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, operational design 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 has 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 two solar regions within Tennessee's poultry industry. Preliminary results show that incentives must exceed current levels before adoption of solar PV systems would be financially beneficial.

Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Portland, Oregon, July29 – August 1, 2007

Draft May 2007

Results are preliminary, please do not cite without authors' permission.

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Keyword(s): solar, poultry, photovoltaic, energy, green power

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Introduction

Rising oil prices and instability in the oil-rich Middle East have led to intense interest in renewable energy sources in the United States once again. Currently, research is being conducted across the nation to ascertain which alternative renewable energy sources are feasible to help reduce the United States' dependence on foreign oil. Likewise, agricultural producers' fossil fuel dependence for the production of the nation's food supply has created a rush toward the inclusion of agricultural products as potential bio-energy sources. This search for alternative energy sources has also led utility companies across the country to develop green power initiative programs. Green power is electricity generated from renewable energy resources such as solar, wind, geothermal, biogas, biomass and low-impact hydro resources.

The search for renewable energy sources has spurred the Tennessee Valley Authority (TVA), the nation's largest utility provider, to develop the Green Power Switch (GPS) program to produce electricity from renewable sources and add it to the Tennessee Valley's power mix. The environmental effects of traditional energy sources like coal, natural gas, oil, and nuclear power can be significant. Green power resources such as solar create less waste and pollution. TVA has the capacity to provide as much as 97 million kWh of green power annually. 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. TVA has agreed to dual-meter 100% of the solar or wind power produced from residential, small commercial and large commercial customers. The energy produced is purchased from residential/small commercial and large commercial customers at 15 and 20 cents per kilowatt-hour output, respectively (Newton 2007). The dual-metering contracts with TVA are presently valid for 10 years from time of installation. This is funded through the GPS Generations Partners program, which sells $4 blocks of green power to customers who wish to contribute to green energy production. The renewable supply from GPS currently includes 78% wind, 21.5% methane, and 0.5% solar.

Approximately 800 MW of wind capacity energy is available within 5 miles of the TVA service area. Since the average capacity factor for wind energy systems in the Tennessee Valley is about 25 percent, 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 (Stephens, Williams, and Nicholas 2003). Tennessee does not have a large amount of economical wind energy capacity that has not already been tapped.

Methane is a potent greenhouse gas (GHG) that, pound-for-pound, contains 21 times the impact of carbon dioxide on global warming (Stephens, Williams, and Nicholas 2003). Because of the environmental issues, TVA has currently capped its capacity of methane production in the region (Carson 2006).

According to TVA, there is roughly 400 MW of solar photovoltaic (PV) capacity in the Tennessee Valley (Stephens, Williams, and Nicholas 2003). In the past, solar PV's high capital costs have deterred widespread investment. However, the cost to produce PV panels in the late 1970s was around $25 per watt but has since dropped to less than $3.50 per watt, an 86% reduction (Bradford 2006). TVA would like to expand its current solar capacity (Carson 2006). Solar photovoltaic (PV) systems use semiconductor cells, or modules, that convert the sunlight directly into usable electricity. The systems contain additional equipment like inverters, which convert the direct current (DC) to usable alternating current (AC). The PV cells usually come in the form of flat panels that can be mounted on rooftops, or integrated into roofing shingles and other metal roofs.

Agricultural producers could produce their own renewable energy through the use of solar PV systems—then use it for production while alleviating electricity demand on utility providers and reducing pollutants. Agriculture—specifically the poultry industry—could potentially play a significant role in reducing environmental pollutants as well as lowering farm production costs. The University of Delaware Center for Energy and Environmental Policy (CEEP) is conducting a study on Delaware's poultry industry and the potential for solar electric applications. Preliminary results indicate that under certain scenarios, solar energy is economical for the state's producers (Byrne et al. 2005). Incentives and support for renewable energy vary by state across the country.

Electricity plays a crucial role in poultry production. Production of poultry relies heavily on electricity for lighting, ventilation, heating and cooling, and running electric motors for feed lines. Rising energy costs have cut into poultry producers' profitability throughout the state and region. In the past, solar PV's large capital costs have deterred widespread investment. However, the cost to produce PV panels in the late 1970s was around $25 per watt but has since dropped to less than $3.50 per watt, an 86% reduction (Bradford 2006). Alternative green energy sources are currently under investigation to determine economic feasibility and environmental benefits.

Tennessee's poultry industry is especially significant to the state's agricultural economy. In 2006, Tennessee's agriculture accounted for 11.7% of the state's economy and generated $38.8 billion in output. Over 40% of Tennessee's total land area is in farm land, with cropland accounting for more than 63% of farm land (NASS 2007). In 2005, broilers were the second leading commodity for cash receipts in the state representing over $431 million, 17.1% of the total, only behind cattle and calves (NASS 2007). In 2002, there were 792 commercial broiler farms located in Tennessee generating $268.4 million or 13.4% of the state's agricultural economy (NASS 2006). As shown in Table 1, commercial broiler industry cash receipts climbed to $431.1 million or 17.1% of the state's agricultural receipts in 2005. Broilers and other meat-type chickens account for the majority of poultry production in Tennessee. Table 2 displays the 1997 and 2002 census data breakdown of poultry production in the state.

Economic feasibility of solar adoption for poultry producers is highlighted in this research. This paper analyzes PV under current economic cost conditions, and its potential to offer the state a variety of economic and environmental advantages over conventional electricity sources.

Literature Review

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" in April 2005, no other research has addressed solar PV system feasibility and uses on poultry farms. In December 2006, the University of Delaware received research funding to investigate the feasibility of PV systems with field studies projected to begin in the first quarter of 2007. Prior to this report, most research has focused on the increasing costs of energy for poultry producers. Simpson, Donald, and Campbell (2007) estimated 2006 electricity costs per house to be about $3,700, an increase of about $1,200 per house from the previous year, for poultry operations in North Alabama. Additional research has addressed high propane and heating costs for producers. Hardy, Clark, and White (1983) estimated a linear programming model for a solar thermal collector to supply a poultry house with 60, 40, and 20 percent of its annual heating needs. Results displayed that the smallest solar heating system, which provided 20 percent of heating needs, was still more expensive than the conventional propane system. In Van Dyne's (1976) study of heating Maryland's poultry houses with solar energy, 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, Dobbs, Christianson (1985). Since that time only a handful of agricultural extension publications from various states have been generated on solar energy utilization for confinement livestock buildings that discuss design, installation, solar heating systems and other offgrid applications. Turner, Dale, and McKenzie (1981) investigated the potential for solar energy and its heating uses on farms and homes. This study aims to expand the literature on solar PV system feasibility due to recent developments in photovoltaic solar modules, state and federal grants and other incentives, and the declining cost of the PV system.

Methodology and Data

Two poultry producing counties in different areas of the state were chosen in order to analyze solar energy's economic potential across Tennessee. Greene County, located in the northeast portion of the state, and Weakley County, positioned in the northwest portion of the state were chosen as the case study regions for this analysis. Another disparity among the counties is the amount of solar radiation each site receives daily. According to the National Renewable Energy Laboratory's (NREL) PVWATTS Calculator, Greene County receives between 4.5-5.0 $kWh/m^2/day$ and the majority of Weakley County receives a larger amount of solar radiation of 5.0-5.5 $kWh/m^2/day$ for flat plate panels tilted south at latitude. The counties also have similar amounts of land area. In 2002, 64.5% and 62.0% of the total land was devoted to agriculture in Weakley and Greene counties, respectively (NASS 2006). Both counties ranked in the top 15 in the state in broiler production in 2002. Additionally, there were 8 farms producing 4,549,508 birds in Weakley County and 27 farms producing 8,937,538 birds in Greene County in 2002 that had any sales of broilers and other meat type chickens (Warren 2002). Greene County ranked first in the state in livestock numbers in 2006, and Weakley County ranks among the top counties in the state in corn, wheat and hog production (NASS 2007). Additionally, both counties are located in different poultry producing clusters in Tennessee. These two regions are analyzed in order to evaluate potential geographical solar advantages.

Electricity output, measured in kilowatt-hours (kWh), was calculated for two size solar PV systems (5 and 20 kW). Output was estimated using PVWATTS Solar Energy Calculator assuming flat plate panels facing south at latitude tilt. PVWATTS is an internet-accessible simulation tool for providing estimates of the electrical energy produced by a grid-connected crystalline silicon PV system for locations across the United States. Monthly energy production is determined by a number of climatic factors and efficiencies (Marion and Anderberg 2000). Annual energy output estimates for Greene and Weakley counties are displayed in Table 3. Results from PVWATTS show that Weakley County has a geographical solar advantage with an average of 5.13 $kWh/m^2/day$ compared to Greene County's average of 4.84 $kWh/m^2/day$.

Poultry producers' electricity costs are usually highest during the warm months of summer when ventilation fans are used to cool the birds frequently. The output for a solar PV system coincides with the higher electricity usage and is highest during the summer months when the sun's radiation is at its peak. Table 4 shows the monthly output for a 20 kW system in each county.

Life of the solar PV system is assumed to be 25 years for the purposes of this study. As noted in the introduction, TVA will pay 15 to 20 cents per kWh output for the first 10 years. Assumptions include that poultry producers will receive the higher commercial rate of 20 cents. In years 11 through 25, it is assumed that all electricity produced from the system is used on farm and represents a decrease in the producers' electricity bill. Local utility providers were contacted for current electricity rates paid by poultry producers (Weakley County- Weakley County Municipal Electric System and Greene County- Greeneville Light and Power). Electricity price increases of 2% annually over the life of the PV system were utilized to predict future electricity savings in years 11 through 25. Estimates for annual PV system electricity output were held constant over the life of the system with annual maintenance costs of 0.6% of initial cost of the system without rebates or grants (Byrne et al. 2005).

Renewable Incentives

State and federal incentives for renewable energy are currently available and are analyzed with the cost of the solar PV system. Effective 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 (North Carolina Solar Center 2007). The grant amounts are 40% of the installed cost for solar PV systems with a maximum grant of $75,000 and minimum of $5,000. Funds allocated to this program for the 2007 fiscal year were $3,750,000.

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 (North Carolina Solar Center 2007). 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 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. 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 corporate tax credit of 30% for solar, modified accelerated cost-recovery system (MACRS) corporate depreciation, and the TVA GPS Generation Partners Program outlined earlier (North Carolina Solar Center 2007).

Electricity output for the 5 and 20 kW systems were estimated using PVWATTS Solar Energy Estimator for both Greene and Weakley Counties. Output was used to determine the dual-metering revenue from TVA over the 10 year contract. Initial cost of the system was estimated under a range of cost scenarios from $6,000 to $9,000 per installed kW. Currently there are two grant incentives that Tennessee poultry producers could apply: 1) Tennessee Clean Energy Technology Grant which provides 40% of the initial cost of the solar PV system and 2) 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 were financed using a 10 year, 7.5% fixed interest rate. The 30% tax credit collected at the end of year 1 accounted for revenue in year 1 for the investment. 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) (Wall Street Journal 2007).

Results

Economic feasibility of solar PV energy adoption was evaluated for poultry producers in both Greene and Weakley Counties in Tennessee. Table 5 displays the results of the case study analysis. Under low cost scenarios along with the 65% cost-share in state and federal grants and the 30% tax credit, solar PV appears economical for poultry producers given TVA's dual-metering contract and that electricity prices increase 2% annually over the next 25 years. Under current solar cost conditions of $7,500 to $8,500 per installed kW (Tripp 2006), PV does not appear to be as competitive with conventional electricity. For example, at a cost of $7,500/kW, a 20 kW system in Weakley County has a net-present value (NPV) of -$1,285.64 and internal rate of return (IRR) of 7.77%. However, at a system cost reduction of $500 per kW ($7,000/kW), the same system appears economical for producers with an estimated NPV of $1,871.42 and IRR of 8.98%.

The study hypothesized that solar differences due to geographical location in the state would create disparity among the two regions of poultry producers and the economic feasibility for solar PV energy. As shown in Table 5, for example, a 5 kW PV system in Greene County under the $7,000/kW system cost delivers a negative NPV of $236.41 whereas the same system delivers a positive NPV of $468.29 for Weakley County producers.

There were no significant differences economies of scale feasibility between the 5 and 20 kW systems. However, initial capital costs and payback periods are large for solar PV systems in general. Results show that under current incentives for solar PV technologies, solar is not economical at today's prices including state and federal incentives. However, solar PV systems have come a long way since the 1970's and could become more economical if more support were given to renewable energy technologies and costs of solar materials continue to decline. Evaluation of solar energy's potential for poultry operations is best conducted on a case-by-case basis. Individual poultry producers should analyze their own situation and finances to determine whether solar PV is a good investment or not. This research presents one approach to evaluating solar PV's potential for Tennessee's poultry producers. An example cash flow chart is illustrated in Table 6.

Another benefit of solar PV adoption among the state's poultry producers is the environmental factor. With approximately 800 broiler producers in the state, widespread adoption of solar PV would alleviate a considerable amount of pollution in the region from conventional "coal-fired" electricity production. Table 7 shows the estimated environmental effects of poultry producers adopting solar PV technologies.

If new laws are passed concerning environmental emissions in the future, solar PV and other renewable energy technologies could become more financially attractive. Once 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. Therefore, while solar photovoltaic (PV) energy is not currently economical on a blanket basis, some scenarios for individual producers could be favorable. As the cost of solar energy declines and federal and state incentives remain, poultry producers in Tennessee could benefit from adopting solar energy to provide electricity for their farm operations.

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Table 1. Broiler Cash Receipts for Tennessee Producers, 2000-2005

Year	Cash Receipts (million $)	% of Total Ag Receipts
2000	229.68	11.9
2001	363.48	17.2
2002	268.41	13.4
2003	322.32	12.9
2004	439.60	17.2
2005	431.16	17.1

Source: Economic Research Service, U.S. Department of Agriculture, 2006.

Table 2. Poultry Production in Tennessee

Poultry Sales- Tennessee	1997	2002	% Change
Any poultry-farms	1,865	2,554	36.9
Layers and pullets-farms	413	893	116.2
#	1,955,981	2,533,497	29.5
Layers 20 weeks old and older-farms	351	664	89.2
#	1,078,028	923,682	-14.3
Pullets for laying flock replacement-farms	113	333	194.7
#	877,953	1,609,815	83.4
Broilers and other meat-type chickens-farms	651	792	21.7
#	137,801,700	181,420,343	31.7

Source: NASS, U.S. Census of Agriculture (1997 and 2002).

Table 3. Annual Energy Output for Solar PV Systems

	Annual Output (kWh)	
System Size (kW)	Greene Co.	Weakley Co.
5	6,242	6,641
20	24,966	26,563

Source: National Renewable Energy Laboratory, PVWATTS Solar Energy Calculator.

Table 4. Annual Energy Output for 20 kW System

Month	Greene Co. (kWh)	Weakley Co. (kWh)
Jan	1,555	1,749
Feb	1,662	1,809
Mar	2,266	2,393
Apr	2,401	2,591
May	2,373	2,433
Jun	2,340	2,484
Jul	2,400	2,548
Aug	2,348	2,568
Sep	2,250	2,356
Oct	2,272	2,333
Nov	1,643	1,678
Dec	1,458	1,620
Total	24,966	26,563

Source: National Renewable Energy Laboratory, PVWATTS Solar Energy Calculator.

Table 5. Economic Results for PV with 65% Incentives and Tax Credit

County	Size (kW)	Cost per kW	Payback (Yrs)	Benefit/Cost	NPV	IRR (%)
Weakley	20	$6,000	10.7	1.19	$8,185.55	11.87
		$6,500	13.2	1.11	$5,028.49	10.34
		$7,000	15.7	1.04	$1,871.42	8.98
		$7,500	18.2	0.98	($1,285.64)	7.77
		$8,000	20.6	0.92	($4,442.71)	6.67
		$8,500	23.0	0.87	($7,599.77)	5.67
		$9,000	BESL*	0.83	($10,756.84)	4.75
	5	$6,000	10.7	1.19	$2,046.82	11.87
		$6,500	13.2	1.11	$1,257.55	10.34
		$7,000	15.7	1.04	$468.29	8.99
		$7,500	18.2	0.98	($320.98)	7.77
		$8,000	20.6	0.92	($1,110.25)	6.67
		$8,500	23.0	0.87	($1,899.51)	5.67
		$9,000	BESL	0.83	($2,688.78)	4.75
Greene	20	$6,000	12.7	1.13	$5,365.02	10.66
		$6,500	15.3	1.05	$2,207.96	9.18
		$7,000	18.0	0.98	($949.11)	7.87
		$7,500	20.6	0.92	($4,106.17)	6.69
		$8,000	23.2	0.87	($7,263.24)	5.63
		$8,500	BESL	0.82	($10,420.31)	4.65
		$9,000	BESL	0.78	($13,577.37)	3.75
	5	$6,000	12.7	1.13	$1,342.13	10.66
		$6,500	15.3	1.05	$552.86	9.18
		$7,000	18.0	0.98	($236.41)	7.87
		$7,500	20.6	0.92	($1,025.67)	6.70
		$8,000	23.2	0.87	($1,814.94)	5.63
		$8,500	BESL	0.82	($2,604.21)	4.65
		$9,000	BESL	0.78	($3,393.47)	3.75

*** BESL indicates "Beyond Estimated System Lifetime of 25 years."**

Table 6. Example Cash Flow, Greene County 5 kW System ($6,000 per kW)

Year	Finance Charges	Maint. Cost	Tax Credit	TVA Income	Savings	Yr. Balance	Total Balance
0							
1	($1,495.68)	($180.00)	$3,150.00	$1,248.40		$2,722.72	$2,722.72
2	($1,495.68)	($180.00)		$1,248.40		($427.28)	$2,295.44
3	($1,495.68)	($180.00)		$1,248.40		($427.28)	$1,868.16
4	($1,495.68)	($180.00)		$1,248.40		($427.28)	$1,440.88
5	($1,495.68)	($180.00)		$1,248.40		($427.28)	$1,013.60
6	($1,495.68)	($180.00)		$1,248.40		($427.28)	$586.32
7	($1,495.68)	($180.00)		$1,248.40		($427.28)	$159.04
8	($1,495.68)	($180.00)		$1,248.40		($427.28)	($268.24)
9	($1,495.68)	($180.00)		$1,248.40		($427.28)	($695.52)
10	($1,495.68)	($180.00)		$1,248.40		($427.28)	($1,122.80)
11		($180.00)			$591.98	$411.98	($710.82)
12		($180.00)			$603.82	$423.82	($287.00)
13		($180.00)			$615.89	$435.89	$148.89
14		($180.00)			$628.21	$448.21	$597.10
15		($180.00)			$640.78	$460.78	$1,057.88
16		($180.00)			$653.59	$473.59	$1,531.47
17		($180.00)			$666.66	$486.66	$2,018.13
18		($180.00)			$680.00	$500.00	$2,518.13
19		($180.00)			$693.60	$513.60	$3,031.73
20		($180.00)			$707.47	$527.47	$3,559.20
21		($180.00)			$721.62	$541.62	$4,100.82
22		($180.00)			$736.05	$556.05	$4,656.87
23		($180.00)			$750.77	$570.77	$5,227.64
24		($180.00)			$765.79	$585.79	$5,813.43
25		($180.00)			$781.10	$601.10	$6,414.53

Table 7. Environmental Emissions Reduced per Year

	Size System	Annual Output	CO2	NOx	SO2	Mercury (Hg)
County	kW	kWh	lbs	lbs	lbs	Milligrams
Weakley	5	6,641	13,767	33	88	113
	20	26,563	55,065	133	351	453
Greene	5	6,242	12,940	31	83	106
	20	24,966	51,755	125	330	426

Source: Leonardo Academy, Inc.
http://www.cleanerandgreener.org/resources/emission_reductions.htm