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IMPACT OF SOLAR ENERGY ON A NATURALLY VENTILATED SWINE BUILDING

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ABSTRACT

While many farmers are considering solar electric systems to power their farms, variables such as installation cost, policy, rate structure, and energy usage can influence the economic viability. As a result, it's essential to have a detailed understanding of how solar generation will impact the farm's energy usage trends. This case study uses research data to compare the on-farm solar generation to the daily and seasonal energy needs of a naturally ventilated hog barn in Northwest Ohio. Our findings indicate the on-farm solar system provided savings by reducing monthly energy usage, however, did not significantly reduce the monthly peak demand.

INTRODUCTION

Swine facilities use energy to heat buildings, operate fans, and perform other functions necessary to maintain a suitable environment for swine production. Iowa State University researchers analyzed energy consumption of 30 swine farms in three states. The tunnel-ventilated barns in this analysis used an average of 25.9 kilowatt-hours (kWh) per pig space for finishing pigs (Harmon and Schweitzer, 2016). A tunnel-ventilated barn in Minnesota finished 6,300 pigs per year and used an average of 14.48 kWh of electricity per finished pig (University of Minnesota Extension, 2017). In comparison, the same University of Minnesota Extension project analyzed consumption in a naturally ventilated side curtain barn. In 2015, the barn required 9,282 kWh of electricity to process 2,970 animals to market yielding an average of 3.13 kWh/pig. In 2016, a total of 2,812 head were marketed, consuming 13,928 kWh of electricity or 5.25 kWh/pig.

Solar as an alternative energy source in homes, businesses, and livestock farms is gaining more interest. Photovoltaic (PV) solar is a technology that directly converts sunlight into electricity. Developed in 1954, solar PV remained an expensive technology until modern manufacturing techniques have driven the price down in recent years. The use of systems to gather solar energy in swine buildings was researched in the 1940s, but cheap fossil fuels made the system cost prohibitive (Fehr, 1978).

PV solar is a renewable energy technology that is perceived by many to have many positive attributes. The potential benefits of solar energy include use of a clean energy source, reduced electric costs, and gaining some level of energy independence (Romich and Hay, 2019). In 2020, solar accounted for 11% of renewable energy consumed in the U.S. and increased 22% over 2019 consumption (U.S. Energy Information Administration, 2021). The U.S. Energy Information Administration (EIA) projected that in 2021 solar energy will account for 39% of all new utility scale electrical generating capacity.

While there has been an increase in on-farm solar energy development in recent years, depending on installation cost, policy, rate structure, and energy usage patterns, it may not be economical on every farm. As a result, it is essential to have a detailed understanding of how on-farm solar generation will impact the farm's energy usage trends. This case study uses detailed research data to compare the on-farm solar generation to the daily and seasonal energy needs of a naturally ventilated hog barn in Northwest Ohio.

METHODS

Energy and solar generation data for this article was acquired from one of the six research farms included in an agricultural energy management research project that was funded by an Outreach and Engagement grant from the Ohio State University Office of Outreach and Engagement. The overriding objective of the agricultural energy management research project was to identify energy management strategies to minimize costs and foster long-term sustainability. To meet this objective, we installed advanced energy metering equipment in agricultural facilities to track electric peak demand trends, energy usage, and power quality to gain a clearer understanding of the farm's energy needs. To maintain privacy, the actual names of the six farms that participated in the research project were coded with an alias name. This article will focus on data from the IGEM farm, which was one of the six research sites that participated in the three-year study. The IGEM farm was unique, as it was the only research site that had installed an on-farm solar generation system to offset the electric needs of the farm. The IGEM farm research site consists of two naturally ventilated swine finishing barns, housing roughly 1,100 hogs each.

To collect the data for this study, the project team installed the Electro Industries Shark MP200 energy metering system (Figure 1) on each research farm. The MP200 is a multifunction energy meter capable of recording energy usage data for up to 24 single phase circuits. The meter which measures 7.6" (L) x 11.28" (W) x 4.36" (H) was mounted on a backing plate and wired to disconnect fuses and shorting blocks before being installed in an electrical safety enclosure box. A combination of solid-core and split-core current transformers were installed on each of the individual electrical circuits to monitor electrical activity of specific farm operations. At the IGEM farm research site, we measured the main electric service feed into both the west and east barns. In addition, we monitored individual electrical circuits in the east barn with large electric loads that were critical to the farms day-to-day operations including:

- Feed Auger #1
- Feed Auger #2
- Pitt Fans West
- Pit Fans Middle
- Pit Fans East
- Water Pump
- Pressure Washer
- Photovoltaic Solar Generation

Figure 1. Electro Industries Shark MP200 multifunction energy meter installed at the main electric panel of the IGEM Farm.

The energy meters were configured to collect data records on 5-minute block windows with a 15-minute rolling demand window. The meter profiles were set to collect readings for voltage, current, frequency, kilowatt-hour (kWh), kilowatt (kW), kilovolt-Ampere (kVa), reactive kilovolt-amperes (KVAR) and power factor using the configured demand features over the averaging period.

Because the IGEM farm had an on-farm solar generation system, it allowed us to compare the on-farm solar generation to the daily and seasonal energy needs of a naturally ventilated hog barn in Northwest Ohio. Using data from this case study example, farmers can better visualize and estimate how solar will impact their overall electric bill and support informed investment decisions on behind the meter on-farm solar projects.

IGEM FARM ENERGY USAGE

In our study we installed current transformers to monitor energy use, demand, and power quality on 10 individual operations. For this analysis, we have condensed the data into five separate categories including: pit fans, feed augers, water pump, pressure washer, and other. We collected energy usage data on each of the operations over a 12-month period from January to December 2020. Over the 12-month period, the IGEM farm swine barns (east and west) used a total of 57,522 kWh of energy for the swine operations. On average, the farm used 4,793 kWh per month, including the minimum of 1,905 kWh in May and a maximum of 7,568 kWh in December. As illustrated in Figure 2, the pit fans represent the largest and most consistent load source accounting for 14,126 kWh or 44% of the annual energy usage.

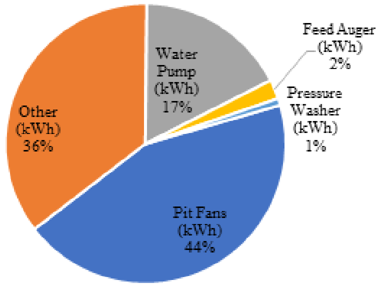

Figure 2. Summary of the IGEM farm annual energy usage (kWh) by operation type.

The second largest consumer of energy was the "other" category, which included all electric loads not metered with a current transformer. Combined, these other electric loads accounted for 36% of the total energy use over the 12-month period. While this category represents the balance of miscellaneous electrical loads not metered, it is estimated that most of the electric usage in the "other" category is for heating, stir fans, and lighting. Finally, the water pump accounted for 5,575 kWh or 17% of the annual energy usage.

ON-FARM SOLAR GENERATION

In October of 2016, the IGEM farm commissioned a behind the meter on-farm solar generation system to offset the electric needs of their two swine barns. The solar system had a peak power rating of 11.4 kW consisting of 51 solar modules with solar edge inverters installed on the rooftop of the eastern finishing barn. Based on the National Renewable Energy Laboratory average commercial rooftop solar system cost of $2.29 per W/dc in 2016, the total estimated system cost when it was originally constructed is estimated at $26,106. In comparison, based on the average installation costs of $1.72 per W/dc, the estimated cost for the same 11.4 kW rooftop solar system in 2020 was $19,608 (Feldman et al., 2020). The National Renewable Energy Laboratory estimates annual operation and maintenance cost of this system at $19 per kW. The system is expected to have a useful life of 25 years. Based on our energy meter data, since 2018 the IGEM farm solar system has generated a total of 49,150 kWh with an average of 14,645 kWh electricity per year. As illustrated in Figure 3, the solar system generated a total of 12,313 kWh in 2020 ranging from a low of 428 kWh in December to a high of 1,639 kWh in July.

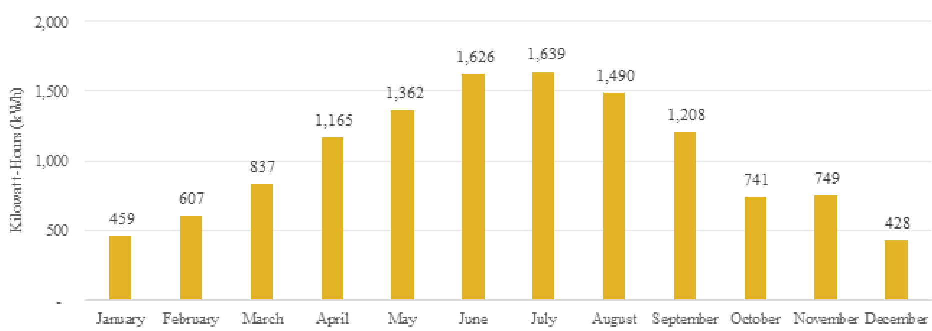

Figure 3. Summary of the 2020 monthly in solar generation from the 11.4 kW rooftop solar system installed on the IGEM farm naturally ventilated hog barn.

IMPACT OF SOLAR ON ENERGY USAGE

Solar generation was measured at IGEM farm during the analysis period. As expected, solar energy production varied from day-to-day and month-to-month during the year. Figure 4 shows 15-minute periods of solar generation measured in kWh for each week of each month. The months of April through September generated the greatest amount of solar energy, with much lesser amounts of solar generated in the months preceding and following the April to September period.

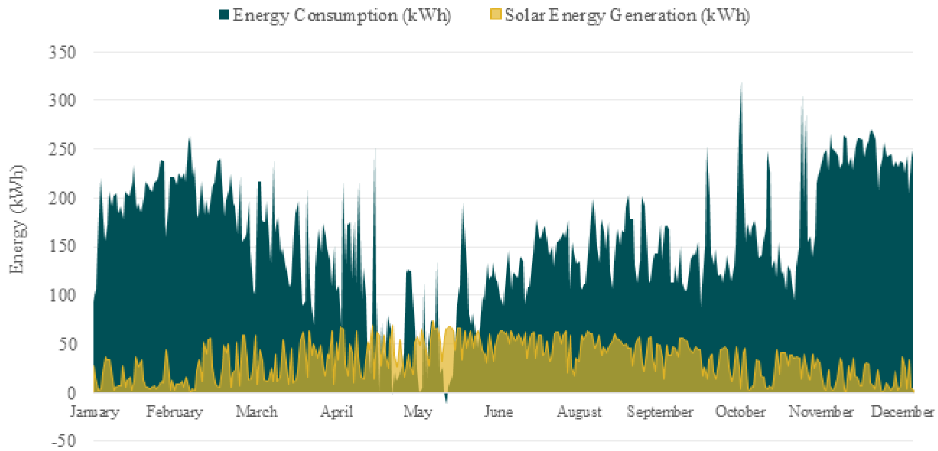

Figure 4. Comparison of the 2020 IGEM farm on-farm energy consumption load profile to the solar generation from the 11.4 kW rooftop solar system based on energy readings over 15-Minute time intervals.

Because the on-farm solar generation system was appropriately sized, there was not a month that experienced net excess generation from solar production. In general terms, this means the solar system did not overproduce in any given monthly billing cycle. As a result, the value of energy savings is equal to the retail electric generation rate of 5.49 cents per kWh. The value of savings from solar generation at IGEM farm is displayed in Table 1. Monthly energy savings from solar generation ranged from a low of $23.51 in December 2020 to a high of $89.97 in July 2020. Combined, the IGEM farm reduced its total energy cost by $675.99 in 2020 (12,313 kWh of solar produced X 5.49 cents per kWh).

Table 1. Monthly solar energy generation (kWh) and value of energy savings based on an energy cost of 5.49 cents per kWh.

Month	**Energy Savings from Solar Generation (kWh)**	**Value of Energy Savings (5.49 cents per kWh)**
January	459	$25.22
February	607	$33.30
March	837	$45.98
April	1,165	$63.98
May	1,362	$74.76
June	1,626	$89.27
July	1,639	$89.97
August	1,490	$81.82
September	1,208	$66.34
October	741	$40.70
November	749	$41.13
December	428	$23.51
Total	**12,313**	**$675.99**

IMPACT OF SOLAR ON PEAK DEMAND

Due to increased electric demand, many farms are now classified as a commercial electric consumer with peak demand charges which are based on the maximum amount of electricity drawn from an electric power system at a single point in time. While demand charges are based on peak usage in a specific time, it is not necessarily an instantaneous peak. Instead, most utilities will measure a monthly peak demand as a rolling average over a specific time interval, typically 15 or 30-minute intervals. Data for the IGEM farm is calculated on a 15-minute rolling demand window and measured in kilowatts (kW).

In many cases, peak demand charges represent roughly half of the total electric bill. As a result, farmers with demand rates are seeking strategies to reduce peak demand charges. One strategy to reduce peak demand is to generate electricity on-site during high demand events. However, timing is critical to implementing an effective peak shaving strategy with on-site generation. As more farmers are considering on-farm solar projects, it is important to understand how the solar generation will impact the farms peak demand charges. Figure 5 illustrates the IGEM farm monthly peak demand with solar and compares it to what it would have been without solar generation. This allows us to calculate the reduction in peak demand that was offset by on-site solar generation. As shown in Figure 5, the maximum demand reduction from on-site solar generation was 2.03 kW in November, while the annual average peak demand reduction was less than 1 kilowatt (0.91 kW). In addition, there were three months (February, March, and December) that did not experience a demand reduction from solar generation. This does not mean there was not any solar generation, it simply suggests that there was not solar generation during the 15-minute window which set the farms monthly peak demand.

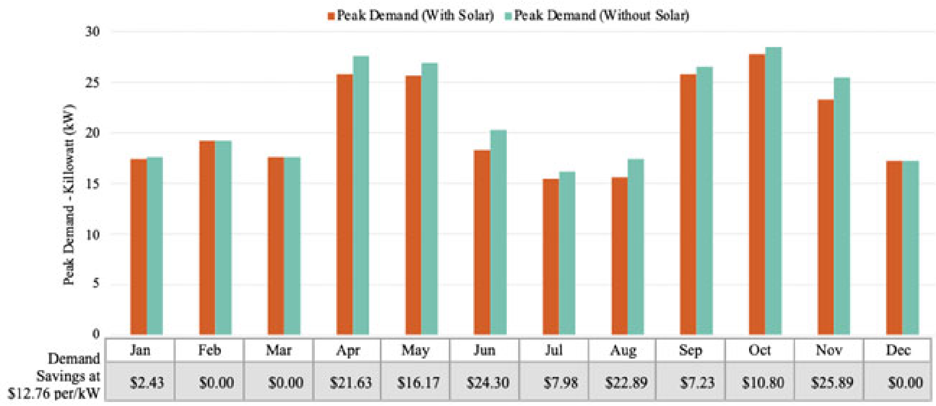

Figure 5. Estimated monthly peak demand savings as a result of solar generation and a comparison of what the monthly peak demand would have been without solar generation.

To further explore the three months that did not experience a reduction in monthly peak demand from solar generation, we will examine the day that the peak demand occurred for February, March, and December. The daily load profile provides a good visualization of the farms peak electricity usage compared to the solar electricity generation based on 15-minute peak demand time intervals. For example, as shown in Figure 6 the IGEM farm set a monthly peak demand of 19.26 kW on February 12th at 7:15 in the morning. Although the on-site solar system generated 10.3 kWh of electricity with a peak power output of 2.14 kW on February 12, the solar generation did not start until 7:45 a.m. which was 30 minutes after the peak demand event occurred.

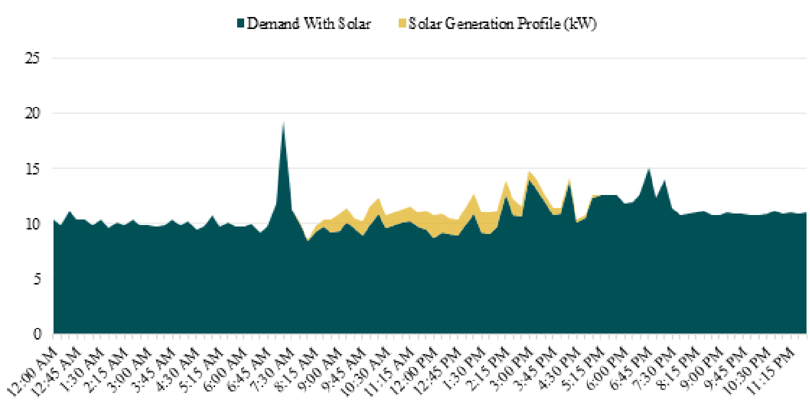

Figure 6. Daily peak electricity usage compared to the solar electricity generation displayed on 15-minute peak demand time intervals on February 12, 2020.

Similarly, as shown in Figure 7, the IGEM farm set the March monthly peak demand of 17.65 kW on March 1st at 7:15 in the morning. There was good solar generation throughout the day reaching 49.71 kWh of electricity with a peak power output of 8.91 kW that afternoon. However, the solar generation did not start until 7:30 a.m. which was 15 minutes after the peak demand event occurred.

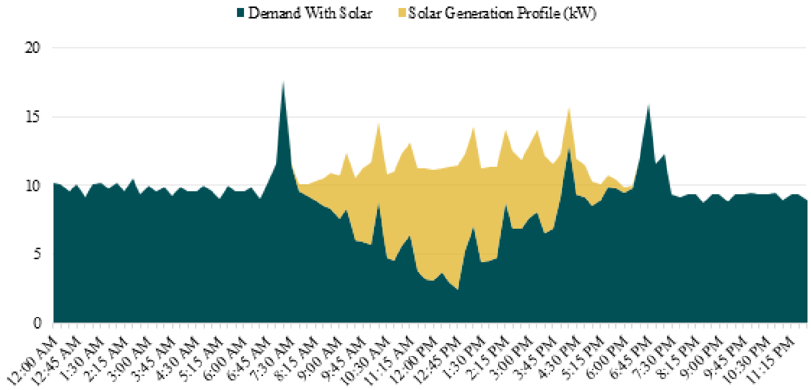

Figure 7. Daily peak electricity usage compared to the solar electricity generation displayed on 15-minute peak demand time intervals on March 1, 2020.

Finally, as shown in Figure 8 the IGEM farm set the December monthly peak demand of 17.18 kW at 4:15 p.m. on December 31st. Due to short days and overcast conditions, this was not a good day for solar generation as the on-site solar system only generated 1.84 kWh of electricity throughout the day with a peak power output of 0.51 kW. While there was not a significant amount of solar generation this afternoon, the solar generation was completed by 4:00 p.m. which was 15 minutes prior to setting the peak demand.

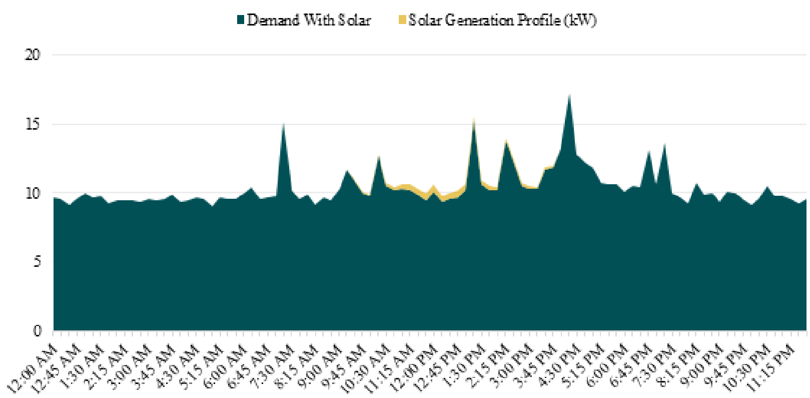

Figure 8. Daily peak electricity usage compared to the solar electricity generation displayed on 15-minute peak demand time intervals on December 31, 2020.

DISCUSSION/RECOMMENDATIONS

In summary, the on-farm solar system at the IGEM farm provided savings by offsetting the energy usage (kWh) throughout the month, however, generally did not significantly reduce the monthly peak demand. The total annual energy cost at IGEM farm in 2020 was $3,158 (57,522 kWh x $0.0549) and the combined demand cost for the year was $3,182 (249 kW x $12.76). The rooftop solar project reduced the energy cost by 17.6% over the year, saving the IGEM farm $676 in annual energy generation charges. In comparison, the on-farm solar project only reduced the annual demand cost by 4.2% saving the IGEM farm $139 in demand charges.

Due to the timing of farm operations at the IGEM farm swine barns, there is not a lot of opportunity for peak demand savings from the on-farm solar generation system. This is because the barns have critical processes such as feed auger motors, water pumps, and ventilation fans that are operational both before the solar generation starts for the day and are also running after the solar shuts down for the day when the sun goes down. As a result, the farm still sets a high peak demand, just at a different time of day, typically early morning, or evening when the solar is off and the animals are still active.

This is a good example of why it is important for farms to evaluate historical usage data from past electric bills to identify daily and seasonal trend patterns. Using the historical energy data and knowledge of the farm operations, farmers can identify large motor loads and daily operations that contribute to peak demand. A clear understanding of how much of a farms bill is based on peak demand charges, what is contributing to the peak demand charges, and when, will help inform the farmer if on-farm solar generation will reduce the peak demand, or not.

If you are an Extension professional working with a swine producer evaluating whether to install solar, it is critical to first review the electric utility rate structures to understand how the producer is charged for electricity and what percentage of the overall electric bill is based on energy charges, versus demand charges. Next, help the farmer organize historical energy bills, identify large motor loads, and critical operations to better understand consumption trends and which operations typically trigger the peak demand. Extension professionals are encouraged to have an understanding of availble grants, tax rebates or other financial assistance that might be available to assist with installation. The availability of these has declined and vary by state. While on-farm solar energy systems can provide emission free energy and, in some cases, offer a good economic return, every farm is unique and may not result in a net savings. Using research data from the IGEM farm, Extension Educators can help farmers better estimate how solar will impact their overall electric bill, determine a payback period, and support informed investment decisions.

LITERATURE CITED

Eric Buchanan, Kirsten Sharpe, Lee Johnston, Ph.D., Michael Reese, and Joel Tallaksen, Ph.D. (2017). Commercial Swine Barn Baseline Energy Audit, University of Minnesota, https://www.lccmr.leg.mn/projects/2014/finals/2014_08d_task_one.pdf

Fehr, R. (1978). Energy in Agriculture: Energy for Swine Facilities Part II: Alternative Sources of Energy,

https://uknowledge.uky.edu/cgi/viewcontent.cgi?article=1033&context=aees_reports

Feldman, David, Vignesh Ramasamy, Ran Fu, Ashwin Ramdas, Jal Desai, and Robert Margolis. (2021). U.S. Solar Photovoltaic System Cost Benchmark: Q1 2020. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-77324. https://www.nrel.gov/docs/fy21osti/77324.pdf.

Harmon, J. and Schweitzer, D. (2016). Benchmarking Energy Usage for Swine Producers, Iowa State University Extension https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1008&context=abe_eng_extensionpubs

Romich, E. and Hay, J. (2019). Solar Electric Investment Analysis Series

https://energizeohio.osu.edu/sites/energizeohio/files/imce/SARE%20Solar%20Bulletin%20%28v4.0%29.pdf

Sharp, K. (2017). Electric and Thermal Energy Consumption in Commercial Swine Facilities, University of Minnesota Extension, https://conservancy.umn.edu/bitstream/handle/11299/217584/mfec_2017_energy_use_swine_barns_sharpe.pdf?sequence=1

United States Department of Agriculture Economic Research Service (2016). Trends in U.S. Agriculture's Consumption and Production of Energy: Renewable Power, Shale Energy, and Cellulosic Biomass, https://www.ers.usda.gov/webdocs/publications/74658/60128_eib159.pdf?v=0

United States Energy Information Administration (2021). Today in Energy, Renewables Account for Most New U.S. Electricity Generating Capacity in 2021, https://www.eia.gov/todayinenergy/detail.php?id=46416

United States Energy Information Administration (2021). Today in Energy, The U.S. Consumed a Record Amount of Renewable Energy in 2020, https://www.eia.gov/todayinenergy/detail.php?id=48396
