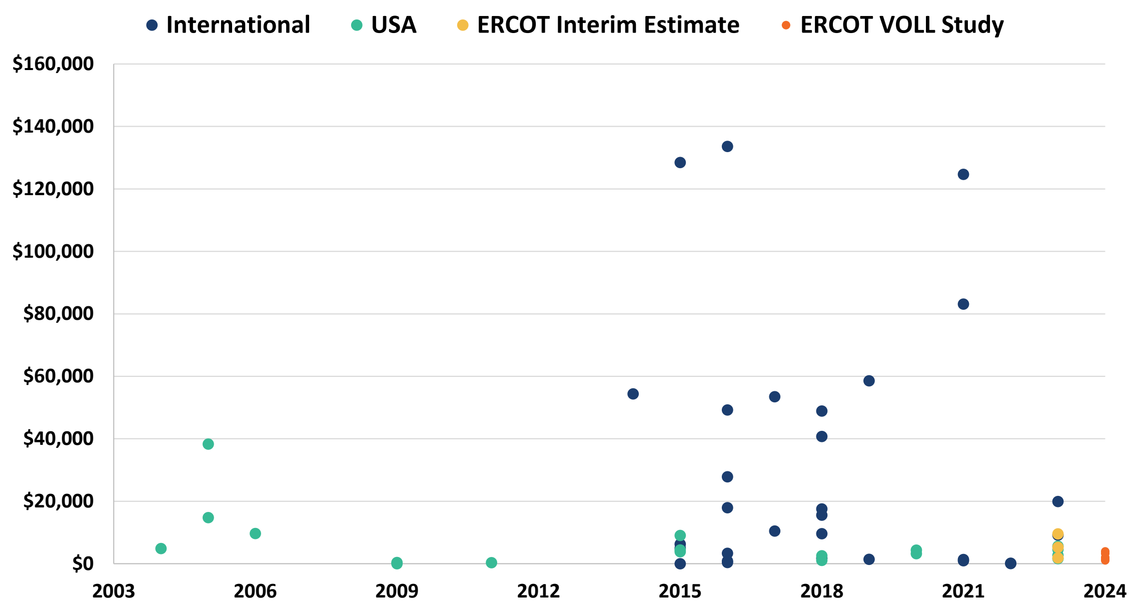
Source: ERCOT PUC filing, December 21, 2023.

5. Comparison of VOLL estimates for individual customer classes from this study to the interim VOLL estimates reveal that, while residential values are generally comparable, C&I values are drastically different. There are several potential reasons for this. First, the interim estimate was fundamentally driven by the underlying response function from the US metadata from the LBNL study, though we made adjustments to reflect ERCOT usage characteristics. Second,

VOLLs per unserved MWh are very sensitive to the assumptions about the level of unserved load for a given outage duration. This study relied on the ERCOT-provided customer usage data to develop the average unserved load assumptions, whereas the interim VOLL estimates relied upon the more generic EIA 861 consumption estimates for Texas and customer class definitions that may not align perfectly with those used in this study.

6. Based on the literature reviewed in Part I of this study,[32] ERCOT residential VOLLs are on the lower side of the distribution (Figure 14), whereas ERCOT medium/large C&I estimates are comparable to those from other VOLL studies (Figure 16). ERCOT small C&I VOLL estimates, however, are very large and at the high end of the estimates from other studies (Figure 15). The latter is mainly driven by moderate levels of VOLLs per event estimated for the small C&I class, resulting in a very large VOLL per unserved MWh given the small size of the customers in this class.

FIGURE 14: COMPARISON OF ERCOT RESIDENTIAL VOLL ESTIMATES TO LITERATURE (2024$/UNSERVED MWH)



Note: An outlier of $272,009/MWh was excluded from the International cohort for presentation purposes.

[32] Brattle Part I Study.

FIGURE 15: COMPARISON OF ERCOT SMALL C&I VOLL ESTIMATES TO LITERATURE (2024$/UNSERVED MWH)

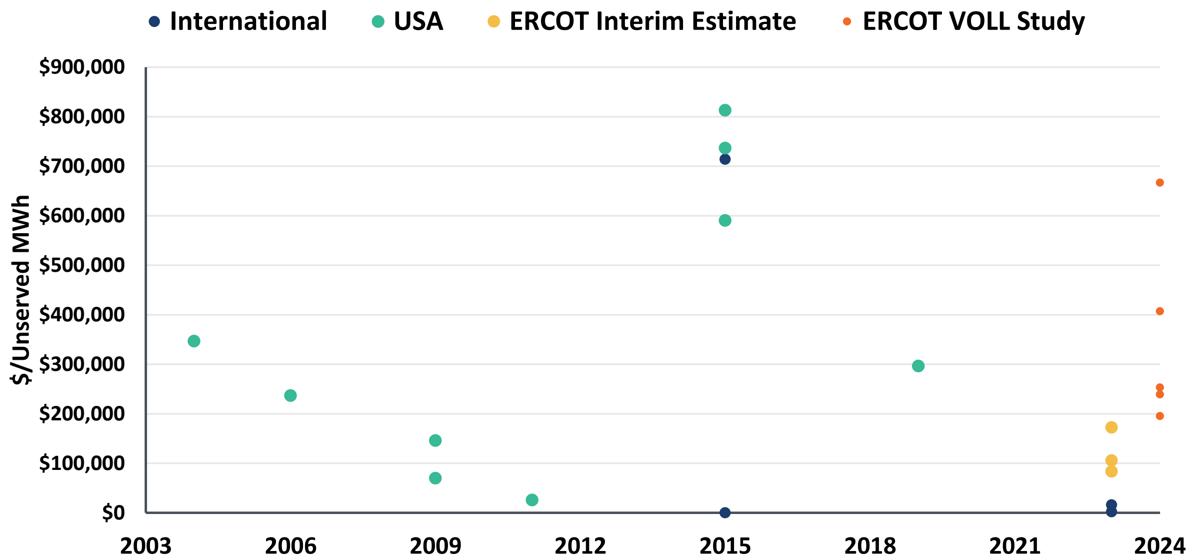
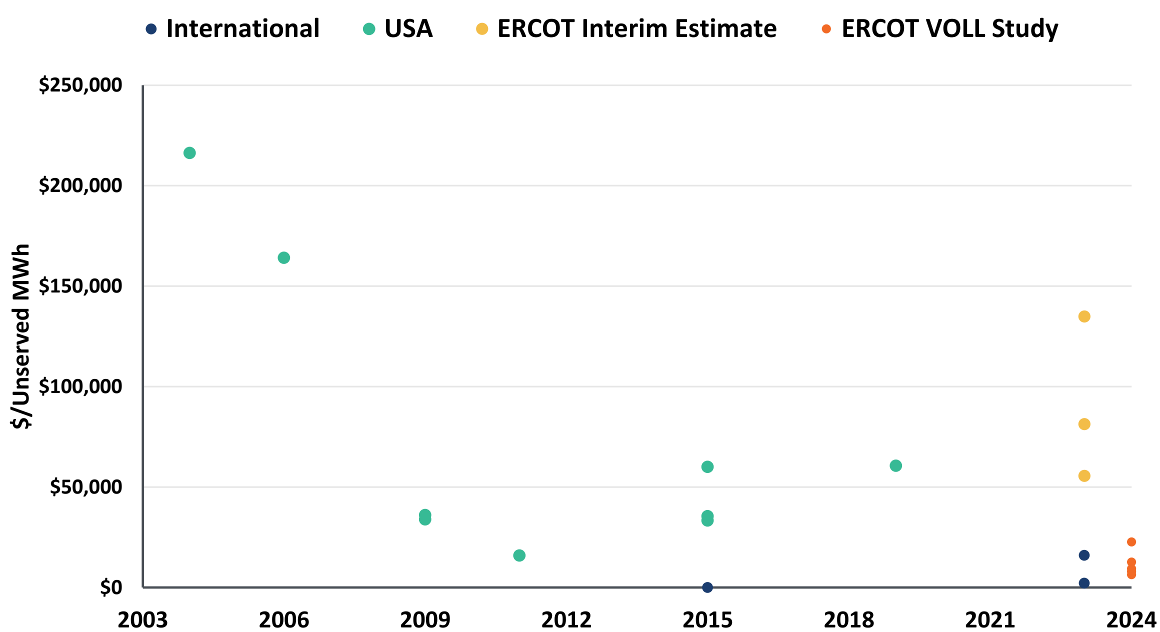


FIGURE 16: COMPARISON OF ERCOT MEDIUM/LARGE C&I VOLL ESTIMATES TO LITERATURE (2024$/UNSERVED MWH)



Note: An outlier of $713,807 was excluded from the International cohort for presentation purposes.

Appendix A: Survey Instruments

Electric Reliability Cost Survey

Residential Customers

Thank you for participating in this important survey. At the direction of the Public Utility Commission of Texas, the Electric Reliability Council of Texas (ERCOT) is conducting this survey to study the costs customers may experience from power interruptions.

This survey is voluntary and takes approximately **10 minutes** to complete. Your answers will be kept confidential and will not be associated with your name, company's name, utility account, or address.

By continuing, you consent to providing your survey responses to the survey administrator, PlanBeyond Research, for use in this study. Your email address, which was used to invite you to take the survey, will be associated with your responses but kept confidential. If you do not wish to participate, you may close the survey at any time.

Q0. To see whether you qualify to participate in the study, we would like to gather some information on your household characteristics.

Q1. Which of the following best describes [DISPLAY “FACILITY_ADDRESS” if “FACILITY_ADDRESS” IS “*”, ELSE DISPLAY “the address listed in the invitation email”]?

- ◯ Primary residence
- ◯ Secondary residence or residential rental property [TERM]
- ◯ Business / Commercial site [TERM]
- ◯ Other [TERM]
- ◯ I’m not sure [TERM]

Q2. What is your age?

- ◯ Younger than 18 years [TERM]
- ◯ 18 – 24 years
- ◯ 25 – 29 years
- ◯ 30 – 39 years
- ◯ 40 – 49 years
- ◯ 50 – 59 years
- ◯ 60 – 69 years
- ◯ 70 years or older
- ◯ Prefer not to answer [TERM]

Q3. How long have you lived in your current residence?

- ◯ Less than 1 year [TERM]
- ◯ 1-2 years
- ◯ 3-5 years
- ◯ 6-10 years
- ◯ 10 or more years

Q4. Which of the following best describes your role in paying your household's electricity bills?

- ◯ I am the primary person responsible for paying my household's electricity bill
- ◯ I share responsibility for paying my household's electricity bill
- ◯ I am not at all responsible for paying my household's electricity bill [TERM]

Q5. Are you currently employed by the PUCT, ERCOT, or any retail electric provider or distributor?

- ◯ Yes [TERM]
- ◯ No

[DISPLAY IF RESPONDENT DOES NOT QUALIFY] Thank you for your time and interest in taking this survey. Unfortunately, we have already received enough responses from customers with similar household characteristics. You may now close the survey.]

Q6. Including yourself, how many people live in your household?

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

Q7. Which of the following best describes your **primary residence**?

- ◯ Rented
- ◯ Owned by you or someone in your household
- ◯ Neither

Q8. What type of home best describes your **primary residence**?

- ◯ Single-family detached
- ◯ Townhome/townhouse (single-family attached to two or more houses)
- ◯ Duplex (two-family building)
- ◯ Small apartment or condominium building (3 to 9 units)
- ◯ Medium apartment or condominium building (10-49 units)
- ◯ Large apartment or condominium building (50 or more units)
- ◯ A mobile or manufactured home
- ◯ Other: ______________________________

Q9. 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: wages, salaries, tips, commissions, or bonuses; business or investment income; social security, unemployment benefits, or welfare payments; child support or alimony; etc.

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

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

◯ Yes
◯ No
◯ Don't know

Q11. We're now going to ask you a series of questions about power outages. Please consider a power outage to mean the **COMPLETE** loss of electricity to your residence and community. During this outage, items in your home that run on electricity would not work unless you have a form of backup electric power.

If you have a backup system, assume that it is at full capacity at the start of the outage. If you have solar panels installed without a battery storage system, your household will still experience the power outage and your solar system will not feed electricity into the grid.

Q12A. Over the past 12 months, have you experienced any power outages at your primary residence?

◯ Yes
◯ No
◯ Don't know

*Q12*B. [DISPLAY IF Q12A = "Yes"] How long did those power outages last? (Select all that apply)

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

Q13. What is the longest power outage that you have experienced **<u>in the last five years</u>**?

◯ 5 minutes or less
◯ Greater than 5 minutes to less than 4 hours
◯ 4 hours to less than 24 hours
◯ 24 hours to less than 3 days
◯ 3 days or more
◯ I have not experienced a power outage in the last 5 years
◯ Don't know

Q14. How often do you or anyone in your household work from home to earn their income **and** would be impacted by an outage?

◯ Every day
◯ A few days per week
◯ A few times per month
◯ A few times per year
◯ Never

Q15. Does anyone in your household have any health conditions that could be worsened by a power outage? For example, someone might need an oxygen machine powered by electricity or take medication that requires refrigeration.

◯ Yes
◯ No
◯ Don't know

Q16. Please estimate how long a power outage can last at your home before the costs and inconvenience become significant. Some impacts to consider include the loss of income or online education, the inability to prepare meals at home, and replacing spoiled food.

◯ 5 minutes or less
◯ Greater than 5 minutes to less than 2 hours
◯ 2 hours to less than 8 hours
◯ 8 hours to less than 16 hours
◯ 16 hours to less than 24 hours
◯ 24 hours to less than 3 days
◯ 3 days or more
◯ Don't know

Q17. If your electric utility notified your household of the start time and duration of an upcoming power outage before it occurred, how much advance warning would you need to **significantly** reduce the costs and inconvenience caused by a power outage? Please give your best estimate.

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

In the following sections, we present [IF 1_season, show “two”; IF 2_season, show “four”] possible scenarios, each involving a different electric power outage situation. For each scenario, we ask how your household would respond to the outage and for you to estimate any extra expenses your household would experience due to the outage. We will also ask you how much you and your household would be willing to pay to avoid this hypothetical outage.

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

Scenario 1

Without any warning, on a typical [**SEASON**] [**DAYTYPE**], a complete power outage occurs at **[START]**. Your household's electricity is fully restored after **[DURATION]**.

S1. On a scale from 1 to 5, how disruptive would this power outage be to your household, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

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

S2. How much do you think it would cost your household to adjust to this outage? This could include lost wages, transportation or lodging to relocate, dining out, replacing spoiled food, or operating a backup generator.

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

S3. Suppose that a company that is not your retail electric provider developed a new service that can instantaneously deliver temporary backup power to your household during this outage. With the purchase of this backup service, you would not experience the outage or need to take any additional actions. The cost of the service is a one-time fee that covers your household's normal electric usage during this single outage.

Would your household purchase the backup service to avoid this **single outage** for a **one-time fee** of ***[RANDOMIZE SHOWING COSTLOWER OR COSTUPPER]?***

- ◯ Yes
- ◯ No

S3A. ***[DISPLAY IF (S3 SHOWED COSTLOWER & S3 = "YES") OR (S3 SHOWED COSTUPPER & S3 = "NO")]*** Would your household purchase the backup service

to avoid this outage for a **one-time fee** of $*[IF S3 SHOWED COSTLOWER SHOW COSTUPPER; IF S3 SHOWED COSTUPPER SHOW COSTLOWER]*

◯ Yes
◯ No

S4. Suppose that your utility notified your household of the start time and duration of the outage **before it occurred**. Think about how being able to prepare for the outage might change your circumstances.

Would your household purchase the backup service to avoid this **single outage** for a **one-time fee** of *[RANDOMIZE SHOWING COSTWARNINGLOWER OR COSTWARNINGUPPER]?*

◯ Yes
◯ No

S4A. *[DISPLAY IF (A4 SHOWED COSTWARNINGLOWER & S4 = "YES") OR (S4 SHOWED COSTWARNINGUPPER & S4 = "NO")]* Would your household purchase the backup service to avoid this outage for a **one-time fee** of $*[IF S4 SHOWED COSTWARNINGLOWER SHOW COSTWARNINGUPPER; IF S4 SHOWED COSTWARNINGUPPER SHOW COSTWARNINGLOWER]*

◯ Yes
◯ No

Scenario 2

Without any warning, on a typical [**SEASON**] [**DAYTYPE**], a complete power outage occurs at **[START]**. Your household's electricity is fully restored after **[DURATION]**.

S1. On a scale from 1 to 5, how disruptive would this power outage be to your household, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

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

S2. How much do you think it would cost your household in additional expenses that you would **otherwise not have to pay** to adjust to this outage? This could include lost wages, transportation or lodging to relocate, dining out, replacing spoiled food, or operating a backup generator.

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

S3. Suppose that a company that is not your retail electric provider developed a new service that can instantaneously deliver temporary backup power to your household during this outage. With the purchase of this backup service, you would not experience the outage or need to take any additional actions. The cost of the service is a one-time fee that covers your household's normal electric usage during this single outage.

Would your household purchase the backup service to avoid this **single outage** for a **one-time fee** of ***[RANDOMIZE SHOWING COSTLOWER OR COSTUPPER]?***

- ◯ Yes
- ◯ No

S3A. ***[DISPLAY IF (A3 SHOWED COSTLOWER & S3 = "YES") OR (S3 SHOWED COSTUPPER & S3 = "NO")]*** Would your household purchase the backup service

to avoid this outage for a **one-time fee** of $*[IF S3 SHOWED COSTLOWER SHOW COSTUPPER; IF S3 SHOWED COSTUPPER SHOW COSTLOWER]*

◯ Yes
◯ No

S4. Suppose that your utility notified your household of the start time and duration of the outage **before it occurred**. Think about how being able to prepare for the outage might change your circumstances.

Would your household purchase the backup service to avoid this **single outage** for a **one-time fee** of *[RANDOMIZE SHOWING COSTWARNINGLOWER OR COSTWARNINGUPPER]?*

◯ Yes
◯ No

S4A. *[DISPLAY IF (S4 SHOWED COSTWARNINGLOWER & S4 = "YES") OR (S4 SHOWED COSTWARNINGUPPER & S4 = "NO")]* Would your household purchase the backup service to avoid this outage for a **one-time fee** of $*[IF S4 SHOWED COSTWARNINGLOWER SHOW COSTWARNINGUPPER; IF S4 SHOWED COSTWARNINGUPPER SHOW COSTWARNINGLOWER]*

◯ Yes
◯ No

[IF RESPONDENT IS 1_SEASON, MARK AS COMPLETE AND DISPLAY MESSAGE]
Thank you for your time and interest in taking this survey. Your responses have been recorded. You can now close your browser.

Scenario 3

Without any warning, on a typical [**SEASON**] [**DAYTYPE**], a complete power outage occurs at **[START]**. Your household's electricity is fully restored after **[DURATION]**.

S1. On a scale from 1 to 5, how disruptive would this power outage be to your household, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

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

S2. How much do you think it would cost your household in additional expenses that you would **otherwise not have to pay** to adjust to this outage? This could include lost wages, transportation or lodging to relocate, dining out, replacing spoiled food, or operating a backup generator.

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

S3. Suppose that a company that is not your retail electric provider developed a new service that can instantaneously deliver temporary backup power to your household during this outage. With the purchase of this backup service, you would not experience the outage or need to take any additional actions. The cost of the service is a one-time fee that covers your household's normal electric usage during this single outage.

Would your household purchase the backup service to avoid this **single outage** for a **one-time fee** of ***[RANDOMIZE SHOWING COSTLOWER OR COSTUPPER]?***

- ◯ Yes
- ◯ No

S3A. ***[DISPLAY IF (S3 SHOWED COSTLOWER & S3 = "YES") OR (S3 SHOWED COSTUPPER & S3 = "NO")]*** Would you purchase the backup service to avoid this outage for a **one-time fee** of $***[IF S3 SHOWED COSTLOWER SHOW COSTUPPER; IF S3 SHOWED COSTUPPER SHOW COSTLOWER]***

- ◯ Yes
- ◯ No

S4. Suppose that your utility notified your household of the start time and duration of the outage **before it occurred**. Think about how being able to prepare for the outage might change your circumstances.

Would you purchase the backup service to avoid this **single outage** for a **one-time fee** of ***[RANDOMIZE SHOWING COSTWARNINGLOWER OR COSTWARNINGUPPER]?***

- ◯ Yes
- ◯ No

S4A. ***[DISPLAY IF (S4 SHOWED COSTWARNINGLOWER & S4 = "YES") OR (S4 SHOWED COSTWARNINGUPPER & S4 = "NO")]*** Would your household purchase the backup service to avoid this outage for a **one-time fee** of $***[IF S4 SHOWED COSTWARNINGLOWER SHOW COSTWARNINGUPPER; IF S4 SHOWED COSTWARNINGUPPER SHOW COSTLWARNINGOWER]***

- ◯ Yes
- ◯ No

Scenario 4

Without any warning, on a typical [**SEASON**] [**DAYTYPE**], a complete power outage occurs at **[START]**. Your household's electricity is fully restored after **[DURATION]**.

S1. On a scale from 1 to 5, how disruptive would this power outage be to your household, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

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

S2. How much do you think it would cost your household in additional expenses that you would **otherwise not have to pay** to adjust to this outage? This could include lost wages, transportation or lodging to relocate, dining out, replacing spoiled food, or operating a backup generator.

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

S3. Suppose that a company that is not your retail electric provider developed a new service that can instantaneously deliver temporary backup power to your household during this outage. With the purchase of this backup service, you would not experience the outage or need to take any additional actions. The cost of the service is a one-time fee that covers your household's normal electric usage during this single outage.

Would your household purchase the backup service to avoid this **single outage** for a **one-time fee** of ***[RANDOMIZE SHOWING COSTLOWER OR COSTUPPER]?***

- ◯ Yes
- ◯ No

S3A. ***[DISPLAY IF (S3 SHOWED COSTLOWER & S3 = "YES") OR (S3 SHOWED COSTUPPER & S3 = "NO")]*** Would your household purchase the backup service

to avoid this outage for a **one-time fee** of $*[IF S3 SHOWED COSTLOWER SHOW COSTUPPER; IF S3 SHOWED COSTUPPER SHOW COSTLOWER]*

- ◯ Yes
- ◯ No

S4. Suppose that your utility notified your household of the start time and duration of the outage **before it occurred**. Think about how being able to prepare for the outage might change your circumstances.

Would your household purchase the backup service to avoid this **single outage** for a **one-time fee** of *[RANDOMIZE SHOWING COSTWARNINGLOWER OR COSTWARNINGUPPER]?*

- ◯ Yes
- ◯ No

S4A. ***[DISPLAY IF (S4 SHOWED COSTWARNINGLOWER & S4 = "YES") OR (S4 SHOWED COSTWARNINGUPPER & S4 = "NO")]*** Would your household purchase the backup service to avoid this outage for a **one-time fee** of $***[IF S4 SHOWED COSTWARNINGLOWER SHOW COSTWARNINGUPPER; IF S4 SHOWED COSTWARNINGUPPER SHOW COSTWARNINGLOWER]***

- ◯ Yes
- ◯ No

[**DISPLAY MESSAGE]** Thank you for your time and interest in taking this survey. Your responses have been recorded. You can now close your browser.

Electric Reliability Cost Survey

Commercial Customers

Thank you for participating in this important survey. At the direction of the Public Utility Commission of Texas, the Electric Reliability Council of Texas (ERCOT) is conducting this survey to study the costs customers may experience from power interruptions.

This survey is voluntary and takes approximately **20-30 minutes** to complete. Your answers will be kept confidential and will not be associated with your name, company's name, utility account, or address.

By continuing, you consent to providing your survey responses to the survey administrator, PlanBeyond Research, for use in this study. Your email address, which was used to invite you to take the survey, will be associated with your responses but kept confidential. If you do not wish to participate, you may close the survey at any time.

Q0. To see whether you qualify to participate in the study, we would like to gather some information on your business characteristics.

Q1. Which of the following best describes [DISPLAY “FACILITY_ADDRESS” if “FACILITY_ADDRESS” IS “*”, ELSE DISPLAY “the address listed in the invitation email”]?

- ◯ Business / Commercial / Industrial site
- ◯ Residential property [TERM]
- ◯ Other [TERM]
- ◯ I’m not sure [TERM]

Q2. How long has your business been in operation?

- ◯ Less than 1 year [TERM]
- ◯ 1 year to less than 2 years
- ◯ 2 years to less than 5 years
- ◯ 5 years to less than 10 years
- ◯ 10 or more years

Q3. Which of the following best describes your role in monitoring your organization’s electricity usage and costs at [DISPLAY “FACILITY_ADDRESS” if “FACILITY_ADDRESS” IS “*”, ELSE DISPLAY “the address listed in the invitation email”]?

- ◯ I regularly monitor my organization’s electricity usage and costs at this address
- ◯ I do not monitor my organization’s electricity usage and costs at this address

[DISPLAY IF RESPONDENT DOES NOT QUALIFY] Thank you for your time and interest in taking this survey. Unfortunately, we have already received enough responses from customers with similar business characteristics. You may now close the survey.

Please answer the following questions about your facility located at [DISPLAY “FACILITY_ADDRESS” if “FACILITY_ADDRESS” IS “*”, ELSE DISPLAY “the address listed in the invitation email”] only. Do not answer for other locations or facilities where your organization operates.

Q4. Which of the following sectors best describes this facility?

- ◯ Accommodation and Food Services
- ◯ Administrative and Support Services
- ◯ Agriculture, Forestry, Fishing and Hunting
- ◯ Arts, Entertainment, and Recreation
- ◯ Construction
- ◯ Data Center
- ◯ Educational Services
- ◯ Finance and Insurance
- ◯ Health Care and Social Assistance
- ◯ Management of Companies
- ◯ Manufacturing (excluding refining)
- ◯ Mining

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

Q5. How many employees are currently employed at this facility?

- ◯ Less than 5
- ◯ 5-19
- ◯ 20-49
- ◯ 50-99
- ◯ 100-249
- ◯ 250-499
- ◯ 500-999
- ◯ 1,000 or more

Q6. On a typical day, what percentage of your employees are working remotely?

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

Q7. What is the approximate square footage of your organization's facility?

__________ square feet

- ◯ Don't know

Q8. Which of the following critical load designations, if any, applies to your organization?

◯ Critical load public safety customer (e.g., hospitals, police stations, fire stations, critical water or wastewater facilities)
◯ Critical load industrial customer (e.g., organization where the suspension of electric service will create a dangerous and/or life-threatening condition on premise)
◯ Critical load serving electric generation or co-generation (e.g., gas or pipeline infrastructure)
◯ Critical care residential or chronic condition residential customer
◯ Other critical load designated customer
◯ None of the above

Q9A. Does your facility have some form of **backup** generation that can supply electric to your facility during a power outage?

◯ Yes
◯ No

Q9B. [Display if Q9A="Yes"] What percentage of your electric demand could be supplied by your backup generation equipment? Please provide your best estimate.

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

Q9C. [Display if Q9A="Yes"] How long can your **backup** electrical system operate while the power is out? If the backup generator consumes fuel such as diesel or propane, consider how much is readily available at your facility.

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

We're now going to ask you a series of questions about power outages. Please consider a power outage to mean the **COMPLETE** loss of electricity to your business and community. During this outage, items in your facility that run on electricity would not work unless you have a form of backup electrical power.

If you have a backup system, assume that it is at full capacity at the start of the outage. If you have solar panels installed without a battery storage system, your facility will still experience the power outage and your solar system will not feed electricity into the grid.

Please answer the following questions about your facility located at [DISPLAY "FACILITY_ADDRESS" if "FACILITY_ADDRESS" IS "*", ELSE DISPLAY "the address listed in the invitation email"] only. Do not answer for other locations or facilities where your organization operates.

Q10A. Over the past 12 months, have you experienced any complete power outages at your facility?

- ◯ Yes
- ◯ No

Q10B. [Display if Q10A = "Yes"] How long did those power outages last? (Select all that apply)

- ◯ 5 minutes or less
- ◯ Greater than 5 minutes to less than 2 hours
- ◯ 2 hours to less than 8 hours
- ◯ 8 hours to less than 16 hours
- ◯ 16 hours to less than 24 hours
- ◯ 24 hours to less than 3 days
- ◯ 3 days or more
- ◯ Don't know [EXCLUSIVE]

Q11. What is the longest power outage that you have experienced at your facility in the last five years?

- ◯ 5 minutes or less
- ◯ Greater than 5 minutes to less than 2 hours
- ◯ 2 hours to less than 8 hours
- ◯ 8 hours to less than 16 hours
- ◯ 16 hours to less than 24 hours
- ◯ 24 hours to less than 3 days
- ◯ 3 days or more
- ◯ Don't know

Q12. Please estimate how long a power outage can last at your facility before it has a substantial impact on your operations.

- ◯ 5 minutes or less
- ◯ Greater than 5 minutes to less than 2 hours
- ◯ 2 hours to less than 8 hours
- ◯ 8 hours to less than 16 hours
- ◯ 16 hours to less than 24 hours
- ◯ 24 hours to less than 3 days
- ◯ 3 days or more
- ◯ Don't know

Q13. If your electric utility notified your organization of the start time and duration for an upcoming power outage, how much advance warning is needed to **significantly** reduce the costs and problems caused by a power outage? Please give your best estimate.

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

Q14A. Does your organization own, rent, or operate any additional facilities besides the location at [DISPLAY "FACILITY_ADDRESS" if "FACILITY_ADDRESS" IS "*", ELSE DISPLAY "the address listed in the invitation email"] **?**

- ◯ Yes
- ◯ No

Q14B. [Display if Q14A = "Yes"] Assume that the outage only causes your facility at [DISPLAY "FACILITY_ADDRESS" if "FACILITY_ADDRESS" IS "*", ELSE DISPLAY "the address listed in the invitation email"] to lose power. Would an outage at this location financially impact other sites or facilities used by your organization assuming that those facilities do not experience the outage?

- ◯ Yes
- ◯ No

Q14C. [Display if Q14A = "Yes"] How long could an outage last at [DISPLAY "FACILITY_ADDRESS" if "FACILITY_ADDRESS" IS "*", ELSE DISPLAY "the address listed in the invitation email"] **before** it begins to financially impact other organization's other facilities?

- ◯ Less than 5 minutes
- ◯ 5 minutes to less than 2 hours
- ◯ 2 hours to less than 8 hours
- ◯ 8 hours to less than 24 hours
- ◯ 24 hours to less than 3 days
- ◯ 3 days or more
- ◯ Other (please specify) ____________

In the following section, we present [If 1_season, show “two”; If 2_season, show “four”] possible scenarios, each involving a different electric power outage situation. Assume that for these scenarios the power outages:

- Are local to your facility at [DISPLAY “FACILITY_ADDRESS” if “FACILITY_ADDRESS” IS “*”, ELSE DISPLAY “the address listed in the invitation email”]
- [Display if Q6 does not equal 0%] Do not impact your employees’ ability to work remotely
- [Display if Q14A = “Yes”] Do not impact the other locations mentioned previously

For the first scenario, we will walk you through different ways that the outage may affect your business to estimate its financial implications. **We will only ask for this level of detail in this first scenario**. For the others, we will ask for the total financial impact on your business.

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

Scenario 1

Season	Day of Week	Start Time	Duration
[1_Season]	[1_DayType]	[1_Start]	[1_Duration]

[Note: Program table to be visible throughout the scenario questions. Show at the top of the page, but do not freeze in place]

Without any warning, on a typical **[1_Season] [1_DayType]**, a complete power outage occurs at **[1_Start]**. Assume that this outage is:

- Local to your facility at [DISPLAY "FACILITY_ADDRESS" if "FACILITY_ADDRESS" IS "*", ELSE DISPLAY "the address listed in the invitation email"]
- [Display if Q6 != 0%] Does not impact your employees' ability to work remotely
- [Display if Q14A = "Yes"] Does not impact the other locations mentioned previously.

Your facility's electricity is fully restored after **[1_Duration]**.

S1**.** On a scale from 1 to 5, how disruptive would this power outage be to your organization, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

◯ 1 – Not disruptive
◯ 2
◯ 3
◯ 4
◯ 5 – Very disruptive

S2A. Would your operations or services typically stop or slow down as a result of this power outage?

◯ Yes
◯ No

S3. What is the approximate dollar value of the operations or services that typically would be lost, at least temporarily, during the power outage and any impacted period after the power outage? Please make your best estimate.

$ __________ value of lost work or services

S4. [Display if S3 IS NOT = 0] What percentage of the operations or services lost would typically be made up, either at this facility at [DISPLAY "FACILITY_ADDRESS" if "FACILITY_ADDRESS" IS "*", ELSE DISPLAY "the address listed in the invitation email"] after the power outage, or by another facility operated by your organization?

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

[Assign S4 as the midpoint of the selected range: If the respondent chooses "1-25%" then S4 = 13%; "26-50%" = 38%, etc. If S4 = 0% or 100%, store that direct value.]

S5A. Would there be any **incremental or additional labor costs** associated with this power outage, such as salaries and wages for staff needed to deal with any **outage-related issues** or overtime pay to make up for lost operations or services?

◯ Yes
◯ No

S5B. [Display if S5A = "Yes"] Please estimate the value for each of the following.

$ __________ overtime/extra shifts to make up lost output [S5B_1]
$ __________ extra labor costs to restart activities [S5B_2]
$ __________ other labor-related costs [S5B_3]

[Display if S5A = "Yes" AND S5B_1 AND S5B_2 AND S5B_3 = 0] You mentioned there would be labor costs associated with the outage. Please enter a value that represents the labor costs incurred.

S6A. Would there be any **damage costs** associated with this power outage, such as damage to equipment, material spoilage, or costs to dispose of hazardous materials?

◯ Yes
◯ No

S6B. [Display if S6A = "Yes"] Please estimate the value for each of the following.

$ __________ damage to equipment [S6B_1]
$ __________ damage/spoilage to materials [S6B_2]
$ __________ cost of disposing hazardous materials [S6B_3]

[Display if S6A = "Yes" AND S6B_1 AND S6B_2 AND S6B_3 = 0] You mentioned there would be damage costs associated with the outage. Please enter a value that represents the labor costs incurred.

S7A. Would there be any other **material or fuel costs** associated with this power outage, such as fuel to run a backup generator?

◯ Yes
◯ No

S7B. [Display if S7A = “Yes”] Please estimate any other materials or fuel costs.

$ __________ other materials [S7B_1]
$ __________ fuel to run a backup generator [S7B_2]

[Display if S7A = "Yes" AND S7B_1 AND S7B_2 AND S7B_3 = 0] You mentioned there would be material or fuel costs associated with the outage. Please enter a value that represents the labor costs incurred.

S8A. Would there be **any other tangible costs** associated with this power outage, such as extra restart costs?

◯ Yes
◯ No

S8B. [Display if S8A = “Yes”] Please estimate the other costs associated with this power outage.

$ __________ other tangible costs

[Display if S8A = "Yes" AND S8B = 0] You mentioned there would be other tangible costs associated with the outage. Please enter a value that represents the other tangible costs incurred.

S9A. In addition to the costs discussed above, some organizations may avoid expenses because of electric outages. Some examples include a lower electricity bill, lower material outlays, and lower personnel costs. Would you experience any **savings** associated with this power outage?

◯ Yes
◯ No

S9B. [Display if S9B = “Yes”] Please estimate the savings for each of the following.

$ __________ savings from wages that were not paid [S9_1]
$ __________ savings from unused raw and intermediate materials (except fuel) or from the scrap value of damaged products or materials [S9_2]
$ __________ savings on your firm’s fuel or electricity bill [S9_3]

[Display if S9A = "Yes" AND S9_1 AND S9_2 AND S9_3 = 0] You mentioned there would be savings associated with the outage. Please enter a value that represents the savings incurred.

S10A. Here is a recap of the costs associated with this outage:

[Display costs determined by respondent in the table below. Save Subtotal and Total values tabulated below in the response data.]

Category	Amount
Operations and Services Lost (minus revenue made up afterwards)	$ [Display S3 * (1-S4)]
Overtime/Extra Shifts to Make Up for Lost Time	$ [Display S5B_1]
Extra Labor Costs to Restart Activities	$ [Display S5B_2]
Other Labor-Related Costs	$ [Display S5B_3]
Damage to Equipment	$ [Display S6B_1]
Damage/Spoilage to Materials	$ [Display S6B_2]
Cost of Disposing Hazardous Materials	$ [Display S6B_3]
Additional Materials	$ [Display S7B_1]
Fuel Cost to Run Backup Generator	$ [Display S7B_2]
Other Tangible Costs	$ [Display S8B_1]
Subtotal:	**$ [Display Subtotal]** [S10A_1]

Savings on Wages	$ [Display S9B_1]
Savings from Unused Materials (Except Fuel)	$ [Display S9B_2]
Savings on Fuel/Electricity	$ [Display S9B_3]

TOTAL:	**$ [Display TOTAL]** [S10A_2]

S10B. Based on your responses to the prior questions, we estimate that your most likely total cost for this outage is **[S10A_2]**. Does this sound correct?

◯ Yes
◯ No

S10C. [Display if S10B = "No"] What do you think your most likely total cost is?

$ __________ total cost [Prepopulate with S10A_2]

S11. Keeping this most likely total in mind for this outage, please estimate the total costs you would incur for a **best-case** (lowest-cost) scenario and the costs for a **worst-case** (highest-cost) scenario.

$ ___________ [S11_1]	**$ [Display S10C]**	**$ ___________** [S11_2]
Lowest Total Outage Cost	Most Likely Total Outage Cost	Highest Total Outage Cost

S12. [Display if Q13 != "Advance warning would not reduce the costs caused by a power outage"] Suppose that your utility notified your organization of the start time and duration of the outage **[INSERT ANSWER TO Q13] before it occurred]**. Think about how being able to prepare for the outage might change circumstances at your facility. If your total cost for this power outage is approximately **[S10C]**, what do you think your total cost would be for the same outage if you received **advance notice**?

$ __________ total cost

Scenario 2

Season	Day of Week	Start Time	Duration
[2_Season]	[2_DayType]	[2_Start]	[2_Duration]

[Note: Program table to be visible throughout the scenario questions. Show at the top of the page, but do not freeze in place]

Without any warning, on a typical **[2_Season] [2_DayType]**, a complete power outage occurs at **[2_Start]**. Assume that this outage is:

- Local to your facility at [DISPLAY "FACILITY_ADDRESS" if "FACILITY_ADDRESS" IS "*", ELSE DISPLAY "the address listed in the invitation email"]
- [Display if Q6 != 0%] Does not impact your employees' ability to work remotely
- [Display if Q14A = "Yes"] Does not impact the other locations mentioned previously.

Your facility's electricity is fully restored after **[2_Duration]**.

S1. On a scale from 1 to 5, how disruptive would this power outage be to your organization, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

◯ 1 – Not disruptive
◯ 2
◯ 3
◯ 4
◯ 5 – Very disruptive

S2. Would your operations or services typically stop or slow down as a result of this power outage?

◯ Yes
◯ No

[Note: The table below summarizes the respondent's total cost estimates to the previous scenario. Recap each scenario's total cost so they can use it as a reference point when answering the following questions. Keep the table visible for all questions in this scenario.]

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

Scenario	Season	Time of Week	Start Time	Duration	Outage Cost
1	[1_Season]	[1_DayType]	[1_Start]	[1_Duration]	**$[1_S10C]**

S10C. What do you think your most likely total cost would be for this outage?

$ __________ total cost

S11. Keeping this most likely total in mind for this outage, please estimate the total costs you would incur for a **best-case** (lowest-cost) scenario and the costs for a **worst-case** (highest-cost) scenario.

$ __________ [S11_1]	**$ [Display S10C]**	**$ __________** [S11_2]
Lowest Total Outage Cost	Most Likely Total Outage Cost	Highest Total Outage Cost

S12. Suppose your utility notified your organization of the power outage **[INSERT ANSWER TO Q13] before it occurred**. Think about how being able to prepare might change circumstances at your facility. If your total cost for this power outage is approximately **[S10C]**, what do you think your total cost would be for this outage if you received **advance notice**?

$ __________ total cost

Scenario 3

Season	Day of Week	Start Time	Duration
[3_Season]	[3_DayType]	[3_Start]	[3_Duration]

[Note: Program table to be visible throughout the scenario questions. Show at the top of the page, but do not freeze in place]

Without any warning, on a typical [3_**Season] [3_DayType**], a complete power outage occurs at **[CStart]**. Assume that this outage is:

- Local to your facility at [DISPLAY "FACILITY_ADDRESS" if "FACILITY_ADDRESS" IS "*", ELSE DISPLAY "the address listed in the invitation email"]
- [Display if Q6 != 0%] Does not impact your employees' ability to work remotely
- [Display if Q14A = "Yes"] Does not impact the other locations mentioned previously.

Your facility's electricity is fully restored after **[3_CDuration]**.

S1. On a scale from 1 to 5, how disruptive would this power outage be to your organization, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

◯ 1 – Not disruptive
◯ 2
◯ 3
◯ 4
◯ 5 – Very disruptive

S2. Would your operations or services typically stop or slow down as a result of this power outage?

◯ Yes
◯ No

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

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

Scenario	Season	Time of Week	Start Time	Duration	Outage Cost
1	[1_Season]	[1_DayType]	[1_Start]	[1_Duration]	**$[1_S10C]**
2	[2_Season]	[2_DayType]	[2_Start]	[2_Duration]	**$[2_S10C]**

S10C. What do you think your most likely total cost would be for this outage?

$ __________ total cost

S11. Keeping this most likely total in mind for this outage, please estimate the total costs you would incur for a **best-case** (lowest-cost) scenario and the costs for a **worst-case** (highest-cost) scenario.

$ ___________ [S11_1	**$ [Display S10C]**	**$ ___________** [S11_2]
Lowest Total Outage Cost	Most Likely Total Outage Cost	Highest Total Outage Cost

S12. Suppose your utility notified your organization of the power outage **[INSERT ANSWER TO Q13] before it occurred**. Think about how being able to prepare might change circumstances at your facility. If your total cost for this power outage is approximately **[S10C]**, what do you think your total cost would be for the same outage if you received **advance notice**?

$ __________ total cost

Scenario 4

Season	Day of Week	Start Time	Duration
[4_Season]	[4_DayType]	[4_Start]	[4_Duration]

[Note: Program table to be visible throughout the scenario questions. Show at the top of the page, but do not freeze in place]

Without any warning, on a typical **[4_Season] [4_DayType]**, a complete power outage occurs at **[4_Start]**. Assume that this outage is:

- Local to your facility at [DISPLAY "FACILITY_ADDRESS" if "FACILITY_ADDRESS" IS "*", ELSE DISPLAY "the address listed in the invitation email"]
- [Display if Q6 != 0%] Does not impact your employees' ability to work remotely
- [Display if Q14A = "Yes"] Does not impact the other locations mentioned previously.

Your facility's electricity is fully restored after **[4_Duration]**.

S1. On a scale from 1 to 5, how disruptive would this power outage be to your organization, with 1 meaning "Not disruptive" and 5 meaning "Very disruptive"?

◯ 1 – Not disruptive
◯ 2
◯ 3
◯ 4
◯ 5 – Very disruptive

S2. Would your operations or services typically stop or slow down as a result of this power outage?

◯ Yes
◯ No

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

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

Scenario	Season	Time of Week	Start Time	Duration	Outage Cost
1	[1_Season]	[1_DayType]	[1_Start]	[1_Duration]	**$[1_S10C]**
2	[2_Season]	[2_DayType]	[2_Start]	[2_Duration]	**$[2_S10C]**

3	[3_Season]	[3_DayType]	[3_Start]	[3_Duration]	**$[3_S10C]**

S10C. What do you think your most likely total cost would be for this outage?

$ __________ total cost

S11. Keeping this most likely total in mind for this outage, please estimate the total costs you would incur for a **best-case** (lowest-cost) scenario and the costs for a **worst-case** (highest-cost) scenario.

$ ___________ [S11_1]	**$ [Display S10C]**	**$ ___________** [S11_2]
Lowest Total Outage Cost	Most Likely Total Outage Cost	Highest Total Outage Cost

S12. Suppose your utility notified your organization of the power outage **[INSERT ANSWER TO Q13] before it occurred**. Think about how being able to prepare might change circumstances at your facility. If your total cost for this power outage is approximately **[S10C]**, what do you think your total cost would be for the same outage if you received **advance notice**?

$ __________ total cost

[Mark respondent as complete. Display the following message.] Thank you for participating in this valuable study. Your responses will be used to better understand how electricity outages affect customers like you.

Appendix B. Technical Appendix

1. Residential Model

Residential customers were asked whether they would be interested in purchasing a service that would provide protection against an outage of a given type for a given price. In this section, we derive a model for these choices.

a. Utility and Willingness-to-Pay

Let u_{ij} be the utility that customer i receives from purchasing protection against outage j. It is a function of the price p_{ij} and outage characteristics X_{ij}, plus an error term ϵ_{ij}. The utility can be written as:

$$u_{ij} = -\alpha p_{ij} + X_{ij}\tilde{\beta} + \epsilon_{ij}. \tag{1}$$

A consumer's willingness-to-pay ("WTP") for a characteristic is the price they would pay such that their utility is unchanged if they pay that price and the receive the characteristic. For example, suppose that X_{ij} is the length of the outage. If the length of the outage avoided increases by 1 hour, then the utility goes up by $\tilde{\beta}$. To keep the utility unchanged, price must increase by $\tilde{\beta}/\alpha$. Define this WTP to be β.

Using the definition of the WTP ($\tilde{\beta} = \alpha\beta$), we can reparameterize the model to be:

$$u_{ij} = -\alpha p_{ij} + \alpha X_{ij}\beta + \epsilon_{ij}. \tag{2}$$

Under this formulation, we estimate the price sensitivity α and the WTP value β directly, rather than first obtaining $\tilde{\beta}$ and taking a ratio.

b. Logit Model

Let the utility from not purchasing the service be:

$$u_{i0} = \epsilon_{i0}.$$

Conceptually, there is no price or characteristics for this "product" and is normalized to be just an error term. The consumer purchases the service if $u_{ij} > u_{i0}$. Because we observe utility only with error, we estimate the probability of purchase:

$$\begin{aligned}\Pr(u_{ij} > u_{i0}) &= \Pr(-\alpha p_{ij} + \alpha X_{ij}\beta + \epsilon_{ij} > \epsilon_{i0}) \\ &= \Pr(-\alpha p_{ij} + \alpha X_{ij}\beta > \epsilon_{i0} - \epsilon_{ij}).\end{aligned}$$

Assume that $\epsilon_{i0} - \epsilon_{ij}$ is a random variable with the extreme value distribution. With Y_{ij} an indicator for the respondent choosing to buy the product, this probability can be written as:

$$\Pr(Y_{ij} = 1 \mid p_{ij}, X_{ij}; \alpha, \beta) = \frac{\exp(-\alpha p_{ij} + \alpha X_{ij}\beta)}{1 + \exp(-\alpha p_{ij} + \alpha X_{ij}\beta)}. \tag{3}$$

This is the logit model and is the standard model for consumer choice in economics.

c. Mixed and Hierarchical Logit Models

The standard logit model assumes that every customer has the same WTP for service characteristics. Suppose instead that these preferences vary across consumers—that is, α and β are replaced by α_i and β_i. Unless the researcher observes many purchase opporunities for similar products by the same customer, it is difficult to estimate these values reliably. To avoid issues arising from possessing only a small number of observations for each respondent i, structure is added to constrain the model.

Mixed Logit. Our *mixed logit* model assumes that $\log(\alpha_i)$ is distributed normally with mean $\log(\alpha)$ and variance σ_α^2. Similarly, β_i is distributed normally with mean β and variance-covariance matrix Σ, where the off-diagonal (*i.e.*, covariance) terms are typically assumed to be 0; this assumes that one parameter for a respondent is not correlated with another. σ_α^2 and Σ are estimated from the data along with α and β.

Hierarchical Bayesian Models. It is possible to add further structure. Let:

$$\alpha_i = Z_i^a \gamma + \zeta_i$$
$$\beta_i = Z_i^b \delta + \eta_i.$$

As with the mixed logit case, we need to specify the distribution for α_i and β_i; here, it is equivalent to specifying the distributions of ζ_i and η_i. We assume that each has mean 0 and variances Σ_γ and Σ_δ respectively.[1] As with the mixed logit case, the off-diagonal terms of these covariance matrices are typically assumed to be 0. While this assumption requires that, conditional on the Z values, two parameters are uncorrelated, they can be related through the Z values.

For example, suppose that annual use is included in Z^a and Z^b. While α_i and β_i are uncorrelated given annual use, they can be correlated unconditionally through each parameter's relationship with annual use. Hence, this hierarchical structure is a way to induce relationships among the parameters. This approach is easier to estimate because it can use differences in characteristics across respondents to estimate the relationships (*e.g.,* respondents with higher use have higher WTP values), rather than estimating correlations directly using within-respondent relationships only (of which there are necessarily fewer points of comparison).

The superscripts indicate that different factors may be used to model each term. After reviewing the data, we included the following factors:

- Predictors for $\log(\alpha)$
  - None (*i.e.*, just an intercept term)
- Predictors for β
  - Whether the customer is above or below median residential usage

1 Assume that Z_i includes a constant term.

- Whether the customer is above or below median statewide income
- Whether the customer lives in a rural or urban county (the latter defined as having a Rural-Urban Classification Code of 3 or lower)
- Whether the customer has health needs that require access to electricity
- Whether the customer works from home daily.

In terms of predictors for the purchase decision, we included:

- Duration bin (momentary, 1 hour, 2-16 hours, 1 day, 3 days)
- Numeric duration for durations between 2 and 16 hours
- Whether there was a warning

In this model, there are four sets of unknown parameters: γ, δ, Σ_γ, and Σ_δ. We can enhance the reliability of the model by placing constraints on the direction and magnitude of these terms using distributional assumptions known as *hyperpriors*. Hyperpriors can prevent incorrectly "signed" coefficients (*e.g.,* preferring higher prices to lower ones) or extreme values from arising from a small number of data points, for example. When there are sufficient data, then the weak constraints imposed by the hyperpriors are dominated by the data themselves. The use of hyperpriors applied to population distributions of coefficients is called *hierarchical Bayesian* modeling.

Calculating the VOLL. For residential customers, the VOLL is equal to the WTP. Hence, we can write the VOLL for residential (R) customer i for product j as:

$$\text{VOLL}^R(X_{ij}, Z_{ij}) \equiv X_{ij}\beta_i(Z_{ij}). \tag{4}$$

This notation makes the dependence of the VOLL on the characteristics of the product and the demographics of the customer explicit.

d. Estimation

The survey instrument uses a one-and-one-half-bound contingent valuation ("OOHB CV") approach. The respondent is asked whether they would buy the service at a particular price. Depending upon the price and the response, the respondent may be asked whether they would purchase the same product at a different price. Table **??** gives the potential combinations of responses and resulting probabilities for the pattern. These probabilities are used to create a standard likelihood function.

2. Commercial & Industrial Model

Commercial & industrial ("C&I") customers were asked open-ended questions about the costs that they would experience for outages with different characteristics. This is a fundamentally different approach to eliciting the VOLL for this customer class. For this reason, the statistical model used to estimate the VOLL is different than that used for the residential

Table 1: Probability of Choice Patterns in OOHB-CV Experimental Designs

First choice	Second choice	Probability
Yes to p_H Yes to p_L	- Yes to p_H	$\Pr(Y = 1 \mid p_H, X; \alpha_i, \beta_i)$
No to p_L No to p_H	- No to p_L	$\Pr(Y = 0 \mid p_L, X; \alpha_i, \beta_i)$
No to p_H Yes to p_L	Yes to p_L No to p_H	$\Pr(Y = 0 \mid p_H, X; \alpha_i, \beta_i) - \Pr(Y = 1 \mid p_L, X; \alpha_i, \beta_i)$

class. Before discussing the statistical model, however, we outline the approach we used to assess the validity of the data.

a. Data Quality Checks

In our review of the C&I survey data, we noticed patterns in some survey responses that suggested that the information provided may not be reliable. To ensure the quality of the data inputs used in our analysis, we developed a methodology to eliminate any responses that likely did not accurately reflect the costs C&I respondents would incur from an outage. We describe our approach below.

Rapid completion time. As an initial validation step, we excluded any respondents who completed the survey too quickly, which indicates a lack of attention or thoughtfulness in their responses. In particular, we removed respondents with completion times that were shorter than two median absolute deviations less than the median. This step removed 4 respondents.

All responses were $0. Some respondents indicated that an outage would have no financial impact in any scenario presented to them in the survey. While it is possible that a business's operations would not be impacted at all by a particular outage, responses to other questions suggested that the participant's business would be impacted to some degree. We retained the all-$0 responses if any of the following conditions held:

- In no scenario did the respondent indicate that the disruptiveness of the outage was above a 2 on a scale from 1 to 5.
- The respondent stated that 100% of the operations or services lost could be made up at that facility or another facility.
- The respondent gave a non-zero answer in at least one scenario as the worst case total cost.

There were 33 respondents who answered zero in all scenarios and failed to meet one of these conditions and were excluded from the survey.

Same non-zero cost in every scenario. Some respondents stated that the cost of an outage would be the same regardless of the duration, start time, day of the week, or season of the outage. There may be reasons why the effect of an outage would be insensitive to these factors, such as if the respondent's facility was closed during all presented scenarios. Alternatively, these responses may reflect a lack of diligence. We retained respondents who gave the same answer in all scenarios if any of the following conditions were met:

- All scenarios had a start time of 7 p.m. and were shorter than 14 hours (*i.e.*, likely occurred outside business hours).
- All scenarios occurred on a weekend and were shorter than 48 hours.
- The sum of costs that may be unaffected by outage duration (such as extra labor required to restart activities) represented the entirety of the total cost estimate.

This assessment resulted in 19 respondents being excluded from the final dataset.

Higher cost for a shorter outage. Our survey instrument presented respondents with outage scenario pairs in which both scenarios had the same start time, season, and weekend/weekday characteristics, but different outage durations. Some respondents provided higher total cost estimates for the shorter scenario, which is contrary to our expectations. We dropped all 662 scenarios (332 pairs) in which a respondent gave a lower total cost for a longer duration.

All the same non-detailed scenario total costs. Every respondent received an initial scenario that asked them to attribute outage costs to various specific categories. We call this the "detailed" scenario. After this scenario, the respondent received additional scenarios in which they were only asked to estimate the total cost of the outage; we call these scenarios "non-detailed." Some respondents gave the same most likely cost estimate in all three non-detailed scenarios. This response pattern suggests that the respondent may have answered the initial scenario carefully, but provided less care when considering the three other scenarios in the survey. We included the respondent only if one of the following conditions were met:

- The three remaining outage scenarios all had a start time of 7 p.m. and were shorter than 14 hours.
- The three remaining outage scenarios all occurred on a weekend and were shorter than 48 hours.

This is analogous to our treatment of respondents who gave the same non-zero answer in all scenarios. This step resulted in an additional 61 commercial respondents being omitted from the final dataset.

Creating sectors. Lastly, we recategorized the respondent's industry into a smaller number of sectors:

- Consumer Industries
  - Accommodation and Food Services
  - Arts, Entertainment, and Recreation
  - Retail Trade
- Finance, Technology, and Professional Services
  - Administrative and Support Services
  - Finance and Insurance
  - Information
  - Management of Companies
  - Professional, Scientific, and Technical Services
  - Real Estate, Rental, and Leasing Services
  - Technology/Software
  - Wholesale Trade
- Health Care and Social Assistance
- Infrastructure
  - Data centers
  - Refineries
  - Transportation
  - Utilities
- Manufacturing (excluding refining)
- Resource Management
  - Agriculture, Forestry, Fishing, and Hunting
  - Construction
  - Mining, Quarrying, and Oil and Gas Extraction
  - Warehousing and Storage
  - Waste Management and Remediation Services
- Other Services
  - Educational Services
  - Other Services (except Public Administration)
  - Public Administration/Government

b. Statistical Model

One feature that is apparent in the responses is that a non-trivial share of customers report experiencing no costs associated with a particular outage. Other customers experience very large costs. Hence, we use a two part model for the distribution of costs C:

$$
\begin{aligned}
F(C \mid X; \delta_0, \delta_+, \sigma) &= \Pr(C > 0 \mid X; \delta_0) \times F(C \mid C > 0, X; \delta_+, \sigma) \\
\Pr(C > 0 \mid X; \delta_0) &= \frac{\exp(X_0 \delta_0)}{1 + \exp(X_0 \delta_0)} \\
\log(C) \mid C > 0, X &\sim \mathrm{N}(X_+ \delta_+, \sigma^2);
\end{aligned}
$$

that is, a logit model is used to determine whether costs are positive and, conditional on being positive, costs are distributed lognormal.

As with the residential model, we allow the coefficients to vary according to respondent characteristics:

$$
\begin{aligned}
\delta_{0i} &= Z_{0i} \gamma_0 + \epsilon_{0i} \\
\delta_{+i} &= Z_{+i} \gamma_+ + \epsilon_{+i} \\
\sigma &= Z_{\sigma i} \gamma_\sigma .
\end{aligned}
$$

See that, while the coefficients themselves are permitted to vary by respondent conditional on Z (*i.e.*, there is an error term ϵ in these equations), the standard deviation of the lognormal distribution is fixed conditional on Z. This is because variance terms are more difficult to identify in these models generally, let alone specific to each respondent. Based on our assessment, we use the following predictors:

- Predictors for δ_{0i} and δ_{+i}
  - Availability of backup power (0%, 1-25%, 26-75%, 76-99%, 100%)
  - Critical load designation
  - Customer class
  - Employee count (less than 5, 5-19, 20-49, 50-249, 250+)
  - Sector
  - Whether the customer is located in a rural or urban county
  - Whether the customer is transmission connected
- Predictors for σ
  - Customer class
  - Sector

For outage characteristics, we used the following:

- Predictors for positive costs

- Duration bin
- Numeric duration for durations between 2 and 16 hours
- Whether there was a warning
- Day type
- An indicator for a momentary outage at 7 a.m. or 7 p.m.
- An indicator for a 1 hour outage at 7 a.m. or 7 p.m.
- An indicator for a 2-16 hour outage at 7 p.m.

- Predictors for positive costs
  - Duration bin
  - Numeric duration for durations between 2 and 16 hours
  - Whether there was a warning

The VOLL is given by:

$$\text{VOLL}^C(X_{ij}, Z_{ij}) = \Pr\left(C > 0 \mid X_{ij}; \delta_0(Z_{0i})\right) \times F\left(C \mid C > 0, X; \delta_+(Z_{+i}), \sigma(Z_{\sigma i})\right). \quad (5)$$

As with the residential case, this formulation makes the relationship between the VOLL and the characteristics of both the outage and the customer explicit.

3. Post-Stratification

In the preceding sections, we derived residential and C&I VOLL values that are a function of outage characteristics and customer characteristics. To calculate the overall VOLL for each customer class, we take an average over the distribution of characteristics in the customer class, yielding a VOLL only as a function of outage characteristics. This approach is called *post-stratification* weighting.

Because the re-weighting occurs at the end (*post*-stratification), rather than during estimation, we avoid the possibility that any given respondent has excessive influence over the model. The modeling approaches used to estimate the customer-level VOLLs above smooth over respondent differences and the weights applied below reflect the actual frequency of each group in the population. In this way, post-stratification yields more stable results than approaches that re-weight observations during model estimation.

Residential. The demographics that we consider for residential customers include:

- Whether the customer's income is above or below the statewide median
- Whether the customer's annual usage is above or below the ERCOT Region median for residential customers
- Whether the customer is located in a rural or urban county (defined as having a Rural-Urban Classification Code of 3 or lower)

We use US Census data to ascertain how many households fall into each combination of these categories.

Note that the VOLL is also a function of whether the customer has health needs that require electricity and whether the customer works from home daily. Because these attributes are not available in the Census data, we calculate the share of customers that have each of these characteristics according to our survey responses within each combination of the characteristics in the list above. When multiplied together, this provides population shares for each attribute.

C&I. The characteristics used for commercial customers include:

- Employee count (less than 5, 5-19, 20-49, 50-249, 250+)
- Sector
- Whether the customer is located in a rural or urban county

We begin by assuming that the other characteristics not available in the County Business Pattern data (availability of backup power, critical load designation, customer class, and transmission connection status) are distributed within these categories as observed in the survey response data. Because we have an ERCOT Region share of customers that are transmission connected, we perform a three-iteration raking procedure to re-weight large transmission-connected customers so as to better align the share of these customers implied by our sample with that found in the CBCI data.

VOLL. Given a characteristic set d and population weight for that set w_d, the VOLL becomes a weighted average for each customer class.

$$\text{VOLL}(X) = \sum_d w_d \text{VOLL}(X, Z_d).$$