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# Cost of Power Interruptions to Electricity Consumers in the United States (U.S.)

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Environmental Energy
Technologies Division

**February 2006**

http://eetd.lbl.gov/ea/EMS/EMS_pubs.html

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# Cost of Power Interruptions to Electricity Consumers in the United States (U.S.)

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**Abstract**

The massive electric power blackout in the northeastern U.S. and Canada on August 14-15, 2003 catalyzed discussions about modernizing the U.S. electricity grid. Industry sources suggested that investments of $50 to $100 billion would be needed. This work seeks to better understand an important piece of information that has been missing from these discussions: what do power interruptions and fluctuations in power quality (power-quality events) cost electricity consumers? We developed a bottom-up approach for assessing the cost to U.S. electricity consumers of power interruptions and power-quality events (referred to collectively as "reliability events"). The approach can be used to help assess the potential benefits of investments in improving the reliability of the grid. We developed a new estimate based on publicly available information, and assessed how uncertainties in these data affect this estimate using sensitivity analysis.

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## 1. Introduction

The highly publicized power outage in the Northeastern U.S. and Canada on August 14-15, 2003 produced criticism that the U.S. power system was "antiquated", comparable to that of a "Third-World nation", and in need of modernization [1, 2]. Qualitative critiques of the power system have been published [3, 4], but these assessments have largely neglected to quantify an important piece of information: how much do power interruptions and fluctuations in power quality (power-quality events) actually cost electricity consumers? Accurately estimating this cost will help assess the potential benefits of investments in improving the reliability of the grid. This work develops a bottom-up approach for estimating this cost in order to better understand the significance of uncertainties inherited in these estimates.

There have been several efforts to assess the cost of power interruptions and power quality. In 1992, Keane and Woo [5] applied customer outage costs to derive an optimal reserve margin for generation that minimizes the sum of customer outage and generation capacity costs. The resulting optimal reserve margin is compared with and determined to be less than the one implied from the commonly used "1-day-in-10-years loss-of-load" criterion. Because very few data were available on outage costs, rules of thumb were widely used to derive the estimates in the study.

Shortly after, the Electric Power Research Institute (EPRI) reported the first ever power-quality-cost estimate of $26 billion per year for the U.S.[1] [6]. However, power quality is only a subset of reliability events that affect customers and does not include losses of power for periods longer

than a few seconds. In addition, the estimate does not address the residential and commercial

sectors. Finally, the estimate is based on the assumption derived anecdotally from professional

judgment that 1.5 to three cents of spending per dollar sales went to power-quality equipment.

Later, EPRI extrapolated from this figure and began reporting power-interruption costs of $50

billion per year [7].

During the same period, a U.S. Department of Energy (DOE) study published cost-of-reliability

estimates ranging from $150 to $400 billion per year, based on an extrapolation from a value-of-

service study of the Duke Power service territory to the entire U.S. [8]. Sources of potential error

and bias in this estimate include the extrapolation from a single utility service territory to the

entire U.S. and the focus only on costs to the industrial sector [9].

In 2001, Eto et al. [10] performed a scoping study of electricity reliability trends in the U.S.,

which began by updating a comprehensive list of literature on electricity reliability costs. The

report also described three distinct end-use approaches for tracking trends in reliability needs and

presented an insurance industry perspective on electricity reliability as an example of a financial

tool for addressing customers' reliability needs.

Finally and most recently, EPRI estimated the national cost of power interruptions including

power-quality events at $119 billion per year [11]. The estimate is based on a limited national

survey of selected customer groups asking these customers to estimate costs for several distinct

power-outage scenarios.  Key assumptions of this study, which are reviewed in LaCommare and

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[1] Billion refers to $10^9$ U.S. dollars.

Eto [12], are that the costs experienced by the non-surveyed customer groups (excluding residential customers) were 25 to 50 percent of the costs experienced by the surveyed population. Costs to residential customers were not estimated. The outage cost scenarios all asked customers to estimate costs they would experience on summer weekday afternoons, which is the time when customers typically reported the highest costs from outages.

These studies have helped improve our understanding of the sources of uncertainty associated with estimating customer outage costs, which is essential for valuing the overall cost of power interruptions to U.S. electricity customers. However, little has been done to analyze systematically the significance of these uncertainties.

A number of recent analyses, which seek to improve energy demand forecasts, are suggestive of an approach that may facilitate and improve our ability to understand the cost of power interruptions and power-quality events using a bottom-up approach. In particular, research using end-use approaches has improved our understanding of how energy is used. For example, Turiel et al. [13] estimates the energy intensity of major end uses in the commercial sector using an end-use approach, work that is important to understanding how each end use contributes to the overall demand for electricity in the commercial sector. Bottom-up analyses such as these, allow for more accurate estimates of energy consumption patterns and help improve the modeling accuracy of energy forecasting models. Chateau and Lapillonne [14] stress the importance of end-use models and approaches as an important tool for forecasting energy demand in long term energy planning. Our work builds upon the analytical rigor and strengths inherent in these

bottom-up approaches for energy analysis by adapting it to improve our understanding of the

cost of outages.

In the work described in this article, we developed a bottom-up approach for estimating the cost

of power interruptions to U.S. electricity consumers. We illustrated the use of the approach by

drawing on existing data from a variety of sources to develop a new ("base case") estimate of the

total economic cost to U.S. electricity consumers (not including power quality events.) We

examined uncertainties and gaps in the information used to develop our estimate as one

application of our end-use approach in order to define the degree of variability that might be

expected in future estimates. Based on the identified uncertainties, we prioritized future data-

collection activities whose results can be used to refine estimates of outage costs.

**2. A Bottom-Up Approach for Estimating the Economic Cost of Power Interruptions and Power-Quality Events**

A key aspect of our work is the development of a bottom-up approach for estimating the

economic costs of power interruptions and power-quality events to U.S. electricity consumers.

The framework relies on a simple mathematical expression that determines the economic cost of

power interruptions and power-quality events as follows:

$$\text{Cost of Power Interruptions and Power Quality} = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{p} N_{i,j} \times F_{i,j,k} \times C_{i,j,k} \times V_{i,j,k} \qquad (1)$$

where,

$\qquad N$ = number of electricity customers in customer class $i$ for region $j$

$F$ = the frequency of reliability events of type $k$ experienced annually by customer class $i$

in region $j$

$C$ = the cost of reliability event type $k$ per customer in customer class $i$ for region $j$ (2002-

Consumer-Price-Index-weighted dollars/event)

$V$ = the vulnerability of customers to reliability event type $k$ in customer class $i$ for region

$j$ (a fraction between 0 and 1)

$m$ = the number of customers in each customer class

$n$ = the number of regions

$p$ = the number of types of reliability event

$i,j,k$ = indices for customer class, region, and type of reliability event, respectively

The simplicity of this formula belies the complexities involved in estimating each of the four

parameters in equation (1). Indeed, the data used to estimate the parameters are often difficult to

define clearly. The following subsections outline current limitations on availability of the data

needed to estimate each parameter, while section 3 describes the process we used to collect these

data for our study.

## 2.1   Customer Data

The number of customers considered in estimating the cost of power interruptions or power-

quality events will have a significant impact on the magnitude of the estimate. Substantial

uncertainty can result from differences in how customers are defined. In the U.S., customers may

be defined in any of the following ways: (1) as a single electricity account with one (or more)

meter(s), such as a single-family detached residence; (2) as a single site/facility with multiple

accounts, each possibly consisting of multiple meters, such as an apartment building; or (3) as multiple premises under common ownership, each with one or more accounts/meters, such as a chain of retail establishments. It is important to note that customers do not equal people and that one electricity customer often refers to one household, residence, or commercial or industrial facility or business.

## 2.2 Reliability Event Data

Although many U.S. utilities maintain detailed records of customer outage experience, these data are usually reported in summarized form as two reliability-event indices [15]: the System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI). SAIDI and SAIFI describe the duration and frequency, respectively, of *sustained* interruptions experienced by customers of a utility in one year [16, 17]. According to the Institute of Electrical and Electronics Engineers (IEEE), a "sustained interruption" is any interruption that lasts at least five minutes and is not classified as "momentary". Consistent with IEEE's definition of a sustained interruption, a momentary outage is defined as any event lasting less than five minutes.

SAIDI represents the average duration of customers' power interruptions, while SAIFI represents the average number of interruptions per customer per year for a specified electricity supply system. We used SAIDI and SAIFI data to quantify the duration and frequency of sustained electricity interruption events for a typical year. We also used the Momentary Average

Interruption Frequency Index (MAIFI) index, which is a useful measure for assessing the frequency of momentary interruptions; however, these data are not as commonly collected.

Unfortunately, SAIDI, SAIFI, and MAIFI data do not distinguish among the types of customers experiencing reliability events. Because of the way electricity distribution systems are designed and operated, larger commercial and industrial customers in some areas may experience fewer and shorter power interruptions than smaller commercial and residential customers [18].

Power quality, or the degree to which voltage and current deviate from a perfect 60-cycle sinuosoid, has emerged as an important issue in recent years. Despite the growing importance of power-quality events as a category of reliability events, there is even less information available on these events than on power outages. There has been only one comprehensive study of power quality, and the data collected for it are now more than a decade old [19]. Currently, there are no ongoing public-domain data-collection efforts for power quality [17]. Hence, although the bottom-up approach we designed allows for consideration of power-quality events, the lack of sufficient power-quality data prevented us from considering these events in our base-case estimate.

### 2.3 Cost per Outage Data

Estimating customer outage costs involve several sources of uncertainty, two of which pertain to the accuracy of the cost measurement as well as how representative the estimate is of the area it covers. Typically, outage-cost estimates are based on what customers *say* they will experience

under different hypothetical outage circumstances in surveys [9]. The key source of uncertainty in these estimates is the degree to which the costs customers report for hypothetical circumstances correspond with the actual costs they would experience [20]. No studies have attempted to validate the results obtained from these surveys, yet this is a significant source of uncertainty in the cost estimates that have been prepared to date. Another important source of uncertainty inherent to customer survey data is small sample size; this can lead to significant errors if the sample is insufficient to appropriately represent the population. A common manifestation of this uncertainty arises from extrapolation to a wide geographic area from a smaller subset that is not representative of the wider geography.

Assessing actual costs is complicated by the differing impacts of reliability events on various classes of customers – residential, commercial, and industrial. Costs experienced by non-residential customers or firms are, in principle, simpler to estimate than the difficult-to-quantify "hardship" costs experienced by residential customers. Basic accounting categories for commercial customers, such as labor and materials costs and revenue losses, are straightforward (though not necessarily easy to use) to apply in determining the cost of work interruptions caused by power losses. Residential-sector costs, however, include elements such as the cost of consumable goods (e.g. flashlights and candles) and inconvenience costs (e.g. resetting clocks, changing plans, and coping with inconvenience, fear, anxiety, etc.).

A subtle issue that is gaining recognition is that business losses are not always directly proportional to the duration of a reliability event [21]. In such cases, the key factor is the length of business or production downtime caused by an outage of any length. For example, a partial

loss of voltage or a voltage sag can cause the same amount of downtime as a complete loss of power, if, for example, machines need to be rebooted or production processes need to be restarted. This issue poses a major challenge in estimating the economic cost of power interruptions and power-quality events.

## 2.4 *Vulnerability*

The economic cost and perceived risk of reliability events has led many customers to invest in a wide variety of technologies and measures to reduce their vulnerability to these events. Back-up or stand-by generators are probably the most well known customer investments; smaller investments like strip-surge protectors should be considered in this same category, however. In between are a host of energy-storage technologies, such as batteries and flywheels, which can reduce a customer's vulnerability to power interruption and power-quality events. Comprehensive, national data on these investments are lacking. Hence, in the illustrative example presented in the next section, we did not explicitly consider the potential of these measures to reduce customers' vulnerability to reliability events. That is, we implicitly set this factor to be equal to 1.0.

## 3. Deriving a New Estimate of the Economic Cost of Power Interruptions to U.S. Electricity Consumers

Having established our framework, we applied it to develop a new estimate of the cost of power interruptions, based on a review of the best data available in the public domain (the "base case").

As described earlier, even the best data available have important limitations and our new estimate ultimately represents a mix of nationally aggregated and regional data components.

### 3.1 Customers by Class and Region

We used residential, commercial, and industrial electricity demand sectors to describe customer classes as shown in Table 1. Customer population data were taken directly from the Energy Information Administration (EIA) *Electric Sales and Revenue* publication [22]. The data are reported for the year 2001 by state and demand sector. We partitioned the U.S. into regions so that we could represent variations in outage costs as a function of differences in the population. The regions correspond to U.S. Census Divisions as mapped by EIA, with a slight variation in the Pacific; we extracted California, where most of the Pacific region population resides, and treated it as a separate region.

### 3.2 Duration and Frequency of Reliability Events

Despite the existence of well-defined indices for a majority of reliability events, reliability event data are not collected systematically or consistently. The National Regulatory Research Institute reports that only 23 of 40 surveyed states require annual reporting of reliability statistics [23]. As a result, deriving reliability event data on a national scale is a challenge.

We conducted an Internet search to gather publicly available reliability-event data. To address biases introduced by extreme outlying values, we used "trimmed means": we removed the

highest and lowest five percent of observations and then calculated the means of the reduced

observations [24]. Table 2 shows the trimmed means and standard deviations for SAIDI, SAIFI,

and MAIFI used for our base case calculation. Trimming the data sets had a noticeable effect on

the resulting average duration of outages in the U.S.[2] Because our Internet search did not

produce adequate data for all regions, national reliability event data were used in the base case

with regional considerations presented in our sensitivity analysis.

Several other studies have also examined national SAIDI, SAIFI, and MAIFI statistics (see Table

3). Our calculated trimmed means of 106 minutes, 1.2 sustained interruptions, and 4.3

momentary interruptions for SAIDI, SAIFI, and MAIFI, respectively, are very similar to the

estimates reported from these studies.Our data thus appear to be reasonable inputs for calculating

the cost of power interruptions to U.S. electricity customers.

Since we did not find similarly comprehensive data on the frequency of power-quality events, we

elected to exclude the costs of these events in our base-case estimate.

*3.3    Cost of Reliability Events*

Limited information is available on the cost of reliability events. The cost data is taken from a

recent analysis of the cost of power interruptions to customers [9]. The study is a meta-analysis

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[2] When we removed the outliers, the SAIDI average decreased by 13 percent, from 122 to 106 minutes, but the SAIFI and MAIFI means changed very little. The standard deviation for both SAIDI and SAIFI were roughly halved when the outlying 10 percent of the data points were removed; the MAIFI standard deviations were reduced by more than 10 percent f. This suggests that trimming the highest and lowest five percent of data points helped to improve significantly the robustness of our means.

of 24 independent customer surveys conducted by eight electric utility companies in the U.S. during the past 13 years.

The study developed analytic expressions, called "customer damage functions", using a regression approach that expresses customer outage costs as a function of customer class, region, event duration, and other descriptive variables based on survey responses from more than 2,000 large commercial and industrial (C&I), 5,200 small and medium C&I, and 11,000 residential customers. The resulting cost per outage per customer data we derived using the damage functions were normalized and reported in year-2002 Consumer-Price-Index (CPI)-weighted dollars. The independent descriptive variables used to derive customer outage costs were obtained from the most recently available EIA Commercial Building Energy Consumption Survey (CBECS) and Manufacturing Energy Consumption Survey (MECS) data.

To account for outage cost differences by time of day, week, and season, we weighted the costs for morning, night, weekend, weekday, and summer and winter time periods. The outage cost associated with each time period was then weighted to derive the cost per outage per customer throughout the year.

Table 4 shows the costs per outage per customer used to calculate the total cost of power interruptions to U.S. electricity customers in our base case analysis. The table includes costs for momentary and sustained interruptions as well as costs for the typically reported one-hour outage length as a basis of comparison to external estimates. Again, the U.S. outage cost is used in our base case estimate with regional consideration in the sensitivity analysis.

*3.4    Base-Case Estimate of the Economic Cost of Power Interruptions*

We find that, based on publicly available data and subject to the limitations discussed in this section, the economic cost of power interruptions to U.S. electricity consumers is $79 billion annually.

Figure 1 shows how these costs are distributed among the three customer classes. The commercial sector accounts for more than 72 percent ($57 billion) of the total outage cost. This large share is due to the high outage cost for this sector (shown in Table 4) coupled with the large population of commercial customers. The industrial sector represents nearly 26 percent of the total cost, and the residential sector accounts for less than 2 percent of the total.

Although per outage per customer costs were significantly higher for the industrial sector than for the commercial and residential sectors, the industrial sector's smaller population-- 1.6 million customers, compared to 14.9 million commercial customers--led to a lower total estimated cost than for the commercial sector. Commercial sector outage costs were roughly one order of magnitude lower than those for the industrial sector. The 114.3 million residential customers represent by far the largest population of customers in the three sectors, but their outage costs are two to three orders of magnitude lower than for the commercial sector. Therefore, despite its large customer population, the residential sector's contribution to the total is minor.

Figure 2 shows that momentary outages accounted for two-thirds of the overall annual U.S. outage cost; the 4.3 momentary outages that were derived from a trimmed mean of collected Internet data cost the U.S. $52 billion each year; the 1.2 sustained outages (totaling 106 minutes together) also representing a reduced mean of the collected data account for the remaining $26 billion of the $79 billion total.

Figure 3 shows our base-case estimate by region and customer class. The South Atlantic region bears the largest burden, $14.7 billion, or nearly 19 percent, of the total outage cost for the nation. The Pacific-region cost, with only $2.8 billion (or 3.6 percent of the total) has the lowest share of national outage costs.

Figure 3 also compares our regional estimates to the population of commercial and industrial customers in each region to determine how well correlated the regional estimates are to population density.[3] The differences in the total costs by region appear to correspond well to these regional population differences. In the South Atlantic region, the higher total cost is clearly linked to the large population. The lowest total costs are seen in the Pacific and New England regions where the customer populations are the smallest.

These findings point to the underlying parameters (i.e., customer definitions and populations, outage characteristics, and outage costs) that likely have the greatest influence on our estimate. Next, we explore the sensitivity of each of these parameters to understand better the effects of their inherent uncertainties on the total cost of power interruptions.

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[3] The residential population is not included because it is such a large share of the total population, yet has little overall impact on the total cost of power interruptions in the U.S.

**4.    Using Sensitivity Analysis to Explore Uncertainty in Power Interruption Cost Estimates**

To understand the impacts of uncertainty on results from our bottom-up approach, we performed a sensitivity analysis in which we varied the key parameters to quantify their impact on our results. This sensitivity analysis expresses the degree of uncertainty associated with the input parameters as well as the variability in the resulting cost estimate.

Figure 4 shows the resulting total cost of power interruption estimates for each of the following sensitivity analyses, in which we varied:

1.  The duration and frequency of reliability events and the cost per outage per customer by region, using the limited region-specific data we collected;

2.  The duration and frequency of reliability events by one standard deviation greater and less than the values used in our base-case estimate;

3.  The value of outages based on two assumptions of their timing--whether they occur on a summer weekday afternoon or summer weekend night; and

4.  The duration and frequency of reliability events experienced by commercial and industrial sectors to reflect the fact that they tend to be disproportionately shorter in duration and of decreased frequency relative to events experienced by the residential sector.

We found that the annual cost of power interruptions:

- Could be as low as $22 billion or as high as $135 billion when we consider a reasonable range in the annual duration and frequency of power interruptions, which accounts for gaps in the data for certain regions and possible year-to-year variations in reliability;

- Could be as high as $119 billion if, as many studies (incorrectly) assume, all reliability events take place during summer weekday afternoons when power usage and costs are high;

- Could be as low as $23 billion if the typically fewer and shorter interruptions experienced by larger commercial and industrial customers are accounted for, which is the result of the design of many utility distribution systems; and

- Is relatively insensitive to regional variation in reliability event and outage cost data—the $90 billion estimate accounting for this variation is only 14 percent higher than the base-case estimate that used U.S.-averaged values.

Each sensitivity exercise helped shed light on key uncertainties associated with calculating the cost of power interruptions. The modest impact of regional differences suggests that climate and the distribution of customers by class across the country has a limited impact on the overall cost of power interruptions in the U.S. However, we detected significant differences in the other three sensitivity studies. Changing the base-case SAIDI, SAIFI, and MAIFI values by just one standard deviation, changes the overall estimate by one order of magnitude, from $22 billion to $135 billion annually. This illustrates the large effect that outage duration and frequency, which can realistically be expected to vary within this range, have on the overall cost. Assumptions about the timing of events have almost as large an impact, mainly because commercial and industrial customers' outage costs depend on whether events occur during their operating hours. This demonstrates the importance of using time-representative outage costs when calculating

total costs. Finally, the total cost estimate is dramatically lowered when we account for higher levels of electric reliability typically enjoyed by industrial sector customers relative to commercial and residential customers. This variable, too, has a significant influence on overall cost-of-power-interruptions estimates and should be accounted for in future analyses.

## 5. Conclusion

Our analysis establishes a bottom-up approach for systematically comparing and analyzing estimates of the economic cost of power interruptions and power quality to U.S. electricity customers. Using this approach, our base-case estimate of the annual cost for power interruptions to U.S. electricity consumers is $79 billion. Our analysis of the uncertainty in this estimate suggests that the costs could be as high as $135 billion or as low as $22 billion based on the particular sensitivity assumptions we employed. Thus, we present these figures not as the final word on the cost of power interruptions, but rather to illustrate the range of variability in estimates, which is directly related to the assumptions on which the estimates are based and the uncertainty inherent to these assumptions. In view of the large range of plausible estimates and the enormous costs associated with the private and public decisions that may be based on them, we encourage policy makers, regulators, and industry to work jointly to undertake activities needed to improve the information available on reliability events and their costs. The cost of such improved data collection would be modest relative to the potential costs of reliability events in the U.S.

Using our bottom-up approach, we find that the majority of outage costs are borne by the commercial and industrial sectors, not the residential sector. Although there are important variations in the composition of customer types within each region of the country, the total cost of reliability events by region tend to correlate roughly with the number of commercial and industrial customers in each region. In addition, costs tend to be driven by the *frequency* rather than the *duration* of reliability events. Momentary power interruptions, which are more frequent, have a larger impact on the total cost of interruptions than sustained interruptions, which are less frequent.

Priorities for future improvements in outage cost data collection fall into two broad categories: better information is needed on customers' reliability experiences and on the cost of power interruptions to individual customers. Specific improvements include: undertaking a coordinated, nationwide collection of updated information on the cost of reliability events to customers; validating the outage costs obtained from customer surveys with actual market data (e.g., customer ownership of backup generation), establishing consistent definitions and tracking protocols for the frequency, duration, timing, and number and type of customers affected by reliability events, including power-quality events, by customer class; and collecting information on efforts by customers to reduce their vulnerability to reliability events through investments in technology and other measures.

**Acknowledgements**

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**Figure and Table Captions**

Figure 1. Base-Case Estimate of the Cost of Power Interruptions by Customer Class[1]

Figure 2. Base-Case Estimate of the Cost of Power Interruptions by Type of Interruption[1]

Figure 3. Base-Case Estimate of the Cost of Power Interruptions by Region and Customer Class with C&I Population[1]
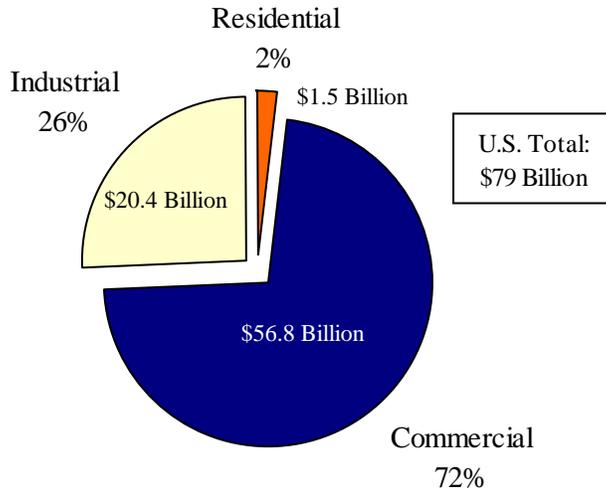
Figure 4. Summary of U.S. Cost of Power Interruption Sensitivity Cases[1]

Table 1. Number of Customers by Region and Sector in 2001

Table 2. Summary of Trimmed Mean Reliability Event Data

Table 3. Summary of U.S. Reliability Event Estimates by External Studies

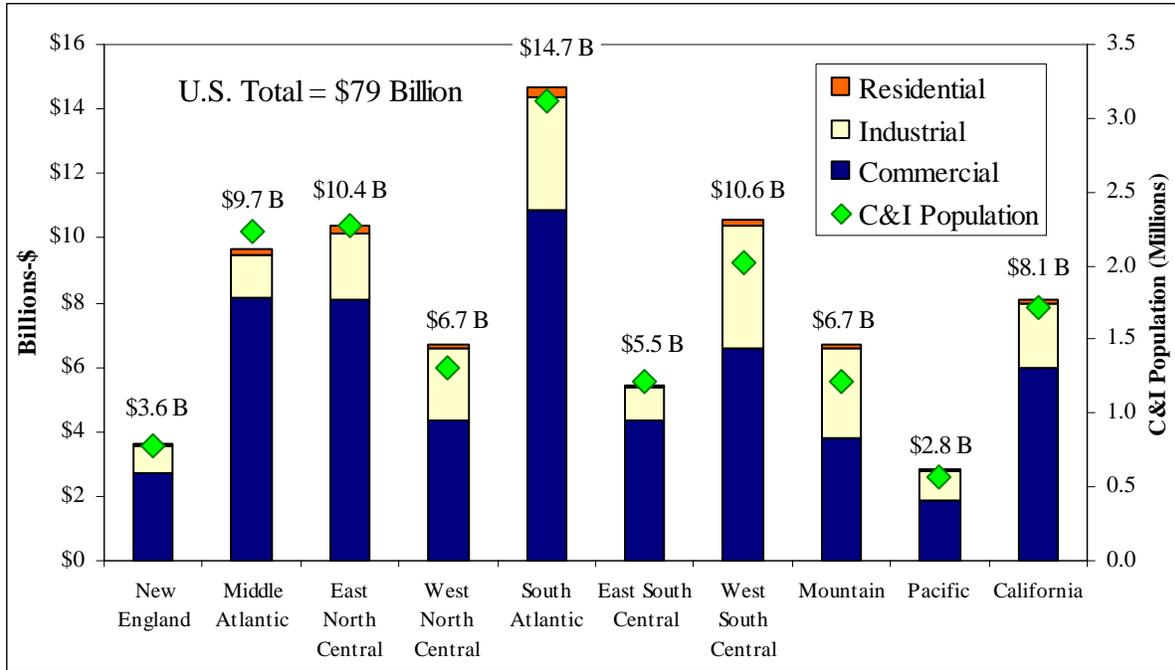Table 4. Customer Outage Costs for the U.S. in 2001

<sup>1</sup>Costs shown in U.S. 2002 CPI-weighted dollars

**Figure 1. Base-Case Estimate of the Cost of Power Interruptions by Customer Class[1]**

U.S. Total: $79 Billion

Sustained Interruptions 33%

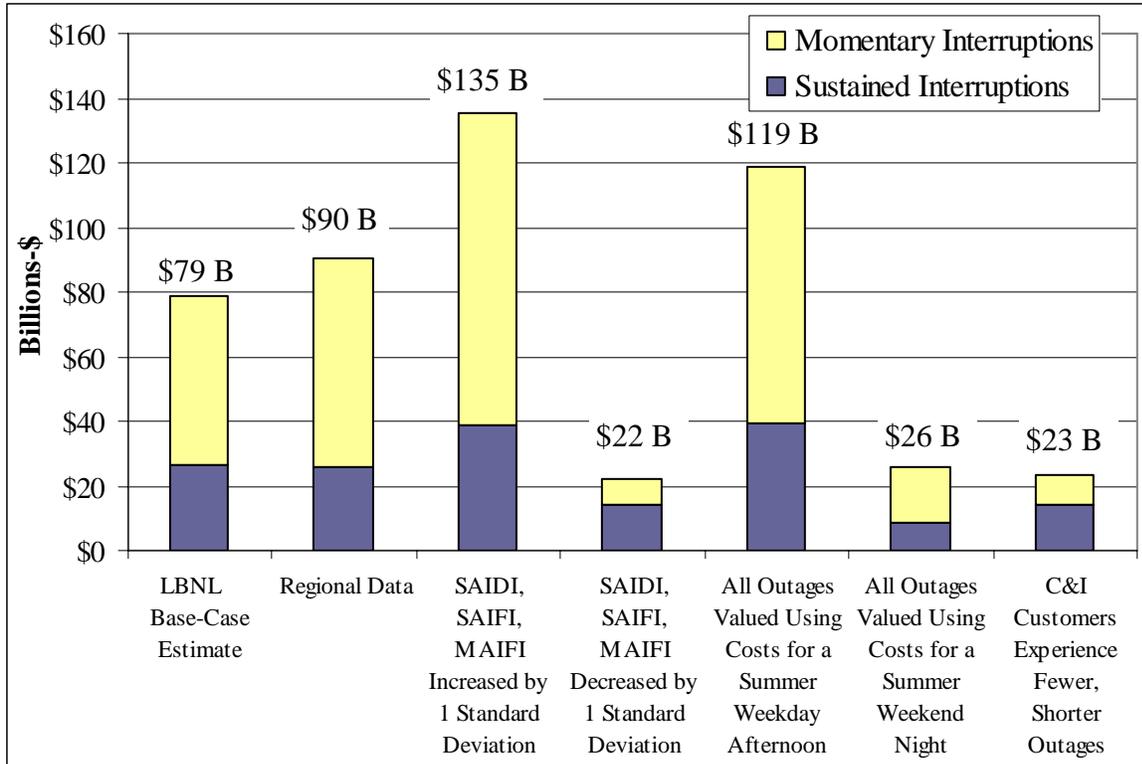$26.3 Billion

$52.3 Billion

Momentary Interruptions 67%
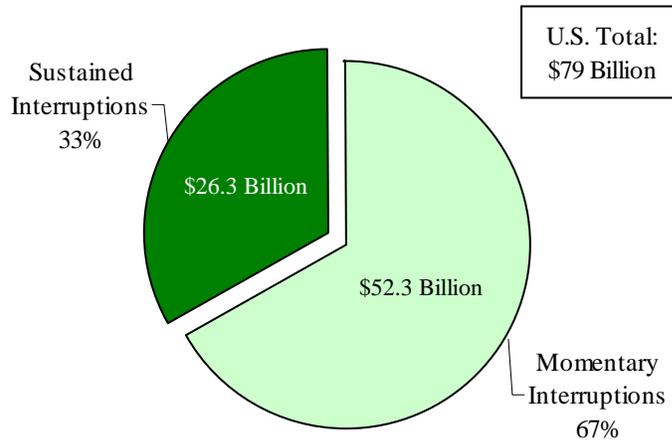
[1]Costs shown in U.S. 2002 CPI-weighted dollars

**Figure 2. Base-Case Estimate of the Cost of Power Interruptions by Type of Interruption[1]**

[1]Costs shown in U.S. 2002 CPI-weighted dollars

**Figure 3. Base-Case Estimate of the Cost of Power Interruptions by Region and Customer Class with C&I Population[1]**

[1]Costs shown in U.S. 2002 CPI-weighted dollars

**Figure 4. Summary of U.S. Cost of Power Interruption Sensitivity Cases[1]**

**Table 1. Number of Customers by Region and Sector in 2001**

|  | RESIDENTIAL | COMMERCIAL | INDUSTRIAL | TOTAL |
|---|---|---|---|---|
| U.S. ESTIMATE | 114,317,707 | 14,939,895 | 1,582,573 | 130,840,175 |
| BY REGION |  |  |  |  |
| New England | 5,822,935 | 714,049 | 62,677 | 6,599,661 |
| Middle Atlantic | 15,045,495 | 2,127,033 | 103,713 | 17,276,241 |
| East North Central | 18,705,754 | 2,110,172 | 158,780 | 20,974,706 |
| West North Central | 8,287,837 | 1,139,609 | 170,937 | 9,598,383 |
| South Atlantic | 22,473,797 | 2,842,220 | 270,840 | 25,586,857 |
| East South Central | 7,356,975 | 1,135,507 | 78,545 | 8,571,027 |
| West South Central | 12,883,403 | 1,722,873 | 292,035 | 14,898,311 |
| Mountain | 7,368,280 | 1,001,310 | 212,842 | 8,582,432 |
| Pacific | 3,922,426 | 494,778 | 66,699 | 4,483,903 |
| California | 11,841,144 | 1,559,258 | 154,261 | 13,554,663 |

Source: Energy Information Administration. 2003. *Electric Sales and Revenue 2001*. EIA/DOE. January. Washington D.C.

**Table 2. Summary of Trimmed Mean Reliability Event Data**

|                        | SAIDI      | SAIFI | MAIFI |
|------------------------|------------|-------|-------|
| Trimmed Mean           | 106 min.   | 1.2   | 4.3   |
| (Standard Deviation)   | (54 min.)  | (0.5) | (3.6) |

**Table 3. Summary of U.S. Reliability Event Estimates by External Studies**

|  | SAIFI | SAIDI | MAIFI |
|---|---|---|---|
| EPRI Report[a] | 1.1 | 107 |  |
| IEEE 1995 Survey[b] | 1.3 | 120 | 5.5 |
| EEI Annual Report[c] |  |  |  |
| 1998 | 1.2 | 118 | 5.4 |
| 1999 | 1.4 | 101 | 11.6 |

[a]Source: EPRI 2003 *Distribution Reliability Indices Tracking Within the U.S.* TR-1008459. May. Palo Alto CA.
[b]Source: IEEE 1995 Survey (http://resourceinsight.com/work/naruc_pbr_97.pdf)
[c]Source: Power Sources Manufacturer's Association (http://www.psma.com/HTML/newsletter/Q2_2001/page11.html)

**Table 4. Customer Outage Costs for the U.S. in 2001[a]**

|                           | Residential | Commercial | Industrial |
|---------------------------|-------------|------------|------------|
| Momentary Interruption    | $2.18       | $605       | $1,893     |
| Sustained Interruption    | $2.99       | $1,067     | $4,227     |
| One-hour Interruption     | $2.70       | $886       | $3,253     |

[a]Costs shown in U.S. 2002 CPI-weighted dollars