DISTRIBUTED ENERGY PROGRAM **REPORT**

2006 Update of Business Downtime Costs

July 2006

By

SENTECH, Inc.

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

ABSTRACT

The distributed, renewable, and fuel cell energy communities have frequently cited “business downtime costs” from the table “Selected Outage Costs” when discussing the value that power reliability and quality from onsite energy generation can provide to building owners.

These downtime cost data, although extensively cited, have limited applicability to many building owners in 2006 for several reasons. First, downtime costs are provided for only five industry types—ones that typically need high degrees of power reliability and quality. Also, the table’s downtime costs are listed as an average hourly rate with no consideration given to the duration of a power outage. From the data presented, it is not clear if these outage costs only account for lost revenue, or if they include other costs that can be caused by power outages such as damaged equipment and lost product. Finally, the original sources[1] from which this information was gathered were published in 1996, raising the possibility that these costs are out of date due to technological changes that have occurred in the U.S. economy.

The objective of this paper is to assess the cost of power outages to businesses in the commercial and industrial sectors using the best and most current data available, short of surveying a statistically significant pool of building owners. Using existing studies, a compilation can be made of data that 1) applies to a wider set of “industry” types 2) reflects more current downtime costs, 3) accounts for the time duration factor of power outages, and 4) includes the range of costs imposed by real-world outages in a well-defined market.

This assessment will be more aligned with the growing business trend of “business continuity planning.” According to KPMG, companies are developing continuity plans that prepare their firms for power quality or outage events lasting from milliseconds to entire days. Since downtime can be costly and even force companies out of business, KMPG advises clients to focus on ensuring financial continuity, customer satisfaction, and productivity despite a catastrophe.

Most small businesses underestimate the loss of profit that comes with a disaster related to power outage and business downtime. About 50 percent of disaster damages are business claims, including those for the interruption of business, and “the No. 1 killer of businesses is not the loss of the property, because they get enough coverage to rebuild. It's the loss of profits while the business is closed, because they operate on such a thin margin."

With a growing trend in the business world of business continuity planning that would ensure financial continuity, customer satisfaction, and productivity despite a catastrophe, business owners in select subsectors that suffer most from business downtime could realize substantial financial gains from reliable power achievable through onsite power.

With a greater understanding of the current costs and cost components of downtime, the variability in downtime costs due to business type, and the change in downtime costs over time, business owners may be better able to calculate the true value in reliable, high quality, power from onsite energy.

I. BACKGROUND

Business Downtime Costs and the Value of Onsite Energy

The distributed, renewable, and fuel cell energy communities have frequently cited "business downtime costs" from the following table, "Selected Outage Costs," when discussing the value that power reliability and quality from onsite energy generation can provide to building owners.

Table 1. Selected Outage Costs

INDUSTRY	AVERAGE COST OF DOWNTIME	SOURCE
Cellular Communications	$41,000 per hour	Teleconnect Magazine
Telephone Ticket Sales	$72,000 per hour	Contingency Planning Research-1996
Airline Reservations	$90,000 per hour	Contingency Planning Research-1996
Credit Card Operations	$2,580,000 per hour	Contingency Planning Operations-1996
Brokerage Operations	$6,480,000 per hour	Contingency Planning Operations-1996

These downtime cost data, although extensively cited, have limited applicability to many building owners in 2006 for several reasons. First, downtime costs are provided for only five industry types—ones that typically need high degrees of power reliability and quality. Also, the table's downtime costs are listed as an average hourly rate with no consideration given to the duration of a power outage. From the data presented, it is not clear if these outage costs only account for lost revenue, or if they include other costs that can be caused by power outages such as damaged equipment and lost product. Finally, the original sources[2] from which this information was gathered were published in 1996, raising the possibility that these costs are out of date due to technological changes that have occurred in the U.S. economy.

Attempts to contact *Teleconnect Magazine*, *Contingency Planning Research*, and *Contingency Planning Operations* to better understand their data were not successful. Thus, alternative methods are needed to update and possibly improve upon these downtime cost data.

The objective of this paper is to assess the cost of power outages to businesses in the commercial and industrial sectors using the best and most current data available, short of surveying a statistically significant pool of building owners. Using existing studies, a compilation can be made of data that 1) applies to a wider set of "industry" types 2) reflects more current downtime costs, 3) accounts for the time duration factor of power outages, and 4) includes the range of costs imposed by real-world outages in a well-defined market.

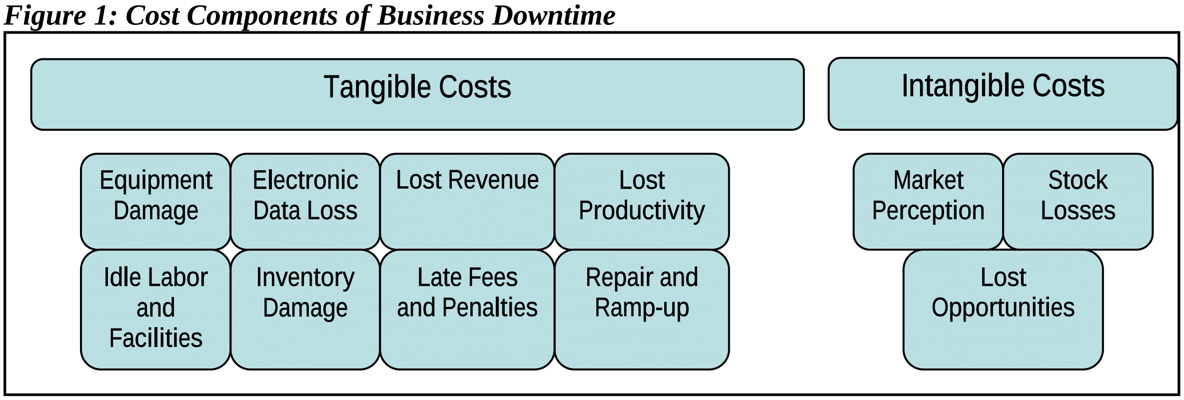
This assessment will be more aligned with the growing business trend of "business continuity planning." According to KPMG – an international firm that provides information risk management, audit, tax, and advisory services to businesses worldwide[3] – companies are developing continuity plans that prepare their firms for power quality or outage events lasting from milliseconds to entire days. Since downtime can be costly and even force companies out of business, KMPG advises clients to focus on ensuring financial continuity, customer satisfaction, and productivity despite a catastrophe.[4]

Factors to Consider when Discussing Downtime Costs

To accurately assess the costs of downtime and to make an update of downtime costs that is useful to a wide spectrum of business types, it is essential to identify and consider data on how the following factors affect downtime costs:

1. Downtime Cost Components. Lost revenue is the most visible and easily identified cost of downtime, yet there are many other tangible and intangible impacts that must be factored into calculating a company's total downtime costs:
    a. *Tangible cost components* can be identified and measured in terms of hard dollars and may include equipment damage, electronic data loss, lost revenue, lost productivity, idle labor and facilities, inventory damage, late fees and penalties, repair and ramp-up costs[5]—as illustrated below.
    b. *Intangible cost components* are more difficult to ascertain and quantify but may include market perception of the company, stock losses, and lost opportunities[6]—as illustrated below.

Figure 1: Cost Components of Business Downtime



2. Business Type. The downtime costs for the five business types included in the table above account for only a fraction of the total economy-wide costs of a power outage. In addition, because some types of businesses are more sensitive to power outages than others, outage costs vary drastically from one subsector of the economy to another. Since "power sensitive" businesses were selected for inclusion in the "Selected Outage Costs" table, these results are not likely to be representative of downtime costs for most sectors of the economy.

    The "2006 UPDATE OF BUSINESS DOWNTIME COSTS" paper examines outage costs for a broad range of businesses in the commercial and industrial sectors, using published reports, personal contacts, and databases. Sources include the U.S. Census Bureau's North American Industry Classification System (NAICS), DOE's Commercial Buildings Energy Consumption Survey (CBECS), researchers at the National Laboratories, business analysts such as KPMG, and think tanks such as the Uptime Institute.

3. Power Outage Duration. Much of the published discussion on electricity interruption costs assumes that downtime costs stay the same over the duration of an outage. Yet, as many reports and data show, downtime costs change significantly over the duration of an outage, making simple dollar per hour cost figures inaccurate and imprecise.

    A study by Lawrence Berkeley National Laboratory, for example, shows that marginal outage costs to large commercial and industrial businesses tend to increase as the outage duration increases from one to eight hours.[7] However, some businesses experience the greatest damage in the first seconds or even milliseconds of a power interruption. Traditionally, businesses have planned for natural or man-made disasters disrupting production, distribution and data processing in the *power reliability* timescale, i.e. seconds to minutes. Now, the economics of information, globalization, and technology has put new impetus on businesses planning for *power quality* events – voltage sags, power blips, or out-of-synch events lasting from milliseconds to two seconds – that affect sensitive equipment such as computers and processors.

II. METHODOLOGY

The goal of this analysis is to obtain annual downtime costs for various subsectors of the economy for outages of different durations. The following methodology lays the groundwork for how this report assesses business downtime costs.

Data Sources

After a careful examination of several potential sources of data on downtime costs, one study was identified—"Electrical Power Interruption Cost Estimates for Individual Industries, Sectors, and U.S. Economy"—that satisfied the three "Factors to Consider when Discussing Downtime Costs." Namely, the study:

1. Considered a large number (70) of business types,
2. Contained cost data for power outages of varying duration, and
3. Is based on an end-user survey method designed to capture many of the tangible costs of downtime.

This study was written by Balducci et al. and published by Pacific Northwest National Laboratory (PNNL) in 2002 (hereinafter referred to as the "Balducci study"), and was based on a survey that covered outages of 20 minutes, 1 hour, and 4 hours in duration. Because this data is based on surveys from actual end-users, they capture costs including:

- Lost revenue,
- Lost production,
- Idle facilities and labor,
- Damage to electronic data,
- Damaged or spoiled product,
- Damage to equipment, and
- Customer refunds.

The Balducci study was chosen as the primary source of data because it was the best data set available. As many types of tangible costs as possible are included in order to accurately portray the costs of downtime; however, intangible costs to be too difficult–and too dependent on factors unique to individual businesses–to ascertain and quantify in general terms.

Data Analysis

The Balducci study expresses downtime costs in the unit of dollars per peak annual kilowatt of electricity used by a facility. To make the Balducci data more useful for businesses, this data was combined with publicly available information to calculate average downtime costs for individual businesses and for aggregate sectors of the economy.

The survey data for the Balducci study were initially collected by the University of Saskatchewan in 1992 and 1996. The survey responses are divided into 70 subsectors of the commercial and industrial sectors and the residential sector, and list costs for 20-minute, 1-hour, and 4-hour outages.

For this paper's analysis, the dollars per peak annual kilowatts (kW) unit was converted to dollars per annual kilowatt-hours (kWh), using the ratio of 1 peak kW equals 2000 annual kWh, as inferred from the listed values for the Saskatchewan 1991 study in Eto et al., 2001.[8] The value for each subsector was then converted from 1996 dollars to 2006 dollars using a conversion factor of 1.285, obtained from an inflation conversion calculator made available by the University of Oregon.[9]

Next, numbers of kWh's annually consumed by each subsector of the commercial, residential, and industrial sectors in the United States were identified. Energy use data for the industrial subsectors for

1996 are published in the Balducci study. Because the level of industrial electricity consumption in the U.S. in 2003 is nearly identical to what it was in 1996, it was not adjusted to estimate current costs.[10] The number of kWh of electricity consumed by the residential sector in 2003 was obtained from EIA's *Electric Power Annual*. The number of kWh of electricity consumed by each commercial subsector in 2003 was obtained from EIA's *Commercial Buildings Energy Consumption Survey* (CBECS) database.

For the most part, the commercial subsectors listed in CBECS directly translate to subsectors for which downtime cost data is available in the Balducci study. However, the Balducci study lists both a "personal services" subsector and a "business services" subsector, while CBECS only lists a "services" subsector. To resolve this, the assumption was made that the CBECS "services" category was comprised of one-half business services and one-half personal services.

The outage cost per annual kWh for each subsector was then multiplied by the number of annual kWh's used by that subsector to obtain a cost for a 20 minute, 1 hour, and 4 hour power outage for that subsector. The subsector costs were then aggregated to calculate the cost of an outage for each major sector and for the entire U.S. economy. Finally, by obtaining the number of establishments in each industrial subsector from NAICS data and in each commercial subsector from the CBECS data, it was possible to calculate the costs of business downtime for the average establishment in each subsector.

Data Limitations

The largest drawback to using the Balducci data is that it was collected in 1996. However, as has been demonstrated above, more recent data of adequate comprehensiveness, detail, or accuracy is not available. It is likely that the U.S. economy's vulnerability to power outages has changed to some extent over the past decade as technology has changed. In particular, increased use of technologies like computers and the Internet may have made the economy more vulnerable to power interruptions. Unfortunately, it is extremely difficult to accurately quantify the impact of that change.

Another potential source of uncertainty is that, because the Balducci data was collected in Canada, it may not be an entirely accurate representation of outage costs for the United States economy. In particular, greater reliance on air conditioning in the United States may lead to higher outage costs in this country. However, because most businesses close when they lose power, one would suspect that the added costs caused by the loss of air conditioning are small. Overall, variations in outage costs caused by technological differences between the economies of the United States and Canada are likely to be small.

A final drawback is that the Balducci data does not cover momentary power interruptions shorter than 20 minutes and sustained outages longer than 4 hours. Several studies have documented that momentary power interruptions make up a large share of outage costs in the United States, largely because there is an average of 4.3 momentary interruptions per year compared to 1.2 sustained outages.[11] However, based on this paper's cost results for 20 minute outages, one can get a sense of the costs imposed by momentary outages. Ultimately, the Balducci data is the best source for making an accurate and comprehensive assessment of business downtime costs.

III. RESULTS

Results on the costs of downtime to average establishments (building, facility, campus, multi-building application, etc.) in certain business subsectors are discussed below. To assess the downtime costs to a simple straight line pattern of economic loss, downtime cost results will be charted against straight line losses. Finally, as a validity check, these results are compared to other similar reports and then to actual market data from two smaller, well-defined markets.

Average Establishment Results

The table referenced at the beginning of this study, "Selected Outage Costs," provided the onsite generation community with useful statistics to inform discussions of the benefits of higher power reliability and quality. The results of the "2006 UPDATE OF BUSINESS DOWNTIME COSTS" will hopefully prove similarly useful to the onsite generation community, government agencies, and real-world end-users who may be interested in investing in and realizing the benefits of higher power reliability and quality from onsite generation.

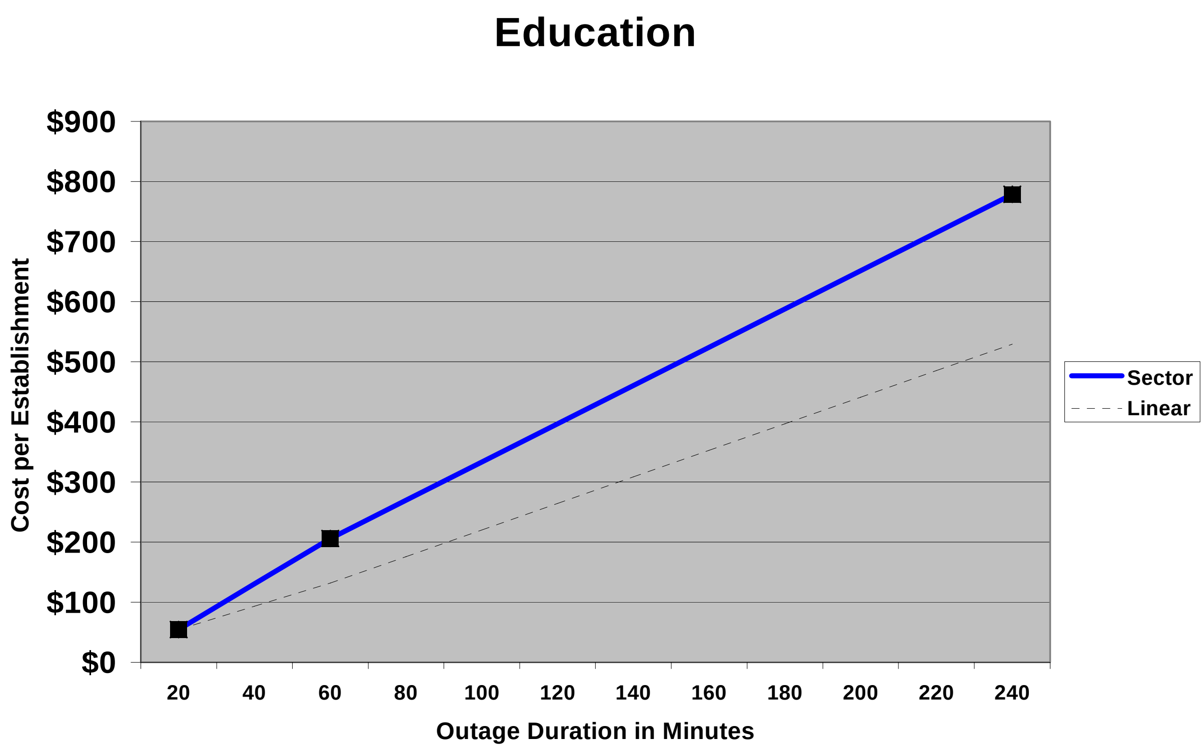
Data on the costs of business downtime per typical establishment in the table below are organized by select commercial and industrial subsectors. With the notable exception of the refrigerated warehouse subsector, it can generally be stated that industrial subsectors lose more money/unit of time from business downtime than commercial subsectors.

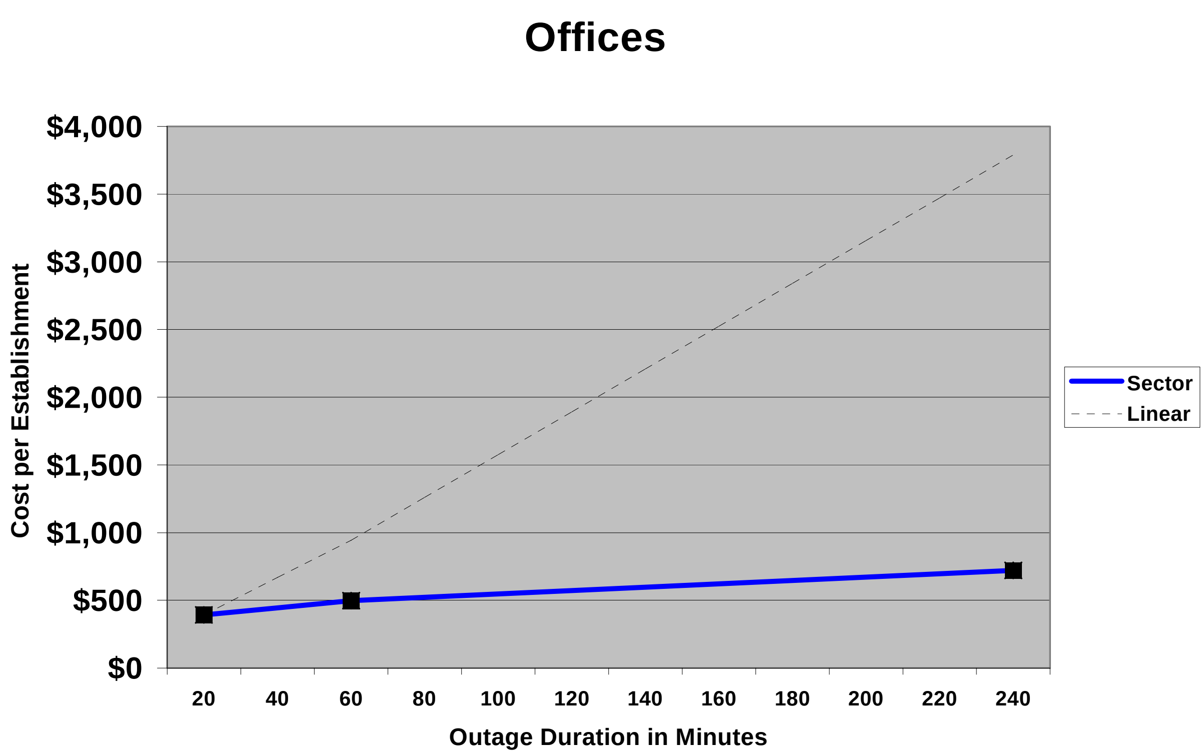
Figure 3: Cost of Business Downtime per Average Establishment in Select Subsectors

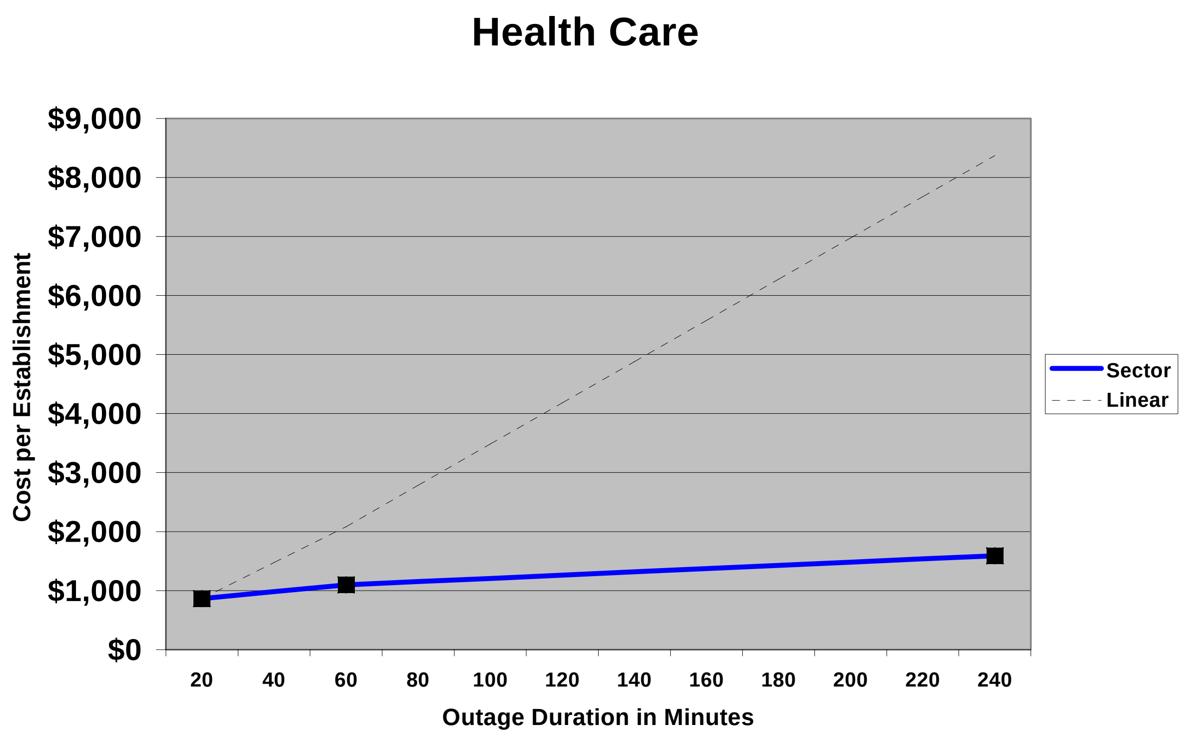
Commercial Subsector	**20 minutes**	**1 hour**	**4 hours**
Non-Refrigerated Warehouses	$118	$189	$399
Refrigerated Warehouses	$7,707	$23,121	$120,390
Food sales	$1,679	$5,038	$26,234
Food service	$1,291	$3,872	$20,161
Mercantile	$227	$1,668	$4,892
Lodging	$128	$353	$952
Service	$488	$1,036	$3,091
Health care	$865	$1,098	$1,593
Offices	$392	$497	$721
Education	$55	$206	$779
Public Order	$777	$1,286	$3,052
Industrial Subsector	**20 minutes**	**1 hour**	**4 hours**
Food and Kindred Processes	$6,442	$20,521	$68,656
Chemicals and Allied Products	$12,390	$23,832	$130,673
Primary Metal Industries	$27,448	$44,094	$93,147
Industrial Machinery	$16,211	$28,987	$99,040
Transportation Equipment	$20,490	$50,469	$394,900

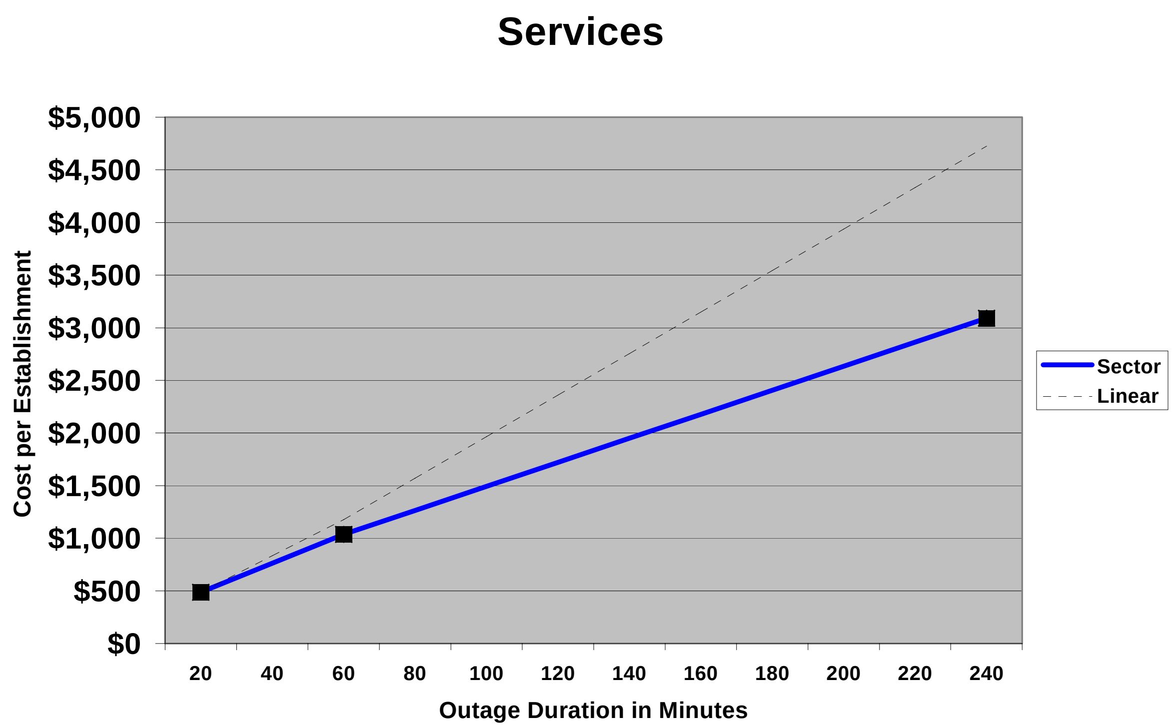
Comparison of Downtime Costs Relative to Linear Loss Pattern

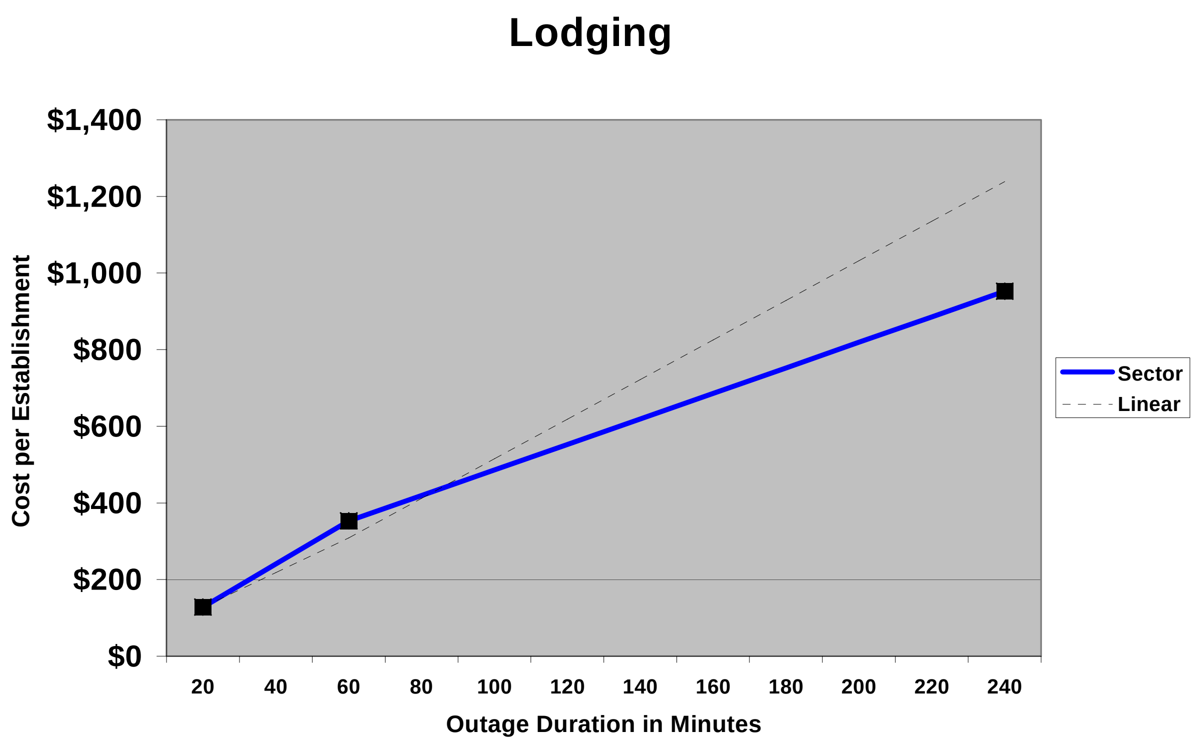
The following graphs illustrate power interruption costs as a product of blackout duration for average establishments in select commercial and industrial subsectors. These graphs illustrate whether these subsector downtime costs—represented by calculated cost points and connected by colored lines—increase at a rate faster or slower than a constant linear growth rate—represented by a dashed line. Colored lines that move above the dashed line indicate that marginal costs accelerate faster than linear growth over time, while colored lines that fall below the dashed line indicate that marginal costs decelerate over time, compared to linear growth.

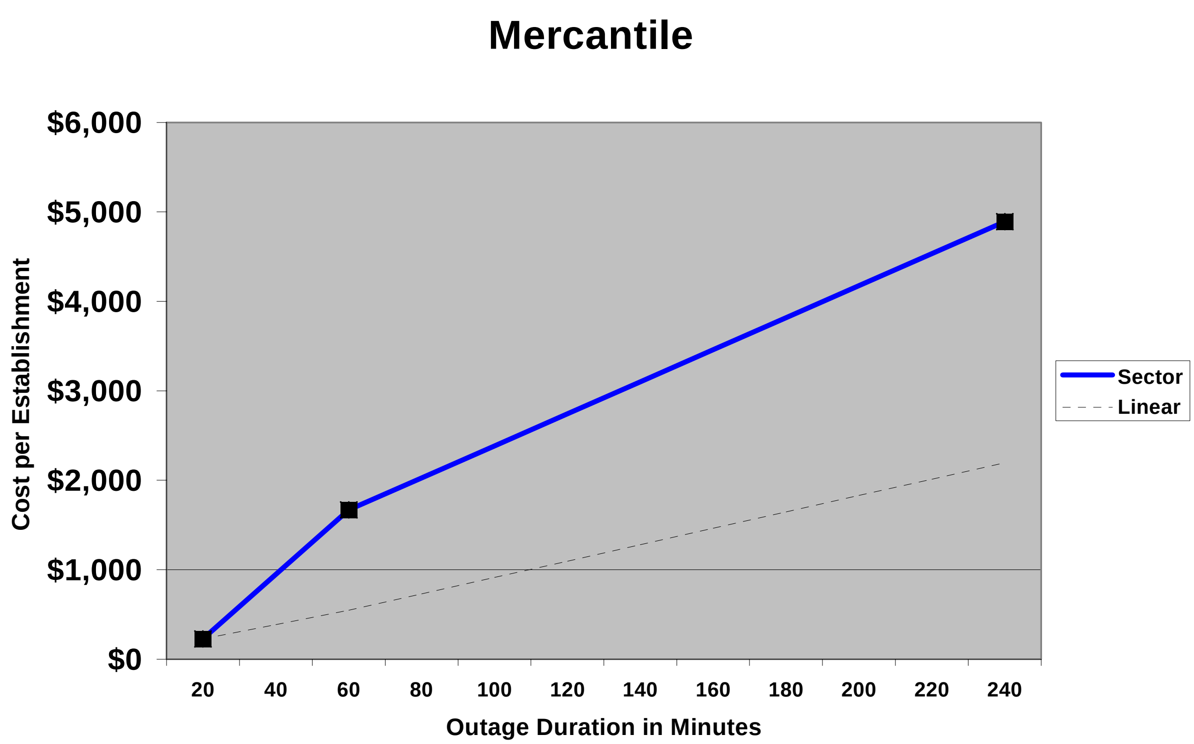


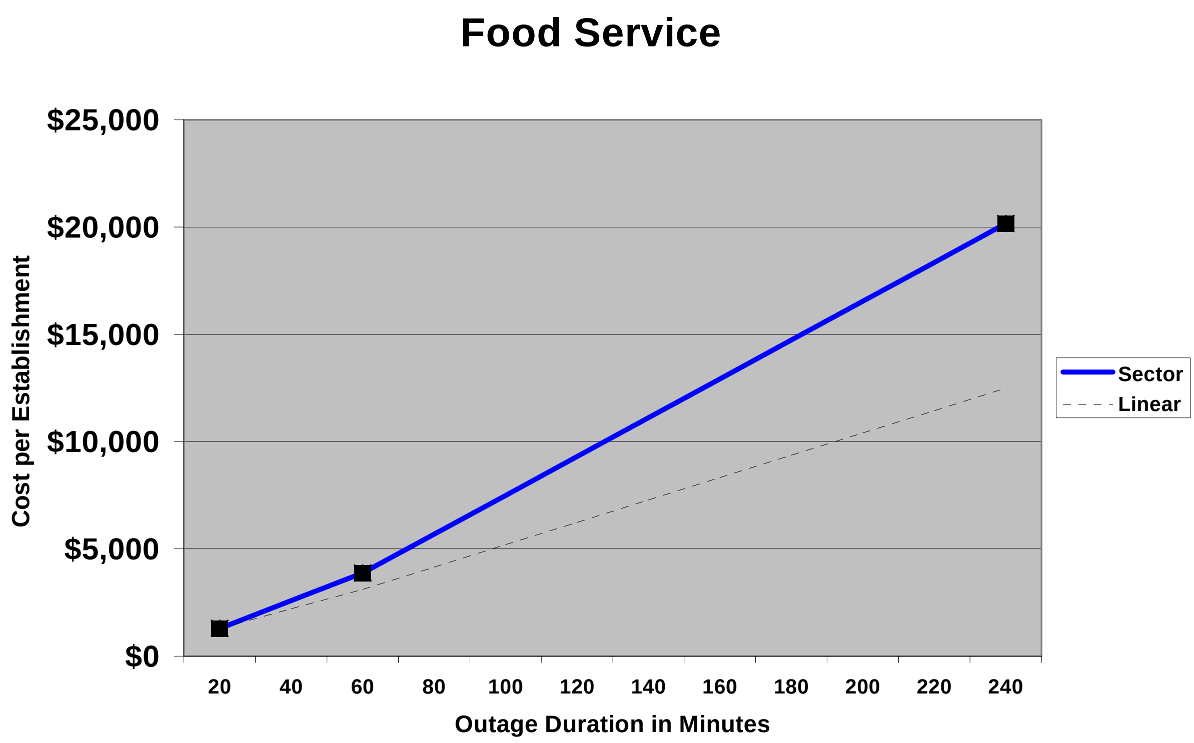


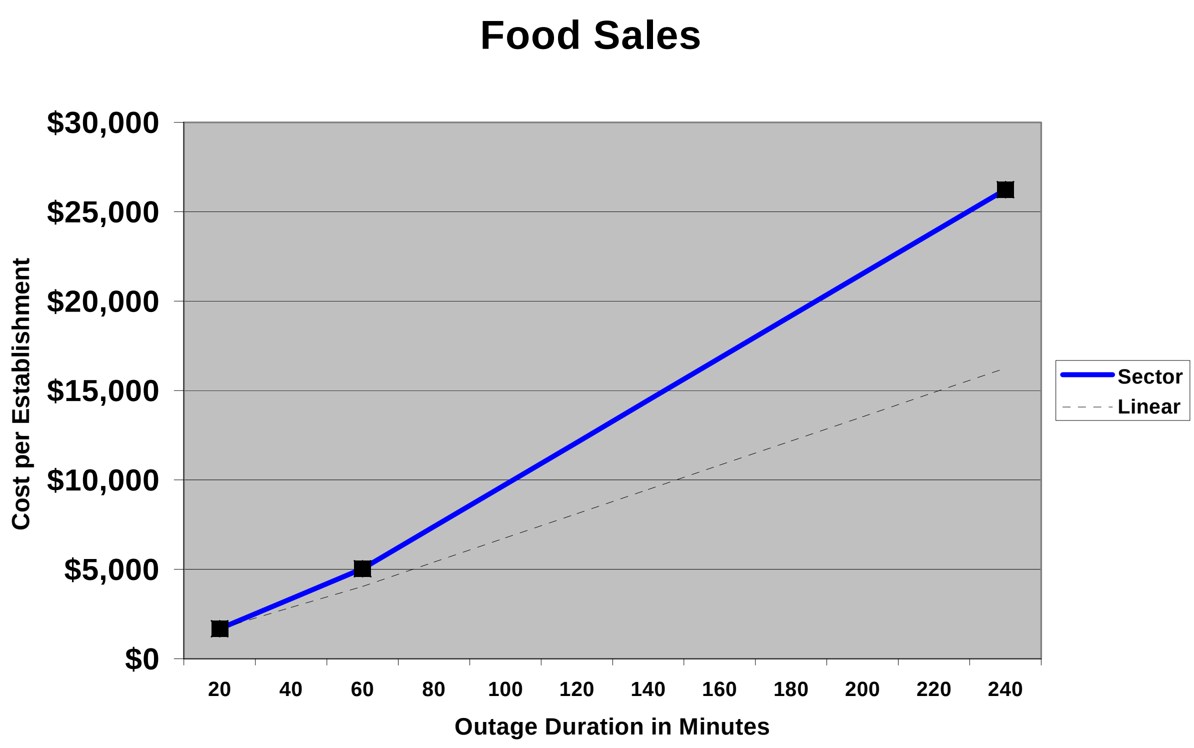

Health Care
$9,000
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Cost per Establishment
20
40
60
80
100
120
140
160
180
200
220
240
Outage Duration in Minutes
Sector
Linear

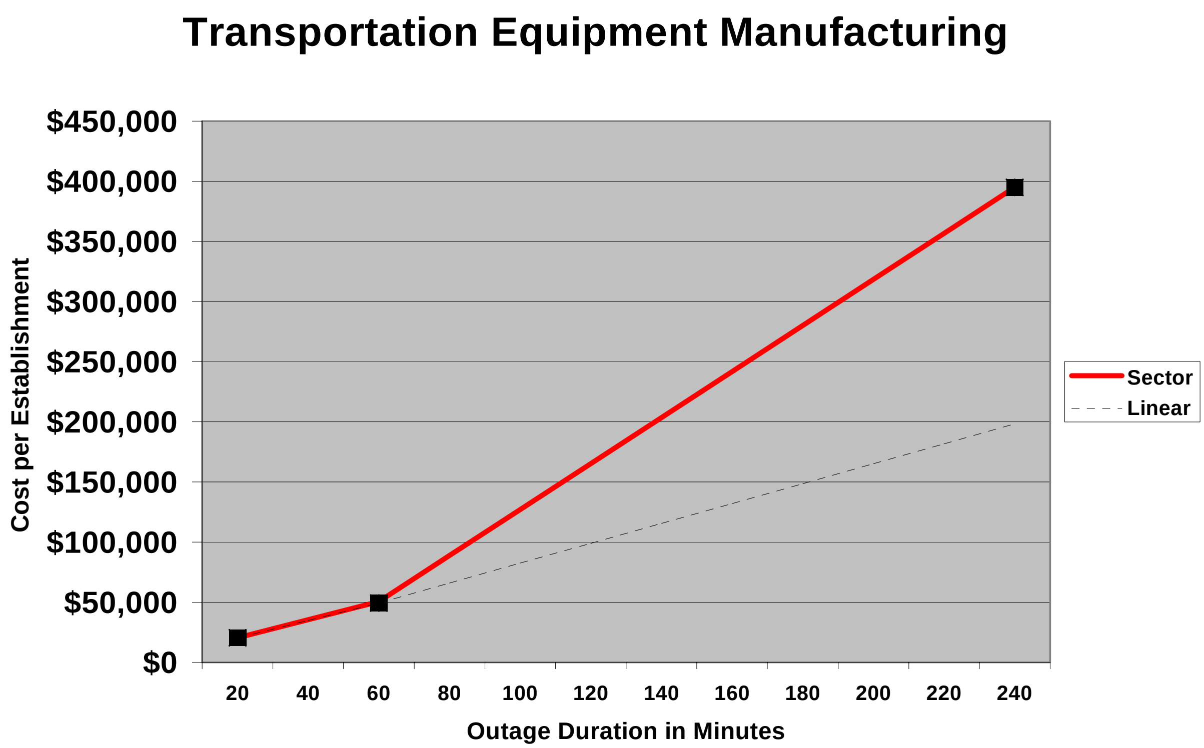

Services
$5,000
$4,500
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Cost per Establishment
20
40
60
80
100
120
140
160
180
200
220
240
Outage Duration in Minutes
Sector
Linear

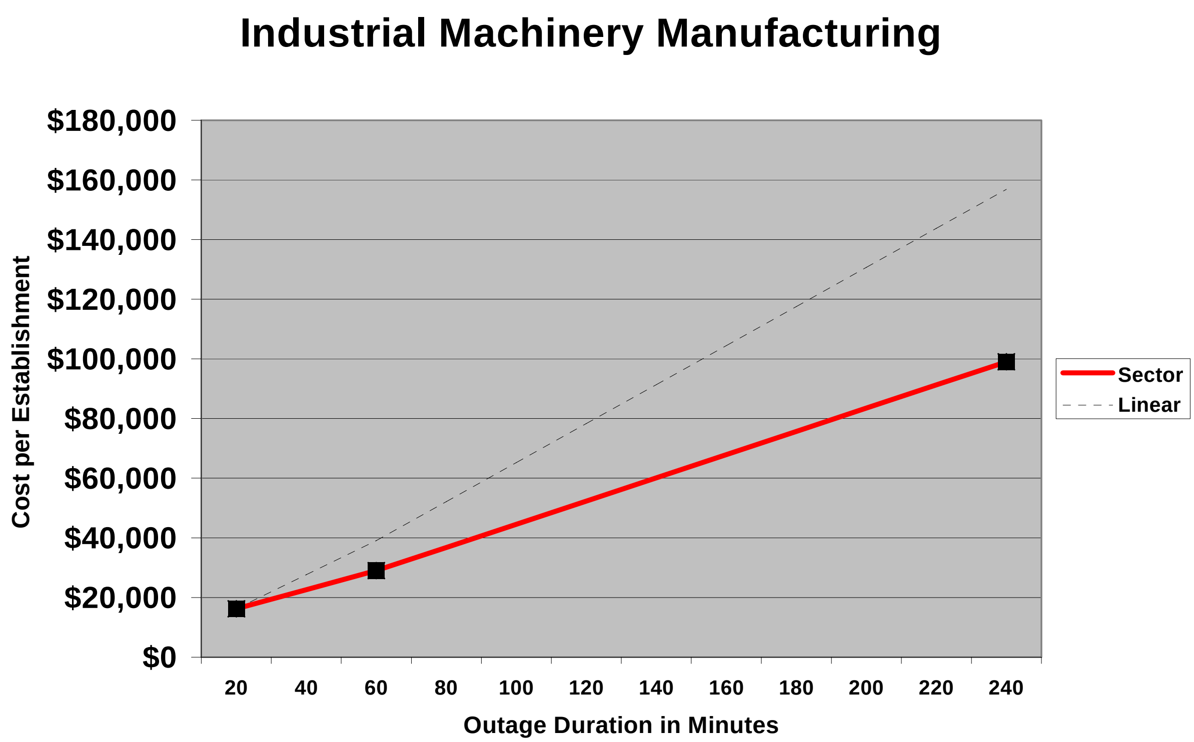

Lodging
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
Cost per Establishment
20
40
60
80
100
120
140
160
180
200
220
240
Outage Duration in Minutes
Sector
Linear

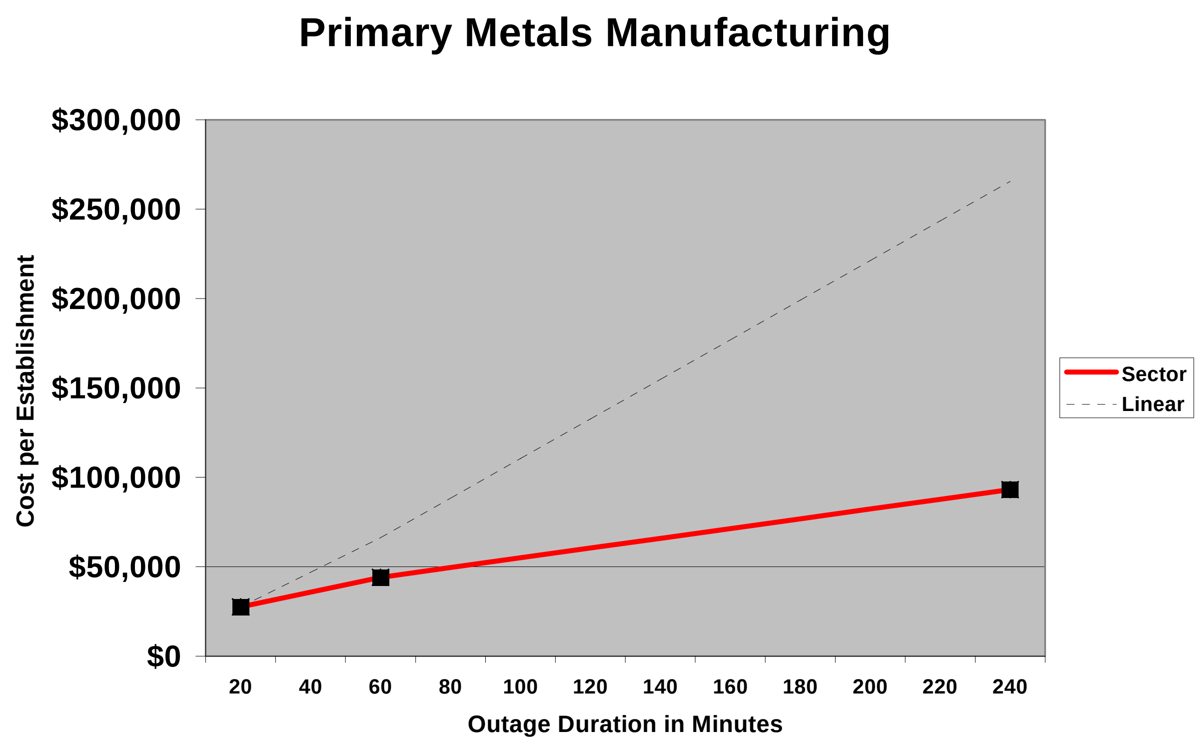

Mercantile
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Cost per Establishment
20
40
60
80
100
120
140
160
180
200
220
240
Outage Duration in Minutes
Sector
Linear

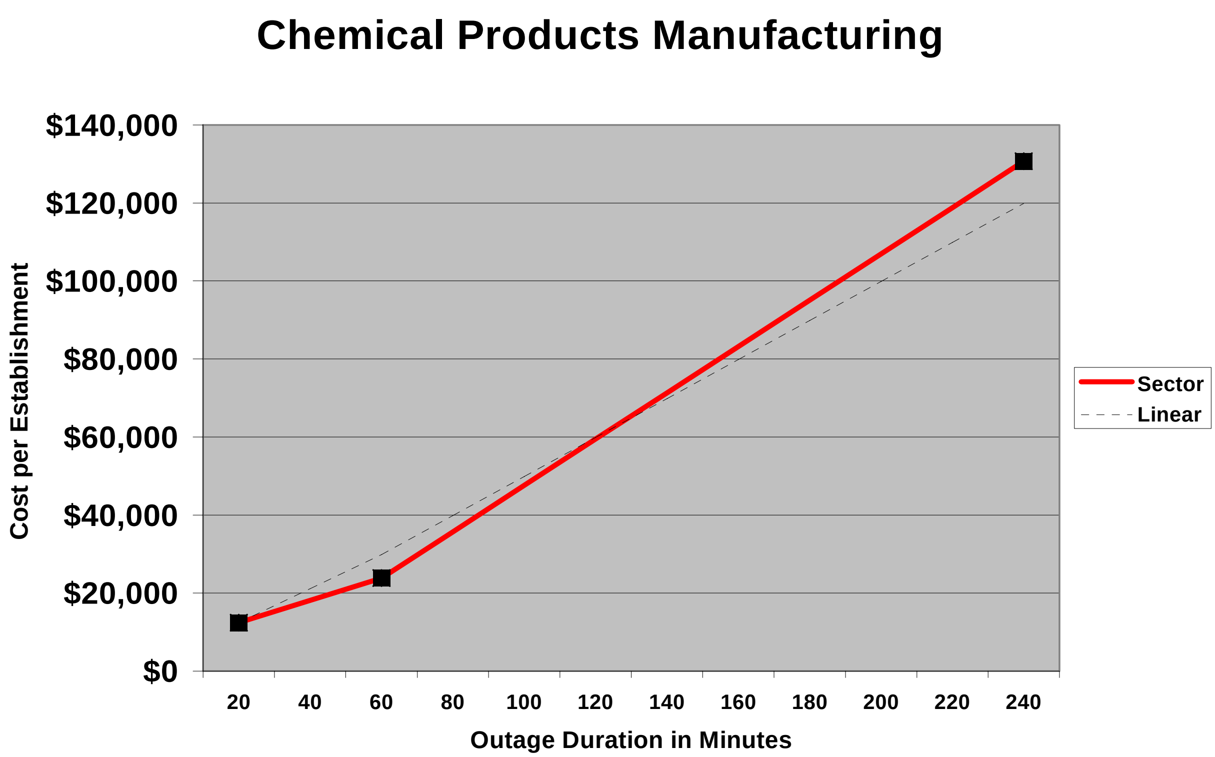

Food Service
$25,000
$20,000
$15,000
$10,000
$5,000
$0
Cost per Establishment
20
40
60
80
100
120
140
160
180
200
220
240
Outage Duration in Minutes
Sector
Linear

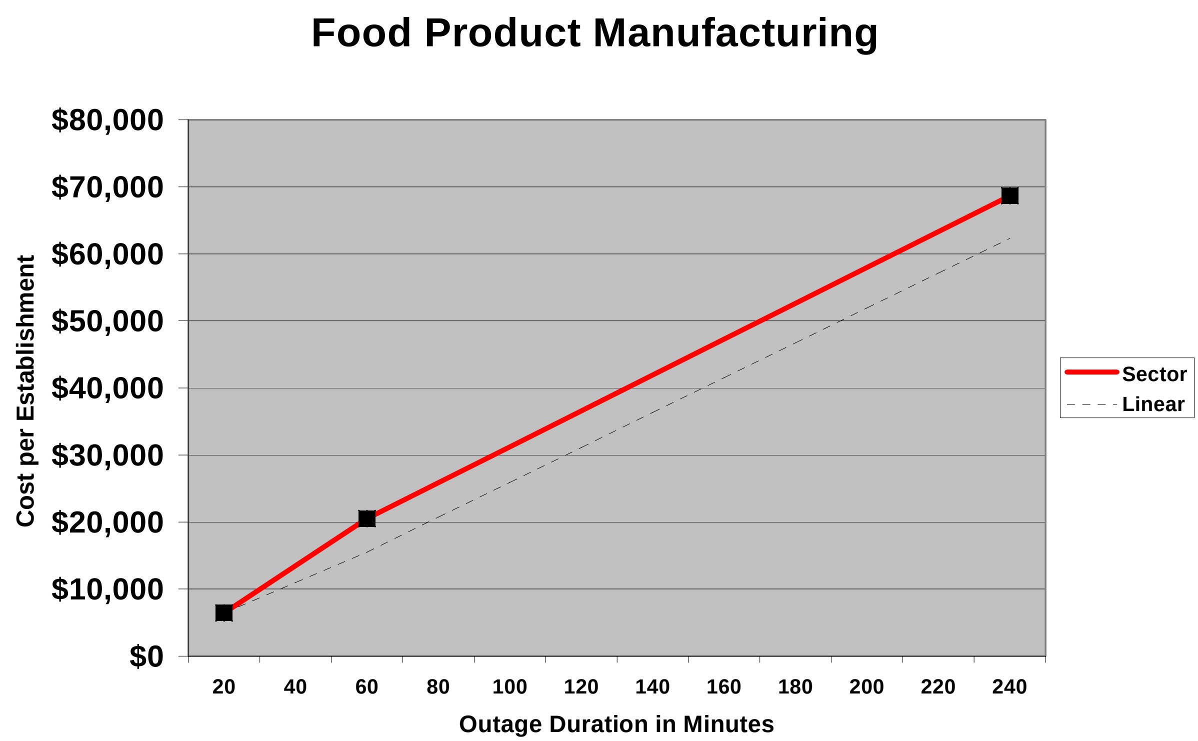

Food Sales
$30,000
$25,000
$20,000
$15,000
$10,000
$5,000
$0
Cost per Establishment
20
40
60
80
100
120
140
160
180
200
220
240
Outage Duration in Minutes
Sector
Linear

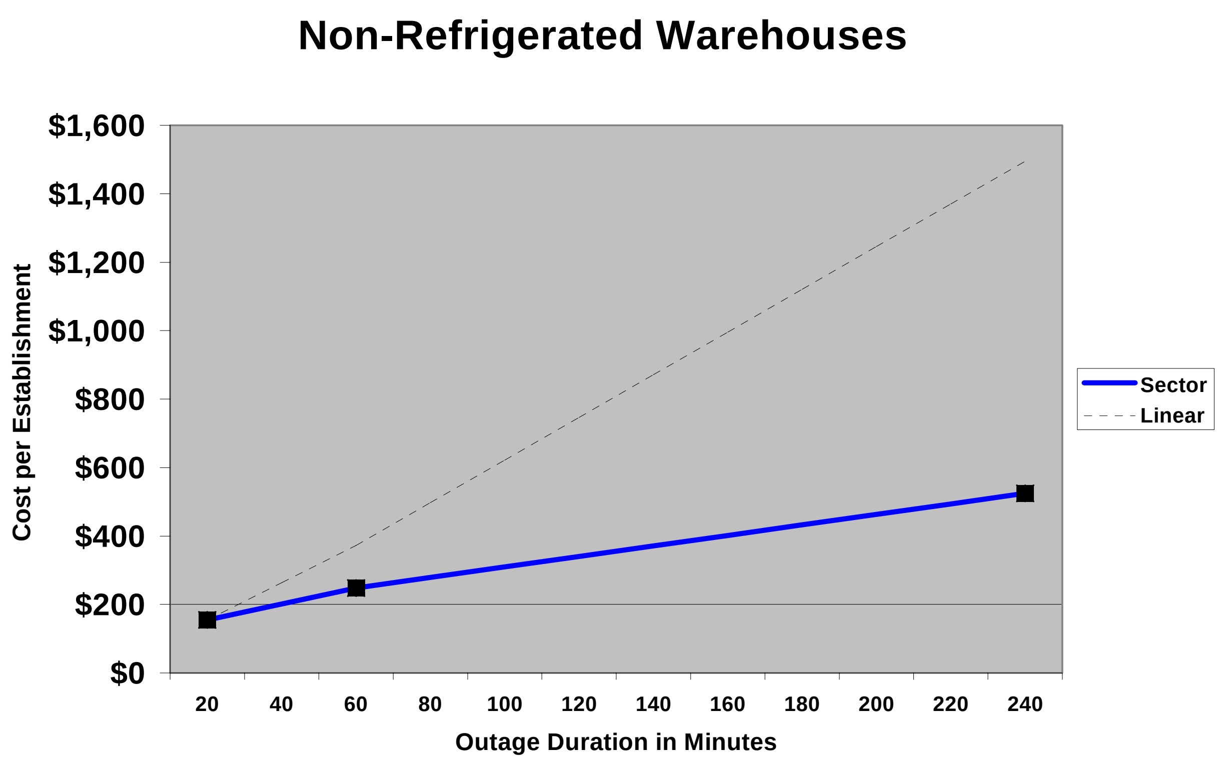

Transportation Equipment Manufacturing
$450,000
$400,000
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
Cost per Establishment
20
40
60
80
100
120
140
160
180
200
220
240
Outage Duration in Minutes
Sector
Linear

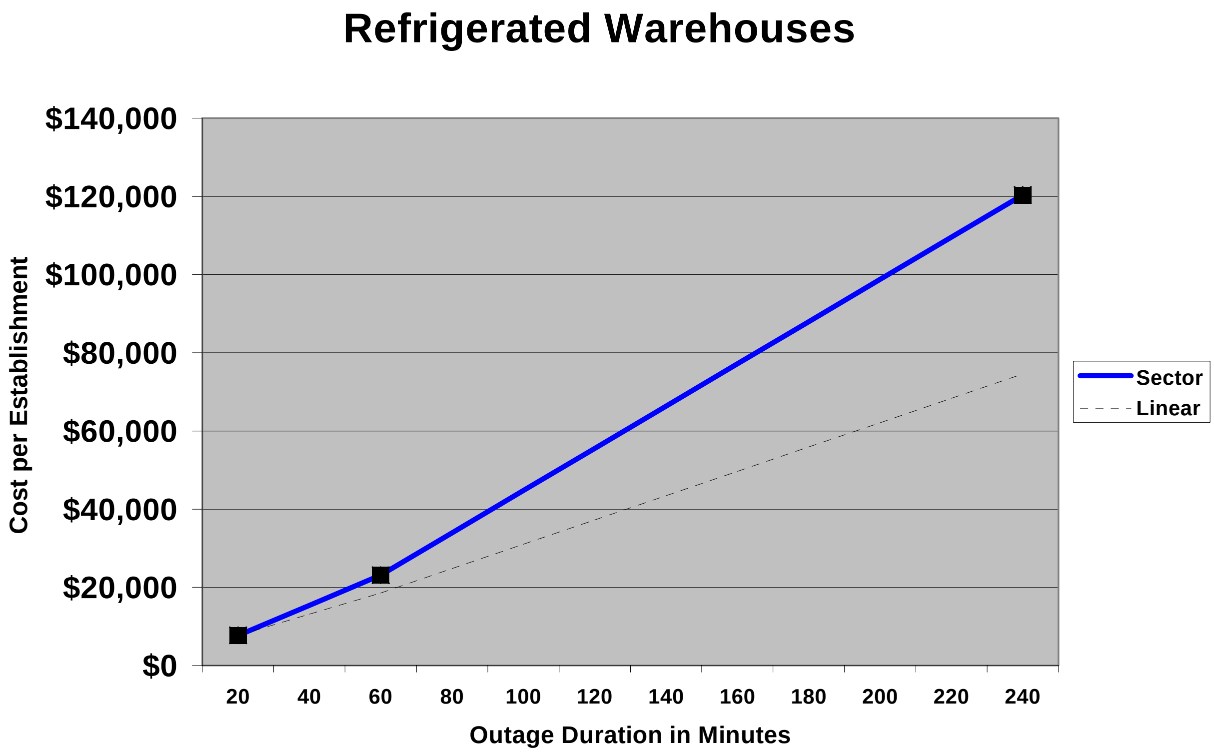

Industrial Machinery Manufacturing
$180,000
$160,000
$140,000
$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$0
Cost per Establishment
20
40
60
80
100
120
140
160
180
200
220
240
Outage Duration in Minutes
Sector
Linear


Primary Metals Manufacturing
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
Cost per Establishment
20
40
60
80
100
120
140
160
180
200
220
240
Outage Duration in Minutes
Sector
Linear


Chemical Products Manufacturing
$140,000
$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$0
Cost per Establishment
20
40
60
80
100
120
140
160
180
200
220
240
Outage Duration in Minutes
Sector
Linear


Food Product Manufacturing
Cost per Establishment
$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$0
20 40 60 80 100 120 140 160 180 200 220 240
Outage Duration in Minutes
Sector
Linear


Non-Refrigerated Warehouses
Cost per Establishment
$1,600
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
20 40 60 80 100 120 140 160 180 200 220 240
Outage Duration in Minutes
Sector
Linear



Comparison of Results to Those of Other Published Reports

The Balducci study was chosen as the basis for this analysis because it includes data on a large number of subsectors, incorporates the outage duration element, and includes many tangible costs. The decision to use the Balducci data was made after an extensive review of other studies that have been published on downtime costs. Even though these other studies were not ultimately used, it is important to look at their conclusions to make sure that the conclusions of this analysis appear to be reasonable. The results of these studies can also be used to make extrapolations beyond the limits of chosen data, such as assessing the costs of longer power outages.

The Balducci study looked at 17 data sets before deciding that the data set it used was the best.[12] Several of the other data sets they examined were obtained more recently than the data they ultimately used, and thus would likely better capture the impact of technological changes that have occurred in the economy since 1996. Some of these studies were not used because they were conducted in countries with economies that are very different from the U.S., like Greece, Nepal, and Mexico. Other studies were not used because they only looked at one sector of the economy, while others looked at all sectors but did not examine the important differences in outage costs that exist among subsectors of the commercial and industrial sectors.

The conclusion that the Balducci data set is the best available is also supported by a 2001 literature review compiled by researchers at LBNL.[13] In their review of 14 data sets that have been published on the topic of outage costs, the data used by Balducci is the most recent and the most comprehensive. As highlighted in the following table, the literature review also presents a quantitative assessment of the results of these data sets, comparing the figures that each data set found for outage costs. The data sets used by Balducci, et al., are those labeled Saskatchewan 1991 and Saskatchewan 1995. While there are large differences in the data among some of the studies, data from this paper is in the middle of the overall range and is comparable to that produced by many of the other studies, lending additional confidence to preliminary conclusions.

Figure 5: Commercial and Industrial Outage Costs

Table 2-8. Commercial and Industrial Outage Costs

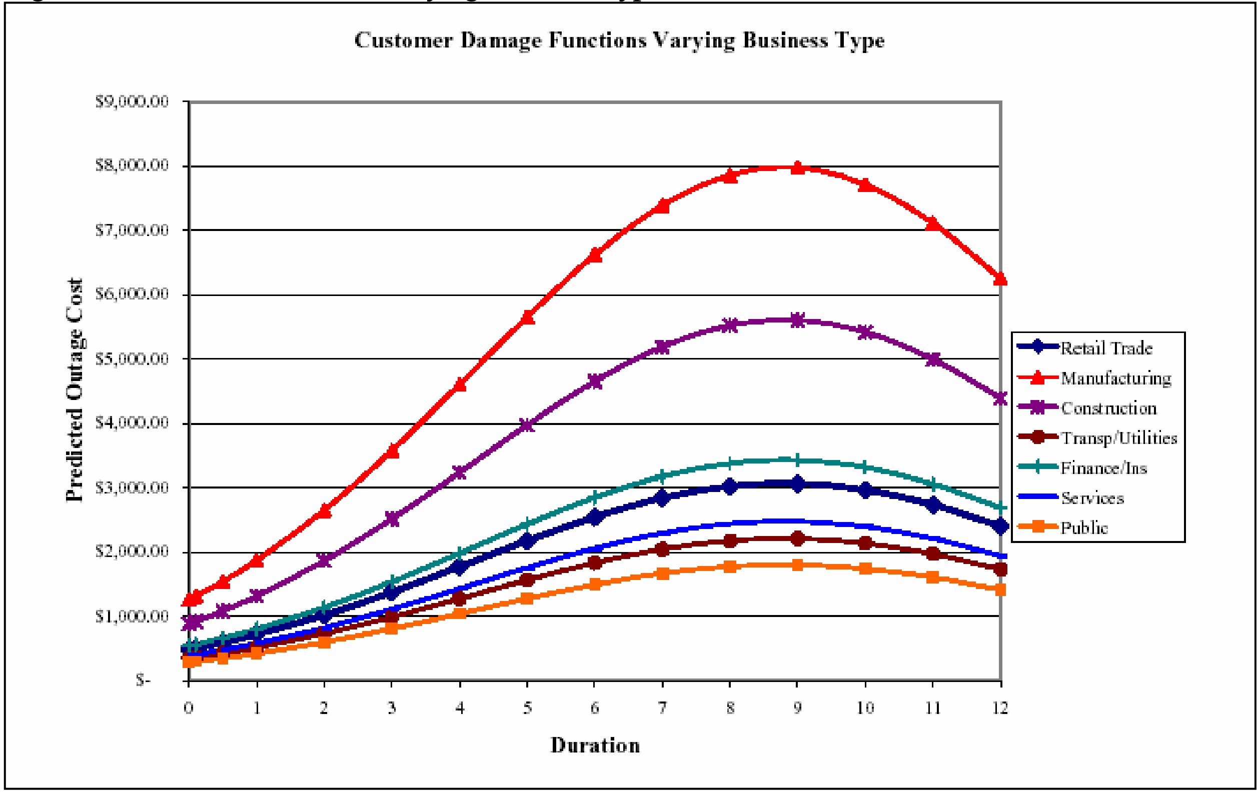
Study	Outage Duration										Notes[9]
	momen-tary	<1 min	1 min	15 min	20 min	1 hr	2 hr	4 hr	8 hr	24 hr	
	$/kW annual peak demand										
Saskatchewan 1988[1]			0.394		3.070	8.844		32.390	85.846		Commercial
Saskatchewan 1988[1]			1.681		4.000	9.395		26.023	57.715		Small industrial
Saskatchewan 1988[1]			1.039		1.560	2.301		4.104	8.522		Large industrial
Saskatchewan 1991[2]	0.281		1.973		5.837	15.769		79.451	127.669	153.767	Commercial
Saskatchewan 1991[2]							33.079				Commercial
Saskatchewan 1991[2]	0.946		2.259		3.233	6.831		24.921	46.118	73.409	Industrial
Saskatchewan 1991[2]							12.121				Industrial
Nordic Study 1992-93[3]	0.653		0.762	1.851		9.254			61.515		Denmark, winter weekday. Commercial.
Nordic Study 1992-93[3]	2.722		2.940	6.859		17.856			97.335		Finland, winter weekday. Commercial.
Nordic Study 1992-93[3]	5.008		5.988	7.295		22.864			104.304		Iceland, winter weekday. Commercial.
Nordic Study 1992-93[3]	0.109		0.109	0.762		4.464			45.510		Denmark, planned outage, winter weekday. Commercial.
Nordic Study 1992-93[3]	1.415		1.524	3.049		11.432			64.999		Finland, planned outage, winter weekday. Commercial.
Nordic Study 1992-93[3]	0.109		0.327	1.633		15.460			88.408		Iceland, planned outage, winter weekday. Commercial.
Nordic Study 1992-93[3]	1.524		4.355	13.065		24.062			77.847		Denmark, unexpected (winter weekday). Industrial.
Nordic Study 1992-93[3]	2.940		4.137	7.948		15.787			83.290		Finland, unexpected (winter weekday). Industrial.
Nordic Study 1992-93[3]	0.218		0.218	9.254		13.610			66.088		Iceland, unexpected (winter weekday). Industrial.
Nordic Study 1992-93[3]	0.327		0.980	1.960		5.553			38.651		Denmark, planned outage (winter weekday). Industrial.
Nordic Study 1992-93[3]	0.762		1.524	2.613		6.533			49.430		Finland, planned outage (winter weekday). Industrial.
Nordic Study 1992-93[3]	0.109		0.109	0.653		3.702			33.969		Iceland, planned outage (winter weekday). Industrial.
Saskatchewan 1995[4]	1.312				2.584	5.720		16.905			Government, institutional and office sector

A 2003 outage cost study by LBNL includes data from more recent surveys.[14] This study compiled data from 24 surveys that were administered by U.S. utilities from 1989 to 2002. Unfortunately, because these surveys are the property of the utilities and contain confidential information, the data of individual studies was not made public. Instead, the data from the 24 studies was combined into one data set, which makes analysis of data from individual surveys impossible.

The data set produced by the LBNL study differs from the Balducci data set in several ways. For one, this data set examines interruption costs for outages up to 12 hours in duration, instead of four hours. However, because only 3 of the 24 studies in the combined data set looked at outage costs for time periods beyond 4 hours, it may be inaccurate to estimate costs for longer outages based on this data. In fact, the combined data set shows total costs for longer outages to be lower than the total cost for shorter outages, a result that does not make intuitive sense and therefore raises questions about the accuracy of those three studies. This anomaly is illustrated in Figure 6. In addition, the LBNL data set only covers several general sectors of the economy, in contrast to the comprehensive and detailed subsector data available from the Balducci study. For this reason, the Balducci data was selected as the primary data set.

However, useful information can still be obtained from the LBNL study. For one, the results of this study lend additional credence to the results of this paper's analysis. E.g., the LBNL study found that outage costs to large commercial and industrial businesses increase nonlinearly as the outage duration increases from one to eight hours. In addition, the study's results for costs for the typical establishment in the manufacturing, retail, office, and service sectors are comparable to the results of this paper's analysis.

Figure 6: Customer Functions Varying Business Type



The results of other studies also support the conclusion that the results of this paper's analysis are reasonable. A 2006 LBNL study estimated that, in an average year in the U.S., sustained power interruptions cost the U.S. economy $26.3 billion.[15] This paper's calculation of $19.2 billion in annual costs from sustained outages thus appears to be reasonable. Furthermore, the LBNL study's breakdown of costs for the commercial, industrial, and residential sectors is similar to this paper's findings, as can be seen by comparing the following chart with Figure 4 above.

Comparison of Results to Actual Market Data

A potential hazard in any theoretical study is that its results don't reflect "real world" applications. In an effort to compare theoretical calculations of business downtime costs with actual market data, the costs were reviewed by representatives of two sets of well-defined, geographically-limited markets:

- California's refrigerated warehouse (RW) market; and
- Michigan's grocery store, or food and beverage retail, market.

California Refrigerated Warehouse Market

As noted above, the refrigerated warehouse (RW) market was the one subsector that stood out as an exception to the generalization that industrial subsectors suffered greater financial losses from downtime than did commercial subsectors. To learn more about the market, data was gathered form the International Association of Refrigerated Warehouse (IARW) website.

RW space in the U.S. currently exceeds 2.35 billion cubic feet spread over 827 facilities, according to IARW. To narrow down the sample size, California was chosen as the state to assess further because it leads the nation in PRWs with 309,960,000 cubic feet, followed by other hot and/or humid climate zone states such as Texas, Georgia, and Florida.

To calculate average RW downtime costs, CBECS data from 1999 on the energy use of RW's was adjusted to 2003 based on the number of RW's in 2003. According to 2003 CBECS data, there are 15,100 RW's, each with an average square footage of 63,776. Each building uses 1,250,000 kWh, or 19.6 kWh/sq ft, for a total sector usage of 18.9 billion kWh. Using the data from CBECS and the Balducci study, the following were calculated to be the business downtime costs for the average RW:

Time after Power Outage	**"Average" RW Business Downtime Costs**
20 minutes	$7,707
1 hour	$23,121
4 hours	$120,390

Data on 20 actual RW's (anonymously numbered below) based in California were gathered from the IARW website. Cubic feet of RW space was converted to area by applying 30 feet as an average RW height. By applying the 19.6 kWh/sq. ft. factor derived from CBECS data, and the Balducci downtime cost factor data, calculations were made to estimate the costs of downtime for the California RWs at 20, 60, and 240-minute points in time after power outage. The results are summarized in the table below:

California Refrigerated Warehouse	**Area (sq. ft.)**	**Avg. Energy Intensity (kWh/sq. ft.)**	**Annual Energy Use (kWh/yr)**	**Downtime Cost (20 Mins.)**	**Downtime Cost (60 Mins)**	**Downtime Cost (240 Mins)**
RW 1	50,242.5	19.6	984,753	**$5,992**	**$17,975**	**$93,596**
RW 2	12,000.0	19.6	235,200	**$1,431**	**$4,293**	**$22,355**
RW 3	90,928.3	19.6	1,782,195	**$10,844**	**$32,531**	**$169,389**
RW 4	63,333.3	19.6	1,241,333	**$7,553**	**$22,659**	**$117,982**
RW 5	70,266.7	19.6	1,377,227	**$8,380**	**$25,139**	**$130,899**
RW 6	115,000.0	19.6	2,254,000	**$13,714**	**$41,143**	**$214,231**
RW 7	100,000.0	19.6	1,960,000	**$11,926**	**$35,777**	**$186,288**
RW 8	48,333.3	19.6	947,333	**$5,764**	**$17,292**	**$90,039**
RW 9	18,274.2	19.6	358,174	**$2,179**	**$6,538**	**$34,043**
RW 10	17,300.0	19.6	339,080	**$2,063**	**$6,189**	**$32,228**
RW 11	46,666.7	19.6	914,667	**$5,565**	**$16,696**	**$86,935**
RW 12	53,868.2	19.6	1,055,817	**$6,424**	**$19,272**	**$100,350**
RW 13	146,666.7	19.6	2,874,667	**$17,491**	**$52,473**	**$273,223**
RW 14	25,751.9	19.6	504,737	**$3,071**	**$9,213**	**$47,973**
RW 15	254,666.7	19.6	4,991,467	**$30,370**	**$91,111**	**$474,414**
RW 16	32,459.3	19.6	636,202	**$3,871**	**$11,613**	**$60,468**
RW 17	18,000.0	19.6	352,800	**$2,147**	**$6,440**	**$33,532**
RW 18	369,303.7	19.6	7,238,353	**$44,042**	**$132,125**	**$687,969**
RW 19	211,770.9	19.6	4,150,710	**$25,255**	**$75,765**	**$394,504**
RW 20	15,303.0	19.6	299,939	**$1,825**	**$5,475**	**$28,508**

To validate these results, they were sent out for review by email to all 20 California IARW members, with 0 email responses. Upon reaching 5 RW contacts willing to talk by phone, with the assurance of anonymity, it became apparent that the theoretical costs of business downtime in this report were extremely high and not representative of the RW industry. For example:

- In terms of total downtime costs, RW representatives noted that the calculated costs were extremely high; not representative of the RW industry. One RW owner noted that he had lost power 3 times over the last 35 years with no resultant inventory or revenue losses.
- Electronic data loss would be minimal, primarily due to UPS backup systems for computers.

- Only potential revenue loss would be from turning customers away from bays which would lose cooling if doors were opened; one RW owner noted that those customers would simply come back when power was restored.
- Idle labor is perhaps the only downtime loss that RW industry would be concerned about, but typical RW staff is not technical and not highly compensated.
- In regards to damaged inventory, RW frozen inventory would be safe for 2-3 days; in this time period, backup diesel generators could be secured. One RW owner noted that he lost power for one week in 2000, but he was able to rent a diesel genset for backup power within 15 hours of the power outage.
- There would be minimal costs associated with turning computers and chillers back on for repair and ramp-up; on-hand staff could handle.

Based on these summary responses from the California RW contacts, the downtime costs calculated in this report show very little resemblance to the actual costs incurred from power outage in the RW industry. In essence, RW representatives calculated that their business downtime costs were negligible—in sharp contrast to this paper's calculated cost of $687,969 over 4 hours for the largest RW in California in this paper's data set.

<u>Michigan Food Retail Market</u>

This paper's downtime cost calculations for food sales were then compared to data from Michigan's food retail market from a post-2003 Blackout survey by the Electricity Consumers Resource Council (ELCON)[16]. On August 14, 2003, North America experienced the largest blackout in history, affecting eight states in the Midwest and Northeast, and parts of Canada. At its peak, over 50 million people were without power, and businesses may have lost at least $6 Billion in direct costs.[17] The ELCON report uses data gathered from the Associated Food Dealers of Michigan, an organization representing Michigan's food industry,[18] which reports that its 3,000 members lost approximately $50 million from the 2003 Blackout, or approximately $18,000/establishment—but at what point in time post-blackout?

To find the most representative downtime point, data from an ICF report can be used to "assume that the initial outage of 61,800 MW lasted for 4 hours and then half of that was restored…."[19] Thus, for purposes of this paper, the 4-hour business downtime cost for Michigan's food and beverage industry was chosen, namely $26,234/establishment—which is within 30% range of this paper's calculations.

IV. CONCLUSIONS

Downtime Cost Components

As seen in the refrigerated warehouse comparison, downtime cost component vary radically from subsector to subsector, market to market, e.g. rather than considering the full list of downtime costs noted earlier in this paper, the RW industry really only needed to take idle labor and backup genset rental costs. Equipment damage, data loss, inventory damage, lost revenue and productivity, late fees and other tangible and intangible costs simply did not apply to this market. The "common sense" assumption that inventory loss would be a major downtime cost component was totally inaccurate, for example, illustrating the importance of understanding a market and its idiosyncratic characteristics before estimating its costs of business downtime.

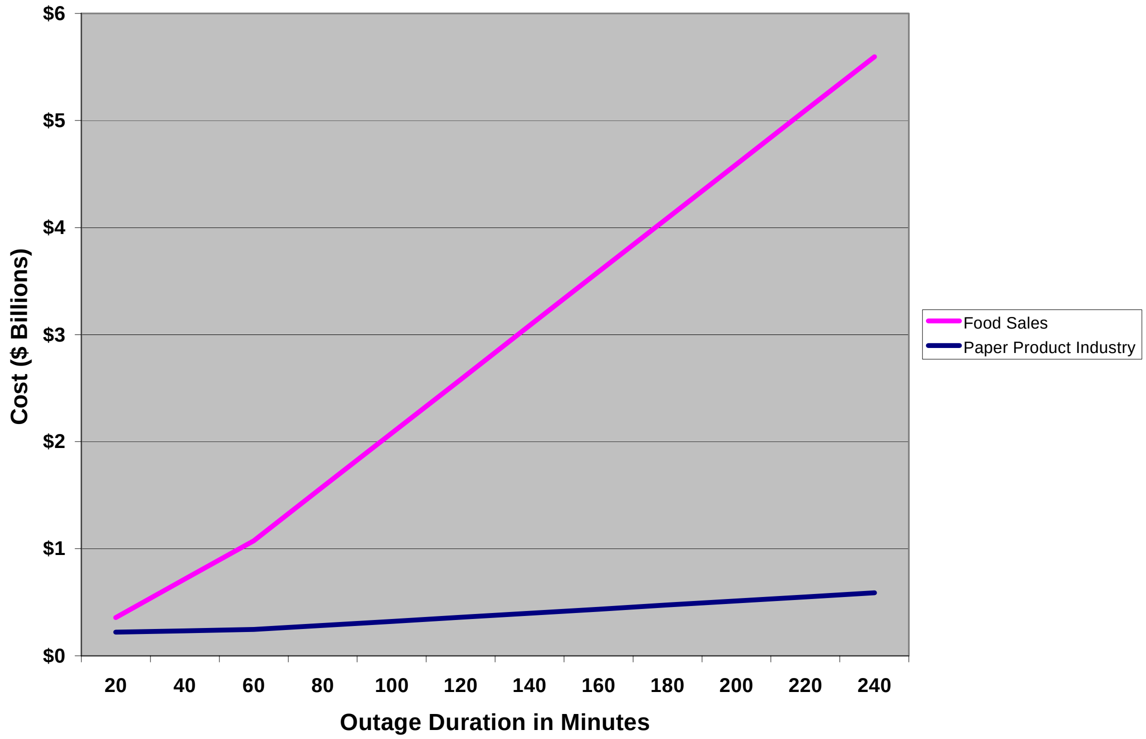
The RW example also serves to show the variability in power reliability and quality needs in a business type. The industries chosen for the "Selected Outage Costs" table originally cited in this paper were all dependent on high levels of power reliability and quality, skewing the downtime costs. If the RW industry had been chosen for this table of outage costs, the results would have been radically different.

On the other hand, downtime costs calculated in this paper for food sales were much more accurate and representative of the industry; surveys could be utilized to portray a more accurate accounting of its downtime cost components.

Business Type

Downtime cost components are logically linked to business type. This paper's findings support the conclusion that total downtime costs are highly dependent on the type of business experiencing the power outage and on the duration of the blackout. For some businesses and industries, it was found that the most costly disruptions and damages occur in the initial minutes of an outage, while other sectors of the economy can endure short outages with minimal costs but are highly vulnerable to prolonged outages. Offices and the health care sector are highly vulnerable to disruptions and damage in the initial minutes of an outage, with more than half of the costs of a four-hour outage occurring during the initial 20 minutes. Many industries are also highly vulnerable to short-term outages, as products and equipment can be irreversibly damaged if a production process is interrupted due to a power outage. In contrast, grocery stores, refrigerated warehouses, and restaurants can endure short outages with minimal costs, but they face large expenses if an outage continues for enough time that refrigerated and frozen food begins to spoil and must be discarded.

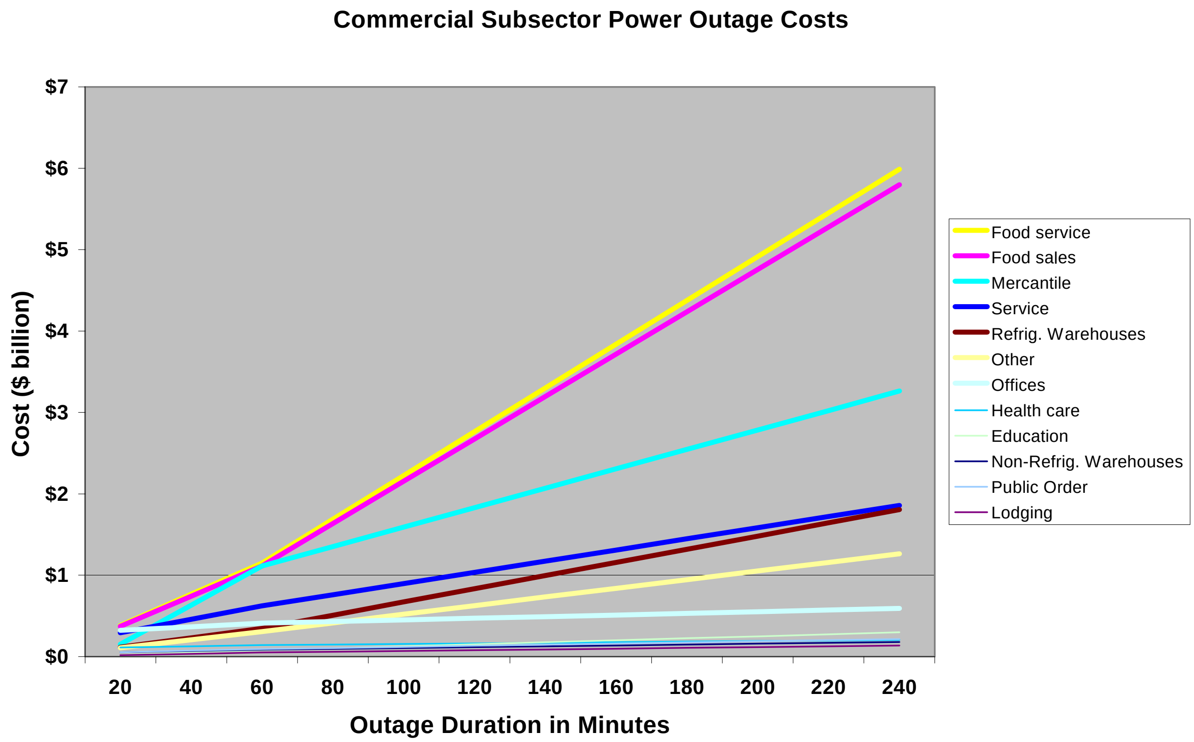
The following figure illustrates differences in how two business types—paper product manufacturers and food sales—vary in response to outages of different durations. While the two subsectors face comparable costs for a 20 minute outage, downtime costs for the food sales business rapidly escalate for longer outages, presumably as food begins to spoil. In contrast, the majority of the outage costs for the paper industry occur during the initial 20 minutes of an outage, and costs are only slightly higher for longer outages; more data collection and analysis would be needed to confirm this assumption.



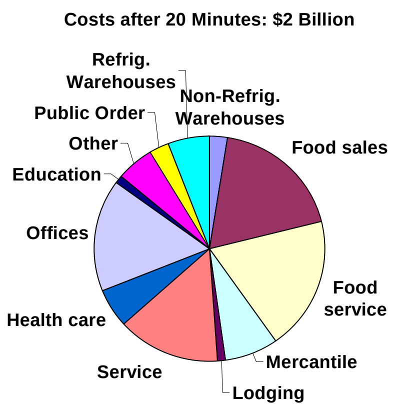
Power Outage Duration

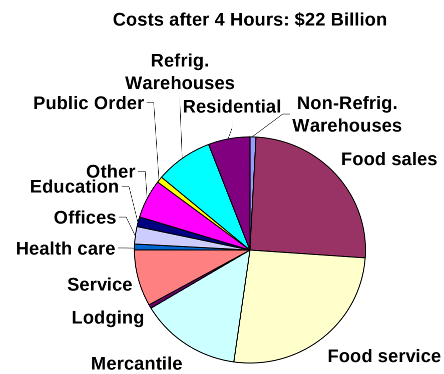
The Selected Outage Costs table presented "average cost of downtime" for five industries, but did not take into account the way in which businesses lose different amounts of money as a function of post-Blackout time. This paper shows a definite time factor in calculating business downtime costs.

The following chart presents a breakdown of outage costs over time for the commercial subsectors. As one can see, at 20 minutes duration, almost all commercial subsectors have comparable downtime costs. However, as an outage persists and food spoilage sets in, costs for restaurants (food service), refrigerated warehouses, and grocery stores (food sales) increase faster than for other sectors.

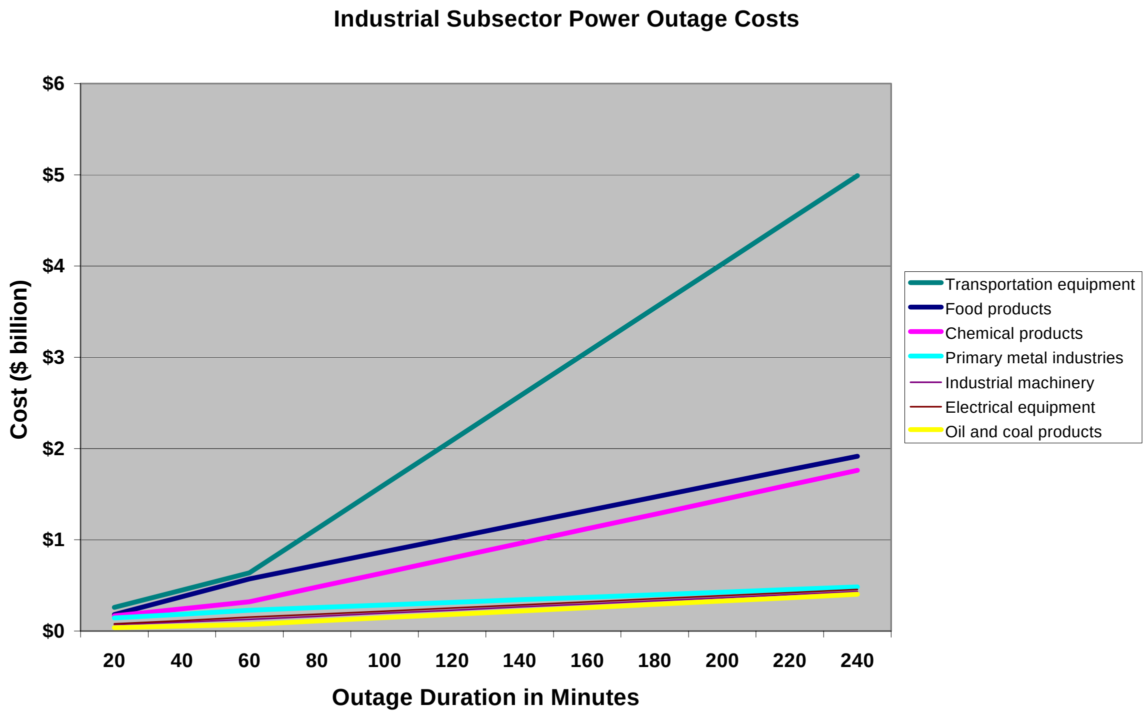


The next two charts provide another way to illustrate these changes in the distribution of costs for commercial subsectors over the duration of a blackout. One can see that the share of costs experienced by food service and sales grows until it accounts for the majority of costs after four hours of outage duration. These charts also illustrate that offices incur large costs during the initial minutes of a blackout, but subsequent losses are much smaller. Presumably, this is because of the high cost of data loss and damage to computer equipment that occurs during the initial moments of a blackout; more data collection and analysis would be needed to confirm this assumption.





Similar trends can be seen among industrial subsectors. In general, most industries have relatively flat downtime cost lines, indicating that a large share of the total costs is incurred during the initial minutes of an outage. This makes intuitive sense, as significant damage can result when a factory is unable to finish an industrial process because of a power outage. For example, if the power needed to continue heating or stirring a molten substance is suddenly lost due to an outage, the material can congeal in its container and ruin both the product and the equipment in a matter of minutes. The transportation equipment industry, i.e. automobile factories, appears to be the exception to this rule in that they experience increasing marginal costs over time. This may be a result of the fact that short outages can be compensated for by simply running the assembly line a little longer, but longer interruptions can cause serious disruptions in product supply that cannot be made up.



Implications for Onsite Energy for Greater Business Continuity

Most small businesses underestimate the loss of profit that comes with a disaster related to power outage and business downtime, according to Robert Hartwig, Chief Economist for the Insurance Information Institute. About 50 percent of disaster damages are business claims, including those for the interruption of business, according to Hartwig, who notes that “the No. 1 killer of businesses is not the loss of the property, because they get enough coverage to rebuild. It's the loss of profits while the business is closed, because they operate on such a thin margin."[20]

With a growing trend in the business world of “business continuity planning” that would ensure financial continuity, customer satisfaction, and productivity despite a catastrophe, business owners in select subsectors that suffer most from business downtime could realize substantial financial gains from reliable power achievable through onsite power.

A 2004 report by business consulting firms summarized the findings of an industry survey conducted of 142 companies during the months immediately following the 2003 blackout. Question #6 on this survey was:

> “As a consequence of The Blackout, do you think your firm will be more likely to consider investments in alternate energy generation, storage and/or distribution systems?”

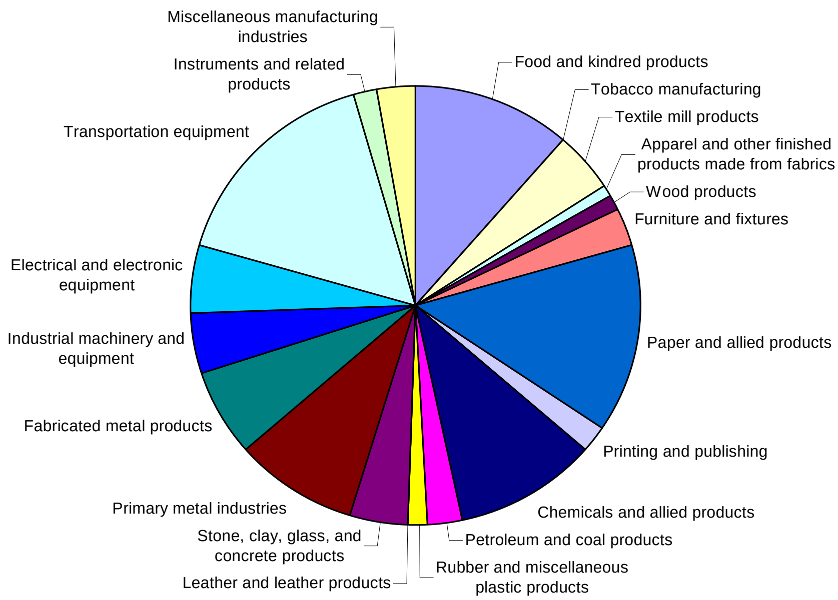
In response to this question, 38.7% of businesses surveyed said they'd be "somewhat" or "very likely" to invest in alternate energy systems.[21]

With a greater understanding of the current costs and cost components of downtime, the variability in downtime costs due to business type, and the change in downtime costs over time, business owners may be better able to calculate the true value in reliable, high quality, power from onsite energy.

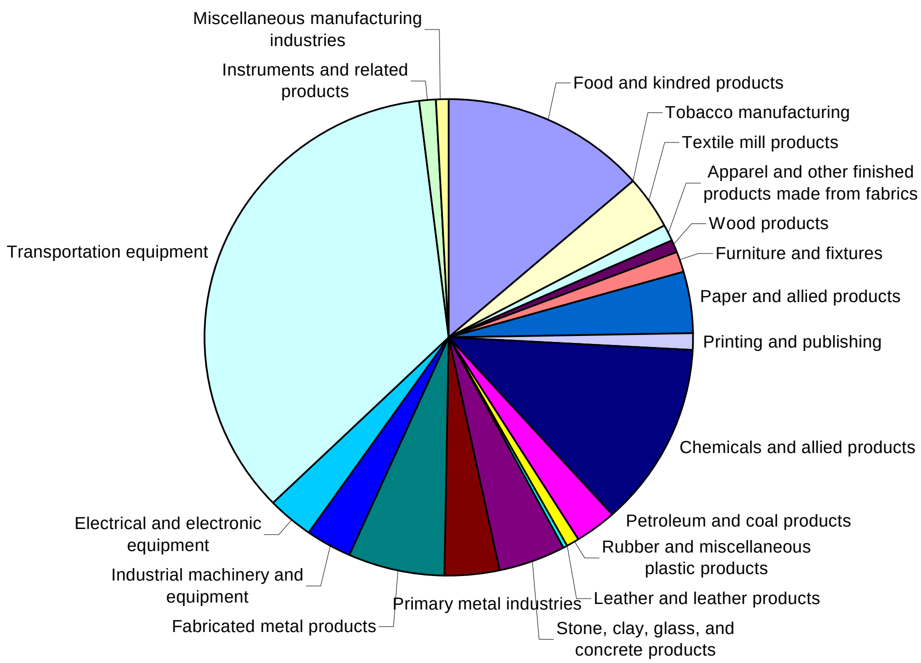
APPENDIX

Sector Results

Total Industrial Sector Outage Costs after 20 Minutes: $1.6 billion



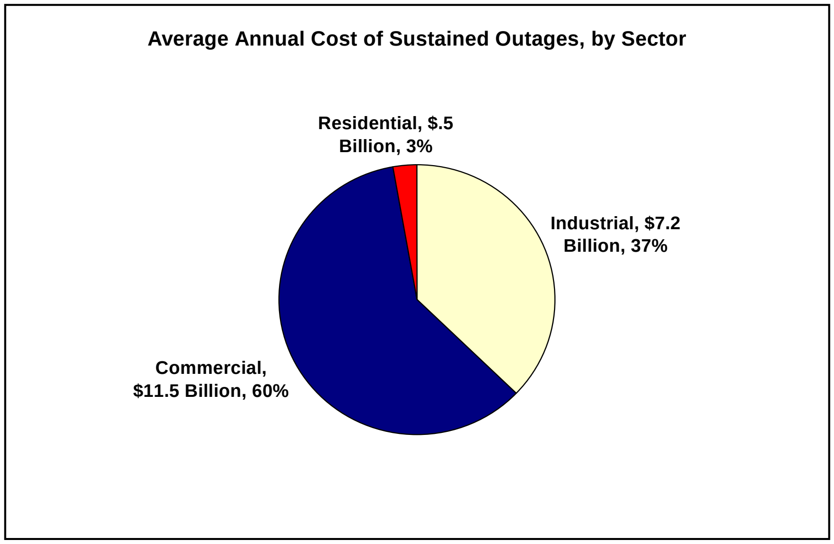
Total Industrial Sector Outage Costs after 4 Hours: $14.2 billion



To provide a glimpse of the impact of power outages to the American economy, one output of our analysis is the aggregate cost of power outages for the three major sectors of the economy. To calculate this cost, data was obtained on the average duration and average frequency of real power outages in the United States. The average customer on a power system in the United States experiences 1.2 sustained outages per year, and the average sustained outage lasts for 106 minutes.[22] The average customer also experiences 4.3 momentary power interruptions per year, but because comprehensive data on the cost of momentary power interruptions is not available these interruptions were not included in the calculation. The cost of a 106 minute outage was then calculated using the Balducci data, and the result was multiplied by 1.2 to reflect the average annual cost of power outages for each sector.

As one can see in chart at right, the commercial and industrial sectors account for the majority of costs caused by power outages.

Figure 2: Average Annual Cost of Sustained Outages, by Sector



Average Sustained Outage Costs for Different Sectors of the Economy, Based on 1.2 Annual Outages of 106 Minutes Each

Sector	**Average Annual Outage Cost**
Industrial	$7,190,777,083.74
Commercial	$11,548,011,443.33
Residential	$529,374,065.09
Total	$19,268,162,592.17

Cost of Economy-wide Outages of Varying Durations for Different Sectors

Sector	***20 Minutes***	***1 Hour***	***4 Hours***
Industrial	$1,591,678,360	$3,173,308,592	$14,204,200,245
Commercial	$2,003,199,350	$5,510,304,875	$21,604,801,375
Residential	$24,933,884	$124,669,421	$1,363,052,334
Total	$3,619,811,594	$8,808,282,887	$37,172,053,955

Economy-wide Cost of Business Downtime—Commercial Subsectors

Subsector	***20 minutes***	***1 hour***	***4 hours***
Non-Refrigerated Warehouses	$52,781,375	$84,790,725	$179,116,150
Refrigerated Warehouses	$115,605,025	$346,815,075	$1,805,855,475
Food sales	$371,152,975	$1,113,458,925	$5,797,746,525
Food service	$383,321,925	$1,149,965,775	$5,987,836,575
Mercantile	$151,385,850	$1,112,784,300	$3,262,659,975
Lodging	$18,176,325	$50,095,725	$135,214,125
Service	$293,583,950	$622,929,450	$1,857,763,050
Health care	$111,627,950	$141,645,550	$205,432,950

Offices	$322,650,650	$409,413,850	$593,785,650
Education	$21,009,750	$79,136,725	$299,038,775
Public Order	$55,158,625	$91,312,100	$216,702,400

Economy-wide Cost of Business Downtime— Industrial Subsectors

Subsector	***20 minutes***	***1 hour***	***4 hours***
Food products	$179,817,682	$572,836,918	$1,916,537,822
Tobacco manufacturing	$2,960,386	$4,906,565	$21,709,494
Textile mill products	$71,405,849	$118,348,583	$523,642,892
Apparel and other finished products made from fabrics	$11,395,059	$34,241,311	$141,062,977
Wood products	$17,067,245	$32,109,563	$105,151,588
Furniture and fixtures	$43,717,778	$90,034,311	$219,930,183
Paper and allied products	$221,749,127	$244,896,217	$588,399,041
Printing and publishing	$29,591,963	$55,618,629	$168,044,320
Chemical products	$166,961,335	$321,155,039	$1,760,951,022
Oil and coal products	$38,137,438	$73,358,483	$402,237,801
Rubber and miscellaneous plastic products	$22,156,643	$35,791,501	$128,394,908
Leather and leather products	$0	$988,581	$12,562,217
Stone, clay, glass, and concrete products	$65,368,959	$162,746,166	$649,406,793
Primary metal industries	$142,566,079	$229,025,508	$483,804,888
Fabricated metal products	$99,481,652	$199,398,672	$915,797,177
Industrial machinery	$71,022,243	$126,993,415	$433,894,167
Electrical equipment	$79,555,334	$150,880,806	$454,699,885
Transportation equipment	$258,975,760	$637,872,658	$4,991,144,696
Instruments and related products	$26,441,343	$47,279,223	$161,537,347
Miscellaneous manufacturing industries	$43,306,484	$34,826,440	$125,291,031

END NOTES

[1] Attempts to contact the original data sources did not yield results.
[2] Attempts to contact the original data sources did not yield results.
[3] KPMG website, http://www.kpmg.com/About/
[4] "Managing Business Continuity: Twenty-First Century Challenges for Competitiveness," KPMG article, 2003, available online at http://www.kpmg.com.au/aci/docs/bus-continuity.pdf
[5] "The True Cost of Downtime," Bill Merchantz, *Contingency Planning & Management* magazine, Volume VII, Number 4 May/June, 2002.
[6] June 2006 phone interview with Julian Krudritsky, Executive Director of The Uptime Institute.
[7] "A Framework and Review of Customer Outage Costs: Integration and Analysis of Electric Utility Outage Cost Surveys," LBL paper, November 2003, available at http://eetd.lbl.gov/ea/EMS/EMS_pubs.html
[8] "Scoping Study on Trends in the Economic Value of Electricity Reliability to the U.S. Economy," Eto, J., et al., LBNL, June 2001.
[9] Inflation Conversion Factors, http://oregonstate.edu/dept/pol_sci/fac/sahr/sahr.htm#_Download_Conversion_Factors_1, accessed May 26, 2005.
[10] Electric Power Annual, EIA, November, 2005.
[11] "Understanding the Cost of Power Interruptions to U.S. Electricity Consumers," LaCommare, K., and Eto, J., LBNL, September 2004.
[12] "Electrical Power Interruption Cost Estimates for Individual Industries, Sectors, and U.S. Economy," Balducci, P., et al., PNNL, February 2002.
[13] "Scoping Study on Trends in the Economic Value of Electricity Reliability to the U.S. Economy," Eto, J., et al., LBNL, June 2001.
[14] "A Framework and Review of Customer Outage Costs: Integration and Analysis of Electric Utility Outage Cost Surveys," LBNL, November 2003, available at http://eetd.lbl.gov/ea/EMS/EMS_pubs.html
[15] "Cost of Power Interruptions to Electricity Consumers in the United States," LBNL, February 2006, available online at http://eetd.lbl.gov/ea/EMS/EMS_pubs.html)
[16] "The Economic Impacts of the August 2003 Blackout," Electricity Consumers Resource Council (ELCON), 2004.
[17] "An Analysis of the Consequences of the August 14th 2003 Power Outage and its Potential Impact on Business Strategy and Local Public Policy," miriflex and REI@Weatherhead, February 2004.
[18] http://www.afdom.org/
[19] http://www.solarstorms.org/ICFBlackout2003.pdf
[20] http://www.bizjournals.com/bizresources/toolbox/topics/home_office/commercial_insurance.html
[21] "An Analysis of the Consequences of the August 14th 2003 Power Outage and its Potential Impact on Business Strategy and Local Public Policy," miriflex and REI@Weatherhead, February 2004.
[22] "Understanding the Cost of Power Interruptions to U.S. Electricity Consumers," LaCommare, K., and Eto, J., LBNL, September 2004.

The Distributed Energy Program would like to acknowledge Oak Ridge National Laboratory for its Technical Project Input for this Report.

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

For more information contact:

EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov