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Estimates of the Economic Impacts of Long-Duration, Widespread Power Disruptions in Puerto Rico

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Prepared for the Federal Emergency Management Agency and
U.S. Department of Energy Grid Deployment Office

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Acronyms and Abbreviations

BCA	Benefit-Cost Analysis
BEA	Bureau of Economic Analysis
BUG	Backup Generator
CDF	Customer Damage Function
CIC	Customer Interruption Cost
DOE	Department of Energy
FEMA	Federal Emergency Management Agency
GDP	Gross Domestic Product
GLM	Generalized Linear Model
IBTS	Institute for Building Technology
ICE Calculator	Interruption Cost Estimate Calculator
IRB	Institutional Review Board
IRP	Integrated Resource Planning
LBNL	Lawrence Berkeley National Laboratory
LDWI	Long-Duration and Widespread Interruption
LNR	Large Non-Residential
LNRP	Large Non-Residential and Public
MED	Major Event Day
MISO	Midcontinent Independent System Operator
NDA	Non-Disclosure Agreement
PREB	Puerto Rico Energy Bureau
PREPA	Puerto Rico Electric Power Authority
RIMS	Regional Input-Output Modeling System
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SMNR	Small/Medium Non-Residential
VOLL	Value of Lost Load
WTP	Willingness-To-Pay

Executive Summary

A typical electricity customer in Puerto Rico experienced nearly 27 hours of power interruptions in 2023–with many customers experiencing extremely long duration outages during a single event (i.e., greater than one month). This project involved conducting state-of-the-art surveying to assess the direct costs of power outages occurring across Puerto Rico, developing customer-specific models to estimate future costs over varying outage durations, and comparing these estimates to FEMA's Value of Unit Service for Electricity. We estimate that a territory-wide power outage may cost customers $1, $5 and $29 billion during one-, 14-, and 30-day interruptions, respectively. However, these are lower-bound estimates because our study focused on direct economic costs and, by necessity, did not fully incorporate (1) indirect impacts to the economy; (2) costs to repair or replace damaged utility infrastructure; and (3) the broader societal consequences including increased morbidity- and mortality-related costs. The information contained in this study can be used to estimate the direct economic value of past or proposed investments in power system resilience. We conclude with a discussion of this study's limitations and suggest additional research to improve stakeholder understanding of the impacts of power outages across Puerto Rico.

Electric power is essential for daily life, yet long-duration and widespread power interruptions (LDWIs) are becoming more frequent, posing significant economic and societal risks. Island communities like Puerto Rico face unique challenges due to their geographic isolation and significant vulnerability to both short-term hazards and long-term environmental threats. The territory's recent experiences with hurricanes, including Fiona in 2022 and Tropical Storm Ernesto in 2024, have demonstrated the fragility of its power infrastructure with both storms resulting in LDWIs that left large parts of the territory without electricity for weeks or longer. For example, the typical customer in Puerto Rico experienced 1,572 minutes (or nearly 27 hours) of power interruptions in 2023–significantly above the U.S. national average of 342 minutes (approximately 5.7 hours) (EIA, 2024).[1] These events underscore the urgent need for tailored strategies to strengthen Puerto Rico's power system resilience. Puerto Rico faces significant challenges in assessing its power system reliability and resilience, primarily due to the absence of robust metrics, including local estimates of the value of lost load (VOLL). Existing estimates mainly address short-duration events, typically defined as lasting less than 24 hours, and focus on short-term reliability rather than long-term resilience. Stakeholders in Puerto Rico have adapted VOLL estimates from external studies for planning, but these are not well-suited for LDWIs and do not reflect the unique situation in Puerto Rico. Without accurate VOLL data, stakeholders in Puerto Rico, like other island communities, rely on Federal Emergency Management Agency's (FEMA) standardized Value of Unit Service for Electricity in benefit-cost analyses (BCAs) of proposed investments to enhance resilience. These estimates were developed based on contiguous U.S. utilities with higher reliability performance and use a static per-day, per-capita value of unit service that do not account for the temporal dynamics of LDWIs. As a result, they are limited in their ability to reflect the true costs and challenges of prolonged power disruptions.

[1] The 2023 SAIDI value--collected via EIA-861--reflects a system-wide average of all interruptions experienced by customers across the territory. This SAIDI statistic includes outages originating from the generation system, which is not managed by LUMA Energy.

This project builds upon traditional valuation methodologies to evaluate a wide range of power interruption scenarios, from shorter-duration localized events to LDWIs and across different customer segments. Our approach includes developing realistic power interruption scenarios, evaluating the costs for each customer segment, and generating duration-dependent customer damage functions (CDFs) to estimate the average direct economic costs of interruptions across different outage durations. We designed and administered state-of-the-art customer interruption cost (CIC) surveys targeting electricity customers across Puerto Rico to assess the impact of LDWIs. These surveys focused on customers served by LUMA Energy, the private company responsible for operating and managing the territory's electric power transmission and distribution system.

These surveys collected detailed information on the impacts of power interruptions, including operational disruptions, mitigation strategies, and costs or potential savings due to the interruptions. We worked closely with LUMA Energy and local stakeholders to develop tailored power interruption scenarios that reflect the region's specific challenges. These scenarios varied in duration and geographic scale: the first scenario involved a one-day interruption in a single neighborhood; the second a 14-day interruption affecting an operational region within the territory (see Figure 5 in Section 3.1); and the third a 30-day interruption impacting the entire territory. We categorized LUMA Energy's customers into four segments: residential, small/medium non-residential (SMNR) including businesses in retail, accommodation, and food services; and large non-residential and public sector (LNRP), including industrial customers in manufacturing and agriculture, and municipalities. Table ES-1 contains our survey targets and actual response rates.

Table ES-1.Targeted samples with completed and valid responses by customer segment

Segment	Target responses	Completed responses	Valid responses	% Achieved
Residential	408	637	540	132%
SMNR	197	186	135	69%
LNR	39	31	19	49%
Public	66	54	45	68%
Total	**710**	**908**	**739**	**104%**

The survey results provided valuable insights into the direct economic impacts of power interruptions across different customer segments. Residential CICs are estimated using the willingness-to-pay (WTP) elicitation approach, as a large portion of these costs can be intangible and reflective of inconvenience. In this context, residential customers reported their median WTP to avoid a hypothetical outage was $15, $200 and $600 for one-, 14-, and 30-day interruptions, respectively. Non-residential customers' interruption costs are quantified using the direct cost elicitation method, as their incurred costs and realized savings are tangible and measurable. SMNR customers reported median direct costs of $3,700 for a one-day outage, increasing to $13,000 and $33,000 for the 14-day and 30-day outages, respectively. LNRP customers reported median direct costs of $15,000 for a one-day outage, with costs increasing to $180,000 and $520,000 for 14-day and 30-day outages, respectively. It is important to note, however, that some businesses reported much higher costs. Damage to equipment and material were consistently reported as cost drivers for both the SMNR and LNRP groups for shorter duration outages, while lost revenue, especially for LNRP customers, grew significantly with longer duration outages.

We developed duration-dependent CDFs to estimate the direct economic impacts of power interruptions across various customer segments and outage durations (see Figure ES-1). These models were selected based on their ability to align with the observed cost data, especially the median values, and follow established literature, ensuring that costs consistently increase with the length of the outage (see Table ES-2). In this study, we focused on the relationship between average interruption costs and outage duration, aligning with FEMA's current valuation of unit service of electricity and its application in their BCAs. Future studies could enhance this approach by incorporating additional explanatory variables (e.g., income, electricity consumption). We also compared the CDFs to monthly household income for residential customers and average monthly GDP for non-residential customers (SMNR and LNRP). This comparison revealed the disproportionate economic burden that LDWIs impose on non-residential customers, especially LNRP, whose operational scale significantly contributes to Puerto Rico’s economy.

Figure ES-1. Distribution of the CICs collected from the residential (top), SMNR (middle), and LNRP (bottom) electricity customers with the fitted CDFs

Table ES-2. Equations to estimate CICs by customer class (duration is expressed in hours without electricity)

Segment	Equation
Residential	$(4.78 + (0.030 \times Duration))^2$
SMNR	$e^{8.07+(0.0034 \times Duration)}$
LNRP	$e^{9.82+(0.0051 \times Duration)}$

We also estimated regional CICs for various outage durations using the duration-dependent CDFs, revealing significant economic impacts across Puerto Rico (see Figure ES-2). A one-day outage could cost between $141M in Arecibo and $270M in San Juan, while the cost of a 30-day outage increases to $3.8B in Bayamón and $7.1B in San Juan. The higher costs in San Juan are primarily driven by its large number of customers. Territory-wide power outages may cost customers an estimated $1, $5 and $29 billion during one-, 14-, and 30-day interruptions.

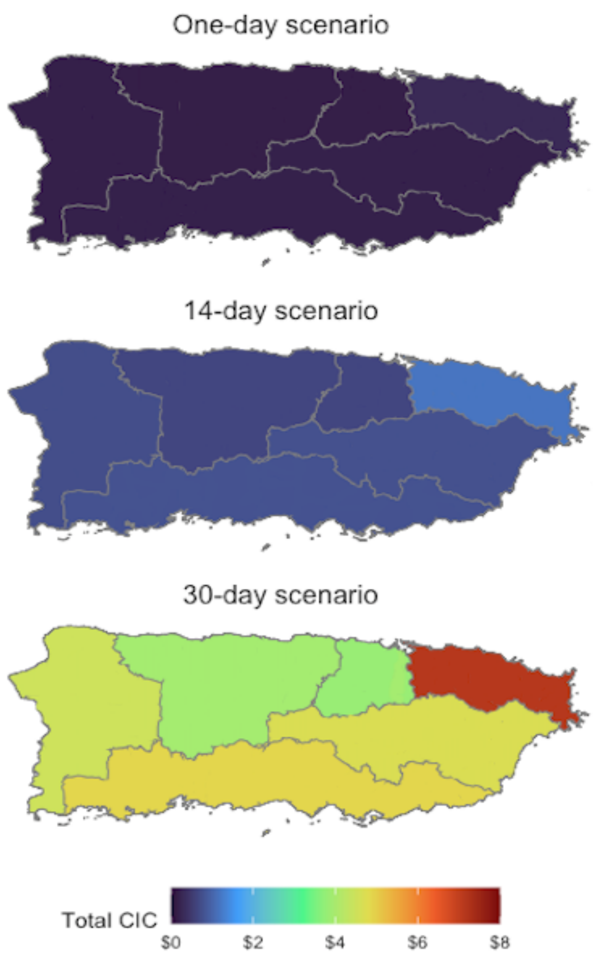

Figure ES-2. Regional total CICs for one-day, 14-day, and 30-day power interruption scenarios ($billions)

We also calculated the value of electricity service in Puerto Rico, arriving at a value of $322 per person for a one-day outage, approximately 1.5 times higher than FEMA's current default value of $214 per person for a one-day outage. The duration-dependent unit service values reflect the higher costs associated with even short-duration outages due to fixed costs, which gradually increase before accelerating beyond a certain threshold. The necessity of a nonlinearity in CDF-based unit service values arises from three key factors. First, the inherent nature of power interruption costs, as captured by the selected CDFs (quadratic polynomial for residential and exponential for non-residential), demands a non-linear representation because these CDFs themselves illustrate that costs escalate gradually for short outages but accelerate sharply with longer durations. Second, the widespread adoption of backup generators (BUGs) in Puerto Rico, reported by over 50% of customers, introduces a non-linear mitigation effect; a linear form would fail to capture the diminishing returns and threshold effects of BUG usage. Third, the observed customer adaptation to prolonged outages, where short interruptions become less impactful due to familiarity but longer outages trigger sharply escalating economic consequences beyond mitigation capabilities, fundamentally requires a non-linear function to accurately model this complex response. This inherently non-linear functional form is further validated by its alignment with constraints ensuring non-negative momentary outage costs, appropriate cost scaling across outage types, consistency with established literature, and the best performance among potential sets of functional forms via goodness-of-fit testing. In contrast, FEMA's linear approach does not capture the non-linear nature of power interruption impacts, leading to an over-estimation for outages lasting between 2 and 26 days and an under-estimate for those exceeding 26 days (see Figure ES-3). Further discussion and recommendations are provided in the accompanying FEMA memorandum.

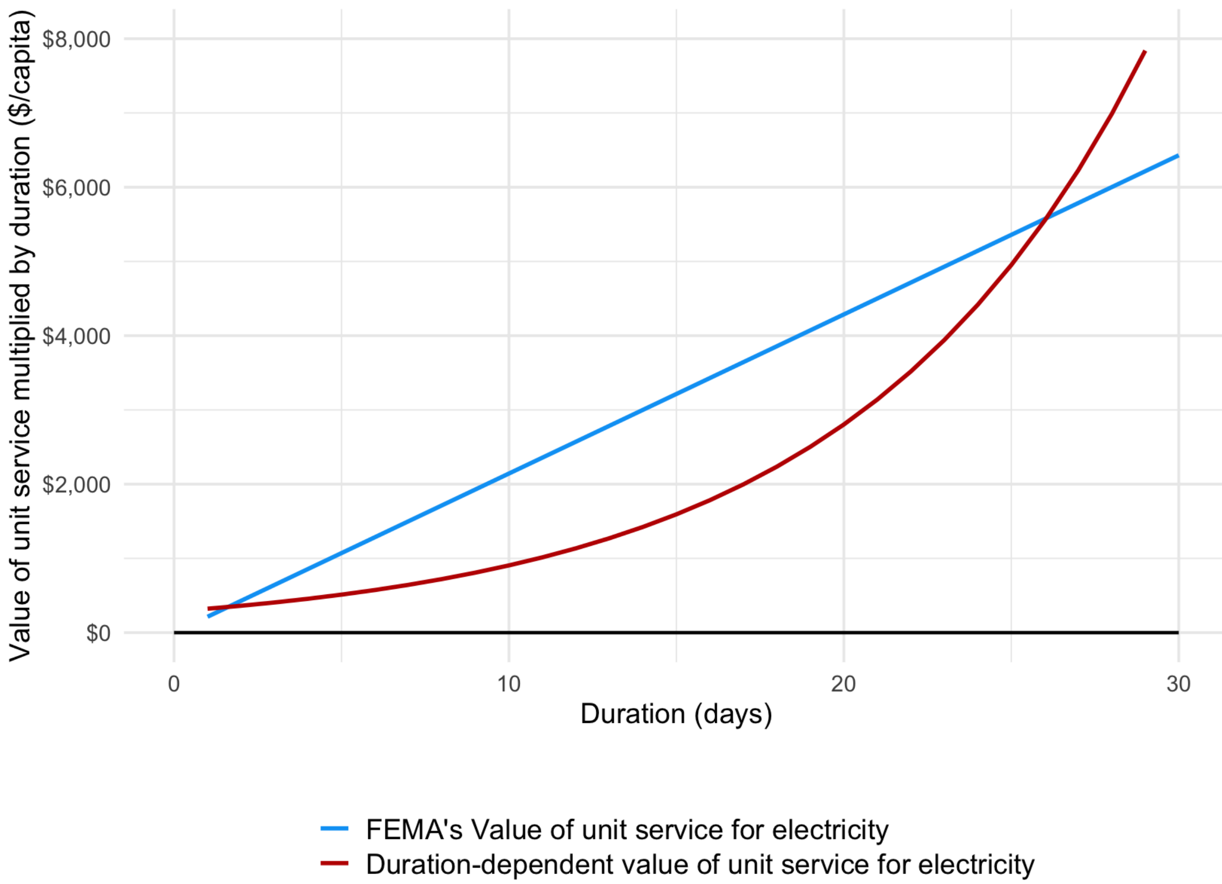

Figure ES-3. Comparison of the value of unit service calculated using the duration-dependent CDF for outage durations ranging from one to 30 days (red) with FEMA's default value of unit service estimate multiplied by duration (blue)

It is important to mention several caveats that should be considered when interpreting our findings. First, the CDFs primarily cover interruptions lasting one day or longer and focus on reported costs to residential and non-residential electricity customers. We did not incorporate the broader inter-industry indirect economic impacts, including effects on businesses with power that are nonetheless impacted by outages affecting their customers and supply chains. Nor did we account for utility costs to repair or replace damaged infrastructure after a precipitating event. We also did not account for increased morbidity- and mortality-related costs due to increased societal risk to health and safety. Finally, the survey sample was not statistically-representative, with notable under-representation from key sectors like pharmaceuticals, medical industries, and certain public sector entities.

Additional research could include assessing CICs for all power interruptions, including short and localized events, as well as including other explanatory variables beyond duration – including region, industry type, electricity consumption, household income, remote work capability, and availability of backup service– into the CDF parametrization. Incorporating qualitative survey data –especially involving operational decisions during outages of different durations, including which operations are sustained with backup power, how these change as outage duration and geographic scope expand, and the community impacts of losing unsustainable operations– could help evaluate the impacts of LDWIs on the most critical customers. Further exploration could also examine the role of backup electricity sources in mitigating customer impacts. Finally, the development of the equations (i.e., CDFs) that related power interruption cost to duration could be incorporated into Berkeley Lab's Interruption Cost Estimate (ICE) Calculator as an auxiliary feature customized for Puerto Rico. Updating this online platform would allow stakeholders–within Puerto Rico and beyond–to evaluate the economic impacts of power interruptions and the value of investments in power system reliability/resilience. The findings from this research effort allows key stakeholders to move beyond qualitative assessments of investments and justify their decisions based on the economic value of past or proposed resilience strategies.

1. Introduction

Electric power is essential for nearly all aspects of individual, household, commercial, industrial, and governmental activities. This reliance underscores the critical importance of addressing our collective vulnerability to power disruptions in electric utility planning. While less frequent than short and localized power interruptions, long-duration and widespread power interruptions[2] (LDWIs) are occurring more frequently than predicted by historical models (National Academies of Sciences, 2017). LDWIs can have substantial economic and societal impacts, not only to electricity customers and utilities that are directly affected, but also on regional economies.

Island communities are particularly vulnerable to both short-term hazards (e.g., tropical storms, cyclones, and hurricanes) and long-term environmental changes, which pose unique challenges to their energy infrastructure. Additional risk to electricity and energy infrastructure is expected with the increasing frequency, intensity, and duration of extreme weather events (DOE, 2013, 2015; National Academies of Sciences, Engineering, and Medicine, 2017; USGCRP, 2018; Zamuda et al., 2018; Pörtner et al., 2022).

Recent hurricanes in Puerto Rico have demonstrated the vulnerability of the territory's power infrastructure. Hurricane Fiona, which made landfall on September 18, 2022 as a Category 1 hurricane, brought intense winds and record-breaking rainfall. The storm damaged the electricity system resulting in over 1.4 million customers losing electricity service (World Bank, 2022). Figure 1 shows the impact to the electric power system caused by Hurricane Fiona, which resulted in heavy rainfall, mudslides, extensive flooding, and a territory-wide outage from severe damage to the electricity system. Tropical Storm Ernesto, which made landfall on August 17, 2024 as a Category 1 storm, caused widespread power outages affecting more than 730,000 homes and businesses (Acevedo, 2025). These large-scale natural disasters and resulting LDWIs underscore the urgent need for proactive strategies and investments to mitigate risks to critical infrastructure and bolster system-wide resilience.

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[2] Throughout this study, we use the terms “interruption” and “outage” interchangeably. Technically, outages refer to times when utility infrastructure is out-of-service and interruptions refer to disruptions in service experienced by customers.

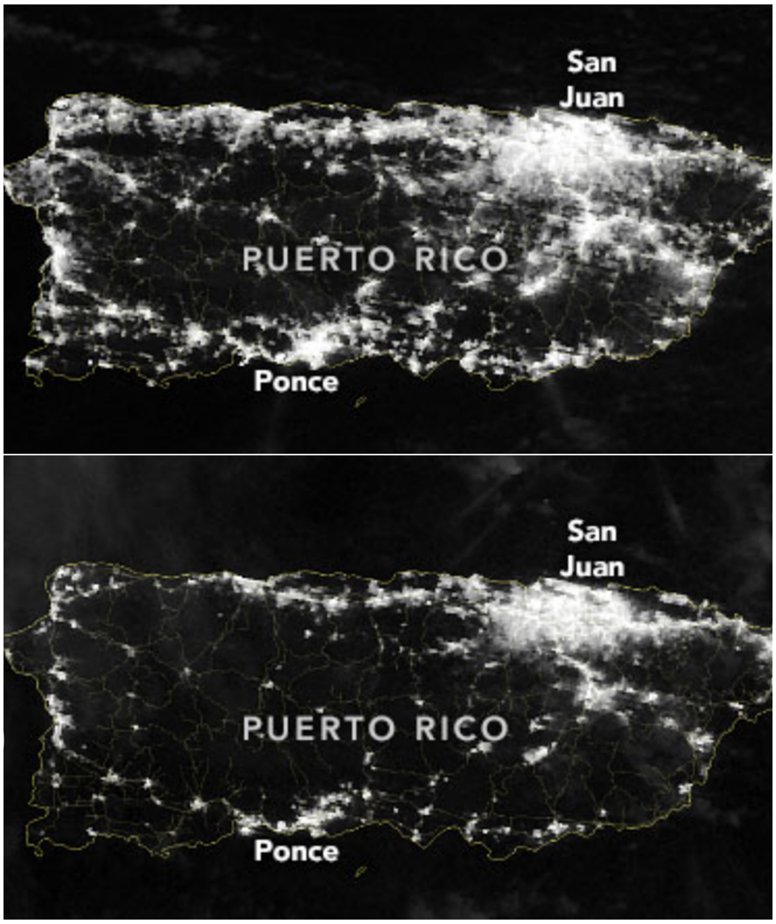


Figure 1. Satellite image of Puerto Rico before and after Hurricane Fiona (NASA Earth Observatory, 2024)

Improved understanding of the economic impacts of power interruptions is necessary to enable utilities, governments, and stakeholders to value and prioritize resilience investments. Unfortunately, there is a lack of reliable economic impact information for island communities to inform existing decision frameworks that could enhance power system resilience. When estimating the value of energy resilience projects, many island communities rely on a standardized Value of Unit Service for Electricity[3] calculation used by the FEMA in their benefit-cost analysis (BCA) tool (FEMA, 2020). These estimates, however, may not be suitable for assessing resilience benefits in island service territories for two reasons. First, the Unit Service for Electricity calculation is constrained to only changes in outage duration and assumed to be a fixed value over time. However, research suggests that the economic impact of power interruptions may not follow a linear relationship with duration. Prior studies (Ericson & Lisell,

[3] The Value of Unit Service for Electricity consists of two components: the regional economic impact and the impact on the affected population. The first component is calculated by multiplying the daily national gross domestic product (GDP) by the outage duration in days, representing the loss of electric service impact on economic activity. The second component is determined using the willingness to pay (WTP) to avoid a 24-hour outage for residential electricity customers, divided by the average household size and multiplied by the outage duration, representing the impact on the affected population. See Section 2.1 of the memorandum for more details.

2020; Leddy et al., 2023; Rickerson et al., 2024) highlight that power outage costs do not increase at a constant rate, with costs escalating due to factors such as damage thresholds, cascading failures, and constraints on recovery resources. Customer damage functions (CDFs), which account for these nonlinear cost effects, offer a more accurate approach to resilience valuation compared to static VOLL metrics (refer to Section 2.1 for a more detailed discussion). Second, FEMA's VOLL component—derived from daily national gross domestic product (GDP) and per capita WTP to avoid a one-day power interruption—is dated and is based on surveys from the contiguous U.S. Baik et al. (2024) demonstrated that power interruption costs for island communities differ significantly from those communities that are on the mainland. These shortcomings highlight the need for tailored power interruption cost assessments and island-specific CDFs to guide infrastructure investment decisions.

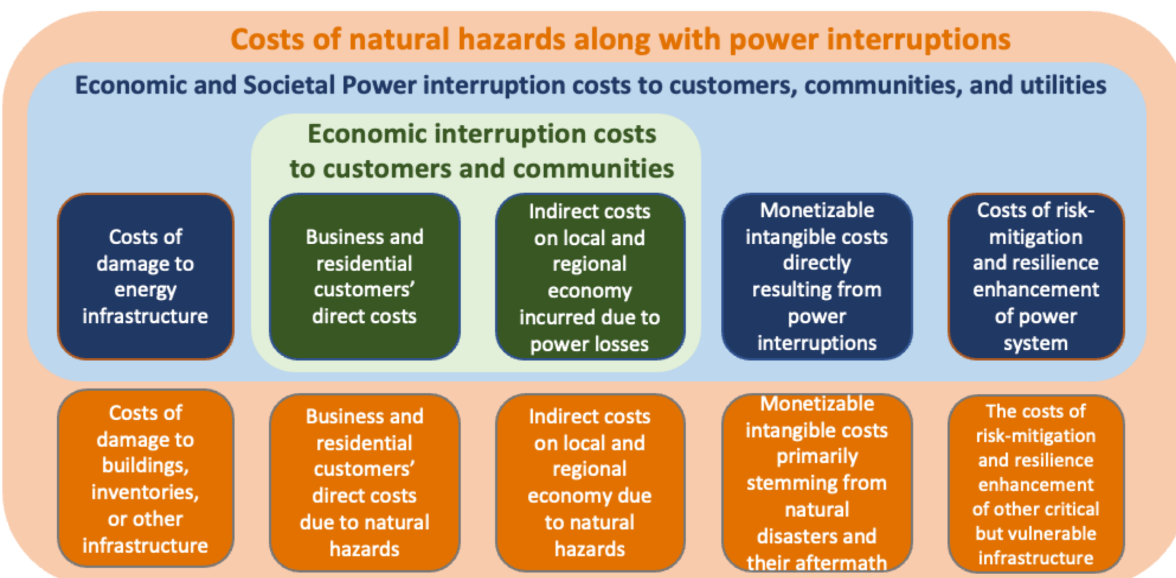
This report builds on our previous study (Baik et al. 2024), which systematically elicited the value of maintaining electricity service across varying outage durations and geographic scopes, and developed duration-dependent CDFs. We quantified customer interruption cost (CIC) for electricity customers across Puerto Rico by leveraging a state-of-the-art CIC estimation methodology. The approach was tailored to address Puerto Rico's distinct risks, challenges, and historical context, resulting in duration-dependent CDFs that reflect the temporal dynamics of LDWIs. These CDFs provide critical data to inform resilience investment decisions, serving as essential inputs for BCAs that support investments in both reliability and resilience of the power system.

The remainder of this report is organized as follows. Section 2 reviews traditional CIC studies and their evolution to measure CICs for events ranging from short and localized events to LDWIs. Section 3 details the survey methodologies for the Puerto Rico study, including survey design, sampling, and administration strategies. Section 4 presents the results and the development of the constructed CDFs. Finally, Section 5 concludes with limitations of this effort and future research directions.

2. Advancing Customer Interruption Cost Survey Design for Long Duration and Widespread Interruptions

LDWIs are often caused by extreme weather events, natural disasters, and physical or cyber attacks that affect critical infrastructure. The costs associated with these events can be categorized into five main areas: (1) damage to utility infrastructure; (2) disruptions for residential and non-residential customers; (3) indirect or spillover effects on local and regional economies; (4) monetizable intangible costs, such as health risks, environmental damage, and legal liabilities (see Zamuda et al., 2019); and (5) the costs of proactive risk reduction and resilience measures implemented before an interruption (Meyer et al., 2013).

Figure 2 below illustrates the costs associated with power interruptions and natural hazards, categorized by the causes and types of costs incurred across three nested levels: power interruption costs directly incurred by customers, power interruption costs impacting customers, utilities, and communities, and the total costs associated with natural hazards that lead to power interruptions, encompassing the costs of the triggering events themselves. This report focuses primarily on the direct power interruption costs to electricity customers (shown on the left within the green box in Figure 2), capturing only the economic impacts on electricity customers directly attributable to these interruptions. However, when evaluating investment decisions, it is essential to consider a wider range of costs, including those affecting local and regional economies, electric utilities, interconnected critical infrastructure, and other related expenses.



Note: Economic costs to customers and communities (green box); combined economic and societal costs to customers, communities, and utilities from power interruptions (blue and green boxes); and the comprehensive costs of natural hazards, including power interruptions (orange, blue, and green boxes). Adapted and modified from Baik et al. (2021).

Figure 2. Cost components related to direct customer power interruption cost assessments, total power interruption cost assessments, and damage assessments for power interruptions along with natural disasters. Adapted from Baik et al. (2021).

Traditionally, generation, transmission, and distribution system planning for electricity reliability has been driven by engineering criteria, determining the necessary capacity to meet specific reliability targets, such as a loss of load expectation of 1 day in 10 years (NERC, 2011). Economic analyses based on these criteria have primarily focused on utility costs, particularly the cost-effectiveness of reliability improvements. Over time, however, methods have evolved to include customer power interruption costs in the evaluation of reliability investments. Munasinghe (1979) introduced the concept of value-based reliability planning, which posits that the optimal level of system reliability is one that minimizes the combined costs of both utility outages and customer power interruptions. This approach has been widely adopted in the U.S., with many utility reliability improvement projects incorporating CIC estimates derived from extensive customer surveys.

2.1 Traditional CIC studies estimating residential and non-residential power interruption costs

Traditional CIC studies categorize electricity customers–-according to their consumption characteristics and the severity of interruption impacts—into three segments: (1) residential; (2) small/medium non-residential (SMNR); and (3) large non-residential (LNR). This segmentation aligns with the initial goal of CIC surveys, which aim to quantify reliability value by utility customer classes. CIC studies use two main methods to measure interruption costs: (1) direct cost measurement and (2) WTP for a hypothetical backup service.

CIC studies often employ direct cost measurement for non-residential customers, as their interruption costs are often quantifiable and can be directly estimated. The direct cost of an interruption is defined as follows:

$$\begin{aligned} Direct\ cost\ &= Value\ of\ lost\ production\ +\ Interruption\ related\ costs \\ &\quad -\ Interruption\ related\ savings \end{aligned}$$

where

- Value of lost production is the net loss in revenue resulting from a power interruption. This represents the difference between the revenue a business would have generated without the outage and the revenue it actually earned during the outage. This calculation considers only incremental losses, or costs exceeding normal operating expenses. If a business can partially recover lost production through overtime or off-peak hours, the interruption cost reflects the unrecoverable portion of lost production.

- Interruption-related costs cover additional expenses directly resulting from the outage, including:
  - Labor costs for compensating lost production;
  - Labor costs for restarting production;
  - Material costs for restarting;
  - Costs for damage to input materials;
  - Re-processing costs, if applicable; and

    - Costs for running backup generators.

- Interruption-related savings account for reductions in costs due to the interruption. While often minimal, these savings can be significant for businesses with high energy or material costs. These savings include:
    - Unpaid wages during the interruption;
    - Costs saved on raw materials;
    - Fuel costs saved; and
    - Scrap value for any damaged materials.

These surveys generally begin by outlining hypothetical interruption scenarios, including conditions that led to the interruption, duration, start and end times, and whether any advance notice was given. To estimate these losses, non-residential customers provide itemized costs, including lost revenue, restart expenses, and equipment damage. Respondents are then asked to estimate total interruption costs across best-case, typical, and worst-case scenarios (Sullivan et al., 2018).

Conversely, estimating residential customers' interruption costs using direct cost methods is more challenging due to the intangible costs associated with inconvenience or discomfort. These costs, including the inability to use appliances or the lack of air conditioning during extreme heat, cannot easily be quantified through market data. Instead, these costs are typically evaluated using stated preference methods like WTP elicitation. Residential surveys usually introduce a hypothetical interruption scenario, ask respondents to detail any resulting expenses or inconveniences, and conclude by asking for the maximum amount they would pay for a hypothetical backup service to mitigate the interruption's impact (Sullivan et al., 2018).

The next step after collecting survey responses is the cleaning of the data and the construction of CDFs to extrapolate the findings to the general population of customers. These CDFs enable a comprehensive representation of power interruption costs across interruption attributes, customer characteristics, and environmental factors. By leveraging CDFs, utilities can estimate outage costs across a broad range of hypothetical scenarios defined by these variables. The CDFs proposed here are duration-dependent, reflecting the nonlinearity of power interruption costs, an assumption well-supported by existing studies.

Existing literature confirms that power interruption costs exhibit a nonlinear relationship with outage duration. Ericson and Lisell (2020) note that "power outage costs can vary nonlinearly with outage duration," indicating that financial losses do not increase at a constant rate as outages persist. Instead, these costs evolve dynamically, influenced by various customer attributes and external conditions. Leddy et al. (2023) emphasize that CDFs provide a more accurate representation of how losses accumulate over time, offering a duration-dependent approach to resilience valuation. Unlike static VOLL metrics, which assume fixed per-unit costs, CDFs account for nonlinear cost effects and customer-specific characteristics, making them better suited for investment and operational planning. However, these models are more complex to calculate due to the intricate interplay of economic and social impacts.

As outage duration extends, nonlinearities become more pronounced, particularly during large-scale, high-impact events. Leddy et al. (2023) identify key factors driving these effects, including damage thresholds that amplify consequences over time, cascading failures across critical infrastructure and supply chains, and constraints on recovery resources. These compounding disruptions contribute to escalating costs, making resilience planning increasingly vital. Supporting this, the National Association of Regulatory Utility Commissioners (Rickerson et al., 2024) finds that costs can rise exponentially during extended outages, further reinforcing the need for duration-sensitive valuation methods.

Traditional outage cost metrics, which primarily focus on average outage duration and frequency, fall short in capturing the true economic impact of extended outages. Murphy et al. (2020) highlight that these conventional approaches fail to reflect the value of resilience solutions, underscoring the necessity of tools that explicitly account for duration-dependent cost structures. By incorporating CDFs into resilience planning, decision-makers can better assess the financial risks associated with prolonged outages and develop targeted mitigation strategies.

The ICE Calculator represents one well known example of a publicly-available tool based on existing CIC studies to develop CDFs from a two-part regression model. The tool was developed by LBNL and Resource Innovations, Inc. (formerly Nexant, Inc.).[4] The first step of the two-part regression uses a probit model to estimate the probability that customers will experience a non-zero outage cost considering independent variables related to the interruption, the customer, and the environment. The second step applies a Generalized Linear Model (GLM) to relate outage costs to the same independent variables, focusing only on customers who reported non-zero outage costs in the first step. This step generates outage cost estimates for all customers, including those who initially reported zero costs. Using both parts, the researchers produce outage cost estimates by customer class that vary depending on the duration of the event.

CIC surveys have been recognized as one of the most effective methods for determining the VOLL (Ratha et al., 2013), particularly for capturing the direct costs that customers experience due to lost load. However, CIC survey activities across the contiguous U.S. have traditionally focused on estimating the costs of short-duration and localized outages, typically those lasting less than 24 hours. As a result, the current ICE Calculator model can reliably predict costs for outages of up to 16 hours but is not designed to be extrapolated for longer-duration interruptions (Sullivan et al., 2015). For resilience planning involving power outages of 24 hours or longer, the nature of costs becomes more complex, requiring a deeper understanding of customer responses and behaviors. Accurately capturing these impacts necessitates tailored survey designs capable of reflecting the broader and evolving consequences of extended power interruptions. This highlights the need for specialized survey protocols and data collection methods that can provide a comprehensive assessment of LDWI costs.

[4] https://icecalculator.com/home

2.2 State-of-the-art CIC estimation from short and localized power interruptions to LDWIs

This work expands on traditional CIC approaches and recent efforts that use CIC methodology to assess the economic impact of power interruptions. It applies this methodology to evaluate a wide range of outage scenarios, from short-duration and localized events to LDWIs across different customer segments. Previous work by Baik et al., 2024 introduced a comprehensive CIC methodology to assess LDWI costs across customer segments that is applied in this study. We employed a systematic approach that: (1) develops realistic power interruption scenarios, ranging from typical to extreme; (2) evaluates interruption costs for each customer segment, covering short and localized interruptions to LDWIs; and (3) generates duration-dependent CDFs to estimate the average direct costs of interruptions for each segment. Figure 3 below illustrates this process. Using this approach, we assessed the power interruption costs for electricity customers in Puerto Rico, creating CDFs based on duration-dependent VOLL estimates. This section focuses on outlining the methodology, while details of the survey design, cost elicitation, and CDF construction for the Puerto Rico survey will be provided in Section 3.

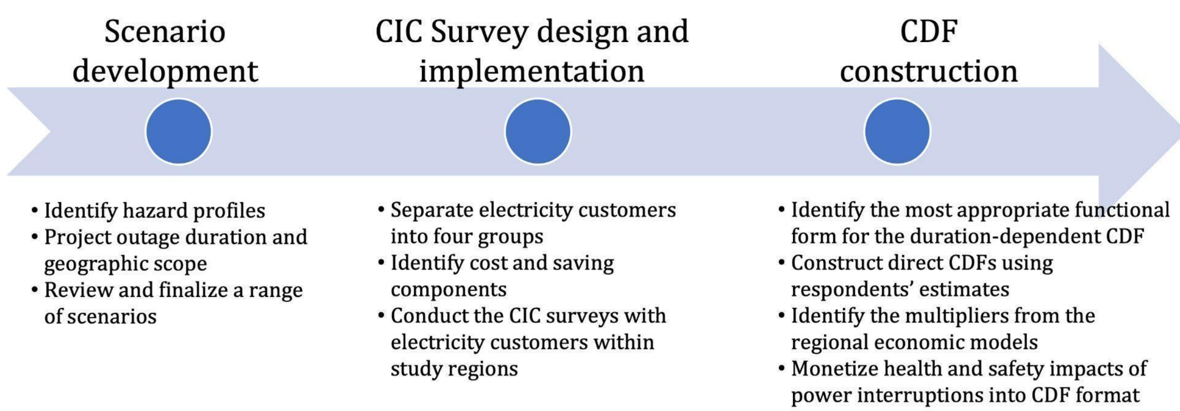


Figure 3. Systematic process for estimating informed CICs and constructing duration-dependent CDFs across different customer segments. Adapted from Baik et al. (2024)

2.2.1 Scenario development

Developing realistic power interruption scenarios is the first step in estimating informed power interruption costs. This process involves the following steps:

1. Identifying hazard profiles specific to the study regions;
2. Analyzing how identified hazards impact the electric grid topology;
3. Collecting information on community risk mitigation strategies (e.g., backup power capacity and its usage);
4. Estimating outage durations and geographic scope using simulations and/or expert judgment;
5. Creating scenarios representing a spectrum of events, from common occurrences to

worst-case interruptions affecting energy infrastructure;[5] and
6. Validating the scenarios with external stakeholders.

To simplify the process, we make two key assumptions to streamline the development of the scenarios and efficiently estimate the CDFs: (1) the duration and geographic extent of power interruptions correlate with the extent of damage to the power system, and (2) weather conditions are fixed to those associated with the highest economic and societal costs of power interruptions.

2.2.2 CIC Survey design and implementation

As described earlier, CIC studies traditionally categorize customers into residential, SMNR, and LNR customer classes. We expand this framework by reorganizing customers into four classes based on cost components and the magnitude of economic and societal impacts:

1. Residential customers, whose costs are predominantly intangible and challenging to monetize (e.g., discomfort, inconvenience).
2. SMNR customers, whose costs include lost revenue, incurred expenses, and savings realized during outages. Most SMNR customers are commercial and not considered customers that are critical for the functioning of society.
3. LNR customers, whose metrics align with SMNR customers, but on a larger-scale. Most LNR customers are industrial electricity customers.
4. Critical public sector customers, including hospitals, government agencies, and utilities, who play a vital role in maintaining community operations.

For residential customers, we assess their WTP to avoid the impacts of hypothetical outages using a multiple-bounded discrete choice approach, where respondents indicate their certainty at various price points by choosing 'definitely yes,' 'not sure,' or 'definitely no.'[6] For non-residential customers, we elicit estimates of lost production, incurred costs, and savings during outages. Public sector surveys focus on operational disruptions, including response rates, increased injury or fatality rates, and interruption-related costs.

Our survey framework builds on advanced tools (e.g., Baik et al., 2018, 2020; Sullivan et al., 2019) and incorporates detailed and realistic interruption scenarios further explained in Section 2.1, based on regional hazard profiles, analysis of grid topology impacts, and community risk

[5] Regions face diverse threats, and while power outages vary widely in temporal and geographic scope, practical constraints—such as survey length—necessitate simplifying assumptions, including that outage duration and geographic extent correlate with power system damage and that weather conditions align with those causing the highest economic and societal costs.
[6] Unlike the ICE 2.0 studies, which used one-and-one-half-bound dichotomous choice questions to estimate WTP ranges, residential surveys for LDWIs adopted a multiple-bounded discrete choice method for greater flexibility and accuracy given the longer duration scenarios. This method allows respondents to evaluate a broader range of price thresholds with more response options, providing more detailed data and precise WTP estimates. It also captures respondents' uncertainty in preferences, which is crucial given the diverse impacts of LDWIs. Factors like critical appliance use, remote work, and backup generators make a single price range insufficient to reflect all customers' preferences.

mitigation strategies. Furthermore, information about the consequences of initiating events is considered, including questions about operations and activities that can continue during outages, assessments of lost production, interruption-related costs, savings (for non-residential customers) or WTP to avoid outages (for residential customers). Figure 4 illustrates the elicitation design for residential, SMNR/LNR, and public sector customers.

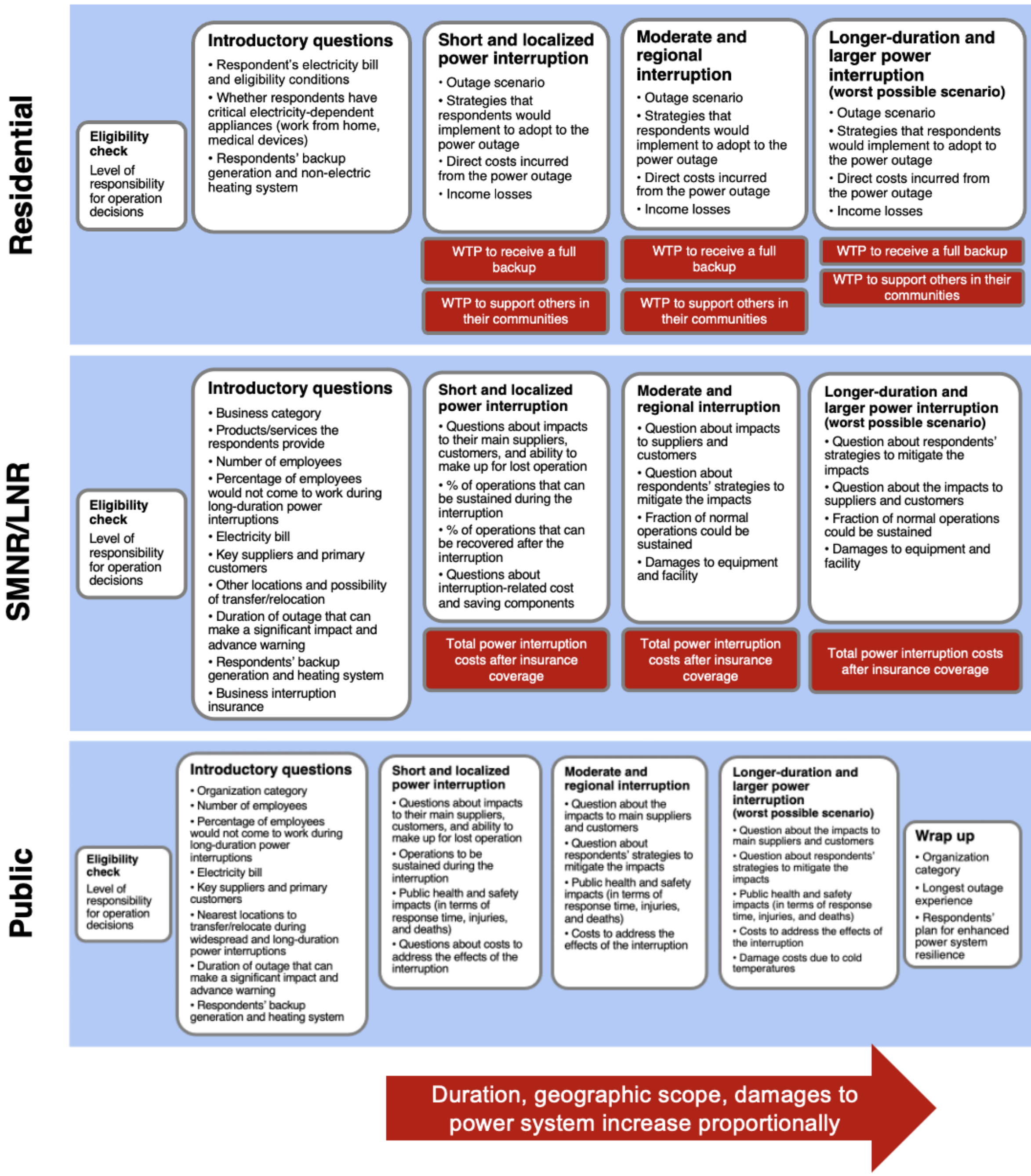


Figure 4. Elicitation design framework for assessing the impacts of power interruptions on residential, SMNR, LNR, and public customers, illustrating the questions for collecting general customer and electricity consumption information, presenting tailored interruption scenarios, guiding respondents in better understanding potential impacts, and eliciting estimates of interruption-related costs and savings. Adapted from Baik et al. (2024)

2.2.3 CDF construction

Power interruption costs fall into three main categories, each necessitating the construction of corresponding CDFs. First, some economic costs are borne directly from electricity customers and are typically gathered through survey-based approaches. This information is then used in the construction of duration-dependent CDFs. Constructing these CDFs involves ensuring that momentary outage costs remain non-negative, cost increases for short and localized outages grow more gradually than those for LDWIs, and expected injuries or fatalities for short outages do not surpass those for LDWIs. To maintain consistency, functional forms and cost estimates must align with established literature, including earlier studies by Apt et al. (2004), Sullivan et al. (2010, 2015), Shuai et al. (2018), and Hanna et al. (2019).

Second, indirect costs reflect economic losses caused by disruptions in the production chain and changes in household spending patterns due to income disruptions. Businesses upstream from the directly affected industries often suffer lost sales, while household spending patterns shift as a result of income losses stemming from business interruptions. Short and localized outages typically have minimal indirect impacts, but LDWIs can impose substantial indirect costs that often surpass direct costs. Researchers have estimated these impacts using regional economic models (e.g., U.S. Bureau of Economic Analysis's (BEA) Regional Input-Output Modeling System (RIMS) II multipliers), which evaluate ripple effects across the economy. Alternatively, multiplier values may be derived from prior regional economic modeling studies, including those examined by Sullivan and Schellenberg (2013), which propose a range of 0.5 to 2 times direct costs as a reasonable estimate for indirect costs.

Third, societal costs encompass the broader community impacts of power outages, particularly focusing on health and safety effects, as evidenced by increases in morbidity and mortality rates. Public surveys conducted with critical private and public organizations—such as hospitals, police and fire departments, schools or emergency shelters, and government agencies—collected data on anticipated increases in response times, mortality rates, morbidity rates, and disruptions to operations during LDWIs. Although disentangling the impacts of natural hazards from those of power interruptions is challenging, the responses can be converted into morbidity- and mortality-related costs under specific assumptions. To estimate deaths and injuries attributable to power interruptions, the study operated under two key assumptions. First, the expected percentage increase in deaths is primarily linked to initiating events, while the expected percentage increase in injuries (including non-fatal injuries and injury-related deaths) is tied to the power interruptions themselves. Second, the numbers of non-fatal injuries and injury-related deaths were assumed to be proportional to the duration of the outages.

This report focuses on the direct economic costs and impacts of LDWIs, thus the analysis primarily focuses on these direct effects. We provide a preliminary discussion on how indirect and societal costs can inform decision-making in Section 5. A more detailed analysis of these broader cost considerations and their integration into BCA is outlined as a potential next step.

2.3 Previous Value of Lost Load Assessments in Puerto Rico

Puerto Rico faces significant challenges in assessing and improving the reliability of its power system, primarily due to the absence of a well-established metric for evaluating power system reliability and the value of lost load. The development of such metrics are integral to the integrated resource planning (IRP) process, as mandated by the Puerto Rico Energy Transformation and Relief Act of 2014 (Government of Puerto Rico, 2014). This act requires Puerto Rico's power utility to regularly develop an IRP with the Puerto Rico Energy Commission overseeing this process.

The 2019 Puerto Rico Electric Power Authority (PREPA, precursor to LUMA Energy) IRP marked a significant improvement as it was the first to explicitly address resilience and reliability, particularly in the wake of Hurricane Irma, Maria, and subsequent earthquakes (Kallay et al., 2021; PREPA, 2019). PREPA introduced a new benefit assessment for reliability improvements using two distinct methods. The first method involved a review of relevant VOLL studies. PREPA's cost was then estimated using its expected unserved power per customer segment, the number of customers served by each customer segment, and Puerto Rico's reliability index. Table 1 lists the nine VOLL studies PREPA deemed most similar to Puerto Rico (PREPA, 2019). Of the nine studies, the New Zealand Electric Authority study was deemed most applicable due to its similar economic and demographic factors, electricity consumption, and market design characteristics. This study reported a system-wide VOLL of $41,269/MWh in 2012 dollars. PREPA adapted these estimates to Puerto Rico's context, resulting in an average VOLL of $31,895/MWh across the territory and customer groups in 2018 dollars, as summarized in the left column of Table 2 below.

Table 1. VOLL estimates for selected regions. Adapted and modified from PREPA (2019), Exhibit 7-16. All values are reported in 2012 dollars per MWh.

Region/Market	System-wide VOLL	Residential VOLL	SMNR VOLL	LNR VOLL
U.S. - Northeast	$9,300-$14,000			
U.S. - Southwest		$0	$35,000	$8,800
U.S. - Midcontinent Independent System Operator (MISO)		$1,700	$42,000	$29,000
Austria		$1,500		
New Zealand	$41,000	$11,000	$31,000	$78,000
Australia - Victoria	$44,000	$4,100	$10,000	$29,000
Australia	$46,000			
Republic of Ireland (2010)	$9,500	$18,000	$3,300	$10,000
Republic of Ireland (2007)	$16,000			

Table 2. VOLL estimates derived from New Zealand's VOLL and the ICE Calculator,[7] adjusted using Puerto Rico's reliability metrics and other relevant inputs. Adapted and modified from PREPA (2019), Exhibit 7-18 and 21. All values are reported in 2018 dollars.

Customer segment	Number of customers	Unserved energy (MWh)	Estimated VOLL from New Zealand's study		Estimated VOLL using the ICE calculator	
			Cost per average MWh ($/MWh)	Total cost ($M)	Cost per average MWh ($/MWh)	Total cost ($M)
Residential	1,335,643	10,345	$12,269	$127	$4,037	$42
SMNR	116,094	3,490	$84,045	$293	$219,237	$765
LNR	11,707	13,650	$33,401	$456	$57,488	$785
Total	1,463,444	27,471	$31,895	$876	$57,940	$1,592

LUMA Energy is currently tasked with developing a new IRP. To date, LUMA's assessments have incorporated system-wide estimates of the VOLL, including analyses of the economic impacts of load-shedding events (PREB, 2022) and evaluations of the benefits of reducing outage frequency and duration by meeting performance metric targets in key focus areas (PREB, 2021).

[7] PREPA (2019) used the ICE calculator with Puerto Rico's reliability metrics, including a System Average Interruption Duration Index (SAIDI) of 683 minutes per customer per year and a System Average Interruption Frequency Index (SAIFI) of 4.2 interruptions per customer per year. This results in a Customer Average Interruption Duration Index (CAIDI) of 163 minutes per event per customer, based on all outages, including generation, transmission, and distribution, but excluding the effects of Major Event Days (MEDs) for the period from 2013 to 2016. The analysis also incorporated additional Puerto Rico-specific inputs, such as annual usage per customer, number of customers per segment, household income, the distribution of power interruptions across hours, and the percentage of customers with backup generation. This approach led to higher VOLL estimates (see the right columns of Table 2 below). However, the authors observed that the VOLL values for small and medium/large commercial and industrial customers deviated from the trends found in the literature and other reviewed documents. Furthermore, they noted that their VOLL estimates for Puerto Rico, based on weakly correlated markets such as the MISO in the U.S., were similar to those derived from the New Zealand VOLL study ($27,450 in 2018$/MWh). As a result, they selected the VOLL estimate from the New Zealand VOLL study as a more appropriate proxy for representing the VOLL for PREPA customers.

3. Survey Methodology

We designed state-of-the-art customer survey instruments for electricity customers of LUMA Energy to assess the power interruption costs of LDWIs and administered these surveys to customers of LUMA Energy located across the territory of Puerto Rico. These surveys collected information about the impacts of LDWIs on their operations, strategies to mitigate the impact as well as costs and potential savings due to the interruption. This section outlines the survey methodology, including the survey design, sampling procedures, recruitment and administration.

We build on prior work (Baik et al., 2024) by adopting a systematic methodology that encompasses three key steps: (1) designing realistic power interruption scenarios, ranging from common events to worst-case scenarios; (2) estimating the costs of power interruptions for various customer segments, ranging from short and localized interruptions to LDWIs; and (3) constructing duration-dependent CDFs to calculate the average costs of power interruptions for each customer segment.

3.1 Survey design

Power interruption scenarios tailored to the study region were developed in collaboration with LUMA Energy and local stakeholders to identify plausible initiating events and the consequences of these power interruptions. Table 3 below summarizes the scenarios, including the durations, the time of year when the events occurred, and the geographic scopes of the outages. The scenarios were designed to increase in duration and geographic extent: the first scenario involves a one-day interruption affecting a single neighborhood, the second involves a 14-day interruption impacting a region (as defined by LUMA Energy's operational boundaries in Figure 5), and the third involves a 30-day interruption affecting the entire territory.

Table 3. Summary of the power interruption scenarios

	Scenario 1	Scenario 2	Scenario 3
Duration	24 hours (One day)	14 days (Two weeks)	30 days (One month)
Time of year	August weekday		
Initiating event	Equipment failure	Generation failure due to a series of earthquakes	A major hurricane
Weather condition	Typical summer morning	A warm and humid summer day	High winds with heavy rain
Geographic scope	Households and businesses in the neighborhood	Entire LUMA Energy operational region where the household is located or organization is located (see Figure 5)	Entire territory of Puerto Rico

Electricity customers in Puerto Rico are acutely familiar with LDWIs due to the devastating impacts of, for example, Hurricanes Maria and Fiona in 2017 and 2022, respectively. We limited the longest outage duration scenario to one month despite the fact that many customers in Puerto Rico have experienced outages that exceed one month. This determination was made in close consultation with external stakeholders and allowed us to focus on evaluating the economic impacts of power interruptions while avoiding the complexities associated with broader societal impacts.

We segmented electricity customers into four classes: residential, SMNR, LNR, and public sector customers to represent the diverse impacts of power interruptions. For residential customers, the survey assessed their maximum WTP to avoid a power interruption, given that interruption costs are often intangible (e.g., discomfort, inconvenience). For SMNR and LNR customers, the survey focused on estimating costs incurred and savings realized from the given hypothetical power interruptions. The public sector surveys focused more on operational impacts to the services that these organizations provide.

The survey design was informed by CIC design guidelines, building on the work of Baik et al. (2020) and Sullivan et al. (2018). The residential survey included questions designed to help respondents consider their preferred coping strategies during outages, the costs incurred—such as spoiled food and additional expenses beyond normal costs—and income losses for those unable to work. This was followed by questions about their WTP to avoid the considered power interruptions. The SMNR and LNR surveys included scenario descriptions, questions on impacts to suppliers and customer demand, operations sustained during outages, and assessments of value of lost production, interruption-related costs, and interruption-related savings. The public sector surveys included scenario descriptions, questions on impacts to suppliers and customer demand, operations sustained during outages, the percentage increase in response time, injuries and fatalities due to power loss, and additional costs associated with mitigating outage impacts. See Table 4 below for the cost and savings components assessed for each customer class, and refer to Appendices A–D for the survey instruments used for the residential, SMNR, LNR, and public customer segments.

Table 4. Direct power interruption cost and saving components elicited from each customer segments

Customer Class	Direct Cost and Saving Components
Residential	WTP for hypothetical backup service
SMNR	Additional labor costs to make up for lost production + Lost revenue + Damage to raw materials/inventory + Damage to equipment + Additional labor costs to address outage-related issues + Other tangible costs (e.g., extra materials, fuel, labor to restart facilities, regulatory costs to dispose of hazardous materials) with the costs to run/rent backup generation - Savings due to outage (e.g., reduced personnel costs, reduced electricity and material consumption) - Losses covered by insurance
LNR	Cost to operate backup generation + Additional labor costs to make up for lost production + Lost revenue + Damage to raw materials/inventory + Damage to equipment + Additional labor costs to address outage-related issues (e.g., labor costs to replace damaged equipment) + Other tangible costs (e.g., extra materials, fuel, labor to restart facilities, regulatory costs to dispose of hazardous materials) - Savings due to outage (e.g., reduced personnel costs, reduced electricity and material consumption) - Losses covered by insurance
Public	Costs associated with addressing the effects of a power outage

This study differed from the methodologies used in previous research by eliciting respondents' perceptions of critical infrastructure consequences following an initiating event (e.g., availability of cellular and landline telephone networks during the given power interruption). This modification served two purposes. First, LUMA Energy requested these questions to analyze public perceptions of infrastructure availability during LDWIs. Second, Puerto Ricans' familiarity with such scenarios was expected to make this exercise valuable, helping respondents fully conceptualize the potential impacts of the hypothetical scenarios.

3.2 Sampling

We collected information on the population of LUMA Energy's customers to determine the sample size for each customer segment. The data provided by LUMA Energy included the following details:

- premise and account ID;
- service agreement start date;
- municipalities;

- customer class and rate information;
- organization/entity name; and
- Standard Industrial Classification (SIC) codes (where applicable).

LUMA Energy defines six distinct customer classes: (1) residential, (2) commercial, (3) industrial, (4) government, (5) public housing, and (6) PREPA company use. We focused on four primary customer segments: residential, commercial, industrial, and government[8]. A subset of rate schedules was selected to best represent each customer class. Table 5 summarizes the assumptions used to estimate the population of the selected rate and customer segments in Puerto Rico:

Table 5. Assumptions for estimating the population of selected rate and customer segments in Puerto Rico

Topic	Assumption
Rate Schedules	Focused on customers served by specific rate schedules to align with our expectations for each segment and ensure representativeness.
Commercial and Industrial Class	Used LUMA Energy's definitions, classifying "commercial customer class" as SMNR and "industrial customer class" as LNR.
Unique Entity Counting	Counted the number of unique entities (based on entity names) instead of individual accounts for a more accurate representation
SIC-Coded Customers	Only considered SMNR and LNR customers with available SIC codes.
Public Sector Class	The public sector encompassed two categories: (1) unique entities served by predetermined government class rate schedules (General service at primary distribution voltage (GSP), General service at secondary distribution voltage (GSS), and General service at transmission voltage (GST)); and (2) commercial class customers aligned with public service sectors identified by their SIC codes in education, healthcare, social assistance, and public administration.
Regionality	Adopted LUMA Energy's regional operating boundaries for consistency with their system planning and operation (see Figure 5 below). This approach applies to residential and SMNR customers. However, public customers sometimes serve multiple regions, and LNR customers have a limited population within each region. We combined the entire territory into a single region for these two segments.

Table 6 summarizes the calculated population size by region and customer segment based on the assumptions outlined above.

[8] We excluded public housing residents from this study for two key reasons. First, LUMA Energy's classification system categorizes public housing as "non-residential," which suggests potential differences in their characteristics compared to typical residential customers. Second, residents in (multi-unit) public housing dwellings may not have complete control over decisions related to resilience (e.g., building regulations might restrict the installation of solar panels with battery storage systems).

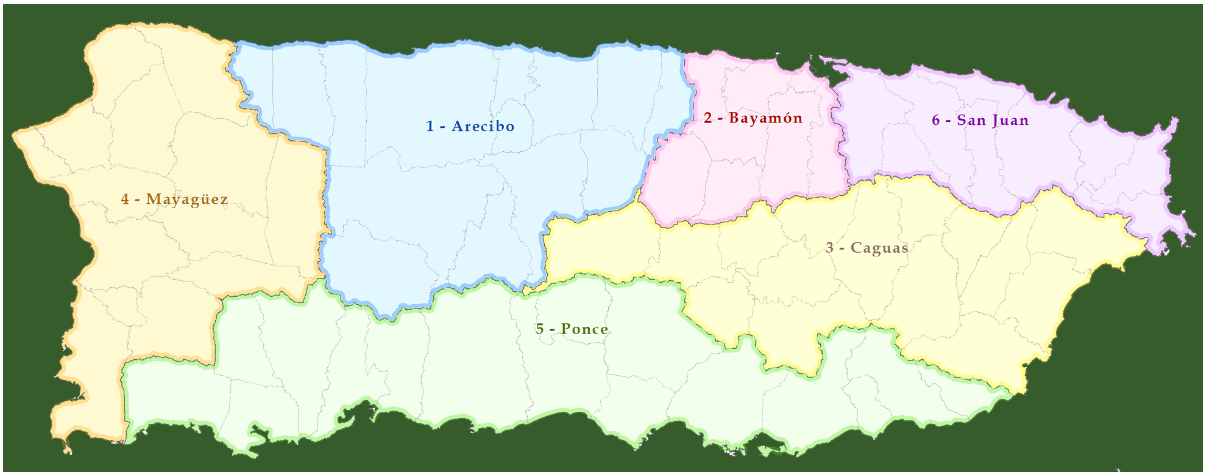


Figure 5. Operational regional boundaries of LUMA Energy. Adapted from LUMA Energy Emergency Response Plan (2022)

Table 6. Customer counts by segment and region (as of February 2024, provided by LUMA Energy), based on the assumptions outlined in Table 5.

Customer segment	Customer count						
	Mayaguez	Arecibo	Bayamón	San Juan	Ponce	Caguas	**Sum**
Residential	210,029	185,517	214,509	310,997	219,923	249,766	1,390,741
SMNR	2,353	1,587	2,858	6,001	2,223	2,419	17,441
LNR	353						353
Public	3,282						3,282
						Total	**1,411,817**

We employed Dillman's methodology to determine the necessary response sizes for each customer segment and region. The parameters employed in this calculation align with those from our previous studies, taking into consideration the available resources and timeline. These parameters include a sampling error set at +/-10%, a confidence level of 90% for residential, LNR, and public segments, and 85% for SMNR. Because it is uncertain how residential and public customers might respond to LDWIs, we assumed a 50% likelihood that they would answer in a particular way. For SMNR and LNR customers, which are mainly in specific industries—such as manufacturing for industrial customers and retail/service for commercial customers—we assumed an 80% likelihood based on their sector concentration. Table 7 summarizes the target number of responses needed for determining the sample size for each customer segment and region. While this provides a guideline for response collection, it is not intended to be a statistically-representative sample.

Table 7. Target number of responses to be collected from each region and customer segment.

Customer segment	Targeted number of responses						
	Mayaguez	Arecibo	Bayamón	San Juan	Ponce	Caguas	Total
Residential	68	68	68	68	68	68	408
SMNR	33	32	33	33	33	33	197
LNR	39						39
Public	66						66
						Total	**710**

3.3 Survey administration approach

This section provides an overview of the recruitment efforts implemented to encourage a diverse number of respondents to complete the surveys. We received customer contact information from LUMA Energy, in accordance with a non-disclosure agreement (NDA), for customers who are not classified as confidential. This information included customer classification, names, contact information, and billing details. Using this data, we curated samples for each customer segment and developed tailored advertisement and recruitment plans.

In July 2024, the research team implemented a range of recruitment strategies to ensure broad participation in the survey. Outreach materials, including postcards, emails, flyers, and digital ads, were developed–in collaboration with LUMA Energy–to ensure consistent messaging and cohesive branding. Outreach to key stakeholders, including trade associations, company leadership, and government representatives, further promoted participation from potential respondents. Our recruitment strategies were tailored to the unique characteristics of each customer segment as discussed below.

To motivate responses, we offered targeted incentives in the form of gift cards to popular retailers in Puerto Rico (Marshalls, Walmart, or Amazon). Residential respondents who completed the survey received $20 gift cards, SMNR respondents received $70 gift cards, and LNR respondents were offered $100 gift cards. Public sector respondents did not receive incentives due to restrictions on government workers accepting payment for participating. Additionally, our team created a bilingual website that provided information on the survey process and project updates.

In accordance with Department of Energy (DOE) and Lawrence Berkeley National Laboratory's (LBNL) policy, the survey process was subject to review and approval by LBNL's Institutional Review Board (IRB). The approved IRB Protocol No. Pro00023334 establishes the guidelines detailing the approach for interacting with electricity customers for this project, ensuring consideration of any potential sensitivities and protections of customer information.

All surveys were officially launched on July 16, 2024, following a pre-test to ensure that the survey platforms were fully-functional and ready for broader distribution. Refer to Table 8 below for a summary of the recruitment strategies, incentives offered, target responses, and the launch and close dates for each survey.

Table 8. Summary of the recruitment strategies, incentives, target responses, and timelines of the surveys

Customer segment	Recruitment strategy	Incentive amount	Target responses	Launch date	Close date
Residential	• Postcard • Email/text • Social media campaign • Newspaper and digital ad	$20	408	7/16/2024	8/16/2024
SMNR	• Postcard • Networking with industry associations • Flyer distributions at key business networking events • Email/text • Social media campaign • Newspaper and digital ad • Direct engagement (phone call, door-to-door outreach)	$70	197	7/16/2024	10/10/2024
LNR	• Postcard • Networking with industry associations • Email/text • Social media campaign	$100	39	7/16/2024	11/8/2024
Public	• Requests through the Office of the Governor • Social media campaign • Direct engagement (phone call, door-to-door outreach)	None	66	7/16/2024	10/31/2024

3.3.1 Residential survey

The residential survey remained open until August 16, 2024. Outreach efforts targeted a sample derived from the LUMA-provided residential contact list (the “sample”). Initially, survey access required a unique, randomized code assigned to each recipient. However, the participation rates fell short, thus we revised the process by removing the unique code requirement, allowing anyone who passed the eligibility check to participate.[9]

We employed a multi-pronged outreach strategy to maximize participation:

[9] Removing the unique identifier requirement streamlined the survey process, making participation more accessible for residents. Although this adjustment made it more difficult to track completions by specific recruitment methods, it enabled a more flexible approach to outreach. Residents could directly access the survey link and respond immediately, which contributed to improved participation rates.

- Postcards sent by mail: Institute for Building Technology (IBTS) distributed 5,914 postcards in three waves. The first two waves focused on addresses from the sample. In the third wave, after removing the unique identifier requirement, we expanded the reach by randomly selecting addresses from a territory-wide residential mailing list within each of our target regions.
- Email and text invitations: IBTS sent recruitment emails and personalized text messages to the sample using the MailChimp platform before removing the unique identifier requirement.
- Social media campaigns: IBTS ran organic and paid ads on platforms (e.g., Meta) targeting municipalities with lower initial response rates. Each week, IBTS adjusted the messaging and targeting approach based on ongoing response rates.
- Newspaper and digital advertisements: IBTS placed ads in both print and digital versions of widely-circulated newspapers as well as on television and radio station websites. Initially, these ads promoted awareness of the study and directed residents to expect mail containing access to the surveys.

3.3.2 Small and medium non-residential survey

The SMNR survey remained open until October 10, 2024. We employed various outreach efforts targeting business managers to maximize participation:

- Postcards sent by mail: A total of 8,778 postcards were distributed in three waves, targeting only the businesses within the sample.
- Networking with industry associations: IBTS engaged with organizations, including the Puerto Rico Chamber of Commerce and smaller regional associations, to share information directly with their members. Additionally, IBTS expanded its outreach by engaging professionals responsible for managing business facilities, leveraging its extensive network of contacts.
- Flyers: IBTS distributed informational flyers at key business networking events attended by both public and private sector representatives. These flyers provided details on how to participate and highlighted the incentives for completing the survey.
- Social media campaigns: We posted both organic and paid advertisements on platforms, adjusting our approach over time to optimize engagement. This strategy proved highly-effective, resulting in a significant increase in the number of survey responses.
- Newspaper and digital advertisements: Advertisements appeared in widely-circulated print and digital newspapers, as well as television and radio station websites.
- Door-to-door outreach: We conducted door-to-door visits in various municipalities, targeting commercial districts to directly engage businesses and encourage participation.[10]
- Phone outreach: IBTS made targeted calls to business owners using both contact within our sample and our own network, explaining the importance of the project and encouraging involvement.

[10] The door-to-door outreach was resource-intensive and time-consuming. Locating business owners was challenging, and follow-up calls were needed to confirm participation. A larger team would have been required to cover multiple areas simultaneously for broader reach in a shorter timeframe.

- Email invitations, text messages: Tailored emails and text messages, emphasizing the benefits of participation, were sent to business contacts.
- WhatsApp organic advertisement: IBTS created a message containing an image with a QR code to direct recipients to the survey. This message was designed to be either personalized or generalized, with the latter facilitating broader dissemination. To expand our reach, IBTS leveraged local contacts, tailoring the messaging for specific individuals to enhance engagement and ensure a more personalized approach.

3.3.3 Large non-residential survey

The LNR survey, which closed on November 8, 2024, required targeted outreach to large businesses and key stakeholders. Initially, we collaborated with LUMA Energy's customer service account managers for outreach, but later adapted our approach to more directly engage with the LNR customers, focusing on major businesses and influential stakeholders. Key recruitment efforts included the following:

- Postcards sent by mail: A total of 334 postcards were distributed to the sample of LNR customers.
- Networking: We conducted extensive networking with industry associations (e.g., Puerto Rico Manufacturers Association). These organizations distributed our recruitment materials via social media, WhatsApp, and email. We also engaged directly at industry events, distributing flyers and sharing information about the importance of the study.
- Phone outreach: We made phone calls to organizations in the sample to explain the survey and encourage participation.
- WhatsApp organic advertisement: We shared QR codes to the survey via WhatsApp, allowing key stakeholders to forward the message organically.
- Social media organic posts: We tailored social media posts on platforms (e.g., LinkedIn, Meta) targeting decision-makers at major businesses to raise awareness about the study and increase participation.

The survey recruitment effort for LNR encountered challenges that contributed to a low response rate. Concerns over confidentiality and uncertainty about who should complete the survey within an organization impacted participation. Some industry leaders questioned the survey's legitimacy, while others showed little interest in the $100 incentive. Efforts to address these concerns, including clarifying the study's context, led to some additional participation, but the response rate remained lower than expected. Due to the small population size and limited cooperation from LNR businesses, we merged this group with the Public sector to ensure robust data analysis, as further detailed in Section 4.

3.3.4 Public survey

The public survey, which closed on October 31, 2024, targeted government representatives and public organizations. We employed several strategies to reach this group:

- Direct engagement: IBTS and their partners facilitated meetings and connected research staff with municipalities, government agencies, nonprofit organizations, and associations. This multi-faceted approach required significant time and effort, including in-person meetings, phone calls, and communications via email, LinkedIn, WhatsApp, and text to encourage participation. The survey team was able to effectively engage with municipal leaders, foster collaboration, and conduct direct outreach to all 48 mayors on the territory.[11]

- U.S. DOE Request: The former U.S. Secretary of Energy issued a request to the former Governor of Puerto Rico Pedro Pierluisi, who sent a memorandum to all public agencies, encouraging their participation. This endorsement provided the study with crucial legitimacy and reinforced its significance.
- Social Media organic posts: Tailored posts targeted public sector audiences were used to raise awareness and encourage participation.
- WhatsApp organic advertisement: Imagery featuring a QR code linking directly to the survey was sent to key stakeholders via WhatsApp, with generalized messaging that could be easily shared across the platform.

[11] However, the survey's broad scope, covering human resources, finance, and facility operations across multiple locations, sometimes made it difficult for organizations to provide complete responses. This required municipalities to coordinate internally to ensure accuracy.

4. Results

4.1 Processing the raw survey data

The analysis team conducted data cleaning after closing the surveys (see the "Collected Responses" column in Table 9) to (1) ensure responses came from valid LUMA Energy electricity customers, (2) prevent duplicate participation, (3) verify that organizations took the appropriate survey, and (4) remove protest responses.

The residential survey included 38 respondents who were not identified as LUMA Energy residential customers and did not provide proof of their customer status when requested by IBTS. These respondents were removed from our analysis. Next, we found that there were some residential respondents indicating that they would not be willing to pay anything for a hypothetical backup service regardless of duration. Several factors may have contributed to these zero values, including: (1) over the half of the residential study respondents owned backup generators (BUGs); (2) many respondents had experience with, and were relatively well-prepared for, LDWIs; and (3) the framing of the question—asking how much they would pay for additional service—may have evoked protest responses, given their dissatisfaction with their electricity service provider. Accordingly, we excluded 59 respondents who reported a maximum WTP of $0 across all three interruption scenarios.

The SMNR, LNR, and public surveys included participants who used a single account to respond multiple times or did not provide account or business information and failed to verify their status. These responses were removed. Some organizations also participated in the wrong survey type—such as large facilities in the SMNR survey, small businesses in the LNR survey, and commercial businesses in the public survey. The analysis team reclassified these responses accordingly. The "Valid Responses" column in Table 9 represents the number of completed and correctly classified responses for each customer segment. Residential responses exceeded the target, while non-residential categories did not reach the hoped-for response counts by the end of data collection.

Table 9. Targeted samples with completed and valid responses by customer segment

Segment	Target responses	Completed responses	Valid responses	% Achieved
Residential	408	637	540	132%
SMNR	197	186	135	69%
LNR	39	31	19	49%
Public	66	54	45	68%
Total	**710**	**908**	**739**	**104%**

The following subsections present the CICs derived from three power interruption scenarios. We also include key survey information that provides insights into the factors influencing the CICs and the constructed CDFs.

LNR and public entities were grouped into a single category due to several key considerations, even though the survey design and data collection initially treated them as separate groups:

- The number of valid responses collected from the LNR sector were insufficient for a robust analysis when disaggregated by sector and industry type.
- Certain industries classified as LNR, such as the pharmaceutical sector, faced significant barriers to data sharing. These included concerns about confidentiality and difficulties in securing internal approvals for survey participation and data release. Analyzing LNR separately could have misrepresented their impacts due to the limited data available, potentially introducing bias into the results.
- Public entities, which play a critical role during LDWIs but have been classified as either SMNR or LNR in previous CIC studies (e.g., municipalities, hospitals, senior housing facilities, federal safety and security organizations), also incur outage-related costs. Although not all public organizations were able to report these costs, those that did required inclusion in the CIC calculations and CDF constructions to ensure comprehensive analysis. A review of reported CICs and bills revealed that most public entities in this study were large-scale consumers, often representing multiple municipal facilities or large organizations with substantial electricity usage (e.g., large nonprofit hospitals). Given their size and energy consumption patterns, classifying public entities with LNR was more appropriate than grouping them with SMNR.

These constraints made it difficult to accurately represent impacts when analyzing public and LNR as separate sectors, limiting a more nuanced understanding of non-residential CICs. To address this, LNR and public entities were combined into a single category, referred to as Large Non-Residential and Public (LNRP). This approach allows for a more detailed and representative analysis, providing valuable insights into the factors influencing VOLL and the economic impacts of power interruptions across non-residential customers with varying electricity consumption levels and outage-related consequences.

4.2 Survey results for residential customers

We collected information on key factors influencing residential survey respondents' CICs. These factors include household income category, ownership of backup generation, average monthly electricity expenses, work from home status, and homeowner insurance coverage for losses due to power outages. Table 10 below summarizes the number of residential responses collected for some of these influential categories.

Table 10. Summary of key characteristics of the residential survey respondents.

Category	Response	Residential count (% share)[12]
Indicated region	Arecibo	81 (15%)
	Bayamón	74 (14%)
	Caguas	83 (15%)
	Mayagüez	74 (14%)
	Ponce	117 (22%)
	San Juan	111 (21%)
Annual household income category	Less than $15,000	208 (39%)
	$15,000 to $29,999	162 (30%)
	$30,000 to $44,999	74 (14%)
	$45,000 to $59,999	44 (8.1%)
	Above $60,000	52 (9.6%)
Household employment status	Yes	351 (65%)
	No	189 (35%)
Work from home?	Yes	88 (25%)
	No	263 (75%)
Has critical medical appliances?	Yes	352 (65%)
	No	188 (35%)
Has access to backup service?[13]	Yes	285 (53%) ● Portable: 212 (85%) ● On-site: 21 (7.4%) ● Solar panel with storage: 69 (24%) ● Solar panel without storage: 13 (4.6%) ● Other: 12 (4.2%)
	No	255 (47%)
Provided average monthly	$0-50/month	53 (9.8%)

[12] Total for general categories and relevant subset for conditional categories.
[13] Residential respondents were allowed to indicate more than one type of backup service.

Category	Response	Residential count (% share)[12]
electricity bill amount (May-November)	$51-100	195 (36%)
	$101-200	116 (21%)
	$201-350	145 (27%)
	Above $350	31 (5.7%)
Provided average monthly electricity bill amount (December-April)	$0-50/month	65 (12%)
	$51-100	198 (37%)
	$101-200	96 (18%)
	$201-350	157 (29%)
	Above $350	24 (4.4%)

The residential survey respondents indicated their WTP to avoid impacts from the given power interruption scenarios while allowing them to express their uncertainty around the estimates provided. We focus our analysis on the upper-bound of WTP as typical VOLL studies estimate the maximum amount customers are willing to pay to avoid an outage. As shown in

Table 11 and Figure 6, respondents reported average upper-bound WTP values of $20, $400, and $800 for one-day, 14-day, and 30-day interruptions, respectively, with a significant increase as outage duration lengthened. This trend was statistically validated by paired Wilcoxon signed-rank tests (all $p < 0.05$).

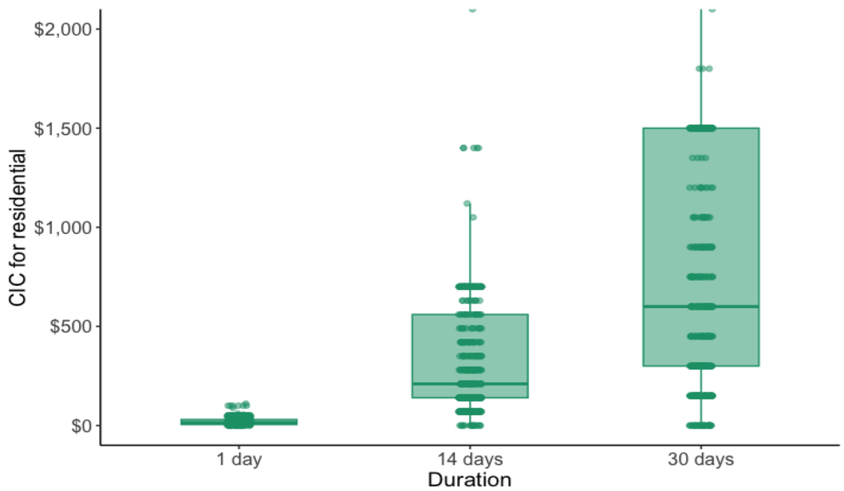


Figure 6. Boxplots of maximum WTP for one-day (left), 14-day (middle), and 30-day (right) power interruptions. Note: Display is limited to $2,000 to enhance visualization of the majority of responses

Table 11. Summary statistics for the maximum WTP across one-day (left), 14-day (middle), and 30-day (right) power interruptions

Summary statistics	One-day	14-day	30-day
Minimum	$0	$0	$0
Median	$15	$210	$600
Mean	$21	$400	$800
Maximum	$110	$14,000	$9,000
% indicating zero WTP for the scenario	8%	3%	7%

4.3 Survey results for small and medium non-residential customers

We collected key information from SMNR survey respondents, similar to the residential customer surveys, to understand factors influencing their CICs. This included their industry, the products or services they provide, business size (measured by the number of employees and electricity bills), and whether they have BUGs or business interruption insurance. Table 12 summarizes these key characteristics.

Table 12. Summary of key characteristics of the SMNR survey respondents.

Category	Response	SMNR count (% share)[14]
Region[15]	Arecibo	6 (4.4%)
	Bayamón	30 (22%)
	Caguas	18 (13%)
	Mayagüez	24 (18%)
	Ponce	20 (15%)
	San Juan	37 (27%)
Industry Type	Accommodation and food services	21 (16%)
	Administrative and support services	4 (3.0%)
	Arts, entertainment, and recreation	3 (2.2%)
	Construction	5 (3.7%)
	Educational services	6 (4.4%)
	Finance and insurance	2 (1.5%)

[14] Total for general categories and relevant subset for conditional categories.
[15] Multiple region selection was allowed for LNR and Public as they could have facilities in more than one area.

Category	Response	SMNR count (% share)[14]
	Health care and social assistance	6 (4.4%)
	Manufacturing (including food and beverage processing)	11 (8.2%)
	Professional, scientific, and technical services	17 (13%)
	Real estate, rental, and leasing	6 (4.4%)
	Retail	25 (19%)
	Transportation, warehousing, and logistics	1 (0.7%)
	Utilities	3 (2.2%)
	Wholesale trade	4 (3.0%)
	Other	21 (16%)
Access to backup service?[16]	Yes	77 (57%) ● portable: 40 (52%) ● on-site: 32 (42%) ● solar with storage: 13 (17%) ● solar without storage: 3 (3.9%) ● battery alone: 5 (6.5%)
	No	58 (43%)
Provided average monthly electricity bill amount (May-November)	Min	$3
	Median	$400
	Mean	$6,500
	Max	$50,000
Provided average monthly electricity bill amount (December-April)	Min	$1
	Median	$450
	Mean	$9,700
	Max	$750,000

The SMNR surveys collected data on costs incurred and savings realized due to power interruptions. Figure 7 and Table 13 summarize the total costs reported by SMNR survey respondents. For a one-day power interruption, the median cost incurred by non-residential

[16] Non-residential respondents were allowed to indicate more than one type of backup service.

organizations is $3,700. This cost increases significantly as the duration of the interruption lengthens, reaching $13,000 for a 14-day interruption and $33,000 for a 30-day interruption. However, some businesses reported higher power interruption costs, which skew the average costs well above the median. These outliers result in average costs of $9,000 for a one-day interruption, $39,000 for a 14-day interruption, and $75,000 for a 30-day interruption.

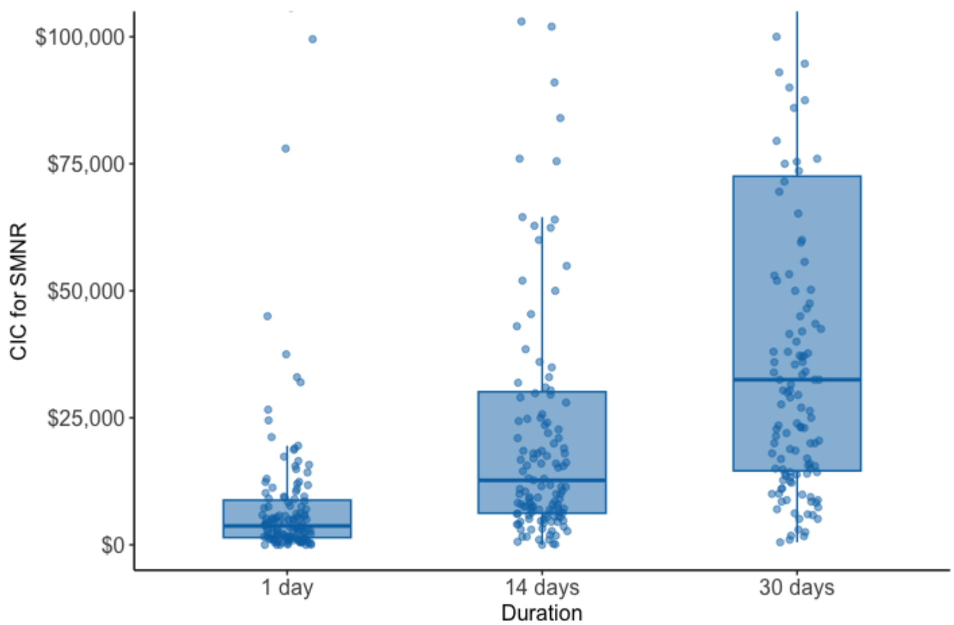


Figure 7. Boxplots of the SMNR's total costs for one-day (left), 14-day (middle), and 30-day (right) power interruptions. Note: Display is limited to $100,000 to enhance visualization of the majority of responses

Table 13. Summary statistics for the SMNR's power interruption costs across one-day (left), 14-day (middle), and 30-day (right) power interruptions

Summary statistics	One-day	14-day	30-day
Minimum	$0	$0	$500
Median	$3,700	$13,000	$33,000
Mean	$9,000	$39,000	$75,000
Maximum	$119,000	$1,000,000	$780,000
% indicating zero power interruption costs for this scenario	2.2%	0.7%	0%

We analyzed average costs and savings across different categories to better understand the drivers of power interruption costs (see Figure 8 below).[17] A one-day power interruption results

[17] This breakdown analysis excludes data from public survey participants for two reasons: (1) the public survey focused on the operational and community impacts of power interruptions on organizations; and (2) cost questions focused on organizations' additional expenses related to mitigating power interruption impacts (e.g., equipment replacement and insurance coverage), but did not collect detailed cost breakdowns. Consequently, this analysis focuses on the costs and savings for SMNR and LNR. See the Appendix for the survey instruments and questions used for each customer segment.

in financial impacts, with equipment damage (averaging $4,300) and lost revenue (averaging $2,900) making up a notable portion of total expenses. Equipment damage can occur regardless of outage duration and may lead to high costs. Business interruption insurance is not widely held, with only 13 out of 135 SMNR businesses (9.6%) reporting coverage. When averaged across all SMNR businesses, the financial protection appears limited ($510 on average), but for those with coverage, insurance provides more meaningful support.

As the outage extends to two weeks, the financial burden increases, though not in direct proportion to duration. Lost revenue becomes the largest expense (averaging $19,000, about 4.5 times higher than for a one-day outage), followed by equipment damage ($6,400 on average) and labor costs to compensate for lost operations ($4,700 on average). Savings also rise, with expected losses covered by insurance increasing to $6,100 on average. The non-linear cost increase suggests businesses can mitigate some impacts, but also reveals the growing challenge of maintaining operations during extended outages, making lost revenue a more pronounced concern.

A 30-day outage amplifies these financial impacts, with costs rising more than the increase in duration alone would suggest. Lost revenue remains the largest expense, averaging $55,000 (nearly three times the cost of a 14-day outage), followed by labor costs for lost operations ($19,000 on average) and equipment damage ($9,100 on average). Savings from outages also increase by two to three times. Insurance coverage, reported as a percentage of lost revenue after deductibles, rises to $25,000 on average. These trends indicate that costs and savings accelerate as outage duration grows, likely due to diminishing returns from mitigation efforts and the increasing difficulty of sustaining operations beyond the two-week mark.

This analysis highlights two key factors. First, equipment damage consistently contributes to total interruption costs, even during short outages. While its share of total costs decreases over longer durations, the absolute expense escalates, underscoring the importance of reducing both outage frequency and duration. Second, lost revenue remains the primary cost driver but does not increase linearly with outage length. While some revenue loss mitigation is evident in the shift from a one-day to a 14-day outage, longer interruptions strain operational sustainability, leading to a sharp increase in lost revenue.

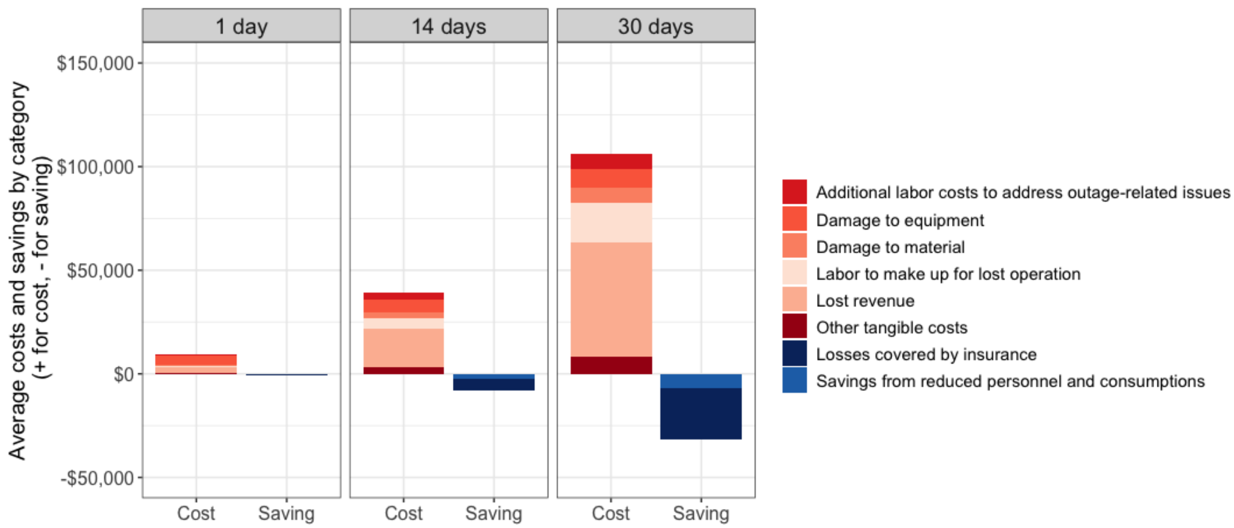


Figure 8. Breakdown of average costs and savings for SMNR across one-day (left), 14-day (middle), and 30-day (right) power interruptions

4.4 Survey results for large non-residential and public customers

Table 14 provides a summary of key factors influencing the CICs of LNRP survey respondents, including their industry, the products or services they provide, business size (measured by the number of employees and electricity bills), key suppliers and primary customers, the impact of outages on operations, and whether they have BUGs or business interruption insurance. These characteristics are organized by customer segment.

Table 14. Summary of key characteristics of the LNRP survey respondents

Category	Response	LNR count (% share)[18]	Public count (% share)[16]
Region[19]	Arecibo	3 (16%)	12 (27%)
	Bayamón	3 (16%)	6 (13%)
	Caguas	1 (5.3%)	9 (20%)
	Mayagüez	3 (16%)	12 (27%)
	Ponce	6 (32%)	7 (16%)
	San Juan	4 (21%)	9 (20%)
Reported industry	Agriculture and agribusiness	2 (11%)	

[18] Total for general categories and relevant subset for conditional categories.
[19] Multiple region selection was allowed for LNR and Public as they could have facilities in more than one area.

<table>
<tr><th>Category</th><th>Response</th><th>LNR count (% share)[18]</th><th>Public count (% share)[16]</th></tr>
<tr><td rowspan="10"></td><td>Construction</td><td>1 (5.3%)</td><td></td></tr>
<tr><td>Educational services</td><td></td><td>2 (4.4%)</td></tr>
<tr><td>Environmental and natural resources</td><td></td><td>1 (2.2%)</td></tr>
<tr><td>Health care and social assistance</td><td>1 (5.3%)</td><td></td></tr>
<tr><td>Manufacturing (including food and beverage processing)</td><td>12 (63%)</td><td></td></tr>
<tr><td>Municipal services</td><td></td><td>37 (82%)</td></tr>
<tr><td>Professional, scientific, and technical services</td><td>1 (5.3%)</td><td></td></tr>
<tr><td>Public administration</td><td></td><td>3 (6.6%)</td></tr>
<tr><td>Transportation, warehousing, and logistics</td><td>1 (5.3%)</td><td></td></tr>
<tr><td>Other</td><td>1 (5.3%)</td><td>2 (4.4%)</td></tr>
<tr><td rowspan="2">Access to backup service?[20]</td><td>Yes</td><td>18 (95%)
• portable: 18 (100%)
• on-site: 2 (11%)
• solar with storage: 1 (5.5%)
• solar without storage: 1 (5.5%)
• battery alone: 1 (5.5%)
• other: 1 (5.5%)</td><td>38 (84%)
• portable: 29 (76%)
• on-site: 20 (53%)
• solar with storage: 5 (13%)
• other: 2 (5.3%)</td></tr>
<tr><td>No</td><td>1 (5.3%)</td><td>7 (16%)</td></tr>
<tr><td rowspan="3">Provided average monthly electricity bill amount (May-November)[21]</td><td>Min</td><td>$250</td><td>$0</td></tr>
<tr><td>Median</td><td>$81,000</td><td>$0</td></tr>
<tr><td>Mean</td><td>$130,000</td><td>$34,000</td></tr>
</table>

[20] Non-residential respondents were allowed to indicate more than one type of backup service.

[21] All residential, SMNR, and LNR survey participants provided their bill information. However, public customers, particularly municipalities, faced challenges with this question since they receive electricity directly from PREPA and are not responsible for the bills. Among 45 public survey participants, 19 entered zero, and 8 skipped the bill questions. As a result, the bill information summary was based on the 19 LNR survey respondents and the 18 public customers who provided relevant data.

Category	Response	LNR count (% share)[18]	Public count (% share)[16]
	Max	$600,000	$500,000
Provided average monthly electricity bill amount (December-April)[20]	Min	$250	$0
	Median	$76,000	$0
	Mean	$150,000	$40,000
	Max	$900,000	$600,000

The LNRP surveys gathered data on costs incurred and savings realized from power interruptions. Figure 9 and Table 15 present the total costs reported by LNRP survey respondents. LNRP organizations incur a median cost of $15,000 for a one-day power interruption. Costs increase significantly with duration, reaching $180,000 for a 14-day interruption and $520,000 for a 30-day interruption.

Some organizations reported exceptionally high power interruption costs, which skew the average well above the median. These outliers raise the average costs to $300,000 for a one-day interruption, $1,200,000 for a 14-day interruption, and $2,600,000 for a 30-day interruption. The disparity between median and average costs stems from both the wide variability in power interruption impacts across LNRP customers and the small sample sizes. Factors such as organization size, industry type, electricity dependency, and the presence of mitigation measures likely contribute to this variation.

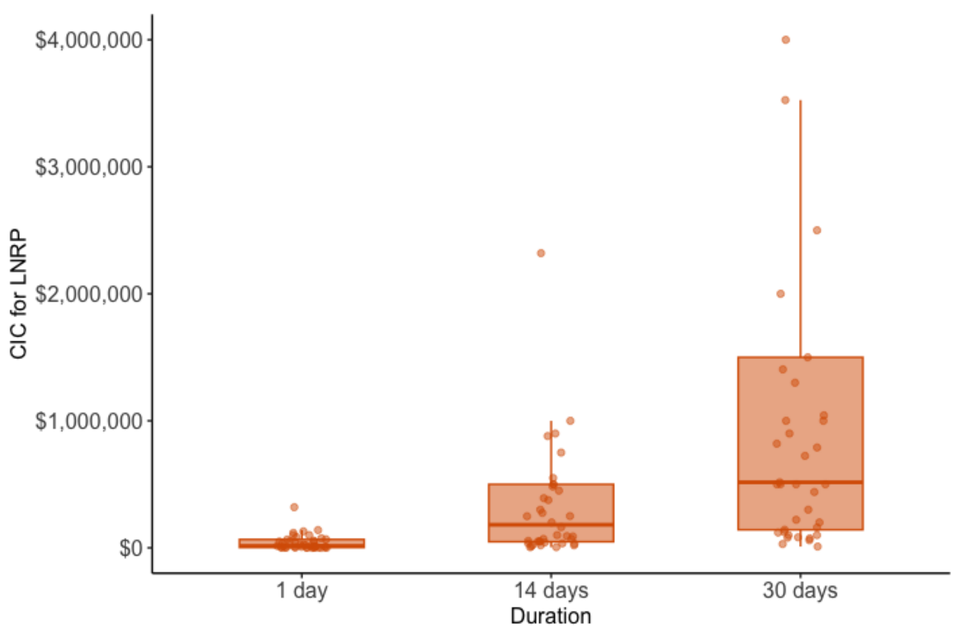


Figure 9. Boxplots of LNRP's total costs for one-day (left), 14-day (middle), and 30-day (right) power interruptions. Y-axis is limited to $4,000,000 to focus visualization on the majority of the responses.

Table 15. Summary statistics for LNRP' power interruption costs across one-day (left), 14-day (middle), and 30-day (right) power interruptions

Summary statistics	One-day	14-day	30-day
Minimum	$120	$5,000	$10,000
Median	$15,000	$180,000	$520,000
Mean	$300,000	$1,200,000	$2,600,000
Maximum	$6,100,000	$18,000,000	$34,000,000

The analysis of average costs and savings by category provides deeper insight into the sources of power interruption costs (see Figure 10 below).[22] A one-day interruption, which many organizations can manage effectively, results in additional labor costs as the largest expense, averaging $230,000. Equipment damage follows at $66,000, with lost revenue averaging $62,000. These findings suggest that short interruptions are primarily managed through increased labor efforts and temporary adjustments, with limited impact on revenue.

As the interruption duration extends to two weeks, the financial burden shifts significantly. Lost revenue becomes the largest cost, averaging $1,600,000, indicating a substantial disruption to business operations. Damage to equipment emerges as the second-largest expense at $240,000, followed by other tangible costs at $57,000 on average. This pattern reflects the growing difficulty organizations face in maintaining operations during prolonged interruptions. Business interruption insurance starts to cover losses after 14 days, with an average recovery of $69,000. However, only a small portion of organizations (11 out of 64) owns insurance and began to observe benefits only after 14-day power interruptions, due to high deductibles.

For a 30-day interruption, the financial impact intensifies. Lost revenue increases to $3,600,000 on average. Equipment damage rises to $300,000, while other tangible costs increase to $150,000, further compounding the overall economic burden. Insurance coverage increases to an average of $150,000, providing more meaningful support during extended outages.

Two key patterns emerge from the analysis. First, many LNRP organizations use BUGs to maintain operations—56 out of 64 respondents report owning such systems. However, lost revenue increases significantly as the interruption duration extends. Specifically, lost revenue grows 26 times from one-day to 14-day outages. While organizations manage short outages, longer disruptions reduce the effectiveness of mitigation strategies, resulting in a sharp rise in lost revenue. For SMNR, this shift occurs between 14 and 30 days, while for LNRP, it happens between one and 14 days. Second, equipment damage consistently contributes to total interruption costs across all durations similar to SMNR. The expense rises with each outage and escalates as the duration lengthens, emphasizing the importance of minimizing both the

[22] This breakdown analysis excludes data from public survey participants for two reasons: (1) the public survey focused on the operational and community impacts of power interruptions on organizations; and (2) cost questions focused on organizations' additional expenses related to mitigating power interruption impacts (e.g., equipment replacement and insurance coverage), but did not collect detailed cost breakdowns. Consequently, this analysis focuses on the costs and savings for SMNR and LNR. See the Appendix for the survey instruments and questions used for each customer segment.

frequency and length of power interruptions.

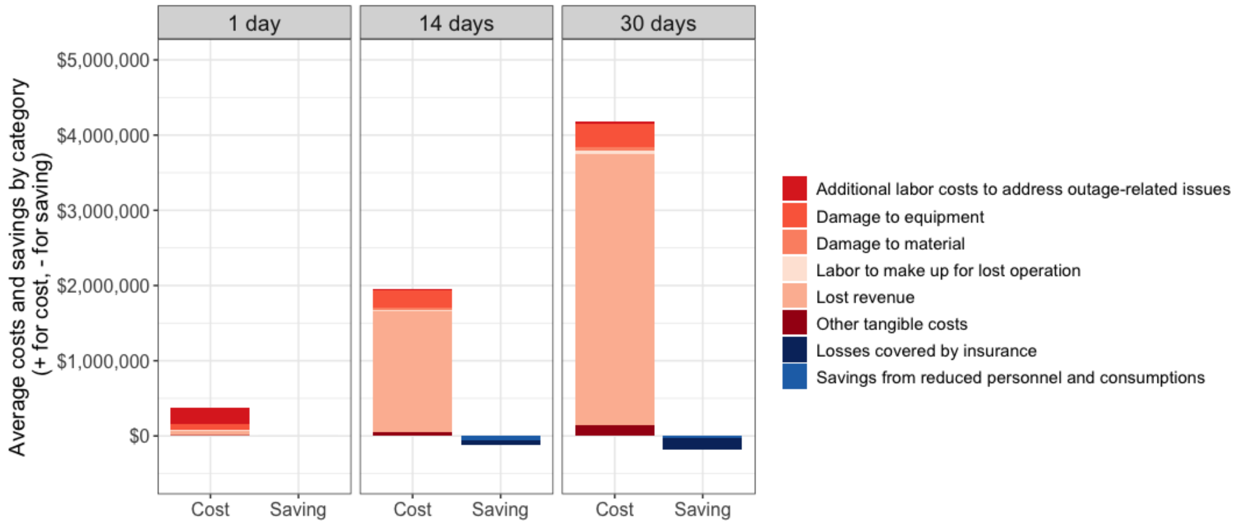


Figure 10. Breakdown of average costs and savings components across one-day (left), 14-day (middle), and 30-day (right) power interruptions

4.5 Development of the customer damage functions

We developed CDFs to estimate how the reported interruption costs for a typical customer vary with the duration of a power outage. The concept of CDFs was initially introduced by Goel and Billinton (1994) as a simple linear relationship between average interruption costs and outage duration, but has since evolved to incorporate additional explanatory variables. In this report, we adopted the fundamental form of the power interruption cost function, which emphasizes the relationship between outage duration and median costs.[23] This approach aligns with FEMA's current valuation of unit service of electricity and its application in their BCAs.

We developed CDFs using different functional forms and evaluated how well the predicted values aligned with the three CIC estimation durations. These CDFs represent residential, SMNR, and LNRP electricity customers based on interruption durations in hours. The analysis applied three functional forms: (1) a polynomial model incorporating duration and its square to predict CICs, (2) a square-root transformed model applying a square-root transformation to costs before fitting with duration, and (3) an exponential model using a log transformation on costs before fitting with duration. The evaluation compared predictions to CIC estimates for outages lasting one day (24 hours), 14 days (336 hours), and 30 days (720 hours). We identified the quadratic model as the most suitable for residential LDWIs and the exponential

[23] Our goal in developing the CDF was to predict median power interruption costs rather than averages for several reasons. First, open-ended responses from residential survey participants with WTP above the upper-bound, or from non-residential participants, often result in excessively high values that disproportionately affect averages. Even after applying an outlier removal strategy based on the 1.5 Interquartile Range (IQR), the averages still deviate from the medians. To avoid misrepresenting typical costs and potential overestimation, we focused on identifying a CDF that more accurately reflects changes in median CICs based on duration.

model as the best fit for non-residential LDWIs. These models provided the closest alignment between predicted values and median CICs across the three durations for each customer segment. These selections align with the criteria that CICs should consistently increase with duration and ensure that functional forms and cost estimates follow established literature. Refer to Figure 11 and Table 16 below for the selected CDFs for residential, SMNR, and LNRP electricity customers in Puerto Rico. This analysis used simplified CDFs to examine the relationship between average interruption costs and outage duration. This methodological choice was driven by the constraints of our data sample size, and is further justified by our aim to align with FEMA's valuation methods for unit service of electricity and BCAs. Choosing a simple and focused model in this context was not a compromise, but rather a strategic approach to enhance the validity and reliability of our conclusions by using a model best suited to the available data and established valuation practices. While the current analysis benefits from this focused approach, we acknowledge the potential for future research, using richer datasets, to valuably expand upon these models. Incorporating additional explanatory variables, including income and electricity consumption, could further enrich the level of detail and explanatory power of CDFs, potentially revealing more nuanced relationships. We elaborate on these promising avenues for future research in Section 5. We use these CDFs to compare duration-dependent CICs with FEMA's Value of Unit Service of Electricity estimates, which we discuss further in Section 4.6.

Table 16. Equations to estimate CICs by customer class

Segment	Equation
Residential	$(4.78 + (0.030 \times Duration))^2$
SMNR	$e^{8.07+(0.0034 \times Duration)}$
LNRP	$e^{9.82+(0.0051 \times Duration)}$

We constructed a CDF based on reported CIC values and adjusted these values relative to household income for residential customers and monthly average GDP per non-residential electricity customers (see Figure 12 below). For residential customers, the CDF indicates that a one-day outage results in a CIC equivalent to 1.1% of monthly household income, increasing to 4.4% for a 14-day outage and reaching 26% for a 30-day outage. For SMNR customers, losses amount to 4.7% of monthly average GDP per non-residential customer for a one-day outage, rising to 14% for a 14-day outage and 50% for a 30-day outage.

LNRP customers experience significantly higher impacts. A one-day outage leads to losses equivalent to 28% of monthly average GDP per non-residential customer, escalating to 140% for a 14-day outage and 1,000% for a 30-day outage. These larger impacts are expected given LNRP’s substantial contribution to GDP and the assumption of evenly distributed monthly GDP among non-residential customers. However, the results highlight the disproportionate economic burden of LDWIs on LNRP and their broader economic consequences for Puerto Rico.

Figure 11. Distribution of the CICs collected from the residential (top), SMNR (middle), and LNRP (bottom) electricity customers with the fitted CDFs

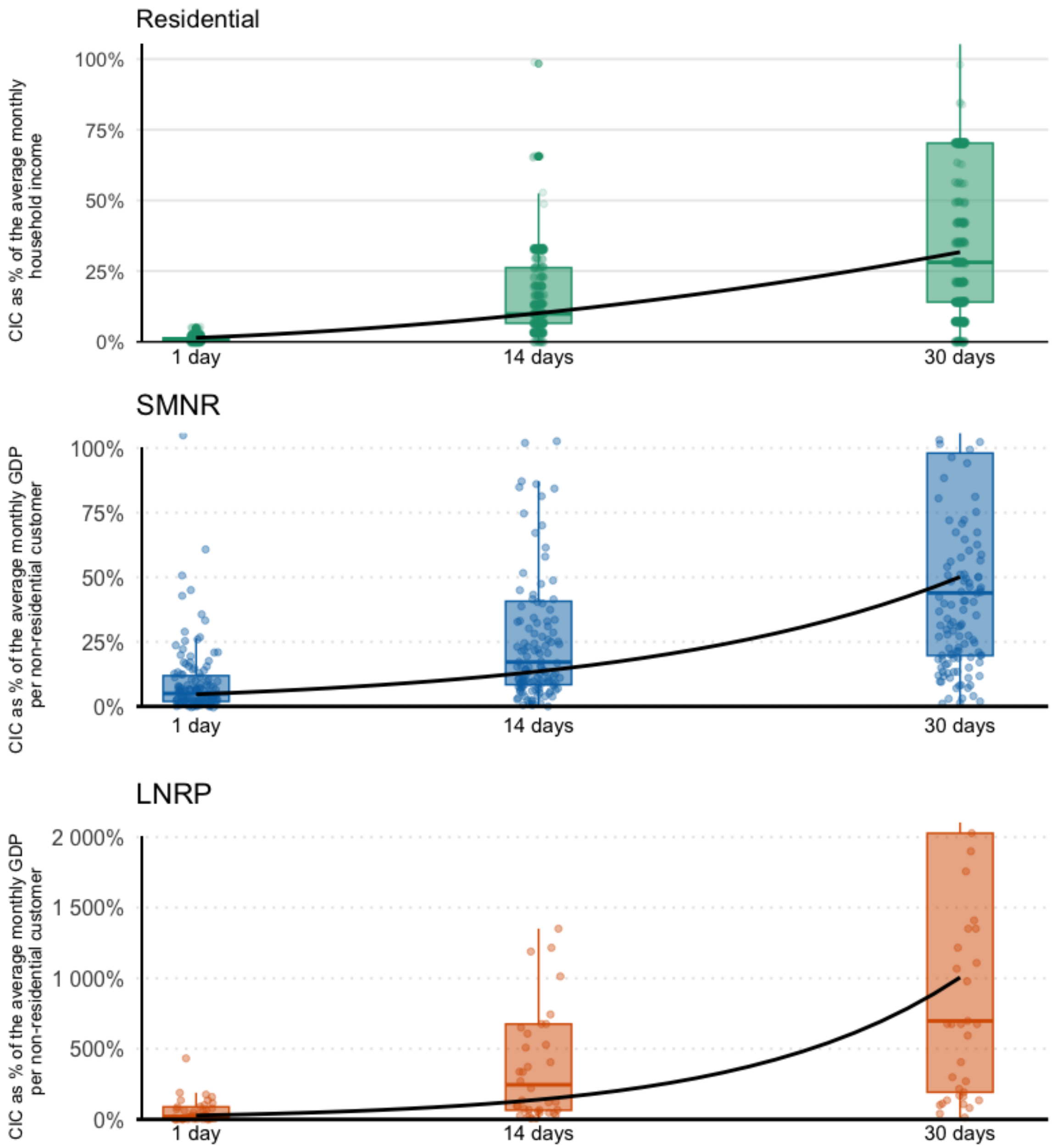


Figure 12. Distribution of CICs as a fraction of monthly household income for residential customers (top) or average monthly GDP per non-residential customer (SMNR: middle, LNRP: bottom), with the fitted CDFs

We estimated the region-level CICs for one-day, 14-day, and 30-day outages using the median CICs predicted by the duration-dependent CDF (see Figure 13 below). In our calculations, we utilized the total number of electricity customers reported by the utility in 2024. Regional costs for a one-day outage range from $141M in Arecibo to $270M in San Juan. A 14-day outage increases costs to between $628M in Bayamón and $1.2B in San Juan, while a 30-day outage further raises costs to between $3.8BM in Bayamón and $7.1B in San Juan. San Juan's costs are nearly double those of other regions, primarily due to its higher number of non-residential customers—nearly 34,000 compared to 16,000 to 20,000 in other regions. San Juan receives more focus due to its higher costs, but the overall trend reveals a gradual increase in costs from a one-day to a 14-day outage, followed by a steeper rise as the duration extends. This pattern is evident in the total territory-wide costs, which start at ~$1B for a one-day outage, grow to $5B for a two-week outage, and reach $29B for a one-month outage

Figure 13. Regional total CICs for one-day, 14-day, and 30-day power interruption scenarios

4.6 Estimating Puerto Rico's Value of Unit Service from LUMA Energy's CDFs

We estimated the duration-dependent value of unit service for electricity in Puerto Rico using LUMA Energy's CDFs by applying the constructed CDFs for residential, SMNR, and LNRP customers. These calculations were based on the total electricity customer accounts as shared by LUMA Energy, and we categorized them into residential, SMNR, and LNRP based on their respective tariffs. We estimated the daily outage costs for residential, SMNR, and LNRP customers across Puerto Rico, as well as the total combined cost. The results are summarized in Table 17 below.

Table 17. Estimated power interruption costs across Puerto Rico for a 24-hour territory-wide outage (rounded to nearest $M)

Customer Segment	Total electricity customers	CDF ($/customer)	Outage length (hrs)	Cost of one-day outage ($M)
Residential	1,557,541	$(4.78 + (0.030 \times Duration))^2$	24	$47
SMNR	94,744	$e^{8.07+(0.0034 \times Duration)}$	24	$329
LNRP	32,728	$e^{9.82+(0.0051 \times Duration)}$	24	$683
Total				**$1,059**

The units for the value of unit service in FEMA's BCA tool are expressed on a per-person (rather than per-customer) per-day basis. To align with this framework, the total daily outage impacts must be divided by Puerto Rico's population of 3.3 million.

$$Value\ of\ Unit\ Service\ (\$/person/one\ day\ interruption) = \frac{\$1{,}059M}{3{,}285{,}874} = \sim\$322/person$$

This adjustment yields a new value of unit service of approximately $322 per person for a one-day outage, which is about 1.5 times greater than FEMA's current default value of $214 per person for the one-day power interruption. A longer-term perspective (1 to 30 days), however, reveals a more nuanced picture. The CDF-based duration-dependent unit service values capture the cost dynamics revealed in the surveys, where short-duration outages incur significant fixed costs from operational adjustments and equipment vulnerabilities, businesses manage disruptions through labor and backup systems during moderate-duration outages, and costs escalate sharply beyond critical thresholds as mitigation efforts weaken, with lost revenue and equipment damage becoming dominant over prolonged durations. In contrast, FEMA's linear approach does not capture the non-linear nature of power interruption impacts, leading to an over-estimation for outages lasting between 2 and 26 days and an under-estimate for those exceeding 26 days (see Figure 14).

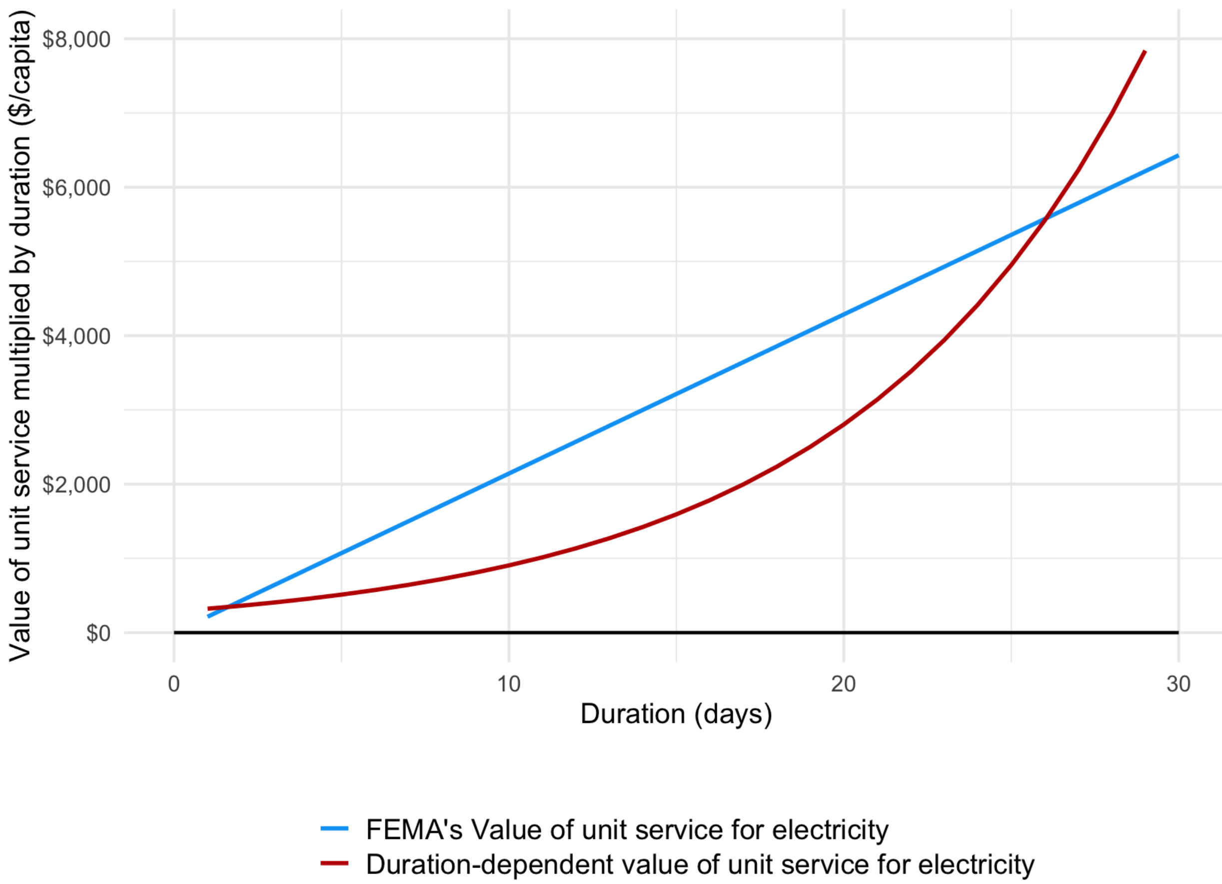


Figure 14. Comparison of the value of unit service calculated using the duration-dependent CDF for outage durations ranging from one to 30 days (red) with FEMA's default value of unit service estimate multiplied by duration (blue). The y-axis represents the value of unit service multiplied by duration, illustrating the economic impact per capita of lost electric service ($/capita) for the specified outage duration.

Several factors contribute to the nonlinearity of CDF-based unit service values, shedding light on these observed distinctions.

- First, the selected CDFs used to estimate electric customers' power interruption costs differ by sector—quadratic polynomial for residential customers and exponential for non-residential customers. As a result, power interruption costs increase gradually for shorter outages but rise more sharply as outage durations lengthen.
- Second, more than 50% of surveyed Puerto Rico customers across all sectors own BUGs. While BUGs mitigate some of the impact of power interruptions, they do not eliminate the associated costs and disruptions.
- Third, Puerto Rico's customers are accustomed to prolonged and widespread outages, which reduces the relative impact of shorter interruptions. However, once outages extend beyond a certain threshold—approximately two to three weeks—the economic consequences of LDWIs escalate significantly.

Further discussions on CDF-based unit service values for other islanded regions, along with recommendations for improving unit service value assessments, are provided in the memorandum prepared for FEMA, which accompanies this final report.

5. Discussion and Next Steps

Recent hurricanes in Puerto Rico have demonstrated the vulnerability of the territory's aging power infrastructure and the significant challenges faced in maintaining power reliability and resilience. The territory's reliability metrics are just one example of this system's fragility. The typical customer in Puerto Rico experienced 1,572 minutes (or nearly 27 hours) of power interruptions in 2023–significantly above the U.S. national average (EIA, 2024).[1]
Utilities across the world have assessed the costs of short and localized power interruptions for decades to inform planning decisions. Power system planners often determine necessary investments to achieve specified reliability outcomes at the lowest cost under normal operating conditions, which exclude low-probability, high-consequence events. Because LDWIs and their initiating events often fall outside "normal" operations, justifying resilience investments within the current planning framework has been challenging. Although studies have estimated the costs of short and localized interruptions, research on LDWI costs remains limited and has not been adequately incorporated into utility investment decisions. Decision-makers often rely on proxies, including FEMA's Value of Unit Service for Electricity, in the absence of these estimates.

This study provides policymakers with a defensible approach to incorporate duration-dependent CDFs into their resilience investment decisions. These CDFs quantify interruption costs across a range of durations and customer classes, thus allowing stakeholders to assess financial impacts and determine the value of mitigation strategies. Policymakers can begin by analyzing historical outage data with CDFs to estimate the economic impact of interruptions under current conditions. With this baseline, they can compare outage statistics before and after an investment to quantify the avoided costs or the economic benefit of past or proposed investments. These insights can then help guide funding allocations, ensuring that investments prioritize the most impactful resilience improvements while maximizing cost-effectiveness. Integrating CDFs into decision-making enables stakeholders to move beyond qualitative assessments and rely on defensible, localized economic information to justify investments in resilience. For example, we used the duration-dependent CDFs from this study to calculate a Value of Unit Service and compared it with FEMA's existing Value of Unit Service. Our preliminary findings show that FEMA's estimate of $214 per capita per day interrupted significantly under-estimates the true costs of the longest duration power interruptions that are occurring somewhat frequently across Puerto Rico. The intent of our research is to provide FEMA with a recommended approach to collect the information needed to assess the economic impact for LDWIs–and ultimately the value of investments in power system resilience and recovery.

The estimated CICs and constructed CDFs provide critical inputs for Puerto Rico's future resilience investment decision-making, yet they are not without their limitations. Below are a few limitations and areas that could benefit from additional research.

Lacking information on the costs of shorter duration power interruptions

The current CDFs for residential and non-residential customers were developed based on survey data for LDWI scenarios lasting from one day to one month. It is widely recognized that the costs of short-duration events (such as momentary outages up to 24 hours) differ significantly from those of long-duration events, particularly in terms of their consequences. Therefore, the CDFs presented in Table 16 are intended solely for LDWIs lasting one day or longer.

Survey-based methods are subject to inherent biases

The survey-based approach offers a bottom-up method for estimating the direct impacts of power interruptions across various scenarios without relying on external data or assumptions (Sullivan et al., 2018). Consequently, CIC surveys have become the most widely-used approach for estimating direct economic CICs, remaining a standard tool for utilities and generally recognized by regulators. Despite their widespread use, CIC survey=based approaches face several challenges. First, customers may struggle to provide precise interruption cost estimates, particularly for long-duration, widespread outages or when lacking adequate support to fully assess the multifaceted consequences during these events (Baik, Davis, and Morgan, 2018; Baik et al., 2020). Second, respondents may not fully account for disruptions across supply chains, making it difficult to capture the broader systemic effects of outages (Baik et al., 2021). Third, CIC estimates from surveys are inherently susceptible to biases associated with their hypothetical nature and stated preference methods, further influenced by the elicitation techniques used. These biases include range and centering bias, strategic bias, and difficulties in precise estimation when using open-ended questions (Kealy and Turner, 1993; Cameron and Quiggin, 1994; Alberini, 1995; Sullivan and Keane, 1995; Cameron et al., 2002). To address these limitations, this study followed established best practices, including careful survey design, providing contextual information, guiding respondents through outage consequences, and conducting multiple pilot tests (Mitchell and Carson, 1989; Arrow et al., 1993; Boyle, 2017; Johnston et al., 2017; Dillman and Smith, 2007). While it is impossible to completely eliminate cognitive biases in practical applications (Arrow et al., 1993; Carson, Flores, and Meade, 2001; Venkatachalam, 2003; Johnston et al., 2017), further adjustments, such as calibration to account for specific biases or the methods used, can refine results for those who seek greater precision (List and Gallet, 2001).

Survey was not statistically-representative of entire population

Given budget and time limitations, we were unable to collect enough survey responses, especially for the largest electricity customers in Puerto Rico. Notably, we did not receive responses from the pharmaceutical and medical industries, which play a crucial role in Puerto Rico's economy, producing approximately $40 billion in pharmaceutical products annually—more than any U.S. state or foreign country by value. Past hurricanes, including Hurricane

Maria, have resulted in significant losses, damaging over 100 drug and medical device manufacturers (Stone, 2017) and disrupting the supply of nearly 10% of all drugs consumed in the U.S. (DHS, 2018) These disruptions led to approximately 3.4 billion customer-hours of lost electricity service (DHS, 2018). Despite extensive outreach through multiple channels, confidentiality concerns and reluctance to share detailed information posed significant barriers in engaging participants from these industries. Similarly, we were unable to collect a significant number of responses from federal agencies, other critical organizations, and the largest electricity customers, despite support from the U.S. DOE, the Governor's office, and LUMA Energy. Given the economic significance of these industries and the challenges in obtaining detailed outage cost estimates for them, their impacts may not be fully captured within general electricity customer estimates. To ensure a more comprehensive assessment of electricity resilience, these high-value sectors should be separately evaluated and incorporated into broader analyses.

Indirect, morbidity- and mortality-related, and utility costs were not included

This report primarily analyzes direct economic CICs, but LDWIs also impose substantial indirect and societal costs that can far exceed direct costs (Sullivan et al, 2018; Baik et al., 2021). Indirect costs include economic losses resulting from the disruption to businesses upstream in the production process–who may still have electricity–and changes in household spending patterns due to reduced income caused by both directly and indirectly affected businesses. Societal costs, on the other hand, encompass broader impacts, including increased response times; and any associated impacts to human health and safety. Indirect costs can be estimated using regional economic models (e.g., U.S. BEA's RIMS II multiplier) or sector-level demand multipliers derived from prior studies (e.g., Ehlen et al., 2011; Santos et al., 2022). Societal costs can partially be quantified through data collected from critical service providers, including metrics on increased response times and health impacts resulting from LDWIs. Examples of estimating these costs can be found in Baik et al. (2024), which explored the estimation of indirect and societal costs in other regions (e.g., Gulf of Alaska, Southeast and Interior Alaska, and a U.S. territory in the South Pacific). Finally, we did not include the costs to repair or replace damage to the electricity systems. For these reasons, our estimates of the economic impact of power interruptions are considered a lower-bound value of the true costs.

CDFs are based on duration and do not include other explanatory variables

This analysis used simplified CDFs to examine the relationship between average interruption costs and outage duration, driven by data sample size constraints and the need to align with FEMA's valuation methods for unit service of electricity and BCAs. The current analysis is constrained by data limitations, including coverage of only three interruption durations and smaller sample sizes for non-residential customers across different industries, particularly the LNR and public sectors. As a result, the model could not incorporate the full set of explanatory variables known to influence CICs (e.g., region, industry type, electricity consumption, household income, ability to work from home, presence of backup service). This project aimed to assess CICs from LDWIs for Puerto Rico's electricity customers and provide FEMA with recommendations to improve the unit service value of electricity (which is discussed in a separate document prepared for FEMA, which accompanies this final report), measured per capita per day. Given this objective, we focused on the relationship between duration and costs. With more comprehensive data to fully specify the regression model, it would be possible to estimate CDFs for calculating customer interruption costs per event, incorporating factors like season, time of day, and day of the week. Expanding the duration-dependent CDFs through further analysis would help decision-makers better understand the impact of power interruptions on customers with different characteristics. Additional data from a broader set of electricity customers and a wider range of interruption scenarios could be further refined to better characterize CICs across varying interruption attributes and customer profiles.

Future research

Additional research could include assessing CICs for all power interruptions, including short and localized events, as well as including other explanatory variables–beyond duration–into the CDF parametrization. Incorporating qualitative survey data, especially involving operational decisions during outages of different durations, could help evaluate the impacts of LDWIs on the most critical customers. Further exploration could also examine the role of backup electricity sources in mitigating customer impacts. The development of the equations (i.e., CDFs) that related power interruption cost to duration could be incorporated into Berkeley Lab's ICE Calculator. Updating this online platform would allow stakeholders–within Puerto Rico and beyond–to evaluate the economic impacts of power interruptions and the value of investments in power system reliability/resilience. Additionally, combining CIC study results with economic modeling—including regional economic modeling—could offer broader insights into the economic consequences of LDWIs. The findings from this research effort allows key stakeholders to move beyond qualitative assessments of investments and justify their decisions based on the economic value of past or proposed resilience strategies.

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Appendix A. Residential Survey Instruments

Below is the survey instrument used to assess CICs among residential electricity customers in Puerto Rico. While the attached instrument is in English, the surveys were administered in both Spanish and English, allowing respondents to switch between languages as needed.

Puerto Rico Customer Power Outage Cost Survey: Residential Customers

We are a group of researchers from Lawrence Berkeley National Laboratory (LBNL), the Institute for Building Technology (IBTS), and LUMA Energy. The purpose of this study is to understand how electricity outages affect customers. This research is funded by the Federal Emergency Management Agency.

How does the study work? We will begin by gathering key demographic information, such as your age, monthly electricity bill, household details, and where you're located. If you qualify, you can start the survey. Initially, we will ask about your backup generator(s) and critical electric appliances. Next, we will see how much you are willing to pay to avoid power outages of varying lengths and impacts. Finally, a short set of questions will be presented for the incentive payment.

Who can participate? To take part in the study, you must be at least 18, live in Puerto Rico, and receive electricity from LUMA Energy. Also, you need information on your home's electricity bills and your LUMA account ID.

Who cannot participate? If you are under 18 years old, live outside of Puerto Rico, and do not receive electricity from LUMA Energy under the specified tariffs, you will be deemed ineligible. If you are unable to provide monthly electricity bills for the periods of December to April and May to November you will be excluded from the survey. We may limit responses from certain groups, such as age, ethnicity, and region, once we have a satisfactory number of responses to make sure the survey represents Puerto Rican households well. Any incoherent, incomplete, or fake answers will not be counted.

How long does the survey take? The survey will take about 20 minutes.

When does the survey close? The survey will close on July 31, 2024.

How do we protect your privacy? Your records will be kept as confidential as possible under the law. However, participation in this study may involve a loss of privacy. The survey responses will be anonymized and analyzed in aggregate. Personal information will be removed before the analysis to protect your privacy.

What are the benefits of this study? This study will help researchers understand the value of electricity service to customers in Puerto Rico during outages and how to avoid them. The study will also give you a chance to think about how to prepare for future power outages.

How will the information from this study be stored and used? The anonymized data will be stored securely at LBNL. Some of the data may be used for future research without asking for further consent from you. Personal information will be used for the incentives, but will not be linked to the survey responses in any way.

Is there a financial incentive to participate in the study? After completion of the survey, you will be compensated with a $20 gift card. To receive this completion bonus, you must not be an employee of LBNL or the U.S. DOE. If you are an employee of another federal government agency,[24] you may be eligible to receive a $20 gift card under 5CFR§2635.204(a). We

[24] "Federal agency" means an Executive agency, military department, a court of the United States, the Administrative Office of the United States Courts, the Library of Congress, the Botanic Garden, the

recommend that you consult with your employer for prior approval before participating in this study, as each agency has specific rules about the receipt of research incentives. You will be asked to attest to the fact that you are eligible to receive payment. We will begin processing your incentive payment at the close of this survey period, which is expected to be July 31, 2024.

For more information about the survey, please contact the research team. This study has been approved by the LBNL's Institutional Review Board (PRO00023334). If you have questions about your legal rights as a participant in the survey, please contact the LBNL Human Subjects Committee (harc@lbl.gov; 510-486-6005).

YOUR PARTICIPATION IS VOLUNTARY, AND YOUR RESPONSES WILL BE ANONYMOUS. You have the right to not take part in this study or to stop taking part at any time. By participating in this study, you are not waiving any legal claims or rights to which you are otherwise entitled. If you choose to withdraw from this study, you may do so at any time and ask for your records to be destroyed. Once the survey is closed and data is de-identified, we cannot remove your records from the dataset as the data cannot identify a specific individual. You may be asked to participate in additional research in the future, but you will be free to refuse to do so.

Do you want to participate in this research and continue with the survey?

○ Yes ○ No

> *[If the respondent selects "No," (s)he will be considered ineligible, and the following prompt will be shown:*
> *"Unfortunately, you have chosen not to participate in the study at this particular time. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please feel free to contact the research team."*
> *If the respondent selects "Yes," (s)he will be directed to the next page.]*

Please answer the following questions to help us determine whether you are eligible:

I live in Puerto Rico.	○ Yes	○ No
I purchase my electricity from LUMA Energy.	○ Yes	○ No
I am at least 18 years old.	○ Yes	○ No
I have read and understand the informed consent.	○ Yes	○ No

> *[If the respondent selects "No", (s)he will be considered ineligible. The following prompt will display:*
> *"Unfortunately, you are not eligible for the study at this particular time. However, we*

Government Publishing Office, the Congressional Budget Office, the United States Postal Service, the Postal Regulatory Commission, the Office of the Architect of the Capitol, the Office of Technology Assessment, and such other similar agencies of the legislative and judicial branches as determined appropriate by the Office of Personnel Management.

would like to thank you for your interest in this research. If you have any questions or concerns, please feel free to contact the research team."

Thank you for your interest in our study. To see if you qualify to participate in the study, we would like to gather some information about you and your household.

E1. What is your age?

- Under 18 years
- 18-29 years
- 30-39 years
- 40-49 years
- 50-59 years
- 60-69 years
- 70 years or older

[If a respondent is under 18, (s)he will be considered ineligible. The following prompt will display when a respondent moves to the next page:
"Unfortunately, you are ineligible to participate in the study. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please contact the research team.]
[To ensure that our survey is representative of households in Puerto Rico, we may restrict some respondents in age groups with sufficient responses from moving to the next page. For those respondents, the following prompt will display when they move to the next page:
"Unfortunately, we have reached the maximum number of responses for this category, so you cannot participate in the study at this specific time. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please contact the research team."]

E2. Roughly how much did you pay for your monthly electricity bill?

Between December and April:

- $0-50/month
- $51-100/month
- $101-200/month
- $201-$350/month
- Above $350 per month
- Don´t know

Between May and November:

- $0-50/month
- $51-100/month
- $101-200/month
- $201-$350/month
- Above $350 per month
- Don´t know

[If a respondent selects "Don´t know" for both questions, (s)he will be considered ineligible. For those respondents, the following prompt will display when they move to the next page:

“Unfortunately, you are ineligible to participate in the study. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please contact the research team."]

E3. Which of the following categories best describes your total annual household income before taxes and other deductions? Please include all household income, including social security, interest, welfare payments, child support, etc.

- Less than $15,000 per year
- $15,000 to $29,999 per year
- $30,000 to $44,999 per year
- $45,000 to $60,000 per year
- Above $60,000 per year

E4. How many people (including yourself) live in your household in each of the following age groups? If there is no one in a specific age group, enter “0.”

Under 18 years: _________
18 to 29 years: _________
30 to 49 years: _________
50 to 69 years: _________
70 years or older: _________

E5. How would you describe your dwelling?

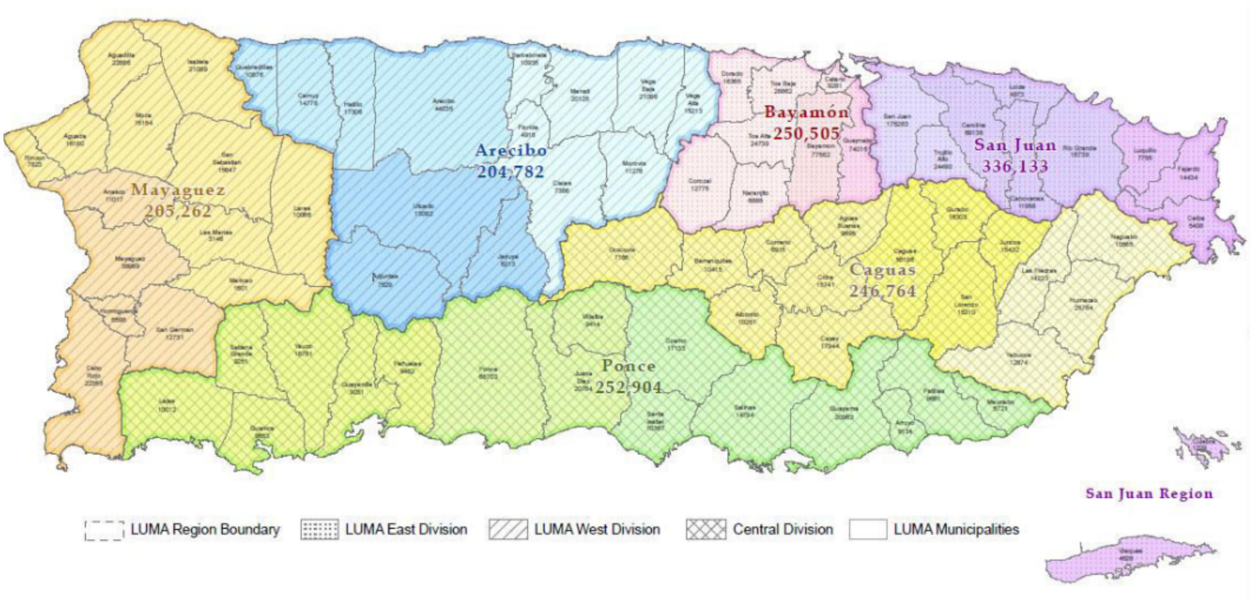
- Single-family detached (including urbanizaciones compuestas de casas)
- Single-family attached (row home or townhouse)
- Apartment or condominium
- Mobile or manufactured home
- Other (please describe) ____

E6. How would you categorize yourself in terms of race or ethnicity? Please select all that apply.

- American Indian or Alaskan Native
- Asian
- Black or African American
- Caucasian
- Hispanic
- Pacific Islander
- Other (please describe) ____
- Prefer not to say

[To ensure that our survey is representative of households in Puerto Rico, we may restrict some respondents in groups with sufficient responses from moving to the next page. For

those respondents, the following prompt will display when they move to the next page: "Unfortunately, we have reached the maximum number of responses for this category, so you cannot participate in the study at this specific time. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please contact the research team."]



E7. In which region of Puerto Rico do you live?

- Arecibo (Adjuntas, Arecibo, Barceloneta, Camuy, Ciales, Florida, Hatillo, Jayuya, Manatí, Morovis, Quebradillas, Utuado, Vega Alta, Vega Baja)
- Bayamón (Bayamón, Cataño, Corozal, Dorado, Guaynabo, Naranjito, Toa Alta, Toa Baja)
- Caguas (Aguas Buenas, Aibonito, Barranquitas, Caguas, Cayey, Cidra, Comerío, Gurabo, Humacao, Juncos, Las Piedras, Naguabo, Orocovis, San Lorenzo, Yabucoa)
- Mayagüez (Aguada, Aguadilla, Añasco, Cabo Rojo, Hormigueros, Isabela, Lares, Las Marías, Maricao, Mayagüez, Moca, Rincón, San Germán, San Sebastián)
- Ponce (Arroyo, Coamo, Guánica, Guayama, Guayanilla, Juana Díaz, Lajas, Maunabo, Patillas, Peñuelas, Ponce, Sabana Grande, Salinas, Santa Isabel, Villalba, Yauco)
- San Juan (Canóvanas, Carolina, Ceiba, Culebra, Fajardo, Loíza, Luquillo, Río Grande, San Juan, Trujillo Alto, Vieques)

[To ensure that our survey is representative of households in Puerto Rico, we may restrict some respondents in groups with sufficient responses from moving to the next page. For those respondents, the following prompt will display when they move to the next page: "Unfortunately, we have reached the maximum number of responses for this category, so you cannot participate in the study at this specific time. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please contact the research team."]

Congratulations! You are eligible to participate in our study. We appreciate your willingness to take part in this important research. Your responses will be kept anonymous.

1. Are you or your household members currently employed?

- Yes
- No

[If a respondent answers "yes," ask the following question]

Do you, or anyone else who lives in your house, work from home?

- Yes
- No

[If a respondent answers "yes," ask the following question]

Do you, or these other household members, need electric power to work at home?

- Yes
- No

2. Do you have backup power (such as a generator or solar panels) for your home?

- Yes
- No

[If a respondent answers "yes," ask the following questions]

What things in your home could you run with this backup power?

- A few lights and the refrigerator
- All the critical electric appliances that I might need, including heaters and cooking appliances
- Whole house
- Do not know

Which of the following do you have? Select all that apply.

- Backup generator
- On-site power generation system
- Solar panel(s) with battery storage
- Solar panel(s) without battery storage
- Battery backup energy storage without solar panels
- Other backup power (non-grid dependent) power source, describe______________________________

[If a respondent selects "backup generator" or "on-site power generation system," ask the following question]

What is the primary fuel source for the generator? Select all that apply.

- Gasoline
- Propane
- Diesel
- Other. Please specify:______________________________

[If a respondent selects gasoline, propane, diesel, or others, ask the following question]

How long can you run your generation system(s) with the fuel you have stored?

_____________ days

[If a respondent selects battery backup energy storage without solar panels, ask the following question]
How long will your home battery backup power your essential appliances on a full charge?

_____________ days

3. Please select all of the appliances and/or devices that are necessary for you or your household members' health:

- ☐ Refrigerator to keep insulin or other medicines at a suitable temperature
- ☐ Respirator/therapy machine
- ☐ Sleep apnea therapy machine
- ☐ Suction equipment
- ☐ Feed pump
- ☐ Others. Please specify:

____

- ☐ Don't have any

[If a respondent selects anything other than "Don't have any," ask the following question]
What would be the maximum duration the selected devices could operate on backup power alone in the absence of electricity from the grid?

- ○ The devices do not have backup power
- ○ Less than one day
- ○ One day to one week
- ○ One week to two weeks
- ○ Two weeks to one month
- ○ Longer than one month but within a defined limit
- ○ Indefinitely

4. Do you have homeowner insurance that covers losses in a power outage?

○ Yes ○ No

[If the respondent answers "yes" ask the following questions]

Your homeowner's insurance might cover power outage damages, but only if the cause is a "covered peril" listed in your policy. Home insurance typically excludes certain events like floods and earthquakes, although you can often add coverage for these with separate policies (think flood insurance or earthquake insurance). Even if your homeowner's insurance applies, the extent of coverage depends on the specific terms of your policy, including coverage limits and deductibles.

How much is your homeowner insurance's deductible?

$ ____________

What is the coverage limit of your policy?

$ ____________

In the sections that follow, we will ask you to think about three different examples of electricity outages that might happen in Puerto Rico. The table below summarizes the scenarios that we will ask about.

	Scenario 1	**Scenario 2**	**Scenario 3**
Outage duration	24 hours	14 days (2 weeks)	30 days (1 month)
Time of year	Weekday(s) in August		
Weather conditions	Typical summer morning	A warm and humid summer day	High winds and heavy rain
Outage geographic scope	Homes and businesses in the neighborhood	Entire region including your residence	Entire island of Puerto Rico
Planned by the utility	No	No	No

Now, we will ask you to answer some questions about the consequences associated with the electricity outages. *There are no right or wrong answers to these questions*. If a question is difficult for you to answer, please give your best guess. At the end of the survey, you can add comments about any of your answers.

Scenario #1: Neighborhood electricity outage lasting one day
It is a typical summer morning in August with clear skies, light winds, and a temperature in the mid-70s. The power in your neighborhood has just gone out with no warning. You find out that an equipment failure has caused an electricity outage to you and other nearby customers. **You are told that the power will be restored by 6:00 AM tomorrow.**

1-1. Which services do you expect to remain operational during this one-day electricity outage?

		Available throughout the outage	Sometimes available	Not available
Public safety	Police	○	○	○
	Fire	○	○	○
	Hospitals	○	○	○
	Emergency shelters and rescue facilities	○	○	○
Transportation	Road	○	○	○
	Rail	○	○	○
	Airports	○	○	○
	Ports	○	○	○
Utilities	Fuel (gasoline, diesel, natural gas, etc.)	○	○	○
	Water	○	○	○
	Wastewater treatment	○	○	○
Communications	Broadcast networks (radio/televisions)	○	○	○
	Cellular and landline telephone networks	○	○	○
	Cable services	○	○	○
	Satellite communication services	○	○	○
	Broadband internet	○	○	○
Essential services	Pharmacies	○	○	○
	Grocery and convenience stores	○	○	○
	Food warehouse	○	○	○
	Banks and ATMs	○	○	○

1-2. Please select all the steps that you would take to adjust to the one-day electricity outage.

☐ Stay home and do activities that do not require electricity

☐ Run your backup power source using the fuel you have stored to meet your most important electrical needs *[option only available if Q3 in the previous section was answered with “yes”]*
☐ Go to a nearby place that has electricity
☐ Use your non-electric cooking appliances for cooking perishable food (for example, a propane/gas stove or grill)
☐ Other

[If a respondent selects “Other,” ask the following question]
Please describe what other steps you would take to adjust to the electricity outage.

1-3. Which of these responses best describes how you would respond to this electricity outage?
○ I have a backup power source or can borrow one; therefore, I would be able to generate some electricity during the electricity outage.
○ I would be able to stay at the home of someone else who still has power or at a business location in a part of town where the power is on.
○ I would not be able to produce electricity or go to other places that have electricity.

[If a respondent answers “I can generate some electricity,” show the following question]
Considering the effects of the electricity outage that have been mentioned so far and any other effects of the electricity outage on your household, how much would this one-day electricity outage cost your household? Please only include the costs that would directly result from this electricity outage, not the costs that your household would have had to pay even if there was no electricity outage.

Costs resulting from the one-day electricity outage	**Cost estimate**
Cost of additional supplies purchased because of the electricity outage (e.g., batteries, candles, battery-powered radio, bottled water, etc.)	$
Cost of fuel to run a generator	$
Cost of fuel for alternative non-electric cooking devices that you would only use because of the outage	$
Other costs because of the one-day electricity outage	$

[If a respondent answers “my home will not have electricity, but I can stay at a neighbor’s home or a business that still has power,” show the following question]
Considering the effects of the electricity outage that have been mentioned so far and any other effects of the electricity outage on your household, how much would this one-day electricity outage cost your household? Please only include the expenses that would directly result from this electricity outage, not the costs that your household would have had to pay even if there was no electricity outage.

Costs resulting from the one-day electricity outage	**Cost estimate**

Cost of additional supplies purchased because of the outage (e.g., batteries, candles, battery-powered radio, bottled water)	$
Cost of staying at a neighbor's home or business	$
Costs of spoiled food	$
Other costs because of the one-day electricity outage, including the cost to travel	$

[If a respondent answers "I would not have access to electricity at all," show the following question]

Considering the effects of the electricity outage that have been mentioned so far and any other effects of an electricity outage on your household, how much would this one-day electricity outage cost your household? Please only include the costs that would directly result from this electricity outage, not the costs that your household would have had to pay even if there was no electricity outage.

Costs resulting from the one-day electricity outage	**Cost estimate**
Cost of additional supplies purchased because of the outage (e.g., batteries, candles, battery-powered radio, bottled water)	$
Cost of fuel for alternative non-electric cooking devices that you would only use because of the outage	$
Costs of spoiled food	$
Other costs because of the one-day electricity outage	$

[Question only for respondents who stated that they have homeowner insurance that covers power outages]

What portion of the costs do you expect to be covered by your insurance?

$ ______________ of the loss covered by the insurance after paying $ ______________ deductible

[Display the following question only to respondents who said they or their household members are currently employed in Question 1]

1-4. If the power goes out at your home and a few nearby homes for one day, will you and/or your household members' employers pay you? Please select all that apply.

- ☐ My work, or other household members' work, would not be affected by this electricity outage.
- ☐ I and/or other household members could not go to work, but would not lose any pay.
- ☐ I and/or other household members could make up the missed work later and get paid.
- ☐ I and/or other household members could not go to work and would not get paid.

[If a respondent answers "Could not go to work and would not get paid," ask the following]

How much in wages would your household expect to lose during the one-day electricity outage?

The household would lose $ ___________ in wages

1-5. Suppose there is a nearby company that can rent you a generator during the electricity outage. The generator will provide all the electric power you need during the outage. Considering the financial losses you would incur and the value of having all your appliances operating during the outage, how much would you be willing to pay for a generator rental service like this during this one-day electricity outage?

For each of the following questions, please indicate whether you would be willing to pay the amount of money stated. For example, consider the first row of the table: Would you be willing to pay $10 or less in exchange for the backup generator service? If yes, please check the "Yes" box. If you are not sure, please check the "Not sure" box. If no, please check the "No" box. Do the same thing for the remaining rows of the table.

Summary of the outage
Time of year: August, weekday
Start time: Typical summer morning
Duration: 24 hours
Affected areas: Your neighborhood

	Would you be willing to pay at least this amount extra ***per day*** to get the full backup service during the electricity outage?		
	Yes	Not sure	No
Less than $5 per day	❑	❑	❑
$5-9.99 per day	❑	❑	❑
$10-14.99 per day	❑	❑	❑
$15-19.99 per day	❑	❑	❑
$20-24.99 per day	❑	❑	❑
$25-29.99 per day	❑	❑	❑
$30-$34.99 per day	❑	❑	❑
$35-$39.99 per day	❑	❑	❑
$40-$44.99 per day	❑	❑	❑
$45-$49.99 per day	❑	❑	❑
More than $50 per day	❑	❑	❑

[If a respondent selects "yes" to "more than $50 per day," ask the following question]

What is the largest amount you would be willing to pay *per day* to receive backup generator service for one day?
$ ___________ per day

1-6. During the electricity outage, some essential services like hospitals and water treatment plants may run out of fuel for their backup generators after a few days. This could lead to these services becoming unavailable. Imagine a situation where everyone in the community pitches in to help those who cannot afford backup electricity or essential social services. This would allow everyone to have additional limited electric service during the outage. If all of your neighbors who can afford to pay contribute the same amount as you, would you be willing to pay an extra amount of money to provide backup electricity services during this one-day electricity outage to those in need? This would be a one-time payment during the outage only.

◯ Yes ◯ No

[If a respondent answers "yes," ask the following question]

What would you pay to provide backup services to the most vulnerable members of your community?

$___________ additional payment

Scenario #2: Regional electricity generation outage lasting two weeks

On a summer morning in August, a series of earthquakes occurred off the northern coast of San Juan, Puerto Rico. Electricity generation infrastructure was damaged due to the residual effects of the earthquake. While your organization and its neighborhood were not directly damaged by the earthquake, the event caused an outage affecting the region where your organization is located. After a few hours, the government of Puerto Rico announced that it would take two weeks to clean up debris on major roads, repair the Port of San Juan, which was significantly damaged, replace critical components of power plants, and restore power to your home and most other communities served by your organization.

2-1. Which services do you expect to remain operational during this two-week outage?

		Available throughout the outage	Sometimes available	Not available
Public safety	Police	○	○	○
	Fire	○	○	○
	Hospitals	○	○	○
	Emergency shelters and rescue facilities	○	○	○
Transportation	Road	○	○	○
	Rail	○	○	○
	Airports	○	○	○
	Ports	○	○	○
Utilities	Fuel (gasoline, diesel, natural gas, etc.)	○	○	○
	Water	○	○	○
	Wastewater treatment	○	○	○
Communications	Broadcast networks (radio/television)	○	○	○
	Cellular and landline telephone networks	○	○	○
	Cable services	○	○	○
	Satellite communication services	○	○	○
	Broadband internet	○	○	○
Essential services	Pharmacies	○	○	○
	Grocery and convenience stores	○	○	○
	Food warehouse	○	○	○
	Banks and ATMs	○	○	○

2-2. Please choose all the steps that you would take to adjust to this two-week-long electricity generation outage.

- ☐ Stay home and do activities that do not require electricity
- ☐ Run your backup power source, using fuel you have stored, to power essential electrical demands
- ☐ Visit or stay at a friend or neighbor's home that has a backup generator and stored fuel
- ☐ Use your non-electric cooking appliances for cooking perishable food (for example, propane/gas stove or grill)
- ☐ Other

[If a respondent selects "Other," ask the following question]
Please describe what steps you will take to adjust to this electricity generation outage.

[Follow-up question for all respondents]
What percentage of your normal activities could you continue during the outage?
________ % of the normal activities

2-3. Which of these responses best describes how you would respond to this electricity generation outage?

- ○ I have a backup power source that could generate electricity during the electricity generation outage. (Note: you should assume that you cannot purchase a backup generator from a store if you do not already have one)
- ○ I would not have electricity at my house, but I would be able to visit or stay at the home of someone with a generator.
- ○ I would not be able to produce electricity or go to other places that have a generator.

[If a respondent answers "I would be able to generate some electricity during the electricity generation outage," ask the following question]

Considering the effects of the electricity generation outage that have been mentioned so far and any other effects of the electricity generation outage on your household, how much would this two-week-long electricity generation outage cost your household? Please only include the costs that would directly result from this electricity generation outage, not the costs that your household would have to pay even if there was no electricity generation outage.

Costs of the two-week-long electricity generation outage	**Cost estimate**
Cost of additional supplies, batteries, etc. purchased because of the outage	$
Cost of fuel to run a generator for up to 14 days	$
Cost of fuel for alternative non-electric cooking that you would only use because of the outage	$
Other costs because of the two-week-long electricity generation outage	$

[If a respondent answers "I would be able to stay with someone else's house," ask the following question]

Considering the effects of the electricity generation outage that have been mentioned so far and any other effects of the electricity generation outage on your household, how much would this two-week-long electricity generation outage cost your household? Please only include the costs that would directly result from this electricity generation outage, not the costs that your household would have to pay even if there was no electricity generation outage.

Costs of the two-week-long electricity generation outage	**Cost estimate**
Cost of additional supplies, batteries, etc. purchased because of the outage	$
Cost of staying at a neighbor's home or business	$
Cost of fuel for alternative non-electric cooking devices that you would only use because of the outage	$
Costs of spoiled food	$
Other costs because of the two-week-long electricity generation outage, including the cost to travel	$

[If a respondent answers "I would not be able to produce electricity or go to other places that have electricity," ask the following question]

Considering the effects of the electricity generation outage that have been mentioned so far and any other effects of the electricity generation outage on your household, how much would this two-week-long electricity generation outage cost your household? Please only include the costs that would directly result from this electricity generation outage, not the costs that your household would have to pay even if there was no electricity generation outage.

Costs of the two-week-long electricity generation outage	**Cost estimate**
Cost of additional supplies, batteries, etc. purchased because of the outage	$
Cost of fuel for alternative non-electric cooking devices that you would only use because of the outage	$
Costs of spoiled food	$
Other costs because of the two-week-long electricity generation outage	$

[Question only for respondents who stated that they have homeowner insurance that covers power outages]

What portion of the costs do you expect to be covered by your insurance?

$ _____________ of the loss covered by the insurance after paying $ _____________ deductible

[Display the following question only to respondents who said they or their household members are currently employed in Question 1]

2-4. If the power goes out in the island of Puerto Rico for two weeks, will you and/or your household members' employers pay you? Please select all that apply.

- ☐ My work, or other household members' work, would not be affected by this electricity generation outage.
- ☐ I and/or other household members could not go to work but would not lose any pay.
- ☐ I and/or other household members could make up the missed work time and get paid.
- ☐ I and/or other household members could not go to work and would not get paid.

[If a respondent answers "Could not go to work and would not get paid," ask the following]
How much in wages would your household expect to lose during the two-week-long electricity generation outage?

The household would lose $ ___________ in wages

2-5. How much would you pay for full emergency backup electricity service during the two-week-long electricity generation outage? Consider the financial losses you would incur and the value of having all your appliances operating during the outage.

Summary of the outage
Time of year: August, weekday
Start time: Warm and humid morning
Duration: 14 days (2 weeks)
Affected areas: Entire region, including your residence

	Would you be willing to pay at least this amount extra ***per day*** to get the full backup service during the electricity generation outage?		
	Yes	Not sure	No
Less than $5 per day	❑	❑	❑
$5-9.99 per day	❑	❑	❑
$10-14.99 per day	❑	❑	❑
$15-19.99 per day	❑	❑	❑
$20-24.99 per day	❑	❑	❑
$25-29.99 per day	❑	❑	❑
$30-$34.99 per day	❑	❑	❑
$35-$39.99 per day	❑	❑	❑
$40-$44.99 per day	❑	❑	❑
$45-$49.99 per day	❑	❑	❑
More than $50 per day	❑	❑	❑

[If a respondent selects "yes" to "more than $50 per day," ask the following question]

What is the largest amount you would be willing to pay *per day* to receive backup generator service for two weeks?

$ ___________ per day

2-6. Would you be willing to contribute an extra amount of money to help provide backup electricity generation services to community facilities without backup power or members of your community who might not have enough money for the service? This would be during the two-week-long electricity generation outage only, and all of your neighbors who can afford to pay will contribute the same amount.

○ Yes ○ No

[If a respondent answers "yes," ask the following question]

What would you pay to provide backup services to the most vulnerable members of your community?

$ ___________ additional payment

Scenario #3: Island-wide electricity outage lasting one month

In August, a major hurricane made landfall in Puerto Rico's southeast, between the municipalities of Humacao and Guayama, knocking out power islandwide. The storm brought high winds and heavy rain as well as widespread flooding and mudslides. Many homes and businesses were damaged. After 24 hours, the storm exited to the northwest, leaving behind significant damage to the island's electricity infrastructure. While your home and neighborhood were not directly in the hurricane's path, LUMA Energy and the government anticipated a month-long recovery period to clear debris, repair damaged infrastructure, and restore electricity service to your community and most others across the island.

3-1. Which services do you expect to remain operational during this one-month outage?

		Available throughout the outage	Sometimes available	Not available
Public safety	Police	◯	◯	◯
	Fire	◯	◯	◯
	Hospitals	◯	◯	◯
	Emergency shelters and rescue facilities	◯	◯	◯
Transportation	Road	◯	◯	◯
	Rail	◯	◯	◯
	Airports	◯	◯	◯
	Ports	◯	◯	◯
Utilities	Fuel (gasoline, diesel, natural gas, etc.)	◯	◯	◯
	Water	◯	◯	◯
	Wastewater treatment	◯	◯	◯
Communications	Broadcast networks (radio/televisions)	◯	◯	◯
	Cellular and landline telephone networks	◯	◯	◯
	Cable services	◯	◯	◯
	Satellite communication services	◯	◯	◯
	Broadband internet	◯	◯	◯
Essential services	Pharmacies	◯	◯	◯
	Grocery and convenience stores	◯	◯	◯
	Food warehouse	◯	◯	◯

	Banks and ATMs	○	○	○

3-2. Please select all the steps that you would take to adjust to this one-month-long electricity outage. (Note: assume you cannot buy a backup generator or additional fuel from local stores).

☐ Stay home and do activities that do not require electricity

☐ Run your backup power source, using the fuel you have stored, to power essential electrical demands

☐ Use your non-electric cooking appliances for cooking perishable food (for example, propane/gas stove or grill)

☐ Rely on perishable food stored in your (or your friends') refrigerator/freezer, non-perishable food, bottled water, and distributed essential supplies

☐ Temporarily move to other places with backup power within Puerto Rico, including other homes or emergency shelters

☐ Other

[If respondent select "Other," ask the following question]
Please describe what other steps you will take.

[Follow-up question for all respondents]
What fraction of your normal activities could you continue during the outage?
________ % of normal activities

3-3. Considering the consequences of the electricity outage and the steps you would take to adjust to the electricity outage, how much would this one-month-long electricity outage cost your household? Please consider only the costs that would directly result from this electricity outage, not the costs that your household would have to pay regardless of the electricity outage.

Costs incurred because of the one-month-long electricity outage	**Cost estimate**
Cost of additional supplies, food, batteries, etc. purchased because of the outage	$
Cost of fuel to run a backup power source for up to 30 days	$
Cost of fuel for alternative non-electric cooking devices that you would only use because of the outage	$
Costs of spoiled food	$
Other costs because of the one-month-long electricity outage	$

[Question only for respondents who stated that they have homeowner insurance that covers power outages]
What portion of the costs do you expect to be covered by your insurance?
$ _____________ of the loss covered by the insurance after paying $ _____________ deductible

[Display the following question only to respondents who said they or their household members are currently employed in Question 1]

3-4. If the power goes out in Puerto Rico for one month, will you and/or your household members' employers pay you? Please select all that apply.

- ☐ My work, or other household members' work, would not be affected by this electricity outage.
- ☐ I and/or other household members could not go to work, but would not lose any pay.
- ☐ I and/or other household members could make up the missed work later and get paid.
- ☐ I and/or other household members could not go to work and would not get paid.

[If a respondent answers "Could not go to work and would not get paid," ask the following] How much in wages would your household expect to lose during the one-month-long electricity outage?

The household would lose $ ___________ in wages

3-5. How much would you pay for full emergency backup electricity service during the one-month electricity outage? Consider the financial losses you would incur and the value of having all your appliances operating during the outage.

Summary of the outage
Time of year: August, weekday
Start time: Summer morning with high winds and heavy rainfall
Duration: 30 days (1 month)
Affected areas: All of Puerto Rico

	Would you be willing to pay at least this amount extra ***per day*** to get the full backup service during the electricity outage?		
	Yes	Not sure	No
Less than $5 per day	❑	❑	❑
$5-9.99 per day	❑	❑	❑
$10-14.99 per day	❑	❑	❑
$15-19.99 per day	❑	❑	❑
$20-24.99 per day	❑	❑	❑
$25-29.99 per day	❑	❑	❑
$30-$34.99 per day	❑	❑	❑
$35-$39.99 per day	❑	❑	❑
$40-$44.99 per day	❑	❑	❑
$45-$49.99 per day	❑	❑	❑
More than $50 per day	❑	❑	❑

[If a respondent selects "yes" to "more than $50 per day," ask the following question]

What is the largest amount you would be willing to pay *per day* to receive backup generator service for one month?
$ ___________ per day

3-6. Would you be willing to contribute an extra amount of money to help provide backup electricity services to community facilities without backup power or members of your community who might not have enough money for the service? This would be during the one-month-long electricity outage only, and all of your neighbors who can afford to pay will contribute the same amount.

○ Yes ○ No

[If a respondent answers "yes," ask the following question]

What would you pay to provide backup services to the most vulnerable members of your community?

$ ___________ additional payment

Thanks for your participation in this valuable study. For the final questions, we would like to hear your thoughts on the study and collect some information for your incentive payment.

1. Please share any additional comments:

2. Please provide your first and last name.

____

[If a respondent does not provide his/her name, a respondent receives the following question]
If you do not provide us with your first and last name, you **cannot** receive your completion bonus. Do you want to proceed without entering your name?

- Yes
- No

[If a respondent answers "yes," (s)he will be directed to the completion page. If a respondent answers "no," (s)he will be directed to the previous page.]

3. Please provide your email address.

____

Retype your email address to confirm: ______________________________

[If a respondent does not provide his/her email address, a respondent receives the following question]
If you do not provide us with your email address, you **cannot** receive your completion bonus. Do you want to proceed without entering your email address?

- Yes
- No

[If a respondent answers "yes," (s)he will be directed to the completion page. If a respondent answers "no," (s)he will be directed to the previous page.]

4. Please provide your LUMA account ID.

____

[If a respondent does not provide his/her LUMA account ID, a respondent receives the following question]
If you do not provide us with your LUMA account ID, you cannot receive your completion bonus. Do you want to proceed without entering your LUMA account ID?

- Yes
- No

[If a respondent answers "yes," (s)he will be directed to the completion page. If a respondent answers "no," (s)he will be directed to the previous page.]

5. To receive this $20 gift card, you must not be an employee of LBNL or the U.S. Department of Energy. Federal employees of a different agency may be eligible for the gift card, however, you will be asked further questions about your eligibility. Before we wrap up, please answer the following question to verify your eligibility.

- I am **not** an employee of LBNL or any other federal agency.
- I am an employee of LBNL or the U.S. Department of Energy.
- I am an employee of some other U.S. federal government agency.

[If a respondent responds, "I am an employee of LBNL or the U.S. DOE," we will not process a respondent's completion bonus]

[If a respondent answers "I am not an employee of LBNL or any other federal agency," ask the following questions]
In some cases, you may not be allowed to receive the completion bonus because of your organization's internal policies. Please confirm that you can receive the gift card.

- I can receive the $20 gift card based on my organization's internal policies.
- I can only accept a $20 gift card, as permitted by the exceptions in 5 CFR §2635.204(a), Exceptions to the prohibition for acceptance of certain gifts.
- I cannot receive the gift card based on my organization's internal policies.

[If a respondent answers "I can receive the gift card based on my organization's internal policies," ask the following question]

By typing your name in the box below, you attest that the above response is true.

Please specify the type of gift card you would prefer from the following options.

- Amazon
- Marshalls
- Walmart

[If a respondent is eligible to receive a gift card, show the following]
Thank you. You will receive your gift card via the email address you provided within 10 business days.

[*If a respondent is not eligible to receive a gift card, show the following*]
Thank you. Due to your status [as an employee of LBNL or DOE/ as a federal employee who cannot receive a gift card based on your organization's internal policies] you will not receive a gift card. If you feel this statement is in error, please contact the research team).

Appendix B. SMNR Survey Instruments

Below is the survey instrument used to assess CICs among SMNR electricity customers in Puerto Rico. While the attached instrument is in English, the surveys were administered in both Spanish and English, allowing respondents to switch between languages as needed.

Puerto Rico Customer Power Outage Cost Survey: Small and Medium Non-residential Customers

We are a group of researchers from Lawrence Berkeley National Laboratory (LBNL), the Institute for Building Technology (IBTS), and LUMA Energy. The purpose of this study is to understand how electricity outages affect electricity customers in Puerto Rico. This research is funded by the Federal Emergency Management Agency (FEMA).

How does the study work? We will begin by collecting information about your business, including its industry, electricity bill, and geographic location. If you qualify, you can start the survey. Initially, we will ask about your business operations, any backup generators you have, and whether you have business interruption insurance. Next, we will ask you to estimate the cost of power outages of varying lengths and impacts. Finally, we will ask you a short set of questions for the incentive payment.

Who can participate? You must operate or manage a business in Puerto Rico, and receive electricity from LUMA Energy.. Also, you should be aware of, and responsible for, the organization’s management and operations, including paying the electricity bills. You will also need the LUMA account ID.

Who cannot participate? If respondents' first and last names or email addresses do not match those of commercial electricity customers of LUMA under the specified tariffs, their responses will be deemed ineligible. Respondents unable to provide monthly electricity bills for the periods of December to April and May to November will also be excluded from the survey. We may restrict responses from specific groups, such as industry type and region, once a sufficient number of responses have been received to ensure the survey's representativeness of Puerto Rican businesses. Furthermore, any responses deemed incoherent, incomplete, or fraudulent will be excluded from the dataset and not considered for incentive payment.

How long does the survey take? The survey will take about 25 minutes.

When does the survey close? The survey will close on September 30, 2024.

How do we protect your privacy? Your records will be kept as confidential as possible under the law. However, participation in this study may involve a loss of privacy. The survey responses will be anonymized and analyzed in aggregate. Personal information will be removed before the analysis to protect your privacy.

What are the benefits of this study? This study will help researchers understand the value of electricity service to customers in Puerto Rico during outages and how to avoid them. The study will also give your organization a chance to think about how to prepare for future power outages.

How will the information from this study be stored and used? The anonymized data will be stored securely at LBNL. Some of the data may be used for future research without asking for further consent from you. Personal information will be used for the incentives, but will not be linked to the survey responses in any way.

Is there a financial incentive to participate in the study? After completion of the survey, you will be compensated with a $70 gift card. To receive this completion bonus, you must not be an employee of LBNL or the U.S. DOE. If you are an employee of another federal government agency,[25] you may be eligible to receive a $20 gift card under 5CFR§2635.204(a). We recommend that you consult with your employer for prior approval before participating in this study, as each agency has specific rules about the receipt of research incentives. You will be asked to attest to the fact that you are eligible to receive payment. We will begin processing your incentive payment at the close of this survey period, which is expected to be September 30, 2024.

For more information about the survey, please contact the research team. This study has been approved by the LBNL's Institutional Review Board (PRO00023334). If you have questions about your legal rights as a participant in the survey, please contact the LBNL Human Subjects Committee (harc@lbl.gov; 510-486-6005).

YOUR PARTICIPATION IS VOLUNTARY, AND YOUR RESPONSES WILL BE ANONYMOUS. You have the right to not take part in this study or to stop taking part at any time. By participating in this study, you are not waiving any legal claims or rights to which you are otherwise entitled. If you choose to withdraw from this study, you may do so at any time and ask for your records to be destroyed. Once the survey is closed and data is de-identified, we cannot remove your records from the dataset as the data cannot identify a specific individual. You may be asked to participate in additional research in the future, but you will be free to refuse to do so.

Do you want to participate in this research and continue with the survey?

○ Yes ○ No

[If the respondent selects "No," (s)he will be considered ineligible, and the following prompt will be shown:
"Unfortunately, you have chosen not to participate in the study at this particular time. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please feel free to contact the research team."
If the respondent selects "Yes," (s)he will be directed to the next page.]

Please answer the following questions to help us determine whether you are eligible:

I operate or manage a business in Puerto Rico.	○ Yes	○ No
My business purchases electricity from LUMA Energy.	○ Yes	○ No
I have read and understand the informed consent.	○ Yes	○ No

[If the respondent answers "No" to any of the questions, (s)he will be considered ineligible, and the following prompt will be shown:
"Unfortunately, you are not eligible for the study at this particular time. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please feel free to contact the research team."

[25] "Federal agency" means an Executive agency, military department, a court of the United States, the Administrative Office of the United States Courts, the Library of Congress, the Botanic Garden, the Government Publishing Office, the Congressional Budget Office, the United States Postal Service, the Postal Regulatory Commission, the Office of the Architect of the Capitol, the Office of Technology Assessment, and such other similar agencies of the legislative and judicial branches as determined appropriate by the Office of Personnel Management.

Which of the following best describes your responsibility for operational decisions for your business? Please select one response that best describes your role.

- I am solely responsible for making financial decisions.
- I share responsibility for making financial decisions.
- I am not actively involved in making financial decisions, but I am asked for my opinion about them.
- Someone else makes most or all of the financial decisions without asking for my opinion.

[If the respondent selects option 4, (s)he will be considered ineligible, and the following prompt will be shown:

"Unfortunately, you are not eligible for the study at this particular time. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please feel free to contact the research team."

Thank you for your interest in our study. To see if you qualify to participate in the study, we would like to gather some information about your business characteristics. Your responses are confidential; results will be reported in aggregate only.

E1. Which of the following categories best describes your business?

- ○ Accommodation and food services (including restaurants, bars, clubs, and lodging)
- ○ Administrative and support services
- ○ Arts, entertainment, and recreation
- ○ Construction
- ○ Educational services
- ○ Finance and insurance
- ○ Health care and social assistance
- ○ Information (e.g., publishing, broadcasting, and telecommunication except for internet, data processing and hosting, software publishing, etc.)
- ○ Manufacturing (including food and beverage processing)
- ○ Management of companies and enterprises
- ○ Professional, scientific, and technical services (e.g., legal, accounting, design services, etc.)
- ○ Real estate, rental, and leasing
- ○ Retail
- ○ Tourism services
- ○ Transportation and warehousing
- ○ Utilities
- ○ Wholesale trade
- ○ Other. Please describe:

____

[To ensure that our survey is representative of businesses in Puerto Rico, we may restrict some respondents in industry categories with sufficient responses from moving to the next page. For those respondents, the following prompt will display when they move to the next page:
"Unfortunately, we have reached the maximum number of responses for this category, so you cannot participate in the study. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please contact the research team."]

E2. Roughly how much does your business pay for its monthly electricity bill during the following months?

Between December and April: $_____________ /month
Between May and November: $_____________ /month

[If a respondent skips both questions, (s)he will be considered ineligible. The following prompt will display when (s)he moves onto the next page:

“Unfortunately, you are ineligible to participate in the study. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please contact the research team."]

E3. In which region of Puerto Rico is your business located?

- Arecibo (Adjuntas, Arecibo, Barceloneta, Camuy, Ciales, Florida, Hatillo, Jayuya, Manatí, Morovis, Quebradillas, Utuado, Vega Alta, Vega Baja)
- Bayamón (Bayamón, Cataño, Corozal, Dorado, Guaynabo, Naranjito, Toa Alta, Toa Baja)
- Caguas (Aguas Buenas, Aibonito, Barranquitas, Caguas, Cayey, Cidra, Comerío, Gurabo, Humacao, Juncos, Las Piedras, Naguabo, Orocovis, San Lorenzo, Yabucoa)
- Mayagüez (Aguada, Aguadilla, Añasco, Cabo Rojo, Hormigueros, Isabela, Lares, Las Marías, Maricao, Mayagüez, Moca, Rincón, San Germán, San Sebastián)
- Ponce (Arroyo, Coamo, Guánica, Guayama, Guayanilla, Juana Díaz, Lajas, Maunabo, Patillas, Peñuelas, Ponce, Sabana Grande, Salinas, Santa Isabel, Villalba, Yauco)
- San Juan (Canóvanas, Carolina, Ceiba, Culebra, Fajardo, Loíza, Luquillo, Río Grande, San Juan, Trujillo Alto, Vieques)

[To ensure that our survey is representative of electricity customers in Puerto Rico, we may restrict some respondents in groups with sufficient responses from moving to the next page. For those respondents, the following prompt will display when they move to the next page: “Unfortunately, we have reached the maximum number of responses for this category, so you cannot participate in the study at this specific time. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please contact the research team."]

Congratulations! You are eligible to participate in our study. We appreciate your willingness to take part in this important research. Your responses will be kept anonymous.

1. Please describe the products or services that your business provides.

2. How many of each type of employee currently work at your business at this location?

Full-time employees	___________
Part-time employees	___________
Seasonal employees	___________
Other (contract or 1099)	___________

3. If you were told that the power would likely be out for 24 hours or more, would any employees be told not to come to work?

- Yes
- No

[If a respondent answers "yes," ask the following question]

What percentage of the employees would be told **not to come to work** during the outage?

___________ %

4. Do you have backup power (such as a generator or solar panels with storage) for your business?

- Yes
- No

[If a respondent answers "yes," ask the following questions]

Which of the following does your organization have (select all that applies):

- Backup generators
- On-site power generation system
- Solar panel(s) with battery storage
- Solar panel(s) without battery storage
- Battery backup energy storage without solar panels
- Other backup power (non-grid dependent) power source, describe_________________
- None

[If a respondent selects any option other than "none," ask the following question]

What percentage of your normal operations can be powered by this power generation system?

_____________ %

[If a respondent selects "backup generators" or "on-site power generation system," ask the following question]

What is the primary fuel source for the generator? Select all that apply.

- Gasoline
- Propane
- Diesel
- Other. Please specify: ____

[If a respondent responds gasoline, propane, diesel, or others as the fuel source(s), ask the following question]
How long can you run your generation system(s) with the fuel you have stored?

_____________ days

[If a respondent selects battery backup energy storage without solar panels, ask the following question]
How long will your business battery backup power your essential appliances on a full charge?

_____________ days

5. How many locations does your business have?

- Single location
- Multiple locations, all in Puerto Rico
- Multiple locations, both within and outside of Puerto Rico

[If a respondent answers "multiple locations, all in Puerto Rico" or "multiple locations, both within and outside Puerto Rico," ask the following questions]
When your location experiences an electricity outage, could you transfer work to locations outside of Puerto Rico that have access to power or other locations within Puerto Rico that have backup power?

- Yes
- No

6. Please indicate where key suppliers for your business are located.

- Only within Puerto Rico
- Only outside of Puerto Rico
- Both within and outside of Puerto Rico

7. Please indicate where your primary customers live.

- Only within Puerto Rico
- Only outside of Puerto Rico
- Both within and outside of Puerto Rico

8. Has your business purchased business interruption insurance?

- Yes
- No

[If a respondent answers "yes," display the following sentences]
Your insurance policy may help your business cover some of the losses that result from an electricity outage. However, you will have to pay your insurance deductible first. Also, your insurance may cover only certain types of damage (for example, property damage, limited business interruption losses, spoilage).

How much is your organization's interruption insurance deductible? $ _____________

What is the coverage limit of your policy? $ ____________

In the sections that follow, we will ask you to think about three different examples of electricity outages that might happen in Puerto Rico. The table below summarizes the scenarios that we will ask about.

	Scenario 1	**Scenario 2**	**Scenario 3**
Outage duration	24 hours	14 days (2 weeks)	30 days (1 month)
Time of year	Weekday(s) in August		
Weather conditions	Typical summer morning	A warm and humid summer day	High winds and heavy rain
Outage geographic scope	Homes and businesses in the neighborhood	Entire region(s) where you operate	Entire island of Puerto Rico
Planned by the utility	No	No	No

We will first describe each outage scenario in detail and then ask you some questions about the costs and savings associated with the outage. There are no right or wrong answers to these questions. If a question is difficult for you to answer, please give your best guess. At the end of the survey, you can add comments about any of your answers.

Scenario #1: Neighborhood electricity outage lasting one day
It is a typical summer morning in August with clear skies, light winds, and a temperature in the mid-70s. The power in your neighborhood has just gone out with no warning. You find out that an equipment failure has caused an electricity outage to your organization and other nearby customers. **You are told that the power will be restored by 6:00 AM tomorrow.**

1-1. Which services do you expect to remain operational during this one-day electricity outage?

		Available throughout the outage	Sometimes available	Not available
Public safety	Police	○	○	○
	Fire	○	○	○
	Hospitals	○	○	○
	Emergency shelters and rescue facilities	○	○	○
Transportation	Road	○	○	○
	Rail	○	○	○
	Airports	○	○	○
	Ports	○	○	○
Utilities	Fuel (gasoline, diesel, natural gas, etc.)	○	○	○
	Water	○	○	○
	Wastewater treatment	○	○	○
Communications	Broadcast networks (radio/television)	○	○	○
	Cellular and landline telephone networks	○	○	○
	Cable services	○	○	○
	Satellite communication services	○	○	○
	Broadband internet	○	○	○
Essential services	Pharmacies	○	○	○
	Grocery and convenience stores	○	○	○
	Food warehouse	○	○	○
	Banks and ATMs	○	○	○

1-2. Would this one-day-long electricity outage affect your main suppliers?

○ Yes ○ No

1-3. Would this one-day-long electricity outage affect customer demand for goods and services that your business provides?

- There would likely be an increase in customer demand.
- There would likely be a decrease in customer demand.
- There would likely be no change in customer demand.

[If a respondent answers "there would likely be an increase in demand," ask the following question]
Please estimate, in terms of revenue, the expected increase in customer demand during the one-day outage.

_____________ % increase

[If a respondent answers "there will likely be a decrease in demand," ask the following question]
Please estimate, in terms of revenue, the expected decrease in customer demand during the one-day outage.

_____________ % decrease

1-4. *[Below are alternative prompts based on how a respondent answered Q5 regarding backup power sources]*

[Prompt for respondents who answer Q5 by stating that the business does not have a backup generation system]
Without backup generation, your business will not be able to operate most of its electrical equipment during an electricity outage. However, you may be able to continue some operations that do not require electricity.
[Alternative prompts for respondents who answer Q5 by stating that their business has a backup generation system and can resume operation]:
Your backup power can be used to resume some operations during an electricity outage. You may also be able to resume operations that do not require electricity.

[Question to be asked following the appropriate prompt is displayed]
What percentage of normal operations could you continue during the one-day outage?
_____________ % of the normal operations

1-5. Can you make up for the lost production after the power comes back on?

- Yes
- No

[If a respondent answers "yes," ask the following questions]
What percentage of lost production of goods and/or services could you recover, in terms of revenue?
_____________ % of the lost production of goods and/or services

How much would it cost your business, in dollars, to make up for the backlog of work resulting from the electricity outage, for example, by working overtime or extra shifts?
$_____________

1-6. Overall, how much revenue, in dollars, would your business lose during and after the electricity outage (for example, from lost sales of goods and/or services)? If your business will not be affected by the outage or is expected to benefit from the electricity outage, enter zero.

$ ______________ lost revenue from the electricity outage

1-7. Would there be any costs of the electricity outage from damage to raw materials and/or inventory, including perishable food that could spoil?

○ Yes ○ No

[If a respondent answers "yes," ask the following question]

Please estimate a dollar amount for the damage cost to raw materials and/or inventory.

$ ______________ damage to raw materials and/or inventory

1-8. Sudden electricity outages can damage equipment. Would your business be likely to have any damage costs from this one-day-long electricity outage, such as costs for damage to sensitive electrical or mechanical devices?

○ Yes ○ No

[If a respondent answers "yes," ask the following question]

Please estimate a dollar amount for the damage to equipment.

$ ______________damage to equipment

1-9. If you had to deal with outage-related issues such as replacing equipment damaged by the loss of power, would there be labor costs, above and beyond the labor costs for normal operations?

○ Yes ○ No

[If a respondent answers "yes," ask the following question]

Please estimate the cost of additional labor to address outage-related issues.

$ ______________ additional labor costs to address outage-related issues

1-10. Would there be other tangible costs from this electricity outage that have not already been mentioned, such as extra materials, fuel, labor to restart your facilities, regulatory costs to dispose of hazardous materials, or costs to run and/or rent backup equipment?

○ Yes ○ No

[If a respondent answers "yes," ask the following question]

Please estimate the additional tangible costs.

$______________other tangible costs

1-11. Some businesses may save money during electricity outages. Examples include savings from reduced electricity and materials use during partial or minimal operations and/or lower labor costs. Would your business save money during the electricity outage?

◯ Yes ◯ No

[If a respondent answers "yes," ask the following question]

Please estimate how much the savings might be.

$_____________ savings due to the electricity outage

[Question only for a respondent who answered Q8 stating that his or her business has business interruption insurance]

1-12. Your business interruption insurance may reimburse you for the amount of your loss and/or food spoilage after you pay your insurance deductible. What percentage of the outage cost do you expect to be covered by your business interruption insurance policy?

_____________ % of the loss covered by the insurance after paying a deductible of $ _____________

1-13. Based on the information you provided, we estimated the total cost to your business from the one-day-long electricity generation outage we described which affects your neighborhood.

Summary of the outage

Time of year: August, weekday

Start time: Typical summer morning

Duration: 24 hours

Affected areas: Your neighborhood

Category	Estimates
Additional labor costs to make up for operations/production lost	$ (Auto generate)
Lost revenue after making up lost production and work/employee transfer	$ (Auto generate)
Damage to raw materials and/or inventory	$ (Auto generate)
Damage to equipment	$ (Auto generate)
Additional labor costs to address outage-related issues	$ (Auto generate)
Other tangible costs, including costs to run backup generators	$ (Auto generate)
Costs subtotal:	$ (Sum)
Savings	$ (Auto generate)
Losses covered by business interruption insurance policy	$ (Auto generate)
Savings subtotal:	$ (Sum)
TOTAL NET COST:	$ (Costs Subtotal – Savings Subtotal)

[After respondent finishes reviewing the table, ask the following question]

The total net electricity outage cost for your business is estimated to be $(total cost estimate from the table). Do you think the estimate is reasonable?

○ Yes ○ No

[If a respondent answers "no," ask the following questions]

Please revise the total net electricity outage cost estimate.

$______________

Please explain why you revised the estimate. Were there any costs or savings we did not include in our table?

Scenario #2: Regional electricity generation outage lasting two weeks
On a summer morning in August, a series of earthquakes occurred off the northern coast of San Juan, Puerto Rico. Electricity generation infrastructure was damaged due to the residual effects of the earthquake. While your organization and its neighborhood were not directly damaged by the earthquake, the event caused an outage affecting the region where your organization is located. After a few hours, the government of Puerto Rico announced that it would take two weeks to clean up debris on major roads, repair the Port of San Juan, which was significantly damaged, replace critical components of power plants, and restore power to your organization and most other communities served by your organization.

2-1. Which services do you expect to remain operational during this two-week outage?

		Available throughout the outage	Sometimes available	Not available
Public safety	Police			
	Fire			
	Hospitals			
	Emergency shelters and rescue facilities			
Transportation	Road			
	Rail			
	Airports			
	Ports			
Utilities	Fuel (gasoline, diesel, natural gas, etc.)			
	Water			
	Wastewater treatment			
Communications	Broadcast networks (radio/television)			
	Cellular and landline telephone networks			
	Cable services			
	Satellite communication services			
	Broadband internet			
Essential services	Pharmacies			
	Grocery and convenience stores			
	Food warehouse			
	Banks and ATMs			

[If a respondent answered Q6 stating that his or her business has multiple locations, ask the following question]

2-2. Does the electricity generation outage have direct or indirect effects on your business's operations at other locations?

○ Yes ○ No

[If a respondent says "yes," ask the following questions]

How would other locations be affected by the outage? Select all that apply.

- ☐ Other locations will also lose power.
- ☐ Other locations will not lose power. However, because the affected facility's products or services are inputs to other locations, supplies to those locations will be disrupted.
- ☐ Although other locations may experience some impacts, they will not lose power. The production of products or services can be transferred to other locations.
- ☐ Other. Please specify: ____

2-3. Would your facility be able to continue normal operations during all or part of the electricity generation outage?

○ Yes ○ No

[If a respondent says "yes," ask the following questions]

What operations would your organization be able to continue during the electricity generation outage?

What percentage of normal operations could your organization continue during the electricity generation outage?

_____________ % of normal operations

2-4. Using the table below, please estimate the costs and savings your business might experience due to this two-week-long regional electricity generation outage.

Summary of the outage
Time of year: August, weekday
Start time: Warm and humid morning
Duration: 14 days (2 weeks)
Affected areas: Entire region where your business is located

Category	Cost or savings estimates
Additional labor costs to make up for the operations/production lost	$
Lost revenue after making up lost production and work/employee transfer	$
Damage to raw materials and/or inventory	$
Damage to equipment	$
Additional labor costs to address outage-related issues	$
Other tangible costs, including costs to run backup generators	$
Costs subtotal:	$ (auto sum)
Reduced personnel costs	$
Other savings (for example, reduced electricity and material consumption)	$
Savings subtotal:	$ (auto sum)

[Only for respondents who answered Q8 stating that their business has business interruption insurance)]
What portion of the costs do you expect to be covered by your business interruption insurance policy?

______________ % of the loss covered by the insurance after paying $ ______________ deductible

[After a respondent finishes filling in the table and/or answering the insurance question, ask the following]
The total net electricity generation outage cost is estimated to be $(total cost estimate; costs subtotal – savings subtotal – insurance coverage). Do you think the estimate is reasonable?
○ Yes ○ No

[If a respondent answers "no," ask the following questions]
Please revise the total electricity generation outage cost estimate.

$______________

Please explain the reason why you revised the estimate. Were there any costs or savings we did not include in the table?

Scenario #3: Island-wide electricity outage lasting one month

In August, a major hurricane made landfall in Puerto Rico's southeast, between the municipalities of Humacao and Guayama, knocking out power islandwide. The storm brought high winds and heavy rain as well as widespread flooding and mudslides. Many homes and businesses were damaged. After 24 hours, the storm exited to the northwest, leaving behind significant damage to the island's electricity generation infrastructure. While your organization and neighborhood were not directly in the hurricane's path, LUMA Energy and the government anticipated a month-long recovery period to clear debris, repair damaged electric infrastructure, and restore electricity service to your community and most others across the island.

3-1. Which services do you expect to remain operational during this one-month outage?

		Available throughout the outage	Sometimes available	Not available
Public safety	Police	○	○	○
	Fire	○	○	○
	Hospitals	○	○	○
	Emergency shelters and rescue facilities	○	○	○
Transportation	Road	○	○	○
	Rail	○	○	○
	Airports	○	○	○
	Ports	○	○	○
Utilities	Fuel (gasoline, diesel, natural gas, etc.)	○	○	○
	Water	○	○	○
	Wastewater treatment	○	○	○
Communications	Broadcast networks (radio/television)	○	○	○
	Cellular and landline telephone networks	○	○	○
	Cable services	○	○	○
	Satellite communication services	○	○	○
	Broadband internet	○	○	○
Essential services	Pharmacies	○	○	○
	Grocery and convenience stores	○	○	○
	Food warehouse	○	○	○
	Banks and ATMs	○	○	○

[If a respondent answered Q6 stating that his or her business has multiple locations, ask the following question]

3-2. Does the electricity outage have direct or indirect effects on your business's operations at other locations?

○ Yes ○ No

[If a respondent says "yes," ask the following question]

How would other locations be affected by the outage? Select all that apply.

☐ Other locations will also lose power.

☐ Other locations will not lose power. However, because the affected facility's products or services are inputs to other locations, supplies to those locations will be disrupted.

☐ Although other locations may experience some impacts, they will not lose power. The production of products or services can be transferred to other locations.

☐ Other. Please specify: ______________________________

3-3. Would your facility be able to continue normal operations during all or part of the electricity outage?

○ Yes ○ No

[If a respondent says "yes," ask the following questions]

What operations would your organization be able to continue during the electricity outage?

What percentage of normal operations could your organization continue during the electricity outage?

______________ % of normal operations

3-4. Please use the table below to estimate the costs and savings your business might experience due to the one-month-long island-wide electricity outage.

Summary of the outage
Time of year: August, weekday
Start time: Summer morning with high winds and heavy rainfall
Duration: 30 days (1 month)
Affected areas: All of Puerto Rico

Category	Cost or saving estimates
Additional labor costs to make up for the operations/production lost	$
Lost revenue after making up lost production and work/employee transfer	$
Damage to raw materials and/or inventory	$
Damage to equipment	$
Additional labor costs to address outage-related issues	$
Other tangible costs, including costs to run backup generators	$
Costs subtotal:	$ (auto sum)
Reduced personnel costs	$
Other savings (for example, reduced electricity and material consumption)	$
Savings subtotal:	$

[Only for respondents who answered Q8 stating that their business has business interruption insurance)]
What portion of the costs do you expect to be covered by your business interruption insurance policy?

_____________ % of the loss covered by the insurance after paying $ _____________ deductible

[After a respondent answers the insurance question, ask the following question]
The total net electricity outage cost is estimated to be $(total cost estimate; costs subtotal – savings subtotal – insurance coverage). Do you think the estimate is reasonable?

○ Yes ○ No

[If a respondent answers "no," ask the following questions]
Please revise the total net electricity outage cost estimate.

$____________

Please explain the reason why you revised the estimate. Were there any costs or savings that we did not include in the table that you filled out?

Thank you for participating in this important study. For the final questions, we would like to hear your thoughts on the study and collect some information for your incentive payment.

1. Please share any additional comments:

2. Please provide your first and last name. Your name will be used **only** to verify your identity and to send you the gift card.

____

[If a respondent does not provide his/her name, a respondent receives the following question]
If you do not provide us with your first and last name, you **cannot** receive your completion bonus. Do you want to proceed without entering your name?
○ Yes ○ No
[If a respondent answers "yes," (s)he will be directed to the completion page. If a respondent answers "no," (s)he will be directed to the previous page.]

3. Please provide your business name.

____

[If a respondent does not provide his/her organization name, a respondent receives the following question]
If you do not provide us with your organization name, you **cannot** receive your completion bonus. Do you want to proceed without entering your organization name?
○ Yes ○ No
[If a respondent answers "yes," (s)he will be directed to the completion page. If a respondent answers "no," (s)he will be directed to the previous page.]

4. Please provide your email address. Your email address will be used **only** to verify your identity and to send you the gift card.

____

Retype your email address to confirm: ______________________________

[If a respondent does not provide his/her email address, a respondent receives the following question]
If you do not provide us with your email address, you **cannot** receive your completion bonus. Do you want to proceed without entering your email address?
○ Yes ○ No
[If a respondent answers "yes," (s)he will be directed to the completion page. If a respondent answers "no," (s)he will be directed to the previous page.]

5. Please provide your LUMA account ID.

____

[If a respondent does not provide his/her LUMA account ID, a respondent receives the following question]
If you do not provide us with your LUMA account ID, you cannot receive your completion bonus. Do you want to proceed without entering your LUMA account ID?
○ Yes ○ No
[If a respondent answers "yes," (s)he will be directed to the completion page. If a respondent answers "no," (s)he will be directed to the previous page.]

6. To receive this $70 gift card, you must not be an employee of LBNL or the U.S. Department of Energy. Federal employees of a different agency may be eligible for a $20 gift card, however, you will be asked further questions about your eligibility. Before we wrap up, please answer the following question to verify your eligibility.

○ I am **not** an employee of LBNL or any other federal agency.
○ I am an employee of LBNL or the U.S. Department of Energy.
○ I am an employee of some other U.S. federal government agency.

[If a respondent responds, "I am an employee of LBNL or the U.S. DOE," we will not process a respondent's completion bonus]

[If a respondent answers "I am not an employee of LBNL or any other federal agency," ask the following questions]
In some cases, you may not be allowed to receive the completion bonus because of your organization's internal policies. Please confirm that you can receive the gift card.

○ I can receive the $70 gift card based on my organization's internal policies.
○ I can only accept a $20 gift card, as permitted by the exceptions in 5 CFR §2635.204(a), Exceptions to the prohibition for acceptance of certain gifts.
○ I cannot receive the gift card based on my organization's internal policies.

[If a respondent answers "Yes, I can receive the gift card based on my organization's internal policies," ask the following question]

By typing your name in the box below, you attest that the above response of "Yes" is true.

Please specify the type of gift card you would prefer from the following options.
○ Amazon
○ Marshalls
○ Walmart

[If a respondent is eligible to receive a gift card, show the following]
Thank you. You will receive your gift card via the email address you provided within 10 business days.

[If a respondent is not eligible to receive a gift card, show the following]
Thank you. Due to your status [as an employee of LBNL or DOE/ as a federal employee who cannot receive a gift card based on your organization’s internal policies] you will not receive a gift card. If you feel this statement is in error, please contact the research team.

Appendix C. LNR Survey Instruments

Below is the survey instrument used to assess CICs among LNR electricity customers in Puerto Rico. While the attached instrument is in English, the surveys were administered in both Spanish and English, allowing respondents to switch between languages as needed.

Puerto Rico Customer Power Outage Cost Interview: Large Non-residential Customers

We are a group of researchers from Lawrence Berkeley National Laboratory (LBNL), the Institute for Building Technology (IBTS), and LUMA Energy. The purpose of this study is to understand how electricity outages affect electricity customers in Puerto Rico. This research is funded by the Federal Emergency Management Agency (FEMA).

How does the study work? We will begin by collecting information about your organization, including its industry, operations, electricity bills, locations, backup generators, potential outage impacts, business interruption insurance, and geographic location. Then, we will ask you to estimate the cost of power outages of varying lengths and impacts. Finally, we will ask a few questions about your organization's plan for improving power system resilience and information for the incentive payment.

Who can participate? Your organization facility should be located in Puerto Rico and receive electricity from LUMA Energy. The person being interviewed should be aware of, and responsible for, the organization's management and operations during normal conditions and power outages, including paying the electricity bills.

How long does the interview take? The interview will take about 35 minutes.

When does the survey close? The survey will close on September 30, 2024.

How do we protect your privacy? Your records will be kept as confidential as possible under the law. However, participation in this study may involve a loss of privacy. The survey responses will be anonymized and analyzed in aggregate. Personal information will be removed before the analysis to protect your privacy.

What are the benefits of this study? This study will help researchers understand the value of electricity service to customers in Puerto Rico during outages and how to avoid them. The study will also give your organization a chance to think about how to prepare for future power outages.

How will the information from this study be stored and used? The anonymized data will be stored securely at LBNL. Some of the data may be used for future research without asking for further consent from you. Personal information will be used for the incentive payments, but will not be linked to the survey responses in any way.

Is there a financial incentive to participate in the study? After completion of the survey, you will be compensated with a $100 gift card. To receive this completion bonus, you must not be an employee of LBNL or the U.S. DOE. If you are an employee of another federal government agency,[26] you may be eligible to receive a $20 gift card under 5CFR§2635.204(a). We recommend that you consult with your employer for prior approval before participating in this study, as each agency has specific rules about the receipt of research incentives. You will be asked to attest to the fact that you are eligible to receive payment. We will begin processing

[26] "Federal agency" means an Executive agency, military department, a court of the United States, the Administrative Office of the United States Courts, the Library of Congress, the Botanic Garden, the Government Publishing Office, the Congressional Budget Office, the United States Postal Service, the Postal Regulatory Commission, the Office of the Architect of the Capitol, the Office of Technology Assessment, and such other similar agencies of the legislative and judicial branches as determined appropriate by the Office of Personnel Management.

your incentive payment at the close of this survey period, which is expected to be September 30, 2024.

This study has been approved by the LBNL's Institutional Review Board (PRO00023334). If you have questions about your legal rights as a participant in the survey, please contact the LBNL Human Subjects Committee (harc@lbl.gov; 510-486-6005).

YOUR PARTICIPATION IS VOLUNTARY, AND YOUR RESPONSES WILL BE ANONYMOUS. You have the right to not take part in this study or to stop taking part at any time. By participating in this study, you are not waiving any legal claims or rights to which you are otherwise entitled. If you choose to withdraw from this study, you may do so at any time and ask for your records to be destroyed. Once the survey is closed and data is de-identified, we cannot remove your records from the dataset as the data cannot identify a specific individual. You may be asked to participate in additional research in the future, but you will be free to refuse to do so.

Please answer the following questions to help us determine whether you are eligible:

My organization has a facility located in Puerto Rico.	○ Yes	○ No
My organization has an account with LUMA Energy.	○ Yes	○ No
I am knowledgeable about the organization's operation.	○ Yes	○ No
I am responsible for, or aware of, the organization's electricity bills.	○ Yes	○ No
I have read and understood the informed consent.	○ Yes	○ No

[If the respondent answers "No" to any of the questions, (s)he will be considered ineligible, and the administrator should wrap up the interview with the following statement:
"Unfortunately, you are not eligible for the study at this particular time. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please feel free to contact the research team.]

We appreciate your willingness to take part in this important research. Your responses will be kept anonymous. For this survey, an electricity outage is defined as a complete loss of electricity to your organization.

A. Information about your facility

A-1. Please provide some background information about your organization.

Name: ____

Address: ______________________________________

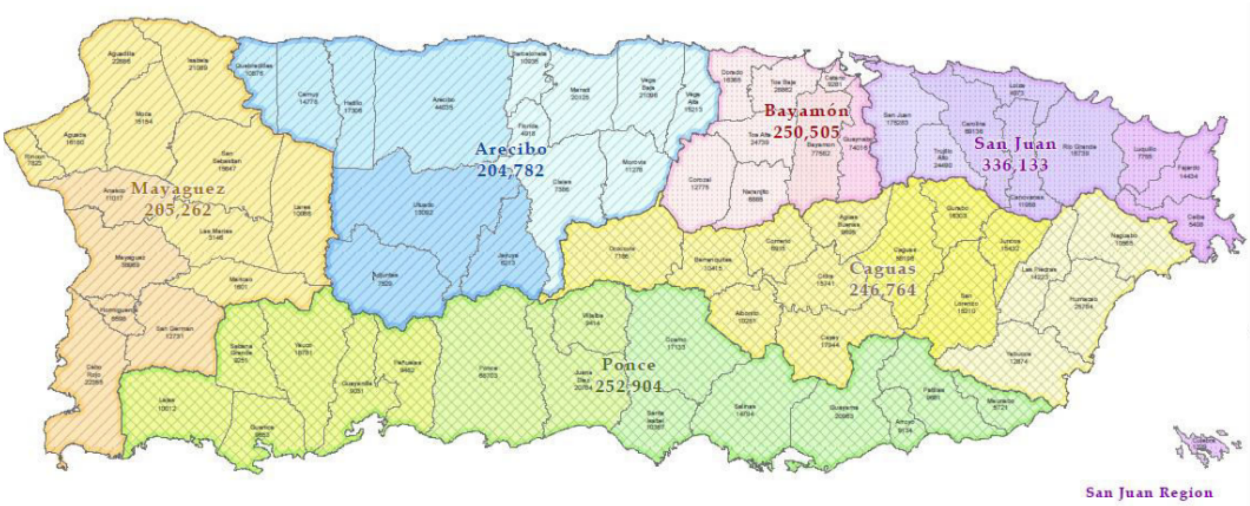
Which of the following best describes your organization?

- Accommodation and food services (including restaurants, bars and clubs, and lodging)
- Agriculture and agribusiness
- Administrative and support services
- Arts, entertainment, and recreation
- Construction
- Educational services
- Finance and insurance
- Health care and social assistance
- Information (e.g., publishing, broadcasting and telecommunication except for internet, data processing and hosting, software publishing, etc.)
- Manufacturing (including food and beverage processing)
- Management of companies and enterprises
- Mining, quarrying, and oil and gas extraction
- Professional, scientific, and technical services (e.g., legal, accounting, design services, etc.)
- Real estate, rental, and leasing
- Retail
- Tourism services
- Transportation, warehousing, and logistics
- Utilities
- Wholesale trade
- Other. Please describe:

____

A-2. How many locations does your organization have?

- Single Location
- Multiple locations, all in Puerto Rico
- Multiple locations, both within and outside of Puerto Rico



In which region(s) of Puerto Rico are your organization's facilities located? Select all that apply. *[Note to the administrator: Please have the map ready for reference during the interview to aid respondents in describing their locations. Note the response to Question A-2 so you can ask the appropriate follow-up questions later in the interview. If a respondent selects multiple locations, choose all regions where the organization's facilities are located.]*

☐ Arecibo (Adjuntas, Arecibo, Barceloneta, Camuy, Ciales, Florida, Hatillo, Jayuya, Manatí, Morovis, Quebradillas, Utuado, Vega Alta, Vega Baja)

☐ Bayamón (Bayamón, Cataño, Corozal, Dorado, Guaynabo, Naranjito, Toa Alta, Toa Baja)

☐ Caguas (Aguas Buenas, Aibonito, Barranquitas, Caguas, Cayey, Cidra, Comerío, Gurabo, Humacao, Juncos, Las Piedras, Naguabo, Orocovis, San Lorenzo, Yabucoa)

☐ Mayagüez (Aguada, Aguadilla, Añasco, Cabo Rojo, Hormigueros, Isabela, Lares, Las Marías, Maricao, Mayagüez, Moca, Rincón, San Germán, San Sebastián)

☐ Ponce (Arroyo, Coamo, Guánica, Guayama, Guayanilla, Juana Díaz, Lajas, Maunabo, Patillas, Peñuelas, Ponce, Sabana Grande, Salinas, Santa Isabel, Villalba, Yauco)

☐ San Juan (Canóvanas, Carolina, Ceiba, Culebra, Fajardo, Loíza, Luquillo, Río Grande, San Juan, Trujillo Alto, Vieques)

A-3. How many of each type of employee work at this location?

Full-time employees ___________

Part-time employees ___________

Seasonal employees ___________

Other (contract or 1099) ___________

What percentage of your employees at your company are primarily responsible for facility safety, security, and operations/maintenance?

___________ % of the total number of employees

A-4. Roughly how much does your organization pay for its monthly electricity bill?
Between December and April: $_____________ /month
Between May and November: $_____________ /month

B. Production and process description

B-1. What are the products or services your organization provides?

B-2. Please specify how electricity is used to produce the goods or deliver your organization's services?

[Note to the administrator: Note the answers to the questions so that you can ask the appropriate follow-up questions later in the interview.]

B-3. Please indicate where key suppliers for your organization are located.*[Note to the administrator: Ask the interviewee to define their key suppliers, which are suppliers that are necessary for the organization to produce its products or provide its services.]*

- ◯ Only within Puerto Rico
- ◯ Only outside of Puerto Rico
- ◯ Both within and outside of Puerto Rico

  [If a respondent answers "only outside of Puerto Rico" or "both within and outside of Puerto Rico," ask the following question]
  What do the key suppliers outside Puerto Rico provide, and where are they located?

B-4. Please indicate where your primary customers are located.

- ◯ Only within Puerto Rico
- ◯ Only outside of Puerto Rico
- ◯ Both within and outside of Puerto Rico

C. Impacts of electricity outages and impact mitigations

C-1. Which of the following does your organization have (select all that applies):

- ☐ Backup generators
- ☐ On-site power generation system
- ☐ Solar panel(s) with battery storage
- ☐ Solar panel(s) without battery storage
- ☐ Battery backup energy storage without solar panels
- ☐ Other backup power (non-grid dependent) power source,

describe_____________________________

- ☐ None

  [If a respondent selects any option other than "none," ask the following question]
  What percentage of your normal operations can be powered by this power generation system?
  _____________ %

[If a respondent selects “backup generators” or “on-site power generation system,” ask the following question]

What is the primary fuel source for the generator? Select all that apply.

- Gasoline
- Propane
- Diesel
- Other. Please specify: ____

[If a respondent responds gasoline, propane, diesel, or others as the fuel source(s), ask the following question]

How long can you run your generation system(s) with the fuel you have stored?

_____________ days

[If a respondent selects battery backup energy storage without solar panels, ask the following question]

How long will your business battery backup power your essential appliances on a full charge?

_____________ days

C-2. At what point does an electricity outage significantly impact operations?

_____________ days

C-3. If your organization was told that the power would likely be out for 24 hours or more, would any employees be told not to come to work?

- Yes
- No

[If a respondent answers “yes,” ask the following question]

What percentage of employees would be told not to come to work during the electricity outage?

Full-time employees: _____________%

Part-time employees: _____________%

Contractors/project-based/temporary employees: _____________%

[If a respondent answered Question A-2 stating that the organization has multiple locations, ask the following questions (C-4 and 5); otherwise, move on to Question C-6]

C-4. If your organization’s facility experiences an electricity outage that affects all of Puerto Rico, would it be possible to transfer work and/or employees to other locations within or outside of Puerto Rico that have access to power?

- Yes
- No

[If a respondent answers “yes,” ask the following questions]

About what percent of work can be transferred to other locations with power?

_____________ %

About what percent of employees can be transferred to the other locations with power?

_____________ %

How long or how widespread would an electricity outage need to be for you to consider transferring work and/or employees to other locations?

How much would the relocation of work and/or employees cost?

$ _____________

C-5. During an electricity outage that lasts multiple days or weeks, can you physically relocate your generation equipment or infrastructure, temporarily or permanently, to a location that has power, in order to enable your organization to continue to operate?

○ Yes ○ No

[If a respondent answers "yes," ask the following question]

How long or widespread would an electricity outage need to be for you to make the decision to relocate generation equipment or infrastructure?

How much would the relocation of equipment cost?

$ _____________

C-6. Has your organization purchased business interruption insurance?

○ Yes ○ No

[Note the answer to the question so that you can ask the appropriate follow-up questions later in the interview. If a respondent answers "yes," ask the following questions]

Your organization's insurance policy may help your organization cover some of the losses that result from an electricity outage. However, you will have to pay your insurance deductible first. Also, your insurance may cover only certain types of damages (for example, property damage, limited business interruption losses, and spoilage).

How much is your organization's interruption insurance deductible?

$ _____________

What is the coverage limit of your policy?

$ _____________

[Note to the administrator: be ready to share the webpage with the scenario summary table, and give respondents a minute to skim through the table. Move on to scenario 1 when the respondents are ready.]

In the sections that follow, we will ask you to think about three different examples of electricity outages that might happen in Puerto Rico. The table below summarizes the scenarios that we will ask about.

	Scenario 1	**Scenario 2**	**Scenario 3**
Outage duration	24 hours	14 days (2 weeks)	30 days (1 month)
Time of year	August weekday(s)		
Weather conditions	Typical summer morning	A warm and humid summer day	High winds and heavy rain
Outage geographic scope	Homes and businesses in the neighborhood	Entire region where your organization operates	Entire island of Puerto Rico
Planned by the utility	No	No	No

We will first describe each electricity outage scenario in detail and then ask you some questions about the costs and savings associated with the electricity outage. *There are no right or wrong answers to these questions*. If a question is difficult for you to answer, please give your best guess. At the end of the survey, you can add comments about any of your answers.

Scenario #1: Neighborhood electricity outage lasting one day

It is a typical summer morning in August with clear skies, light winds, and a temperature in the mid-70s. The power in your facility's neighborhood has just gone out with no warning. You find out that an equipment failure has caused an electricity outage to your facility and other nearby customers. **You are told that the power will be restored by 6:00 AM tomorrow.**

1-1. Which services do you expect to remain operational during this one-day electricity outage?

		Available throughout the outage	Sometimes available	Not available
Public safety	Police	○	○	○
	Fire	○	○	○
	Hospitals	○	○	○
	Emergency shelters and rescue facilities	○	○	○
Transportation	Road	○	○	○
	Rail	○	○	○
	Airports	○	○	○
	Ports	○	○	○
Utilities	Fuel (gasoline, diesel, natural gas, etc.)	○	○	○
	Water	○	○	○
	Wastewater treatment	○	○	○
Communications	Broadcast networks (radio/television)	○	○	○
	Cellular and landline telephone networks	○	○	○
	Cable services	○	○	○
	Satellite communication services	○	○	○
	Broadband internet	○	○	○
Essential services	Pharmacies	○	○	○
	Grocery and convenience stores	○	○	○
	Food warehouse	○	○	○

	Banks and ATMs	○	○	○

1-2. Would this one-day-long electricity outage affect your main suppliers?

○ Yes ○ No

1-3. Would this one-day-long electricity outage affect customer demand for goods and services that your organization provides?

○ There would likely be an increase in customer demand.
○ There would likely be a decrease in customer demand.
○ There would likely be no change in customer demand.

[If a respondent answers "there would likely be an increase in demand," ask the following question]
Please estimate, in terms of revenue, the expected increase in customer demand during the one-day electricity outage.

_____________ % increase

[If a respondent answers "there will likely be a decrease in demand," ask the following question]
Please estimate, in terms of revenue, the expected decrease in customer demand during the one-day electricity outage.

_____________ % decrease

1-4. *[Below are alternative prompts based on how a respondent answered Question C-1 regarding backup power]*

[Prompt for respondents who state that the organization does not have a backup generation system]
Without backup generation, your organization will not be able to operate most of its electrical equipment during an electricity outage. However, you may be able to continue some operations that do not require electricity.
[Alternative prompts for respondents who state that their organization has a backup generation system and can resume operation]:
Your backup power can be used to resume some operations during an electricity outage. You may also be able to resume operations that do not require electricity.

[Question to be asked following the appropriate prompt is displayed]
What percentage of normal operations could you continue during the one-day electricity outage?

_____________ % of the normal operations

1-5. Can you make up for the lost production after the power comes back on?

○ Yes ○ No

[If a respondent answers "yes," ask the following questions]

What percentage of lost production of goods and/or services could you recover, in terms of revenue?

_____________ % of the lost production of goods and/or services

How much would it cost your organization, in dollars, to make up for the backlog of work resulting from the electricity outage, for example, by working overtime or extra shifts?

$_____________

1-6. Overall, how much revenue, in dollars, would your organization lose during and after the electricity outage (for example, from lost sales of goods and/or services)? If your organization will not be affected by the electricity outage or is expected to benefit from the electricity outage, enter zero.

$ _____________ lost revenue from the electricity outage

1-7. Would there be any costs of the electricity outage from damage to raw materials and/or inventory, including perishable food that could spoil?

Yes No

[If a respondent answers "yes," ask the following question]

Please estimate a dollar amount for the damage cost to raw materials and/or inventory.

$ _____________ damage to raw materials and/or inventory

1-8. Sudden electricity outages can damage equipment. Would your organization likely have any damage costs from this one-day electricity outage, such as costs for damage to sensitive electrical or mechanical devices?

Yes No

[If a respondent answers "yes," ask the following question]

Please estimate a dollar amount for the damage to equipment.

$ _____________damage to equipment

1-9. If you had to deal with electricity outage-related issues such as replacing equipment damaged by the loss of power, would there be labor costs, above and beyond the labor costs for normal operations?

Yes No

[If a respondent answers "yes," ask the following question]

Please estimate the cost of additional labor to address electricity outage-related issues.

$ _____________ additional labor costs to address electricity outage-related issues

1-10. Would there be other tangible costs from this electricity outage that have not already been mentioned, such as extra materials, fuel, labor to restart your facilities, regulatory costs to dispose of hazardous materials, or costs to run and/or rent backup equipment?

Yes No

[If a respondent answers "yes," ask the following question]
Please estimate the additional tangible costs.

$______________other tangible costs

1-11. Some businesses may save money during electricity outages. Examples include savings from reduced electricity and materials use during partial or minimal operations and/or lower labor costs. Would your organization save money during the electricity outage?

○ Yes ○ No

[If a respondent answers "yes," ask the following question]
Please estimate how much the savings might be.

$______________ savings due to the electricity outage

[Question only for a respondent who answered Question C-6 stating that his or her organization has a business interruption insurance]
1-12. Your business interruption insurance may reimburse you for the amount of your loss and/or food spoilage after you pay your insurance deductible. What percentage of the electricity outage cost do you expect to be covered by your organization's interruption insurance policy?

______________ % of the loss covered by the insurance after paying a deductible of $ ______________

1-13. Based on the information you provided, we estimated the total cost to your organization from the one-day-long electricity outage we described which affects your neighborhood.

Summary of the outage:
Time of year: August, weekday
Start time: Typical summer morning
Duration: 24 hours
Affected areas: Your neighborhood

Category	Estimates
Additional labor costs to make up for operations/production lost	$ (Auto generate)
Lost revenue after making up lost production and work/employee transfer	$ (Auto generate)
Damage to raw materials and/or inventory	$ (Auto generate)
Damage to equipment	$ (Auto generate)
Additional labor costs to address outage-related issues	$ (Auto generate)
Other tangible costs, including costs to run backup generators	$ (Auto generate)
Costs subtotal:	$ (Sum)
Savings	$ (Auto generate)
Losses covered by business interruption insurance policy	$ (Auto generate)
Savings subtotal:	$ (Sum)
TOTAL NET COST:	$ (Costs Subtotal – Savings Subtotal)

[After respondent finishes reviewing the table, ask the following question]

The total net electricity outage cost for your organization is estimated to be *$(total cost estimate from the table)*. Do you think the estimate is reasonable?

○ Yes ○ No

[If a respondent answers "no," ask the following questions]
Please revise the total net electricity outage cost estimate.

$______________

Please explain why you revised the estimate. Were there any costs or savings we did not include in our table?

Scenario #2: Regional electricity generation outage lasting two weeks

On a summer morning in August, a series of earthquakes occurred off the northern coast of San Juan, Puerto Rico. Electricity generation infrastructure was damaged due to the residual effects of the earthquake. While your organization and its neighborhood were not directly damaged by the earthquake, the event caused an outage affecting the region where your organization is located. After a few hours, the government of Puerto Rico announced that it would take two weeks to clean up debris on major roads, repair the Port of San Juan, which was significantly damaged, replace critical components of power plants, and restore power to your organization and most other communities served by your organization.

2-1. Which services do you expect to remain operational during this two-week electricity generation outage?

		Available throughout the outage	Sometimes available	Not available
Public safety	Police	○	○	○
	Fire	○	○	○
	Hospitals	○	○	○
	Emergency shelters and rescue facilities	○	○	○
Transportation	Road	○	○	○
	Rail	○	○	○
	Airports	○	○	○
	Ports	○	○	○
Utilities	Fuel (gasoline, diesel, natural gas, etc.)	○	○	○
	Water	○	○	○
	Wastewater treatment	○	○	○
Communications	Broadcast networks (radio/television)	○	○	○
	Cellular and landline telephone networks	○	○	○
	Cable services	○	○	○
	Satellite communication services	○	○	○
	Broadband internet	○	○	○
Essential services	Pharmacies	○	○	○

	Grocery and convenience store	◯	◯	◯
	Food warehouse	◯	◯	◯
	Banks and ATMs	◯	◯	◯

2-2. Would the two-week-long regional electricity generation outage affect your key suppliers?
◯ Yes ◯ No

[If a respondent answers "yes," ask the following question]
Would your organization be affected if your suppliers are affected? What measures can you take to mitigate the impact of supply disruptions?

2-3. Would the two-week-long regional electricity generation outage affect customer demand for the goods and/or services that your organization provides?

◯ Yes ◯ No

[If a respondent says "yes," ask the following question]
Please estimate the percentage change in revenue resulting from the change in customer demand.

_____________ % change in revenue due to the change in customer demand

[Note to the administrator: the answer will be >0 if there is an increase in demand, 0 if there is no change in demand, and <0 if there is a decrease in demand]

2-4. Would your facility be able to continue normal operations during all or part of the electricity generation outage?

◯ Yes ◯ No

[If a respondent says "yes," ask the following questions]
What operations would your organization be able to continue during the electricity generation outage?

What percentage of normal operations could your organization continue during the electricity generation outage?

_____________ % of normal operations

[Note to the administrator: if the organization cannot operate at all during the electricity generation outage, enter 0]

[If a respondent answered Question A-2 stating that the organization has multiple locations, ask the following question]

2-5. Does the electricity generation outage have direct or indirect effects on your organization's operations at other locations?

◯ Yes ◯ No

[If a respondent says "yes," ask the following question]
How would other locations be affected by the electricity generation outage? Select all that apply.

- ☐ Other locations will also lose power.
- ☐ Other locations will not lose power. However, because the affected facility's products or services are inputs to other locations, supplies to those locations will be disrupted.
- ☐ Although other locations may experience some impacts, they will not lose power. The production of products or services can be transferred to other locations.
- ☐ Other

[If a respondent answers "other," ask the following question]
Please describe the impact of the electricity generation outage on operations at other locations of your organization.

2-6. Can your organization make up for the lost production of goods and/or services after the power comes back on?

○ Yes ○ No

[If a respondent answers "yes," ask the following question]
What percentage could you recover from the revenue lost during the electricity generation outage due to lost production of goods and/or services?

_____________ % of the revenue lost from lost production of goods and/or services

2-7. Using the table below, please estimate the costs and savings that your organization might experience due to this two-week-long regional electricity generation outage.

Summary of the outage
Time of year: August, weekday
Start time: Warm and humid morning
Duration: 14 days (2 weeks)
Affected areas: Entire region where your business is located

Category	Estimates
Cost to operate backup generation equipment	$
Additional labor costs to make up for the operations/production lost	$
Lost revenue after making up lost production and work/employee transfer	$
Damage to raw materials and/or inventory	$
Damage to equipment	$
Additional labor costs to address outage-related issues	$
Other tangible costs, including re-start cost	$
Costs subtotal:	$ (sum)
Reduced personnel costs	$
Other savings (for example, reduced electricity and material consumption)	$
Savings subtotal:	$ (sum)

[Question only for respondents who answered Question C-6 stating that their organization has a business interruption insurance)]
What portion of the costs do you expect to be covered by your organization's interruption insurance policy?

______________ % of the loss covered by the insurance after paying $ ______________ deductible

[After respondent finishes filling in the table and/or answering the insurance question, ask the following]
The total net electricity generation outage cost is estimated to be *$(total cost estimate; costs subtotal – savings subtotal – insurance coverage)*. Do you think the estimate is reasonable?
○ Yes ○ No

[If a respondent answers "no," ask the following questions]
Please revise the total net electricity generation outage cost estimate.

$ ____________

Please explain the reason you revised the estimate. Were there any costs or savings we did not include in our calculation?

Scenario #3: Island-wide electricity outage lasting one month
In August, a major hurricane made landfall in Puerto Rico's southeast, between the municipalities of Humacao and Guayama, knocking out power islandwide. The storm brought high winds and heavy rain as well as widespread flooding and mudslides. Many homes and businesses were damaged. After 24 hours, the storm exited to the northwest, leaving behind significant damage to the island's electric infrastructure. While your organization and neighborhood were not directly in the hurricane's path, LUMA Energy and the government anticipated a month-long recovery period to clear debris, repair damaged generation infrastructure, and restore electricity service to your organization's community and most others across the island.

3-1. Which services do you expect to remain operational during this one-month outage?

		Available throughout the outage	Sometimes available	Not available
Public safety	Police	○	○	○
	Fire	○	○	○
	Hospitals	○	○	○
	Emergency shelters and rescue facilities	○	○	○
Transportation	Road	○	○	○
	Rail	○	○	○
	Airports	○	○	○
	Ports	○	○	○
Utilities	Fuel (gasoline, diesel, natural gas, etc.)	○	○	○
	Water	○	○	○
	Wastewater treatment	○	○	○
Communications	Broadcast networks (radio/television)	○	○	○
	Cellular and landline telephone networks	○	○	○
	Cable services	○	○	○
	Satellite communication services	○	○	○
	Broadband internet	○	○	○
Essential services	Pharmacies	○	○	○
	Grocery and convenience stores	○	○	○
	Food warehouse	○	○	○
	Banks and ATMs	○	○	○

3-2. Would the one-month-long electricity outage affect your key suppliers?

◯ Yes ◯ No

[If a respondent answers "yes," ask the following question]
Would your organization be affected if your suppliers are affected? What measures can you take to mitigate the impact of supply disruptions?

3-3. Would the one-month-long electricity outage affect customer demand for the goods and/or services that your organization provides?

◯ Yes ◯ No

[If a respondent says "yes," ask the following question]
Please estimate the percentage change in revenue resulting from the change in customer demand.

_____________ % change in revenue due to the change in customer demand

[Note to the administrator: the answer will be >0 if there is an increase in demand, 0 if there is no change in demand, and <0 if there is a decrease in demand]

3-4. Would your facility be able to continue normal operations during all or part of the electricity outage?

◯ Yes ◯ No

[If a respondent says "yes," ask the following questions]
What operations would your organization be able to continue during the electricity outage?

What percentage of normal operations could your organization continue during the electricity outage?

_____________ % of normal operations

[Note to the administrator: if the organization cannot operate at all during the electricity outage, enter 0]

[If a respondent answered Question A-2 stating that the organization has multiple locations, ask the following question]

3-5. Does the electricity outage have direct or indirect effects on your organization's operations at other locations?

◯ Yes ◯ No

[If a respondent says "yes," ask the following question]
How would other locations be affected by the electricity outage? Select all that apply.

☐ Other locations will also lose power.

☐ Other locations will not lose power. However, because the affected facility's products or services are inputs to other locations, supplies to those locations will be disrupted.

☐ Although other locations may experience some impacts, they will not lose power. The production of products or services can be transferred to other locations.

☐ Other

[If a respondent answers "other," ask the following question]
Please describe the impact of the electricity outage on operations at other locations of your organization.

3-6. Can your organization make up for the lost production of goods and/or services after the power comes back on?

○ Yes ○ No

[If a respondent answers "yes," ask the following question]
What percentage could you recover of the revenue lost during the electricity outage due to lost production of goods and/or services?

_____________ % of the revenue lost from lost production of goods and/or services

3-7. Please use the table below to estimate the costs and savings your organization might experience due to the one-month-long island-wide electricity outage.

Summary of the outage
Time of year: August, weekday
Start time: Summer morning with high winds and heavy rainfall
Duration: 30 days (1 month)
Affected areas: All of Puerto Rico

Category	Cost or saving estimates
Additional labor costs to make up for the operations/production lost	$
Lost revenue after making up of production and work/employee transfer	$
Damage to raw materials and/or inventory	$
Damage to equipment	$
Additional labor costs to address outage-related issues	$
Other tangible costs, including costs to run backup generators	$
Costs subtotal:	$ (auto sum)
Reduced personnel costs	$
Other savings (for example, reduced electricity and material consumption)	$
Savings subtotal:	$

[Question only for respondents who answered Question C-6 stating that their organization has a business interruption insurance)]
What portion of the costs do you expect to be covered by your organization's interruption insurance policy?

______________ % of the loss covered by the insurance after paying $ ______________ deductible

[After a respondent answers the insurance question, ask the following question]
The total net electricity outage cost is estimated to be *$(total cost estimate; costs subtotal – savings subtotal – insurance coverage)*. Do you think the estimate is reasonable?

○ Yes ○ No

[If a respondent answers "no," ask the following questions]
Please revise the total net electricity outage cost estimate.

$____________

Please explain the reason why you revised the estimate. Were there any costs or savings that we did not include in the table that you filled out?

Thank you for participating in this important study. For the final questions, please share your organization's plan for improving power system resilience in the future, your thoughts on the study, and some information for your incentive payment.

1. Does your organization have any plans to protect itself from the effects of electricity outages (for example, buying a generator, batteries, battery wall, or stand-by backup generator with a fuel tank)?

○ Yes ○ No

[If a respondent answers "yes," ask the following question]

What types of investments is your organization planning to make?

What is the timeframe for making these investments?

○ 0-6 months
○ 6 months to 1 year
○ 1 year to 2 years
○ 2 years to 5 years
○ Longer than 5 years. Please specify:

What is the main goal of the investment (for example, to be able to continue some critical operations during electricity outages)?

2. Please share any additional comments:

3. Please provide your first and last name. Your name will be used **only** to verify your identity and to send you the gift card.

____

[If a respondent does not provide his/her name, a respondent receives the following question]

If you do not provide us with your first and last name, you **cannot** receive your completion bonus. Do you want to proceed without entering your name?

○ Yes ○ No

[If a respondent answers "yes," (s)he will be directed to the completion page. If a respondent answers "no," (s)he will be directed to the previous page.]

4. Please provide your email address. Your email address will be used **only** to verify your identity and to send you the gift card.

____

[If a respondent does not provide his/her email address, a respondent receives the following question]

If you do not provide us with your email address, you **cannot** receive your completion bonus. Do you want to proceed without entering your email address?

○ Yes ○ No

[If a respondent answers “yes,” (s)he will be directed to the completion page. If a respondent answers “no,” (s)he will be directed to the previous page.]

5. To receive this $100 gift card, you must not be an employee of LBNL or the U.S. Department of Energy. Federal employees of a different agency may be eligible for a $20 gift card, however, you will be asked further questions about your eligibility. Before we wrap up, please answer the following question to verify your eligibility.

○ I am **not** an employee of LBNL or any other federal agency.

○ I am an employee of LBNL or the U.S. Department of Energy.

○ I am an employee of some other U.S. federal government agency.

[If a respondent responds, “I am an employee of LBNL or the U.S. DOE,” we will not process a respondent’s completion bonus]

[If a respondent answers “I am not an employee of LBNL or any other federal agency,” ask the following questions]
In some cases, you may not be allowed to receive the completion bonus because of your organization's internal policies. Please confirm that you can receive the gift card.

○ I can receive the $100 gift card based on my organization’s internal policies.

○ I can only accept a $20 gift card, as permitted by the exceptions in 5 CFR §2635.204(a), Exceptions to the prohibition for acceptance of certain gifts.

○ I cannot receive the gift card based on my organization’s internal policies.

[If a respondent answers “Yes, I can receive the gift card based on my organization’s internal policies,” ask the following question]

By typing your name in the box below, you attest that the above response of “Yes” is true.

Please specify the type of gift card you would prefer from the following options.

○ Amazon

○ Marshalls

○ Walmart

[If a respondent is eligible to receive a gift card, show the following]
Thank you. You will receive your gift card via the email address you provided within 10 business days.

[*If a respondent is not eligible to receive a gift card, show the following*]
Thank you for your participation. Unfortunately, you are not eligible for a gift card. However, we would like to appreciate your time and effort. If you have any questions or believe there may be an error, please contact the research team.

Appendix D. Public Survey Instruments

Below is the survey instrument used to assess CICs among public electricity customers in Puerto Rico. While the attached instrument is in English, the surveys were administered in both Spanish and English, allowing respondents to switch between languages as needed.

Puerto Rico Customer Power Outage Cost Interview: Public Customers

We are a group of researchers from Lawrence Berkeley National Laboratory (LBNL), the Institute for Building Technology (IBTS), and LUMA Energy. The purpose of this study is to understand how electricity outages affect electricity customers in Puerto Rico. This research is funded by the Federal Emergency Management Agency (FEMA).

How does the study work? We will begin by collecting information about your organization, including its sector, operations, electrical bills and locations, backup generators, potential impacts of power outages, and geographic location. Then, we will ask you to estimate the effects of power outages of varying lengths and impacts. Finally, we will ask a few questions about your organization's plan for improving power system resilience.

Who can participate? Your organization facility should be located in Puerto Rico and receive electricity from LUMA Energy. The person being interviewed should be aware of, and responsible for, the organization's management and operations during normal conditions and power outages, including paying the electricity bills.

How long does the interview take? The interview will take about 25 minutes.

When does the survey close? The survey will close on September 30, 2024.

How do we protect your privacy? Your records will be kept as confidential as possible under the law. However, participation in this study may involve a loss of privacy. The survey responses will be anonymized and analyzed in aggregate. Personal information will be removed before the analysis to protect your privacy.

What are the benefits of this study? This study will help researchers understand the value of electricity service to customers in Puerto Rico during outages and how to avoid them. The study will also give your organization a chance to think about how to prepare for future power outages.

How will the information from this study be stored and used? The anonymized data will be stored securely at LBNL. Some of the data may be used for future research without asking for further consent from you.

Is there a financial incentive to participate in the study? While we are unable to offer financial compensation for your participation, your contribution to this study is valuable. The research will provide insights into how Puerto Rico electricity customers prioritize reliable electricity service, particularly during outages.

This study has been approved by the LBNL's Institutional Review Board (PRO00023334). If you have questions about your legal rights as a participant in the survey, please contact the LBNL Human Subjects Committee (harc@lbl.gov; 510-486-6005).

YOUR PARTICIPATION IS VOLUNTARY, AND YOUR RESPONSES WILL BE ANONYMOUS. You have the right to not take part in this study or to stop taking part at any time. By participating in this study, you are not waiving any legal claims or rights to which you are otherwise entitled. If you choose to withdraw from this study, you may do so at any time and ask for your records to be destroyed. Once the survey is closed and data is de-identified, we cannot remove your records from the dataset as the data cannot identify a specific individual. You may be asked to participate in additional research in the future, but you will be free to refuse to do so.

Please answer the following questions:

My organization has a facility located in Puerto Rico. ○ Yes ○ No

My organization has an account with LUMA Energy. ○ Yes ○ No

I am familiar with the organization's operations. ○ Yes ○ No

(optional) I am responsible for, or aware of, the organization’s electricity bills. ○ Yes ○ No

I have read and understood the informed consent. ○ Yes ○ No

[If the respondent answers “No” to any of the questions, (s)he will be considered ineligible, and the administrator should wrap up the interview with the following statement:
“Unfortunately, you are not eligible for the study at this particular time. However, we would like to thank you for your interest in this research. If you have any questions or concerns, please feel free to contact the research team.]

We appreciate your willingness to take part in this important research. Your responses will be kept anonymous. For this survey, an electricity outage is defined as a complete loss of electricity to your organization.

1. Please provide some background information about your organization.

Organization name: ____

Organization address: ____

Please provide your name and role at the organization.
Name: ____

Role: ____

Which of the following best describes your organization?

- ◯ State Executive, legislative, or judicial Branch
- ◯ Municipal services
- ◯ Public corporations (e.g., PREPA and PRASA)
- ◯ Educational institution
- ◯ Healthcare organization
- ◯ Public safety and law enforcement
- ◯ Cultural and recreational organization
- ◯ Housing and urban development
- ◯ Environmental and natural resources
- ◯ State social services
- ◯ Religious or community assistance organization
- ◯ Other (please specify): ____

2. What are the services that your organization provides?

Please specify how electricity is used to deliver services that your organization provides.

[Note to the administrator: Note the answers to the questions so you can ask the appropriate follow-up questions later in the interview.]

3. Roughly how much does your organization pay for its monthly electricity bill?
Between December and April: $______________ /month
Between May and November: $______________ /month

4. How many of each type of employee currently work at this location?

Full-time employees ____________
Part-time employees ____________
Seasonal employees ____________
Other (contract or 1099) ____________

What percentage of employees at your company are primarily responsible for facility safety, security, and operations/maintenance?

___________ % of the total number of employees

5. Which of the following does your organization have (select all that applies):

- ☐ Backup generators
- ☐ On-site power generation system
- ☐ Solar panel(s) with battery storage
- ☐ Solar panel(s) without battery storage
- ☐ Battery backup energy storage without solar panels
- ☐ Other backup power (non-grid dependent) power source, describe_____________________________
- ☐ None

[If a respondent selects any option other than "none," ask the following question]

What percentage of your normal operations can be powered by this power generation system?

_____________ %

[If a respondent selects "backup generators" or "on-site power generation system," ask the following question]

What is the primary fuel source for the generator? Select all that apply.

- ☐ Gasoline
- ☐ Propane
- ☐ Diesel
- ☐ Other. Please specify:

____

[If a respondent responds gasoline, propane, diesel, or others as the fuel source(s), ask the following question]

How long can you run your generation system(s) with the fuel you have stored?

_____________ days

[If a respondent selects battery backup energy storage without solar panels, ask the following question]

How long will your organization battery backup power your essential appliances on a full charge?

_____________ days

6. If you were told that the power was likely to be out for 24 hours or more, would any employees be told not to come to work?

○ Yes ○ No

[If a respondent answers "yes," ask the following question]

What percentage of employees would be told not to come to work during the outage?

Full-time employees: ___________%

Part-time employees: ___________%

Contractors/project-based/temporary employees: ___________%

7. If there is an outage and your organization cannot operate, is there another organization in the region that can provide the same services?

- Yes
- No

[If a respondent answers "yes," ask the following questions]

How far away is the nearest alternative service provider from your current location?

- Within Puerto Rico
- Outside of Puerto Rico

In general, how long would an outage need to last before the individuals served by your organization would need to be transferred to the nearest alternative service provider?

_____________ days

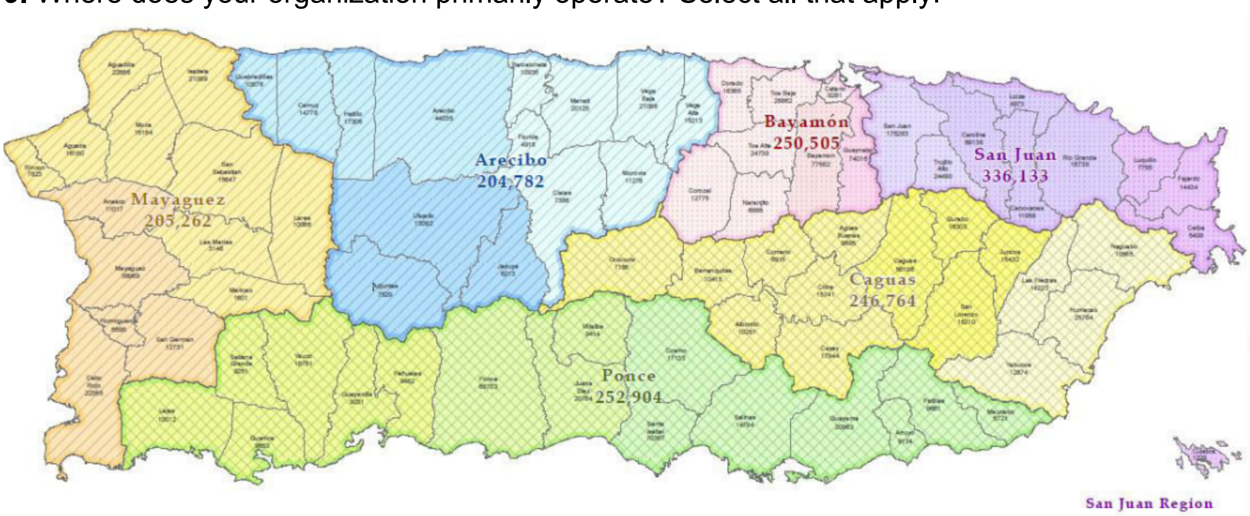
8. Please indicate where key suppliers for your organization are located. *[Note to the administrator: Ask the interviewee to define their own key suppliers, which are suppliers that are necessary for the organization to produce its products or provide its services.]*

- Only within Puerto Rico
- Only outside of Puerto Rico
- Both within and outside of Puerto Rico

[If a respondent answers "only outside of Puerto Rico" or "both within and outside of Puerto Rico," ask the following question]

What do the key suppliers based outside of Puerto Rico provide, and where are they located?

9. Where does your organization primarily operate? Select all that apply.



[Note to the administrator: Please have the map ready for reference during the interview to aid respondents in describing their locations. Note the response so you can ask the appropriate follow-up questions later in the interview.]

☐ Arecibo (Adjuntas, Arecibo, Barceloneta, Camuy, Ciales, Florida, Hatillo, Jayuya, Manatí, Morovis, Quebradillas, Utuado, Vega Alta, Vega Baja)
☐ Bayamón (Bayamón, Cataño, Corozal, Dorado, Guaynabo, Naranjito, Toa Alta, Toa Baja)
☐ Caguas (Aguas Buenas, Aibonito, Barranquitas, Caguas, Cayey, Cidra, Comerío, Gurabo, Humacao, Juncos, Las Piedras, Naguabo, Orocovis, San Lorenzo, Yabucoa)
☐ Mayagüez (Aguada, Aguadilla, Añasco, Cabo Rojo, Hormigueros, Isabela, Lares, Las Marías, Maricao, Mayagüez, Moca, Rincón, San Germán, San Sebastián)
☐ Ponce (Arroyo, Coamo, Guánica, Guayama, Guayanilla, Juana Díaz, Lajas, Maunabo, Patillas, Peñuelas, Ponce, Sabana Grande, Salinas, Santa Isabel, Villalba, Yauco)
☐ San Juan (Canóvanas, Carolina, Ceiba, Culebra, Fajardo, Loíza, Luquillo, Río Grande, San Juan, Trujillo Alto, Vieques)

10. Has your organization purchased business interruption insurance?
○ Yes ○ No

[Note the answer to the question so that you can ask the appropriate follow-up questions later in the interview. If a respondent answers "yes," ask the following questions]

Your organization's insurance policy may help your organization cover some of the losses that result from an electricity outage. However, you will have to pay your insurance deductible first. Also, your insurance may cover only certain types of damages (for example, property damage, limited business interruption losses, and spoilage).

How much is your organization's interruption insurance deductible?

$ _____________

What is the coverage limit of your policy?

$ _____________

[Note to the administrator: be ready to share the webpage with the scenario summary table, and give respondents a minute to skim through the table. Move on to scenario 1 when the respondents are ready.]

In the sections that follow, we will ask you to think about three different examples of electricity outages that might happen in Puerto Rico. The table below summarizes the scenarios that we will ask about.

	Scenario 1	**Scenario 2**	**Scenario 3**
Outage duration	24 hours	14 days (2 weeks)	30 days (1 month)
Time of year	August weekday(s)		
Weather conditions	Typical summer morning	A warm and humid summer day	High winds and heavy rain
Outage geographic scope	Homes and businesses in the neighborhood	Entire region where your organization operates	Entire island of Puerto Rico
Planned by utility	No	No	No

We will first describe each outage scenario in detail and then ask you some questions about the costs and savings associated with the outage. *There are no right or wrong answers to these questions*. If a question is difficult for you to answer, please give your best guess. At the end of the survey, you can add comments about any of your answers.

Scenario #1: Neighborhood electricity outage lasting one day
It is a typical summer morning in August with clear skies, light winds, and a temperature in the mid-70s. The power in your facility's neighborhood has just gone out with no warning. You find out that an equipment failure has caused an electricity outage to your facility and other nearby customers. **You are told that the power will be restored by 6:00 AM tomorrow.**

1-1. Which services do you expect to remain operational during this one-day electricity outage?

		Available throughout the outage	Sometimes available	Not available
Public safety	Police	○	○	○
	Fire	○	○	○
	Hospitals	○	○	○
	Emergency shelters and rescue facilities	○	○	○
Transportation	Road	○	○	○
	Rail	○	○	○
	Airports	○	○	○
	Ports	○	○	○
Utilities	Fuel (gasoline, diesel, natural gas, etc.)	○	○	○
	Water	○	○	○
	Wastewater treatment	○	○	○
Communications	Broadcast networks (radio/television)	○	○	○
	Cellular and landline telephone networks	○	○	○
	Cable services	○	○	○
	Satellite communication services	○	○	○
	Broadband internet	○	○	○
Essential services	Pharmacies	○	○	○
	Grocery and convenience stores	○	○	○
	Food warehouse	○	○	○
	Banks and ATMs	○	○	○

1-2. How will the one-day-long electricity outage affect client demand for the services your organization provides?

1-3. Would your facility be able to continue normal operations during all or part of the outage?

◯ Yes ◯ No

[If a respondent says "yes," ask the following questions]
What operations would your organization be able to continue during the outage?

What percentage of normal operations could you continue during the one-day-long outage?
[Note to the administrator: if the organization cannot operate at all during the electricity outage, enter zero].

_____________ % of normal operations

1-4. Would this loss of electric power to your organization directly result in public health and safety issues?

◯ Yes ◯ No

[If a respondent answers "yes," ask the following questions]
Please describe the public health and safety issues directly related to your organization that would result from this electricity outage.
[Note to the interviewer: help respondents think more about how outages affect response time, injuries, and deaths due to the reduced operations of their organizations.]

Compared to your organization's normal operations, approximately how much of a percentage increase would the outage cause in your organization's response time to requests for public safety assistance?

___________% increase in response time (for fire, police, ambulance services, and public safety services)

What percentage increase would you expect to see in injuries or deaths during the outage?

___________% increase in the number of injuries among population served
___________% increase in the number of deaths among population served

1-5. Would your organization have any additional costs associated with addressing the effects of the electricity outage, including replacing equipment damaged by the outage?

◯ Yes ◯ No

[If a respondent answers "yes," ask the following questions]
Please describe the additional costs your organization might experience due to the outage.
[Note to interviewer: Help the interviewee think through the potential costs and savings of an outage. Costs include damage to raw materials and/or inventory, damage to equipment, additional labor costs to address outage-related issues, and other tangible costs, such as the costs to run backup generators. Savings could include reduced personnel costs, reduced electricity and material consumption, and so on.]

Please estimate the dollar amount of the additional costs that your organization may experience due to the outage.

$ ___________ additional costs to address outage-related issues

[Question only for respondents who that their organization has business interruption insurance]

1-6. What portion of the costs do you expect to be covered by your organization's interruption insurance policy?

$ _____________ of the loss covered by the insurance after paying $ _____________ deductible

Scenario #2: Regional electricity generation outage lasting two weeks

On a summer morning in August, a series of earthquakes occurred off the northern coast of San Juan, Puerto Rico. Electricity generation infrastructure was damaged due to the residual effects of the earthquake. While your organization and its neighborhood were not directly damaged by the earthquake, the event caused an outage affecting the region where your organization is located. After a few hours, the government of Puerto Rico announced that it would take two weeks to clean up debris on major roads, repair the Port of San Juan, which was significantly damaged, replace critical components of power plants, and restore power to your organization and most other communities served by your organization.

2-1. Which services do you expect to remain operational during this two-week outage?

		Available throughout the outage	Sometimes available	Not available
Public safety	Police	○	○	○
	Fire	○	○	○
	Hospitals	○	○	○
	Emergency shelters and rescue facilities	○	○	○
Transportation	Road	○	○	○
	Rail	○	○	○
	Airports	○	○	○
	Ports	○	○	○
Utilities	Fuel (gasoline, diesel, natural gas, etc.)	○	○	○
	Water	○	○	○
	Wastewater treatment	○	○	○
Communications	Broadcast networks (radio/television)	○	○	○
	Cellular and landline telephone networks	○	○	○
	Cable services	○	○	○
	Satellite communication services	○	○	○
	Broadband internet	○	○	○
Essential services	Pharmacies	○	○	○
	Grocery and convenience stores	○	○	○
	Food warehouse	○	○	○

	Banks and ATMs	○	○	○

2-2. Would the two-week-long regional electricity generation outage affect client demand for the services your organization provides?

2-3. Would your organization be able to continue operations for all or part of the outage?

○ Yes ○ No

[If a respondent says "yes," ask the following questions]

What operations would your organization be able to continue during the outage?

What percentage of normal operations could you continue during the two-week-long regional outage? *[Note to the administrator: if the organization cannot operate at all during the electricity generation outage, enter zero]*.

_____________ % of normal operations

2-4. Would this loss of power to your organization directly result in public health and safety issues?

○ Yes ○ No

[If a respondent answers "yes," ask the following questions]

Please describe the public health and safety issues directly related to your organization that would result from this electricity generation outage. *[Note to the interviewer: help respondents think more about how outages affect response time, injuries, and deaths due to the reduced operations of their organizations.]*

Compared to your organization's normal operations, approximately how much of a percentage increase would the outage cause in your organization's response time to requests for public safety assistance?

___________% increase in response time (for fire, police, ambulance services, public safety services)

What percentage increase would you expect to see in injuries or deaths during the outage?

___________% increase in the number of injuries among population served

___________% increase in the number of deaths among population served

2-5. Would your organization have any additional costs associated with addressing the impacts of the electricity generation outage, including replacing equipment damaged by the outage?

○ Yes ○ No

[If a respondent answers "yes," ask the following questions]

Please describe the additional costs your organization might experience due to the outage.

[*Note to interviewer: Help the interviewee think through the potential costs and savings of an outage. Costs include damage to raw materials and/or inventory, damage to equipment, additional labor costs to address outage-related issues, and other tangible costs, such as* *the costs to run backup generators. Savings could include reduced personnel costs, reduced electricity and material consumption, and so on.]*

Please estimate the amount of additional costs your organization might experience due to the outage.

$ ___________ additional costs to address outage-related issues

[Question only for respondents who that their organization has business interruption insurance]

2-6. What portion of the costs do you expect to be covered by your organization's interruption insurance policy?

_____________ % of the loss covered by the insurance after paying $ _____________ deductible

Scenario #3: Islandwide electricity outage lasting one month
In August, a major hurricane made landfall in Puerto Rico's southeast, between the municipalities of Humacao and Guayama, knocking out electricity infrastructure islandwide. The storm brought high winds and heavy rain as well as widespread flooding and mudslides. Many homes and businesses were damaged. After 24 hours, the storm exited to the northwest, leaving behind significant damage to the island's electricity infrastructure. While your organization and its neighborhood were not directly in the hurricane's path, LUMA Energy and the government anticipated a month-long recovery period to clear debris, repair damaged infrastructure, and restore electricity service to your organization's community and most others across the Island.

3-1. Which services do you expect to remain operational during this one-month outage?

		Available throughout the outage	Sometimes available	Not available
Public safety	Police	○	○	○
	Fire	○	○	○
	Hospitals	○	○	○
	Emergency shelters and rescue facilities	○	○	○
Transportation	Road	○	○	○
	Rail	○	○	○
	Airports	○	○	○
	Ports	○	○	○
Utilities	Fuel (gasoline, diesel, natural gas, etc.)	○	○	○
	Water	○	○	○
	Wastewater treatment	○	○	○
Communications	Broadcast networks (radio/television)	○	○	○
	Cellular and landline telephone networks	○	○	○
	Cable services	○	○	○
	Satellite communication services	○	○	○
	Broadband internet	○	○	○
Essential services	Pharmacies	○	○	○
	Grocery and convenience stores	○	○	○

	Food warehouse	◯	◯	◯
	Banks and ATMs	◯	◯	◯

3-2. Would the one-month-long island-wide electricity outage affect client demand for the services your organization provides?

3-3. Would your organization be able to continue operations for all or part of the outage?
◯ Yes ◯ No

[If a respondent says "yes," ask the following questions]
What operations would your organization be able to continue during the outage?

What percentage of normal operations could you continue during the one-month-long island-wide outage? *[Note to the administrator: if the organization cannot operate at all during the electricity outage, enter zero]*.
______________ % of normal operations

3-4. Would this loss of power to your organization directly result in public health and safety issues?
◯ Yes ◯ No

[If a respondent answers "yes," ask the following questions]
Please describe the public health and safety issues directly related to your organization that would result from this electricity outage.
[Note to the interviewer: help respondents think more about how outages affect response time, injuries, and deaths due to the reduced operations of their organizations.]

Compared to your organization's normal operations, approximately how much of a percentage increase would the outage cause in your organization's response time to requests for public safety assistance?

____________% increase in response time (for fire, police, ambulance services, public safety services)

What percentage increase would you expect to see in injuries or deaths during the outage?

____________% increase in the number of injuries among population served
____________% increase in the number of deaths among population served

3-5. Would your organization have any additional costs associated with addressing the impacts of the electricity outage, including replacing equipment damaged by the outage?
◯ Yes ◯ No

[If a respondent answers "yes," ask the following questions]
Please describe the additional costs your organization might experience due to the outage.
[Note to interviewer: Help the interviewee think through the potential costs and savings of an outage. Costs include damage to raw materials and/or inventory, damage to equipment,

additional labor costs to address outage-related issues, and other tangible costs, such as the costs to run backup generators. Savings could include reduced personnel costs, reduced electricity and material consumption, and so on.]

Please estimate the amount of additional costs your organization might experience due to the outage.

$ ___________ additional costs to address outage-related issues

[Question only for respondents who that their organization has business interruption insurance]

3-6. What portion of the costs do you expect to be covered by your organization's interruption insurance policy?

$ _____________ of the loss covered by the insurance after paying $ _____________ deductible

Thank you for participating in this important study. For the final questions, please share your organization's plan for improving power system resilience in the future and your thoughts on the study.

1. Does your organization have any plans to protect itself from the effects of electricity outages (for example, buying a generator, batteries, battery wall, or stand-by backup generator with a fuel tank)?

○ Yes ○ No

[If a respondent answers "yes," ask the following question]
What types of investments is your organization planning to make?

What is the timeframe for making these investments?

○ 0-6 months
○ 6 months to 1 year
○ 1 year to 2 years
○ 2 years to 5 years
○ Longer than 5 years. Please specify:

What is the main goal of the investment (for example, to be able to continue some critical operations during electricity outages)?

2. Please share any additional comments: