Vote Solar

QUANTIFYING THE BENEFITS OF SOLAR POWER FOR CALIFORNIA

A WHITE PAPER

by

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THE VOTE SOLAR INITIATIVE

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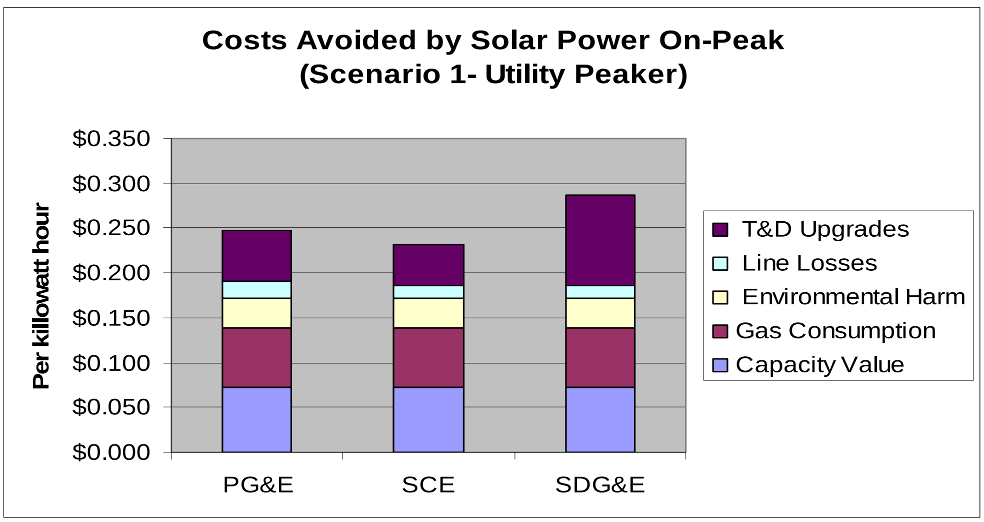
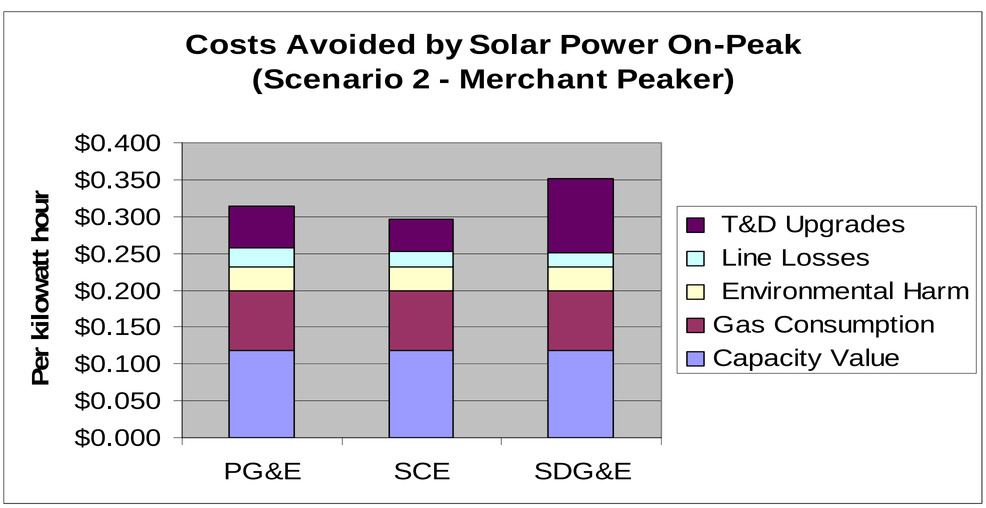
EXECUTIVE SUMMARY

This paper provides a quantitative analysis of key benefits of solar energy for California based on the best available data. It is not intended to be a comprehensive analysis of all of the benefits of solar power, many of which are difficult to quantify. However, it does document the value of solar energy to reduce peak demand for electricity, lessen the consumption of natural gas in power plants, avoid environmental damage from power plant emissions, help the electric grid operate more efficiently by reducing line losses and save investment capital by delaying costly upgrades to the electrical transmission and distribution system.

The findings of this study indicate that the value of on-peak solar energy in 2005 is between 23.1 cents and 35.2 cents per kilowatt hour depending, in large part, on the location of the solar electric systems. This analysis provides robust support for the large-scale expansion of solar power in California consistent with Governor Schwarzenegger's Million Solar Roofs Initiative.





SUMMARY OF FINDINGS

Reducing Peak Demand

In California peak demand for electricity occurs on hot summer days when air conditioners are at their maximum use. Properly oriented solar power systems can produce electricity that closely matches the use of air conditioning loads, thus reducing peak demand. Electric utilities build or purchase power from natural gas-fired peaking power plants to meet this need, which only occurs for several hundred hours over the course of a year. Avoiding investments in the construction and operation of new peaking power plants is valued between 7.3 cents to 11.9 cents per kilowatt hour.

Lessening the Consumption of Natural Gas

California has a diverse portfolio of power supplies including hydroelectric, nuclear, geothermal, wind, biomass, solar thermal and natural gas-fired power plants. However, for almost all of the hours of the year natural gas power plants are "on the margin." That means a new solar power plant will displace the use of natural gas during the hours the solar plant produces electricity. Each kilowatt hour of electricity produced by solar power saves ratepayers between 5.6 cents and 7.5 cents per kilowatt hour by avoiding the purchase of natural gas. Another 0.5 cents per kilowatt hour is saved by avoiding other power plant consumables such as water and ammonia.

Avoiding Environmental Damage

The burning of fossil fuels generates pollutants like oxides of nitrogen, small particulates and carbon dioxide that threaten public health and the natural and built environment. The estimate of the avoided public health and environmental damage used in this study from using solar power instead of natural gas for electricity is 3.3 cents per kilowatt hour.

Improving Grid Efficiency

Electricity is lost as it is transmitted over power lines from power plants to end users. Because of these losses more electricity has to be generated to meet customers' needs. Avoiding power line losses multiplies the other benefits described above. Solar power is typically located at the point of use, on a customer's roof or next to the facility using the electricity. By siting the power plant at the point of load, line losses are avoided. The value of avoiding line losses from solar generated electricity is estimated between 0.7 cents to 2.6 cents per kilowatt hour.

Avoiding Transmission and Distribution Upgrades

Transmission and distribution power lines are most heavily utilized during times of peak power demand. Power lines tend to be less efficient under hot conditions and when more fully loaded. As demand for power increases from economic growth or new development, the utility needs to invest in new power lines. Because solar power is located at the point where it is consumed it can help avoid or defer the need for new power lines. The value that solar provides in avoiding these investments is very dependent on matching the location of the solar project with growth in demand for power. The estimated benefit from avoiding or deferring power line upgrades is estimated to be between 4.5 cents and 10 cents per kilowatt hour.

Other Non-Quantified Benefits of Solar Power

- Solar electricity provides local voltage support that can reduce the need for other utility equipment.
- Large-scale, dispersed solar deployment can reduce the need for operating and spinning reserves needed to assure electric reliability.
- Large-scale solar deployment can reduce the cost of natural gas for other uses like heating, industrial processes and transportation through a price elasticity effect.
- The ease of deploying solar projects and their short lead times reduces the risk of forecasting mistakes that can result in costly power generation overcapacity.
- The broad public support for solar power and short development time for projects reduces financial risk by beginning capital returns more quickly and minimizing the likelihood of project failure.
- The low operational and maintenance costs for solar energy and the opportunity to leverage customer investment reduce the risk of technological obsolescence that could add to an electric utility’s stranded costs.

OVERVIEW & METHODOLOGY

Solar electric technologies promise to become a rapidly growing proportion of California's electric resource portfolio. Solar electric technologies are fast to build, modular in size, dispersed in many locations, environmentally clean and easy to deploy. They also provide electricity during summer peak periods at or near the location where the electricity is used. In many cases solar systems are located on the customer's side of the meter rather than the utility's side. All of these attributes of solar power can provide significant benefits to society, electric utilities and the end-use customers. The purpose of this paper is to define many of the benefits and to quantify those that are most readily quantifiable (all data comes from public sources). This paper draws on several seminal documents:

- *Small is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size*, Amory Lovins, et.al. 2002 (Small is Profitable)

- *Methodology and Forecast of Long Term Avoided Costs for the Evaluation of California Energy Efficiency Programs,* Energy and Environmental Economics, Inc., October 25, 2004 (California Long-term Avoided Costs)

- *Accelerating residential PV expansion: demand analysis for competitive electricity markets*, Richard Duke, Robert Williams and Adam Payne in *Energy Policy,* March 2004 (Accelerating PV Expansion)

The benefits of solar power that are quantified fall into five broad categories:

1. the benefit of avoiding investments in developing new peaking power plants and operating those plants
2. the benefit of not having to use natural gas or other finite fossil fuel to produce electricity
3. the benefit of not producing pollution or other damaging environmental impacts
4. the benefit of improving the operation of the electric grid by reducing the losses associated with transmitting electricity
5. the benefit of deferring investments in upgrading and expanding the electric grid to meet growing loads

The benefits of solar power are location specific. For the purpose of this study the benefits were analyzed for each of the three major investor-owned electric utilities in California, Pacific Gas and Electric (PG&E), Southern California Edison (SCE), and San Diego Gas and Electric (SDG&E).

COMPARING TWO SCENARIOS

The analysis looks at avoided costs under two alternative scenarios for the year 2005. The two scenarios vary two of the largest uncertainties facing electric utilities and their customers; the cost of developing new power plants and the price of natural gas.

Scenario 1 Assumes:

- new peaking generation will be built by the electric utility at a cost of capital of 9.5% with cost recovery over a 20 year period
- the price of natural gas is based on the 2005 summer market price (average gas price)

Scenario 2 Assumes:

- new peaking generation will be built by a merchant power plant developer at a cost of capital of 15% with cost recovery over a 10 year period
- the price of natural gas is based on the average gas price in California for the period of May 2000 through June 2001 (high gas price – 24% higher)

Summary of the Quantified Benefits of Solar Power

The value of the solar electric system in meeting utility peak requirements will be influenced by the orientation of the system towards the sun and the specific location of the system. Likewise, siting systems at locations where they can effectively defer costly T&D upgrades can greatly add value to the solar electric system.

The benefits that solar electric power brings to electric utilities and society are significant. Many of the quantifiable benefits result from the coincidence of solar power output with the peak demand for electricity and its location at or near load. Tables 1, 2 and 3 summarize the benefits of on-peak solar generated electricity for each of the California investor-owned utility service areas.

Table 1 - Summary of Benefits of On-Peak Solar Power in PG&E Service Area

	Scenario 1	**Scenario 2**
Avoided Peak Capital Costs	$0.062	$0.108
Avoided Peak O&M Costs	$0.011	$0.011
Avoided Fuel and Other Consumables	$0.066	$0.080
Environmental Benefits	$0.033	$0.033
Line Loss Adder	$0.019	$0.026
Avoided T&D Upgrades	$0.056	$0.056
Total	**$0.247**	**$0.314**

Table 2 – Summary of Benefits of On-Peak Solar Power in SCE Service Area

	Scenario 1	**Scenario 2**
Avoided Peak Capital Costs	$0.062	$0.108
Avoided Peak O&M Costs	$0.011	$0.011
Avoided Fuel and Other Consumables	$0.066	$0.080
Environmental Benefits	$0.033	$0.033
Line Loss Adder	$0.014	$0.020
Avoided T&D Upgrades	$0.045	$0.045
Total	**$0.231**	**$0.297**

Table 3 – Summary of Benefits of On-Peak Solar Power in SDG&E Service Area

	Scenario 1	**Scenario 2**
Avoided Peak Capital Costs	$0.062	$0.108
Avoided Peak O&M Costs	$0.011	$0.011
Avoided Fuel and Other Consumables	$0.066	$0.080
Environmental Benefits	$0.033	$0.033
Line Loss Adder	$0.014	$0.019
Avoided T&D Upgrades	$0.101	$0.101
Total	**$0.286**	**$0.352**

In addition to the peak benefits provided by solar electric systems, they also provide significant societal and utility benefits even when they produce electricity during non-peak periods. Tables 4, 5 and 6 summarize the benefits of non-peak solar energy production in each of the investor-owned utility service areas in California.

Table 4 – Value of Non-Peak Solar Electricity in the PG&E Service Area

	Scenario 1	**Scenario 2**
Avoided Natural Gas	$0.056	$0.076
Variable O&M Costs	$0.005	$0.005
Environmental Benefits	$0.033	$0.033
Line Loss Adder	$0.007	$0.009
Total	**$0.101**	**$0.123**

Table 5 – Value of Non-Peak Solar Electricity in the SCE Service Area

	Scenario 1	Scenario 2
Avoided Natural Gas	$0.063	$0.085
Variable O&M Costs	$0.005	$0.005
Environmental Benefits	$0.033	$0.033
Line Loss Adder	$0.008	$0.010
Total	**$0.109**	**$0.133**

Table 6 – Value of Non-Peak Solar Electricity in the SDG&E Service Area

	Scenario 1	Scenario 2
Avoided Natural Gas	$0.063	$0.085
Variable O&M Costs	$0.005	$0.005
Environmental Benefits	$0.033	$0.033
Line Loss Adder	$0.008	$0.010
Total	**$0.109**	**$0.133**

Much of the benefit of solar energy produced during non-peak periods comes from its displacement of electricity generated by inefficient power plants that are on the margin. Most of these plants are old (many over 30 years) and potentially will be replaced by more efficient combined cycle power plants. However, rapid deployment of solar energy projects could impact the rate at which these plants are retired potentially avoiding investments in new combined cycle plants. Analysis of the potential benefits of this impact is beyond the scope of this study but could be significant.

QUANTIFICATION OF SOLAR BENEFITS

It is possible to quantify the benefits of the deployment of solar electric projects by calculating the costs that their deployment avoids for the customer, the utility and society as a whole. This type of analysis is often referred to as an avoided cost study. Avoided cost studies are a standard practice in the electric utility industry. However, what gets counted is important and sometimes controversial.

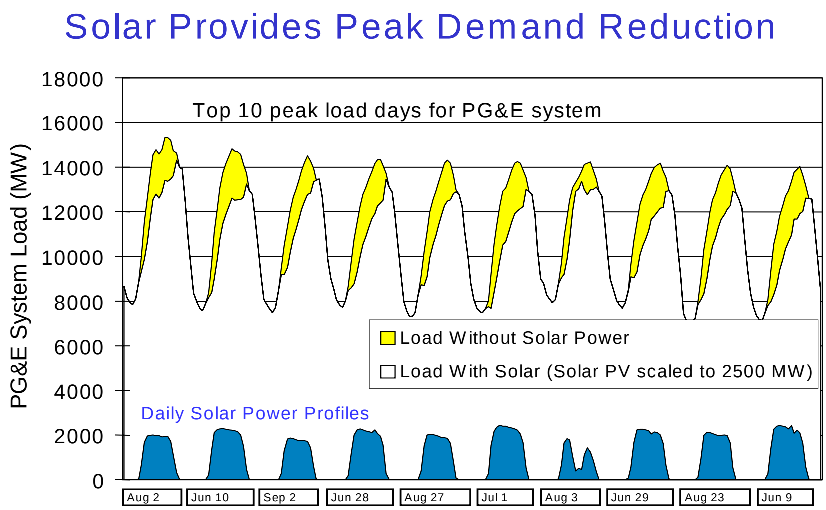
Five key avoided costs will be analyzed:

1. deferral of investments in new peaking power capacity
2. avoided purchase of natural gas used to produce electricity
3. avoided emissions of carbon dioxide and nitrogen oxides that impact global climate and local air quality
4. reduction in transmission and distribution system power losses
5. deferral of transmission and distribution investments that would be needed to meet growing loads.

Peaking Generation Avoided Cost

Peak demand for power at the three California investor-owned utilities occurs during the summer weekdays from noon to 6 pm. The annual system peak has a high probability of occurring on a weekday during June, July, August or September. High peak demand days can also occur during weekdays in May and October. A peaking power plant needs to operate from 200 to 500 hours a year to meet summer peak demand requirements.

While solar electric generation is not dispatched like a peaking power plant it can be valuable in meeting peak demand. In California, there is a substantial coincidence between the availability of solar power generation and peak demand for electricity. This is not surprising since the use of air conditioning in both commercial and residential buildings drives peak power consumption.



Source: PG&E Report "The Value of Photovoltaics in the Distribution System" 1995. This figure uses actual PG&E system-wide demand data and actual output from PG&E's 500-kW solar power plant in Kerman, CA.

However, the correlation between solar generation and peak power consumption is not exact since air conditioning requirements continue into the late afternoon while peak production of a solar system facing due south occurs near 1 pm PDT. Determining the amount of credit that solar should receive in meeting peak demand is critically important to arriving at the appropriate value of solar energy.

This value will depend on the time of system peak demand as well as the orientation of the solar electric system. This value is called effective load carrying capability (ELCC). ELCC is defined as "the ability of a power generator to effectively contribute to a utility's capacity or system load."

Multiple studies have been conducted to determine the appropriate ELCC for solar in various locations. The National Renewable Energy Laboratory has conducted an analysis of 20 utility service areas that shows that fixed solar electric systems have matches to load shapes ranging from 36% to 70%[1]. For this presentation an ELCC of 50% was selected. This is consistent with the output of a solar system in Sacramento with a 20% tilt that is aimed 30 degrees west of due south[2]. According to this study such a system is capable of producing 50 percent of its rated output at 6 pm when peak demand for electricity occurs in Sacramento. The system peak for California's investor-owned utilities typically occurs several hours earlier in the day than in Sacramento due to the moderating influence of coastal environments.

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[1] "Solar Resource-Utility Load-Matching Assessment," Richard Perez, National Renewable Energy Laboratory, 1994

[2] "Photovoltaic Economics and Markets: The Sacramento Municipal Utility District as a Case Study, Howard Wenger et.al., SMUD, California Energy Commission and US Department of Energy, 1996.

Once the ELCC for solar is selected, calculating the value of solar energy in avoiding the need for more peak generation is straightforward. The cost of installing a simple cycle gas turbine peaking plant is estimated to be $475 per kilowatt of capacity[3]. The annual capital cost of a peaking plant can be determined by multiplying this cost by a capital recovery factor. The capital recovery factor for Scenario 1 (*utility generation with 9.5% interest over 20 years)* is 0.114. The capital recovery factor for Scenario 2 (*merchant generation with 15% interest over 10 years) is 0.199.* These factors yield annual capital costs of $54.15 and $94.53 per kilowatt-year respectively.

These costs can then be converted into costs per kilowatt hour by dividing them by the expected hours of on-peak operation. A peaking plant that operates 438 hours or five percent of the total hours in a year would need to recover 15 cents per kilowatt hour under scenario one and 21.6 cents in scenario 2 to cover its capital costs. Solar electric projects with 50 percent ELCC would create value equal to 50 percent of those costs. Another way of expressing this is that it would take 100 megawatts of solar electric generation to reliably provide meet 50 megawatts on peak. Table 7 summarizes the value of solar electric generation in reducing the need for peaking capacity.

Table 7 – Capacity Value of Solar Power Generation

	Scenario 1	**Scenario 2**
Gas Turbine Capital Costs	$475/kilowatt	$475/kilowatt
Capital Recovery Factor	0.114	0.199
Annualized Capital Costs	$54.15/kw-yr.	$95.43/kw-yr.
Hours of operation	438	438
Capital Cost per kWh	$0.124	$0.216
Value provided by solar (50% ELCC)	**$0.062**	**$0.108**

Developing sufficient solar generation to avoid a peaking power plant not only avoids the cost of building the plant but also avoids the fixed costs of operating and maintaining the plants. The California Energy Commission estimates that fixed costs (principally labor) of operating a peaking power plant are $9.81 per kilowatt of capacity each year[4]. Table 8 summarizes the avoided fixed costs of operating a peaking power plant.

[3] California Energy Commission, 2003 Cost of Generation Report, Appendix D, Table D-2.
[4] Ibid.

Table 8 - Value of Avoided O&M Costs
(Values are the same for both scenarios)

Fixed O&M costs of Peaking Power Plant	$9.81/kw-yr.
Hours of Operation	438
O&M Costs per kWh	$0.022
Value provided by solar (50% ELCC)	**$0.011**

Benefits of Avoided Natural Gas Use

In California, natural gas is the fuel used by power plants on the margin both for peak demand periods and non-peak periods. Therefore it is reasonable to assume the solar electric facilities will displace the burning of natural gas in all hours that they produce electricity.

Calculating a long-term fixed price cost of natural gas is challenging and controversial. Some observers believe that North American natural gas resources are in permanent decline[5] and that current high gas prices are likely to continue and increase further. Unquestionably, during the past two years the low natural gas prices that prevailed during the 1990s have disappeared. Furthermore, volatility in prices has accelerated, starting with the California energy crisis of 2000-2001. On December 9, 2000 gas prices in Southern California spiked to an all-time high of $50/MMbtu. During the entire period of the California energy crisis (May 2000 through June 2001) gas prices averaged $8.05/MMbtu[6]. While prices returned to pre-crisis levels through the fall of 2003 they spiked again in the winter of 2003 topping the $7/MMbtu in December, 2003 and January 2004. And in November, 2004 in anticipation of a possible cold winter, prices in the NYMEX future market reached $8.75/MMbtu[7].

Federal and state agencies conduct long-term forecasts of natural gas prices. However, the most recent forecasts of these agencies diverge significantly from future market prices available in the New York Mercantile Exchange[8] (NYMEX). This inability of government agencies to accurately forecast near-term natural gas prices clearly demonstrates the risk of natural gas price volatility to consumers. Since solar power plants do not use natural gas they reduce exposure to this risk.

[5] Natural Gas Update: Winter 2003-2004, Rich Ferguson, PhD. For the Center for Energy Efficiency and Renewable Technologies, April 2004.
[6] California Long-Term Avoided Costs, Energy and Environmental Economics, Inc., page 235.
[7] NYMEX prices for December natural gas contracts on November 3, 2004.
[8] The most recent forecasts by the California Energy Commission and the federal Energy Information Agency show natural gas prices at $4 per MMBTU for 2005. Market prices are currently more than 50 percent higher than these forecasts.

For the purpose of this presentation two future natural gas prices have been selected to determine the range of avoided natural gas costs provided by solar power plants. The first and lower price is the average NYMEX futures price for the months of June through September 2005. That price is $6.49 per million British thermal units (MMbtu)[9]. The second and higher price is the price that prevailed during the California energy crisis of $8.05/MMbtu. While this price is not expected to occur in 2005 it is certainly a possible price for future years.

The cost of electricity per kilowatt hour can be determined using the heat rate or thermal efficiency of the power plant that is burning natural gas to produce electricity. For a new peaking power plant the heat rate used is 9360 MMBTU/kWh[10]. This heat rate is used to determine the avoided natural gas costs during period of peak demands. Natural gas power plants also use other consumables such as water and ammonia. These costs are estimated to be approximately 0.5 cents per kilowatt hour[11]. Table 9 displays the value that solar energy provides by avoiding the use of natural gas and other consumables in peaking power plants.

Table 9 – Avoided Fuel and Variable O&M for Peak Power

	Scenario 1	**Scenario 2**
Natural Gas Price (MMBTU)	$6.49	$8.05
Peaking Plant Heat Rate (MMBTU/kWh)	9360	9360
Fuel Cost of Electricity Production (kWh)	$0.060	$0.075
Variable O&M Costs (kWh)	$0.005	$0.005
Total	**$0.065**	**$0.080**

Non-Peak Periods of Power Generation

For non-peak periods of time that solar projects are generating electricity they will also displace the use of natural gas[12]. Since there is ample generating capacity during non-peak periods there is no capacity credit given to solar. Any new base-load power plants that are built will principally displace older, less efficient facilities. New combined cycle power plants can be 30 percent more efficient than

[9] December 22, 2004 prices on NYMEX for Henry Hub natural gas.
[10] California Energy Commission, op.cit.
[11] Discussion of Market Price Referents, Energy Division and Strategic Planning Division of the California Public Utilities Commission, March 22, 2004
[12] For the purpose of this paper the term non-peak is used to refer to solar power production during partial peak and off-peak periods during the summer season and all periods during the winter season. As explained elsewhere the operation of avoidable peaker plants is expected to occur five percent of the hours of the year.

existing natural gas steam plants. High natural gas prices provide a strong incentive to capture those efficiencies.

For non-peak periods of time the average heat rates of the existing fleet of natural gas plants will be used for each electric utility's service area. Those heat rates are as follows: PG&E – 8740 MMBTU/kWh, SCE - 9690 MMBTU/kWh, SDG&E – 9720 MMBTU/kWh[13]. These relatively high heat rates are indicative of the age of California's fleet of fossil fuel power plants. Tables 10, 11, and 12 show the value of avoiding natural gas use for non-peak periods of time for each of the state's investor-owned utilities.

Table 10- Avoided Non-Peak Fuel Costs in PG&E Service Area

	Scenario 1	**Scenario 2**
Natural Gas price (MMBTU)	$6.49	$8.05
Ave. Power Plant Heat Rate (MMBTU/kWh)	8740	8740
Avoided Fuel Cost of Electricity (kWh)	**$0.056**	**$0.076**

Table 11 – Avoided Non-Peak Fuel Costs in SCE Service Area

	Scenario 1	**Scenario 2**
Natural Gas price (MMBTU)	$6.49	$8.05
Ave. Power Plant Heat Rate (MMBTU/kWh)	9690	9690
Avoided Fuel Cost of Electricity (kWh)	**$0.063**	**$0.085**

Table 12 – Avoided Non-Peak Fuel Costs in SDG&E Service Area

	Scenario 1	**Scenario 2**
Natural Gas price (MMBTU)	$6.49	$8.05
Ave. Power Plant Heat Rate (MMBTU/kWh)	9720	9720
Avoided Fuel Cost of Electricity (kWh)	**$0.063**	**$0.085**

Environmental Benefits

Since natural gas power plants are on the margin for most hours in California, the environmental benefits from the use of solar power are principally the avoided air emissions created from burning natural gas. The most significant emissions from burning natural gas that cause environmental damage are carbon dioxide and oxides of nitrogen.

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[13] *California Long-Term Avoided Costs*, Energy and Environmental Economics, Inc.

Carbon dioxide is the most ubiquitous of the greenhouse gases that are contributing to global climate change. Carbon dioxide is not currently regulated in the United States. However, there are emerging carbon markets in Europe since the Europeans are taking a more aggressive posture to reducing greenhouse gas emissions. The European Commission has conducted detailed studies of the costs of achieving deep reductions in greenhouse gas emissions. They estimate a cost in the range of $66 to $170 per ton of carbon[14]. The Accelerating PV Expansion study adopted a mid-range cost of $100 per ton for their analysis.

The California Long-Term Avoided Cost study recommends a value for avoided carbon dioxide emissions of $29 per ton of carbon ($8 per ton of carbon dioxide). Separately, in a proposed decision in the renewable portfolio standard proceeding at the California Public Utilities Commission, $92 per ton of carbon ($25 per ton of carbon dioxide) is recommended for use in future resource decisions[15]. For the purpose of this presentation the value of $100 per ton of carbon has been selected.

Oxides of nitrogen are a precursor agent in the formation of smog (ground level ozone). Ground level ozone causes damage to lung tissue, exacerbates asthma and other respiratory conditions and damages the exteriors of buildings and other facilities. Oxides of nitrogen are also small particulates. Long-term, low-exposure to small particulates have been correlated with increased mortality and morbidity. For emissions of oxides of nitrogen the value of $0.014 per kilowatt hour is used as in the Accelerating PV Expansion study. This value is based on detailed analysis of the public health impact of air pollutants[16]. Table 13 presents the environmental benefits of solar power generation.

Table 13 - Avoided Environmental Costs of Solar Generated Electricity

Value of NOx Emissions Avoided (kWh)	$0.014
Value of CO2 Emissions Avoided (kWh)	$0.019
Total Environmental Benefits	**$0.033**

Some may argue that values assigned to the environmental benefits of solar power (3.3 cents per kilowatt hour) are too high. The approach used in the California Long-Term Avoided Costs study assigns a much lower value to the environmental benefits of avoiding using fossil fuels in power generation. On the other hand, if deep reductions in greenhouse gases are desired then the value assigned to carbon dioxide emissions is probably too low. Much of the debate about the value of

[14] European Commission, Common annexes of the ExternE National Implementation Reports. 1997
[15] Proposed decision of ALJ Brown in R.04-04-003, November 2004, at 133-135
[16] Rabl, A., Spadaro, JV, 2000. Public health impact of air pollution and implications for the energy system. Annual Review of Energy and the Environment 25, 601-627.

early reduction of greenhouse gas emissions revolves around how our current generation values the lives of future generations. Using traditional cost-benefit analysis with discount rates based on the opportunity costs of capital results in giving almost no value to environmental benefits that will occur 40 or 50 years into the future. The European Commission, however, suggests that if low discount rates are used (1 to 3 percent) then the value of avoided carbon dioxide emissions would be in the range of $66 to $170 per ton. If values in this range were adopted to shape investments in power resources then solar power would be much closer to being competitive with fossil fuel technologies.

Avoided Line Losses

The placement of solar power systems at or near the point where the power is used avoids the need to transmit the power over a utility's transmission and distribution network. Power that is transmitted is subject to resistive power losses. Those losses vary with the distance the power is transmitted and the voltage level at which the power is delivered. For the purpose of this study it is assumed that the solar generated electricity is delivered at secondary voltage. Resistive line losses are greater during periods of peak demand when more power is being delivered.

The California Long-Term Avoided Costs study has documented average line losses for each of the California investor owned utilities for various time periods[17]. For this presentation the summer peak and the summer shoulder loss factors are used to calculate the additional benefit derived from solar power systems because of their location at load. Tables 14 through 19 demonstrate the benefit of avoiding resistive line losses.

Table14 – Impact of Line Losses on PG&E Peaking Power

	Scenario 1	**Scenario 2**
Avoided Peaking Capacity	$0.062	$0.108
Avoided Fixed O&M	$0.011	$0.011
Avoided Fuel and Consumables	$0.065	$0.067
Avoided Air Emissions	$0.033	$0.033
Subtotal	$0.171	$0.219
Line Loss Multiplier	1.109	1.109
Avoided costs with line losses	**$0.185**	**$0.243**

[17] *California Long-Term Avoided Costs*, Energy and Environmental Economics, Inc., page 66

Table 15 – Impact of Line Losses on SCE Peaking Power

	Scenario 1	Scenario 2
Avoided Peaking Capacity	$0.062	$0.108
Avoided Fixed O&M	$0.011	$0.011
Avoided Fuel and Consumables	$0.065	$0.067
Avoided Air Emissions	$0.033	$0.033
Subtotal	$0.171	$0.219
Line Loss Multiplier	1.084	1.084
Avoided costs with line losses	**$0.190**	**$0.237**

Table 16 – Impact of Line Losses on SDG&E Peaking Power

	Scenario 1	Scenario 2
Avoided Peaking Capacity	$0.062	$0.108
Avoided Fixed O&M	$0.011	$0.011
Avoided Fuel and Consumables	$0.065	$0.067
Avoided Air Emissions	$0.033	$0.033
Subtotal	$0.171	$0.219
Line Loss Multiplier	1.081	1.081
Avoided costs with line losses	**$0.185**	**$0.237**

Table 17 – Impact of Line Losses on PG&E Non- Peaking Power

	Scenario 1	Scenario 2
Avoided Fuel and Consumables	$0.061	$0.063
Avoided Air Emissions	$0.033	$0.033
Subtotal	$0.094	$0.096
Line Loss Multiplier	1.073	1.073
Avoided costs with line losses	**$0.101**	**$0.103**

Table 18 – Impact of Line Losses on SCE Non- Peaking Power

	Scenario 1	Scenario 2
Avoided Fuel and Consumables	$0.068	$0.070
Avoided Air Emissions	$0.033	$0.033
Subtotal	$0.101	$0.103
Line Loss Multiplier	1.080	1.080
Avoided costs with line losses	**$0.109**	**$0.108**

Table 19 – Impact of Line Losses on SDG&E Non- Peaking Power

	Scenario 1	Scenario 2
Avoided Fuel and Consumables	$0.068	$0.070
Avoided Air Emissions	$0.033	$0.033
Subtotal	$0.101	$0.103
Line Loss Multiplier	1.077	1.077
Avoided costs with line losses	**$0.109**	**$0.111**

Deferral of Transmission and Distribution Upgrades

In specific locations where upgrades to the transmission and/or distribution (T&D) system need to be made to meet anticipated load growth the installation of solar electric systems can defer those upgrades. In addition, solar systems can reduce the wear and tear on the T&D system by providing local power at the time of peak demand. The benefits of avoided T&D upgrades are very site specific. The California Long-Term Avoided Costs study noted that the benefits can vary by a factor of seven between utility planning areas. This fact clearly demonstrates that the value of deploying solar electric systems to defer T&D upgrades is very site specific.

The California Long-Term Avoided Cost study has developed T&D avoided costs for planning areas for each of the state's investor-owned utilities[18]. In addition, they have analyzed the times when T&D systems are most heavily loaded. They found that in regions where temperatures can spike dramatically that T&D avoided costs are high because they are spread over a low number of hours. In coastal areas where the temperature is more moderate T&D avoided costs tend to be lower.

For the purpose of this presentation one study area has been selected for each utility to calculate the value of solar electric in avoiding T&D upgrades. Those areas are Sacramento for the PG&E service area and Santa Ana for the SCE service area. SDG&E only has a single study area. Also to simplify the analysis the need for T&D upgrades was assumed to be driven by growth in demand during the peak 438 hours (five percent of the hours in a year). This assumption may be conservative for areas with high temperatures and robust growth like the Central Valley and the San Bernardino/Riverside area. The 50% ELCC used in calculating the credit to give to solar power for avoiding new peaking generation is also used in calculating the value of avoided T&D upgrades. Tables 20, 21 and 22 present the value of avoiding T&D upgrades for the selected areas within the three investor-owned utility service territories.

[18] California Long-Term Avoided Costs, Energy and Environmental Economics, Inc., pages 129-130.

Table 20 – Value of Avoided T&D Upgrades for PG&E

Avoided T&D Upgrades ($/kw-yr.)	$49.11
Hours of peak loading (5% of annual hours)	438
Avoided T&D Upgrades ($/kWh)	$0.112
Value provided by solar (50% ELCC)	**$0.056**

Table 21 – Value of Avoided T&D Upgrades for SCE

Avoided T&D Upgrades ($/kw-yr.)	$39.33
Hours of peak loading (5% of annual hours)	438
Avoided T&D Upgrades ($/kWh)	$0.090
Value provided by solar (50% ELCC)	**$0.045**

Table 22 – Value of Avoided T&D Upgrades for SDG&E

Avoided T&D Upgrades ($/kw-yr.)	$88.23
Hours of peak loading (5% of annual hours)	438
Avoided T&D Upgrades ($/kWh)	$0.201
Value provided by solar (50% ELCC)	**$0.100**

Other Non-Quantified Benefits of Solar

Solar electric systems can also provide local voltage support that reduces reactive power losses and avoids the need to install shunt capacitors on the T&D system and may even allow for the removal of existing capacitors for use elsewhere. The benefit is very site specific and difficult to quantify in general terms.

Large-scale deployment of distributed solar electric systems could allow electric utilities to reduce reserve margins to ensure power system reliability. Some of this benefit is already captured in the avoided cost of peak power generation. However, the benefit of large scale solar deployment may be greater than presented. That is because utilities that rely on large generation facilities require higher reserve margins to assure reliability than do utilities with a large number of smaller generating facilities. The California Long-Tem Avoided Cost study discusses these benefits for energy efficiency program in the reliability adder section of their report (pages 139 to 150). They suggest that a reliability adder may be in the neighborhood of $.002 per kilowatt hour.

Similarly, deployment of solar electric systems on the magnitude envisioned in the Governor's Million Solar Roofs Initiative will have a favorable impact on the price of natural gas through the lessening of demand. This benefit is difficult to quantify because of many other factors influencing natural gas demand and uncertainty about the pace of solar electric deployment. However, the benefit will be broadly distributed throughout society given the use of natural gas for heating, industrial processes and increasingly transportation.

A significant benefit of solar electric systems that has not been quantified is their ease of deployment. Because of solar energy's minimal environmental impact, systems can receive siting approval much faster than traditional power plants. The benign environmental impact opens up a much wider set of potential sites than exist for traditional power plants. Increased siting options can help lower the cost of solar installations. Similarly, a variety of siting locations can enable systems to be installed with orientation to the sun that can increase peak power production.

Many public opinion polls demonstrate that solar energy development enjoys broad public support. Because of this support many early systems are installed in locations like schools and public libraries where they can be used to educate students about science and math and potentially influence career choices. Similarly, since solar enjoys broad public support it is not necessary for developers to hire special interest lobbyists and public relations firms to try to influence government bodies and public opinion.

Finally, much of the quantifiable impacts under the 'Environmental Benefits' section is actually the cost of compliance with current and anticipated environmental laws. Actual future environmental consequences are more difficult to quantify. We do know that fossil fuel electricity generation is a significant contributor to global warming; global warming is already costing upwards of $60 billion a year according to the UN; and there is a near unanimous scientific consensus that unless carbon emission rates are radically reduced in the short term, the warming of the atmosphere will melt polar and glacial ice, raise sea levels, and change current weather patterns—with the cumulative potential to disrupt the ecosystems upon which our way of life is built. A recent report published in Nature magazine estimated that a rise in temperature of 3 degrees would likely result in the melting of the Greenland ice sheet, raising sea levels by around seven meters, inundating many low-lying areas of the world. A recent study[19] published in the Proceedings of the National Academy of Sciences modeled the near-term impacts on California. The study found that heat waves would increase heat-related mortality by up to seven times by the end of the century and the Sierra snowpack would fall by up to 90%, severely disrupting the state's agriculture industry and drinking water supplies. Although it is difficult to quantify the exact

[19] Field, Christopher, et al, *Emission pathways, climate change, and impacts on California*, Proceedings of the National Academy of Sciences, August 24, 2004. http://www.pnas.org/cgi/content/full/101/34/12422

cost of global warming for California, there is a scientific consensus that the costs of failing to curb climate change are significant.

Solar Can Reduce Major Risks Facing the Electric Power Industry

The electric power industry has gone through a series of major shocks recently with attempts at deregulation, increased wholesale price volatility, weakened reliability of service, the exercise of market power by some power plant owners and energy traders, the bankruptcy of several merchant power plant developers and loss of investor confidence in the power sector. Following that experience many industry actors are seeking to minimize regret. Solar energy can help minimize regret by reducing three types of risk.[20] They are:

1) *forecasting risk*: the inherent uncertainty in predicting levels of future demand for electricity
2) *financial risk*: the risk that investment capital will not achieve the anticipated returns or not be returned at all
3) *technological obsolescence*: the possibility that a power asset, once deployed, is devalued in the market because of new technologies or regulations.

Bad forecasts can have dramatic financial consequences for electric utilities and their customers. In the 1970s electric utilities consistently overestimated demand growth. When those mis-forecasts were combined with an increasing cost of capital and long and uncertain lead times for power plant development it created a formula for large rate increases and unhappy consumers. Even when some large power plants were completed they were often underutilized for years creating unrecoverable costs and losses to investors. These problems led to the collapse of the nuclear power industry and a reluctance by electric utilities to develop large power plants in general. With proper incentives and policies, small power plants can be deployed in a manner that better matches dynamic patterns in demand for power over time thus assuring electric reliability while avoiding costly over-capacity.

Smaller scale power plants that have shorter development times before operation tie up less capital and result in earlier returns on capital thus reducing the perception of financial risk in power projects. This can lead to an overall lower market cost of capital for power plant development and increased cash flows into the power sector. In the 1970s and 1980s many large-scale power plants were deferred and even cancelled after significant sunk investments. The risk of project failure is much less with smaller, environmentally friendly technologies that often

[20] Small is Profitable, pg. 117- Valuing modularity and short lead times

do not require additional land and have minimal siting impacts. And in many cases solar power plants can be financed through mortgages or other customer financial instruments reducing the financial risk to the electric utility and other ratepayers. All of these factors make the development of solar power projects less financially risky to society as a whole.

Power plants that have high operating costs either because of their use of an expensive fuel or requirement for significant staffing are at risk of technological obsolescence to emerging technologies that use fuel more efficiently, do not need fuel at all and those that can be operated with few or no staff on-site. The potential of technological obsolescence increases financial risk and pushes investors to demand quicker recovery of capital driving up the cost of developing new power resources. In some cases technological obsolescence has resulted in the creation of utility "stranded costs" with regulators then forcing ratepayers to pay for above market sunk costs which slows technological innovation.

While solar technologies are undergoing rapid evolution, their deployment in an orderly manner can lessen the risk of technological obsolescence in the power sector. This is the case for several reasons. First, solar power requires no fuel and very little maintenance making its continued operation very cost-effective. Once a system is deployed it can be expected to operate for 25 years or longer.[21] Second, solar systems that are on the customer side of the meter usually involve customer investment in the system. Since customers have an equity stake in the power plant they are vested in its continued performance. On the other hand, utility customers may find themselves economically interested in forcing a utility to abandon an asset that is obsolete or represents excess capacity before its investment is recovered. Third, solar power projects can be rapidly dismantled and the site re-used for a more advanced solar technology. The site is not tied up for decades as is the case for power plants that require complex decommissioning.

Solar power's modularity, short-lead times and ease of deployment are potentially very significant to electric utilities and society as a whole although they are difficult to quantify. A most important benefit of the deployment of solar power could be realized by its potential to thoroughly transform the electric power industry. By requiring a deeper understanding of the electric distribution system and the site specific details of small-scale power project deployment, solar power can help foster an evolution of the institutional, market and cultural structures within the electric power industry and create stronger bonds between that industry and other sectors of the economy and society[22].

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[21] The Sacramento Municipal Utility District has operated a one megawatt solar power plant since 1984. The plant continues to produce power at 80 percent of its original capacity.

[22] For a more detailed discussion of this visionary aspect of solar power see "Valuing the Flexibility of Alternative Sources of Power Generation," *Energy Policy,* February 2002.

SPREADSHEETS

Value of Peak PV Generation in PG&E Area	*Utility gen./ave. gas*	*Merchant gen./high gas*
Gas Turbine Capital Cost ($/kW)	$475	$475
Capital Recovery Factor	0.114	0.199
Capacity Factor	5%	5%
Avoided Capital Costs ($/kWh)	$0.124	$0.216
Credit Given to PV (50%)	$0.062	$0.108
Fixed O&M ($/kW-yr.)	$9.81	$9.81
Avoided Fixed O&M ($/kWh)	$0.022	$0.022
Credit Given to PV (50%)	$0.011	$0.011
Total Capacity Credit for PV	**$0.073**	**$0.119**
Gas Fuel Costs ($/MMBTU)	$6.46	$8.75
Peaker Heat Rate (Btu/kWh)	9360	9360
Avoided Fuel Costs ($/kWh)	**$0.060**	**$0.082**
Avoided Variable O&M ($/kWh)	$0.005	$0.005
Avoided Peak Generation Costs	**$0.138**	**$0.206**
NOx Emissions Avoided ($/kWh)	$0.014	$0.014
CO2 Emissions Avoided ($/kWh)	$0.019	$0.019
Avoided Air Emissions	**$0.033**	**$0.033**
Avoided Gen Costs and Emissions	**$0.171**	**$0.239**
Line Loss Multiplier (PG&E)	1.109	1.109
Avoided Gen and Emissions with Losses	**$0.190**	**$0.265**
Avoided T&D Costs ($/kw-yr) (PG&E)	$49.11	$49.11
Capacity Factor	5%	5%
Avoided Peak T&D Costs	$0.112	$0.112
Credit Given to PV (50%)	**$0.056**	**$0.056**
Avoided Peak Gen, Emissions and T&D Costs	***$0.246***	***$0.321***
Value of Non-Peak PV Generation in PG&E Area		
Average SDG&E Area Heat Rate (BTU/kWh)	9690	9690
Gas Fuel Costs ($/MMBTU)	$6.46	$8.75
Avoided Fuel Costs	**$0.063**	**$0.085**
Avoided Variable O&M (kWh)	$0.005	$0.005
NOx Emissions Avoided	$0.014	$0.014
CO2 Emissions Avoided	$0.019	$0.019
Avoided Air Emissions	**$0.033**	**$0.033**
Avoided Fuel and Emissions	**$0.101**	**$0.123**
Line Loss Multiplier (PG&E)	1.073	1.073
Avoided Fuel and Emissions with Losses	***$0.108***	***$0.132***

Value of Peak PV Generation in SCE Area	*Utility gen./ave. gas*	*Merchant gen./high gas*
Gas Turbine Capital Cost ($/kW)	$475	$475
Capital Recovery Factor	0.114	0.199
Capacity Factor	5%	5%
Avoided Capital Costs ($/kWh)	$0.124	$0.216
Credit Given to PV (50%)	$0.062	$0.108
Fixed O&M ($/kW-yr.)	$9.81	$9.81
Avoided Fixed O&M ($/kWh)	$0.022	$0.022
Credit Given to PV (50%)	$0.011	$0.011
Total Capacity Credit for PV	**$0.073**	**$0.119**
Gas Fuel Costs ($/MMBTU)	$6.46	$8.75
Peaker Heat Rate (Btu/kWh)	9360	9360
Avoided Fuel Costs ($/kWh)	$0.060	$0.082
Avoided Variable O&M ($/kWh)	$0.005	$0.005
Avoided Peak Generation Costs	**$0.138**	**$0.206**
NOx Emissions Avoided ($/kWh)	$0.014	$0.014
CO2 Emissions Avoided ($/kWh)	$0.019	$0.019
Avoided Air Emissions	**$0.033**	**$0.033**
Avoided Gen Costs and Emissions	$0.171	$0.239
Line Loss Multiplier (SCE)	1.084	1.084
Avoided Gen and Emissions with Losses	**$0.186**	**$0.259**
Avoided T&D Costs ($/kw-yr) (SCE)	$39.33	$39.33
Capacity Factor	5%	5%
Avoided Peak T&D Costs	$0.090	$0.090
Credit Given to PV (50%)	$0.045	$0.045
Avoided Peak Gen, Emissions and T&D Costs	***$0.231***	***$0.304***
Value of Non-Peak PV Generation in SCE Area		
Average SCE Area Heat Rate (BTU/kWh)	9690	9690
Gas Fuel Costs ($/MMBTU)	$6.46	$8.75
Avoided Fuel Costs	**$0.063**	**$0.085**
Avoided Variable O&M (kWh)	$0.005	$0.005
NOx Emissions Avoided	$0.014	$0.014
CO2 Emissions Avoided	$0.019	$0.019
Avoided Air Emissions	**$0.033**	**$0.033**
Avoided Fuel and Emissions	**$0.101**	**$0.123**
Line Loss Multiplier	1.08	1.08
Avoided Fuel and Emissions with Losses	***$0.109***	***$0.133***

Value of Peak PV Generation in SDG&E Area	*Utility gen./ave. gas*	*Merchant gen./high gas*
Gas Turbine Capital Cost ($/kW)	$475	$475
Capital Recovery Factor	0.114	0.199
Capacity Factor	5%	5%
Avoided Capital Costs ($/kWh)	$0.124	$0.216
Credit Given to PV (50%)	$0.062	$0.108
Fixed O&M ($/kW-yr.)	$9.81	$9.81
Avoided Fixed O&M ($/kWh)	$0.022	$0.022
Credit Given to PV (50%)	$0.011	$0.011
Total Capacity Credit for PV	**$0.073**	**$0.119**
Gas Fuel Costs ($/MMBTU)	$6.46	$8.75
Peaker Heat Rate (Btu/kWh)	9360	9360
Avoided Fuel Costs ($/kWh)	**$0.060**	**$0.082**
Avoided Variable O&M (kWh)	$0.005	$0.005
Avoided Peak Generation Costs	**$0.138**	**$0.206**
NOx Emissions Avoided ($/kWh)	$0.014	$0.014
CO2 Emissions Avoided ($/kWh)	$0.019	$0.019
Avoided Air Emissions	**$0.033**	**$0.033**
Avoided Gen Costs and Emissions	$0.171	$0.239
Line Loss Multiplier (SDG&E)	1.081	1.081
Avoided Gen and Emissions with Losses	**$0.185**	**$0.258**
Avoided T&D Costs ($/kw-yr) (SDG&E)	$88.23	$88.23
Capacity Factor	5%	5%
Avoided Peak T&D Costs	$0.201	$0.201
Credit Given to PV (50%)	**$0.101**	**$0.101**
Avoided Peak Gen, Emissions and T&D Costs	***$0.286***	***$0.359***
Value of Non-Peak PV Generation in SDG&E Area		
Average SDG&E Area Heat Rate (BTU/kWh)	9720	9720
Gas Fuel Costs ($/MMBTU)	$6.46	$8.75
Avoided Fuel Costs	**$0.063**	**$0.085**
Avoided Variable O&M (kWh)	$0.005	$0.005
NOx Emissions Avoided ($/kWh)	$0.014	$0.014
CO2 Emissions Avoided	$0.019	$0.019
Avoided Air Emissions	**$0.033**	**$0.033**
Avoided Fuel and Emissions	**$0.101**	**$0.123**
Line Loss Multiplier	1.077	1.077
Avoided Fuel and Emissions with Losses	***$0.109***	***$0.133***