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Economic and Policy Evaluation of Solar Energy for Indiana Business and Residential Applications

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Introduction

Evaluating the Economics of Solar PV Systems

Solar energy has been expanding in the U.S. and globally recently, as have other renewable energy sources such as wind, hydro, and biomass, because they are clean and sustainable. Solar energy can easily be installed by individual consumers at a relatively small-scale and may be more profitable compared to electricity from grids under certain conditions. Thus, we are interested in evaluating the economics of solar photovoltaic (PV) systems installed in individual homes or farms. Indiana is also expanding solar energy with other renewables to protect its environment because 95% of electricity is generated from coal (U.S. Energy Information Administration (U.S. EIA), 2014). Due to the infancy of the technology, however, there has been little information for citizens who consider adopting solar PV systems in homes and farm businesses. Thus, we need to evaluate the economics of solar PV systems so that people can have information on whether or not it is profitable to adopt solar PV systems.

Why the Economics Will Be Different for Residential and Farm Businesses

Solar energy is expanding in part because of policies encouraging its adoption. In residential sectors in Indiana, net metering (the ability to sell back to the grid excess solar electricity), financing, and federal tax credits are policies currently in effect to reduce the cost of solar PV systems. There are also potential policies such as depreciation or carbon taxes that may be implemented in order to render solar technology cheaper to adopt in houses. These policies are illustrated in more detail later in the publication. A main point here is that income tax deduction from depreciation is not currently available for homeowners, only for businesses.

Research Goals and Implications

Because a depreciation benefit is available for farm businesses with other currently available policies, while it is not for the residential sector, the economics of solar PV systems are likely better for farm businesses than for residential areas. Therefore, in this publication, we compare the economics of solar PV systems in a residence and a farm business in Indiana.

This analysis is based on the annualized cost of solar PV systems and the probability that solar can be cheaper than current electricity from grids. The annualized cost of the solar PV system is the annuity of the net present value (NPV) of the total system cost per kWh of electricity. Also, because there is uncertainty in grid electricity price projections and solar technology, we do a stochastic analysis to capture the uncertainty. The stochastic analysis makes the annualized cost a probability distribution, not just a single value, so that it is possible to calculate the probability that solar can be cheaper. By comparing different policy combinations based on the probability, we can see how policies affect the economics of solar PV systems. Finally, we conduct sensitivity analysis on several important variables to see how changes in variables may affect the robustness of our results.

Methods

Literature Review

Many studies have examined the economics of solar PV systems installed in homes in various areas in the US. Most papers present a levelized cost of electricity (LCOE) of solar PV systems, and they show that solar systems are becoming cheaper although still more expensive than electricity from grids. According to Pickrell et al. (2013), in California, the LCOE has decreased significantly and is around \$0.15/kWh in southern and \$0.20/kWh in northern areas. This difference is attributed to the weather patterns and solar insolation. Also, in North Carolina, the LCOE was estimated around \$0.18/kWh in 2012 and is expected to drop to \$0.11/kWh by 2020 with technological improvement assuming continuation of federal tax credits (Makyoun et al., 2012). Meanwhile, retail electricity price is expected to rise in the future (Cai et al., 2013).

However, while many papers have studied the economics of Southwestern or Southern areas in the U.S., where most of the electricity from solar energy is generated, little has been done for Midwestern areas such as Indiana and Illinois. Because Indiana is also expanding its electricity production from renewables, including solar energy, we analyze the economics in Indiana in order to see if it is attractive for customers to adopt solar PV systems and to provide people with information related to economics of solar PV systems in Indiana.

Definition of Policies

There are three policies currently in effect in Indiana: net metering, financing, and federal tax credits. Net metering is a policy that forces electricity companies to buy any excess electricity generated from solar owners. In Indiana, Northern Indiana Public Service Company (NIPSCO) currently offers net metering. Financing with tax deductible interest is another policy that customers can take advantage of. According to Internal Revenue Service (IRS) Publication 936, if a loan is used to buy, build, or improve homes, it is called a home equity loan, and interest on the home equity loan is tax deductible. Because installing a solar system in a home can be regarded as a home improvement, customers can take a home equity loan when they purchase the solar system. Federal tax credit is applied to renewable energy generation property. Taxpayers can claim a federal tax credit for 30% of the installation cost of renewable technologies, including solar photovoltaic (Database of State Incentives for Renewable and Efficiency (DSIRE), 2012).

There are also two potential policies that could be implemented: depreciation and carbon tax. Depreciation is an annual deduction from taxable income for people to recover the cost of certain property while they use it for business or income-producing activity (IRS Publication 946, 2012). Carbon tax is a policy instrument to tackle issues related to emission. An estimate of Social Cost of Carbon (SCC) is imposed on a negative externality in the form of carbon tax. In most cases, firms or industries with a carbon tax imposed will pass the burden of a carbon price onto customers.

Analytic Methods

Benefit-Cost Analysis

Benefit-cost analysis is used to evaluate the economics of solar PV systems under operating conditions in Indiana. A key indicator of economic viability is a comparison between the annualized cost of installing a solar PV system and the expected annualized electricity price from the grid per kWh. The annualized cost of a solar PV system per kWh is the annuity of the net present value (NPV) of total system costs per kWh of electricity from the system, and it can be estimated from the ratio of annualized cost to the household's annual demand for electricity according to the following reduced equation.

$$\text{Annualized cost per per kWh} = \frac{\text{Annualized Cost}}{\text{Household's Annual Demand for Electricity}}$$

Annualized cost in the numerator is calculated by multiplying NPV by the capital recovery factor (CRF) for the interest rate and time period used. NPV for annualized cost represents the NPV inclusive of all costs and benefits involved in installing and operating the systems, such as initial investment cost, operation and maintenance (O&M) cost, or repair cost.

The expected annualized electricity price from grids per kWh means the NPV of 1kWh of electricity converted to an annuity. Because we consider a 20-year period and the electricity price increases year by year at a 1.08% growth rate, we can't use the base electricity price ($0.1137 per kWh in July 2013) for comparison. Rather, we need to calculate the expected annualized electricity cost. Therefore we compare the annualized solar cost with the annualized grid cost to have a direct comparison.

Stochastic Analysis

In order to make our analysis more realistic, we consider uncertainty in several variables that may have a great impact on the annualized cost of the solar PV systems. There are three uncertain input variables in our analysis, and they are 1) current and expected future residential electricity price from the grid, 2) degradation rate of power generated from solar systems, and 3) failure rate for system panels.

The analytical process is called Monte Carlo simulation. We use an add-in to Excel called @Risk to do the analysis. The spreadsheet calculations are done 5,000 times, with each iteration representing a draw from each of the uncertain distributions. The results for each iteration are stored by @Risk so that we end up with output distributions of NPV or whatever variables we choose. The output distributions reflect the inherent uncertainty in all the input distributions.

Uncertainty in Electricity Price from the Grids

As described above, because we consider a 20-year period and the electricity price is expected to increase at a 1.08% growth rate (Holland et al., 2011), we cannot use the base electricity price ($0.1137/kWh in July 2013, U.S.EIA, 2013) for comparison. Rather, we need to calculate the expected annualized electricity cost. The expected annualized electricity cost means the NPV of 1 kWh of electricity converted to an annuity. In addition, because the actual growth rate is not known with certainty, we use data from 1960 to 2012 to estimate the distribution of annual growth rates. We find that the distribution is normal, so we sample from the distribution of historical data to get the simulated growth rate each year.

Uncertainty in Degradation

Performance of the solar PV system over its lifetime is highly dependent on the assumed degradation rate of the panels. Degradation occurs due to chemical processes such as weathering, oxidation, corrosion, or thermal stress (Realini, 2003; Vazquez and Rey- Stolle, 2008). Due to degradation, electricity produced from the solar PV system decreases gradually year by year. Most studies show that the degradation rate is 0.3% - 3% and expected to rise during its lifetime (19th – 20th year of the system) (Vazquez and Rey-Stolle, 2008; Branker et al., 2011; Jordan and Kurtz, 2013). We use a Pert distribution for the uncertainty in degradation in the future. The Pert distribution is convenient because the inputs for the distribution are the minimum value, the most likely value (mode), and the maximum value. In that sense, it is similar to a triangular distribution but has properties that lead us to choose it over the triangular. Table 1 provides the min, mode, and max values for the degradation rate we obtained from the literature and also the calculated average (mean) value. Years 19 and 20 have higher degradation rates than earlier years.

Uncertainty in Failure Rate

We also consider the failure rate of the solar PV system. The failure rate represents the rate of physical failure of the system panels, for example, defects caused by extreme weather such as hail, thunderstorms, or rocks. The solar PV system usually consists of multiple arrays that are independent each other. In other words, even if a single array is broken, other arrays are still working, and we just need to replace the single broken array. Thus, we use the binomial distribution for failure rate. The expected value for the number of failures can be calculated by multiplying

Table 1. *Values of the Degradation Rate for the Pert Distributions*

Variable Name	*Distribution*	*Period*	*Min (%)*	*Mode (%)*	*Max (%)*	*Mean (%)*
Degradation Rate	Pert	1-18	0.3	0.5	1	0.550
		19-20	0.3	0.75	3	1.050

(*Source:* Vazquez and Rey-Stolle, 2008, Jordan and Kurtz, 2013) the number of arrays and the failure rate, because the failure rate follows a binomial distribution. Then, if we multiply the replacement cost of a single array of the system, the cost for the broken array can be estimated. Because there is no real experience for the failure rate over a 20-year period, we assume the average failure rate of the system is 0.5% a year for each single array, and it remains the same over 20 years, as suggested by New Holland Rochester, Inc., a local retailer of the solar PV systems in Rochester, IN.

Comparison of Residences and Farm Businesses

We compare residences and farm businesses under different policy combinations. The primary difference between residences and farm businesses is that farm businesses can claim the benefit of tax deduction from depreciation in addition to benefits from other policies available for residences. We analyze three cases:

Case 1: Comparison under the current policy set

Case 2: Comparison using a set of policies we define as leveling the playing field

Case 3: Comparison with no net metering

Detailed combinations of policies for each case are summarized in Table 2. We denote "*X*" for a policy included and "-" for a policy excluded. Case 1 is the base case under current policies. We define Case 2 as giving the solar system the same benefits as grid electricity—thus the level playing field name. In Case 3, we remove net metering, which is a very important policy because it permits customers to sell excess electricity back to the grid if more electricity is produced than consumed.

Data and Assumptions

The assumptions of the benefit-cost analysis are listed in Table 3 on page 5. In this study, we mostly use information for the solar PV system based on New Holland Rochester, Inc. because it is a local retailer of solar PV panels in Indiana. This way, our analysis can be more relevant for customers in Indiana. New Holland Rochester, Inc. provides two capacities of solar PV systems, 5.88kW and 7.84kW. The annual electricity generated from solar PV systems also comes from experiments conducted by New Holland Rochester, Inc.

Results and Discussions

Annualized Electricity Price

We have two annualized electricity prices for comparison:

- Annualized electricity price for cases that do not include a carbon tax
- Annualized electricity price for cases that include a carbon tax.

The annualized real grid electricity prices for both cases are shown in Table 4 on page 6. The case with carbon tax is, of course, higher.

This annualized grid electricity price distribution is compared with the distribution of annualized solar costs in each of the cases to be presented below. Then, we get the distribution of the difference between the two by subtracting the distribution of the annualized electricity price from the distribution of the annualized solar costs to determine the probability that the cost of solar systems will be less than the annualized electricity price. The results are in Table 5 on page 6.

Table 2. *Combinations of Policies for Each Case*

Case	*Sector*	*NM*	*F*	*FTC*	*D*	*CT*
Under current policy	Farm	X	X	X	X	-
	Residence	X	X	X	-	-
Level the playing field	Farm	X	X	-	X	X
	Residence	X	X	-	X	X
Remove net metering	Farm	-	X	X	X	-
	Residence	-	X	X	-	-

* NM: Net Metering, F: Financing, FTC: Federal Tax Credits, D: Depreciation, CT: Carbon Tax

Table 3. *Benefit Cost Analysis Assumptions*

Assumption for Analysis of Solar PV System in Indiana			
Parameter	*Value*	*Units*	*Source*
PV Panel Capacity (smaller size)	5.880	kW	New Holland Rochester, Inc.
PV Panel Capacity (larger size)	7.840	kW	New Holland Rochester, Inc.
Installation Cost of PV Panel	2.857	$/W	New Holland Rochester, Inc.
Annual Electricity Generated by PV Panel (5.88kW)	9,018.20	kWh/year	New Holland Rochester, Inc.
Annual Electricity Generated by PV Panel (7.84kW)	12,024.27	kWh/year	New Holland Rochester, Inc.
O&M Cost	0.005	$/kWh	New Holland Rochester, Inc.
O&M Cost Growth Rate (Nominal)	3	%	New Holland Rochester, Inc.
O&M Cost Growth Rate (Real)	0.49	%	Author's Calculation
Wire Cost	6.00	%	New Holland Rochester, Inc.
Failure Rate of Panel	0.5	%	New Holland Rochester, Inc.
Labor Cost of Repair	75	$	New Holland Rochester, Inc.
Growth Rate of Labor Cost (Nominal)	1	%	New Holland Rochester, Inc.
Degradation Rate of Electricity Generated from PV system (Mode, 1st through 18th year)	0.55	%	Vazquez and Rey-Stolle, 2008, Jordan and Kurtz, 2013
Degradation Rate of Electricity Generated from PV system (Mode, 19th through 20th year)	1.05	%	Vazquez and Rey-Stolle, 2008, Jordan and Kurtz, 2013
Solar PV Panel Life	20	years	New Holland Rochester, Inc.
Inflation Rate	2.50	%	Author's assumption
Current Retail Electricity Price	0.1137	$/kWh	EIA
Annualized Electricity Price	0.1206	$/kWh	Author's assumption
Current Electricity Price Growth Rate (Real)	1.08	%	State Utility Forecasting Group, 2011
Discount Rate (Real)	6.00	%	Author's assumption
EPAct 2005 Federal Tax Credit	30.00	%	DSIRE
Loan fraction of total cost	80.00	%	Author's assumption
Loan Interest Rate (Nominal)	7.50	%	Average estimation around Lafayette, IN
Loan Financing Period	10	years	Author's assumption
Salvage Value Rate	15.00	%	Author's assumption
Annual Demand for Electricity	12,428.17	kWh/year	EIA

Table 4. *Annualized Grid Electricity Price without and with Carbon Tax*

	Mean	*Standard Deviation*
	$/kWh	*$/kWh*
Annualized Electricity Price without Carbon Tax	0.1206	0.0259
Annualized Electricity Price with Carbon Tax	0.1447	0.0257

Table 5. *Results for Case Analyses*

Case	*Sector*	*Policy Options Included*	*System Capacity*	*Solar System Annualized Cost*		*Probability Solar Cheaper*
			kW	*$/kWh*		*%*
Under current policy	Farm	NM, F, FTC, D	5.88	Mean	0.0983	92.0
				Standard Deviation	0.0083	
			7.84	Mean	0.0906	92.3
				Standard Deviation	0.0025	
	Residential	NM, F, FTC	5.88	Mean	0.1190	49.4
				Standard Deviation	0.0082	
			7.84	Mean	0.1181	49.4
				Standard Deviation	0.0025	
Level the playing field	Farm	NM, F, D, CT	5.88	Mean	0.1278	83.9
				Standard Deviation	0.0083	
			7.84	Mean	0.1218	84.6
				Standard Deviation	0.0025	
	Residential	NM, F, D, CT	5.88	Mean	0.1278	83.9
				Standard Deviation	0.0083	
			7.84	Mean	0.1218	84.6
				Standard Deviation	0.0025	
Remove net metering	Farm	F, FTC, D	5.88	Mean	0.1019	88.5
				Standard Deviation	0.0089	
			7.84	Mean	0.1058	75.1
				Standard Deviation	0.0057	
	Residential	F, FTC	5.88	Mean	0.1226	40.2
				Standard Deviation	0.0090	
			7.84	Mean	0.1334	24.0
				Standard Deviation	0.0057	

* Mean annualized electricity prices are $0.1206 without CT and $0.1447 with CT

Case 1: Comparison Under the Current Policy

Under the set of policies that constitute the current policy (net metering, financing, and federal tax credit for the homeowner plus depreciation for the business), the solar PV system is economical for farm businesses in Indiana with a 92% probability of being cheaper than electricity from the grid. This very positive outcome is attributed primarily to the tax deduction from depreciation available for farm businesses. On the other hand, for residential customers, the solar system is 50-50, which is about breakeven under current policy.

Case 2: Comparison Using a Set of Policies We Define as Leveling the Playing Field

We define "leveling the playing field" as giving solar the same benefits accorded to grid electricity to both farm business and homeowners. Thus both would have net metering, financing, and depreciation—the benefits available to grid providers, but not the federal tax credit. In addition, the carbon tax would be included because it would be necessary to make grid electricity equivalent to carbon free solar. In this case, residential and farm solar both have an 84% of chance of being less expensive than grid. Because residential and farm businesses get benefits from depreciation and carbon tax, it shows a higher probability of being cheaper than under the current policy case.

Case 3: Current Policy Without Net Metering

Removing net metering from the current policy makes residential solar uneconomical. On the other hand, farm solar is still attractive even if not so much as with net metering in place. Clearly, net metering plays an important role in reducing the cost of solar PV systems. Also, we can see that the larger system without net metering is less attractive than the smaller one, even though the larger one generates more electricity. Without net metering, excess electricity would be discarded instead of being sold to the utility. Thus, the larger system shows lower economic viability. The net metering case is important because not all utilities offer net metering.

Sensitivity Analysis

In the original research and journal article published on this research (Jung and Tyner, 2014), we did extensive sensitivity analyses on several input variables that may affect the results of the analysis. Here we do the sensitivity analysis on panel lifetime and discount rate, two of the most important variables. We have assumed, because New Holland Rochester, Inc. offers and suggests currently in Indiana, a 20-year warranty and panel lifetime for our analysis. However, many panels currently come with a longer period of warranty. Thus, we do the sensitivity analysis over a 25-year and 30-year lifetime. Since most of the 20-year cost of installing a solar PV system is incurred at the beginning of year 1, we do sensitivity on the real discount rate using values of 3%, 4.5%, 7.5%, 9%, and 10.5% in addition to the 6% of the base case. We also did sensitivity analysis for annual operating and maintenance cost, but it is not reported here because there was little impact.

First, we represent how much the probability solar is cheaper will change if we apply longer lifetime periods of 25 and 30 years. As shown in Table 6, the probability increases substantially with longer panel lifetime. This indicates that solar electricity can be more attractive if experience confirms the longer lifetime is appropriate.

Table 6. *Sensitivity Analysis for the Lifetime of PV panels*

Case	*Sector*	*Policy Included*	*System Capacity*	*Probability Solar Less Expensive (%)*		
				Base	*25 years*	*30 years*
Under current policy	Farm	NM, F, FTC, D	5.88kW	92.0	95.3	96.7
			7.84kW	92.3	95.8	97.5
	Residential	NM, F, FTC	5.88kW	49.4	65.7	72.5
			7.84kW	49.4	65.3	73.1
Level the playing field	Farm	NM, F, D, CT	5.88kW	83.9	92.0	93.8
			7.84kW	84.6	89.5	92.3
	Residential	NM, F, D, CT	5.88kW	83.9	92.0	93.8
			7.84kW	84.6	89.5	92.3
Remove net metering	Farm	F, FTC, D	5.88kW	88.5	93.3	95.4
			7.84kW	75.1	85.1	88.1
	Residential	F, FTC	5.88kW	40.2	56.5	65.0
			7.84kW	24.0	38.0	48.9

* Mean annualized electricity prices are $0.1206 without CT and $0.1447 with CT

Table 7. *Sensitivity Analysis for the Discount Rate (-50% to +75% of the base assumption)*

Case	*Sector*	*System Capacity*	*Probability Solar Less Expensive (%)*					
			-50%	*-25%*	*Base*	*+25%*	*+50%*	*+75%*
Under current policy	Farm	5.88kW	97.1	95.8	92.0	88.4	82.3	75.2
		7.84kW	95.0	94.1	92.3	88.2	82.8	75.8
	Residential	5.88kW	74.4	61.8	49.4	35.1	24.1	15.0
		7.84kW	75.7	63.0	49.4	36.6	24.8	15.7
Level the playing field	Farm	5.88kW	94.8	90.8	83.9	75.5	62.6	49.7
		7.84kW	96.2	91.9	84.6	74.2	62.9	50.6
	Residential	5.88kW	94.8	90.8	83.9	75.5	62.6	49.7
		7.84kW	96.2	91.9	84.6	74.2	62.9	50.6
Remove net metering	Farm	5.88kW	95.4	92.8	88.5	82.0	75.7	66.7
		7.84kW	89.5	83.5	75.1	66.1	56.0	45.0
	Residential	5.88kW	67.2	53.7	40.2	27.9	18.0	11.0
		7.84kW	50.0	36.1	24.0	14.4	7.9	3.8

* Mean annualized electricity prices are $0.1206 without CT and $0.1447 with CT

Second, Table 7 illustrates the result for the sensitivity analysis for the discount rate. Mostly, the probability solar is less expensive decreases with an increase in discount rate and vice versa. This change is due to the high capital intensity of solar systems. For solar, most of the 20-year cost is incurred at the beginning of year 1, so a high discount rate that reduces the value of future savings will make solar less attractive, while a lower discount rate that values future benefits more will make solar more attractive.

Conclusions

Farm businesses clearly show a higher chance of solar being cheaper than the grid compared to residential customers, except in the level playing field case, in which they are equal. Business solar is more attractive because of the depreciation benefits currently available to farm businesses.

Under current policy, with the benefit of depreciation, the solar system is much more attractive for farm businesses than for residential customers. Farm solar systems have a 92% chance of solar being cheaper than grid electricity, while residential solar shows a 50-50 chance of being breakeven. For the level playing field case, both residential and farm solar have an 84% chance that solar is less expensive than grid electricity. In this case, residential and farm solar are both economical with an introduction of depreciation and carbon tax. In this case, depreciation levels the playing field, and the carbon tax prices the GHG externality. The economically justifiable policy changes of leveling the field for depreciation and adding a carbon tax are more powerful in inducing investment in solar energy than the current federal tax credit, particularly in the residential sector. Removing net metering from the current policy renders residential solar un-economical. Farm solar shows a lower probability of being less expensive than the grid, but it is still attractive.

We also conduct sensitivity analysis for three variables; lifetime of solar PV panels, discount rate, and O&M cost growth rate. The lifetime of panels and the discount rate change the results significantly, while the O&M cost growth rate does not. The longer period of panel lifetime is important in reducing cost. A higher discount rate makes solar less attractive because solar systems are so capital intensive with the costs being up front and the benefits downstream.

Furthermore, this research also suggests the importance of non-profit rural electric cooperatives partnering with for-profit rural businesses in order to increase use of solar energy. Non-profits cannot take advantage of the tax deductibility of loans, the federal tax credit, or depreciation because they do not pay federal income taxes. Without these provisions, solar clearly is not economical. However, if rural electric cooperatives find creative ways to partner with for-profit rural businesses, then greater solar penetration can be achieved in a way that is beneficial for both entities—a win-win.

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Feb. 2015