The Berkeley FIRST Program: A life-cycle assessment of the costs and greenhouse gas emissions

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Abstract Incentives for solar power were investigated in this study. One of the major barriers to solar electricity is the high up-front costs for solar electric systems that consumers face. The city of Berkeley has attempted to alleviate this barrier with the Berkeley FIRST(Financing Initiative for Renewable and Solar Technology) program. The City loans money to each participant in the program to pay for solar electric systems for their homes. The borrowed money is paid back by the participant over a twenty year period as a special tax added onto their property tax. The analysis within this paper consists of a life-cycle cost assessment (LCA) investigating both monetary and carbon emission differences between this program and regular utility customers. This study aims to answer the question: What degree of monetary and carbon emission reductions does the Berkeley FIRST program offer over a twenty year period to residents when compared to purchasing electricity from a utility? Contrary to my predictions, over a twenty year period of time, the Berkeley FIRST Program had higher costs than purchasing electricity from the utility company. However, as predicted, there were significant carbon emissions reductions for a property participating in the Berkeley FIRST Program. While the Berkeley FIRST Program does reduce carbon emissions, over a twenty year period it is not financially comparable to purchasing electricity from the utility company.

Introduction

Today, there are various types of renewable energy being produced in the United States including wind, solar, hydro, and geothermal. However, even with all these alternatives, more than 50% of electricity is currently being produced in the United States by coal burning power plants (Annual Energy Review (AER) 2008). According to the same report, renewable electricity production has actually decreased over the past decade from 385.4 billion kilowatt hours in 1996 to only 351.1 billion kilowatt hours in 2006. This decrease is due to the lack of new renewable power plant construction, and the fact that older plants, such as the Altamont Pass Wind Farm in Northern California, are becoming outdated and need repairs. During this same time period, total energy consumption in the United States rose by 6% (AER 2008). Renewable resources, especially solar energy, have immense potential for energy production. There is such an emphasis on renewable energy today because of climate change, which research indicates is caused by greenhouse gases such as carbon dioxide (Le Treut *et al.* 2007). Climate change is one of today's most prevalent environmental issues, and moving towards renewable energy such as solar power is a step in making our energy carbon neutral. In fact, the original source of fossil fuel energy is the sun, so why is it not being used (Sen 2004)?

Residential and commercial solar panels or photovoltaic (PV) cells have various advantages including their inconspicuous size, relative cost effectiveness, and the fact that the panels can be placed on rooftops where there is generally little other use for the space. When compared to other renewable sources and more traditional sources such as coal and natural gas, solar energy doesn't have the same kinds of distribution problems because the energy can be used where it is generated. Ignoring the fossil fuels used in solar panel creation and recycling, it is a clean way to produce energy from a practically limitless source, the sun (Sen 2004). In fact, at 2007 levels of energy usage, more energy from the sun hits the earth in one hour than all of humanity uses in an entire year (Lewis 2007). If even a portion of this could be captured by solar panels the results would change the world.

Even with these advantages, solar energy has failed to expand. In 1996 only 0.13% of renewable electricity was solar, and by 2006 this amount had only grown to 0.14% of the renewable electricity produced (AER 2008). Currently solar panels average about 15% efficiency when converting solar energy to electricity, but this ranges from simple panels that are about 7% efficient to newer high-tech panels that are in development and could reach about 80% efficiency

(Bullis 2008). The main benefit of solar power is that production of electricity doesn't result in carbon dioxide emissions. However, it requires energy to produce solar panels, and this energy is often derived from fossil fuels: when doing a life cycle analysis, this carbon has to be taken into account (Battisti 2005). Solar power is also important and advantageous because sunlight is available almost everywhere on earth. Unlike wind and hydraulic power, solar power doesn't require as specific conditions to be viable. Granted, in some climates solar panels will produce more energy than in others. Solar energy has applications both connected to and disconnected from the power grid we normally get electricity from. For example: a remote location could be powered by solar panels and become self-sustaining, not needing power lines. Also, homes that are connected to the electricity grid can sell excess energy to utility providers.

A major barrier to the implementation of solar energy systems is the high upfront costs, which can total to $20,000-$50,000 for a typical residential system, or $8-10 per Watt before rebates or incentives (U.S. Department of Energy 2006). Some researchers tell us that solar electricity is unlikely to become a main source until after 2020 mainly because of the cost barriers to widespread adoption of solar panels (Van der Zwaan and Rabl 2004). Also, that until energy prices go up or PV cell production prices go down, the market will prevent the rapid expansion of solar energy (Duke *et al.* 2005). Decreasing production costs would lower PV cell prices, making solar energy prices more competitive with utility prices. Conversely, if energy prices were to rise high enough, PV cells would become competitive. However, without any other financial incentives, one of these two circumstances would have to occur to make solar panels reasonable for buyers. Even with this economic barrier, California has committed to expanding solar energy, and has become a nationwide leader in legislation promoting solar energy use. In August of 2004, Governor Schwarzenegger helped to jump-start the solar energy initiative in California with the "Million Homes Solar Plan." This plan provided monetary rewards for using solar power on both new and old homes (California Public Utilities Commission (CPUC) 2008). In this plan, homeowners that installed solar panels would receive benefits based on the amount of energy they use from their panels, and that any excess energy could be sold back into the energy grid at retail price (CPUC 2008). In fact, this plan mandated that all solar panel users would pay a time-of-use (TOU) rate for any excess energy they needed from the utility. Because the solar panels would be producing energy during the peak hours when the TOU rate is the highest, the customer would pay very low energy prices because they would

likely only use energy from the grid at night when the TOU rate is the cheapest. This original piece of legislature evolved into the California Solar Initiative, which was approved by the California Public Utilities Commission on January 12, 2006. This nearly $2.2 billion initiative plans to increase solar power production in California to 1,940 MW by 2016 (CPUC 2008). Of this $2.2 billion, $1.7 billion goes directly to paying incentives for consumers.

One of the cities on the forefront of the push to use carbon free renewable energy in California is Berkeley. In order to alleviate the main barrier to solar electric generation, the City is on the verge of implementing a breakthrough way to finance personal solar electrical systems for households and businesses. This program, called Berkeley FIRST (Financing Initiative for Renewable and Solar Technology) aims to expand solar energy in Berkeley. Not only does the Berkeley FIRST program take advantage of state incentives offered by California, but also it offers more help to participants. According to a press release by the city of Berkeley on October 23, 2007, "Berkeley is set to become the first city in the nation to allow property owners to pay for energy efficiency improvements and solar system installation as a long-term assessment on their individual property tax bill" (DeVries 2007). This method would alleviate the high up-front costs that households and businesses face when installing a solar electric generation system. The up-front costs for the system would be paid by the city of Berkeley's Sustainable Energy Financing District, which would then be paid back with a special tax on specific property owners that had the panels installed (City of Berkeley 2008). The Berkeley FIRST program will loan participants up to $37,500 to install solar electric systems on their property. The loan will then be paid off as an added tax over a 20-year period. Through this project, Berkeley hopes to expand its number of solar installations from about 400 today, to 1400 within the next decade (DeVries 2007). The gap here lies in whether or not the solar panels would be worth their costs and benefits both environmentally and economically. Will this new financing program will break down the economic barrier for residents in the long run and/or short run? Also, what is the cost of reducing carbon emissions?

This study aims to determine how cost effective the Berkeley FIRST Program would be for a resident of Berkeley. This project will analyze the monetary and carbon emissions costs of this initiative and compare them to the costs of buying electricity from the utility. This project will analyze the costs by using a life-cycle cost assessment (LCA) investigating both monetary and carbon emission differences between the two consumer choices discussed above. The objective

of this study is to evaluate how effective the Berkeley FIRST initiative is in reducing both financial costs and carbon emissions for a typical Berkeley resident. This study attempts to answer the question: What degree of monetary and carbon emission reductions does the Berkeley FIRST program offer over a 20 year period to residents when compared to purchasing electricity from the local utility (Pacific Gas & Electric (PG&E))? I hypothesize that an LCA will show that both carbon emissions and monetary costs are lower for participants in the Berkeley FIRST program than for utility customers. I expect this because I would expect that potential participants wouldn't want to use the Berkeley FIRST Program unless it saved them money and reduced their carbon emissions.

Methods

The system under study will be the Berkeley FIRST program, which is in its pilot phase. Participants will be Berkeley homeowners who: (1) do not install a solar electric system or (2) install a solar electric system with the help of the Berkeley FIRST program..

There are two main consumer options discussed in this study: participating in the Berkeley FIRST program and not installing a solar electric system at all. I will perform an LCA that will take into account costs and emissions for these two options. The life-cycle costs to a consumer of a utility company are internalized on a utility bill, so for the purpose of this LCA, they will be calculated in the same way. The utility charges take into account costs for transporting the power to customers when setting their rates. However, manufacturing costs for power plants are not paid by utility consumers. This is just another factor that makes utility power more affordable. This LCA will use values for a typical Berkeley resident. An LCA is used for this study because it accurately represents the total emissions and costs over the 20 year period of the loan and allows comparison between Berkeley FIRST Program participants and PG&E customers.

Monetary Costs The monetary costs of the Berkeley FIRST Program and of purchasing electricity from PG&E were calculated over a 20 year period. This period was chosen because it corresponds to the length of the loan the Berkeley FIRST Program provides for participants. Thus, calculating costs over this loan period will allow me to evaluate how cost-effective this program is over the period of the loan.

For this LCA, there were numerous assumptions and definitions that had to be set in order to calculate the costs and emissions (Table 1). These assumptions were necessary in order to

calculate costs for the program. The assumption that the solar PV system, installed in the case using the Berkeley FIRST program, produces 75% of the total electricity used by the residence was used to account for the differences in seasonal electricity use. In a mild climate like the San Francisco Bay Area, energy use per month can vary, therefore a PV system that produces 75% of the electrical needs of the residence will likely never produce more electricity than needed during any given month the property is occupied.

Table 1: Monetary Cost Assumptions

Typical Berkeley residence	A typical Berkeley residence was defined as using 590 kWh/month which is the California average (Annual Energy Outlook 2009).
Solar PV system	The size of the PV system was defined as 3.8 kW with an average installation cost of $8/watt. The PV system supplies 75% of the electricity used by the residence.
Total PV system cost	$30,400.00 as the initial price of the system.
Berkeley FIRST loan rate	3.25% as defined by the Berkley FIRST Program.
Loan payments	Paid as an add-on to the property tax semiannually.
Electricity prices	Taken from the Energy Information Administrations 2009 Annual Energy Outlook.
Maintenance costs	The only maintenance cost is a $1,800 cost in the 12th year after PV system installation for replacement of the inverter.

No solar PV system For the option of not installing a solar PV system, all of the electricity used by the Berkeley residence would be purchased from PG&E. Using the predicted rates taken from the 2009 Annual Energy Outlook and the amount of energy used per month for the average Berkeley residence, the cost per year and total cost over the 20 year period from 2009 to 2028 was calculated.

Berkeley FIRST Participant For the option of being a Berkeley FIRST Program participant, the costs were also calculated. The factors contributing to the costs in this situation were the loan, the 25% of electricity still purchased from the utility, and the cost of maintaining the solar PV system. The cost per year and total cost over the 20 year period was calculated by summing the costs of the semiannual loan payments, the electric costs from PG&E, and the cost of the

inverter.

Carbon Emissions There were various assumptions made regarding carbon emissions for the purpose of calculating emissions from both the Berkeley FIRST Program and from a PG&E customer (Table 2). The assumptions made were based off of data published by PG&E and off of journal articles cited by the US Department of Energy in their Photovoltaic Technologies section.

Table 2: Carbon Emissions Assumptions

PG&E Emissions	0.524 lbs CO_2-e/kWh (Pacific Gas & Electric 2009)
Yearly PG&E Emissions Decrease	1% per year in accordance with 1% increase in California State approved renewables per year
PV Cell Emissions	37 g CO_2-e/kWh (Alsema and Fthenakis 2006)

No solar PV system In the case of only purchasing electricity from PG&E, the emissions were calculated using a published number on the PG&E website. This number is the one that PG&E cites as its carbon emissions per kilowatt hour. This emissions factor was used to calculate the first year of emissions, however a new one was calculated for the next year and every year after. The new emissions factors were calculated using a 1% per year emissions reduction standard. This 1% per year emissions reduction was assumed based on PG&E current commitment to increase renewable electricity generation by 1% per year in order to fulfill California State standards as mandated in Assembly Bill 32 (California Public Utilities Commission 2004). Assembly Bill 32 mandated 20% California approved renewable electricity generation by 2010, and PG&E's long-term resource plan has been to increase renewable electricity generation by 1% per year to meet this standard. For the purpose of this LCA, I assumed that this trend of 1% renewable electricity increase per year would continue over the 20 year period of the LCA, effectively reducing carbon emissions by 1% per year. This assumption is reasonable because for PG&E customers the emissions from constructing a power plant are unable to be estimated. Therefore, because power plant construction emissions are not taken into account, 1% more renewable electricity generation equates to 1% of electricity with no carbon emissions. The total emissions for the 20 year period of the LCA were then calculated using the emissions factors and the total energy use for the typical Berkeley residence.

Berkeley FIRST Participant In order to calculate the carbon emissions for a Berkeley FIRST Program participant, the same process as for emissions for a regular utility customer was used for 25% of the 590 kWh/month used by typical Berkeley residents. These emissions were calculated

over a 20 year period, and then added to the emissions for the solar PV system over the 20 year period as well. The emissions for the PV system were calculated using the assumption of 37g CO_2-e/kWh over the lifetime of the cells. This includes the manufacturing and recycling emissions of the PV cells.

Results

Monetary Costs Calculation of the monetary costs for both utility customers and Berkeley FIRST Program participants was done per year and as a whole (Table 3). As evident from the table, the total costs for Berkeley FIRST Program participants are almost 3.4 times greater than costs for PG&E customers. The semiannual loan payments were $1,039.52, resulting in $2,079.04 costs per year in repaying the loan. The total interest paid on the loan over the 20 year period was $11,180.00. The average yearly cost for the Berkeley FIRST participant was $2,245.62, while for the PG&E customer it was only $666.30.

Table 3: Total and per year monetary costs

Year	Monetary Cost- Berkeley FIRST	Monetary Cost – Utility Customer
2009	$2159.85	$683.22
2010	$2148.52	$637.91
2011	$2149.76	$642.86
2012	$2148.69	$638.62
2013	$2148.87	$639.32
2014	$2148.69	$638.62
2015	$2149.23	$640.74
2016	$2149.93	$643.57
2017	$2151.00	$647.82
2018	$2152.41	$653.48
2019	$2154.36	$661.27
2020	$3955.60	$666.23
2021	$2155.24	$664.81
2022	$2155.77	$666.94
2023	$2157.19	$672.60

2024	$2159.85	$683.22
2025	$2163.03	$695.96
2026	$2165.69	$706.58
2027	$2168.16	$716.50
2028	$2170.47	$725.70
Total:	**$44,912.29**	**$13,325.98**

The cost in the year 2020 is much higher than the other years for the Berkeley FIRST Program (Fig. 1). This is because during this year there is an $1,800 cost for replacing the inverter. Figure 1 shows this clearly along with showing that the costs for the Berkeley FIRST Program participant are more than twice as much per year as for the utility customer.

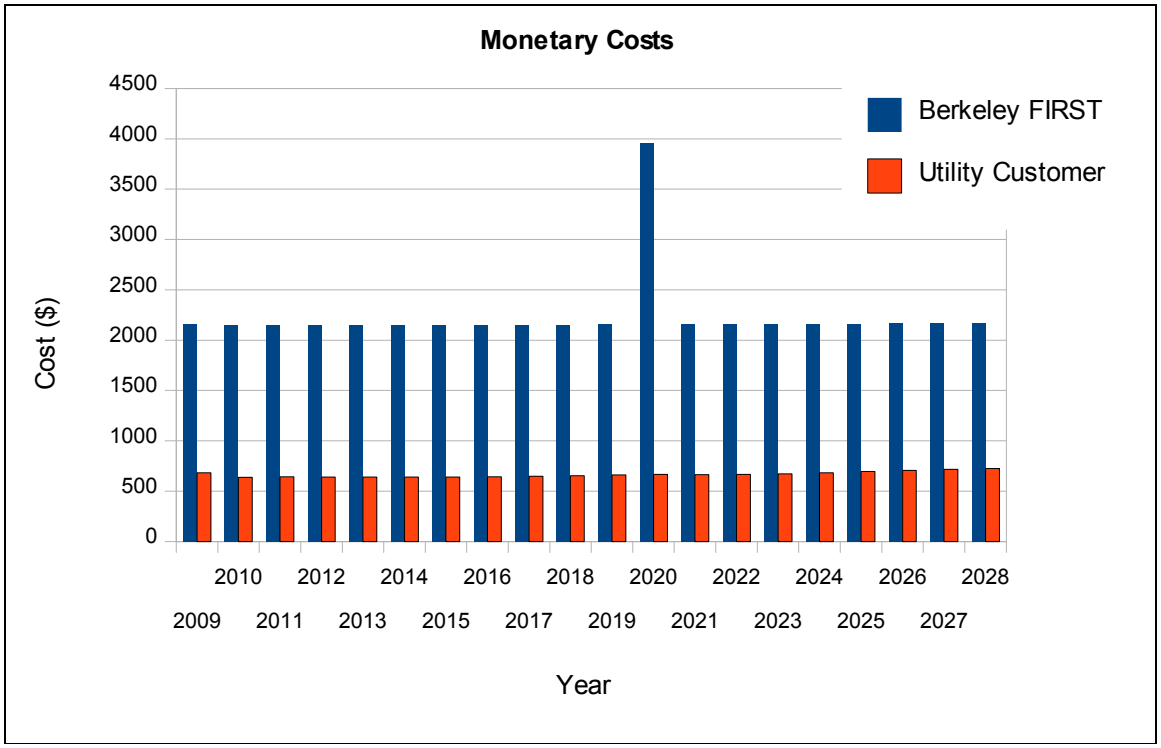

Figure 1: A graphical representation of the costs per year for Berkeley FIRST participants and for PG&E customers.

Carbon Emissions The total and yearly carbon emissions were calculated for both the Berkeley FIRST Program and the PG&E customer (Table 4). The total carbon emissions for the PG&E customer over the 20 year period were 30,642.46 kg CO_2-e. The total carbon emissions for the Berkeley FIRST Participant were 12,899.82 kg CO_2-e. Of these 12,899.92 kg CO_2-e,

5239.2 kg were due to the solar panel installation itself. These emissions are due to the emissions from creating and installing the solar panels themselves. The other 7,660.62 kg were due to the 25% of electricity that the Berkeley FIRST Participant still received from PG&E. The emissions as a result of receiving electricity from PG&E slowly decreased as the percent of renewables increased.

Table 4: Carbon dioxide emissions due to electricity used by a Berkeley FIRST Program participant and by a PG&E Customer.

	PG&E Customer	Berkeley FIRST Participant		
Year	**kg CO2**	**kg CO2 from Solar PV Panels**	**kg CO2 from PG&E**	**total kg CO2**
2009	1682.79	261.96	420.7	682.66
2010	1665.96	261.96	416.49	678.45
2011	1649.3	261.96	412.33	674.29
2012	1632.81	261.96	408.2	670.16
2013	1616.48	261.96	404.12	666.08
2014	1600.32	261.96	400.08	662.04
2015	1584.31	261.96	396.08	658.04
2016	1568.47	261.96	392.12	654.08
2017	1552.79	261.96	388.2	650.16
2018	1537.26	261.96	384.31	646.27
2019	1521.89	261.96	380.47	642.43
2020	1506.67	261.96	376.67	638.63
2021	1491.6	261.96	372.9	634.86
2022	1476.68	261.96	369.17	631.13
2023	1461.92	261.96	365.48	627.44
2024	1447.3	261.96	361.82	623.78
2025	1432.83	261.96	358.21	620.17
2026	1418.5	261.96	354.62	616.58
2027	1404.31	261.96	351.08	613.04
2028	1390.27	261.96	347.57	609.53
Total:	**30642.46**	**5239.2**	**7660.62**	**12899.82**

The total CO_2 emissions from the PG&E customer are about 2.4 times greater than the total CO_2 emissions due to the Berkeley FIRST Participant over a 20 year period. Almost 60% of the CO_2 emissions from the Berkeley FIRST Program calculated total CO_2 emissions were due to the 25% of electricity still purchased from PG&E. The calculated cost of conserved CO_2 due to the Berkeley FIRST Program is \$1.78/kg CO_2.

Discussion

What degree of monetary reductions does the Berkeley FIRST Program offer? The Berkeley FIRST Program ended up being much more expensive than purchasing electricity from the utility company over a 20 year period. My hypothesis that the Berkeley FIRST Program would offer monetary savings to participants over this period of time was incorrect. In fact, the

costs for Berkeley FIRST Participants ended up being almost 3.4 times greater than the costs for PG&E customers. However, if electricity prices were to rise faster than predicted, the Berkeley FIRST Program costs would become more comparable.

What degree of carbon emissions reductions does the Berkeley FIRST Program offer? When compared to the PG&E customer's emissions, the Berkeley FIRST Program had almost 2.4 times less carbon dioxide emissions. This supported my hypothesis that the Berkeley FIRST Program would reduce participant's CO_2 emissions.

In hindsight, there are a few limitations that could be improved upon in a further study. Improving upon these limitations would give a better idea of the cost-effectiveness of the Berkeley FIRST Program. Primarily, a LCA over a longer period of time, possibly 30 years would possibly show the Berkeley FIRST Program to be more cost comparable. This is because after the 20 year period of the loan, the only costs to the participant would be any excess electricity purchased from PG&E. The biggest cost per year for the Berkeley FIRST Participant was the loan payments, therefore perhaps the costs would even out over a longer period of time after the loan was paid off. Also, installing a PV system that produces 100% of the electricity needed would help reduce carbon emissions much more than 2.4 times. In the Berkeley FIRST case, the 25% of the electricity purchased from PG&E accounted for almost 60% of the carbon emissions. Thus, if all of the electricity used were produced by the PV system, emissions would be greatly reduced as there are less CO_2 emissions per kWh from the PV system. In fact, the emissions if the PV system produced 100% of the required electricity would only be about 53% of the emissions calculated for the system producing 75% of the electricity used. However, this would make the costs greater, and would need to be investigated to see whether it would be more cost effective.

Also, this study used published numbers from PG&E and also ignored the power plant construction carbon emissions. If a future study was able to determine PG&E's carbon emissions without basing it off of PG&E's publications, the study would be more accurate. Also, because of resource constraints it was not possible to include power plant construction emissions in this LCA. Including these emissions would likely result in more of a difference between the Berkeley FIRST emissions and the utility company emissions.

The Berkeley FIRST program is the first of its kind, hence the name. Therefore, in this case, there are no real past findings regarding a program of this type. Thus this study is a first step in

filling the gap regarding the effectiveness of possible financing initiatives for solar power. However, the broader implications of a program like this are clear: our country has developed an addiction to fossil fuels and expanding a program like this to a nationwide level could help to reduce dependence on CO_2 emitting forms of energy. Improving technology is very important to the success of solar energy as a whole, but a commitment like the city of Berkeley has made can be fundamental in changing the way we think about renewable energy. Over the next decade or so, our country will be focusing on the major problem of reducing our dependency on fossil fuels. Making solar energy more attractive through the Berkeley FIRST program and others that could be modeled after it, would help move the country towards a carbon free energy system.

Over a 20 year period, the costs of the Berkeley FIRST Program were not comparable to those for a utility customer. However, carbon emissions reductions were substantial, and could be even larger depending on the size of the solar electric system installed. A longer term LCA is needed to further determine the effectiveness of the Berkeley FIRST Program. But, if the purpose of the program were to only reduce carbon emissions, it would serve this purpose well. This study showed the Berkeley FIRST Program to be not fully cost-comparable to the utility company prices, but definitely effective in reducing overall carbon emissions.

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