

Article

Economic Impact of Energy Accounting Schemes for Commercial Systems on a Broiler Farm with Power Demand and Generation

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Abstract: The aim of this study was to assess the impact of the on-farm solar photovoltaic (PV) generation to offset grid electricity consumption on a commercial poultry farm in the US. Hourly electricity production by PV systems was estimated using the System Advisor Model (SAM) of the National Renewable Energy Lab (NREL) and compared with the estimated electric load demand of a broiler house. We analyzed the economic benefits of installing solar systems of three capacities under net energy metering and net energy billing pricing scenarios. Results suggested that a smaller PV installation of 35 kW_p, while substantially short of meeting energy needs, resulted in an 85% self-consumption ratio, whereas the larger 70 kW_p and 105 kW_p PV systems, led to 59% and 42% self-consumption ratios, respectively. This is important when analyzing pricing schemes as lesser amounts of PV energy created are sold to the grid with the smallest system, and, thereby, the least pricing effects on profitability occur across pricing scenarios. Although all scenarios lead to positive net present values (NPVs), under either type of the pricing scenarios, farm business owners realize more favorable energy sales with NEM, which would spur PV system adoption. Results of this study thus provide information to both poultry farmers, considering the size of system installations and policy makers interested in affordably increasing renewable energy supplies and/or rural development.



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Keywords: photovoltaic systems; distributed generation; price support schemes; net metering systems

1. Introduction

Distributed generation (DG) using photovoltaic (PV) technology has become attractive in the past decades primarily because of the dramatic technological development that has led to cost savings. As such, the US Department of Energy (DOE) estimates that solar power will provide 40% of the nations' electricity by 2035 [1] and serve as a cost-effective option for decarbonizing the US electric grid. Net energy metering (NEM), where the timing of solar energy delivery and electricity use from the grid is tracked using a bi-directional meter, allows the accumulation of energy credits when PV production is higher than the use and valued at the same price that utility providers charge (net-to-compensate). Such sales to the grid are usually limited to the amount of electricity consumed over an annual billing cycle. As such, NEM has been consistently recognized as a foundational policy to support DG growth but occurs at a cost to utilities in terms of lost marketing margin. It also leads to a larger number of smaller-scale installations that may not be as scale-efficient as fewer larger installations. More than four-fifths of US states have employed NEM

pricing to encourage adoption in their electricity sectors [2], thereby paving the road to allow renewable resources to be a real and growing part of the US rural energy landscape. Utilities lose their marketing margin, resulting from retail electricity sales bought at cost with solar vs. at a lower wholesale cost; however, some have argued that this lost revenue will lead to cost-shifting to non-solar customers [3].

Some states and utilities are thus engaged in efforts to reform distributed solar compensation rules to better align with the value that such systems generate [4]. The future of NEM is under debate across the US as the DG of solar power has gained electricity market share [5].

In contrast with NEM, a buy-all, sell-all arrangement offers a standard sell rate to a customer for all the PV electricity they generate. Unlike NEM, a “buy-all, sell-all” customer continues to be billed for all the electricity that they consume at the applicable retail rate, independent of electricity generated by their PV system. The PV system exports all electricity directly to the utility grid, and the distributed system owner is compensated at a predetermined and typically fixed sell rate either through utility bill credits or in cash. The sell rates can be set at a fixed long-term contract price or dynamic rates, including Time-of-use pricing schemes. As an example, Indiana allowed utilities to pay solar customers at much lower DG rates after solar reached 1.5% of electricity market penetration [6].

A third metering and billing arrangement is net energy billing (NEB), also called “instantaneous netting”. With NEB, a DG system owner can consume electricity generated by their DG system in real time and export any generation in excess of on-site consumption to the utility grid. When DG production is insufficient to meet the farm’s electricity needs, the farmer buys from the utility at retail rates. Under NEB, the banking of kilowatt-hours (kWh) within a billing cycle to offset future consumption is not allowed. In fact, credits are not granted in kWh terms at all. Rather, all net energy exports are metered and credited at a predetermined sell rate the moment that they are supplied to the grid. A PV system owner’s meter(s) must thus at least record either real-time net electricity consumption using a smart meter or can be designed using two separate meters, one for DG sales to the utility and one for electricity grid use. Using either setup, electricity supplied to the grid and used from the grid are measured in real time and billed/credited separately at the end of the billing cycle. The predetermined sell rates are called avoided costs and typically reflect the cost to an electric utility for purchasing electricity at wholesale prices or what it costs them to generate electricity on their own. By setting the sell rate at the avoided cost rate, NEB may encourage self-consumption, where PV systems are sized to minimize DG export to the grid, as the net export at the avoided cost rate can be compensated at rates as low as 20% of the retail electricity rate that utilities charge to their customers [7].

This is not always the case. The Tennessee Valley Authority (TVA), for example, started a Generation Partner (GP) Pilot program in 2003 to provide customers with an alternative to NEM. The Generation Partners Pilot program was an NEB program, and participation in the program was optional. In 2012, Green Power Providers (GPPs) replaced the GP program with key features of declining generation payment or export rates (referred to as the avoid cost rate above) at retail plus a USD 0.12/kWh premium in 2012 that was incrementally decreased to retail in 2016 (essentially a NEM policy without PV system size restriction). In 2018, GPP generation payments were modified to reflect the valley-wide approximate retail rate of USD 0.09/kWh for residential and GSA-1 systems under 10 kW and USD 0.075/kWh for all other eligible commercial/industrial and residential systems [8].

In the US, NEB or “buy all, sell all” pricing systems have become successors of NEM in some states. As a result, the grid export price is credited at rates close to the utility’s avoided cost [6]. Arkansas followed this path in 2024 when NEM was replaced with NEB using an export rate at the avoided cost rate [9]. Among many influencing factors that

impact the feasibility of PV investment, including the level of solar irradiation, the volume of investment required, and the availability of financial incentives for green energy, the rules for selling and buying energy have a large impact on the financial performance of PV systems.

Poultry is the largest commodity of the agricultural sector in the state of Arkansas in terms of annual sales. It ranks as the second largest poultry producing state in the country [10]. In 2021, 7.46 billion pounds of broiler chicken were produced with an annual value of USD 3.97 billion. Energy is one of the critical inputs to modern poultry farming in the US, and its overall use in poultry production and processing is constantly growing [11]. There are major challenges facing the poultry industry, including high energy intensity with high demand for fossil fuel, and escalating electricity prices, among others. In typical commercial meat-type poultry (i.e., broiler or turkey) houses, electricity is used for feed and water delivery, lighting, ventilation, and warm season cooling (Figure 1), while heating fuels such as natural gas or propane are used for space heating. The energy demand of environment-controlled houses fluctuates with seasons. The relative proportions between heating fuel and electricity use depend largely on the local climate and age of birds. Higher fuel demand for heat occurs during cold seasons with younger birds, and higher electricity demand for cooling occurs during warm seasons and as flocks age.

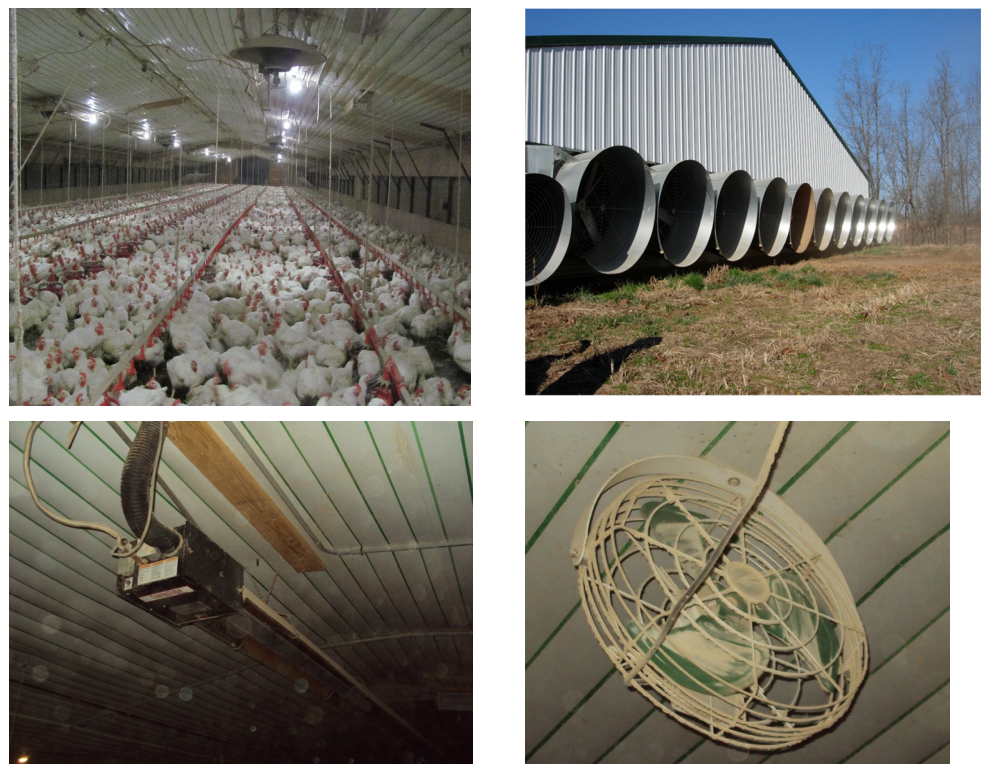


Figure 1. Electrical equipment in a typical broiler house in the US, including feed and water delivery lines, ceiling lights, exhaust and circulation fans, and radiant tube heaters with internal blowers.

Agricultural producers in Arkansas have adopted PV systems (Figure 2) in the past years [12,13]. Under the NEM scheme, commercial PV systems were typically sized up to 100% of the annual electricity consumption (kWh) of the farm business. However, Arkansas' favorable 1:1 renewable NEM was replaced by NEB at avoided cost in 2024 [14], and PV adoption by commercial farms has greatly slowed down.



Figure 2. Two distributed photovoltaics systems of 180 kW (**left**) and 50 kW (**right**) installed on commercial poultry farms.

There are benefits of promoting DG projects in comparison to larger utility-scale PV systems. Among the pros for smaller farm-scale systems are deferring the need for new grid upgrades, reducing line losses, utilizing marginal lands, and locking in energy costs for producers willing to make the PV system investment. At the same time, Kaizuka (2020) [15] argued that future policy schemes should be developed to incentivize DG projects with higher self-consumption ratios. The assessment of different supporting schemes for residential PV systems has also been conducted [16,17]. However, studies on the impact of solar PV on electricity consumption and related cost–benefit analyses for agricultural customers are few [18–22], as are studies on the simultaneity of PV generation and load consumption [23]. Understanding the electricity demand of a poultry farm and how different capacities of designed PV arrays could impact the financial performance of the PV systems under various renewable energy pricing schemes are important as this information may aid future adoption by poultry producers.

Fu (2024) [24] studied regional distributed energy planning including photovoltaic and biogas systems by regulating electric load in greenhouses. In comparison, the aim of this paper is to investigate the economic viability of distributed PV systems on a model poultry farm. The continuous improvement in bird genetics and the vertical integration of broiler production in the US require strict adherence to prescribed thermal environment. This is achieved with high automation for feeding, heating and cooling, which in turn leads to little flexibility for managing the energy load demand of broiler farms. We did not address heating load in broiler buildings since heating fuel such as natural gas and propane are readily available in rural areas and are more cost-effective than electrical heat. Hence, our scope is confined to an analysis of electric load demand of a sample poultry broiler house complex, a focus that is narrower than that of Fu (2024) [24].

Specifically, we perform the following:

1. Quantify the hourly electric power demand/energy consumption of a broiler poultry operation;
2. Simulate the hourly electricity production of on-site PV systems at varying sizes to assess how hourly availability of PV interacts with hourly farm consumption and thereby energy export to the grid;
3. Investigate economic benefits of PV as a function of NEM and NEB at the avoided cost rate.

2. Materials and Methods

2.1. Overall Workflow

Figure 3 below shows the overall workflow of this study.

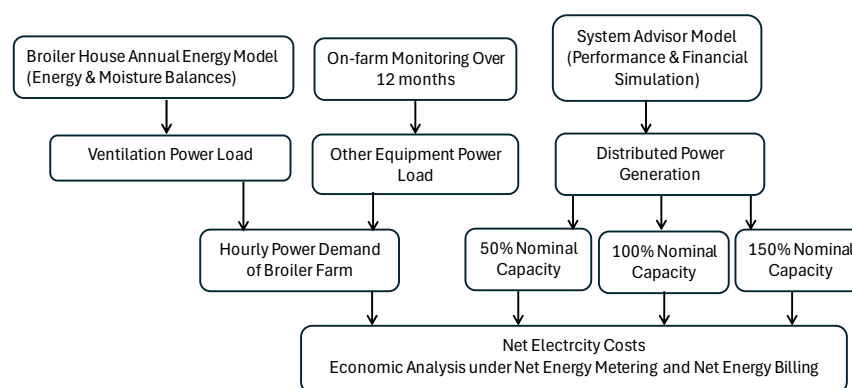


Figure 3. Flow diagram of this study.

2.2. Ventilation Electricity Load Simulation

The ventilation electricity of a commercial broiler poultry farm (36.0627° N, 94.1606° W) was simulated using an annual energy-use spreadsheet model [25]. The model simulated the interactions between broilers (chickens raised for meat) and their environment and considered heat and the moisture production of modern broilers. It requires inputs of weather data, house management factors (i.e., stocking density and growth rates), environmental set points (for heating, ventilation, cooling, etc.) and house characteristics (i.e., dimension, insulation). Equations for balancing heat and moisture flows were used to calculate hourly ventilation and heating rates. Simulation was performed with the broiler production building characteristics, environmental setpoint, and flock management typical of houses managed in the Southern broiler production area (Table 1). The simulation of 12 flocks, each placed on the fifteenth day of every month, was conducted so the effect of seasonal timing of placements on energy consumption could be evened out. Hourly outputs of volumetric ventilation rates were averaged by month and converted to hourly fan power demand, P , in kWh, based on the ventilating efficiency ratio of fans at $\Delta P = 25$ Pa (0.10 inch of water column) of 15 cfm/Watt [26].

Table 1. Input variables and values used for simulation of a broiler house in NW Arkansas.

Variable	Input Values
Gable-roof house dimensions	12 × 122 m, 2.1 m walls
Roof slope	4:12
Roof insulation	3.3 m ² C/W
Wall insulation	1.9 m ² C/W
Door insulation	0.3 m ² C/W
Floor perimeter insulation	0.7 m ² C/W
Overall building heat loss coefficient	586 W/K
Infiltration	0.5 air exchanges/h
Heating	Unvented radiant tube gas heaters with electric blowers
Overall fan efficiency	100%
Number of chickens	17,000 chicks placed
Age at harvest	57 d
Target weight at harvest	4.2 kg per broiler
Heating set points (Weeks 1, 2, 3 and thereafter)	32, 29, 27, and 21 °C
Relative humidity set point	65% for all ages
First-stage cooling set points ^a (Weeks 1, 2, 3 and thereafter)	35.0, 32.2, 29.4, and 23.9 °C
Maximum first-stage ventilation	2.55 m ³ /h per broiler
Maximum supplemental ventilation ^b	15.3 m ³ /h per broiler

^a First-stage ventilation is provided via sidewall exhaust fans; and ^b Supplemental ventilation is provided via tunnel fans.

2.3. Electricity Load of Other Equipment

Electric energy consumption was monitored in one of four commercial-scale broiler houses on a farm in Arkansas, each measuring 12×121 m, during a consecutive 12-month period that included four, 8-week flocks [27]. Power demand of the major equipment such as lights, feed motors, blowers in the heaters, and water well pump were monitored continuously using energy loggers (H22-001, Onset Computers, Inc., Bourne, MA, USA) and the current and voltage transducer (Accu-CT Split-Core Current Transformer 0–20 Amp, Onset Computers, Inc., Bourne, MA, USA). The current and voltage of all electric circuits were sampled every 10 s, averaged, and subsequently recorded every 5 min. Electricity consumption to deliver light, feed, water, and heat varied by hour since broilers received 9 h of dark from 9 p.m. to 6 a.m. after they were one week old. Feed and water consumption were close to zero in the dark period. Electricity usage of these components was averaged over four flocks and compiled into the energy consumption of each circadian hour. This was added to the simulated fan power demand to calculate the hourly total electricity demand of all 12 months.

2.4. Photovoltaic Power Production Simulation

Electricity production by an on-site solar photovoltaic system was simulated using the System Advisor Model (SAM) developed by the National Renewable Energy Laboratory. The SAM provides performance and financial information to estimate the cost effectiveness of grid-connected renewable energy projects to facilitate decision making for developers, policy analysts, engineers, researchers and others. The input data and assumptions used for SAM modeling are provided in Table 2. No additional government subsidy was considered in this study.

Table 2. Assumption and input data used when calculating the annual benefits of solar power generation.

Parameters	Assumed Values
Technical data	
Farm annual power load	Varies (see results below)
Farm annual electricity consumption	127,117 kWh
Annual average global horizontal irradiation	4.53 kWh/m ² /day
PV module nominal efficiency	21%
PV system capacity	35–105 kW _p
Economic data	
PV capital cost	USD 2000/kW
PV annual operation and maintenance cost ^a	USD 7.5/kW-yr
PV system economic life ^a	25 years
PV degradation rate	0.50%
Energy cost escalation rate	3%
Inflation rate	3%
Discount rate	5%
Federal investment tax incentive	30% of project cost
Electricity retail cost rate ^b	USD 0.12/kWh
Electricity avoided cost rate ^c	USD 0.05/kWh

^a Sunshot projection [28]; ^b EIA (2024) [29]; ^c Entergy Arkansas (2021) [7].

We used the SAM (2024.12.12) to design and simulate PV systems of three nameplate capacities that would displace different fractions of the farm electricity demand/consumption (at the nominal 50%, 100% or 150% of annual electricity use) (Figure 4). Figure 5 shows a sample heat map of 365 days of hourly power production output of a simulation with a 70 kW_p system. Hourly power outputs were exported into Excel spreadsheets. The

monthly average hourly PV generation was calculated based on the hourly power output of 365 days.

Figure 4. System Advisor Model simulation interface of a photovoltaic system capacity of 70 kW_p.

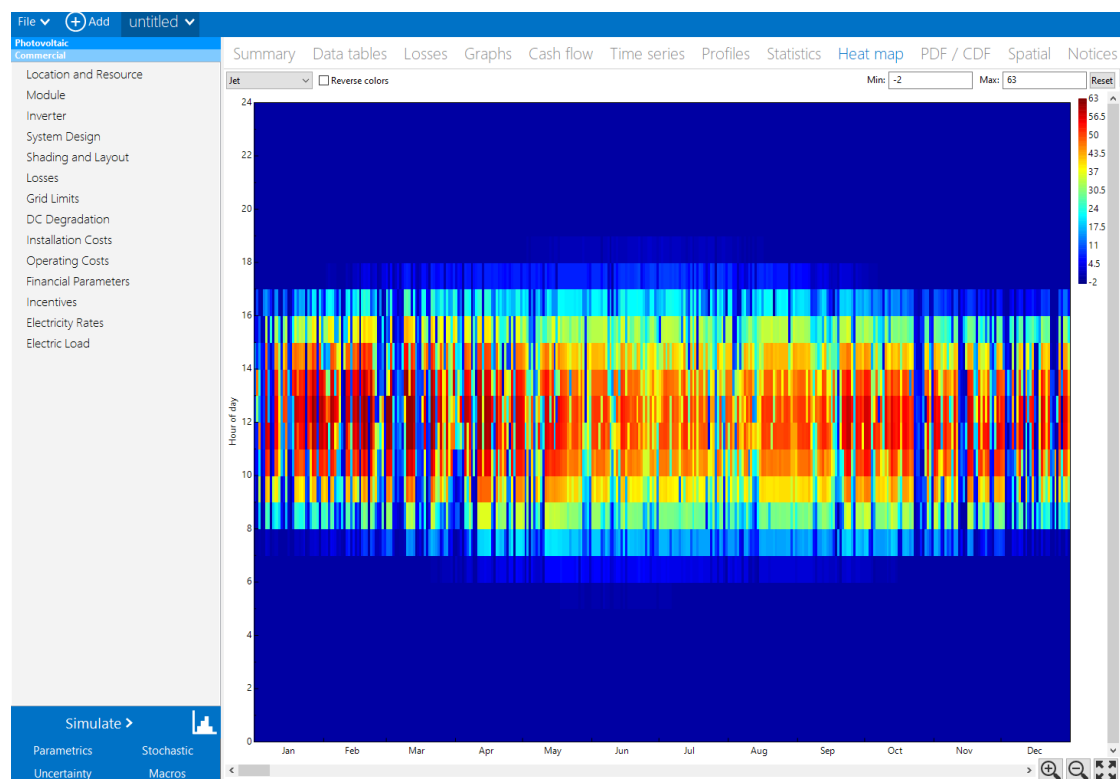


Figure 5. System Advisor Model simulates an hourly AC power output (kW) heat map over the first year for a photovoltaic system capacity of 70 kW_p.

2.5. Financial Feasibility Study

The financial feasibility of simulated energy production and energy load demand for a complex of four poultry houses was evaluated using Excel. Electricity consumption, E , of the farm in each month, in kWh, is given by the following:

$$E = \sum_{j=1}^m \sum_{i=1}^n E_{ij} = \sum_{j=1}^m \sum_{i=1}^n P_{Lij} \quad (1)$$

where P_L is the hourly farm electricity load in kW, where $i = 1, 2, 3, \dots, n$ tracks the hour in a day $j = 1, 2, 3, \dots, m$ for each month, and m tracks the day in a month (i.e., for January, $m = 31$).

The electricity generation by the PV system of each month, G_{PV} , in kWh, is the accumulated hourly production that varies by time of day and month as given by the following:

$$G_{PV} = \sum_{j=1}^m \sum_{i=1}^n G_{PVij} \quad (2)$$

In the case of NEM, *net* electricity, N , in kWh, is the monthly difference between energy consumption, E , and the PV generation, G_{PV} .

$$N = \sum_{j=1}^m \sum_{i=1}^n N_{ij} = \sum_{j=1}^m \sum_{i=1}^n E_{ij} - \sum_{j=1}^m \sum_{i=1}^n G_{PVij} \quad (3)$$

The electricity cost C_E without any PV production, in USD, is given by the following:

$$C_E = \sum_{j=1}^m \sum_{i=1}^n E_{ij} Z_{Rij} \quad (4)$$

where Z_R is the electricity retail cost rate in USD/kWh.

Therefore, with an on-site PV production and under NEM, *net* electricity cost, in USD, is given by the following:

$$C_{NEM} = \sum_{j=1}^m \sum_{i=1}^n N_{ij} Z_{Rij} \quad (5)$$

The net electricity cost with NEB, in USD, is considered separately during hours when consumption is higher than PV production ($N_{ij} > 0$) and when consumption is smaller than PV production ($N_{ij} < 0$) and given by the following:

$$C_{ij} = N_{ij} Z_{Rij} \text{ if } N_{ij} > 0 \text{ or } N_{ij} Z_{Aij} \text{ if } N_{ij} < 0 \quad (6)$$

$$C_{NEB} = \sum_{j=1}^m \sum_{i=1}^n C_{ij} \quad (7)$$

where Z_A is the electricity avoided cost rate in USD/kWh.

The self-consumption ratio, s , is calculated as the fraction of the self-consumed portion of PV generation over the total PV generation.

$$s = \frac{G_{DU}}{G_{PV}} \quad (8)$$

where G_{DU} is the sum of the electricity consumed that is either equal to the simultaneous PV production at each hour (when $P_{Lij} < G_{PVij}$) or the PV production (when $P_{Lij} > G_{PVij}$). Electricity production and consumption are held constant over the useful life of the PV system.

We used the net present value (NPV) of cash flow and internal rate of return to investigate the feasibility of the solar PV project on the model poultry farm. The NPV is given as follows:

$$NPV(i_d, T_{lt}) = \sum_{t=1}^{T_{lt}} \frac{R_t}{(1 + i_d)^t} \quad (9)$$

where t = time of the cash flow (for example one year), T_{lt} = lifetime of the PV technology in years ($T_{lt} = 25$), i_d = discount rate (the rate of return that could be earned on an investment in financial markets with a similar risk), and R_t —net cash flow, i.e., cash inflow and cash outflow at time, t , in USD. Investments during the initial design to the system start-up (assumed to occur in the first year) are summed up with a negative cash flow.

Parameters used for the financial analysis are listed in Table 2. A capital expenditure of USD 2000/kW for the PV systems is used, and a value of USD 7.5/kW-year is assumed for the annual operation and maintenance [22]. The economic life of the PV system is assumed at 25 years with a discount rate of 5% and an average annual inflation rate of 5%. Note that all simulations were conducted using a 30% federal investment tax credit that could be realized in the first year with the passage of the Inflation Reduction Act. As such, the project cost was credited USD 0.30 for each dollar invested in the PV system.

The annual bill savings were defined as the difference between the cost of energy without any PV system (C_E) installed and the cost of energy using PV (C_{NEM} or C_{NEB}). Besides the NPV, we considered the payback period (PP) of each scenario as well. This characterizes the number of years of cumulative savings required to recoup the investment costs of PV installation net of the federal income tax credit.

Different system sizes and pricing scenarios thus led to 6 model outcomes. Each outcome tracked the NPV, the PP, and the self-consumption ratio.

3. Results and Discussion

Broiler farms' electric loads vary by the hour according to the weather's effect on the building environment. The diurnal fluctuation is more prominent in the warm season from May to September (Figure 6) but less significant in winter months. There are also seasonal electric load fluctuations, with overall higher load in the warm season than in the cold season (Figure 7). A maximum hourly power load of 35 kW occurred in July on this four-house broiler farm, while a minimum hourly power demand of 4.6 kW happened in January (Figure 7). The high electric power demand during the afternoon hours of summer months was attributed to the large number of exhaust fans running to cool houses. These fans have electric motors varying from 375 to 1125 W nominal nameplate power that each run up to 2500 h annually to remove heat from and provide cooling to broilers [27]. Overall, the four-house broiler farm consumed approximately 127,000 kWh of electricity annually.

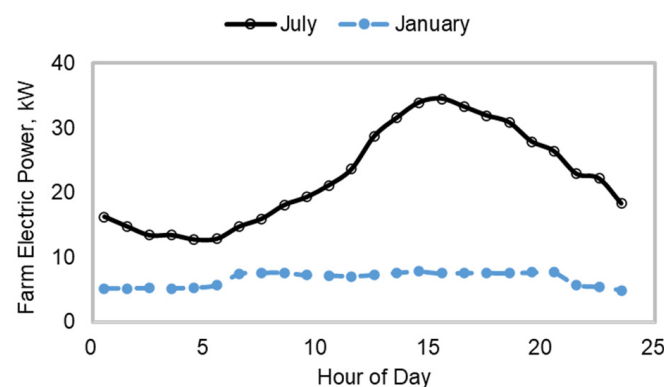


Figure 6. Sample diurnal pattern of hourly electric power load of the broiler farm in January and July.

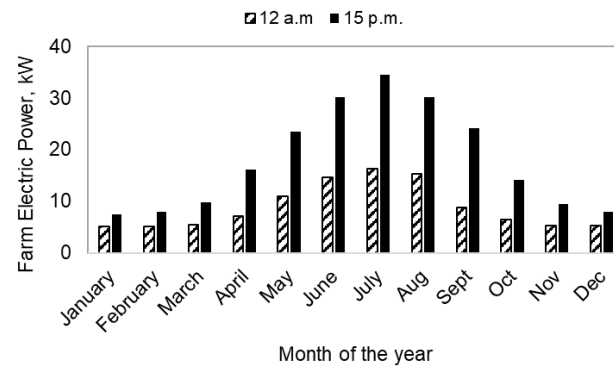


Figure 7. Seasonal trend of hourly electric power load of the broiler farm at midnight and mid-afternoon hours.

3.1. Building Consumption Vs. On-Site PV Generation Under NEM

Solar availability varies daily with solar irradiation, cloud coverage as well as season. The farm is assumed to be located in an area with an annual average global horizontal irradiation of $4.53 \text{ kWh/m}^2/\text{day}$. The effect of the size of the PV system with respect to the NEM and NEB pricing scenarios is examined in this analysis by varying the PV capacity from 35 to 70 and 105 kW_p. The 70 kW_p PV system was assumed to generate about 85% of the farm's annual electricity consumption.

Daily farm electricity consumption and PV generation from a system of 35 kW_p are compared over 12 months (Figure 8). The on-site PV electric generation of 35 kW_p fell short of supplying farm needs especially during the warmer season (Figure 8). On an hourly basis, a system of 35 kW_p exceeds real-time farm consumption from 9 a.m. to 3 p.m. on a December day but is lower than farm needs during every hour of a June day (Figure 9a,b). On the other hand, a 70 kW_p PV system significantly improves the renewable energy supply and offsets about 85% of the annual farm electricity consumption from the power grid and led to 85% electricity costs savings under an NEM scenario (Figure 10, Table 3). This would be a likely proposed system size for this four-house broiler farm if an NEM policy continued. Further increases to a 105 kW_p system resulted in annual negative consumption (overall credit) on the farm (Table 3).

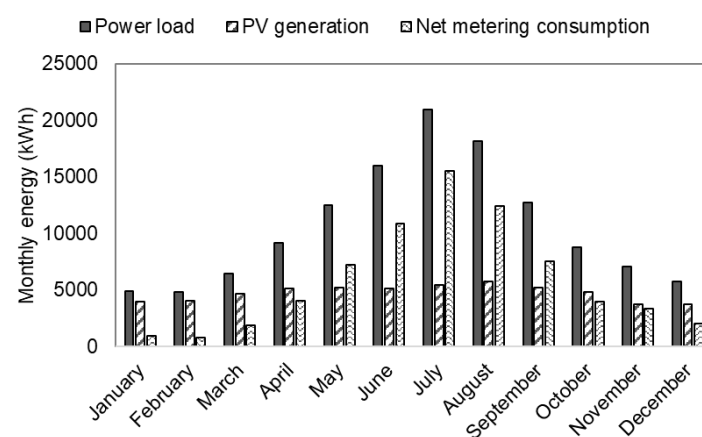


Figure 8. Monthly energy balance in the case of 35 kW_p PV installation with net metering billing arrangement.

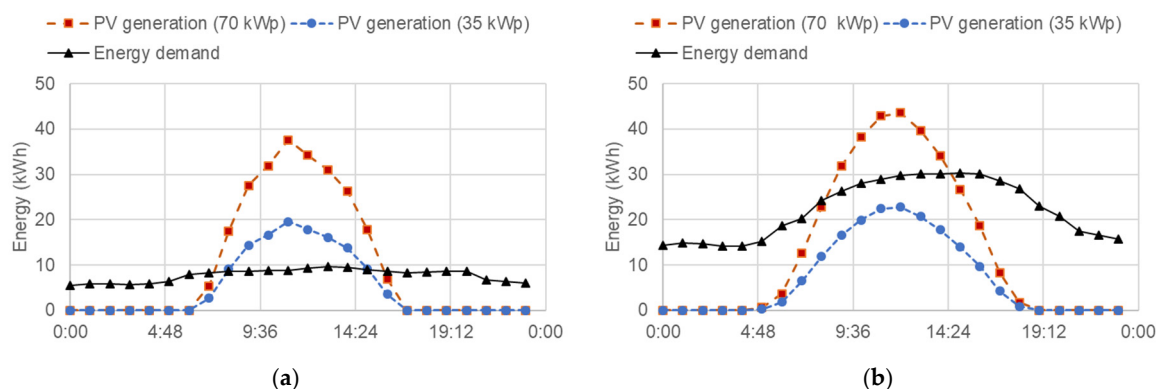


Figure 9. (a) Hourly energy demand and PV generation with system size of 70 kW_p and 35 kW_p in December. Both PV sizes of 35 and 70 kW_p produce more electricity than farm electric demand during a sunny day. The 35 kW_p array will have significantly less export than the 70 kW_p array. (b) Hourly energy demand and PV generation with system size of 70 kW_p and 35 kW_p in June. The 35 kW_p array will not produce enough in any hour of a day in June, while the 70 kW_p array has a smaller net export to the grid than in winter months.

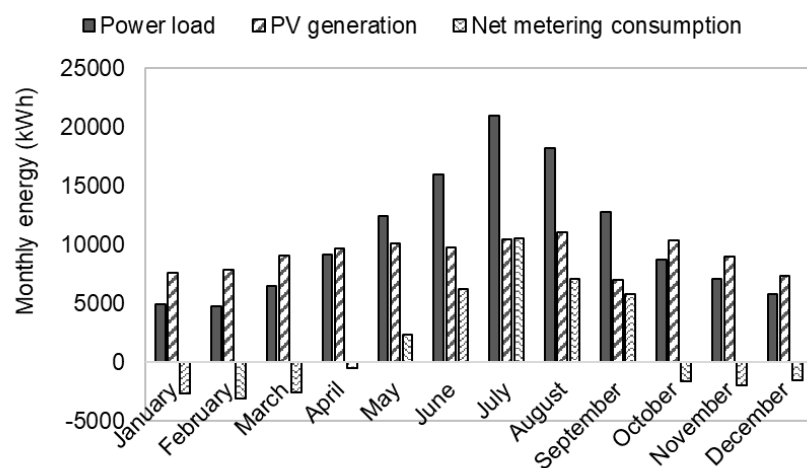


Figure 10. Monthly energy balance in the case of 70 kW_p PV installation with net metering billing arrangement.

Table 3. Simulation results of annual electricity consumption (kWh/yr) without and with PV installation and self-consumption ratios of three system sizes.

PV System Size, kW _p	Annual Electricity Consumption Before PV, kWh	PV Generation, kWh	Annual Electricity Consumption After PV, kWh	Self-Consumption, kWh	Self-Consumption Ratio
35	127,117	56,721	70,396	48,028	85%
70	127,117	109,057	18,060	63,807	59%
105	127,117	162,868	−35,751	68,435	42%

3.2. Building Consumption Vs. On-Site PV Generation Under Net Billing

However, when the billing policy changes from NEM to NEB with a much lower “avoided cost” pricing scenario, a smaller PV installation reduces “avoided cost” rate payments in those incidences when PV generation exceeds real-time consumption (for example, excess electricity generation around noon hours in cooler months in Figure 9a). A smaller PV installation of 35 kW_p resulted in an 85% self-consumption ratio (Table 3), which is much higher than those of the 70 kW_p and 105 kW_p PV systems (59% and 42%, respectively).

Annual costs of farm electricity before and after the solar PV installation of different system sizes under the NEM and NEB are shown in Table 4. Under NEM arrangements, annual farm net electricity costs are greatly reduced from USD 15,254 before PV installation to USD 8448, and USD 2167 with the 35 and 70 kW_p PV installations, respectively (Table 4). These correspondingly increased net annual benefits and led to similar simple payback periods around 7 years.

Table 4. Simulation results of annual electricity costs without and with PV installation (USD/yr) and net annual benefits of three system sizes under two billing arrangements (NEM: net energy metering; NEB: net energy billing).

PV System Size, kW	Billing Arrangement	Annual Electricity Cost without PV (USD)	Net Electricity Costs with PV (USD)	Net Annual Benefit (Net Savings) (USD)	Capital Expenditure (USD)	Simple Payback (yr)
35	NEM	15,254	8448	6806	49,000	7.2
	NEB	15,254	9051	6203	49,000	7.9
70	NEM	15,254	2167	13,087	98,000	7.5
	NEB	15,254	5329	9925	98,000	9.9
105	NEM	15,254	−4290	19,544	147,000	7.5
	NEB	15,254	2314	12,940	147,000	11.4

The NEB arrangements had different impacts on the financial performance for the three system sizes. The larger PV system (i.e., 105 kW_p system) resulted in a longer simple payback of 9.9 years, although it still had higher net annual savings on electric bills (Table 4) compared to a 35 kW_p or a 70 kW_p system.

Without the avoid cost rate penalty, NEM pricing systems make the PV installation more profitable than the NEB scenario, especially for larger systems that aim to offset more annual farm electricity consumption (Figure 11).

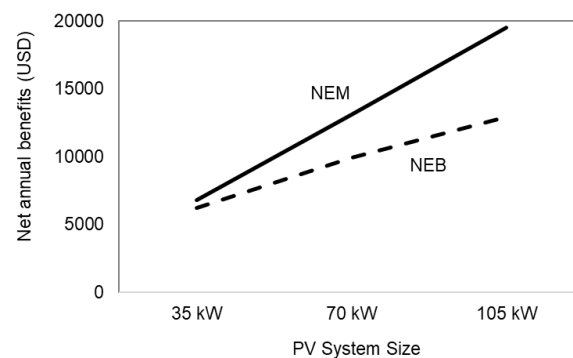


Figure 11. Average net annual benefits over a system's useful life of 25 years as a result of two billing arrangements with three system sizes. NEM, net energy metering; NEB, net energy billing.

3.3. Net Present Value

The net present values discounted net annual benefits of systems and subtracted the net investment in the PV system (project cost – federal income tax credit) using a discount rate to account for the time value of money (Figures 11 and 12). All system sizes and billing arrangements resulted in a positive NPV, indicating projects were capable of paying for themselves over 25 years. In contrast to NEM, a lower NPV was observed with NEB as expected, given the avoid cost rate remuneration penalty with NEB. With higher self-consumption rates, the NEB pricing penalty played a smaller role, and, hence, both poultry farmers and policy makers can expect a slowed DG expansion of PV systems with NEB

compared to NEM. Utilities, on the other hand, likely will continue to invest in utility-scale projects as they have greater control over pricing. Whether and to what degree utilities pass on federal income tax credit savings springing from PV installations to electricity users in the state is at their discretion but are usually also governed by public service commissions.

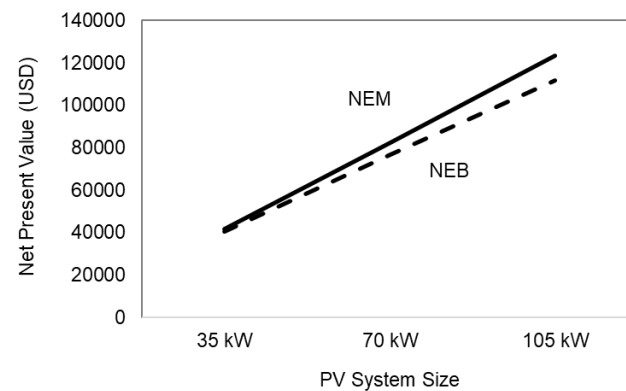


Figure 12. Net present values over system's useful life of 25 years as a result of two billing arrangements with three system sizes. NEM: net energy metering; NEB: net energy billing.

4. Conclusions

This study explores the potential of DG of PV electricity on a broiler poultry farm with various capacities of displacing grid power consumption under two energy pricing scenarios. The power demand of a broiler poultry farm raising four broiler flocks over a year was influenced largely by weather conditions, with lower power demand in winter months and higher demand in warmer seasons. It also exhibits higher daytime demand than nighttime. Broiler farms lack the flexibility of scheduling growing stages or managing power demand. Using the System Advisor Model, we simulated PV-generated electricity of three different sizes of on-site installations and how different energy pricing schemes affect the PV system profitability. Under a net energy metering (NEM) scenario, a 70 kW_p system would reduce 85% of annual farm electricity consumption, resulting in a payback of 7 years. Under the net energy billing (NEB) scenario, the smallest system of 35 kW_p resulted in an 85% self-consumption ratio but only offset less than half of the farm's annual power consumption. With avoided-cost rate pricing penalties of NEB compared to NEM, the 35 kW_p system's profitability was only slightly lower than the NEM's profitability of similar size as, at that system size, only 15% of electricity produced by the solar system was sold back to the grid. The larger 105 kW_p system yielded the highest net present values under both NEM and NEB scenarios but led to longer payback periods with NEB as expected. The results suggest that DG or less than utility-scale projects are less likely to be adopted on-farm under NEB and, if so, system sizes for farm-size projects will likely be smaller.

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Abbreviations

The following abbreviations are used in this manuscript:

DG	Distributed generation
NEB	Net energy billing
NEM	Net energy metering
NPV	Net present value
PV	Photovoltaics
SAM	System Advisor Model

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