Solar San Diego

Econ 450: Energy Economics and Climate Policy

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Abstract

The threat of global climate change has resulted in California legislation aim towards reducing greenhouse gas emissions and conventional fuel consumption. As part of this legislation California is requiring utilities to supply 33% of their energy from clean alternative sources (The California Energy Commission, 2011). This project outlines and analyzes the viability of a solar program sponsored by the utility (specifically SDG&E) which would contribute to its renewable energy profile. This solar program would also pass the benefits of solar energy to the consumer by allowing them to keep the panel once it has paid itself off via energy produced.

In order to assess the viability of this program a variety of scenarios were used. Initially there were a total of four scenarios detailing different rates of electricity consumption (tiers) by the consumer and methods of repayment for the solar arrays. Location was also taken into account by separating the SDG&E territory into four segments based on climate. Once data was collected on the costs associated with installing and purchasing the arrays, and the quantity of energy they produce over time, it was applied to the four scenarios. The resulting data yielded results demonstrating the potential viability of two of the scenarios and the infeasibility of the other two. The first of the feasible scenarios dictated that the rate of payback for the solar array be the rate the consumer pays for electricity minus ten cents to account for the required revenue of the utility company. The other feasible scenario requires the payback rate be half of the consumer rate. Both of these scenarios were only feasible for Tiers 3 or 4 consumers, which is dependent on the solar array size and thereby the power produced. Our results suggest that this program would be economically beneficial to both the consumer (due to the energy savings associated with obtaining a solar array) and the utility by building their renewable portfolio provided the optimal combination of solar array size, energy tier of consumption, and payback scenario be achieved.

Introduction

The release of greenhouse gases (GHGs) associated with the burning of conventional fuels in order to produce energy is the leading anthropogenic cause of global climate change. A significant source of these GHG emissions is electricity production. Statewide legislation has been put into place to decrease our consumption and meet set targets for emission reductions. California Assembly Bill 32 mandates a reduction in GHG emissions to 1990 levels by the year 2020, and further goals set by Governor Schwarzenegger's Executive Order S-3-05 call for a reduction in emissions to 80% below 1990 levels by the year 2050 (Audrey B. Chang, 2010). Reaching these targets and long-term sustainability goals will necessitate investments in alternative and renewable energies statewide. Southern California's notoriously fair and sunny weather lends itself to solar energy, thus making solar the logical choice for alternative energy development in the area. The purpose of this paper is to assess the economic viability of implementing a solar energy program in San Diego, California, which would be facilitated by San Diego Gas and Electric (SDG&E), the local utilities supplier. The feasibility of this project has important implications for the implementation of similar programs in other areas of California, as well as in other states well suited for solar energy production.

The aim of such a project is to incentivize local electric companies such as SDG&E to increase their renewable energy portfolio. Because of the high initial costs of solar energy, and the relatively long payoff time, solar energy is an infeasible option for many businesses and homeowners. The proposed program will help the electric company finance solar procurement for residences, businesses, and public buildings in their county by allowing for the solar panels to pay for themselves over time through the energy they generate. The initial capital of the solar installation project would be fronted by the utility company. The owner of the building where the system is installed will continue to pay their normal energy bill based on their usage to the utility company despite the production of solar energy. For the amount of energy generated by the solar array, the utility company will use a portion of the bill paid to recoup their operating costs as they normally would and the rest of the bill will be considered a payment towards the solar array. Any energy needs beyond what the solar panel provides will be subject to standard rates and none of the revenue will be used as a payment towards the solar array; should more solar energy be supplied then consumed, the utility will purchase that energy at $0.04/kWh (average cost to the utility to purchase energy). After the cost of the array is paid for using this payment method, the utility will maintain ownership until year 20 when the ownership of the panel will change hands to the property owner, who will then be able to receive the cost savings of generating solar energy for the remaining life of the panel. In exchange for providing the funds necessary to purchase and install the panels, the utility company will gain a source of renewable energy to count towards its Renewable Portfolio Standard (RPS).

Project Description and Design

In order to enable the payoff of the solar systems it is important to ensure that the panel systems being used deliver the most energy relative to their cost. It should be noted that only Grid-tied solar systems will be installed, meaning that the solar system is connected directly to the electricity grid. This system is chosen for simplicity and to keep cost down. A variety of panels were compared by the ratio of panel cost to watt produced per panel. This analysis will help set the criteria for the solar energy program. That is, based on our analysis, certain assumptions can be made about if and when this system would pay itself back, and to what degree. There are four scenarios that manipulate rates of pay back for a solar system at each tier.

1. Every kWh produced by the panel is worth 4 cents no matter the tier
2. Every kWh produced by the panel is worth the entire consumer rate
3. Every kWh produced by the panel is worth the consumer rate ($/kWh) minus 10 cents (revenue generated by SDGE from tier 1 without solar program) no matter the tier
4. Every kWh produced by the panel is worth half of the consumer rate

The utility company has four payment tiers to help discourage higher electricity usage. If a customer uses more than the allotted energy in tier one then the customer energy needs spill over into higher tiers depending on how much is used. It was found that the cost of producing or buying electricity for SDG&E was approximately $0.04 per kWh (SDG&E receptionist, 2011). It is important to point out that this rate fluctuates with demand, with the price generally being higher during the same hours the solar panel is at peak production. This was not taken into account in our analysis, and would most likely skew the numbers in a favorable fashion due to the higher value of the energy produced by the panel during peak demand.

There is an important aspect to how utility companies in California are allowed to charge their customers, which is based on decoupling the units of energy sold with the amount of revenue collected. In other words, California energy companies do not make more profit by selling more units of energy. In this system energy rates charged by the company are adjusted annually based on the amount of energy sold in the preceding year, so that the net profit for the utility provider remains the same. Without this program, utility companies would see no benefit to encouraging consumers to conserve electricity. However, under this program, the utility is essentially "locked in" to a certain amount of profit. If in a given year they sell fewer units of energy, they adjust their rates upward to compensate, and vice-versa (Chang, 2010). This is important because after the solar panel is paid off, the utility company no longer retains ownership, and can no longer collect revenue from this. Because the utility is no longer profiting from the panel, it would be a negative incentive to the utility to implement this program. Therefore this project is only feasible in locations with a decoupling program in place.

We also considered a scenario where the utility would retain ownership of the solar panels, while the customer receives a discount on their monthly electric bill from the start of the projects implementation. The main benefit of this would be to the utility, as they would be able to collect profit from the system even after it has paid itself off. However, this system adds several complications to the project. The first is the issue how this plays out with property ownership. It would have to work one of two ways: The solar panel system would be tied to the property, so the next owner is forced into the system, but since the system is still technically owned by the utility it would add less value to the property than if the panel was contributing directly to the value of the property. The other way is to allow future potential owners to opt out of the program, but then the utility is left with an aged solar system and a loss of investment for installing the system. In either of these scenarios, it behooves the consumer to seek alternate ways to abate the upfront costs so they may ultimately own these panels. Another issue which comes up is responsibility for care and maintenance of the solar panel. While there would be a minor cost to the utility for upkeep of the panels, gaining access to hundreds of solar panel systems spread across hundreds of private properties could pose a problem.

Additionally, this program depends on the implementation of new smart meters used to remotely collect energy usage data. In order for this program to work, the utility is going to have to know exactly how much power the panel is producing in real time, along with the power the consumer is producing. This would require “smart” panels which communicate with the smart meters in order to transmit power generation data to the utility. This offers up a couple of additional benefits. First, because the utility owns the panels initially and knows how much power they generate in real time, the utility can count the power generated towards their renewable energy portfolio, which they are mandated to have at least 33% be renewable by 2020 (The California Energy Commission, 2011). Because the utility eventually will not be making profit off of these panels, this will end up being their main incentive to implement this program. The second benefit to these smart panels is their ability to be automatically cut off from the grid. This becomes important in scenarios where the grid has to be shut down for maintenance, as panels still tied into the grid are charging the system during the day, which creates a hazardous situation for utility workers. Making these panels “smart” is relatively simple, and only requires a box in between the panels and the grid consisting of a radio transmitter, a power meter, a cutoff switch, and a controller board. Total cost for this box should not exceed $200 based on research of individual components.

Finally, there is an issue of how to transfer ownership of the panels should the property change hands before the repayment period is up. This can be remedied by tying the value of the panels to the value of the house. The utility is actively keeping track of how much of the panel is paid off at any given time. This value shall be added on top of the appraised value of the property, so that even if the property is foreclosed the panels are still paying themselves off. This also gives the property owner incentive to properly maintain the panels.

Research Methods and Analysis

The first step for this project was gathering the initial costs associated with purchasing a solar panel system. A list of panels were categorized into a spread sheet, which displayed the panel name, the power output per panel, the cost per panel, and the surface area of each panel. We then divided the cost per panel by the wattage per panel, which demonstrated the associated cost per watt. We then organized it from lowest to highest and selected the lowest panel cost to watts produced ratio. The panel we selected was a 230 watt TrinaSolar, which was calculated at $1.57/watt. We then found wholesale prices for different sized grid-tied solar arrays using the 230 watt TrinaSolar panel including inverters and compared their overall cost to wattage ratio. We selected two systems: 1) a 10 panel array with one inverter, which produced 2,300 watts and cost $5,520 ($2.40/watt) and 2) a 36 panel array also with one inverter, which produced 8,280 watts and cost $17,040 ($2.06/watt) (Wholesale Solar(a), n.d.). Multiplying the area per panel by the number of panels, we calculated the total roof space for this system to be 16.36 square meters (176.13 square feet) and 58.91 square meters (634.101 square feet) respectively.

In order to calculate the actual cost of these systems, we needed to determine and include the installation costs and any federal and state tax incentives. We determined that the federal government provides a 30% tax credit for the cost of the solar system, which includes the inverter but not the installation cost (California Energy Commission & California Public, 2011). We also found that the state discounts the price of the panels by a flat amount, which for TrinaSolar panels was $48/panel ($480 discount for a 10 panel system and $17,280 for a 36 panel system) (California Energy Commission & California Public, 2011). Regarding the installation costs, we made the assumption that installation costs would equal the whole sale cost (without tax incentives/discounts), which is a common rough estimation tool for prospective investors in a solar array. Finally, there is a "smart box" which will be in-between the panels and the grid, which will transmit real-time data about the power generated, which should cost no more than $200. The grand total for purchasing and installing our TrinaSolar arrays were calculated as the arrays whole sale price plus the "smart box", minus the federal 30% tax incentive and the $480 / $17,280 state discount, plus the array whole sale price (to account for installation costs), the resulting cost being $9,573.20 and $28,888.40 respectively. There was also an additional cost every 10 years to the utility for the replacement of the inverter. The utility will replace the inverter twice, once at year 10 and again at year 20 before the panel changes hand to the consumer. The prices for these inverters were $1,850 and $3,822 respectively (Wholesale Solar(b), n.d.).

With the cost for the solar systems secured, we then began to calculate the energy that could be generated by the arrays. We started by finding the solar insolation data for the San Diego area. Insolation was given in kWh/m^2/day for each month at 85% of the optimal tilt. We then divided these numbers by 0.85 to convert the insolation data to the optimal tilt (32°) and azimuth (191°) (Socal Solar Services Inc., 2009). These insolation numbers multiplied by the solar array surface area gave us the average kWh/day hitting the panel for each month, which was then converted to average kWh/month (not including leap year) (see Appendix, Table 3).

The TrinaSolar panels are sold with an efficiency of 15% and the product promises a linear 20% reduction of power production over 25 years (Trinasolar, 2011). By dividing this percentage of reduction as a decimal number by the 25 years, the result was a slope of degradation (0.8% degradation per year). Starting then from 15% efficiency as our 100% power generation, we multiplied 0.8% to the efficiency (15), yielding the reduction from the starting efficiency, and subtracted that reduction from the starting efficiency (15-(15*.008)). As an example from our calculation, the efficiency of the panel after the first year decreased by 0.12% which changed the panel efficiency rating from 15% to 14.88%. We carried this calculation out until 40 years from year 0, but we can only be sure that the linear degradation occurs for the first 25 years (see Appendix, Table 1). Therefore, while we still carried all of our analysis to year 40, we could only be certain about the first 25 years.

With the optimal insolation data and the efficiency of the panel over time determined, we began to calculate the energy that would be produced each year. It was important for this section to determine average summer energy production (May-October) and average winter energy production (November-April) for later calculations. So the average kWh/month for summer months and winter months were determined (sum of the seasonal months divided by 6) and multiplied by the degrading efficiency (the efficiency associated with the age of the panel), which resulted in the power output of the panel for both summer months and winter months as the efficiency of the panel degrades over time (see Appendix, Table 1).

With the power output determined for both summer and winter months assuming optimal tilt and azimuth and accounting for degrading efficiency, it became our next task to determine

SDG&E's tiered customer rate system in order to run our payback scenarios. What we found is that there are 4 regions and 4 tiers. Each region is given a baseline allotment for the first tier for both summer and winter months and then the following tiers are determined as a percentage greater than the baseline allotment (t2:101-130%, t3:131-200%, t4:>200%) (San Diego Gas and Electric Company, 2010). The baseline allotments for the 4 settings are summarized in the table below in tier 1 and the remaining tiers were calculated based on SDG&E's tiering structure (San Diego Gas and Electric Company, 2011). Once this data was established, we were then able to begin analysis of our different payback scenarios.

(kWh)	Coastal		Inland		Mountain		Desert	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Tier 1	294	498	330	549	519	855	585	660
Tier 2	85.26	144.42	95.7	159.21	150.51	247.95	169.65	191.4
Tier 3	202.86	343.62	227.7	378.81	358.11	589.95	403.65	455.4
Tier 4	>	>	>	>	>	>	>	>

In our first scenario, the money used to pay off the solar panel is the money SDG&E would otherwise have spent towards energy procurement. SDG&E pays on average 4 cents per kilowatt-hour, so for every kilowatt hour of energy produced by the panel, 4 cents is used to pay off the panel (across all tiers). This is problematic for consumers in the higher tiers, because while they are still consuming electricity at the same tier, the utility isn't necessarily providing at that same tier. We also have to assume that ideally, the utility wants everyone consuming at a Tier 1 level, and that their operating costs can be covered by the revenue generated by charging all consumers at the Tier 1 level. Therefore, if the utility bills the consumer at the higher tier but only provides at a lower tier, there is an element of dishonesty should the utility company still only use 4 cents per kilowatt-hour to pay the panel off. We also showed that in this scenario, the system would not be able to pay itself off within the panel's lifetime and therefore we did not proceed with further analysis for this scenario.

In our second scenario we essentially did the opposite of the first scenario, where we analyzed what would happen if the utility retained none of the revenue. This scenario proved the quickest in paying the system off, but is unrealistic because the utility company sees absolutely no revenue for energy generated by the solar array, and so would probably explore other avenues to increase their renewable portfolio. For this purpose, we will omit this scenario from further analysis.

In our third scenario, we established that the utility would take 10 cents per kilo-watt hour across all tiers for the energy generated by the panel. This number is derived from the amount the utility charges in the first tier minus the 4 cents per kilowatt-hour they pay to produce the electricity. We are assuming that ideally, the utility can still operate if everyone is using and paying at a Tier 1 rate. This repayment structure gives a greater incentive for higher tier consumers to enter the program while still allowing the utility to recover operating costs. The repayment rates start at 4 cents per kilowatt-hour at Tier 1 to up to 21 cents per kilo-watt hour at Tier 4. Preliminary analysis showed that both arrays could be paid off under this scenario within the panel lifetime if given to a higher tier consumer, which will be explored more in depth in the following section (see Appendix, Table 2).

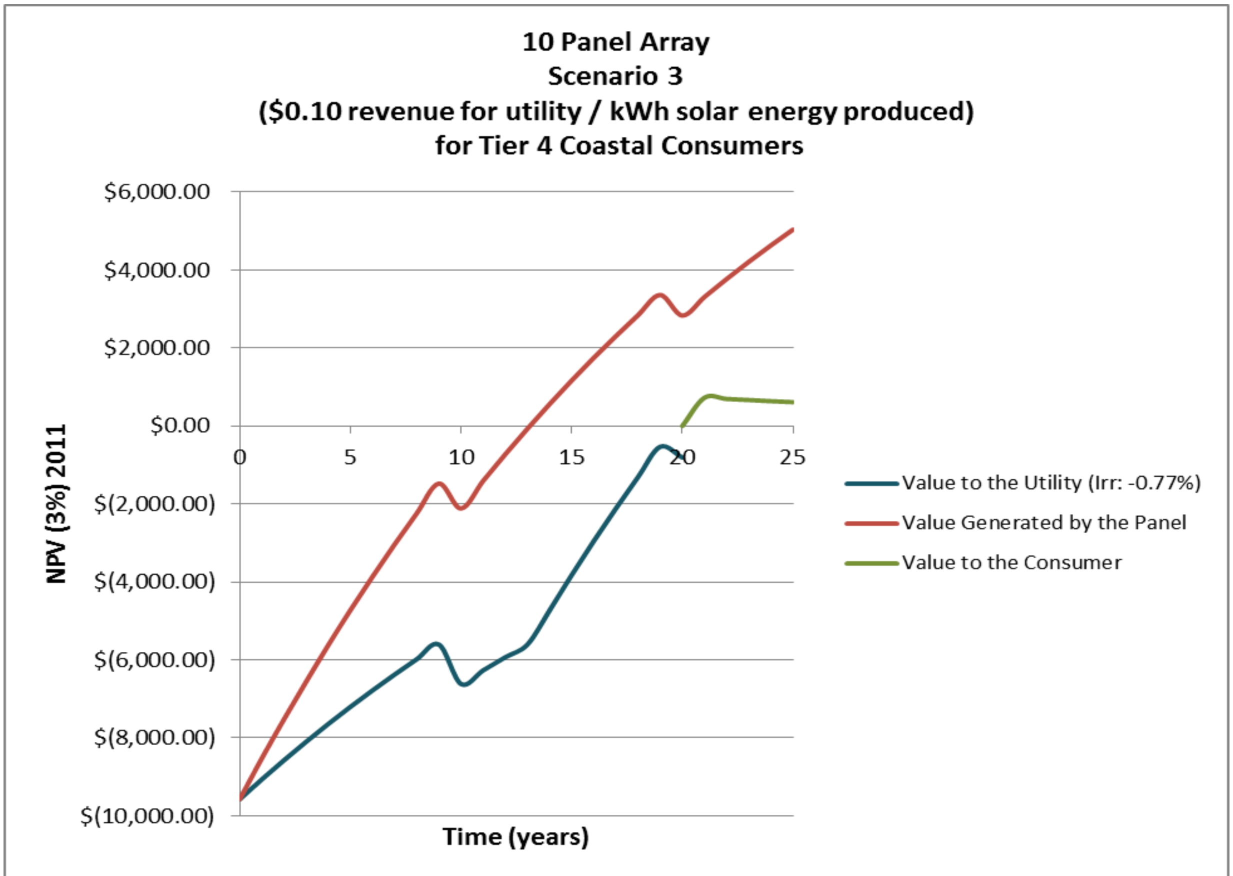
In our fourth scenario, we established that the utility would take half of the consumer's payment for solar energy as revenue, and the other half would be used for panel repayment. This seems to be the most balanced approach of the four scenarios. Again, the Tier 1 users will not see repayment during the life of the panel so for the purposes of this analysis they will be ignored, and Tier 2 users barely break even. However, under this repayment structure the Tier 3 and 4 consumers are heavily incentivized to enter this program. The solar array sees repayment within its lifetime and the utility company still takes home more than the 10 cents per kilowatt-hour they need to operate.

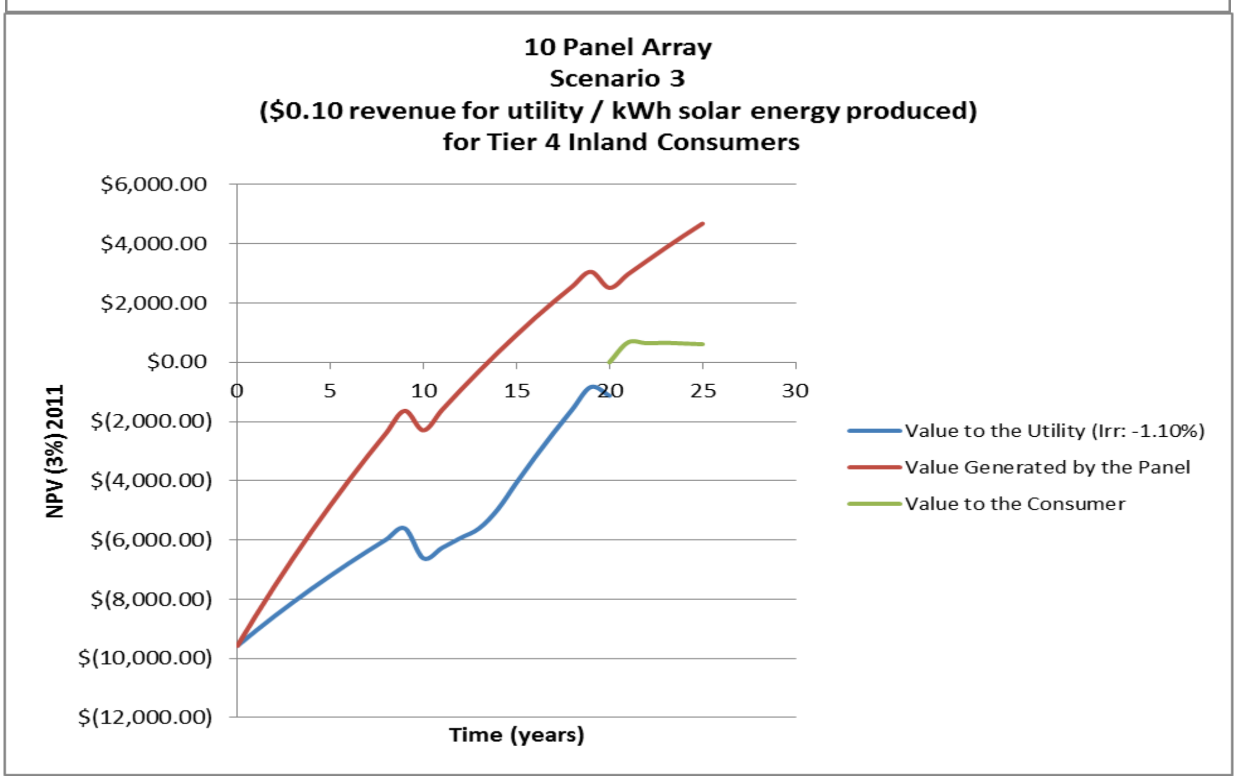
Results

10 Panel Array

Scenario 3 ($0.10 cents revenue for utility across all tiers) For a Tier 4 Consumer				
3% discount rate	Coastal	Inland	Mountain	Desert
Time for Panels cost to be covered (years)	14	14	14	14
Value to Consumer (year 25 at NPV)	$3,340.41	$3,231.27	$3,348.58	$3,362.44
Value to Utility (year 20 at NPV)	-$809.05	-$1,125.81	-$1,092.90	-$1,011.60
IRR for the Utility (NPV)	-0.77%	-1.10%	-1.06%	-0.98%

For the 10 Panel array, the scenario 3 payback system for tier 4 consumers was the only circumstance that allowed for repayment of the panels, which occurred at year 14. The utility then had 6 years where they could take the consumers payment towards the panel as additional revenue. At year 10 and 20, the utility pays for an inverter replacement and then hands over the panels to the consumer at year 20. The value to the consumer is the amount of money saved on their energy bill until year 25. While the solar array is paid for within its lifetime, the utility does not generate profit in this option. The graphs below summarize these results for coastal and inland regions.

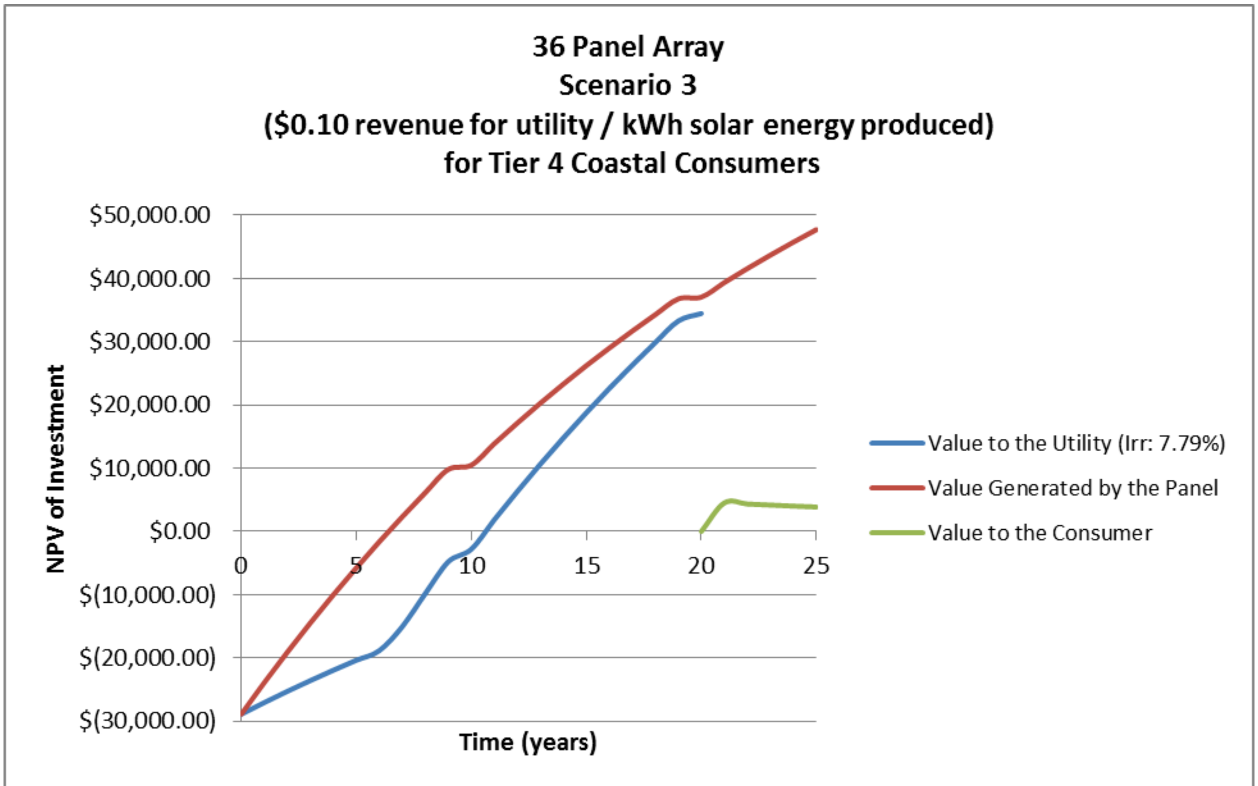

10 Panel Array
Scenario 3
($0.10 revenue for utility / kWh solar energy produced)
for Tier 4 Coastal Consumers
$6,000.00
$4,000.00
$2,000.00
$0.00
$(2,000.00)
$(4,000.00)
$(6,000.00)
$(8,000.00)
$(10,000.00)
0
5
10
15
20
25
NPV (3%) 2011
Time (years)
Value to the Utility (Irr: -0.77%)
Value Generated by the Panel
Value to the Consumer

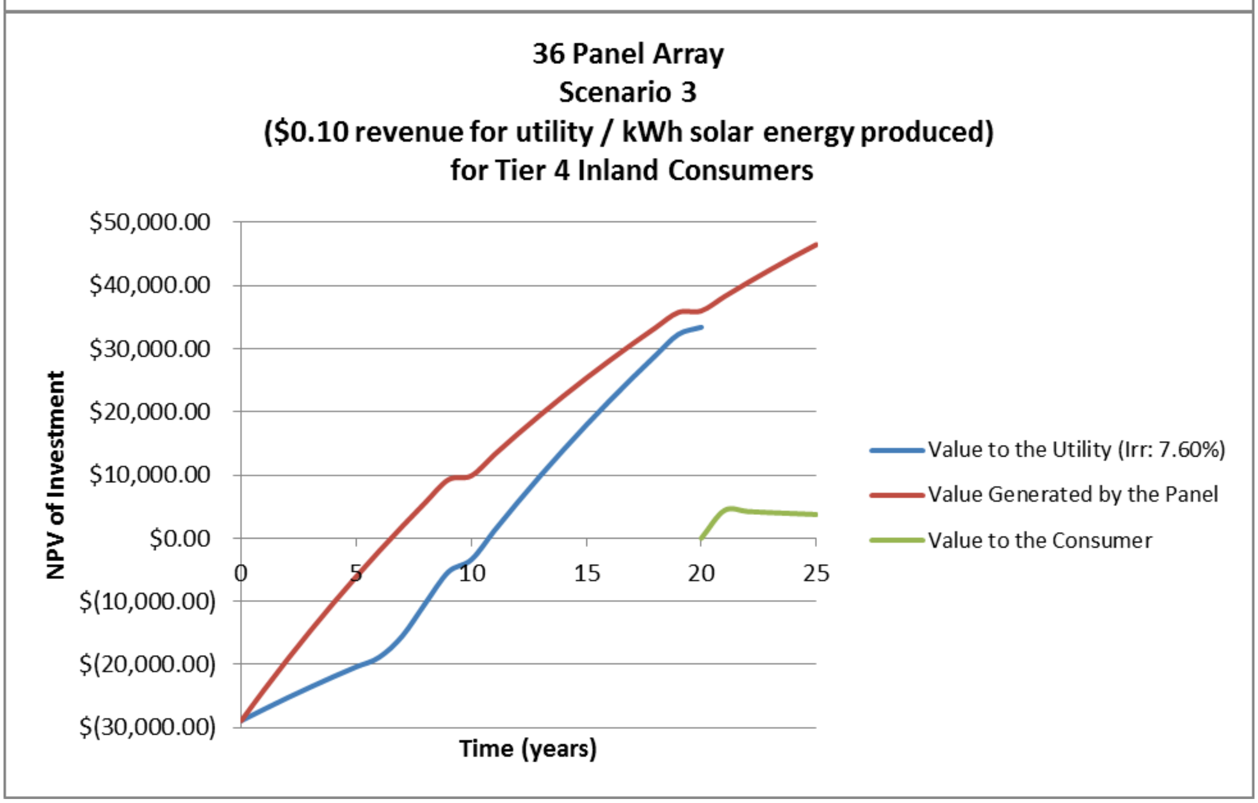

10 Panel Array
Scenario 3
($0.10 revenue for utility / kWh solar energy produced)
for Tier 4 Inland Consumers
$6,000.00
$4,000.00
$2,000.00
$0.00
$(2,000.00)
$(4,000.00)
$(6,000.00)
$(8,000.00)
$(10,000.00)
$(12,000.00)
0
5
10
15
20
25
30
NPV (3%) 2011
Time (years)
Value to the Utility (Irr: -1.10%)
Value Generated by the Panel
Value to the Consumer

36 Panel Array

Scenario 3 ($0.10 cents revenue for utility across all tiers) For a Tier 4 Consumer				
3% discount rate	Coastal	Inland	Mountain	Desert
Time for Panels cost to be covered (years)	7	7	8	7
Value to Consumer (year 25 at NPV)	$20,965.98	$20,382.53	$15,515.46	$16,793.92
Value to Utility (year 20 at NPV)	$34,480.79	$33,426.16	$23,343.40	$28,140.10
IRR for the Utility (NPV)	7.79%	7.60%	5.66%	6.64%

For the 36 Panel array, the scenario 3 payback system only worked for tier 4 consumers. Panels were paid back in ~7 years, which gave the utility ~13 years where they could take the consumers payment towards the panel as additional revenue. At year 10 and 20, the utility replaces the inverter replacement and then hands over the panels to the consumer at year 20. The value to the consumer is the amount of money saved on their energy bill until year 25. The utility generates significant revenue in this option. The graphs below summarize these results for coastal and inland regions.


36 Panel Array
Scenario 3
($0.10 revenue for utility / kWh solar energy produced)
for Tier 4 Coastal Consumers
$50,000.00
$40,000.00
$30,000.00
$20,000.00
$10,000.00
$0.00
$(10,000.00)
$(20,000.00)
$(30,000.00)
NPV of Investment
0
5
10
15
20
25
Time (years)
Value to the Utility (Irr: 7.79%)
Value Generated by the Panel
Value to the Consumer


36 Panel Array
Scenario 3
($0.10 revenue for utility / kWh solar energy produced)
for Tier 4 Inland Consumers
$50,000.00
$40,000.00
$30,000.00
$20,000.00
$10,000.00
$0.00
$(10,000.00)
$(20,000.00)
$(30,000.00)
NPV of Investment
0
5
10
15
20
25
Time (years)
Value to the Utility (Irr: 7.60%)
Value Generated by the Panel
Value to the Consumer

36 Panel Array

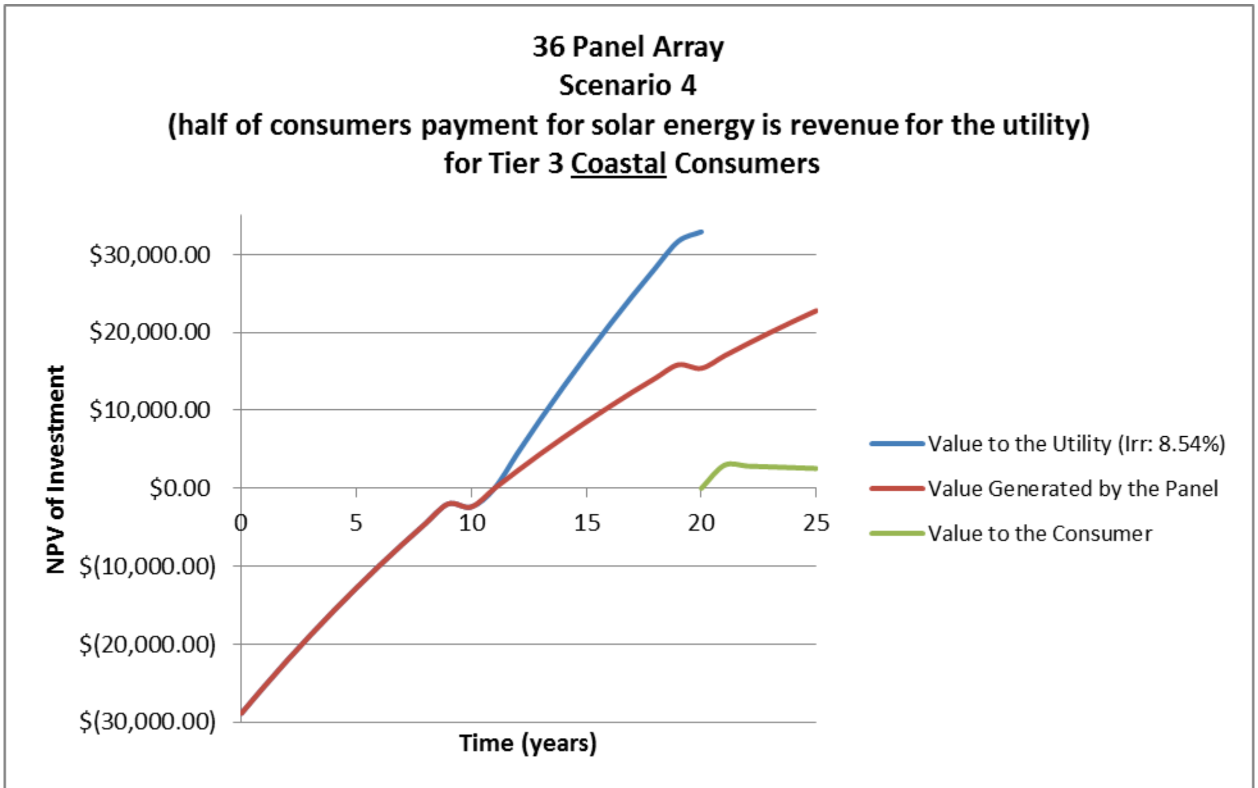
Scenario 4 (half of consumers payment for solar energy is revenue for the utility across all tiers) For a Tier 3 Consumer				
3% discount rate	Coastal	Inland	Mountain	Desert
Time for Panels cost to be covered (years)	12	12	14	14
Value to Consumer (year 25 at NPV)	$13,756.35	$13,244.68	$12,594.97	$12,649.61
Value to Utility (year 20 at NPV)	$32,919.94	$29,976.66	$23,343.40	$20,711.98
IRR for the Utility (NPV)	8.54%	8.03%	5.92%	5.89%

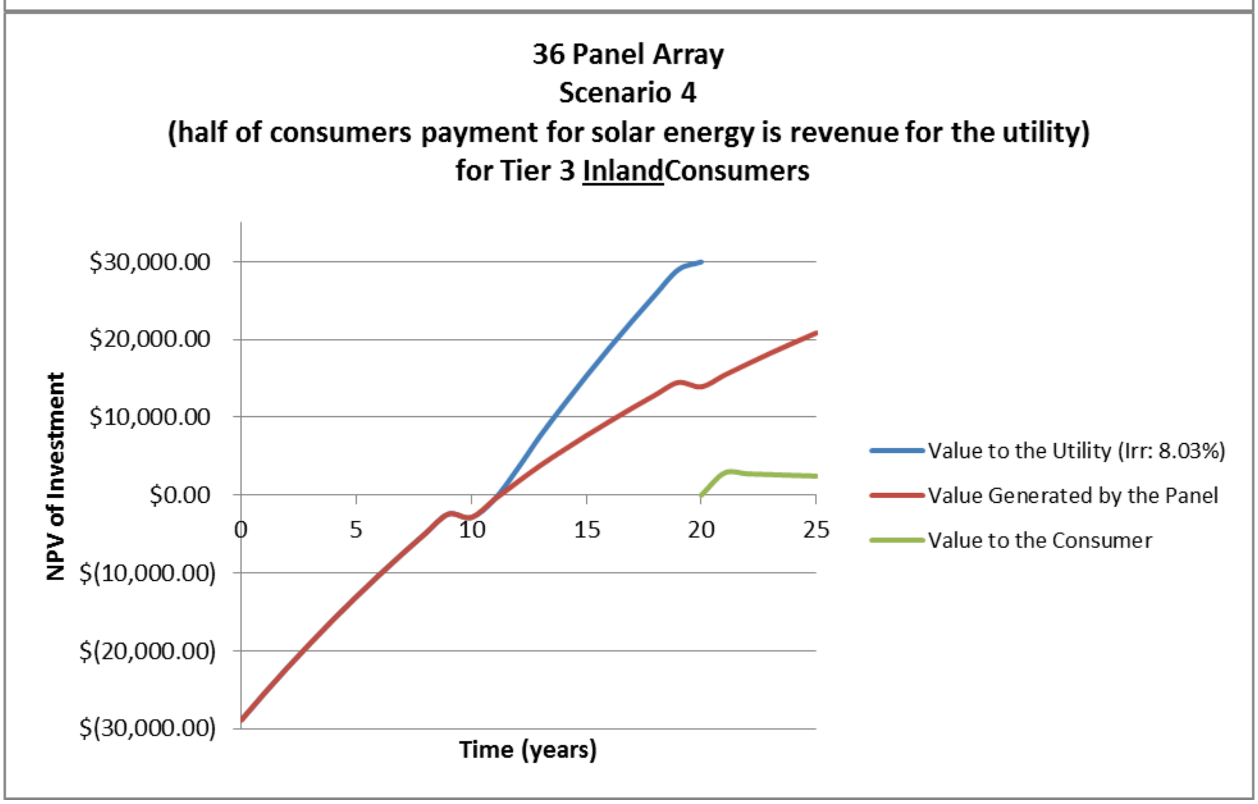
36 Panel Array

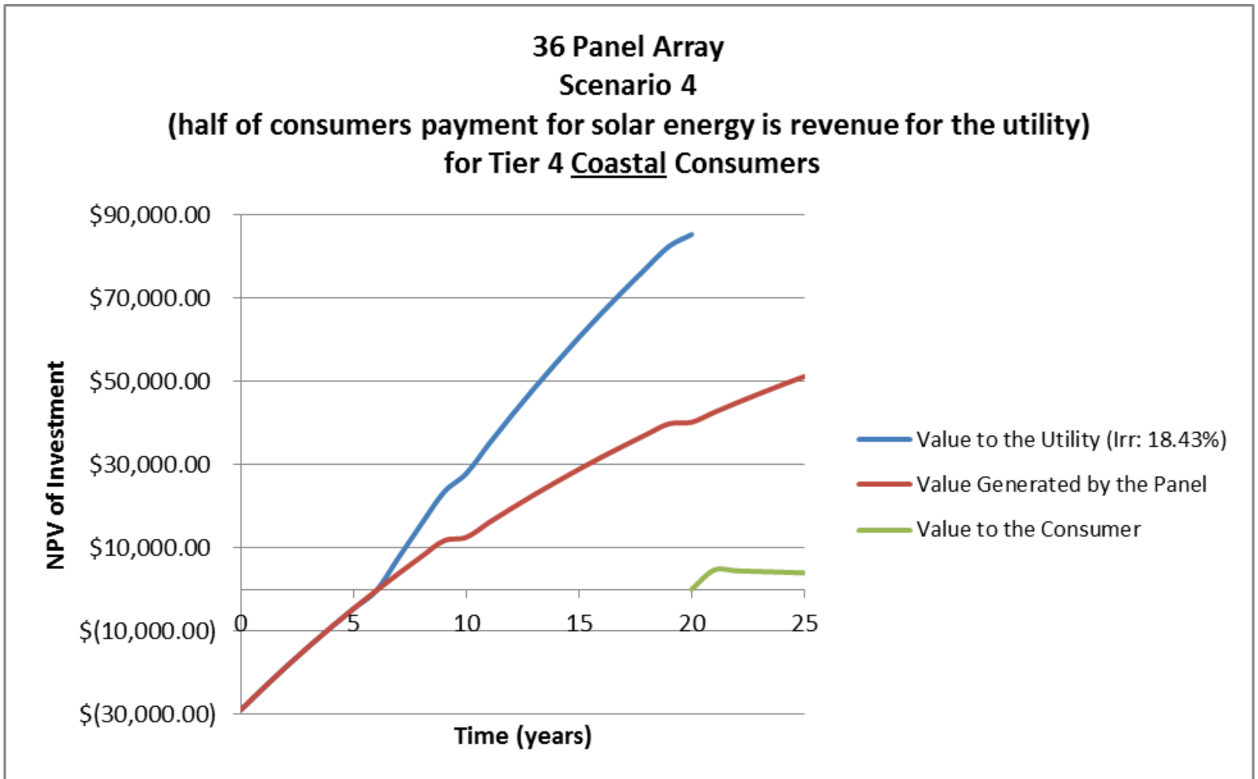
Scenario 4 (half of consumers payment for solar energy is revenue for the utility across all tiers) For a Tier 4 Consumer				
3% discount rate	Coastal	Inland	Mountain	Desert
Time for Panels cost to be covered (years)	7	7	9	8
Value to Consumer (year 25 at NPV)	$21,483.06	$20,841.11	$15,666.94	$16,838.16
Value to Utility (year 20 at NPV)	$85,399.49	$81,289.81	$46,148.67	$59,053.69
IRR for the Utility (NPV)	18.43%	17.74%	11.41%	14.11%

The 36 Panel array also converted the scenario 4 payback system into a viable option for both tier 3 and 4 consumers. Foe Tier 3 consumers, panels were paid back in ~13 years for tier 3 consumers, which gave the utility ~7 years where they could take the consumers payment towards the panel as additional revenue. At year 10 and 20, the utility replaces the inverter and then hands over the panels to the consumer at year 20. The value to the consumer is the amount of money saved on their energy bill until year 25. The utility generates significant revenue in this option.

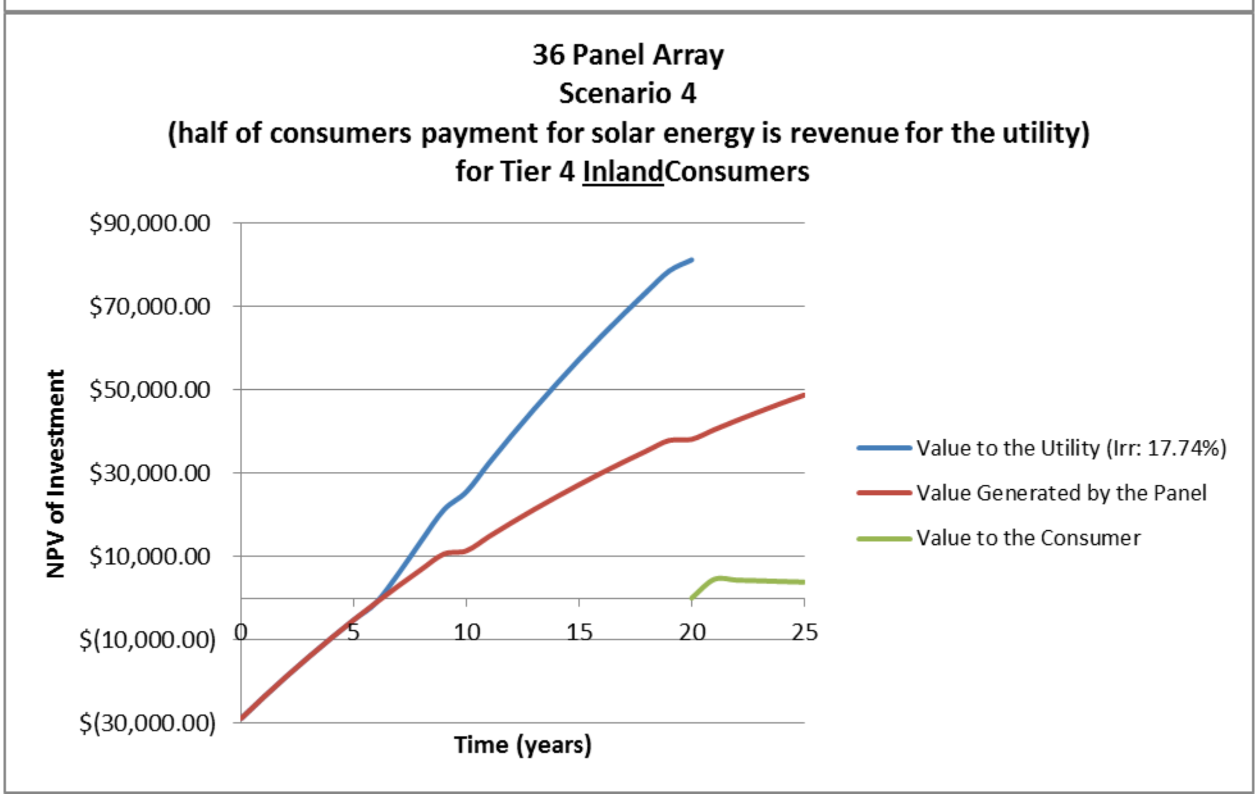
Foe Tier 4 consumers, panels were paid back in ~8 years, which gave the utility ~12 years where they could take the consumers payment towards the panel as additional revenue. At year 10 and 20, the utility replaces the inverter and then hands over the panels to the consumer at year 20. The value to the consumer is the amount of money saved on their energy bill until year 25. The utility generated the most revenue in this option compared to any other option. The graphs below summarize these results for coastal and inland regions.


36 Panel Array
Scenario 4
(half of consumers payment for solar energy is revenue for the utility)
for Tier 3 Coastal Consumers
NPV of Investment
$30,000.00
$20,000.00
$10,000.00
$0.00
$(10,000.00)
$(20,000.00)
$(30,000.00)
0
5
10
15
20
25
Time (years)
Value to the Utility (Irr: 8.54%)
Value Generated by the Panel
Value to the Consumer


36 Panel Array
Scenario 4
(half of consumers payment for solar energy is revenue for the utility)
for Tier 3 InlandConsumers
NPV of Investment
$30,000.00
$20,000.00
$10,000.00
$0.00
$(10,000.00)
$(20,000.00)
$(30,000.00)
0
5
10
15
20
25
Time (years)
Value to the Utility (Irr: 8.03%)
Value Generated by the Panel
Value to the Consumer



36 Panel Array
Scenario 4
(half of consumers payment for solar energy is revenue for the utility)
for Tier 4 Coastal Consumers
NPV of Investment
$90,000.00
$70,000.00
$50,000.00
$30,000.00
$10,000.00
$(10,000.00)
$(30,000.00)
0
5
10
15
20
25
Time (years)
Value to the Utility (Irr: 18.43%)
Value Generated by the Panel
Value to the Consumer



36 Panel Array
Scenario 4
(half of consumers payment for solar energy is revenue for the utility)
for Tier 4 InlandConsumers
NPV of Investment
$90,000.00
$70,000.00
$50,000.00
$30,000.00
$10,000.00
$(10,000.00)
$(30,000.00)
0
5
10
15
20
25
Time (years)
Value to the Utility (Irr: 17.74%)
Value Generated by the Panel
Value to the Consumer

Discussion/Conclusion

As with any project, reality is going to deviate from theory. Weather, panel maintenance, solar activity, temperature, and site selection (specifically shaded areas over the panel) are all going to affect the real performance, and thereby the repayment period, of the array. This is also going to change regionally, especially when going across latitudes and climactic zones. The framework for our analysis will hold true, but the results will differ.

There is also an element of uncertainty concerning the incentives available for solar arrays. California's solar rebate is steadily decreasing by nature, so as more solar systems come online the less the rebate will be. Federal solar rebates are subject to political winds, and so can't be depended on to make future projects viable. Local incentives are, of course, going to change with the locality. Essentially, the final price of installing a solar system is going to change year to year.

The solar panel market is also evolving. Steady increases in efficiency and longevity are working their way to the market as prices are decreasing for current technology. There is also evolving technology to put solar generation in more difficult places; experimental transparent solar films allow windows to generate electricity, solar tiles allow solar generation in communities with restrictive covenant's imposed by neighborhood associations. Ultimately this means that the price per watt of energy is always dropping, and the opportunities for implementation are ever increasing.

What can be taken from this analysis is that this program is most effective when directed towards users who are in Tier 3 or Tier 4. These tiers see repayment periods which are well within the life of the panel (on the order of 7 to 14 years), as well as allowing the utility to still make a profit. In San Diego the average household energy consumption is in Tier 3, which makes payoff of the arrays that much more feasible. In addition, energy intensive businesses and industry are also prime prospects for this program because they consume in higher tiers and likely have greater roof space. Tiers 1 and 2 had repayment periods well beyond the life of the panel, which means low consumption homes and small businesses will not be the target of this program. However, the nature of decoupling, and how the utility is allowed to make profit makes this financial aspect a somewhat moot incentive. This means that the primary incentive is the addition of these solar panels to the utilities' renewable energy portfolio.

In our analysis, we found a wide range of Internal Rate of Returns (IRR's). Ideally, for this project, we are going to be aiming for a net IRR as close to 0% as possible. This is, again, an effect of decoupling. With a high IRR, the utility will be forced to readjust their rates downward – effectively subsidizing electricity for everyone else at the expense of the ratepayer. With a low IRR, the opposite is true – the utility is faced with a loss, and will have to readjust their rates upward, effectively subsidizing solar panels at the expense of everyone else on the grid. When the net IRR is near 0% it represents the point which the panel most efficiently pays itself off, and thereby the most effective incentive for signing on to this program. Therefore, the 10 panel array which has an IRR that hovers around -1% (depending on region) could become viable if balanced with 36 panel array investments with significantly higher IRR's, the goal being to optimize capacity of solar panel array and thereby maximize the utility's portfolio.

Another aspect of this analysis is the different climactic zones within the San Diego area. The areas (Coastal, Inland, Mountain, and Desert) all carry with them different usage levels for the different tiers. That is, a Tier 3 consumer in a coastal region could be a Tier 4 user in a desert region. Because of this we analyzed the scenarios separately. All things being equal, the Coastal region carries a slight edge in the repayment period and ultimate value to the consumer over the other regions, and regions considered mountainous carry a slight penalty. This, however, is based solely on the different rate structures between the regions, and does not take into account the differing performance of the solar panels between these regions.

As far as our scenarios are concerned, the third scenario (where each kWh produced is worth the consumer rate minus ten cents) proved the quickest in repaying the solar panel, though the fourth scenario (where each kWh produced is worth one half of the consumer rate) achieved a similar payback period for tier 4 consumer while also providing a greater return for the utility. Again, with the nature of decoupling, the way utilities are allowed collect revenue, we would recommend a blend of scenario 3 and 4 investments for higher tier consumers (3 and 4). Overall, the benefit to the utility company (in this case SDG&E) would be the increased amount of energy procured from a renewable source which would count towards their RPS. For the consumer, the incentive for hosting the panels would be the promise of owning them after they have paid themselves off, which according to our calculations is within a feasible amount of time.

Appendix

(Degrading Efficiency and Energy output for 10 Panel Array, Table 1)

Year	Panel efficiency (%)	Full array avg. kWh/year with degrading efficiency	(kWh with degrading efficiency) Summer: (May-October)	(kWh with degrading efficiency) Winter: (November-April)
0	15	5247.069261	3249.236047	2005.018573
1	14.88	5205.092707	3223.242159	1988.978425
2	14.76096	5163.451965	3197.456222	1973.066597
3	14.64287232	5122.144349	3171.876572	1957.282065
4	14.52572934	5081.167195	3146.501559	1941.623808
5	14.40952351	5040.517857	3121.329547	1926.090818
6	14.29424732	5000.193714	3096.35891	1910.682091
7	14.17989334	4960.192164	3071.588039	1895.396634
8	14.06645419	4920.510627	3047.015335	1880.233461
9	13.95392256	4881.146542	3022.639212	1865.191594
10	13.84229118	4842.09737	2998.458098	1850.270061
11	13.73155285	4803.360591	2974.470434	1835.4679
12	13.62170043	4764.933706	2950.67467	1820.784157
13	13.51272682	4726.814236	2927.069273	1806.217884
14	13.40462501	4688.999723	2903.652719	1791.768141
15	13.29738801	4651.487725	2880.423497	1777.433996
16	13.1910089	4614.275823	2857.380109	1763.214524
17	13.08548083	4577.361616	2834.521068	1749.108808
18	12.98079699	4540.742723	2811.844899	1735.115937
19	12.87695061	4504.416782	2789.35014	1721.23501
20	12.77393501	4468.381447	2767.035339	1707.46513
21	12.67174353	4432.634396	2744.899056	1693.805409
22	12.57036958	4397.173321	2722.939864	1680.254965
23	12.46980662	4361.995934	2701.156345	1666.812926
24	12.37004817	4327.099967	2679.547094	1653.478422
25	12.27108778	4292.483167	2658.110718	1640.250595