



THE POTENTIAL OF SOLAR ELECTRIC APPLICATIONS FOR DELAWARE'S POULTRY FARMS

FINAL REPORT

A Renewable Energy Applications for Delaware Yearly (READY) Project

Center for Energy and Environmental Policy
University of Delaware

April 2005

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1. INTRODUCTION

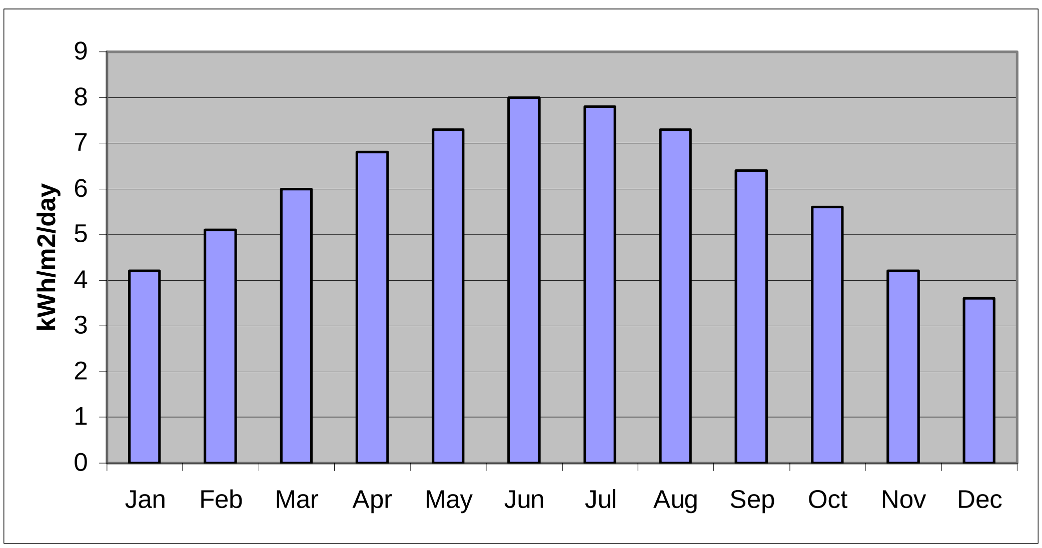
1.1 READY Project Mission

The Renewable Energy Applications for Delaware Yearly (READY) project has the mission of "identifying high-value, high-visibility renewable energy applications; determining approaches to encourage renewable energy suppliers to enter Delaware markets; developing creative and effective education and consumer outreach regarding renewable energy technologies."

1.2 *PV for Poultry Farms*: An Overview

This report explores the feasibility of using photovoltaics (PV) to provide renewable energy to Delaware poultry farm operations. PV—more commonly known as solar electric panels—produces electricity through a photoelectric process triggered by sunlight in cells mounted on panels.

PV offers a number of benefits to Delaware as an alternative energy technology. Delaware has sufficient solar energy to provide more than ten times its current electricity needs (see Figure 1 for an estimate of maximum available solar radiation). PV has the potential to offer the State an array of economic, security of supply, and environmental advantages over conventional electricity supplies from the grid.



Source: NREL Renewable Resource Data Center

Figure 1. Total Solar Radiation in Delaware, Monthly Averages 1961-1990

There are several reasons why poultry farms can be considered a visible and valuable potential user of PV.

- Economic significance — Delaware's poultry farms provided 70% of the state's 2001 cash farm income.

- National profile of the state's poultry industry — With poultry production at around 260 million birds per year, Delaware is visible in the national market. Its utilization of renewable energy would encourage renewable energy suppliers to enter Delaware markets.

- Potential for economic and environmental benefits — Electricity is often a significant cost component for poultry farming. Use of PV on farms would provide energy services in an environmentally-friendly way, has the potential to reduce energy costs, and could offer local economic development benefits.

1.3 Goals of this Study

This study investigates the technical and economic potential of PV applications for Delaware's poultry farms, and has as its goal to produce advice on the optimum use of PV by the sector.

2. BACKGROUND

2.1 Existing Research

To date, there are no major studies of the potential applications of PV for poultry farming in the United States. Explorations of PV use and agriculture largely entail solar water pumping and other off-grid applications (see, e.g., ASA 2001). Most research focuses on the use of agriculture to produce energy—through biomass—and not the use of renewable energy for agricultural production. There is, however, a considerable literature on the applications of PV for a range of domestic, industrial, and commercial applications, and a number of analytical tools and techniques have been developed that can be applied in this investigation (see, e.g., Byrne et al. 1995, Byrne et al. 1998, Byrne and Boo 1999). This study is one of the first investigations into the specific applications of PV to poultry production.

2.2 Delaware's Poultry Industry

In the early 1900s, chickens were raised almost solely to produce eggs. Then, in 1923, Celia Steele of Oceanview, Delaware revolutionized poultry production by raising flocks of broilers and selling them for consumption as young birds. In 1944, Delaware produced 60 million chickens in this manner (Williams 1999). Since then, poultry production has grown into a major national industry and Delaware has remained prominent. From 1990 to 2002, the number of chickens produced annually in Delaware averaged 250 million birds. Production in this period (in terms of live weight) increased 33%, from around 1,160 million pounds to 1,540 million pounds over the 12-year period (DASS 2003). Delaware ranks tenth in the nation in numbers of birds produced and seventh in pounds produced. Delaware's Sussex County produces more birds than any other county in the nation (DASS 2003).

Many of the industry's economic characteristics and operational activities at the farm scale are strongly influenced by the conditions of the contractual obligations between the growers and processing corporations. Five large companies dominate Delmarva Peninsula chicken production: Tyson, Perdue, Allen, Townsends, and Mountaire. Some of these firms produce their own flocks, but the majority of flocks are raised by local farmers under contract with these firms. These contracts specify which costs are borne by each party, determine the value of the poultry produced, and often specify particular aspects of chicken-raising. The companies provide growers with chicks, feed, and gas for winter heating of the sheds. Under such contracts, the birds are the property of the company and the poultry farmer is responsible for growing the birds to market weight. Payment schedules reflect productivity, measured by flock weight at market, accomplished by the grower. Companies often rate growers on their efficiency and reward higher productivity with bonuses and other incentives.

Farmers can exert cost control over a limited set of production variables and profitability is often enhanced through cost-cutting. One of the larger costs of production that farmers can influence is that of electricity, as growers must pay for their own electric power.

2.3 The Role of Energy in Poultry Production

Energy plays a crucial role in poultry production. In a typical commercial poultry house, energy is used for several applications; most importantly for lighting, heating, ventilation and cooling, and running electric motors for feed lines. Many of the functions in the poultry shed are controlled by automatic systems, the parameters of which are established by the grower's contract.

The most significant management aspect of poultry production related to energy is "climatized air" (Auburn University 2001:1). Optimum temperatures and ventilation are required to maximize productivity. Poultry house temperatures are typically controlled by thermostat and ventilation requirements are also calculated by automatic systems. Adequate air conditions are provided through heating and ventilation to attain proper temperature (ranging from 70 to 95^{o}F, depending on the growth stage of the birds) which greatly affects how much food and water birds will consume (Scanes et al. 2004). In houses that are too cold, chickens expend energy to keep their bodies warm which depresses their growth rate; in houses that are too warm, calories are spent on labored breathing and panting (Donald 1999). In the winter, most farms in Delaware use propane heaters linked to thermostats. For cooling and ventilation, large electric fan units located at the end walls (tunnel ventilation) or on the sidewalls move interior air. Ventilation is critical for high productivity. Sufficient air circulation is necessary to minimize breeding of viruses, fungi and bacteria that can afflict the flock. A minimum standard in the industry for air movement is 0.5ft^2 per minute per pound of body weight (Scanes et al. 2004: 202).

As well, lighting plays an important role in bird growth and feeding. Producers vary the intensity and daily hours of lighting by the age of the flock to stimulate poultry growth. There is no one standard for optimal lighting to maximize growth and there is considerable variation in lighting schedules across the industry. It has been estimated that a 40-W incandescent bulb produces sufficient light for 200 ft^2 of floor space (Palmer and Odor 1985: 8).

2.4 Security of Power Supply

Due to the aforementioned factors, security of electricity supply is critical to poultry production; any unexpected loss of power can affect the health and growth of the flock and in extreme cases can prove fatal to the birds (such as a loss of cooling and ventilation during the summer). Birds are very sensitive to their environments and since the conditioned environment of poultry houses is completely reliant on electricity, power outages will cause changes in temperatures and increasing concentrations of ammonia and germs. Extreme heat or cold will result in greatly increased mortality in the flock. In fact, failures of climate control in sheds under certain circumstances have eliminated entire flocks. For example, in Mississippi in 2000, power outages caused by storms resulted in the deaths of over 250,000 birds (OAC 2000).

Loss of electricity to poultry farmers is a source of potential economic loss. To avoid such losses, small generators are used to supply emergency power. There is no licensing system for these units and no firm data is available on their number or hours of use. Anecdotal advice suggests that testing and maintenance ranges from one hour a week to one hour a month, giving an annual range of 12 to 52 hours of operation. Hours of emergency use are difficult to estimate across the state's farms, but industry sources have suggested that emergency use would not usually exceed 10 to 25 hours annually.

Unit size varies, but an industry benchmark for sizing of a backup power system is 1 to 1.5 kW per 1,000 birds in the flock. Anecdotal evidence suggests that generator size varies from 15 kW to 500 kW. Given an average flock size of 23,880 birds per house, average generator size is likely to be between 25 kW and 35 kW per house, or around 150 kW for the typical 5-house farm (Cunningham 2003).

2.5 Energy and the Costs of Production

As mentioned above, under a growing contract with a large poultry company, a producer receives chicks, feed, and gas for winter heating of the houses. As such, producers have no control over many of the basic cost drivers. To maximize returns, the producers seek to minimize those costs under their control and to produce a flock that will receive the best price.

Poultry production is conducted on a cyclic basis throughout the year and energy demand (and energy expenses) varies with this cycle. In the farms studied, total daily electricity use was most highly correlated with bird age (0.745 Pearson correlation coefficient, statistically significant at the 0.01 level) and then with outside temperature and lighting (significant at the 0.05 level). Typically, the growth stage of the production cycle consists of 53 days (+/- a few days), starting with delivery of chicks and concluding with the removal of mature birds. After cleaning and maintenance, the sheds are prepared for the next cycle. Annually, 5.5 flocks are ordinarily cycled through a poultry house (Cunningham 2003).

Energy costs can be quite high for poultry production, especially during the summer and warmer months when there is a high demand for cooling the poultry sheds to maintain an even temperature optimum for production. Energy costs for heating, usually for propane, while often high, generally do not concern the contract growers as these costs are borne by the poultry company.

Any opportunities to lower the contract grower's expenditure on electricity will contribute to the overall profitability for the production of each flock for the contract grower, as this is one of the larger costs that must be met by the growers.

Energy costs vary between producers, depending on such factors as the number and size of poultry sheds, electricity-consuming equipment used, and the manner of its use. There are no comprehensive data on energy use by poultry farmers in the state, but some estimates are possible for annualized electricity expenditure. A typical poultry house (23,880 birds/flock, 5.5 flocks/year) with the normal lighting regime and tunnel cooling using electrical fans consumes around 20,000 kWh per year. At the residential rate supplied by Conectiv, annual electricity expenditure per house (minus flat customer charges) is $1,672. At Delaware Electric Cooperative's residential rate, annual per house expenditure is $1,532. Considering that most poultry operations consist of several houses, electricity cost for poultry farming is a significant component of annual expenditure.

2.6 Basic Design of Poultry Houses

Poultry houses generally follow a fairly basic design. Until recently, a typical Delaware poultry house was 500’ long by 40’ wide, but there has been a trend towards much larger houses, the largest now being up to 500’ long by 66’ wide (Garrett VanWicklen, personal communication, April 2, 2004). This trend is most likely driven by economies of scale for construction. These larger buildings have greater demands for energy consumption, especially for heating, cooling, and ventilation. A typical construction cost for a 500’ by 40’ shed is $150,000 (Cunningham 2002).

Energy efficiency is not typically taken into account in the design and construction of these buildings. Energy consumption could be reduced through energy efficiency and energy conservation measures. It is estimated that 20% of the energy used in poultry production could be saved through conservation and efficiency (Scanes et al. 2004: 141).

Depicted below is a typical modern poultry house of steel construction. Note several fan installations on the side wall used for cooling and ventilation. Note also the considerable exposed roof area, suitable for PV installation.

Figure 2. Typical Modern Poultry House

2.7 PV Systems Suitable for Poultry Farm Operations

The poultry industry seems to be increasing its involvement in environmentally friendly practices. Tyson has entered an agreement with the U.S. Environmental Protection Agency to install more efficient lighting, which should save 85 million kWh yearly (Tyson 2004). Perdue has a program to turn wastes into biomass energy. Allen’s Family Foods, Mountainaire, and Perdue fund the Delaware Environmental Stewardship Program which awards poultry farmers who are making strides in environmental protection.

There are a number of commercial PV manufacturers producing PV systems suitable for applications to the poultry farming sector. These systems would comprise: PV panels, a charge controller, an inverter to convert DC current into AC current, and a battery system. Solar panels charge the battery via the charge controller with DC electricity; electricity drawn from the battery is converted to AC by the inverter and then fed into the existing farm electric system. To best take advantage of this compatibility, it is important that an effective systems controller be in place. It must be able to manage load priorities as a function of available sunlight, keep track of the state of charge of the battery, and monitor and adjust for ambient temperature (Parker 1991: 126). Based upon discussions with PV manufacturers and poultry farm experts coordinated for this study, these standard systems are suitable for poultry farming operations.

As PV systems are modular and therefore flexible, the sizing of the components is optimized to the specific needs of the operator and the available sunlight. Solar panels are rated according to their output in watts. Inverters are also sized in watts and have a typical range of 500 to 4000 watts (Renewable Energy Works 2004). Batteries are sized in Amp-hours. Each of the components must be sized according to system needs.

PV panels could easily be attached to poultry shed roofs. Those with a southern orientation would receive the most solar insolation; the optimal angle of the panels varies according to latitude and to whether winter or summer optimization is sought.

While trees are often planted around poultry houses for aesthetics, wind breaking, filtration for dust, odors and noise, and capture of noxious gases, tree height is not a crucial factor in these functions and shorter tree species can be selected to avoid shading of a PV array (CANR 2001).

2.8 Potential PV Applications for Poultry Farming

There are several ways in which PV can be integrated into the routine production activities of Delaware's contract growing operations. In this study, PV systems were used as additional power sources to grid-supplied power (i.e., these PV systems are not designed to meet all electricity needs).

Matching Peak Daily and Seasonal Loads

Times of peak electrical demand within a grid system are when electricity is most expensive and this cost is often reflected in higher rates set during these periods. Overall electrical demand on a grid is highest during summer daylight hours. Electricity consumption in poultry houses is also usually highest during the summer daylight hours, when cooling and ventilation demands are greatest. Output from PV is usually maximized in the summer and through the middle of the day when solar insolation is greatest. Therefore, PV peak output and the poultry house peak loads will often be coincidental.

Net Metering Potential

Each flock occupies the poultry house for about 53 days; afterwards there are about two weeks during which the house is prepared for the next incoming flock. Over a year, this translates into about five and one-half flocks, leaving a total of ten weeks when there is minimal electricity consumption. While chickens are present, PV is used to meet electricity demands, but when the growth cycle ends, almost all electricity from the PV system becomes available for sale. Selling electricity back into the grid is facilitated by laws that mandate what is called 'net metering,' meaning that the monthly electricity bill met of the contract grower would be offset by credits gained from electricity sales to the utility. In 1999, the Delaware state legislature adopted a policy which requires all utilities in the state to offer net metering to customers operating renewable energy systems of 25 kilowatts or less. The requirement applies to all classes of customers and there is no statewide limit.

Emergency Power

Many contract growers have a back-up diesel generator for use during emergencies when grid power is lost. Such systems impose an additional cost on growers for their purchase, fueling, maintenance, and operation. PV systems with battery or other storage could supply power during times when grid supplies are affected, making PV a potential source of emergency power that does not require an additional back-up system. Even a small amount of PV-battery back-up power, as the proposed system offers, would provide electricity for some ventilation and lighting for those farmers that have chosen not to purchase a generator.

2.9 Electricity Supply to Delaware Poultry Farmers

Kent and Sussex County growers are serviced by the Delaware Electric Cooperative, or Conectiv. Conectiv's electricity is produced primarily from coal (54%) and nuclear plants (33%), with an additional 10% coming from oil and natural gas, and 3% from hydropower. The Delaware Electric Cooperative has a similar fuel mix: 63% from coal, 31% from nuclear, and 6% from natural gas.

3. DATA AND METHODOLOGY

3.1 Overall Research Design

This study assesses the potential for PV applications to the poultry industry by modeling a typical poultry farm operation using data from the typical Delaware farm and the software *PV Planner* (developed by the Center for Energy and Environmental Policy under contract to the National Renewable Energy Laboratory—see CEEP 1996). Analysis includes an assessment of the economic potential of PV for this application. The research focuses on two aspects of the possible use of PV applications for poultry farms in Delaware: technical feasibility and economic feasibility.

Solar radiance data from southern Delaware is examined and an analysis is conducted to determine optimal location and tilt angle of PV panels. Delaware receives an average of 4.6 kWh/m^2/day of global solar radiation (NREL 2004). The data is comparable to data from areas in the U.S. where PV has been successfully deployed.

The economic analysis includes reviewing electricity usage and costs from several farms (which remain anonymous at the request of the growers), assessing the effects of PV on electricity costs, reviewing existing incentives (such as Delaware's Green Energy Fund rebates) and calculating the effects of net metering.

Both residential and commercial rates are examined. Line congestion is a problem in many parts of southern Delaware and a cost for the electricity industry. This study assumes that the costs of this congestion can be captured, for the purposes of this analysis, by using commercial building "demand" charges, which are based on the peak kW load measured monthly for each customer. While many Delaware poultry farmers are not assessed demand charges, the inclusion of this item can be seen as a proxy for the statewide benefits that would accrue if southern Delaware farms employed PV for peak-shaving (see Byrne et al., 1996, 1998, and 2000 for the economics of PV).

3.2 A Description of *PV Planner*

PV Planner is an analytical software program developed by CEEP to assess the resource and economic aspects of PV systems. This software can simulate the performance of a PV system operating in a dispatchable mode (i.e., a system with battery storage) or as a direct or non-dispatchable system (i.e., without battery storage). Economic benefits and costs are assessed using the financial analysis methods employed by utilities and commercial enterprises. Economic performance is measured as net present value, payback period, and benefit-cost ratio. *PV Planner* calculates payback period in years as the time when cumulative cash flow (including annualized O&M costs) first becomes zero.

3.3 Data

Electricity Consumption

Data, including daily kWh, demand and lighting data were available from a typical poultry farm. This farm measured electricity consumption in poultry houses separately from other farm buildings and that data was collected daily. Annual electricity consumption was 102,500 kWh.

This poultry operation consists of five 42' by 500' houses and each house holds 28,000 birds for a grand total of 135,250 chickens. The average bird density is $0.75ft^2$/bird. Average growing season is assumed to be 55 days, with an average kWh use/day/house of 62.4. If 5.5 growing seasons are completed annually, electricity consumption per house is estimated at 18,875 kWh. A maximum demand of 50.5 kW was reached in the summer. Annual electricity costs for this typical farm are $8,360 on the Conectiv residential rate, and $7,660 on the Delaware Electric Cooperative residential rate.

The farm uses electrical appliances with a maximum load of 15.5 kW per house. Some 82% of this potential maximum load is from ventilation, 10% is lighting and 8% from feed lines (see Table 1). The grower uses a lighting scheme that ranges from 24 hours of light per day for the first 5 days and the last week of a cycle, to 14 hours of light per day for about 7 days when birds are about a week old. Data show that lighting comprises 35% of electricity consumption.

Table 1: Electrical Load for a Single Poultry House

Device	Number	Voltage	Power (Watts)	Total Watts
36-inch Sidewall Fans	5	240	580	2,900
48-inch Tunnel Fans	8	240	1,235	9,880
Lighting	64	120	25	1,600
Feed Line Motors	2	240	600	1,200
TOTAL				**15,580**

From consultation with industry experts, it was determined that the sample farm was broadly representative of most operations in terms of scale of operation, type of electrical equipment, levels of cooling and lighting, and size of buildings.[1]

Solar Energy

Solar energy and climate data for Delaware were obtained from the National Renewable Energy Laboratory (NREL) website. *PV Planner* utilizes Typical Meteorological Year (TMY) solar radiation data to determine PV output. TMY data are developed based on 30 years of weather variation at each monitored site, creating 8,760 hourly observations for a "typical year." *PV Planner* converts the TNY data into 24-hour "typical day" profiles for each month. This is done

[1] In the near future, more detailed electricity consumption and other data will be available from the University of Delaware's College of Agriculture and Natural Resources newly-constructed experimental poultry house in Georgetown, Delaware.

to speed calculation and has been shown to have no significant effect on accuracy (Byrne et al., 1996: 181).

Electricity Prices

Poultry farmers in Delaware usually pay the residential rates shown in Table 2 for their electricity in both the Conectiv and Delaware Electrical Cooperative markets. For this study, commercial and alternative residential electricity rates were also examined, although poultry farmers do not currently pay these rates in Delaware. These rates are displayed in Table 3.

Table 2. Electricity Rates for Small Poultry Operations in Delaware

Electric Company Rate Schedule	Demand Charge ($/kW)	Average Energy Charge (Cents per kWh)
Conectiv Residential Rate	0	8.352
Delaware Electrical Cooperative Residential Rate	0	7.621

Table 3. Alternative Energy Rate Schedules

Rate Schedule	Demand Charge ($/kW)	Average Energy Charge (Cents per kWh)	
		On Peak	**Off Peak**
Conectiv			
Residential Time of Use	7.131(winter) 7.958(summer)	4.825	3.76
Medium General Service	9.821(winter) 14.911(summer)	3.982	3.982
Delaware Electric Cooperative			
General Service	0	7.621	

3.4 Parameters

A number of parameter values have to be set for analysis purposes. The major parameters are discussed below.

Sizing of the PV System

The kW size of an appropriate PV system was determined experimentally. A range of kW sizes was analyzed and the optimal size for the farms was chosen. Optimality was determined as the largest (in kW) system offering, on balance, a positive net present value (NPV) earnings stream. For the electricity needs of the typical Delaware poultry house, a system of 1.5 kW appears optimal. A PV array of this capacity would be around $150ft^2$ in size. Poultry farms would normally have well over 25,500 ft^2 of rooftop area.

Costs of PV systems

Estimates of PV system installed prices vary among manufacturers, type of PV system, and differences in installation costs. A range of installed PV costs were used covering low and high values. The analyzed range is: $6,100/kW and $8,000/kW. All analyses of PV systems in Conectiv service territory included a 50% rebate (up to $22,500) offered by the utility through Delaware's Green Energy Fund. A rebate is not available to Delaware Electric Cooperative customers. For modeling purposes, initial cost of the system is entered after the rebate is deducted.

Period of Analysis

The system was analyzed over a period of 25 years.

For a complete listing of assumptions, please see the Appendix.

4. RESULTS

4.1 Economic Performance of PV under a Residential Rate

Analysis of the economic performance of the PV array in the two utility districts shows that PV is marginally more expensive than grid-connected power supplied by the two utilities using the residential rates. Given the costs of electricity over the 25 year period and the costs of the poultry shed, PV is slightly more expensive than grid-connected electricity, but would not be a significant additional cost to poultry farmers. At the end of the system's 25 year operation, the PV system would cost $488.64 more than the cost of electricity using Conectiv energy alone, or $4,288.03 more than Delaware Cooperative electricity, assuming a PV installation cost of $6,100 per kW. A summary of these results are shown at Table 4. The difference between these two results is due mostly to the 50% rebate offered by Conectiv and also to the lower electricity rate offered by Delaware Electric Cooperative.

Table 4. Economic Performance Using a Residential Rate for a 1.5 kW PV Array

	Conectiv	Delaware Electric Cooperative
Net Present Value ($)	-488.64	-4,288.03
Benefit-Cost Ratio	0.86	0.56
Pay Back Period (Years)	N/A	N/A

These results include a valuation placed on the provision of 9.6 kWh of emergency power by the battery of the PV system. Use of emergency power from the PV system replaces the use of all or part of the emergency power supplied by the standard diesel generator systems and therefore provides an additional source of economic value from the PV system. It is unlikely that a PV system of this size can provide full emergency backup power, but the system's battery would be able to provide some lighting and ventilation intermittently in the event of a power outage. The negative result produced by this analysis may of course change under future economic and policy circumstances.

4.2 Economic Performance of PV under a Rate Design to Meet the Costs of Congestion

Delaware's electricity grid periodically suffers from problems of 'congestion' that occur when the load demands created by consumers cannot be efficiently met through the existing transmission system, and thereby creates a number of costs for the utility. Both the extent and the costs of congestion vary considerably over time; for the period 2000-2003, the cumulative cost for Delaware was $95 million (Delaware Public Service Commission, personal communication, 2004). PV and other distributed generation technologies offer a means to lower these congestion costs. Economic savings created by replacing grid electricity with PV can be included as an economic benefit of PV.

At the present time, the costs of congestion (and, more generally, the wider environmental costs of the conventional energy system) are not reflected in the residential rate of both utilities. Deriving an accurate congestion cost is an extremely difficult task, complicated by the considerable annual variations in these costs. Some utilities use 'locational marginal prices' to recover the costs of congestion.

One way of deriving a substitute rate for this value is the 'Time of Use' rate applied by Conectiv. This rate is made available to the first 500 customers requesting it. This is a variable rate according to the time of day; peak hours under this schedule are from 8am to 9pm during standard time and 9am to 10pm during daylight savings time, Monday through Friday, including weekday holidays.

Analysis of the PV system using the Time of Use rate shows that PV is less expensive than grid-electricity for all PV systems with emergency power considered. Without emergency power benefits, a $6,100 PV system has a marginally negative Net Present Value. Results are presented in Table 5. These results incorporate a 5% contingency.

Table 5. Economic Performance Using the Conectiv Residential Time of Use Service Schedule, 1.5 kW PV array

	Low installed cost ($6,100/kW)	**High installed cost ($8,000/kW)**	**With no emergency power benefits**
Net Present Value ($)	901.99	96.13	-94.77
Benefit Cost Ratio	1.16	1.01	0.99
Pay Back Period (Years)	9.68	14.93	N/A

4.3 Economic Performance of PV under a Commercial Electricity Rate

Analysis was conducted to assess the effect of switching the poultry industry from a residential rate to a commercial rate, as is applied to other commercial enterprises. There are no proposals for such a change and this analysis was conducted on a purely speculative basis.

Commercial customers of Conectiv use the 'Medium General Service Schedule' which would be appropriate for the typical Delaware poultry operation (on the basis of a maximum measured demand of less than 300 kW and a monthly maximum usage of more than 3,500 kWh).

Results of this analysis show that PV systems on the typical Delaware poultry farm have a positive Net Present Value when used to replace electricity charged under the commercial rate schedule. These results cover the range of PV installation prices and a positive NPV occurs even when emergency power benefits are not considered. Table 6 displays this information. The first two columns assume emergency power benefits and a 5% contingency. The last column shows the system result for PV installed cost of $6,100 with no emergency power benefits. Even at a higher system cost, this value is still positive. Because the rate appropriate for a typical Delaware poultry operation under Delaware Electric Cooperative, General Service (not shown), does not include a demand charge and this rate is very similar to the Cooperative's residential rate, PV on a farm under this rate schedule would still have a negative value.

Table 6. Economic Performance Using the Conectiv Medium General Service Schedule, 1.5 kW PV Array

	Low installed cost ($6,100/kW)	High installed cost ($8,000/kW)	With no emergency power benefits
Net Present Value ($)	2,626.90	1,821.04	1,630.14
Benefit Cost Ratio	1.46	1.26	1.24
Pay Back Period (Years)	7.37	9.28	12.72

4.4 Environmental and Local Energy Benefits of PV

There are important environmental and local energy benefits associated with PV use. Both benefits are described below and approximate values for these benefits are discussed.

Potential Emission Reductions from Implementation of a PV-for-Poultry-Farms Program in Delaware

Estimates of the reduction in greenhouse gas emissions by reducing electricity consumption from grid-connected sources can be calculated based on the known emissions profile for the supply of electricity to the state. A 1.5 kW PV system replacing Delaware Electric Cooperative electricity would avoid around 123 tons of emissions of the greenhouse gas CO_2 over a 25 year lifetime. The same system replacing Conectiv electricity would avoid emissions of 112 tons of CO_2 over its lifetime. The emissions of pollutants NO_X and SO_X would also be reduced. NO_X emissions lead to the formation of ozone, which causes breathing problems for some people and also leads to acid rain. SO_X emissions affect lung function and causes haze. A 1.5 kW PV system on the Delaware Electric Cooperative system would avoid the emission of 2 tons SO_X and 0.5 tons NO_X

over its lifetime. For a farm in the Conectiv electricity market, some 1.8 tons SO_X and 0.4 tons NO_X would be avoided by this PV system.

Delaware has approximately 2,475 poultry houses on all its poultry farms spread across the three counties (Parvis, personal communication, 2005). Assuming that one-quarter of these houses have a southern orientation, some 620 houses would offer an orientation that allows for maximum receipt of available solar insolation. Were each of these 620 houses to install a 1.5 kW PV array, the Delaware poultry growers would have a total peak generating capacity of 930 kW of PV (i.e. 620 x 1.5 kW).

Annual and lifetime contributions to emissions avoidance can be calculated based on the output of the 930 kW of installed PV. Annually, CO_2 would be reduced by 3,318 tons, SO_X by 45.3 tons, and NO_X by 12.2 tons (see Table 7 below). Lifetime emissions avoidance (i.e. over the assumed 25-year life of the PV arrays) would be 82,950 tons of CO_2, 1,133 tons of SO_X, and 305 tons of NO_X. This will reduce the state annual poultry farm emissions of these pollutants by approximately 4% each.

Potential Grid Consumption Reduction from Full Implementation of PV in Delaware

The typical poultry house consumes approximately 20,000 kWh of electricity per year. Delaware's 2,475 poultry houses, therefore, consume around 49.5 GWh. If 930 kW of PV were installed in the poultry farm sector (i.e. 620 houses x 1.5 kW), these units would provide 1,828 MWh of renewable energy annually, reducing grid electricity consumption by 3.7% (see Table 8).

Table 7. Emissions Reductions through Full Implementation of PV

	CO_2 (tons)	**SO_X (tons)**	**NO_X (tons)**
Lifetime Reduction From PV	82,950	1,133	305
Annual Reduction From PV	3,318	45.3	12.2
Poultry Farm Estimated Annual Emissions	79,003	1,226	301
Potential Annual Poultry Farm Emissions Reduction (%)	4.2	3.7	4.1

The effect of these PV systems on peak demand can be estimated from information depicted in Table 1. Each of the 2,475 poultry houses has a peak demand of 15.6 kW, or an aggregate peak demand of 38.5 MW. The installed PV under the scenario described would have a peak value of 867 kW and could decrease the sector's peak grid electricity use by 2.3% (Table 8).

Table 8: The Effects of PV on Poultry Industry Grid Consumption and Demand

Annual Electricity Consumption (GWh)	Annual PV Systems Production (MWh)	Grid Consumption Reduction Through PV Use (%)	Peak Demand (MW)	Peak Generation of PV Systems (kW)	Peak Demand Reduction Through PV Use (%)
49.5	1,828	3.7	38.5	867	2.3

It is worth noting that the total poultry house maximum demand of 38.5 MW differs significantly from the average load of 2.3 MW (i.e., 20,000 kWh per year divided by 8760 hours per year). The PV systems could reduce average load requirements by 38%.

5. CONCLUSIONS AND DISCUSSION

This study has investigated the technical and economic potential of PV applications in the state's poultry farm sector. Electricity is essential for poultry operations. It provides light (which influences poultry growth), cooling to maintain a stable temperature (and, thereby, to enhance productivity), and ventilation (to reduce dust and diseases). Security of electricity supply is essential; most operations have emergency diesel generators for times of interrupted service.

Electricity also represents a significant annual cost for poultry growers, and importantly, under the contract system with poultry companies, it is a cost born by poultry farmers. We estimate that under the usual contractual obligations for the typical Delaware farm analyzed in this study, annual electrical expenditure would be $8,360 under the Conectiv residential rate.

This study has found that there are no technical barriers to PV applications in the poultry farm sector. The available solar resource is sufficient for select needs, and there are a number of instances, identified in the report, where PV applications would be cost-effective.

The economic feasibility of PV systems is highly sensitive to electricity prices, notably the rates applied to poultry operations and the effect of incentives for renewable energy production (such as rebates from the State's Green Energy Fund). Results from this study show that the economic feasibility of PV for the poultry farm sector depends on the rates levied in the states' two electricity markets.

Poultry farmers are able to purchase grid-connected electricity at residential rates in both the Conectiv and Delaware Electric Cooperative markets. There are several implications of this policy for PV use:

1) Poultry farmers have access to comparatively low-cost electricity for a commercial operation to meet their energy needs;

2) These rates do not provide the level of incentive to the poultry industry for reducing electricity costs that higher commercial rates exert on other industries; and

3) PV systems must compete with this low-cost electricity.

As a simple means to lower costs of electricity, PV is unable to compete against the residential rate in either the Conectiv or Delaware Electric Cooperative markets.

Using the residential rates, a suitably sized PV array is marginally more expensive to operate over a 25-year timeframe than electricity supplied by either of the two utilities. However, as current residential rates do not explicitly take into account important externalities associated with the existing system, such as the costs of congestion and environmental damage, this study investigated the theoretical effect of taking such costs into account. Two alternative rate structures were examined: a time of use rate and a commercial rate. These rates can be indicative of the rate design required to recover the costs of congestion to the utilities. Under a time of use rate, there was a positive Net Present Value for PV systems installed at $6,100 per kW, with a pay back period of around 11 years. Under a commercial rate like that charged by Conectiv to its small business customers, the results were even more encouraging – a positive NPV of nearly $2,700 and a payback period of 7 years. The current rebate for PV is essential for producing positive economic benefits in these two alternative rate applications.

In practice, there are difficult public policy issues over the costs of congestion, especially regarding who should bear the costs and how they should be recovered. In this study, pricing to reflect congestion costs has been considered, but the study does not assume that a change in poultry farm rates is needed. Indeed, it may be more appropriate to provide a rebate to poultry farms installing PV systems in an amount equal to the difference in the residential and commercial or time of use residential rates.

Interruptions to supply threaten flocks and farm income, leading the majority of poultry farmers to acquire emergency power in the form of generators. Farmers could take advantage of the several hours of emergency back-up power provided by a PV system through battery storage. PV systems are unlikely to replace the necessity for a back-up generator entirely, for interruptions to supply can exceed several hours. But there may be applications on poultry farms that furnish several services, from electrical energy to emergency power for selected electrical uses.

Beyond the economics of producing electrical energy with PV, environmental advantages are always present through use of this technology. PV applications replace energy from the grid and, thereby, reduce the release of pollutants such as CO_2, NO_X and SO_X into the environment. A *PV for Poultry Farms* program would allow Delaware to lower emissions from the poultry farm sector by an estimated 4%. As well, PV use would create a local electrical energy resource equal to 2.3% of the poultry farm sector's peak electricity demand. Through the utilization of a local renewable resource, a *PV for Poultry Farms* program would enhance local economic development by circulating energy payments within the region and creating new employment opportunities in the State.

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APPENDIX

1. Technical Assumptions for PV System

- Array DC Conversion Efficiency: 11% (Solar Energy Industry. (2004) Our Solar Power Future).
- Inverter DC to AC Efficiency: 94% (http://www.windsun.com/Inverters/inverterFAQ.htm, http://www.21stcenturysolar.net/solar-qanda/, http://www.101iq.com/solar.htm)
- Battery Efficiency: 85% (http://www.rockymtsolar.com/dankoffsizinginstructions.doc)
- Array Angle: 45°

2. Economic Assumptions

Electricity rate information was obtained from Conectiv and Delaware Electric Cooperative.

- Installed Capital Costs (not including storage): $6,100 to $8,000 per kW (Solar Energy Industry. 2004. *Our Solar Power Future*)
- Installed Battery Cost: $150 (Distributedpowersolutions.com, various manufacturers)
- System Book Life: 25 years
- Battery Replacement Cost: $100
- Annual Maintenance Cost: 0.6% of initial costs (Sandia)
- Evaluation Period: 25 years
- Average Income Tax Rate: 33%
- Discount Rate: 12%
- Customer Debt Ratio: 100%
- Loan Terms
  - Interest Rate 6% (Wilmington Trust, Delaware National Bank)
  - Loan Period 10 years (Wilmington Trust, Delaware National Bank)
- Equipment Depreciation Duration: 5 years
- Escalation Rate for Electric Rates: 3%
- Equipment Life: 25 years