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Feasibility of solar technology (photovoltaic) adoption: A case study on Tennessee's poultry industry

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ABSTRACT

The advantages and limitations of solar photovoltaic (PV) systems for energy generation are reviewed under various physical efficiency limits and financial assistance programs. Recent increases in utility and fuel costs in poultry production as well as public awareness of and demand for green power or renewable energy sources have given renewed interest in alternative energy sources. This study seeks to investigate the impact of alternative energy programs, grants and other incentives on the feasibility of solar PV systems in several solar regions within Tennessee's poultry industry. Preliminary results show that incentives exceeding current levels before adoption of solar PV systems would be financially beneficial.

1. Introduction

Rising oil prices and environmental concerns have led to renewed interest in renewable energy sources. In 2004, renewable energy represented 6% of the energy consumed in the United States, from which 47% and 45% were from biomass and hydroelectric sources, respectively [1]. Wind and solar power present potential sources of growth in renewable energy. According to the U.S. Department of Energy (DOE), America could supply its entire energy needs by covering merely 1.6% of its land area with solar cells [2]. The environmental effects of traditional energy sources like coal, natural gas, oil, and nuclear power can be significant. Green power resources such as solar and wind create less waste and pollution than the traditional energy sources.

The search for renewable energy sources has spurred the Tennessee Valley Authority (TVA), one of the United States' largest utility providers, to develop Green Power Switch (GPS) program. The GPS program started in 2000 in order to increase production of electricity from renewable sources and add it to the region's power mix. TVA sold more than 176 billion kilowatt-hour (kW h) of electricity to customers in fiscal year 2006 [3]. Fossil fuel plants produced about 64% of TVA's generation in 2006, followed by nuclear power (29%), hydropower (6%), and green power (less than 1%) [4]. "In fiscal year 2006, 85.1 million kW h of renewable energy was generated by the Green Power Switch program through the use of solar, wind, and methane gas generating sites" [3]. TVA has the capacity to provide as much as 97 million kW h of green power annually [5]. As part of the GPS program, TVA will dual-meter or purchase certain types of renewable energy systems' energy output within the Tennessee Valley region. Dual metering is a financial incentive that originated with electric companies as a way to encourage customers to invest in renewable energy systems such as solar or wind power [4]. The renewable supply from GPS currently includes 78% wind, 21.5% methane, and 0.5% solar [6].

Approximately 800 MW of wind capacity energy is available within 5 miles of the TVA service area [5]. Since the average capacity factor for wind energy systems in the Tennessee Valley is about 25%, the 800 MW of wind capacity is equivalent to only 267 MW of fossil capacity. Wind energy systems depend on the availability of sufficient wind to produce electricity. The lack of control over when and how much wind energy will be available makes this renewable energy non-dispatchable, thus reducing its value to the system [5]. Tennessee does not have a large amount of economical wind energy capacity that has not already been utilized [6].

Methane is a potent greenhouse gas (GHG) that, pound-for-pound, contains 21 times the impact of carbon dioxide on global warming [5]. Because of the environmental issues, TVA has currently capped its capacity of methane production in the region

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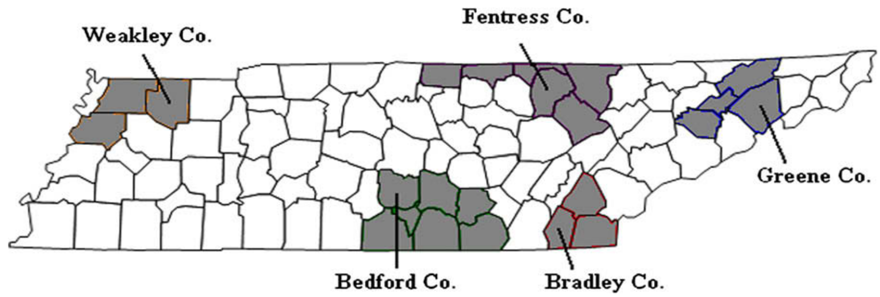

Fig. 1. Poultry production clusters in Tennessee.

[6]. Therefore, TVA could expand its current solar energy production to meet growing electricity demand.

Agriculture can play a significant part in renewable energy production. Tennessee poultry producers could produce their own renewable energy through the use of solar photovoltaic (PV) panels—then use the electricity for bird production running fans and lighting while alleviating demand on utility providers and reducing pollutants. A solar PV system is a module that converts sunlight into usable electricity. Agriculture—specifically the poultry industry—could potentially export green energy (via PV panels) back to the grid during peak electricity demand periods and play a significant role in reducing environmental pollutants as well as lowering farm production costs. Since energy plays a crucial role in poultry production and there is sufficient roof space on poultry houses, the chicken industry is a solid candidate for solar energy adoption [7].

Tennessee's poultry industry has demonstrated steady growth in recent years. Broilers constitute the majority of poultry production in the state in terms of cash receipts. In 2002, there were 186.4 million broilers produced in the state with a value of over $268.4 million. Production of broilers grew to 213.5 million in 2006 with a value over $413.7 million [8,9]. The poultry industry has consistently ranked second only behind cattle in cash receipts among the state's leading agricultural products. Since energy prices have escalated in recent years, research efforts must evaluate alternatives in order to maintain the economic viability of poultry production in the state. Farmers across the southeast are feeling the hit from electricity price hikes. "Energy costs have pushed production costs far beyond the level of making a profit and they still have other bills to pay," [10]. Although propane costs have increased at higher rates than electricity, cheap coal currently used for electricity production by TVA is running low when looking at a 10-year horizon [6]. This paper aims to expand the literature on solar PV system's feasibility due to recent developments in photovoltaic solar modules, state and federal grants and other incentives as well as the declining cost of the PV system.

Table 1
Estimated annual energy output for solar PV systems in selected Tennessee Counties

County	County area	kW h/m^2/day	Annual kW h output per kW installed
Bedford		4.93	1271
Bradley		4.80	1234
Fentress	W	5.01	1297
	E	4.80	1247
Greene		4.84	1248
Weakley	NW	5.13	1328
	NE	4.87	1258
	SW	4.92	1273
	SE	5.09	1314

Source: National Renewable Energy Laboratory, PVWATTS Solar Energy Calculator [24]. Bradley County was divided into four separate solar regions according to PVWATTS. The difference was minimal and did not affect the financial feasibility of the investment. Therefore, an average for Bradley County was utilized in the analysis.

2. Literature review

In the past, high solar PV material costs have restricted consumers from adopting the technology. However, the cost to produce PV panels in the late 1970s was around $25 per W but has since dropped to less than $3.50 per W, an 86% reduction [11]. Existing literature illustrates that as PV module production increases, prices will drop considerably [11,12]. A significant factor in the feasibility of PV systems is the financial incentives for renewable projects, both state and federal. New research investigating Tennessee's current incentives for renewables is needed. Currently, some of the available incentives include state and federal grants, 0% loans for qualified users, accelerated depreciation, federal tax credits, and TVA's Green Power Switch dual-metering program [13].

A number of extension publications have addressed rising energy costs in poultry production. Smith [14] lists several farm management practices and maintenance suggestions such as insulating poultry houses and sealing curtains in order to reduce energy costs. Cunningham [15] estimated that North Georgia broiler producers with four 40′ by 500′ houses incur $11,600 in electricity costs (not including fuel for heat). Simpson et al. [16] analyzed cost trends in poultry production and agree that

Table 2
Base case conditions for sensitivity analysis

Variable	Description	Base value	Hypothesized effect on NPV
$COST_{kw}$	Installed cost of solar PV system per kW	$8000	–
$SIZE_{kw}$	Size of solar PV system (kW)	20	+
$ELEC_{esc}$	Annual electricity price escalation	3%	+
$OUTPUT_{kw}$	Estimated annual electricity output per kW	Cluster specific	+
TVA_{dual}	TVA GPS dual-meter payment (cents/kW h)	$0.15	+
GRANT	Percent of installed cost shared by state/federal grant programs	65%	+
TAXCR	Percent of installed cost eligible for federal tax credit	30%	+
DISCRATE	Discount factor rate	8.25%	–
MAINT	Annual maintenance cost (percent of initial installed cost)	0.6%	–
INS	Annual insurance cost (rate per initial installed cost)	$7.25 per $1000	–
FIN_{yr}	Length of finance terms (in years)	10	–
FIN_{rate}	Financing interest rate for borrowed capital	7.5%	–

Table 3
Economic results under current base conditions in selected Tennessee Counties

County	County area	Cost per kW installed	Payback (yrs)		Benefit–cost	NPV	IRR (%)
			Undiscounted	Discounted			
Bedford		$8000	4.7	12.2	1.06	$3096	10.5
Bradley		$8000	5.1	16.2	1.04	$2021	9.8
Fentress	W	$8000	4.5	9.8	1.07	$3851	11.1
	E	$8000	4.9	14.8	1.04	$2399	10.1
Greene		$8000	4.9	14.6	1.04	$2428	10.1
Weakley	NW	$8000	4.3	9.1	1.08	$4751	11.7
	NE	$8000	4.8	13.6	1.05	$2718	10.3
	SW	$8000	4.7	12.1	1.06	$3154	10.6
	SE	$8000	4.4	9.4	1.08	$4344	11.4

electricity costs are the second largest cost item in dollar amounts to producers. Simpson et al. [16] also estimated in 2006 electricity costs per house to be about $3700, an increase of about $1200 per house from the previous year, for poultry operations in North Alabama.

Most on-farm research has analyzed solar thermal technologies that are used for heating and/or drying purposes. Hardy et al. [17] estimated a linear programming model for a solar thermal collector to supply a poultry house with 60%, 40%, and 20% of its annual heating needs. Results displayed that the smallest solar heating system, which provided 20% of heating needs, was still more expensive than the conventional propane system. Van Dyne [18] estimated the economic feasibility of heating Maryland's poultry houses with solar energy using a simulation model, and results showed that solar thermal collectors could deliver a portion (42%) of its heating needs while being less expensive than propane. Previous economic analysis of on-farm solar systems has involved prospecting for multipurpose on-farm solar energy intensifier systems with grain-drying, livestock ventilation air heating, and summertime water heating by Van Zweden et al. [19].

To date, there have been no major studies completed on the potential applications of solar PV systems for poultry farming in the United States. With the exception of the University of Delaware which published a report titled "The Potential of Solar Electric Applications for Delaware's Poultry Farms" [7] in April 2005, no other research has addressed solar PV system's feasibility and uses on poultry farms. The researchers conducted a feasibility study and utilized a simulation model approach, testing alternative scenarios and cost conditions. The study indicated that under certain policy scenarios, solar energy is economical for the state's producers [7]. Results outlined that a system size of 1.5 kW was the most economical for the electricity needs of a typical Delaware poultry house. Environmental benefits for the 1.5 kW PV system included avoided emissions of 112 tons of CO_2 over its lifetime as well as reducing 1.8 tons of sulfur dioxide (SO_x) and 0.4 tons of nitrogen oxides [7].

In spring of 2007, the poultry integrator Allen Family Foods Inc. of Delaware partnered with the University of Delaware and solar companies to install a 42 kW solar system for one of its grow-out houses in Delaware. The system cost approximately $500,000 of which about 50% was paid by a rebate from the Delaware Green Energy Program. Allen also receives Renewable Energy Certificates (RECs) in the amount of $0.20 per kW h the system generates [20]. Allen estimates saving $7500 per year on its electricity bill as well as receiving the 30% Federal investment tax credit along with other tax advantages. Estimate payback on the solar investment is anticipated at 2.5 years [20]. However, these figures seem optimistic compared to the Tennessee analysis for the two following reasons: (1) the Delaware calculations likely do not account for federal income taxes on rebates (e.g., state rebates, buydowns, grants or other incentives do not decrease the amount eligible for the federal investment tax credit if the farmer or company is required to pay federal income tax on the incentive [21]); and (2) the Delaware study does not appear to directly account for annual maintenance and insurance costs.

3. Methodology and data

Broiler production in Tennessee is generally located in five clusters across the state as shown in Fig. 1, with the majority of production in Bedford and Bradley Counties [22]. In order to analyze potential geographical advantages of solar adoption across the state, five counties (Bedford, Bradley, Fentress, Greene, and Weakley), each representing a separate production cluster, are compared in this study. All of these counties were in the top 12 in 2001 in terms of number of broilers produced. In 2001, these five counties accounted for about 46% of total production in the state [23]. However, geographical distances between each county also account for the varying amounts of solar resource each location receives.

This study uses a simulation benefit–cost model for each county cluster to estimate the feasibility of solar PV energy production

Table 4
Net present values for various cost conditions in selected Tennessee Counties

County	County area	Cost per kW							
		$5200	$5600	$6000	$6400	$6800	$7200	$7600	$8000
Bedford		$14,931	$13,240	$11,549	$9859	$8168	$6477	$4786	$3096
Bradley		$13,856	$12,165	$10,475	$8784	$7093	$5403	$3712	$2021
Fentress	W	$15,686	$13,995	$12,304	$10,614	$8923	$7232	$5542	$3851
	E	$14,234	$12,543	$10,852	$9162	$7471	$5780	$4090	$2399
Greene		$14,263	$12,572	$10,881	$9191	$7500	$5809	$4119	$2428
Weakley	NW	$16,586	$14,895	$13,204	$11,514	$9823	$8132	$6442	$4751
	NE	$14,553	$12,862	$11,172	$9481	$7790	$6100	$4409	$2718
	SW	$14,989	$13,298	$11,607	$9917	$8226	$6535	$4845	$3154
	SE	$16,179	$14,489	$12,798	$11,107	$9417	$7726	$6035	$4344

Table 5
Net present values for base case with 60% grant funding in selected Tennessee Counties

County	County area	Cost per kW							
		$5200	$5600	$6000	$6400	$6800	$7200	$7600	$8000
Bedford		$9731	$7640	$5549	$3459	$1368	($723)	($2814)	($4904)
Bradley		$8656	$6565	$4475	$2384	$293	($1797)	($3888)	($5979)
Fentress	W	$10,486	$8395	$6304	$4214	$2123	$32	($2058)	($4149)
	E	$9034	$6943	$4852	$2762	$671	($1420)	($3510)	($5601)
Greene		$9063	$6972	$4881	$2791	$700	($1391)	($3481)	($5572)
Weakley	NW	$11,386	$9295	$7204	$5114	$3023	$932	($1158)	($3249)
	NE	$9353	$7262	$5172	$3081	$990	($1100)	($3191)	($5282)
	SW	$9789	$7698	$5607	$3517	$1426	($665)	($2755)	($4846)
	SE	$10,979	$8889	$6798	$4707	$2617	$526	($1565)	($3656)

across the state. Several scenarios are analyzed under various policies and economic conditions to comprehend the current status of solar PV energy production. It should be noted that values of solar energy production are estimated by PVWATTS Solar Energy Calculator [24] since there are no solar PV systems currently in use on poultry farms in the state. Methods in this study for PV analysis include estimating the annual electricity output (kW h) for a 20 kW PV system for each of the counties listed.

The 20 kW PV system was chosen first based on its potential to maximize the amount of the Tennessee Clean Energy Technology Grant under current cost ($8000 per installed kW) which includes 40% of the total cost of the system, with a maximum grant award of $75,000 and secondly, based on the estimated electricity usage for each broiler house of 20,000–35,000 kW h of electricity each year [25]. For Tennessee, on average, a 20 kW PV system will produce approximately 25,000 kW h each year [26]. Therefore, a 20 kW system could potentially provide all of the electricity to power one broiler house. Solar output is estimated by a software model, PVWATTS Version 2 [24]. PVWATTS Version 2 is an Internet-accessible simulation tool developed by the National Renewable Energy Laboratory (NREL) for providing quick estimates of the energy produced by a grid-connected crystalline silicon PV system. NREL collects data on solar radiation at 239 stations across the United States [27]. Because some of the counties consisted of more than one solar region, two of the counties, Weakley and Fentress, are divided into separate solar zones. Bradley County was also divided into separate solar regions. However, the differences in solar resource were minimal, so for purposes of this study, an average for Bradley County was provided. PVWATTS' estimates of solar output are shown in Table 1.

Annual TVA dual-metering revenues are calculated for the first 10 years by multiplying this estimated output by the respective payment, 15 cents/kW h or 20 cents/kW h, depending on whether the system is classified as residential or commercial. Costs of PV systems are estimated given the range of $5200–$8000 per installed kW [26,7]. Incentives such as cost-share grants for PV systems are taken into account on the initial cost outlay. Federal tax credits are taken into account at the end of year one. After the dual-metering contracts expire in 10 years, it is assumed that the producer gains the benefit or value of the electricity produced by the PV system. Therefore, foregone electricity costs in years 11 through 25 offer a benefit to producers that adopt. Producers will benefit more and solar PV will become more financially attractive as the electricity rate rises. Table 2 provides a list of variables and the hypothesized effect each will have on the economic feasibility of solar PV adoption.

The economic analysis for all scenarios includes the discounted and undiscounted payback of the PV system in years, the benefit-to-cost ratio of the solar investment, as well as the net present value (NPV) and internal rate of return (IRR) of the investment. The impact of each variable and its impact on the IRR are projected in the sensitivity analysis.

4. Financial incentives for solar energy

State and federal incentives for renewable energy are currently available and are analyzed with the cost of the solar PV system. Effective from September 2006, the Tennessee Economic and Community Development Energy Division is offering a grant program for businesses to install renewable energy systems at their facilities [13]. The grant (Tennessee Clean Energy Technology Grant, TN-CET) amounts are 40% of the installed cost for solar PV systems with a maximum grant of $75,000 and minimum of $5000. Funds allocated to this program for the 2007 fiscal year were $3,750,000 [13].

The United States Department of Agriculture (USDA) created the Renewable Energy Systems and Energy Efficiency Improvements Program through Section 9006 of the 2002 Farm Bill [13]. Funds were appropriated for fiscal year 2002 through 2007. The maximum grant award is 25% of eligible project costs up to $500,000 for renewable energy projects and up to $250,000 for

Table 6
Net present values for base case with 55% grant funding in selected Tennessee Counties

County	County area	Cost per kW							
		$5200	$5600	$6000	$6400	$6800	$7200	$7600	$8000
Bedford		$4531	$2040	($451)	($2941)	($5432)	($7923)	($10,414)	($12,904)
Bradley		$3456	$965	($1525)	($4016)	($6507)	($8997)	($11,488)	($13,979)
Fentress	W	$5286	$2795	$304	($2186)	($4677)	($7168)	($9658)	($12,149)
	E	$3834	$1343	($1148)	($3638)	($6129)	($8620)	($11,110)	($13,601)
Greene		$3863	$1372	($1119)	($3609)	($6100)	($8591)	($11,081)	($13,572)
Weakley	NW	$6186	$3695	$1204	($1286)	($3777)	($6268)	($8758)	($11,249)
	NE	$4153	$1662	($828)	($3319)	($5810)	($8300)	($10,791)	($13,282)
	SW	$4589	$2098	($393)	($2883)	($5374)	($7865)	($10,355)	($12,846)
	SE	$5779	$3289	$798	($1693)	($4183)	($6674)	($9165)	($11,656)

Table 7
Net present values for base case with 1% annual electricity price escalation in selected Tennessee Counties

County	County area	Cost per kW							
		$5200	$5600	$6000	$6400	$6800	$7200	$7600	$8000
Bedford		$11,820	$10,129	$8439	$6748	$5057	$3367	$1676	($15)
Bradley		$10,836	$9146	$7455	$5764	$4073	$2383	$692	($999)
Fentress	W	$12,512	$10,821	$9130	$7440	$5749	$4058	$2367	$677
	E	$11,182	$9491	$7801	$6110	$4419	$2729	$1038	($653)
Greene		$11,209	$9518	$7827	$6136	$4446	$2755	$1064	($626)
Weakley	NW	$13,336	$11,645	$9955	$8264	$6573	$4883	$3192	$1501
	NE	$11,474	$9784	$8093	$6402	$4712	$3021	$1330	($360)
	SW	$11,873	$10,183	$8492	$6801	$5111	$3420	$1729	$39
	SE	$12,964	$11,273	$9582	$7892	$6201	$4510	$2820	$1129

Table 8
Net present values for base case with 20% tax credit in selected Tennessee Counties

County	County area	Cost per kW							
		$5200	$5600	$6000	$6400	$6800	$7200	$7600	$8000
Bedford		$5323	$2893	$464	($1966)	($4396)	($6825)	($9255)	($11,685)
Bradley		$4249	$1819	($611)	($3040)	($5470)	($7900)	($10,330)	($12,759)
Fentress	W	$6078	$3649	$1219	($1211)	($3641)	($6070)	($8500)	($10,930)
	E	$4626	$2197	($233)	($2663)	($5093)	($7522)	($9952)	($12,382)
Greene		$4655	$2226	($204)	($2634)	($5064)	($7493)	($9923)	($12,353)
Weakley	NW	$6978	$4549	$2119	($311)	($2740)	($5170)	($7600)	($10,030)
	NE	$4946	$2516	$86	($2343)	($4773)	($7203)	($9633)	($12,062)
	SW	$5381	$2952	$522	($1908)	($4338)	($6767)	($9197)	($11,627)
	SE	$6572	$4142	$1712	($717)	($3147)	($5577)	($8006)	($10,436)

energy efficiency improvements. Solar PV systems are considered eligible renewable technologies for this federal grant program. Guaranteed loans are also offered under the program. Under the guaranteed loan option, funds up to 50% of eligible project costs are available with a maximum project cost of $10 million. Currently, this program is due to expire at the end of the 2007 fiscal year but proposals to extend the program are underway for the 2007 Farm Bill. There is approximately $11.4 million available for competitive grants and $176.5 million in authority for guaranteed loans for 2007. Other incentives include a federal tax credit of 30% for solar, modified accelerated cost-recovery system (MACRS) corporate depreciation, and the TVA GPS Generation Partners Program outlined earlier [13].

Available grants included in this analysis are: (1) The Tennessee Clean Energy Technology Grant which provides 40% of the initial cost of the solar PV system (max $75,000) and (2) The USDA Rural Development Grant which provides up to 25% of the initial cost of the system. For feasibility analysis, the remaining portion of the system costs was financed using a 10-year loan with a 7.5% fixed interest rate. The 30% federal tax credit collected at the end of year one accounted for revenue in year one for the investment. State rebates, buydowns, grants or other incentives do not decrease the amount eligible for the federal investment tax credit if the farmer or company is required to pay federal income tax on the incentive [21]. Because of the complexity of calculating the federal tax rates of individual poultry producers across the state, this analysis does not include federal income tax payments on incentives received by producers. The basis for tax credit is the entire cost of the solar PV system.

The discount factor rate used for this study was 8.25% or the current prime rate (base rate as posted by 75% of the nation's largest banks) [28]. Annual maintenance costs for the PV system include 0.6% of the installed cost of the system [7]. Annual insurance costs for solar PV systems have not been previously addressed for Tennessee farmers. Cashion from Tennessee Farm Bureau Insurance Division confirmed that the PV system, if attached to the roof of the existing poultry house, would be insured at the same rate as the building. Current rate estimates show that annual insurance costs would include $7.25 per $1000 of installed costs of the PV system [29].

5. Results

Economic feasibility of solar PV energy adoption was evaluated for poultry producers in each of the five clusters in Tennessee. Table 3 displays the economic results of the base case analysis for each cluster region. Results were estimated varying each parameter from its base value. Since the base case values displayed positive NPVs, the sensitivity analysis analyzed various scenarios that predictably would negatively affect the NPV.

Table 4 illustrates that as the cost per installed kW declines, the NPV increases as expected. The models that delivered in Tables 5 and 6 used base case values while varying the total amount of the grants used for cost share. The original base case value of 65% was obtained from the 40% TN-CET Grant and adding the 25% USDA Grant. Both scenarios (60% and 55% grant fundings) show that solar PV is not a positive investment at the current estimated price of $8000 per kW. However, if the installed cost of the PV system declines, the investment can bring a positive return.

Table 7 displays the NPVs if the cost of electricity rises at a lower rate (1%) than the base case analysis (3%). Table 8 shows the effect on NPV of a reduction in the federal tax credit from 30% to 20% and Table 9 shows the effect of a reduction in the TVA GPS dual-metering payment from 15 cents/kW h produced to 10 cents/kW h. Both sensitivity analyses show a decrease in NPV of the solar PV system investment.

Table 10 shows the NPVs given a higher discount rate of 12% that was used in the Delaware feasibility study [7]. The results show that the 20 kW solar PV system is not a positive investment across the state unless the cost of solar PV systems falls 10% ($7200). The hypothesis that solar differences due to geographical location in the state would create disparity among the regions of poultry producers and the economic feasibility for solar PV energy was verified in certain scenarios. For example, in Table 10 under the 12%

Table 9
Net present values for base case with 10 cents/kW h TVA dual-metering payment in selected Tennessee Counties

County	County area	Cost per kW							
		$5200	$5600	$6000	$6400	$6800	$7200	$7600	$8000
Bedford		$6497	$4807	$3116	$1425	($265)	($1956)	($3647)	($5337)
Bradley		$5668	$3978	$2287	$596	($1094)	($2785)	($4476)	($6166)
Fentress	W	$7080	$5389	$3699	$2008	$317	($1373)	($3064)	($4755)
	E	$5960	$4269	$2578	$888	($803)	($2494)	($4184)	($5875)
Greene		$5982	$4291	$2601	$910	($781)	($2471)	($4162)	($5853)
Weakley	NW	$7774	$6084	$4393	$2702	$1012	($679)	($2370)	($4060)
	NE	$6206	$4515	$2825	$1134	($557)	($2247)	($3938)	($5629)
	SW	$6542	$4852	$3161	$1470	($221)	($1911)	($3602)	($5293)
	SE	$7461	$5770	$4079	$2389	$698	($993)	($2683)	($4374)

Table 10
Net present values for base case with 12% discount rate in selected Tennessee Counties

County	County area	Cost per kW							
		$5200	$5600	$6000	$6400	$6800	$7200	$7600	$8000
Bedford		$8751	$7262	$5774	$4285	$2797	$1308	($180)	($1669)
Bradley		$7933	$6444	$4956	$3467	$1979	$490	($998)	($2487)
Fentress	W	$9326	$7837	$6349	$4860	$3372	$1883	$394	($1094)
	E	$8220	$6732	$5243	$3755	$2266	$778	($711)	($2200)
Greene		$8242	$6754	$5265	$3777	$2288	$800	($689)	($2177)
Weakley	NW	$10,011	$8522	$7034	$5545	$4057	$2568	$1080	($409)
	NE	$8463	$6975	$5486	$3998	$2509	$1021	($468)	($1956)
	SW	$8795	$7306	$5818	$4329	$2841	$1352	($136)	($1625)
	SE	$9701	$8213	$6724	$5236	$3747	$2259	$770	($718)

discount rate, a system in the northwest portion of Weakley County brings a positive NPV of $1080 under the $7600 per kW cost scenario. Under the same cost, a system in Bradley County delivers an NPV of −$998.

Table 11 displays the impact of each variable on the NPV of the 20 kW solar PV system. The variables with the largest impacts on NPV include the percent of grant funding (35%), percent of the federal tax credit (15%), and the installed cost per kW (−10.6%). For example, a 1% increase in the discount rate yields a 3.5% decrease in the NPV compared with the base case analysis. The electricity escalation rate variable had the least impact on the NPV (1.6%).

Results show that under current incentives for solar PV technologies, solar energy can be economical at today's prices given that all state and federal incentives are actually obtained. If the cost of solar PV declines, it would be beneficial to research the effects of the declining costs as well as the amount of government support needed to make solar energy economical. Evaluation of solar energy's potential for poultry operations is best conducted on a case-by-case basis. Individual poultry producers are advised to analyze their own situation and finances to determine whether solar PV systems are a good investment or not. This research presents one approach to evaluate solar PV's potential for Tennessee's poultry producers.

Table 11
Impact of variables on net present value of solar investment

Variable	Base value	New value	% Change	Avg. % effect on NPV	% Effect on NPV per 1% ⊿ in variable
Grant (%)	65	55	−15.4	−539	35.0
Tax credit (%)	30	20	−33.3	−498	15.0
Cost per kW	$8000	$5200	−35.0	370	−10.6
TVA payment (cents/kW h)	15	10	−33.3	−283	8.5
Discount rate (%)	8.25	12	45.5	−159	−3.5
Electricity escalation (%)	3	1	−66.7	−104	1.6

Another benefit of solar PV system adoption among the state's poultry producers is the environmental factor of reduced emissions. With approximately 800 broiler producers in the state, widespread adoption of solar PV systems would alleviate a considerable amount of pollution in the region from conventional "coal-fired" electricity production. If new laws are passed concerning environmental emissions in the future, solar PV systems and other renewable energy technologies could become more financially attractive. If the external costs of pollution from conventional "coal-fired" electricity production are enforced on utility providers, the relative cost of solar energy should become more and more competitive.

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