

Quantifying the Cache: The Premium for Solar Homes is Not Explained by Reduced Energy Costs

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South Carolina has a tax policy that is very favorable to those wishing to install photovoltaic (PV) panels on their homes. A local resident contacted Clemson University for guidance on investing in PV. This paper uses the homeowner's situation as a framework to investigate the value of solar from a financial perspective. By modeling multiple PV arrays, this paper demonstrates that solar panels are a good investment overall, largely due to favorable tax policies and rebates. Further, this study shows that the size of the system and the timing of the sale of the home (after installing solar panels) significantly influences the investment choice. Building on prior research which shows that homebuyers depreciate solar faster than straight-line depreciation, this study finds that a 9kW array will add a $28,000 premium to a home sold 1 year after installing solar panels but only $14,000 to a home sold 8 years after installing panels. Finally, this paper shows that the premium paid for solar-homes is only partial explained by reduced energy costs. While homebuyers will pay a $28,000 premium for a 9kW array, only $11,000, or 39%, can be attributed to future energy savings. The remaining 61% is driven by non-financial benefits to solar.

Key Words: Solar, Photovoltaic, Net Present Value, Home Premium, Investment

Introduction

This study analyzes the decision to install solar panels on a residential home, from a financial perspective. The data are based on the home of a resident of Clemson, South Carolina, who was interested in installing solar panels on her home and contacted Clemson University for guidance on how to optimize her investment. This research analyzes the following questions: 1) Are solar panels a good investment for a residential homeowner?, 2) What factors influence the profitability of this investment, and 3) When the home is sold, are potential buyers rational in their assessment of the value of solar panels?

South Carolina has a progressive tax policy to encourage homeowners and businesses to invest in renewable energy. In South Carolina, homeowners are allowed to deduct 25% of the cost of a photovoltaic (PV) array from their tax liability. This tax credit is in addition to the 30% tax credit allowed under the current federal tax code. Combined, the citizens of South Carolina can have PV panels installed on their homes for less than half the retail cost. In addition to this, South Carolina is a net metering state meaning that the energy produced beyond what is immediately used is credited to the customer at the same rate that they purchase power from their utility provider. In the fall of 2015, Duke Energy, which is the electrical service provider for roughly a third of the state, received approval to provide a $1 per Watt rebate for PV installed on customers' homes and businesses. Duke Energy was motivated to pursue the rebate program for several reasons which includes increase diversity in their energy portfolio, peak load shaving, public perception and deferred capital investment in energy production. The rebate program was a watershed moment for solar in the state. The $1 per Watt rebate (which is roughly 20% the cost of residential scale PV installations) in combination with the federal and state tax incentives, made the investment in solar very attractive.

Aware of the tax incentives and recent utility rebate, a resident of Clemson, South Carolina contacted Clemson University for guidance on how to optimize her investment in solar panels. The homeowner had a working understanding of solar power and knew that her home's orientation, low shade, and roof pitch made her home optimal for solar energy production. She also understood that many factors such as solar efficiency, solar degradation, and the cost of energy also influenced the investment. Using the homeowner's situation as a case study this paper shows the analysis completed and finds that the premium homebuyers will pay for solar panels is only partially explained by reduced future energy costs.

Literature Review

Residential sector, small-scale PV electrical production has increased remarkably since the late 1990's. The Energy Information Agency (EIA) estimates that in 2012 approximately 6K megawatts of energy were produced in the residential sector alone. The production more than doubled to 14K megawatts in 2014 and then more than doubled again in 2016 to 29K megawatts (EIA, 2017). The EIA predicts further increases to production with an estimate of approximately 50k megawatts of electrical energy produced in the residential sector by the end of 2018 (EIA, 2017). There has been no shortage of publications addressing the marketing and valuation of new PV systems (NAR, 2014; Klise, G.T., Johnson, J.L., and Adomatis, S.A., 2013; CNT Energy & National Home Performance Council, 2014). However, because of how quickly the market has grown over a relatively short period of time and the noise in the data from the recent housing bubble, there are far fewer publications that address the premium enjoyed by home sellers with PV solar arrays. Farhar and Coburn (2008) were one of the earliest to show a premium for solar vs non-solar homes but was limited to 15 homes in a single California subdivision. The findings of the study, however, were later corroborated with a larger sample size in San Diego and Sacramento by Dastrup et al. (2012). Desmarais (2013) found premiums for solar homes within a sample of 30 homes in Denver. In 2013, Hoen et al. also found a premium for solar homes with a significantly larger sample size of nearly 2,000 homes.

The most comprehensive study of the premium that PV arrays add to homes at resale was published by Hoen et al. in 2015. The study was conducted by Lawrence Berkeley National Laboratory (LBNL) and funded by the U.S. Department of Energy. The LBNL research team analyzed nearly 23,000 homes, of which 4,000 were solar-homes, which more than doubles the number of homes previously evaluated in other studies. The homes evaluated were sold from 2002-2013 in 8 different states (the closest of which to our case study was North Carolina). Consistent with previous studies, Hoen et al. (2015) found that home buyers pay a premium for solar homes over similar sized non-solar homes. On average, a 3.6kW PV system (common size) added approximately $15,000 to the home's resale price. The Hoen et al. (2015) study significantly added value to the field by modeling how solar premiums are influenced by the size and age of the array at the time of sale. This paper uses the Hoen et al. (2015) findings regarding size and age depreciation to model three typical PV sizes for the Clemson homeowner.

A key finding in Hoen et al. (2015) is that the premiums paid by home buyers for solar homes decrease as the size of the panel increases. We use data in Hoen et al. (2015) to plot the average premium per Watt paid by home buyers for solar panels of various sizes (see figure 1). Home buyers are willing to spend $5.33/Watt for a small 1kW system, however, they are only willing to spend $3.21/Watt for a large 9kW system. A 1kW system will increase the value of the home by $5,330 ($5.33/W * 1,000W) whereas a 9kW system will increase the value by $28,890 ($3.12/W * 9,000W). Since a 9kW system produces roughly 9 times the electricity of a 1kW system, it is somewhat puzzling that home buyers are only willing to pay about 5 times more for the larger system. Hoen et al. (2015) assert that there is a "green cache" in solar where home buyers are willing to pay a fixed sum "for any size [] PV system and some increment more depending on system size (p. IV)." Because the green cache is a fixed dollar amount, the premium per Watt decreases with larger panels which is why the line in figure 1 is downward sloping.

A second key finding in Hoen et al. (2015) is that home buyers significantly depreciate solar panels as they age. Some of this depreciation can be attributed to a loss in efficiency in converting solar radiation to electrical energy as panels age. This "solar degradation" varies by panel and manufacturer but a 0.5% year over year decrease is common (Hoen et al., 2015). Hoen et al. (2015) found that home buyers depreciate panels faster than solar degradation or straight-line depreciation. In figure 2 we plot data from Hoen et al. (2015) to show the decrease in the premium paid by home buyers as solar panels age as a percentage of the year 1 solar premium. After 3 years, home buyers devalue solar panels by approximately 8%. This is significantly more than the solar degradation of the panel which would typically only be 1.5% in the first three years, but is slightly less than straight-line depreciation of 15%. Home buyers however, decrease solar significantly faster after year three. From year 3 to year 8, the premium home buyers will pay for solar decreases another 44%. There is limited data available about how aggressively home buyers continue to devalue solar panels after year 8. For this study, the researchers used straight line depreciation of approximately 4% per year until the end of their useful life (assumed year 20) where the panels had no value left. The work Hoen et al. (2015) did to model premiums based on size and age were used in the NPV and IRR calculations for this study and significantly influence the recommendations to the Clemson homeowner.

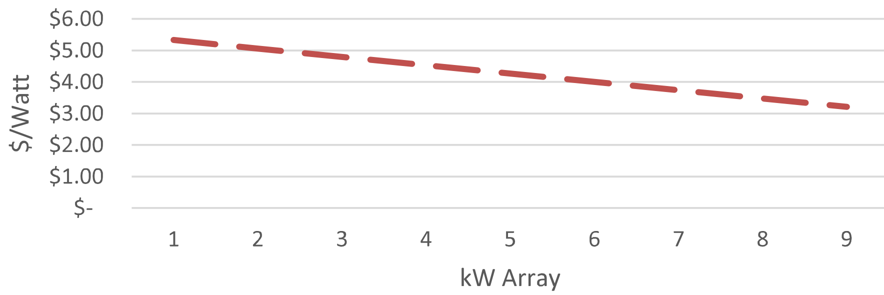

Figure 1: Premium Home Buyers Will Pay Per Watt

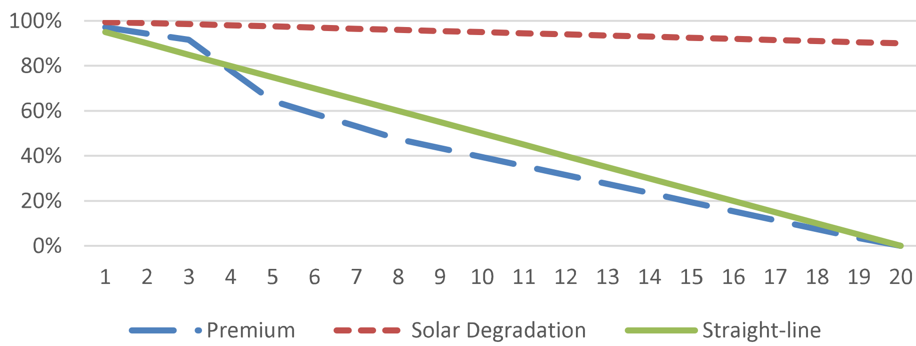

Figure 2: Discount in Premium as PV Array Ages

Methodology

We use the Net Present Value (NPV) decision rule to evaluate investment in solar panels from a financial perspective. The NPV framework compares the upfront cost of installation to the future benefits of solar. The benefits are the reduction in energy bills plus the premium (if the home is sold), minus the increased cost of insurance and property taxes due to the solar panels. Future benefits are discounted to obtain their present value. Finally, NPV is computed as the present value of future benefits less the upfront cost of installation. If NPV is positive, then investment in solar panels is good from a financial perspective, and if NPV is negative then the investment is not good from a financial perspective. As a secondary metric, we calculate the Internal Rate of Return (IRR). The IRR is the discount rate for which NPV is equal to zero. This rate can then be compared to the appropriate discount rate for the solar project. If the appropriate discount rate is less than the IRR, then solar panels are a good investment from a financial perspective, and vice versa.

The homeowner provided the researchers a copy of her energy bills for the past 24 months as well as the layout and basic design information of the home. Conventional practice with high performance building is to reduce energy consumption as much as possible before adding renewable energy to the home. However, the home had already received several energy efficiency upgrades and there were no obvious retrofits that would provide significant energy savings. The one exception to this was the HVAC system which had two aging air source heat pumps. The home was 26 years old and since that time 1 condensing unit and two air handlers had been replaced but all at different times and with different manufactures. The efficiency of the mismatched units is unknown but the researchers estimated an efficiency of SEER 10 at most. The homeowner expects to replace the old units with SEER 13 units the next time they required repair. The researchers used energy modeling software (BEopt), calibrated with current utility bills, to estimate the homeowner's annual energy usage assuming new units. As South Carolina is a net metering state, it is very important to know the expected energy use and not to exceed it with solar production. With South Carolina's net metering policy, utility companies will credit homeowners the energy supplied to the grid at the same rate as they sell it; however, energy supplied in excess of what is used is credited at wholesale prices annually. At the time of the study, energy cost were $0.11/kW retail but $0.04/kW wholesale.

This study calculated the financial performance of a 3kW, 6kW and 9kW solar array over its assumed 20 years life span using NPV and IRR. These arrays were chosen as the lowest, middle and highest size that could practically be installed and not exceed annual energy usage. The interest rate chosen in the NPV analysis is somewhat subjective but also influential in determining the value of the investment. A high interest rate decreases the worth of future energy making the panels less valuable. A lower interest rate would do the reverse and tend to make solar panels worth more. When making NPV calculations it is ideal to discount future benefits using an interest rate that reflects the risk of the project. In this case, solar panels are assumed to be low risk because the future energy benefits are virtually guaranteed. In addition, they are insured against damage and have warranties against excessive solar degradation. Because of their low risk, this study use a discount rate equivalent to the current yield on 20-year U.S. Treasury Bonds, 2.5%, plus an additional 1.0% premium. The researchers feel a 3.5% discount rate is a reasonable rate considering the low risk of the investment.

Upfront Costs, Inflows, and Outflows

The upfront cost of the panels is calculated based on actual price quotes from the contractor who ultimately installed the panels. The 3kW, 6kW and 9kW arrays were approximately $4.27/W or $12,800, 25,600 and $38,400 respectively. From this cost, we subtract the 30% federal tax credit, 25% state tax credit, and the $1/W utility rebate. The federal and state tax credits are based on the total installation cost.

The annual inflows for the investment in solar are based on the annual energy production and premium added to the home at resale. The energy production for each of the PV systems was calculated with NREL's PVWatts Calculator (http://pvwatts.nrel.gov/). Energy production was decreased by 0.5% each year to account for solar degradation. Solar panels are commonly assumed to have a useful life of 20 – 25 years. We assume that energy costs are stable over the life of the solar panels (the NPV calculation implicitly accounts for inflation). For this study we assumed a conservative 20-year useful life with a negligible salvage value. One of the most difficult factors to calculate but also most important to the NPV is the premium that solar panels add to the selling price of a home. Hoen et al. (2015) found that the premium per watt decreases with larger systems (figure 1) and that the premium decreases quickly as the panels age (figure 2). These inflows are non-linear and therefore the timing of the sale significantly influences the NPV and IRR.

The annual outflows for the investment are the increased homeowners insurance premiums and property taxes. Quotes from the homeowner's insurance company and estimates from the municipality's online property tax calculator were used to calculate the outflows. The homeowner had just installed a new roof so no additional costs associated with reroofing or significant maintenance were included. A summary of the inflow and outflow assumptions is provided in table 1. The values shown are specific to the case study location; however the calculations used can be downloaded at https://sites.google.com/site/d27greene/home and made specific to other locations.

Results

The researchers modeled three PV sizes to show the homeowner the range in expected returns on the investment. The NPV, which includes all inflows and outflows discounted at 3.5% per year, is shown in figure 3. In our analysis, we calculated NPV for 60 scenarios, assuming a sale of the home in year 1 through 20 for each of the three PV sizes. Figure 3 illustrates that NPV is positive for each of the scenarios. By definition, this means that they are good investments from a financial point of view. However, to get an appreciation for the magnitude of how good of an investment it is, an IRR calculation is helpful. If the panels are sold in the first year, the IRR for a 3kW, 6kW and 9kW is 417%, 333%, and 249%, respectively (figure 4). These returns drop quickly though and start to level off at year 8 with IRRs between 8% - 20% depending on PV size and year sold. Even with these sharp declines the financial returns are favorable. However, much more can be gleaned from this information than that it's just a "good investment."

Table 1

Summary of Inflow and Outflow Assumptions

Cost Factor	Inflows	Outflows	Source of Information
Installation cost		4.27/W	Contractor quote
Increase in homeowners insurance (annually)		.56% of value	Insurance quote
Property tax increase (annually)		.81% of value	Pickens tax calculator
Federal tax credit	30% retail costs		Federal tax code
State tax credit	25% retail costs		SC tax code
Utility rebate	$1/Watt		Local utility rate
Energy costs	$0.11/kWh		Actual rate
Solar degradation	0.50% annually		Hoen et al., 2015
NPV discount rate	3.50%		20 Year T-Bond + 1.0%
PV premium discounted for size	Figure 1		Hoen et al., 2015
PV premium discounted for age	Figure 2		Hoen et al., 2015

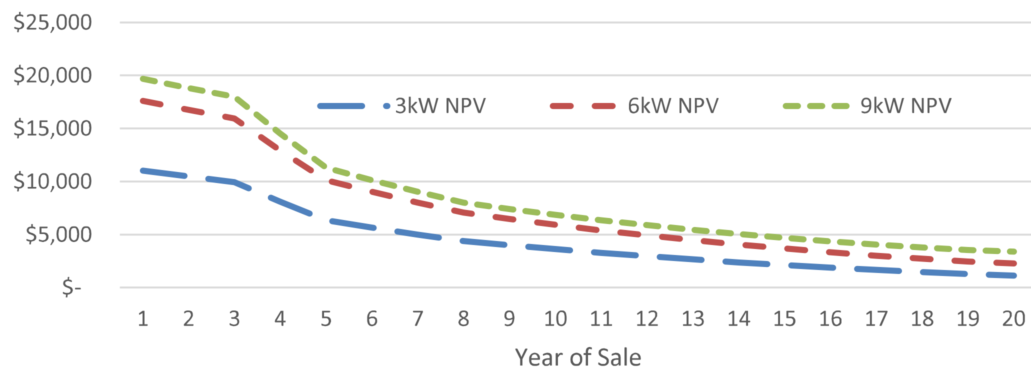

Figure 3: Net Present Value for 3kW, 6kW and 9kW Array

First, it is important to note that the arrays that are modeled here were heavily subsidized by federal and state governments and the local utility provider. The installation cost was $4.27/Watt; however, after the subsidies, the homeowner's cost is $1.35/W which is less than a third of the retail cost. The loss of either of the tax credits or the utility rebate significantly decreases the NPV. Then, the timing of the sale becomes a much more important factor when considering solar panels. Under some of our assumptions, the NPV could be negative if one of the credits/rebates is removed and the sale does not result in a large enough premium. Overall, the NPV of the investment in solar is extremely dependent on the premium added to homes with PV.

Secondly, it's important to notice the proximity of the NPV lines to one another. In year 1, the NPV of the 3kW system is $11,000 and the 6kW system is $18,000. This is a difference of $7,000; however, the difference between the 6kW and 9kW is only $2,000. The difference in energy production is the same from 3kW to 6kW as it is from 6kW to 9kW. Why isn't the 6kW curve half way between the 3kW and 9kW? The answer is that home buyers are willing to pay a premium just to have solar and then some marginal and decreasing amount more for larger systems. Figure 1 illustrates the decline in premiums the buyers are willing to pay as systems increase in size. Hoen et al. (2015) referred to this as a "green cache." This phenomenon is shown in figure 3 and 4 as well with the performance of the NPV and IRR of the three system being reversed. While the NPV for a 3kW is the smallest, in year 1, the IRR of 417% is by far the highest with the 6kW and 9kW returning yields of 333% and 249% respectively.

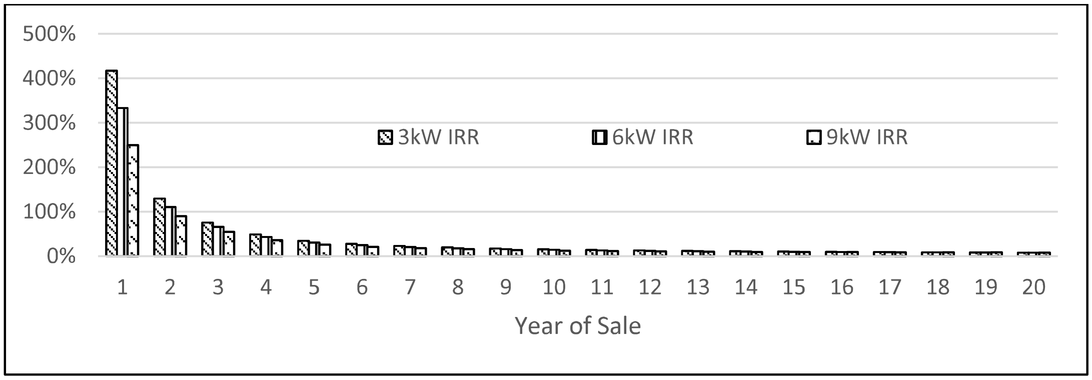

Figure 4: IRR for 3kW, 6kW and 9kW Array

Another important detail shown in figure 3 is that the NPV decreases as the homeowner remains in the home for a longer period of time. If the value of solar was only from the financial benefit of reduced energy costs then the NPV would be roughly linear throughout its useful life. In the first year, the premium that home buyers would pay for a solar house would equal the NPV of all future electricity that the PV array produces. As the PV system ages, home buyers would pay less, as there would be less future energy production. The NPV would decrease linearly as future energy production decreases as the panels' useful life runs out. This model, while completely rational and logical, does not at all explain comprehensively what we see in actual home buyer behavior. Given that NPV decreases non-linearly, the value of solar to a home owner cannot be fully explained by savings of energy.

Quantification of the Cache

In this section, the researchers attempt to make sense of the non-linearity in NPV. We do so by estimating the percentage of the premium paid by home buyers that can be explained by savings on future energy costs. Figure 3 shows the NPV of PV panels for sales of the home in a given year. As was just explained, a portion of this decline is attributed to less future energy the panels will create. The older the system is, the fewer the kWh it will produce in the future. In figure 5, we divide future inflows of a 9kW system into two components: 1) the "NPV of future energy production" (energy savings – taxes – insurance) and 2) the "premium when sold." The first component (the lower, dashed line) is the pure fiscal value of a PV system. The second component (the upper, dotted line) is the premium that buyers are willing to pay for homes with PV over non-solar homes, and may represent a "green cache." The premium is affected by the size of the system (figure 1) and the age of the system (figure 2). Stated another way, the bottom line is what the PV system is worth in reduced energy costs and the top line is what it is actually worth on the open market. The area between the lines is what this paper is referring to as the "green cache." The space between the lines is the quantification of the value that home buyers place in solar above and beyond the reduced energy costs.

Figure 6 shows the percent of the green cache that can be explained by future energy savings (after subtracting taxes and insurance). As an example, for homes sold in year 1, the premium from the sale is $27,258. The value of savings on future energy from years 2 through 20, which will be realized by the home buyer, is only $10,748. Thus, the future energy savings explains only 39.4% of the premium paid. In figure 6, the plot is always below 100%, meaning that future energy savings never fully explains the premium paid by the home buyer. In fact, it isn't until the panels are five years old that the actual future energy savings explains even half of the premium paid. What is driving the premium beyond energy production is unclear. The surplus could come from altruism in the reduction of carbon emission, public display of social responsibility, ignorance of actual NPV of future energy or PV subsidizes, uncertainty of future energy costs or a whole host of other factors. What is clear is that whatever is driving the premium for solar homes isn't explained by reduced future energy bills.

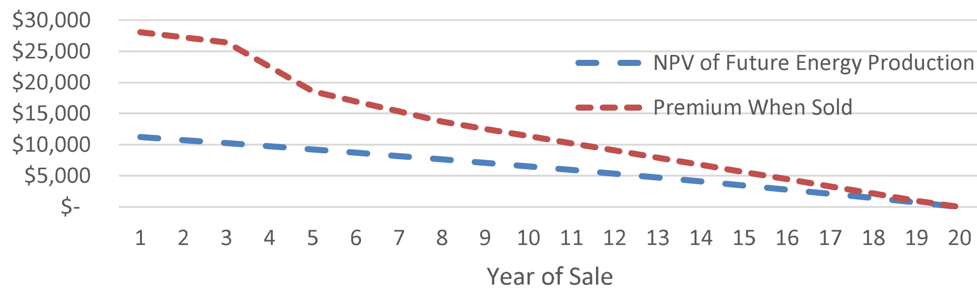

Figure 5: Difference between Financial and Actual Value of PV of a 9kW Array

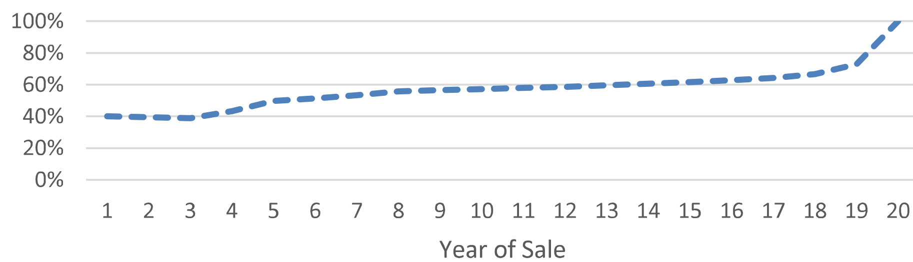

Figure 6: Percent Premiums Attributable to Future Energy Savings

Recommendation to the Homeowner and Robustness of the Model

After conducting the analysis the researchers felt confident providing recommendations to the homeowner. First, because of the subsidies provided by the federal, state and utility provider, PV in Clemson, South Carolina is a good investment from a financial point of view. Each of the three models had positive NPVs throughout their 20 year useful life. It was difficult to provide a "one size fits all" investment strategy as the NPV was largely based on the premium added to the house. Assuming that liquidity is not a concern for the homeowner, the 9kW system seemed to be the best investment as it had the highest NPV. Here again, the timing of the sale of the house greatly influences the value of the investment. The longer the homeowner stayed in the house, the lower the NPV, due to potential home buyers reducing the premium they will pay for older systems. If the homeowner never sold her home, then the investment in solar generates an NPV of $3,400, which is a significant sum of money for most individuals. However, if she sold the house at the end of year 1, the NPV would be $18,800, which is considerably larger. Most of the value is driven by tax incentives, rebates, and the increased value of her house. Obviously many factors go into the decision to sell your home but as the homeowner articulated well, from an NPV standpoint the best thing to do is to "…slap panels on my roof and put a 'For Sale' sign in the yard!"

Robustness of the Model

This study made several key assumptions when calculating investment in solar which needed to be challenged to show the model's robustness. For example, while we had no reason to suspect otherwise, what would the returns be if the utility provider cancelled the rebate program mid installation? The rebate program reduced the cost of installation by approximately 20% and significantly changed the financial performance. Under that situation, the investment into a 9kW system would still have a positive NPV (good investment) until year 8. At that point, the premium that buyers would pay for a used solar array in today's dollars would be insufficient to cover the initial investment. The models were fairly resilient to future energy cost fluctuations. This is explained primarily as the NPV is driven by the home premium and not the future value of energy. The cost of electrical energy would need to drop by 32% before the 9kW array would return a negative NPV over 20 years. Not surprisingly, the model was very sensitive to the premium assumed when the home was sold. In this case, because the panels are so well subsidized, the premium for solar at resale would have to decrease by 70% before the 9kW array would yield a negative NPV. The premium being discounted so severely would cause the NPV to primarily be impacted by energy cost. With a lower premium, the NPV increases when the homeowner decides to stay in the house longer. This is because the longer the investment horizon, the more opportunities the panels have to decrease future energy costs. The NPV would range from under $1,000 if the home is sold in year 1 to under $4,000 for a sale in year 20.

The discount rate used for the NPV calculations was 3.5%. This percentage was assumed because solar as an investment is low risk. While confident in the value, if the homeowner felt the investment was in a higher risk tier and wished to use higher interest rates, then the models would be impacted as the NPV would mechanically decrease. However, as long as the discount rate remained less than 8%, then the NPV for the 9kW array would remain positive throughout its useful life.

Future Study

While conducting this study a question was raised by the homeowner that was not adequately addressed in the literature. First, we know from the Hoen et al. (2015) study that the premium per watt goes down as the system gets larger. Hoen et al. (2015) speculates that this is because people have a green cache that they assign to having a solar home. The authors of this paper speculate that this is because the average home owner does not know the value of energy or could even tell you what they pay each month per kWh. What is unclear at this time is if the premium per watt would increase in value if the home seller could say the home was net zero energy (NZE) as opposed to just having a lower energy bill. To use the Hoen et al. (2015) term, is there a green cache for NZE as well as one for being in a solar home? The homeowner speculated that while the literature suggests that a 9kW system will command a $3.2/W premium on year 1, that same 9kW system will command a larger premium if it can be said to the buyer "…and you'll never have a power bill again." Additional study on this question is recommended.

This study shows that the premium that homebuyers will pay for solar panels is only partially explained by reduced energy costs. The paper does not address what else contributes to the premium beyond energy cost. Quantifying the surplus would be particularly useful in predicting future solar premiums and it worthy of additional study.

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