Tax Revenue Protection Through Outage Risk Mitigation: The Value of Distributed PV to The Federal Government

Thomas E. Hoff	Christy Herig	Lynne Gilllette
Clean Power Research	NREL	US DOE
10 Glen Ct.	1617 Cole Blvd.	1000 Independence Ave.
Napa, CA 94558	Golden, CO 80401	Washington, DC 20585
tomhoff@clean-power.com	herigc@tcplink.nrel.gov	lynne.gillette@ee.doe.gov

Abstract

The existing electric system was not designed to withstand multiple terrorist acts. One solution is to protect the system. This, however, is likely to be prohibitively expensive and may not even be successful. Another solution is to reduce the economic payoff from a terrorist attack, thus making it an unattractive target. Distributed PV is one technology that could be used to make the system a less attractive target because distributed PV could withstand a simultaneous attack on both the electric and the natural gas systems.

A more secure electric grid will provide the federal government with revenue protection. This paper found that the economic value of PV to the federal government is highly dependent upon (a) which customers install the PV and (b) how much PV is installed. Supplying all of the grid power with distributed PV would prevent a tax revenue loss of $90 per kW for a 1 week power outage (and four subsequent weeks of GDP interruption). Supplying a small amount of power with PV (the 0.4 percent of the electrical energy that provides 20 percent of the GDP), however, would prevent a tax revenue loss of more than $6,000 per kW from a 1 week power outage.

The federal government should consider establishing an incentive for customers installing distributed PV because of the revenue protection it provides the government. (The incentive may not need to be as high as the value referred to above.) It is likely that customers with the lowest energy intensity will be the ones that install the PV and thus the government will obtain the greatest amount of revenue protection.

Introduction

Fragile Electric Grid

The Council on Foreign Relations recently issued a report titled *America Still Unprepared — America Still in Danger*. One of the eight risks identified in the report is that "an adversary intent on disrupting America's reliance on energy need not target oil fields in the Middle East. The homeland infrastructure for refining and distributing energy to support the daily lives of Americans remains largely unprotected to sabotage." Part of the study's seven recommendations is that the U.S. should "fund a stockpile of modular backup components to quickly restore the operation of the energy grid should it be targeted."[1]

Distributed Resources

Two critical weaknesses in the energy infrastructure system are electric transmission networks and natural gas pipelines. These represent easy targets with a high potential payoff. A coordinated attack on a selected set of key points in the electrical power system could result in multi-state blackouts. While power might be restored in parts of the region within a matter of days or weeks, acute shortages could mandate rolling blackouts for as long as several years.[2] A coordinated attack on both the electrical power system and the natural gas delivery system would be even more devastating.

The electric grid was constructed and operated under a standard to maintain uninterrupted operations, even with the loss of the largest single resource on the system (generation, a substation, or a transmission line). This is the N minus 1 standard, where N represents the sub-parts of the whole system and minus 1 represents the loss of the largest single resource (contingency) on the system. This is an operational engineering standard, set by engineering criteria. Traditionally, both operators of the system and regulators viewed this standard as being the same as an assessment of the risk of system failure. However, the underlying assumption does not hold true in the face of multiple external forces, whether intentional acts of sabotage or the confluence of independent events.[3]

An important option that distributed generation technologies have brought to customers is that they allow customers to construct a portfolio of electricity supplies that satisfies their risk preferences to prevent outages. For example, a customer may choose to supply a portion of their power with highly reliable (and higher cost) distributed resources to hedge against a total power outage.

One commercially available technology that could continue to produce power during a prolonged combined electric and natural gas outage anywhere in the U.S.[4] is distributed photovoltaics (PV): PV does not need an electricity grid to provide power to customers; PV does not need fuel to generate power.

---

[1] *America Still Unprepared — America Still in Danger*, pp 10-11, 27, 36. Source: http://www.cfr.org/pdf/Homeland_Security_TF.pdf

[2] *America Still Unprepared — America Still in Danger*, p. 36.

[3] http://www.rapmaine.org/Part1.html.

[4] Other distributed renewable technologies, such as wind, could survive such an attack if there were adequate resource available.

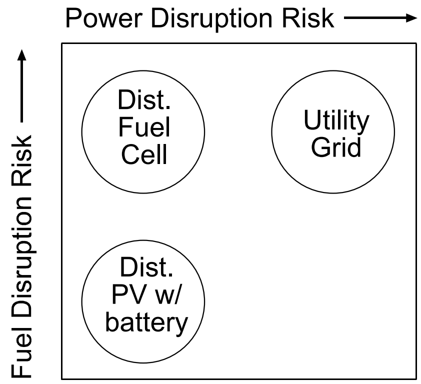

Figure 1. Distributed PV avoids fuel disruption and reduces the risk of power disruption.

Objective

Incentives Driving PV Market

The availability of economic incentives (i.e., buy-down programs, tax credits, rebates, etc.) is a major impetus that is increasing PV system sales. These incentives are often viewed as short-term policy mechanisms necessary to grow the PV market. The underlying thesis of this paper, however, is that there is economic justification for these incentives. That is, the incentives should not only be viewed as short-term policy mechanisms designed to grow the PV market. Rather, the incentives will provide tangible economic benefit to the government. As a result, the question then shifts from "Should the government provide incentives for PV?" to "What is the appropriate incentive amount and incentive structure that the government should provide for PV?"

It is in this vein that the Department of Energy (DOE) through the National Renewable Energy Laboratory (NREL) is undertaking a series of projects that will provide additional guidance to federal, state, and local governments with regard to setting appropriate incentive levels. DOE, through NREL, has contracted with Clean Power Research to provide a series of papers, reports, and Internet-based tools that will support this goal. This first paper attempts to quantify the energy security value of distributed PV to the federal government. It particular, it calculates the value of PV for preventing a one week grid outage.

It is important to note that the federal government will receive other benefits from distributed PV in addition to the energy security benefit discussed in this paper. These other benefits include increased jobs, reduced pollution, and stable electricity prices. The total value of PV to the federal government should also include these values.

Qualitative Discussion

Introduction

Three crucial components required to provide a customer with a product are: inputs to make the product, equipment and/or personnel to transform the inputs into a product, and a system to deliver the product. When electricity is the product, these components correspond to fuel (such as natural gas), generation plants, and a transmission and distribution system (Table 1).

Table 1. Components required to provide customers with a product.

Generic Product	Electricity
Inputs to manufacture the product	Fuel
Equipment/personnel to transform inputs	Generation plants
System to deliver the product	Transmission and distribution system

While a disruption in any of these three components would prevent the product from being delivered, fuel has historically been seen as the potential weak link in supplying electricity. This is due to the fact that a significant portion of the fuel was obtained from foreign sources; events in other countries could cause the disruption of electrical service.

The September 11, 2001 tragedy has forced Americans to re-evaluate the security of many things previously taken for granted.[5] One area that this tragedy has sparked an interest in is the security of the electricity system (including fuel, generation facilities, and the transmission and distribution system).

If terrorist activity does not threaten human life,[6] two key factors that determine the economic consequences of a single terrorist attack are (1) the necessity of the product and (2) the modularity of the system used to produce and deliver the product.

While a terrorist attack on the electricity network is not likely to be directly life threatening, the lack of modularity in substantial parts of the electricity system make it susceptible to attack. The lack of modularity will cause the major system failures in the event certain portions are disabled. Figure 2 and Table 2 qualitatively present the susceptibility of the various components of the electricity system to attack and the economic consequences of the attack. The circles are for central generation (using natural gas) and the squares are for distributed PV. The colors correspond to the portions of the electric generation, transmission, and distribution process.

The figure shows that the less modular the particular element, the easier it is to attack and the greater the economic damage of an attack. The transmission system may be the weakness part of the electricity system. The reason for this is that large amounts of power are transported over a few transmission lines (see Appendix E) and destruction of any link in the transmission line will disable the entire line. An electric network that is

[5] There are also natural events (e.g., hurricanes, tornadoes, tropical storms, earthquakes, hailstorms, floods, ice storms) that can cause a system to break down or poor market structures (e.g., CA) that can cause a system to fail.

[6] If a single attack takes or threatens to take human life, the economic cost will be high even if the systems are highly modular was the case for the airline attack on September 11, 2001 and the anthrax attack in the mail system.

based on distributed PV generation, however, is highly modular and thus is highly protected from terrorist activity.

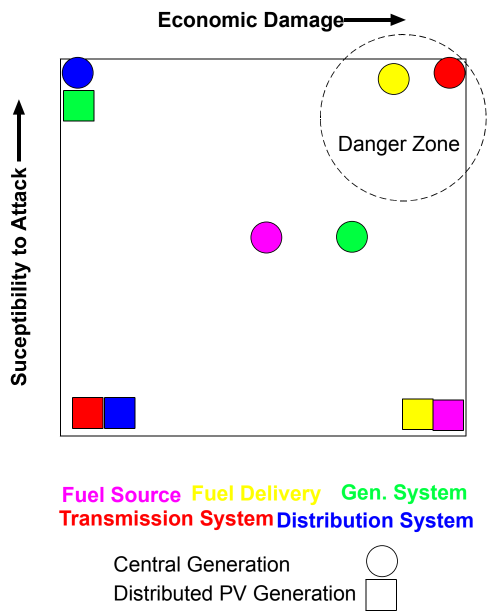

Figure 2. Vulnerability of generation types to single terrorist attack

Table 2. Vulnerability of generation types to single terrorist attack.

	Central Generation (Natural Gas)		**Distributed Generation (PV)**	
Component	***Susceptibility to Attack***	***Economic Damage of Attack***	***Susceptibility to Attack***	***Economic Damage of Attack***
Fuel source	Moderate	Moderate	None	High
Fuel delivery	High	Moderate to High	None	High
Generation system	Moderate	Moderate to High	High	Low
Transmission system	**High**	**High**	N/A	N/A
Distribution system	High	Low	N/A	N/A

Example of Effect of Lack of Modularity

For example, suppose that a terrorist has the goal of totally disabling a traditional central generation power system that has the components as presented in Table 3. As shown in the table, one way to disable the electricity network is to damage is the transmission system (10 attacks would eliminate the ability to deliver power). Furthermore, since each transmission line is non-modular (i.e., the whole system fails if one part fails), disabling a transmission line only requires destroying a single transmission tower within the system to totally disable the entire transmission line. That is, the overall transmission system is non-modular and each transmission line within the transmission system is non-modular.

What would it take to protect the system? Due to the high modularity of the distribution system, it is unlikely that any protection would be required (i.e., it would take such a large number of attacks to disable the distribution system). In terms of the generation and transmission systems, Table 4 suggests that it might require as many as 10 times the resources to protect the transmission system as the generation system.

The point of this discussion is that it will be difficult to protect the transmission system from attack. In addition, since distributed generation resources are even more modular than the distribution system, they are much more resistant to attack. Thus, they reduce the likelihood of an attack, enhance the resiliency of the grid, and reduce fuel system risks.

Table 3. Components of a hypothetical 30,000 MW electric system.

	Avg. Typical size per subsystem	***Length per subsystem***	***Number of subsystems***	***Total Capacity***	***Power loss per attack***
Generation	500 MW	N/A	60	30,000 MW	1.6%
Transmission[7]	3,000 MW	200 miles	10	30,000 MW	10.0%
Distribution	10 MW	10 miles	3,000	30,000 MW	0.03%

Table 4. Protection requirements for each subsystem.

	People per subsystem	***People per mile***	***Total People***
Generation	10	N/A	600
Transmission	N/A	4	8,000

It is important to note that not only is it easy it is to take the system down, but it is also difficult to get the system back up again. The difficulty increases with the availability of parts to fix the problem.

There are several actual and potential economic costs that could be evaluated in regard to the electricity system's vulnerability. The actual cost is how much it costs to protect the system based on other terrorist activities. This includes the cost of protecting the fuel source (domestic and overseas), the fuel delivery system (i.e., natural gas pipelines), the

[7] See Appendix F for a discussion about the amount of power that can flow through transmission lines.

generation facilities, and the transmission system. The potential costs are the amount it would cost (direct as well as indirect costs) in the event of an attack.

The focus of this work is only on what it would cost the federal government in lost tax revenue if the electricity system were disabled for one week.

Quantitative Analysis

Assumptions
This paper attempts to quantify the cost to the federal government from lost tax revenue in the event of a one-week disruption to the power grid.

Lost tax revenue equals the GDP per time period times the outage duration times the GDP multiplier times the tax rate.

$$\text{Lost Revenue} = [\text{Outage Duration}][\text{GDP per Time Period}][\text{GDP Multiplier}][\text{Tax Rate}] \quad (1)$$

The analysis is based upon the following assumptions:

Outage Duration
The analysis will be performed assuming that it takes one week to repair the electric grid.

GDP Per Time Period
GDP for the U.S. averaged $190 billion per week in 2000.

Total GDP Loss vs. Immediate GDP Loss
Total GDP lost is defined to be the total loss in productivity due to an electric grid outage. Immediate GDP lost is defined to be the loss in productivity only during the time of the outage. Total GDP loss is typically much high than the immediate GDP loss.

Appendix A suggests that the total GDP loss in NYC due to 9/11 is 12 to 15 times higher than the immediate loss (the immediate loss is the loss associated with lower Manhattan from 9/11/2001 through 12/31/2001). Appendix C suggest that the total GDP loss for the August 1996 WSCC Breakup (due to an electric power outage) is 10 times higher than the immediate loss. It is conservatively assumed for purposes of this analysis that the total GDP loss is 5 times the immediate loss.

Federal Tax Rate
Appendix D uses three different methods to evaluate the relationship between federal tax revenues and GDP. Tax revenues are shown to be 20 to 30 percent of GDP. For this analysis, it is conservatively assumed that lost federal tax revenues are 20 percent of lost GDP.

*The effect of a Total to Immediate GDP Loss of 5 and a tax rate of 20 percent is that lost federal tax revenues equal immediate GDP loss (5 * 20% = 1).*

PV System Output

A 1 kW PV system produces an average of 30 kWh per week.[8] This represents the performance of a typical PV system at a location in the U.S. with moderate solar availability (17.8% capacity factor).

Option 1: Protect Entire Grid

One option would be to try to protect the entire electric grid using distributed resources. GDP for the U.S. averaged $190 billion per week in 2000. Retail electricity sales were 65 billion kWh per week[9] (this represents 37 percent of the 100 Quads of total energy consumption in 2000 – Appendix E). 2.2 billion kW of PV would be required to satisfy all of the electricity needs. Thus, the GDP saved per kW of PV equals $88 per kW. Using a GDP multiplier of 5 and tax revenues of 20 percent of GDP, the preserved revenues equal $88 per kW of PV.

Option 2: Protect High GDP Customers

Rather than protecting the entire electric grid with distributed PV, another option is to target a small amount of PV to the customers and industries with the lowest energy-intensity per GDP customers.

Gross Domestic Product by Industry

In order to perform this analysis, the relationship between GDP and electricity consumption needs to be developed on an industry basis. GDP and number of people employed by industry (1972 SIC basis) were obtained from the Bureau of Economic Analysis (BEA).[10] This provided both GDP and GDP per worker information.

Energy Consumption by Industry

Unfortunately, no comprehensive source was found that provided energy consumption by industry. Several sources were used to estimate this value. The 1998 Manufacturing Energy Consumption Survey (MECS) provides energy consumption per dollar of value added by NAICS code.[11] Total energy consumption for the various manufacturing fields is found by multiplying GDP from the BEA times energy consumption per dollar of value added.

The 1999 Commercial Building Energy Consumption Survey (CBECS) provides energy consumption by employee for various commercial building types.[12] Total energy consumption is found by dividing energy consumption per employee by the BEA's GDP per employee.

The manufacturing and commercial industries for which estimates were made accounted for 22.6 Quads of energy consumption.

---

[8] The temporal mismatch is addressed through the use of storage.

[9] http://www.eia.doe.gov/emeu/aer/txt/ptb0805.html.

[10] Source: GPO72SIC.WK1 available at http://www.bea.gov/bea/dn2/gpo4700.exe.

[11] Main Internet page is http://www.eia.doe.gov/emeu/mecs/mecs98/datatables/contents.html#ratios and specific file is Ratios of Manufacturing Fuel Consumption to Economic Characteristics by Manufacturing Industry and Value of Shipments ftp://ftp.eia.doe.gov/pub/consumption/industry/d98e7_2.xls.

[12] http://www.eia.doe.gov/emeu/cbecs/set8.html, table C3.

Total energy consumption in the commercial and industrial sectors was 52.0 Quads of energy.[13] This leaves 29.4 Quads unaccounted for. The BEA's GDP estimates were also provided for transportation and public utilities; agriculture, forestry, and fishing; mining; and construction ($1,550 billion or 16 percent of GDP). It is assumed that the unassigned GDP ($1,550 billion per year) required the unassigned energy (29.4 Quads).

<u>Electricity Consumption by Industry:</u>
Electricity consumption by industry was estimated as follows. According to the 2002 Annual Energy Outlook, 7.55 Quads of the total 52 Quads consumed (14.5 percent) was electricity in 2000. Electricity consumption for each industry was estimated by multiplying total energy consumption by 14.5 percent and converted to kWh. The result is presented in Figure 3. For comparison purposes, the red dashed line presents the weekly electricity production from 50 GW of PV (50 GW of PV provide less than 4 percent of the total electricity needs of the nation).

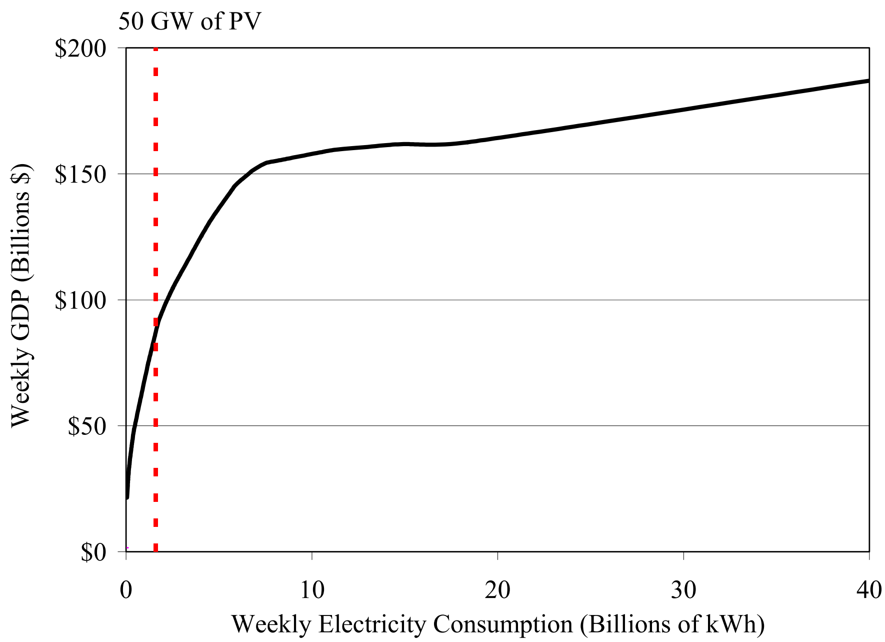

Figure 3. There is a highly non-linear relationship between cumulative GDP and cumulative electricity consumption.

<u>Model of GDP vs. Electricity Consumption</u>
A model was developed that showed the relationship between GDP and electricity consumption for 0 to 7.5 billion kWh electricity consumption per week. Figure 4

[13] 2002 Annual Energy Outlook.

suggests that the model (dashed line) is a fairly accurate representation of actual data (solid line).

$$\text{Weekly GDP} = (\$71\text{ billion})(\text{Weekly Electricity Consumption in billion kWh})^{0.4} \quad (2)$$

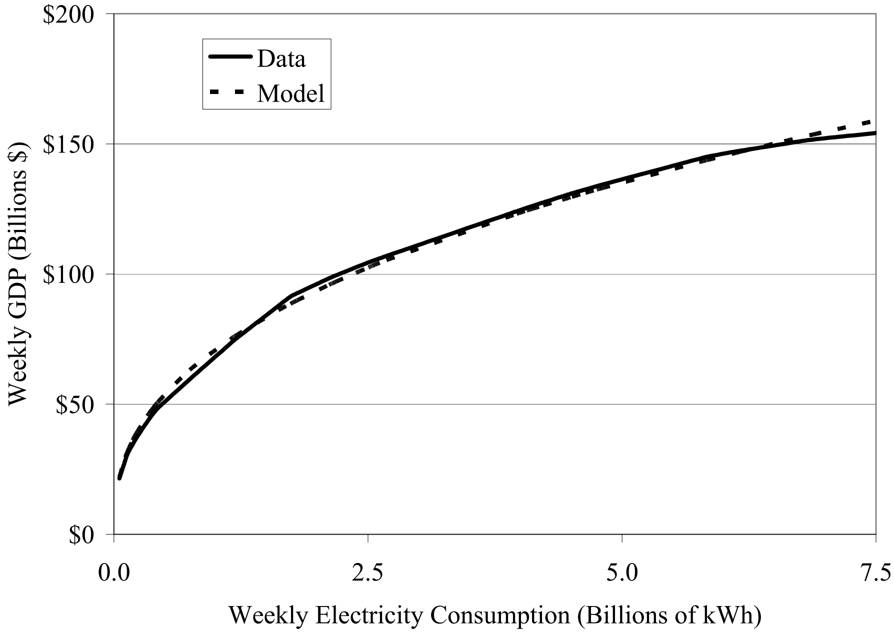

Figure 4. Model and data for relationship between weekly GDP and electricity consumption

GDP vs PV

Equation (2) can be restated in terms of kW of PV: 33 million kW of PV are needed to produce 1 billion kWh of electricity per week for up to 250 million kW of PV. Thus, substitute (kW of PV/33 x10^6) into equation (2) to obtain GDP in terms of PV.

$$\text{Weekly GDP} = (\$71\text{ billion})(\text{PV in kW}/33 \times 10^{6})^{0.4} \quad (3)$$

which simplifies to

$$\text{Weekly GDP} = (\$70\text{ million})(\text{PV in kW})^{0.4} \quad (4)$$

Figure 5 presents weekly GDP versus PV system size. The solid black line is the total GDP; it corresponds to the left y-axis. The sold red line is the GDP per kW of PV; it corresponds to the right y-axis.

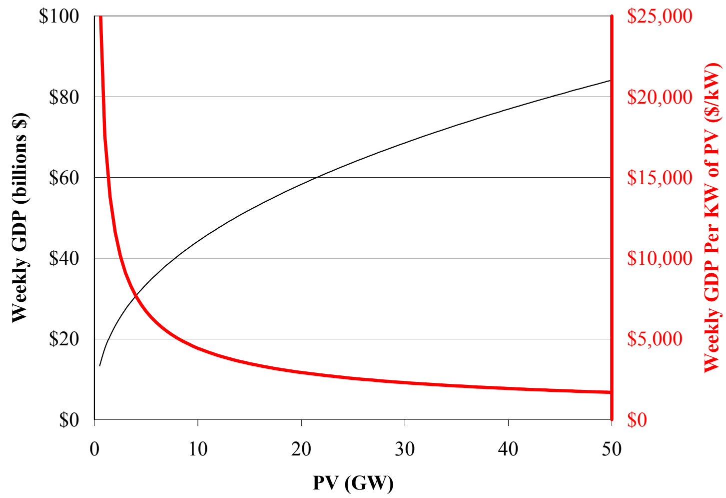

Figure 5. Weekly GDP versus PV.

<u>Preserved Tax Revenues</u>
Weekly GDP is obtained from Figure 5. It is multiplied by a factor of 5 and multiplied by 20 percent to compute the preserved tax revenue.

Assume that the highest value customers install 5 GW of PV. This corresponds to $6,700 per kW of PV. Multiply this by 5 and multiply by 20 percent. The preserved tax revenue is $6,700 per kW.

Thus, 5 GW of PV has a per unit value that is almost 100 times as great as the average value of protecting the entire electric grid.

Conclusions

The existing electric system was not designed to withstand multiple terrorist acts. One solution is to protect the system. This, however, is likely to be prohibitively expensive and may not even be successful. Another solution is to reduce the economic payoff from a terrorist attack, thus making it an unattractive target. Distributed PV is one technology that could be used to make the system a less attractive target because it could withstand a simultaneous attack on both the electric and the natural gas systems.

A more secure electric grid will provide the federal government with revenue protection. This paper found that the economic value of PV to the federal government is highly dependent upon (a) which customers install the PV and (b) how much PV is installed. Supplying all of the grid power with distributed PV would prevent a tax revenue loss of $90 per kW for a 1 week power outage (and four subsequent weeks of GDP interruption). Supplying a small amount of power with PV (the 0.4 percent of the electrical energy that provides 20 percent of the GDP), however, would prevent a tax revenue loss of more than $6,000 per kW from a 1 week power outage.

The federal government should consider establishing an incentive for customers installing distributed PV because of the revenue protection it provides the government. (The incentive may not need to be as high as the value referred to above.) It is likely that customers with the lowest energy intensity will be the ones that install the PV and thus the government will obtain the greatest amount of revenue protection.

Appendix A: 9/11 Cost to New York City

Introduction

A disruption in electrical service caused by a terrorist act on the utility grid could result in both direct and indirect costs to the federal government. The direct costs include funds to repair the system and economic incentives to mitigate the negative consequences of the act. The indirect costs include the lost tax revenue caused by a decline in productivity and lost jobs.

One way to gain insights into the potential costs of such a terrorist act is to examine the cost of the 9/11 terrorist act. On September 2, 2002 the New York City (NYC) comptroller issued a detailed study that quantified the economic cost of 9/11 from the perspective of NYC at between $83 and $95 billion.[14] The study categorized two components to the loss: (1) lost wealth & capital; and (2) lost gross city product (GCP). As shown in Table 1, lost wealth & capital included the physical damage ($22 billion) and the lost lifetime earning potential associated with the immediate loss of life ($9 billion). Lost GCP included the economic effect due to lost productivity and lost jobs; lost GCP was estimated to range from $52 to $64 billion between 9/11/2001 and the end of 2004.

Table 1. Economic Impact on NYC of the WTC Attacks, $ in billions

	Amount	Total
Lost Wealth/Capital		
Physical	$21.8	
Human (measured in lost wages)	$8.7	
Subtotal		*$30.5*
Lost Gross City Product (GCP): 2001-04		
2001 (three months in 2001); first 4 days = $1.8 billion	$11.5	
2002	$15.8	
2003-2004	$25-37	
Subtotal		*$52.3-$64.3*
Total		**$82.8-$94.8**

There are several things to notice in the table. First, the total loss is close to $100 billion dollars. To put this into perspective, NYC's annual GCP is $400 million. Second, the majority of the loss is due to the lost productivity and long-term loss of jobs: the immediate lost wealth & capital accounts for less than one-third of the total loss while the lost productivity and lost jobs accounts for more than two-thirds. Third, there was almost a $2 billion loss in the first 4 days.

[14] The full report is available at http://www.comptroller.nyc.gov/press/2002_releases/02-09-054.shtm.

A key observation is that the economic loss in productivity and jobs (reduced GCP) is twice the economic cost of property damage and loss of life. This is true even for an event with the magnitude of destruction of 9/11. Furthermore, the comptroller's estimate is only from the perspective of New York City, not for the country as a whole. Thus, the loss in productivity will be even greater than what was estimated.

Direct Costs to Federal Government (Not Lost Tax Revenue)
In addition to estimating the cost to NYC, the report estimated the direct costs to the federal government. The estimates are presented in Table 5. About three-quarters of the costs are related to emergency relief and grants to repair damage.

Table 5. Federal Aid Pledged to New York City, $ in billions (Table A4, page 59).

I. FEMA		
Disaster Relief Funds for Emergency Construction, Housing, etc.	$6.350	
Disaster Relief Funds for Transportation System	$2.750	
Subtotal		**$9.100**
II. LIBERTY ZONE ECONOMIC PACKAGE		
Issuance of Tax Exempt Bonds	$1.228	
Advanced Municipal Bond Refunding	$0.937	
Acceleration of Equipment and Property Depreciation	$1.568	
Acceleration of Leasehold Depreciation	$0.595	
Tax Credit to Businesses of 200 Employees or Less	$0.631	
All Other Net Tax Benefits	$0.070	
Subtotal		**$5.029**
III. LMDC		
Community Development Building Grants	$2.000	
Business Assistance	$0.700	
HUD CDBG for Private Utilities (Con Edison/Verizon)	$0.750	
Subtotal		**$3.450**
IV. Other		
Transit Station	$1.800	
Highway & Other Transportation Repairs	$0.552	
Repair/Relocation Federal Offices & Counter-Terrorism Activities	$0.346	
SBA Loans, Health Related Funding, Aid to Individuals & All Other	$1.081	
Subtotal		**$3.779**
Total		**$21.358**

Indirect Costs
NYC estimates that it lost 83,100 jobs from September 2001 to July 2002 (page 8). There was also the loss of job growth of 63,000 jobs which would have resulted from trends in place as of early September 2001 had the 9/11 attacks not occurred.[15] In

[15] The City estimates that there was $2.0 billion in lost tax revenues in 2002 alone as a result of reduced non-property taxes. Actual taxes collected in 2002 was $22 billion, thus, the projected revenue would have

addition to the jobs lost in NYC, 96,000 people were laid off in the airline industry in September 2001 (see Appendix C). At an average income of $50,000 and a GDP multiplier of 2, this translates to an annual GDP loss of almost $20 billion for a two-year period.

Total GDP vs. Direct GDP Loss
Suppose that the crisis is defined to be what occurred in the Lower Manhattan area from September 11, 2001 through December 31, 2001. According to the report, this contributed to $5.7 billion of the total amount lost by NYC. (page 15) Given that the total lost GDP was between $72 and $84 billion between NYC and airline losses, the indirect losses were between 12 and 15 times the direct GDP loss.

---

been $24 billion. Thus, the tax loss represents about 8.3% of the total tax revenues (including property taxes); if only non-property tax revenue was included, this percentage would have been even higher.

Appendix B: Airline Industry

Direct Costs

There was an immediate cost of $5 billion in direct cash for the U.S. airlines and $10 billion loan guarantee.

Estimated cost on October 4, 2001. Safer skies won't come cheap. Aides to Sen. Fritz Hollings, D-S.C., chairman of the Senate Commerce Committee, say the federalization measures could cost between $3 billion and $4 billion. Transportation Secretary Norman Y. Mineta, in recent congressional testimony, put the amount at $1.8 billion. (http://abcnews.go.com/sections/business/DailyNews/WTC_airlinesecurity011004.html).

The Transportation Security Administration (TSA), the newest Department of Transportation (DOT) organization, was established to enhance security for the traveling public. Its budget provides $4.8 billion for aviation security, with an estimated $2.2 billion of the 2003 costs to be raised through passenger and air carrier fees. (http://www.whitehouse.gov/omb/budget/fy2003/bud21.html). There will be 50,000 federal screens.

Thus, the direct cost to the federal government is about $10 billion.

Indirect Costs

Table 6 presents the airline industry layoffs in September 2001.

Table 6. Layoffs in the airline industry for September 2001.[16]

Airline	*Layoffs*
Continental	12,000
US Airways	11,000
Boeing	30,000
AMR Corp	20,000
Northwest	10,000
Delta	13,000
Total	96,000

Assume an average income of $50,000 and a GDP multiplier of 2. This translates to an annual GDP loss of almost $10 billion. Assume that this loss occurs for 2 years, this is a $20 billion loss in GDP. Assuming 20 percent of GDP is paid in federal taxes, this equals $4 billion.

[16] http://www.cbsnews.com/htdocs/economy/unemployment/framesource_pink.html

Appendix C: Electrical System Outage Case Study: August 1996 WSCC Breakup[17]

Background

The power system response to a terrorist attack may be similar to historical widespread outages with significant loss of load. Recent major outages to the western power grid are shown in Table 7. These events were triggered by a variety of causes, but in each case the operation of transmission-level protective relays resulted in breakup of the power system into isolated island grids.

Table 7. Major Outages in the Western Power System, 1994-1998

Date	Event/Causes	Lost Load / Customers	Generation Lost
Jan 17, 1994	System breakup (5 islands); Los Angeles earthquake	7,500 MW	6,400 MW
Dec 14, 1994	System breakup (5 islands); Relays/controller coordination	9,336 MW 1,700,000	11,300 MW
July 2, 1996	System breakup (5 islands); Relays/controller coordination	11,743 MW 2,000,000	9,909 MW
July 3, 1996	Near miss for repeat of July 2; Relays/operator error	600 MW	0 MW
Aug 10, 1996	System breakup (4 islands); VAR support/controller coordination	30,489 MW 7,500,000	25,578 MW
Dec 8, 1998	San Francisco blackout; Human error/relays	600 MW 370,000	402 MW

While these illustrate the response of the system and the consequent loss of load, the duration of these outages -- up to several hours -- may be small by comparison to a terrorist attack in which critical equipment may take weeks or months to repair or replace. Consequently, it is possible that in the aftermath of an attack, the isolated grids would have insufficient primary or reserve units to handle their respective loads, and customers would be subjected to rolling blackouts for the duration of the repairs.

---

[17] Ben Norris, Gridwise Engineering, is the primary contributor for this section.

August 1996 WSCC Breakup

The most significant of these outages was the August 10, 1996 breakup of the Western States Coordinating Council[18] (WSCC) grid, the largest regional blackout in the U.S. since the New York City blackout of 1965. This event began with a transmission line fault on the California/Oregon border that sagged under heavy load in high heat conditions. Other facilities were subsequently taken out by system operators and protective relays designed to prevent further failure, resulting in a series of outages that stretched across several states. Altogether, 30,000 MW of load was interrupted, and 7.5 million customers were affected, some remaining without power for as long as 9 hours. The California Energy Commission estimated the economic cost of this outage to the California economy alone at $1 billion.

On that day, temperatures and loads were high. Northwest hydroelectric power was still available, and Canadian imports had increased to about 2300 MW. Over a few hours, line to ground faults caused by lines sagging into trees tripped a number of 500 kV lines near Portland, weakening the voltage support in the lower Columbia River area.

The critical event occurred at 13:42 p.m. when the 500 kV Keeler-Allston line from Seattle to Portland tripped off line. Power was rerouted from Seattle to Hanford (eastern Washington) then back to Portland, causing oscillations in the north-south transmission corridor. The McNary plant near Hanford was critical since it was the only plant in the area designed for voltage control. Oscillations spread throughout the northern half of the power system.

At 15:47, the heavily loaded Ross-Lexington 230 kV line (near Portland) was lost through another tree fault, and protective relays progressively tripped all 13 of the units in the area. Governors and the automatic generation control system attempted to make up this lost power by increasing generation north of the Seattle-Hanford-Portland path. Growing oscillations produced voltage swings that severed the Pacific AC Intertie. The outage quickly cascaded through the western system, fracturing it into four islands.

Economic Impacts

The California Independent System Operator (CAISO) has analyzed the economic impacts of the August 1996 WSCC outage, based upon a survey[19] conducted by the California Energy Commission. As shown in Table 8, customers representing all classes (residential, commercial, and industrial) participated in the survey, reporting whether they experienced outages and the cost of the outage to them. As expected, residential customers on average did not incur significant costs ($15), but in some cases were as high as $5,500, perhaps due to lost productivity in home offices and damaged equipment.

---

[18] The WSCC was merged with the Western Transmission Association (WRTA) and the Southwest Regional Transmission Association (SWRTA) to create the Western Electricity Coordinating Council (WECC) in April 2002.

[19] CEC Survey of the Implications to California of the August 10, 1996 Western States Power Outage, released June 1997.

The outage cost commercial customers an average of $1,990, and industrial customers were the most severely affected, suffering average losses of $4,590 up to a maximum of $5 million. In each case, the range of impacts was wide, depending upon the specific customer.

Table 8. Customer Losses
August 1996 WSCC Outage

Customer Class	Customers Surveyed	Customers Noting Outage	Customers Reporting Losses	Range of Loss per Customer	Average Loss for All Surveyed
Residential	200	91	7	$49-5,500	15
Commercial	203	40	9	$1,700-12,000	1,990
Industrial	201	51	20	$0-5,000,000	4,590

Depending upon the location of the customer, the outage duration ranged from a few minutes to several hours. As shown in Table 9, a few isolated customers continued to experience outages for over a day.

Table 9. Length of Outage
August 1996 WSCC Outage

Length of Outage	Customer Class					
	Residential		Commercial		Industrial	
	No.	%	No.	%	No.	%
1 to 20 min	7	7.7	1	2.5	5	9.8
20 min to 1 hour	8	8.8	6	15.0	5	9.8
1 to 2 hours	21	23.1	10	25.0	10	19.6
2 to 4 hours	23	25.3	7	17.5	10	19.6
4 to 6 hours	15	16.5	1	2.5	2	3.9
6 hours to 1 day	10	11.0	3	7.5	10	19.6
More than 1 day	2	2.2	5	12.5	0	0
Don't Know	5	5.5	7	17.5	9	17.7
Total	91		40		51	

Based upon average loads by customer class, the CAISO has estimated the cost of the outage as shown in Table 10. With an average residential load of 2 kW, the estimated outage cost was about $10 per kW of lost load with an upper bound of $25/kW. The cost to commercial customers was $125/kW, and the cost to industrial customers was $195/kW. The weighted average across all customer classes was $95/kW. Based upon this analysis, the total cost due to the single outage loss of 30,000 MW would have been about $2.8 billion.

Table 10. CAISO Estimates of Outage Cost

	Percent of Peak Load	Average Customer Peak Load (kW)	Estimated Average Loss ($/Customer)		Estimated Loss ($/kW)	
			8/10/96 Outage	Upper Bound	8/10/96 Outage	Upper Bound
Residential	42%	2	20	50	10	25
Commercial	33%	16	2,000	5,100	125	320
Industrial	25%	24	4,600	7,800	195	330
			Weighted Average		95	200

This analysis can be extended to include a time element. Rounding conservatively all outages in excess of one day to 24 hours, and eliminating all customer responses in which the outage duration was not known, the weighted average outage duration for each customer class may be calculated as shown in Table 11. Then the average costs may be calculated on a per unit energy basis for residential ($2.26/kWh), commercial ($19.64/kWh), and industrial ($38.50/kWh) customers. The weighted cost across all customer classes is $17.06/kWh.

Table 11. Estimates of Outage Cost

	Percent of Peak Load	Avg Customer Peak Load (kW)	Avg Loss ($/Customer)	Avg Duration (hours)	Average Loss ($/kWh)
Residential	42%	2	20	4.4	2.26
Commercial	33%	16	2,000	6.4	19.64
Industrial	25%	24	4,600	5.0	38.50
		Weighted Avg			17.06

Total GDP vs. Direct GDP Loss

The August 1996 WSCC breakup interrupted 30,000 MW of load for an average of 6 hours and cost customers $2.8 billion. How does the total GDP loss related to what the direct GDP should have been? The total U.S. peak was 616,790 MW in 1996.[20] Assuming that all peaks were coincident, a 30,000 MW loss represents about 5 percent of the total peak load (30,000/616,790). Total GDP was $7,813 billion in 1996.[21] This translates to about $0.9 billion per hour. A 6 hour outage that affected 5 percent of the load would be expected to cost $0.27 billion. Since the total GDP loss was $2.8 billion, the total loss is 10 times the direct loss.

[20] http://www.eia.doe.gov/emeu/aer/txt/ptb0808.html
21 http://www.bea.gov/bea/dn/gdplev.xls

The terminology is unclear - is the $2.8B the “total GDP loss” or the “direct GDP loss”? You say the “total” GDP was $7T from which you derive the $0.27B - so I was thinking that this is the “total” GDP losses. Maybe defining terms this way: call the $2.8B the “actual loss” and the $0.27B the “GDP loss” or the “expected loss”.

Deleted: ¶

Appendix D: Federal Tax Effects and GDP

This appendix discusses the relationship between lost GDP and federal tax revenues.

Aggregated Approach

One way to evaluate the relationship between reduced tax revenue and GDP decline is to examine aggregate historical data. Total government receipts can be obtained from the Office of Management and Budget[22] and GDP estimates can be obtained from the Bureau of Economic Analysis.[23] Figure 6 presents the relationship between tax revenue and GDP for the last 70 years. The figure suggests that the government received 15 to 20 percent of GDP since WWII with the current rate being 20 percent.

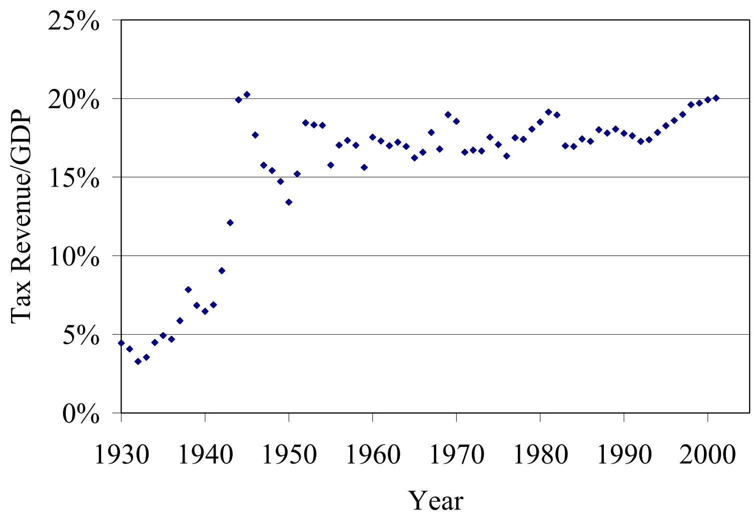

Figure 6. Tax revenue as a percent of GDP.

Disaggregated Approach

An alternative approach is to estimate the economic effect on the government of lost productivity for individual employers or employees (i.e., reduced wages or production).

Suppose that there is an event that results in lost productivity. The economic cost of lost worker productivity could be borne by the employer or by the employees. The employer bears the loss if employees are paid full wages with reduced production. Employees bear the loss if they take a pay cut or if they are laid off/fired.

Consider the economic effect from the government's perspective depending upon whether the employer or the employees bear the loss.

[22] http://w3.access.gpo.gov/usbudget/fy2001/sheets/hist01z1.xls
[23] http://www.bea.doc.gov/bea/dn/gdplev.xls

Employees Bear Loss

Suppose that the employees bear the loss through either reduced wages or through job loss. Individuals pay the federal government income taxes, and social security and medicare taxes.

Social security and medicare taxes are calculated based on the person's total income (i.e., there are no deductions and they do not depend upon the tax filing status of the wage earner). Social security taxes equal 12.4 percent on the first $80,400 of income and nothing after that; medicare taxes equal 2.9 percent of income. The employer pays half and the employee pays the other half of these taxes.

Federal taxes are based on a percent of income after deductions and exemptions. They depend upon income, adjustments to income, number of exemptions, amount of deductions, and the person's tax filing status. It is assumed that the average person has four exemptions (worth $11,000) and the standard deduction ($7,600) so that federal taxes are paid on income minus $18,600. The person files taxes as married filing jointly. The tax tables for a tax status of married filing jointly are shown in Table 12.

Table 12. Federal income tax rates for married filing jointly or qualifying widower (2001 federal tax tables).

Schedule Y-1 —Use if your filing status is Married filing jointly or Qualifying widow(er)

If the amount on Form 1040, line 39, is: Over—	But not over—	Enter on Form 1040, line 40	of the amount over—
$0	$45,200	15%	$0
45,200	109,250	$6,780.00 + 27.5%	45,200
109,250	166,500	24,393.75 + 30.5%	109,250
166,500	297,350	41,855.00 + 35.5%	166,500
297,350	....	88,306.75 + 39.1%	297,350

Figure 7 presents the marginal tax rate components paid versus income (income taxes, and employer & employee social security and medicare taxes). Figure 8 presents the sum of the marginal tax rate components and the average tax rate versus income.

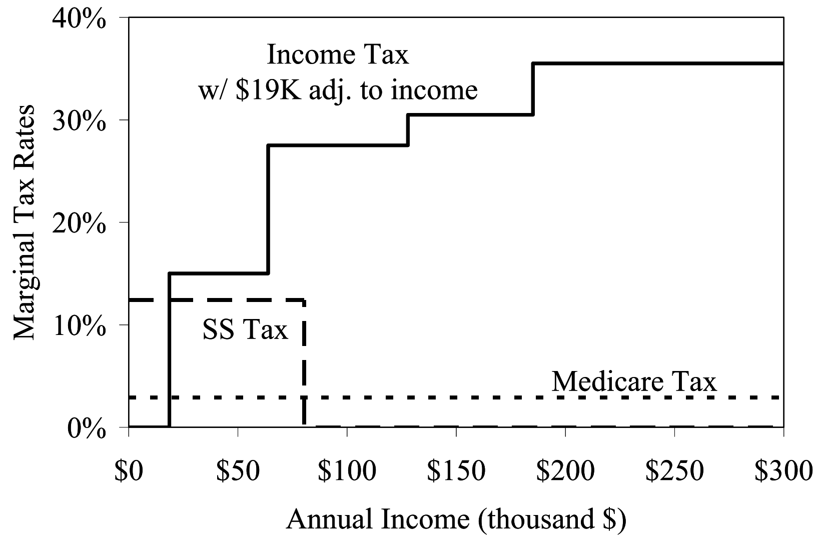

Figure 7. Marginal tax rate components.

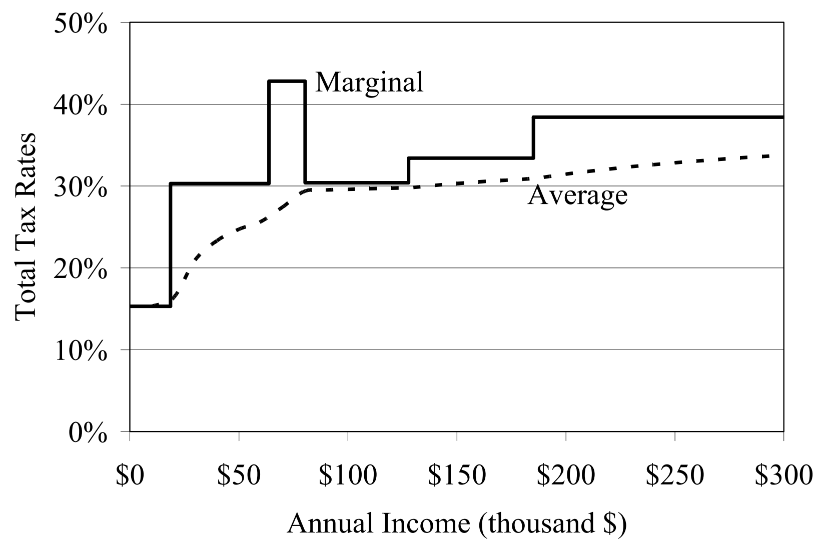

Figure 8. Total marginal and average federal tax rates versus income.

Two observations can be made based on the figure. First, once an employee pays any federal income tax (annual income exceeds $19K deduction), their total marginal tax rate is over 30 percent.

The median income in was $42,000 in 2001.[24] The average tax rate for this income level is 23 percent while the marginal tax rate is 30.3 percent. While government revenues consist of more than taxes from individuals, the 23 percent average compares well with the 20 percent revenue to GDP ratio from the previous section.

Employer Bears Loss

In the event of lost productivity, another option is for the employer to pay employees their full wages. In this case, the employer experiences reduced revenue. Since its costs remain the same, the profits are reduced and the employer pays the government less in taxes. Thus, while there is no loss in taxes from employees (because wages remain constant), there is a tax loss from employers.

Table 13 presents the corporate tax rate schedule for 2001. Figure 9 presents the information graphically. The marginal tax rate between $335,000 and $10,000,000 per year is 34 percent.

Table 13. Corporate tax rate schedule

Tax Rate Schedule

If taxable income (line 30, Form 1120, or line 26, Form 1120-A) on page 1 is:

Over—	But not over—	Tax is:	Of the amount over—
$0	$50,000	15%	$0
50,000	75,000	$ 7,500 + 25%	50,000
75,000	100,000	13,750 + 34%	75,000
100,000	335,000	22,250 + 39%	100,000
335,000	10,000,000	113,900 + 34%	335,000
10,000,000	15,000,000	3,400,000 + 35%	10,000,000
15,000,000	18,333,333	5,150,000 + 38%	15,000,000
18,333,333	- - - - -	35%	0

[24] http://www.census.gov/hhes/income/income01/statemhi.html

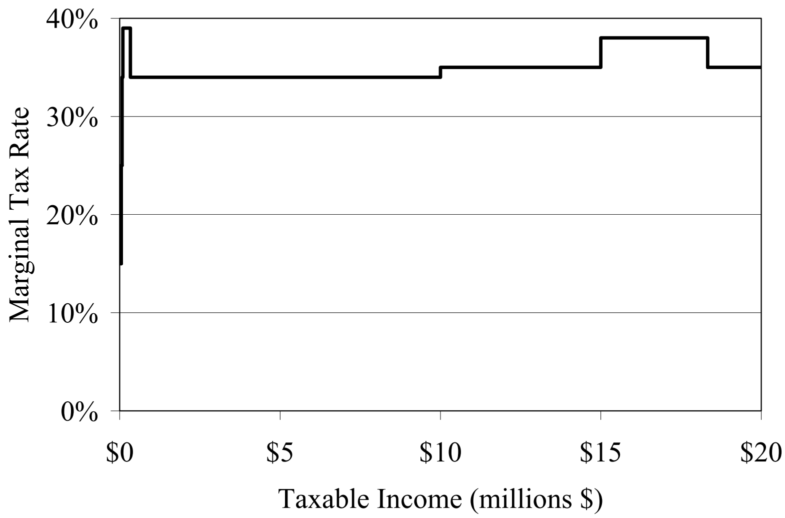

Figure 9. Corporate taxes as a percent of taxable income.

Summary

These results suggest that the federal government will lose tax revenues between 20 percent (computed on average basis) to 30 percent (computed on marginal basis) of the change in GDP.

Appendix E: GDP and Energy Consumption

GDP in 2000 was $9,825 billion or $26.9 billion per day.[25] A total of 3,400 or 9.3 billion kWh were sold in the US in 2000.[26] As shown in Table XX, electricity sales (including generation and distribution losses) accounted for 37 percent of total energy consumption.

Table XX. Consumption and cost of energy by sector and source.

	Consumption		**Cost**	
	Electricity[27]	Primary Energy (not electricity)	Electricity	Primary Energy (not electricity)
Residential	13%	7%	13%	8%
Commercial	12%	4%	11%	3%
Industrial	12%	24%	7%	18%
Transportation	0%	27%	0%	39%
Total	37%	63%	31%	69%

[25] http://www.bea.doc.gov/bea/regional/gsp/
[26] Annual Energy Outlook 2002, http://www.eia.doe.gov/oiaf/aeo/ pp. 126-127.
[27] Electricity consumption includes the losses incurred in generating and distributing the electricity.

Appendix F: Major Transmission Lines in California

The major transmission paths (groups of lines) between California and other portions of the WSCC, used for interregional transactions, are shown below. In many cases, these paths are served by multiple lines, so a terrorist attack would require disabling all lines in the path. In some cases, a single transmission tower carries two lines (e.g., the Gates-Panoche #1 and #2 lines), so an attack on a single tower would be sufficient to remove two lines. Therefore, the effective number of towers is provided for reference.

California-Oregon Interties (COI) Rated Capacity: 4,800 MW 3 Lines / 3 Towers	Pacific AC Intertie (PACI) 500-kV line between the Malin Substation in southern Oregon and the Tesla and Vaca-Dixon 500-kV Substations in central California. PACI 500-kV line between Malin Substation and the Vaca-Dixon 500-kV Substation in central California. 500-kV California-Oregon Transmission Project (COTP) line between the Captain Jack Substation in southern Oregon and the Tracy 500-kV Substation in central California.
Pacific DC Intertie Rated Capacity: 3,100 MW 1 Line / 1 Tower	DC line between the Celilo Substation in north-central Oregon and the Sylmar Substation in southern California.
The Intermountain Power Project Rated Capacity: 1,920 MW 1 Line / 1 Tower	DC line between the Intermountain Power Project in west-central Utah and the Adelanto Substation in the high desert (Victorville) area of southern California.