Energy Use, Energy Savings, and Energy Efficiency Policy Recommendations for Pennsylvania Agriculture

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1. EXECUTIVE SUMMARY

Agriculture is very important to Pennsylvania's overall economy, with farm products providing $7.7 billion in annual revenue[1], a number that is multiplied several-fold by the economic activity that supports farming. The state has a diversity of agricultural operations and ranks within the nation's top 10 states producing milk, poultry and eggs, and greenhouse crops.

The Pennsylvania Department of Environmental Protection (DEP) wanted to better understand the energy impact of the state's agriculture and prioritize areas with the highest potential for energy savings and renewable energy generation. They also wanted to better understand the current suite of offerings for agricultural energy efficiency within the state, and the barriers that prevent farms from fully realizing their potential for cost-effective energy efficiency investments. Ultimately, the DEP is seeking a set of recommendations to consider in shaping policy and programs to increase the energy efficiency of the state's farms.

To accomplish these objectives, this report's authors analyzed the baseline energy use and savings potential for seven sectors of Pennsylvania agriculture chosen by the DEP: dairy, beef, poultry, swine, orchards, greenhouses and crops. Dairy and poultry were found to have the greatest energy use, energy intensity the highest potential for energy savings.

This report lists common energy efficiency measures per sector, as well as a set of measures for mobile equipment and for non-energy intensive farms. Lighting efficiency, primarily conversion of older lighting types to LED lighting, presents the greatest opportunity for savings across all agricultural sectors. However, each sector has additional measures that also yield savings, such as milk production and milk cooling equipment for dairies, building envelope improvements for swine and poultry, and irrigation and tractor efficiency for orchards and crops.

While there are a variety of public and private programs that offer some form of financial or technical assistance to farms wishing to improve their energy efficiency, there are very few programs that offer targeted energy information specifically to a farm audience.

To better serve Pennsylvania agriculture and encourage farm adoption of energy efficiency technologies, the DEP may consider sponsoring a series of complementary program offerings for farmers. To best serve the diverse needs of Pennsylvania farms, this report recommends that the DEP offer the following energy efficiency services, listed in order from least-cost to highest-cost: education about energy efficiency best practices and existing financial assistance, promotion of energy audits and incentive funds, a low-interest revolving loan fund, competitive grants for energy efficiency projects, and a comprehensive energy efficiency program that offers multiple program components as well as incentives. It is also recommended that all farms be eligible to receive services through the program, and that this program should endeavor to coordinate with other sources of funding applicable to agriculture so that farmers can leverage funding where appropriate. The DEP has an opportunity to take

[1] USDA Census of Agriculture, 2017, Table 2, Market Value of Agricultural Products Sold

a lead role in creating agricultural energy efficiency programs that benefit the full spectrum of the state's farms and can position Pennsylvania as a leader in agricultural energy efficiency.

2. BASELINE ENERGY USE AND SAVINGS

2.1 NUMBER OF FARMS AND ECONOMIC IMPACT

To determine the number of farms in the designated sectors and their economic impact, the authors reviewed the United States Department of Agriculture (USDA)'s 2017 Census of Agriculture, released in spring 2019 by the USDA's National Agricultural Statistics Service. Conducted every five years, the Census of Agriculture is the authoritative source for farmer-reported data on the production level, demographics, and economic impact of U.S. agriculture. Data is available at a national, state, and county level.

The Census of Agriculture defines a farm as "any place from which $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the year[2]." Because this definition includes many very small farms and ones with a limited energy footprint, our subsequent analysis of energy use and savings used an adjusted number of farms. The adjusted number included farms that were likely to use enough energy to result in cost-effective energy efficiency recommendations. Farms below this threshold include farms with low production levels and farms that are not very energy intensive. These farms are unlikely to justify major energy efficiency investments from an economic perspective but can still benefit from certain low-cost measures and behavioral changes. A discussion of activities that can best help these smaller or less energy-intensive farms is included in Section 3.3.

Table 1 provides a definition of the types of agricultural products included in each sector, based on USDA Census of Agriculture definitions and the DEP's preference. The focus of this analysis is on agricultural production of food products for human consumption. However, many of the conclusions regarding production of food products can be extrapolated to the production of non-food products in the crop and greenhouse sectors, should the DEP wish to consider these farms in the future.

Table 2 provides the total number of farms per sector regardless of size and the total economic impact per sector. The table also includes Pennsylvania's ranking among the 50 states for production of each commodity based on total annual sales.

[2] USDA Census of Agriculture, 2017, Appendix A, Census of Agriculture Methodology https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/usappxa.pdf

Table 1: Agriculture Sector Definitions

Sector	Description
Dairy	Milk cows
Beef	Beef cattle and calves
Swine	Hogs and pigs
Poultry/Egg	Broiler chickens, layer chickens and turkeys
Orchards	Trees growing fruits and tree nuts, does not include Christmas trees, berries, or maple syrup production
Greenhouse/Indoor Agriculture	Includes food crops (vegetables, fresh cut herbs, fruits, and berries) grown under glass or other protection. Does not include floriculture/bedding, nursery crops, propagative materials (seeds/transplants), sod, or mushrooms
Crops	Grains, oilseeds, dry beans & peas, vegetables, melons, potatoes, sweet potatoes. Does not include tobacco, cotton, tree fruits & nuts (included in orchards category), Christmas trees or maple syrup production. Does not include crops grown for non-human consumption such as hay.

Table 2: Number of Farms Per Sector and Associated Economic Impact

	Dairy	Beef	Poultry	Swine	Orchards	Greenhouse	Crop	Total
Total number of farms	6,092[3]	9,731[4]	7,346[5]	2,878[6]	1,970[7]	689[8]	21,218[9]	**49,924**
Total annual Market value ($1,000)	$1,979,362	$199,801	$1,684,535	$572,495	158,426	21,587	1,168,296	**5,784,502**
U.S. Rank out of 50 states' market value	6	27	8	13	11*	3**	18***	

*Ranking includes fruits, tree nuts and berries; the remaining analysis excludes berries.

** Ranking includes all nursery, greenhouse, floriculture, sod; the remaining analysis includes only food crops

*** Ranking includes vegetables, melons, potatoes, and sweet potatoes. The remaining analysis includes grain crops.

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[3]USDA Census of Agriculture, 2017, Table 2, Milk from Cows
[4] USDA Census of Agriculture, 2017, Table 16, Cattle and Calves Sales, total beef cow herd
[5] USDA Census of Agriculture, 2017, Table 2, Poultry and Eggs
[6] USDA Census of Agriculture, 2017, Table 2, Hogs and Pigs
[7] USDA Census of Agriculture, 2017, Table 2, Fruits and tree nuts
[8] USDA Census of Agriculture, 2017, Table 39, Total greenhouse vegetables and fresh cut herbs
[9] USA Census of Agriculture, 2017, Table 2, Grains, oilseeds, dry beans, and dry peas plus vegetables, melons, potatoes and sweet potatoes

The maps in *Appendix D: Distribution Maps of Pennsylvania Agriculture by Sector* show the value of the seven sectors of agriculture per county as a percent of the total market value of agricultural products sold. These maps can be used as a proxy for the geographic concentration of farms in Pennsylvania, as the areas with the highest market value are also likely to have a higher quantity of farms. Separate maps are provided for vegetables and grains, which together are equivalent to the number of crop farms.

2.2 ADJUSTED NUMBER OF FARMS

The number of farms in the Census of Agriculture were adjusted to reflect the operations that are likely to spend at least $1,000 annually on energy costs—an amount that is likely to yield cost-effective energy efficiency recommendations. Data on market value of products per farm size is available for some sectors, but not all. It can be assumed that the largest producers are responsible for the majority of the market value. These thresholds are based on EnSave's personal experience in auditing farmers, as shown in our database of audits.

Table 3: Farm Sizes Included in Analysis

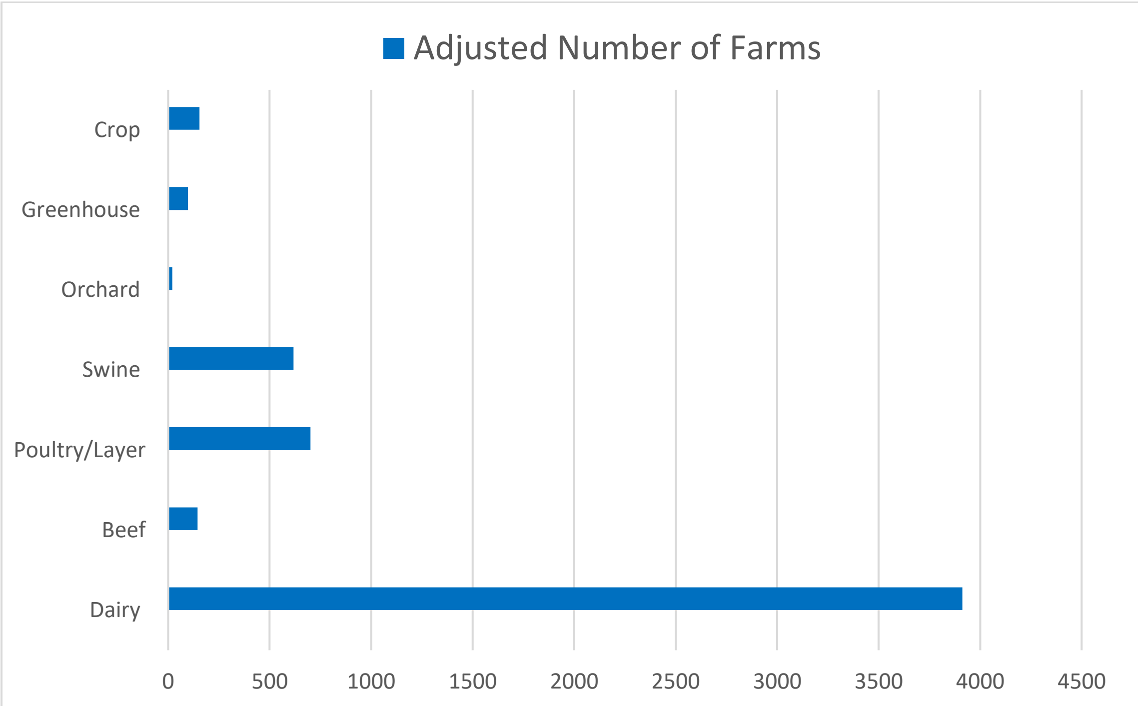
Sector	Farm Size Included in Analysis
Dairy	50 cows or more
Beef	100 beef cattle and calves or more
Poultry	Farms raising at least 100,000 meat birds annually or 10,000 laying birds
Swine	Farms with at least 100 pigs
Orchards	Farms using at least $1,000 per year in diesel fuel for irrigation pumping
Greenhouse/ Indoor Agriculture	At least 2,000 square feet under glass or other protection
Field crops	Farms using at least $1,000 per year in diesel fuel for irrigation pumping

Table 4: Adjusted Number of Farms per Sector

	Dairy	Beef	Poultry	Swine	Orchards	Greenhouse	Crop
Adjusted number of farms	3,913[10]	145[11]	701[12]	617[13]	18[14]	474[15]	140[16]

[10] USDA Census of Agriculture, 2017, Table 17, Milk cow herd sales, total farms 50 cows and above
[11] USDA Census of Agriculture, 2017, Table 16, Beef cow herd sales, total farms 100 cows and above
[12] USDA census of Agriculture, 2017, Table 30, Number sold layers 10,000 or more plus pullets 100,000 or more, plus broilers 100,000 or more, plus turkeys 100,000 or more.
[13] USDA Census of Agriculture, 2017, Table 20, Sales above 200
[14] Refer to Appendix A, Energy Use Methodology, Section 3.1
[15] Refer to Appendix A, Energy Use Methodology, Section 2.1
[16] Refer to Appendix A, Energy Use Methodology, Section 3.1

Figure 1: Adjusted Number of Farms Per Sector



2.3 ESTIMATED RANGE OF ANNUAL ENERGY USE AND COST PER SUBSECTOR

To estimate the energy consumption and savings for various farm sectors, the analysis relied primarily on EnSave's Farm Energy Audit Tool (FEAT) database, as well as publications by University extension, the USDA, and other subject matter experts. EnSave's FEAT™ database contains baseline energy use and savings recommendations for thousands of farms across the United States who received an energy audit from EnSave. This analysis reviewed energy use (energy purchased and utilized by the farm) and did not consider the embedded energy in agricultural operations. An example of embedded energy use would be the energy used to grow crops for animal feed as a component of livestock energy use.

The FEAT dataset is richest for livestock farms, particularly poultry and dairy. FEAT data was also used to estimate energy use and savings for beef and swine. More details of our FEAT methodology are included in Appendix A.

Fewer data points in FEAT were available for greenhouses, orchards, and crops. Also, these farm sectors have wide variability in energy use and savings opportunities based on the systems used on the operation. For example, the presence of supplemental heating and lighting systems in a greenhouse make a big difference in the energy use and corresponding energy efficiency opportunities for a greenhouse. However, the USDA Census of Agriculture does not have information about which greenhouses have these systems, which creates challenges for accurately estimating energy use and savings. Similarly, the energy profile of crop farms varies greatly based on the tillage systems in use and the presence of irrigation on the farm, but the USDA Census data do not always present data on these systems that can be used to estimate energy use.

Assumptions of greenhouse energy use were based on previous research by the authors. To determine orchard and crop energy use, USDA Census of Agriculture production data was overlaid with available Census data on energy costs and combined with previous research. Refer to Appendix A for a description of the methodology used to create these estimates.

Pennsylvania has the nation's largest population of Plain Sect communities, many of whom are engaged in farming. Generally, Plain Sect-owned farms are "off-grid," meaning that the farm is not connected to a traditional electric power grid and the energy needed to power the farm is generated on-site, such as with a generator or with renewable energy. Off-grid farms that rely on diesel or natural gas generators tend to pay significantly more for their energy than grid-connected farms[17]. Since information about the number of off-grid farms in Pennsylvania is not readily available, estimates of energy use do not take these off-grid farms into consideration. Off-grid farms have an opportunity to reduce fossil fuel use and greenhouse gas emissions by implementing renewable energy technologies and energy storage, discussed further in Section 3.5. The DEP may wish to consider the unique energy use profile and needs of off-grid farms due to their prevalence in Pennsylvania.

Most farms use electricity and many also use other fuels such as diesel, propane, gasoline, and natural gas. For livestock, the primary fuel found in our dataset is propane. For crops and orchards, the primary fuel is diesel used in field operations. Our analysis of livestock farms did not evaluate for fuel used in field operations, as this is not a component of most of the audits in our dataset which focus on stationary equipment only.

Table 5: Annual Baseline Energy Use

	Dairy	Beef	Poultry	Swine	Orchard	Greenhouse	Crop	Total
Electricity[18] (kWh)	440,019,440	3,065,526	72,531,597	11,767,920	402,172	7,064,589	3,045,015	537,896,259
Fuel (diesel, propane, gasoline, natural gas, as appropriate) (MMBtu)	864,813	Nominal*	444,045	160,144	1,758	70,645	13,310	1,554,715
Total MMBtu	2,362,260	12,976	690,679	199,681	3,130	94,751	23,700	3,387,177
% of Total MMBtu	69.74%	0.38%	20.39%	5.90%	0.09%	2.80%	0.70%	100%

[17] Organic Valley Best Practices Guide
[18] Electricity is site electricity, not source electricity

*The FEAT dataset did not include any beef farms who used a heating fuel. While some beef farms do indeed use heating fuels, use is very nominal and normally for space heating within the office buildings. There is no need for heat within the primary agricultural operation

The baseline energy cost was determined by reviewing 2017 data on Pennsylvania retail energy prices for electricity, propane, natural gas, gasoline, and diesel from the United States Department of Energy's Energy Information Administration. 2017 data was used to match the year of the Census of Agriculture data.

Table 6: 2017 Retail Energy Prices

	Cost	Unit
Electricity[19]	$0.101	kWh
Gasoline[20]	$2.53	Gallon
Diesel[21]	$2.65	Gallon
Natural Gas[22]	$10.28	ccf
Propane[23]	$3.12	Gallon

Table 7: Annual Baseline Energy Cost

	Dairy	Beef	Poultry	Swine	Orchard	Greenhouse	Crop	Total
Electricity	$44,573,969	$310,538	$7,347,451	$1,192,090	$40,740	$715,643	$308,460	**$54,488,891**
Fuel	$18,437,813	$0	$9,467,039	$3,414,270	$33,915	$957,040	$256,785	**$32,566,862**
Total Energy Cost	$63,011,782	$310,538	$16,814,490	$4,606,360	$74,655	$1,672,683	$565,245	**$87,055,753**

2.4 ENERGY INTENSITY PER SUBSECTOR

To determine the energy intensity per sub-sector, the total estimated energy used was divided by the number of farms. This exercise provides an estimated MMBtu utilized per farm. There is no universal metric for energy-intensity for agriculture, such as energy used per acre or per animal, so therefore a per-farm approach normalizes the energy intensity. Based on this information, poultry and dairy farms

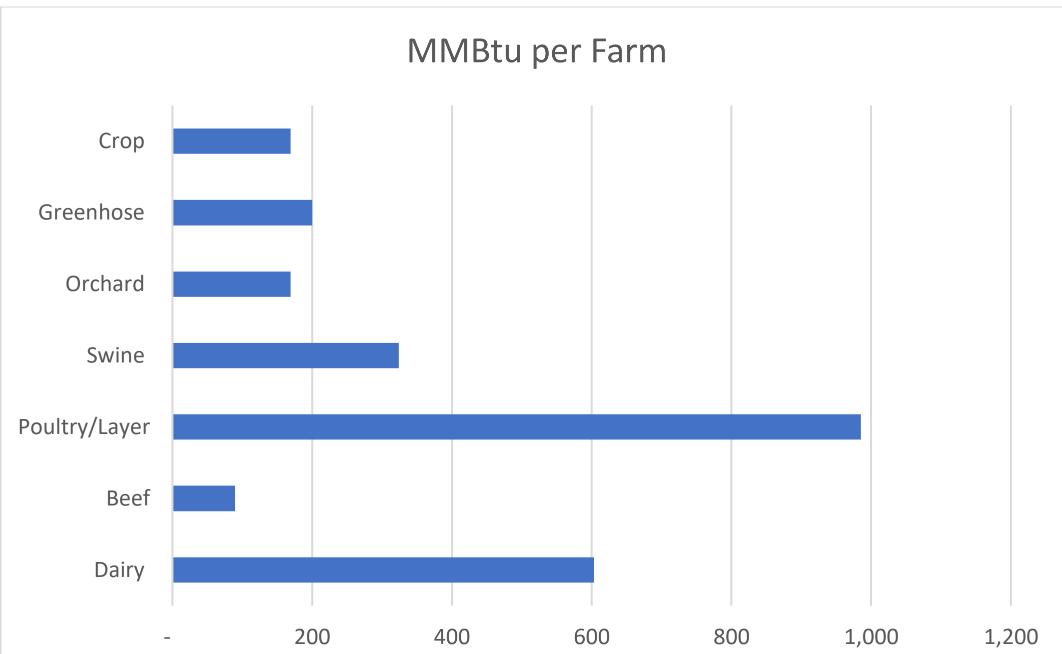
[19] EIA, State Electricity Profiles, Data for 2017, Release date January 8, 2019. https://www.eia.gov/electricity/state/
[20] EIA, Weekly Retail Gasoline and Diesel Prices, 2017, all grades, https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_a.htm
[21] EIA, Weekly Retail Gasoline and Diesel Prices, 2017, ultra-low sulfur, https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_a.htm
[22] EIA, Natural Gas Prices for Pennsylvania, annual, 2017, https://www.eia.gov/dnav/ng/ng_pri_sum_dcu_SPA_a.htm
[23] EIA, Weekly Pennsylvania Propane Residential Price, 1990-2019, for week ending December 4, 2017, https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=W_EPLLPA_PRS_SPA_DPG&f=W

have the highest energy intensity. This intensive energy use means that these sectors are most likely to view energy as a significant farm expense and could be more likely to be receptive to reducing energy use. The DEP may want to consider these high-intensity sectors as a priority in shaping future energy efficiency policies and programs.

Table 8: Energy Intensity per Subsector

	Dairy	Beef	Poultry	Swine	Orchard	Greenhouse	Crop
Total MMBtu	2,362,260	12,976	690,679	199,681	3,130	94,751	23,700
Number of Farms	3,913	145	701	617	18	474	140
MMBtu per farm	603.7	89.5	985.3	323.6	169.4	199.9	169.4

Figure 2: MMBtu per Farm



2.5 ESTIMATED TECHNICAL POTENTIAL OF ENERGY AND COST SAVINGS PER SUBSECTOR

The term "technical potential" refers to the energy savings possible if all farms implemented all appropriate energy efficiency measures regardless of cost or the farmer's willingness to adopt the measures[24]. This technical potential represents a theoretical upper limit of energy savings but is

[24] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy https://www.energy.gov/eere/slsc/energy-efficiency-potential-studies-catalog

unattainable given economic and societal constraints. The "achievable potential[25]" represents the energy savings that could be achieved within an energy efficiency program. In an agricultural program, between 5% and 10% of the technical potential can be achieved over a multi-year program duration. There are many factors affecting the achievable potential, including the strength of the program's marketing and outreach campaign, eligibility criteria, incentive levels, the financial strength of the farms, the farmer's cash on hand, market volatility and changes to commodity prices, and other priorities affecting the farm's willingness to invest in energy efficiency. The estimate of 5% and 10% is based on the authors' prior experience running comprehensive agricultural energy efficiency programs.

Table 9: Technical Annual Energy Efficiency Potential

	Dairy	Beef	Poultry	Swine	Orchard	Greenhouse	Crop	Total
Technical potential-electricity (kWh)	77,568,860	587,935	16,364,358	384,737	(85,642)*	1,766,147	(648,430)*	95,937,965
Technical potential-electricity cost savings	$7,834,455	$59,381	$1,652,800	$38,858	($8,650)	$178,381	($65,491)	$9,689,734
Technical potential-fuels (MMBtu)	239,386	0	148,433	82,796	1,466	17,661	11,097	500,839
Technical potential – fuel cost savings	$5,103,710	$0	$3,164,592	$1,765,211	$31,304	$376,533	$237,020	$10,678,368
Total Cost Savings								**$20,368,103**

*Note: The primary energy efficiency measure for crops and orchards is conversion of diesel irrigation pumps to electric irrigation pumps, which will result in a net increase in electricity, a decrease in diesel use, but a net decrease in total energy consumption.

[25] Ibid

Table 10: Achievable Annual Energy Efficiency Potential- 10% of Technical Potential

	Dairy	Beef	Poultry	Swine	Orchard	Greenhouse	Crop	Total
Achievable potential- electricity (kWh)	7,756,886	58,794	1,636,436	38,474	(8,564)	176,615	(64,843)	9,593,797
Technical potential- electricity cost savings	$783,445	$5,938	$165,280	$3,886	($865)	$17,838	($6,549)	$968,973
Technical potential- fuels (MMBtu)	23,939	0	14,843	8,280	147	1,766	1,110	50,084
Technical potential – fuel cost savings	$510,371	$0	$316,459	$176,521	$3,131	$37,653	$23,702	$1,067,838
Total Cost Savings								**$2,036,811**

3. ENERGY EFFICIENCY OPPORTUNITIES

3.1 OVERVIEW OF ENERGY CONSUMPTION AND ENERGY EFFICIENCY OPPORTUNITIES BY SECTOR

The description of each agricultural sector below (3.1.1-3.1.6) includes a discussion of how the sector uses energy and a narrative description of the most common energy efficiency measures. Section 3.2 lists the common energy efficiency measures broken out by applicable sector and measure type. Sections 3.3-3.5 include a discussion of efficiency opportunities for small or low-energy intensity farms, stationary equipment on the farm, and renewable energy potential.

3.1.1 DAIRY

Dairies primarily consume energy in the course of housing and milking the dairy cows. Major energy uses include lighting (for barns, milking parlors, and work areas), ventilation (for cooling and air exchange), motors and pumps for harvesting the milk, and refrigeration for cooling and storing the milk.

There are multiple opportunities for dairies to reduce their energy input by installing more efficient lighting, implementing variable speed drives for the milk vacuum and transfer pumps and fans, and increasing the efficiency of the milk cooling process through milk pre-coolers, scroll or high efficiency compressors, and compressor heat recovery. In climates such as Pennsylvania’s with regular sub-freezing temperatures, dairies can benefit from energy-free or solar stock waterers that reduce the energy costs of heating the cows' drinking water.

Energy savings from fan replacement varies widely based on the run time of the fan and is less often recommended as a cost-effective measure. Similarly, high efficiency electric motors are not often recommended. When determining when a motor replacement becomes cost-effective (lifetime energy cost savings are greater than the motor's cost), most agricultural motors (typically less than 10 hp except for irrigation pump motors) would need to run at least 2,000 hours before an early replacement with an energy efficient motor is cost-effective. However, higher-use motors or those that reach the end of their useful life should be replaced with NEMA Premium® motors that are certified by the National Electric Manufacturers Association (NEMA).

3.1.2 BEEF

Beef cattle farms use less energy than many other livestock farms due to the lack of climate-controlled housing or on-site processing. The major energy uses on a beef cattle farm are lighting and heating for farm outbuildings and shops, using tractors to haul drinking water to the animals, and heated stock waterers for the cattle.

Beef farms can benefit from installing energy efficient lighting and solar-powered, energy-efficient or energy-free stock waterers that reduce the energy costs in pumping and heating drinking water for livestock. Beef farms can reduce the energy and labor associated with hauling drinking water to the stock waterers by implementing an efficient piping and pumping system to deliver water to the stock waterers.

Like dairy operations, electric motors are not typically cost-effective to replace with high efficiency models unless they run more than 2,000 hours per year or are at the end of their useful life.

Beef farms can benefit from some of the low-energy intensity farm recommendations discussed in section 3.3.

3.1.3 POULTRY

Poultry farms encompass the production of meat birds such as broilers and turkeys as well as egg layers. In broiler facilities, the poultry houses must be kept at a consistent temperature and humidity level to maximize bird growth, which involves heaters and fans. The houses must also be well-ventilated to remove ammonia generated by the poultry litter, maintain a consistent temperature and provide a constant supply of fresh air. Lighting is utilized between 18-24 hours per day to stimulate birds to eat and drink and promote their overall health. These processes can use a significant amount of heating fuel and electricity.

There are opportunities to increase poultry house energy efficiency by tightening up the building envelope and therefore reducing heating costs. Common building envelope measures include sealing air leaks, insulating solid sidewalls, installing attic inlets and brooding curtains, and insulating end wall doors.

Implementing a radiant heating system provides more efficient heat than forced-air heaters, and efficient tunnel ventilation systems and tunnel doors improve the ventilation efficiency of a poultry house. Automatic climate controllers for poultry houses can save energy by automatically adjusting the heating and ventilation systems.

Poultry operations can save a significant amount of energy by converting their lighting to LEDs. There has been a dramatic increase in the use of LEDs on poultry farms in recent years due to lower costs and increased reliability. For farms with older lighting systems, conversion to LED lighting presents an easy and highly cost-effective energy efficiency project.

Egg layers use energy differently than meat-bird operations. Lighting is still used in layer housing, although less than in broiler houses. Ventilation is a major energy consumer on layer operations, and refrigeration is used to cool and store the eggs. Common energy efficiency measures include energy-efficient LED lighting and energy efficient chillers.

Like dairy operations, electric motors are not typically cost-effective to replace with high efficiency models unless they run more than 2,000 hours per year or are at the end of their useful life.

3.1.4 SWINE

Swine housing has several similarities to poultry broiler housing and the energy use has a similar profile. Lighting, ventilation, and heating are used to keep the pigs at an optimal temperature for growth and to control airflow.

Common efficiency measures include energy efficient lighting, radiant heaters, heat pads/mats, timers and controllers, high efficiency fans, and insulation/building envelope improvements.

Like dairy operations, electric motors are not typically cost-effective to replace with high efficiency models unless they run more than 2,000 hours per year or are at the end of their useful life.

3.1.5 CROPS & ORCHARDS

Field crops in Pennsylvania use energy through tractors and implements used for tilling, planting, and harvesting. A subset of crop farms in Pennsylvania irrigate their crops, in which case they use energy to power their irrigation pump and to distribute water. Some farms also harvest crops that are then mechanically dried on site, which uses energy to run the drying process. Still other crops have on-site cold storage for their harvest.

The field operations of a farm use significant energy, typically in the form of diesel fuel used to power the tractors. The practice of conservation tillage minimizes soil disturbance by reducing or eliminating the process of tilling the soil prior to planting. Conservation tillage is often practiced to reduce soil erosion on the farm, but the practice also saves fuel because the tractor makes fewer passes across the field.

Aside from tillage, crop farmers have an opportunity to save energy in the operation of their tractor. There are many low-cost maintenance activities that reduce fuel consumption, such as keeping tires properly inflated, replacing air and fuel filters promptly, using the proper ballast for each operation, cleaning dirty fuel injectors, keeping ground-engaging tools sharp, and properly matching the horsepower to the load. For high horsepower tractors pulling lighter loads, “gear-up, throttle-down” is a fuel-saving practice that runs a light load in a higher gear and lower engine speed to save fuel.

Because a relatively small number of farms in Pennsylvania use irrigation and most have small acreage, irrigation does not represent a large aggregate opportunity for energy savings. However, farms that use irrigation can save energy through a variety of means, such as converting their diesel irrigation pump to more efficient and cleaner electric-powered pump, converting from sprinkler to drip irrigation, installing well pump variable frequency drives, implementing irrigation scheduling, improving distribution uniformity, overhauling the pumping plant, and utilizing low-pressure sprinkler nozzles. More so than other farm types, opportunities for improving irrigation energy efficiency are highly site specific and vary with the existing pump type, water distribution technique, soil type, crop, topography, water table, and various other factors. For this reason, site evaluations or energy audits are particularly important before implementing an energy efficiency measure or practice.

The largest opportunity for energy efficiency on Pennsylvania’s irrigated farms is fuel switching from diesel and gasoline to electricity for irrigation pumping stations. The energy savings is driven by the inherent difference in efficiency between an internal combustion engine compared to an electricity powered motor (~30% vs ~90% respectively). As an example, a farmer using 1,000 gallons of diesel to operate a 30 hp irrigation pump who switches to an electric pump can reap energy savings of roughly 67%. In some cases, fuel switching is not economical due to the cost of installing new power lines to the pumping plant. An alternative solution for these cases is to install solar-powered pumps, which can replace the entire fossil fuel generator or can be used in conjunction with the generator to achieve a lower levelized cost of energy. While a switch from diesel to electric irrigation motors results in some energy conversion losses inherent in electric generation, large-scale electric generation is still more energy efficient than using farm-scale diesel equipment and also creates far fewer greenhouse gas emissions. Pollution is also easier to control in an electric power plant representing a single point source of pollution rather than widely dispersed individual diesel motors. Also, greenhouse gas emissions from an electric motor will reduce over time as the power grid becomes cleaner overall.

The USDA’s 2018 Irrigation and Water Management Survey provides insight into the reasons why Pennsylvania irrigators are not making improvements to reduce energy and water use. Among the 1,400 irrigators who responded to the survey, the leading barrier by a wide margin is that investigating in improvements is not a priority, accounting for 59% of respondents.

Table 11: Barriers to Reduce Energy Use or Conserve Water Among Pennsylvania Irrigators[26]

Barrier to Making Improvements	Percentage of Farms
Investigating improvements not a priority	59%
Will not be farming long enough to justify improvements	18%
Cannot finance improvements	17%
Improvements will not reduce costs enough to cover installation costs	15%
Risk of reduced yield or poorer quality	9%
Physical field/crop condition limit system improvements	4%
Uncertainty about future availability of water	3%
Improvements will increase management time or cost	2%
Landlord will not share in cost	2%

In addition to energy reduction opportunities for field operations and irrigation, crop and orchard operations often use additional post-harvest processing equipment, primarily for grain drying and cold storage. It has typically not been cost-effective to replace grain dryers with more efficient models based on energy savings alone. Instead, famers replacing a dryer would seek to install the most efficient model possible since they are already investing in a major equipment replacement. Emerging technologies such as radio-wave grain dryers promise more dramatic energy savings but are still undergoing third-party measurement and verification. Crop farms and orchards that utilize cold storage can benefit from measures that increase the efficiency of the refrigeration system such as evaporator fan controls, outside air economizers, scroll compressors, floating head pressure controls, and high-efficiency compressors.

3.1.6 GREENHOUSES

According to the 2017 USDA Census of Agriculture, Pennsylvania has approximately 4.1 million square feet of food crops grown under glass or other protection, which represents a 33% increase from 2012[27]. The dominant crop grown under protection is tomatoes, which accounts for 60% of this area. Furthermore, food crops grown under protection are dominated by large operations, with 60% of production taking place in operations with at least 10,000 square feet[28]. In addition to greenhouses, there are various growing styles encompassed on the USDA's definition of "other protection," most notably seasonal hoop houses and high tunnels, which typically use minimal to no energy. The area of cultivation under high tunnels in Pennsylvania is unknown, but has been expanding rapidly over the past decade and is expected to triple over the next five years.[29] Our energy use baseline and savings

[26] USDA 2018 Irrigation and Water Management Survey, Table 9
[27] USDA Census of Agriculture, 2017, Table 39, Food crops grown under glass or other protection
[28] Ibid
[29] https://vegetablegrowersnews.com/article/high-tunnels-use-grows-in-mid-atlantic-region

calculations assume that 70% of food crops grown under protection take place in high tunnels or hoop houses that use a negligible amount of energy.

In contrast to high tunnels and seasonal hoop houses, commercial greenhouses constructed of glass or rigid plastic typically grow year-round and use supplemental heating to maintain an optimal temperature for growing crops in colder weather. Many greenhouses also use refrigeration for storage of their crops. Depending on the crop light requirements, greenhouses may also use supplemental lighting to increase plant growth and yield.

There are many opportunities for greenhouses to save energy within the heating system. Infrared/anti-condensation film, energy curtains, insulated side walls, multi-layer glazing and poly film covers can reduce air leaks and retain heat in the greenhouse. Condensing unit heaters, root zone heating, and radiant heating systems offer energy savings compared to conventional heating methods.

Greenhouses using supplemental heating can also benefit from dynamic temperature control, which involves using advanced computerized control systems to take advantage of ambient outdoor temperatures and solar radiation, and reduce heating requirements through various techniques including "temperature integration," whereby the daily average greenhouse temperature remains the same but daytime temperatures increase from greater storage of solar heat and nighttime temperatures decrease from reduced fuel use. Thermal electric storage is an additional emerging technology that allows greenhouses to store thermal energy generated off-peak for usage later, thereby reducing heating costs and reducing use of fossil fuels.

Greenhouses using refrigeration can reduce the energy use of walk-in coolers and freezers by installing evaporative fan controls, replacing compressors with more efficient models, and utilizing outside air economizers and floating head pressure controls.

For greenhouses using supplemental lighting, horticultural LEDs and advanced high intensity discharge (HID) fixtures can provide significant energy savings. Lighting is a critical factor in creating appropriate plant growth and nutritional value, and the Design Lights Consortium has recently created a policy for horticultural lighting to help greenhouse producers choose efficient lighting with the appropriate light spectrum needed for plant growth[30]. Adaptive lighting controllers provide further savings opportunities for greenhouses using supplemental lighting by dynamically dimming or switching off lighting fixtures based on real-time measurements of available sunlight to provide the optimal light level.

Greenhouses are part of a broader sector of agriculture called controlled environment agriculture (CEA) or controlled environment horticulture (CEH). These terms encompass traditional greenhouses as well as other types of indoor agriculture such as vertical farms, container farms, and other configurations with a tightly controlled environment for growing plants. Some of these farms use little to no natural lighting, heating, or ventilation, and instead use precise controls to grow plants using much less water and pesticides, but far greater energy, than open-air crops.

[30] https://www.designlights.org/horticultural-lighting/technical-requirements/ Also, refer to the American Society of Agricultural and Biological Engineers' lighting standards for horticultural applications: S640, S642 and EP344.

CEA is generating increased interest and investment in response to public demand for high-quality, pesticide-free, and locally grown produce, and investors like the stability of a controlled environment crop versus a crop grown in the open and susceptible to climate fluctuations. The level of greenhouse food production is expected to grow rapidly in Pennsylvania over the next decade, as illustrated by BrightFarm's newly constructed 250,000 square foot facility in Synder County, which is expected to go begin producing salad greens and herbs in 2020[31]. There is not yet enough data on non-greenhouse indoor farms to estimate their prevalence in Pennsylvania or their energy footprint, but it is important for DEP to be aware of this emerging sector and its possible involvement in a future energy efficiency program.

The DEP did not wish to consider mushroom growing a focus of this study since mushroom growers are included with indoor agriculture in the Census of Agriculture but have an energy profile very different from other indoor agriculture. Mushrooms are grown in dark buildings that are sometimes underground and therefore do not have the same lighting, heating, and ventilation needs as other types of indoor agriculture. However, the DEP may want to consider mushrooms as part of a future analysis because Pennsylvania is the leader in U.S. mushroom production. Pennsylvania grows over half of the button mushrooms in the United states with production concentrated in a few very large operations, primarily in Chester county. DEP recognizes that Pennsylvania is the leader in U.S. mushroom production and some of the energy efficiency recommendations provided in this analysis could be applied to that sector.

This study specifically reviewed greenhouses producing food crops for human consumption, but this represents a minority (approximately 17%) of crops grown under protection. Many of the energy efficiency measures and practices applicable to food crops grown in greenhouses are also applicable to other crops grown in greenhouses such as flowers and nursery plants.

Cannabis growing has recently caught the attention of specialists focusing on CEA energy use because cannabis uses significant supplemental lighting and cooling. Indoor cannabis production is extremely energy intensive due to the high lighting requirements and the need to control temperature and humidity. Indoor cannabis production generally requires between 150 kWh and 500 kWh of electricity per square foot per year depending on the facility's efficiency. For comparison, this is approximately 10-30 times greater than the energy use of a typical office building. Numerous states have conducted studies on cannabis energy impacts and have found that cannabis production accounts for between 2% and 5% of their total electricity use. Greenhouse operations are significantly more efficient due to utilization of natural light, and typically consume 50% to 75% less energy than indoor operations. Outdoor production is the most energy efficiency, but has significant disadvantages such as susceptibility to mold, weather-related damage, pests, theft, and the inability to produce year-round. If Pennsylvania expands production of medical cannabis, indoor hemp production, and/or legalizes recreational cannabis production facilities, the energy use of this agricultural subsector will increase significantly. Therefore, the DEP should be aware of this impact and potential for efficiency and explore options to mitigate cannabis-related energy use.

[31] https://www.thepacker.com/article/brightfarms-build-second-greenhouse-pennsylvania

3.2 RECOMMENDED ENERGY EFFICIENCY MEASURES

EnSave identified the individual energy efficiency measures for each subsector of agriculture including the energy savings potential and cost range. The savings and cost vary substantially based on farm size, production level, frequency of equipment use, quantity of equipment, baseline condition and efficiency of the equipment being replaced, and interactive effects with other equipment on the farm. To better understand the energy savings potential and cost-effectiveness of various energy efficiency measures, farmers can receive a customized energy audit that analyzes the energy efficiency potential of the farm's specific situation.

The most worthwhile measures for consideration are identified based on their feasibility of implementation for farms in Pennsylvania. "Feasible" is defined as *cost-effective* (the energy savings exceeds the initial investment cost within the useful life of the measure), *affordable* (farms can reasonably afford the initial cost of the measure) *practical* (the measure is commercially available in Pennsylvania), *proven* (the measure has been demonstrated and proven successful in the field, with little risk to production levels) and *value-added* (when possible, the measure has a benefit to the farm beyond energy savings).

Table 12 includes a list of all recommended measures with a ranking system of stars and dollar signs (1 being the lowest and 3 being the highest) to rank the respective energy savings and cost for each measure. While the recommendations are based on a review of the most commonly recommended energy efficiency measures across a large dataset of completed energy audits and energy efficiency installations, the ranking system is subjective and based on professional judgement. Table 12 also indicates which sectors of agriculture can benefit from each measure. Technologies that are pre-commercial or underutilized are identified with an asterisk (*). The measures are further delineated by color-coding (green for high, yellow for medium, and red for low) to indicate which measures have the greatest potential for overall energy savings based on the measure's applicability to the agricultural sectors in Pennsylvania. For example, because dairies are energy-intensive and there are many dairies in Pennsylvania, the dairy sector uses far more energy than any other sector. Therefore, measures affecting dairies have the highest overall savings potential among Pennsylvania agriculture. In contrast, measures that affect food crops in greenhouses may provide significant energy savings to an individual farm, but because there are far fewer greenhouses than dairies the greenhouse measures are less impactful overall. Pennsylvania DEP can therefore consider the green-shaded measures to be the most important to include in an energy efficiency program.

Guidance from the American Society of Agricultural and Biological Engineers (ASABE) *Standard S612: Performing On-Farm Energy Audits* was used determine the major categories of measures and applicable sectors. This standard provides guidance on what elements should be included in an energy audit based on the type of farm.

Table 12: Energy Efficiency Measures

Energy Efficiency Measure	Measure Energy Savings	Measure Cost	Applicable Sectors
Lighting			
LED lighting (general, animal production, horticultural, security)	✯✯✯	$$$	Dairy, swine, poultry, cattle, greenhouses
Lighting controls (photocell, timeclock, occupancy sensors and dimmers)	✯✯	$	Dairy, swine, poultry, cattle, greenhouses
Grow lighting control systems (adaptive lighting)	✯✯✯	$	Greenhouses
Ventilation			
High efficiency exhaust fans	✯	$$$	Dairy, swine, poultry, greenhouses
High efficiency circulation fans	✯	$$$	Dairy, swine, poultry, greenhouses
Adding cones to exhaust fans	✯	$	Dairy, swine, poultry, greenhouses
Variable speed drive for circulation fans	✯✯✯	$$	Dairy
High volume, low speed fans	✯✯✯	$$	Dairy
Refrigeration			
High efficiency evaporator & condenser fan motors & controls for refrigeration systems	✯	$	Dairy, poultry, orchards, greenhouses
High efficiency scroll compressors	✯✯✯	$$	Dairy, poultry, orchards, greenhouses
Improved refrigerated room insulation	✯✯✯	$$	Poultry, orchards, greenhouses
Energy Star® refrigerators	✯	$$	Dairy, swine, poultry, cattle, crops, orchards, greenhouses
Chiller/ chiller condenser/chiller compressor	✯✯	$$$	Dairy
Well water plate coolers	✯✯	$$$	Dairy
Evaporator fan controls	✯✯	$$	Dairy, cold storage
Milk Harvesting			
Variable speed drive on milking vacuum pump	✯✯	$$	Dairy
Milk Precooler with variable speed drive on milk transfer pump	✯✯	$$	Dairy
Automatic milker takeoffs	✯	$$	Dairy
Controllers			
Master system automation	✯	$$	Dairy, swine, poultry, greenhouses

Peak demand response controls	Cost saving measure	$	Dairy, swine, poultry, cattle, crops, orchards, greenhouses
Grid energy router *	✮✮	$$	Dairy, swine, poultry, cattle, crops, orchards, greenhouses
Other motors and pumps			
High efficiency motors (minimum 2,000-hour annual use)	✮	$$	Dairy, swine, poultry, cattle, crops, orchards, greenhouses
Pumps/agitators for manure pumps	✮✮	$$	Dairy
Water heating			
Compressor heat recovery	✮✮✮	$$	Dairy
Heat pump hot water	✮✮✮	$$	Dairy
Solar, energy-free or energy efficient stock waterers	✮✮	$$	Dairy, cattle
Ozone laundry*	✮✮	$$$	Dairy
Air heating/building environment			
High efficiency furnace and boilers	✮✮	$$$	Greenhouse
Forced-air furnace to radiant heater or heating pad conversion	✮✮✮	$$$	Poultry, swine
Wall insulation (loose, batten, spray foam)	✮✮✮	$$	Poultry, swine
Sealing air leaks	✮✮✮	$	Poultry, swine
Improved attic insulation (loose, batten, spray foam)	✮✮✮	$	Poultry, swine
Solid sidewall conversion	✮✮✮	$$$	Poultry, swine
Attic inlets	✮✮	$$	Poultry
Tight vent boxes	✮✮	$$	Poultry
Insulated tunnel doors	✮✮	$$	Poultry
Insulated brood curtains	✮✮✮	$$	Poultry
Pipe, fitting, and water heater insulation	✮	$	Dairy, swine, poultry
Cold climate heat pump (general conditioned farm areas)	✮✮✮	$$	Dairy, swine, poultry, cattle, crops, orchards, greenhouses
Off-peak thermal storage	Cost savings only	$$	All (office areas only)
Infrared/Anti-Condensation Coating (IRAC)	✮✮	$$	Greenhouses
Greenhouse energy curtain	✮✮✮	$$$	Greenhouses
Root zone heating	✮✮	$$	Greenhouses
Dynamic temperature control	✮✮✮	$$	Greenhouses
Shade curtains	✮✮✮	$$	Greenhouses
Bench heating systems	✮✮	$$	Greenhouses
Waste heat recovery *	✮✮✮	$$	Poultry, greenhouse

Heat pads/mats	✯✯	$$	Swine
Drying			
High efficiency grain dryer	✯✯	$$$	Crops
Efficient grain storage ventilation	✯✯	$$$	Crops
Radio wave grain drying *	Pre-commercial	Pre-commercial	Crops
Waste Handling			
Energy Star® washing machines	✯	$$	Dairy
Energy Star® clothes dryers	✯	$$	Dairy
Air cooling			
Evaporative cooling	✯✯	$$	Dairy, poultry, swine, greenhouse, crop, orchard
Cultural practices			
Conservation tillage practices	✯✯✯	$$$	Crop, orchard
Tractor maintenance	✯	$	Dairy, swine, poultry, cattle, crops, orchards, greenhouses
Engine block heater timers	✯✯✯	$	Dairy, swine, poultry, cattle, crops, orchards, greenhouses
Irrigation			
Variable speed drive on electric irrigation motor	✯✯✯	$$	Crops, orchards
Variable speed drive on booster and well pumps	✯✯	$$	Crops, orchards
Irrigation pump fuel switching from diesel to electricity	✯✯✯	$$$	Crops, orchards
Low-pressure irrigation nozzles	✯✯	$	Crops, orchards
Sprinkler to drip irrigation conversion	✯✯	$$$	Crops, orchards
Drop tubes	✯✯	$	Crops, orchards

3.3 SMALL FARM AND LOW-ENERGY INTENSITY FARM RECOMMENDATIONS

Small and low-energy intensity farms can still benefit from energy conservation and energy efficiency activities.

Nearly all farms use tractors, and smaller farms can utilize the same tractor maintenance activities described in Section 3.1.5. Many smaller farms can also benefit from engine block heater timers on tractors and other mobile diesel equipment during cold weather. Engine block heater timers are further described in Section 3.4.

Small and low-energy intensity farms can also implement standard energy efficient commercial equipment in their shops and office spaces. These measures include LED lighting, efficient heating, cold climate heat pumps, insulation of the building envelope, power strips, and Energy Star® office and break room equipment such as computers, printers, and refrigerators.

Table 3 lists the types of measures that are typically cost-effective for small farms.

Table 13: Measures for Small and Low-Energy Intensity Farms

Measure/Activity	Energy Savings Potential	Cost
Engine block heater timers	✯✯✯	$
LED lighting for non-production use, such as shops and offices	✯✯✯	$
Power strips for office equipment	✯	$
Tractor maintenance	✯	$
Cold climate heat pump for shops and offices	✯✯	$$
Building insulation and pipe/fitting insulation for shops and office building	✯	$
Energy Star® refrigerators for animal medications	✯	$$
Adding cones to exhaust fans	✯	$
Pipe, fitting, and water heater insulation	✯	$

3.4 NON-STATIONARY ENERGY USE

Most of the energy use analyzed in this report is from stationary equipment such as lighting, motors, heating systems, and pumps. Mobile energy use from farm vehicles and tractors should also be factored into a discussion of Pennsylvania's agricultural energy use and savings potential.

There are over 71,000 trucks in use on Pennsylvania farms[32]. It is difficult to quantify the gasoline or diesel use of these trucks without knowing their average annual mileage. Nonetheless, these trucks make up about 5% of the total trucks under 11,000 pounds registered in Pennsylvania in 2017[33].

While immediate measures to improve truck efficiency are limited, the prevalence of hybrid and electric-only trucks are expected to increase dramatically in the coming years. Some diesel-powered farm trucks could utilize alternative fuels such as biodiesel.

[32] USDA Census of Agriculture, 2017, Table 45, trucks, including pickups

[33] Commonwealth of Pennsylvania, Department of Transportation, Bureau of Motor Vehicles, Report of Registrations for Calendar Year 2017, Page 1, summary of registered vehicles by vehicle type: http://www.dot.state.pa.us/public/dvspubsforms/BMV/Registration%20Reports/ReportofRegistration2017.pdf

There are over 135,000 tractors in Pennsylvania, 30,000 of which are over 100 horsepower[34]. Without better data on the use of tractors in Pennsylvania, it is difficult to quantify energy use because tractor energy use varies substantially based on the size of the farm, the purpose of the tractor, and the crop being cultivated. Likewise, the estimated energy savings is very difficult to quantify without more granular data.

Regardless of tractor utilization, most farms can see an immediate and low-cost improvement in tractor fuel efficiency by implementing a maintenance plan and other fuel reducing techniques, the details of which are further discussed in Section 3.1.5.

Farms who use an electric engine block heater overnight to warm their diesel tractor or other farm vehicle engines in sub-freezing temperatures can benefit from an engine block heater timer. The timer turns on the heater a few hours before start-up rather than having the heater run all night, thus saving energy. This measure is very inexpensive and should be part of every farm's cold-weather maintenance plan.

Finally, several companies are working on prototypes of electric farm tractors and a small selection are commercially available. While electric tractors currently have a very small share of the market, they are expected to become widespread in the coming years. As the concept of beneficial electrification gains traction among energy efficiency program administrators, the Pennsylvania DEP should watch this emerging technology for eventual deployment among Pennsylvania farms. Electrification of farm tractors and other farm vehicles such as skid steers, loaders, and all-terrain vehicles would have a significant impact on the energy use and greenhouse gas emissions of the farm sector.

3.5 ANALYSIS OF RENEWABLE ENERGY POTENTIAL

Pennsylvania farmers have an opportunity to invest in renewable energy to reduce their greenhouse gas emissions and their reliance on fossil fuels. Many farms have resources that can be well-suited to renewable generation. These resources can be utilized to offset the farm's own energy needs and to generate additional revenue for the farm by providing power to third-party renewable energy developers. Third-party renewable energy development, whether a private investment or utility-sponsored, presents an opportunity for farmers to develop a new income stream from their operation. This is especially true of solar and wind development. Typically, renewable energy is bought and sold over long-term contracts with stable pricing. These long-term payments can provide a secure financial return that can hedge against the volatile nature of farming.

Common types of renewable energy applicable to farms include solar, wind, and biomass. Solar presents an attractive financial proposition for many farms due to the dramatic decrease in solar costs over the past decade coupled with favorable tax treatment including tax credits and depreciation. Any available incentives can provide further financial benefit by reducing the up-front cost of solar, and thereby

[34] USDA Census of Agriculture, 2017, Table 45

reducing the interest paid along with the overall cost of the system. Additionally, Renewable Energy Credits (RECs) can provide an additional revenue stream that can also strengthen the financial performance of the farmer's investment over time. Many renewable energy installations can be cash-positive within the first few years.

The utilization of renewable energy-driven thermal (heating & cooling) solutions in conjunction with energy storage (electric &/or thermal) can further reduce costs and emissions on the farm. Combining these types of systems, as well as heat transfer & exchange technology (heat pumps) can result in dramatic synergies with benefits including off-setting operating costs and revenue generation opportunities.

Renewable energy storage can be particularly important for off-grid farms, as they provide a cleaner alternative to fossil fuel use. However, maintaining a traditional fossil fuel generator can provide a strong backup in the case of problems with a renewable energy technology.

4. BARRIERS TO IMPLEMENTING ENERGY EFFICIENCY PROJECTS

Like all agricultural producers throughout the United States, Pennsylvania farmers face several challenges. The primary focus for farmers is production—raising their animals or crops to the level of quality and quantity that will enable them to obtain the best price and maintain contractual relationships with their buyers. To make a change to their operation to increase energy efficiency, the farmer must be assured that the change will not negatively impact their production.

Agricultural producers are driven to implement energy efficiency for a wide variety of reasons. Cost savings, an increase in production, reduction in maintenance costs, improved performance, and a desire for environmental stewardship all factor into producers' decisions to implement energy efficient equipment. Some sectors of agriculture, such as poultry, may be further driven by external requirements such as poultry integrator specifications to install particular equipment. There are also secondary benefits associated with energy efficiency measures in some agricultural subsectors, including a more pleasant and safe work environment. Other examples include production efficiency gains through the use of LED lighting in the poultry and greenhouse industries, and inhibition of bacterial growth in milk by the use of well water plate coolers on dairy farms.

Below is a discussion of some of the barriers to adoption of energy efficient practices that EnSave has witnessed on farms.

4.1 COST

Individual farms generally have total cost-effective savings potential of between 10% and 35% of their total energy use[35]. However, the level of customer engagement in energy efficiency can vary substantially between agricultural subsectors depending on the cost of energy relative to other variable operating costs. For example, energy comprises a relatively small percentage of variable operating costs on dairy farms, typically ranging from 3% to 8%. Conversely, energy represents the most significant variable cost for poultry farmers, ranging from 30% to 50%[36]. The farm sectors that are the most energy-intensive are generally more receptive to energy efficiency programs because energy costs have a larger impact on their total budget and therefore there is greater motivation to reduce the cost. Even for farms with high energy intensity, there are many other costs that compete with energy costs as an area of focus.

While farms have many other costs competing for attention, energy represents one of the few inputs that can be adjusted on the farm. Most farms operate within a commodity market where they cannot control the price they receive for their product and they have little control over other major costs such as labor, feed and seed. The challenge lies in bringing these energy-reducing opportunities to the farmer's attention in the first place and finding technologies that meet the farmer's definition of an acceptable payback.

4.2 BUSINESS ENVIRONMENT

The precarious nature of farming is also a barrier to the implementation of energy efficiency projects. While there are always farmers who are highly successful, many farms live with significant volatility due to changing market prices and spikes in production costs. They are also affected by international issues such as the global commodity markets and tariffs. Several sectors of farming have been under severe financial stress in recent years, limiting both the cash farmers have to invest in energy efficiency projects and the attention they can pay to operational changes beyond what's required to stay afloat each month. Pennsylvania's dairy sector has been particularly hard-hit in recent years, mirroring the experience of dairies across the United States. Recent news reports have illustrated a drop in milk prices of 40% between 2014 and 2018 due to an oversupply of milk[37]. Many dairies have consequently gone out of business, with Pennsylvania losing 956 dairies between 2012 and 2017.[38]

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[35] EnSave's repository of over 3,000 farm energy audits for all farm types and sizes has shown energy efficiency measures can reduce energy use on most farms between 10% to 35% of total energy use.

[36] Cunningham, D.L., Fairchild, B.D. 2012. Broiler Production Systems in Georgia: Costs and Returns Analysis. University of Georgia Cooperative Extension.

[37] Centre Daily News, "Here's how the Dairy 'Crisis' is Affecting Centre County," June 9, 2018.

[38] 2017 USDA Census of Agriculture, Table 2: Market Value of Agricultural Products Sold

4.3 FARMER AGE AND LACK OF SUCCESSION PLAN

The age of the primary operator of the farm is also a factor influencing the farmer's likelihood to implement an energy efficiency practice. Pennsylvania's farms have an average age of 54.8 years, with 20% over age 65[39]. These demographics mirror those of farmers in the United States as a whole. With many older farmers in a precarious financial situation or lacking a family member to take over the farm, farmers can be reluctant to invest in a new technology when they might not be farming long enough to see a return on their investment.

5. CURRENT FINANCAL AND TECHNICAL ASSISTANCE PROGRAMS

A variety of organizations offer financial and technical assistance for agricultural energy efficiency projects in Pennsylvania, including higher education institutions, non-profit organizations, state government, federal government, utilities, and commercial entities.

Most programs have been in existence at least 5 years, with several having been around for decades. Of these programs, the majority make funds available to a variety of businesses which may include farms, but only a few specifically target farms. Of the farm-specific programs, only the federal programs (the U.S. Department of Agriculture's Rural Energy for America Program and the Environmental Quality Incentives Program) are specifically focused on energy efficiency and/or renewable energy. Penn State Extension offers a broad range of technical assistance services to farms, some of which include energy efficiency information.

The DEP provided EnSave with a spreadsheet listing programs serving Pennsylvania, and EnSave has reviewed the information online about each program. EnSave also conducted an email survey to ask program managers further questions about the historical participation of agricultural producers in these programs and their opinion on how to make the program more attractive to agriculture. Of the 30 programs originally listed in the spreadsheet, 16 program managers responded to the survey. The original spreadsheet, the survey, and the survey responses are provided in Appendix B.

The information below provides an overview of the programs available, organized by program sponsor.

[39] 2017 USDA Census of Agriculture, Table 52, Selected Producer Characteristics: 2017 and 2012

5.1 HIGHER EDUCATION

Table 14: Higher Education Programs

Program Title	Program Sponsor
Energy Assessment Program, Emerging Technologies Application Center	Northampton Community College
Energy Assessment Program	Penn State Ag Extension
Energy Assessment Program, Pennsylvania Technical Assistance Program (PennTAP)	The Pennsylvania State University
Energy Assessment Program	St. Francis University Institute for Energy
Farm Energy Day Workshops	Penn State Ag Extension
Farm Energy IQ Training	Penn State Ag Extension
Resource materials and Extension educators	Penn State Ag Extension

Four colleges and universities in Pennsylvania provide energy assessments to businesses with a varying degree of focus on agriculture. St. Francis University offers free energy assessments to agriculture facilities, whereas Northampton does not mention agriculture specifically and is focused on business and manufacturers. Still other University programs emphasize industrial facilities through the U.S. Department of Energy's Industrial Assessment Program. It is likely that the emphasis varies based on the overlap of the institution's service area with the concentration of farming areas.

Penn State offers a series of energy-focused workshops along with workshops on other agricultural topics. The Pennsylvania Technical Assistance Program through Penn State ("PennTAP") provides resources for farmers about financial assistance programs. Penn State Ag Extension also offers extensive technical assistance in the form of its publications and its staff of professional extension educators, both of which offer practical advice and dissemination of research findings to farms.

Five college or university-sponsored programs responded to the survey. Identified barriers to farm participation included scheduling/travel (for workshops), lack of interest, lack of technical or financial resources, lack of awareness of the program, and lack of time to complete an energy assessment. Of the survey respondents who had ideas for how the DEP could further help Pennsylvania farmers, they suggested hosting energy efficiency webinars to reach a broader audience, and instituting grants to implement energy efficiency projects.

5.2 NONPROFIT

Table 15: Nonprofit Programs

Program Title	Program Sponsor
Act 129 Micro-Loan	West Penn Power Sustainable Energy Fund
Financing	West Penn Power Sustainable Energy Fund
Penelec Sustainable Energy Fund Grants	Penelec Sustainable Energy Fund at the Community Foundation for the Alleghenies
Sustainable Energy Fund	Sustainable Energy Fund for PPL
Met-Ed Sustainable Energy Fund Grants	Met-Ed

Pennsylvania's sustainable energy funds were created as a result of electric utility deregulation and subsequent settlement agreements by Pennsylvania electric utilities. The funds are designed to promote the development of sustainable and renewable energy programs and clean-air technologies on both a regional and statewide basis. The Statewide Sustainable Energy Board enhances communication among the four funds, and the DEP is a member of this board.

These five funds provide grants and loans for energy efficiency and renewable energy studies and projects.

Two of the five fund administrators responded to the survey. They reported serving between 2-15 participants per year and do not currently have agricultural participants.

5.3 STATE GOVERNMENT

Table 16: State Government Programs

Program Title	Program Sponsor
First Industries Fund Loans	Pennsylvania Industrial Development Authority
Small Business Pollution Prevention Assistance Account	Pennsylvania Department of Environmental Protection
Small Business Advantage Grants	Pennsylvania Department of Environmental Protection
Alternative Fuels Incentive Grant	Pennsylvania Department of Environmental Protection
Alternative Clean Energy Program (closed)	Pennsylvania Department of Community and Economic Development
Solar Energy Program (closed)	Pennsylvania Department of Community and Community Development
Renewable Energy Program (closed)	Pennsylvania Department of Community and Community Development
Commercial Property Assessed Clean Energy (C-PACE)	Allegheny, Chester, Lawrence, Lebanon, Northampton, Philadelphia, and Wayne counties

Pennsylvania state government offers a range of energy programs through the Department of Environmental Protection and the Department of Community and Economic Development.

The DEP offers two grant programs, the Small Business Advantage Grant and the Alternative Fuels Incentive Grant. It also offers the Pollution Prevention Assistance Account Loan program.

The Department of Community and Economic Development offers the Alternative and Clean Energy Program which provides grants and loans for clean energy projects including efficiency and conservation projects.

C-PACE, administered at the county level, provides a mechanism to finance energy efficiency improvements alongside a property tax bill. C-PACE is currently active in seven counties and may expand to other areas in the coming years.

Four of the state program administrators responded to the survey. These state programs issued varied amounts of funding and served between 3-187 total clients per year, of which 0-12 were farms.

Program managers identified several barriers to farm participation, including the farmer's lack of necessary matching funds, knowledge of energy efficiency, and knowledge of the program's existence. The Alternative and Clean Energy Program requires competitive bidding and prevailing wages, which the program manager saw as a barrier to farm participation.

The state programs who responded to the survey pointed to a need for increased marketing to agricultural producers to increase awareness. For the Alternative and Clean Energy Program, it was suggested that a list of companies that can provide design/build services for anaerobic digesters be provided.

5.4 FEDERAL GOVERNMENT

Table 17: Federal Government Programs

Program Title	Program Sponsor
Farm Services Agency Loans	USDA Farm Services Agency
Small Business Administration Loans	Small Business Administration
Environmental Quality Incentives Program	USDA Natural Resources Conservation Service
Rural Energy for America Program	USDA Rural Development
Business Energy Investment Tax Credit	Internal Revenue Service
Section 179 D Tax Credit	Internal Revenue Service
Modified Accelerated Cost Recovery System (MACRS)	Internal Revenue Service

The Federal Government offers several incentives for energy efficiency. Two of these programs (Environmental Quality Incentives Program and Rural Energy for America Program) are offered by the U.S. Department of Agriculture and are specifically geared to energy efficiency and renewable energy for farms.

The Environmental Quality Incentives Program offers funding for agricultural energy management plans (AgEMPs, commonly called farm energy audits) through a network of non-government technical service providers, and also provides financial assistance for a prescriptive list of energy efficiency technologies. The program typically covers around 75% or more of the cost of the energy audit or energy efficiency project. Farmers apply for services and go through a multi-phase ranking, approval, and contracting process before funds are authorized for projects.

The Rural Energy for America Program offers competitive grants and loan guarantees for energy efficiency and renewable energy projects. Non-agricultural rural businesses are also eligible to apply, but the Pennsylvania REAP program administrator states that about half of their 40 annual applicants are farms.

The REAP program administrator pointed to the need for matching funds and other farm priorities being barriers to participation. They pointed to load curtailment, load shifting, and energy storage as being areas the DEP could investigate.

Other available loans and tax credits (Small Business Administration-backed loans, Business Energy Investment Tax Credit, Section 179 D, MACRS) are available for energy projects but not specific to farms.

It is unknown how many farms participate in these tax incentives. The participation of farms likely varies based on the knowledge of the farmer’s accountant and the knowledge of vendors helping farms install energy efficiency projects.

5.5 UTILITY

Table 18: Utility Programs

Program Title	Program Sponsor
Act 129 Incentives	First Energy
Act 129 Incentives	PPL
Act 129 Incentives	PECO
Act 129 Incentives	Duquesne Light
PJM Energy Efficiency Capacity Program	PJM
Various efficiency programs	Pennsylvania electric cooperatives

In 2008, Pennsylvania enacted Act 129 which mandated that all electric distribution companies with at least 100,000 customers to develop and file an energy efficiency and conservation plan. As such, the major electric utilities (Duquesne Light Company, , Met-Ed, Penelec, Penn Power, West Penn Power, PECO, PPL and FirstEnergy which includes Met-Ed, Penelec, Penn Power and West Penn Power) offer energy efficiency programs to customers which are overseen by the Pennsylvania Public Utility Commission.

Each utility is required to file annual reports on program performance. Customers are divided into residential, commercial, and industrial classes and a range of programs are offered to each sector (for example appliance recycling, lighting incentives, and energy audits offered to residential customers). Agricultural customers may be on residential utility accounts, which can often limit the applicable energy efficiency measures for which they can apply. None of the utilities offers a stand-alone agricultural program, so therefore it is unknown from the annual reports how many agricultural customers have participated in these programs and what their savings have been.

The administrator of the Duquesne Light Watt Choices Program confirmed via email that their energy efficiency rebates cover all commercial and industrial customers, but they do not have a dedicated program or carve-out for agriculture. The administrator also stated that they do not specifically identify agricultural customers and they would be part of the commercial/industrial rate class.

The PPL non-residential energy efficiency program reports serving 117 agricultural producers in the 2013-2016 program period. PPL has served multiple types of farms and provides incentives up to 50% of the project cost based on energy savings.

The Pennsylvania Public Utility Commission publishes a Technical Reference manual to measure and verify applicable energy efficiency measure that are part of Act 129 programs. The manual includes methodology and calculations to determine energy savings from energy efficiency measures included in the programs, and includes eight agricultural measures: Automatic milker takeoffs, dairy scroll compressors, high-efficiency ventilation fans, heat reclaimers, high volume low speed fans, livestock waterers, variable speed drives for dairy vacuum pumps, and low pressure irrigation systems. The presence of these measures indicates that some agricultural producers may have participated in Act 129 incentives. These measures are included on the measure list in Section 3.2.

The PJM Interconnect regional transmission organization coordinates the movement of wholesale electricity throughout parts of 13 states including Pennsylvania. Farmers whose utilities are part of PJM can be eligible for some rebates. PJM is not accessible to individual customers, but customers access the incentives through the services of an aggregator who collects project data on behalf of several individual customers. EnSave works with an aggregator to help agricultural customers receive rebates throughout PJM territory. Incentives are available for completed energy efficiency projects and are paid out over several years.

Pennsylvania's thirteen rural electric cooperatives are not required to offer customer energy efficiency programs through Act 129, although most offer some form of energy efficiency education and rebates to their members. Most energy efficiency resources and rebates are geared to residential customers. Energy efficiency programs include home energy audits, energy efficiency financing, load shifting, and free LEDs in exchange for CFLs. Equipment eligible for cooperative rebates includes EnergyStar® rated appliances, heat pumps, electric thermal storage, geothermal heating, hot water heaters, and attic insulation.

5.6 COMMERCIAL ENTITIES

Table 19: Commercial Programs

Program Title	Program Sponsor
Farm credit loans	AgChoice Farm Credit
Agriculture financing	Compeer Financial

Private entities such as banks and credit unions offer financing to farms. Some financial institutions are specifically geared to farms or market a significant portion of their services to farms.

Several of these firms also offer consulting services such as accounting and tax planning, business advising, or succession planning. These commercial entities did not respond to the survey, so it is unclear how many loans have been issued for energy projects or what the loan rates and terms are.

6. NEAR-TERM POLICY RECOMMENDATIONS FOR DEP

Recognizing that the DEP has limited funding to address agricultural energy efficiency, the recommendations below prioritize activities that can achieve greater adoption of energy efficiency technologies for Pennsylvania's farms. These recommendations are informed by EnSave's decades of experience designing and implementing agricultural energy efficiency programs and our awareness of agricultural energy efficiency programs administered by others.

Dairy, poultry, swine, greenhouses, and crops represent the primary agricultural subsectors for energy efficiency opportunities in Pennsylvania, with dairy and poultry farms accounting for the vast majority of potential savings. It is recommended that any energy efficiency program focus heavily on dairy and poultry while still providing assistance to farms with less opportunity for energy savings. This approach helps ensure an equitable approach to serving the state's farmers.

Section 6.1 below reviews some overarching principles that are important for a program designer to keep in mind when shaping an agricultural energy efficiency program. These principles are important to consider regardless of the size or scope of the program. Section 6.2 discusses our prioritized program designs for the DEP to consider, beginning with the lowest cost and simplest option. The level and complexity of each proposed program is variable based on the size and scope of the program; for instance, a more complex program piloted in a small region of the state could cost less than a single-channel program that is promoted heavily statewide. Given DEP's limited budget for agricultural energy efficiency program funding, the DEP's approach should focus on lower-cost efficiency opportunities before scaling up efforts. However, with the possibility of Pennsylvania joining the Regional Greenhouse Gas Initiative, the commonwealth could soon have more funding for energy efficiency projects and could therefore implement some of the more comprehensive and costly programs sooner than anticipated.

While in general the program concepts listed first should be implemented first, the DEP may wish to combine elements of multiple recommendations to create a program that best fits the DEP's scope of services and available funding. The DEP should also keep in mind that the level of achieved energy savings within the agricultural sector correlate to the cost of the program, and the DEP should therefore balance its budget and staffing constraints against its mandates for achieving energy savings.

The DEP can administer an energy efficiency program using existing staff or can choose an administrator to deliver the program, such as a private consulting firm, government agency, or non-profit organization. Some states use a single administrator to design and deliver all energy efficiency activities. Others design energy efficiency programs and then select administrators through a competitive bid process. Still other states allow administrators to create their own program designs and present them through a competitive bid process. The "program administrator" below refers to whichever entity—whether DEP staff or an outside consultant—is responsible for promoting the program component to agricultural producers, securing their engagement, and delivering services.

6.1 OVERARCHING PROGRAM DESIGN CONSIDERATIONS

6.1.1 THE AGRICULTURAL COMMUNITY SHOULD BE ENGAGED

Organizations such as the Farm Bureau, Penn State Extension, the Pennsylvania Department of Agriculture, the U.S. Department of Agriculture and commodity-specific groups like poultry integrators and milk cooperatives are responsible for serving agriculture and advocating on their behalf. They are known and trusted by farmers and are therefore essential partners in the promotion of an agricultural energy efficiency program. These organizations are part of Pennsylvania's "agricultural community" and are key allies in keeping farmers aware of programs that can help them.

The DEP should keep the agricultural community apprised of its efforts to develop an energy efficiency program and utilize the community to inform farmers of resources available through DEP-sponsored efforts. These organizations often have a robust communication network of newsletters, social media, farm visits, and events that complement DEP's own public relations efforts to publicize the availability of a farm energy efficiency program.

6.1.2 THE PROGRAM SHOULD PROVIDE SERVICE TO ALL FARMS BUT PRIORITIZE DAIRY AND POULTRY

It is recommended that a DEP-sponsored energy efficiency program should be available to all farmers regardless of their utility, utility rate class, geography, farm size, or farm type. This allows the program administrator to cast the widest possible net for outreach, and program stakeholders are more easily able to promote a program when it applies to their entire constituency. Having the program broadly available does not mean that all interested farms will qualify for all program services. For example, some small farms may not use enough energy to qualify for financial assistance and would not have as many cost-effective opportunities for major equipment upgrades. They can, however, still benefit from implementing low-cost or no-cost maintenance and conservation activities that can make a difference to their farm. The best way to serve smaller farms is by making educational opportunities available, either through stand-alone best practices material or by including best practices material for smaller farms alongside a larger-scale offering for more energy-intensive farms.

Similarly, many farms are on residential rate classes and are locked out of being able to access commercial incentives that can be more flexible and applicable to their farm. A DEP-sponsored energy efficiency program should not make a distinction between utility rate class so that farms can access the most appropriate incentives.

Considering the outsized energy use and savings potential of dairy and poultry farms in the state, any agricultural energy efficiency effort should prioritize these sectors. If measures are to be promoted as part of best practices material or through a grant or incentive program, the measures listed in Table 20 are most important to consider and should be prioritized unless the farm's specific circumstances point to higher energy savings for another measure.

Table 20: Prioritized Measures

Measure	Dairy	Poultry	Other
LED lighting and lighting controls	X	X	X
High efficiency circulation fans and variable speed drives for circulation fans	X	X	
High efficiency scroll compressors	X	X	
Chillers	X		
Well-water plate coolers	X		
Variable speed drive for milking vacuum pump	X		
Compressor heat recovery	X		
Milk precooler with variable speed drive for milk transfer pump	X		
Energy efficient stock waterer	X		X
Wall insulation		X	X

Sealing air leaks		X	X
Attic insulation		X	
Attic inlets		X	
Solid sidewall conversion		X	
Insulated brood curtains		X	
Fuel switching from fossil fuels to electrical equipment	X	X	X
Low-Cost/No-Cost Measures			
Engine block heater timers	X	X	X
Energy Star® washing machines, clothes dryers, refrigerators, office	X	X	X
Tractor maintenance	X	X	X
Pipe, fitting, and water heater insulation	X	X	X
Maintenance of equipment	X	X	X

6.1.3 PROGRAM SHOULD ADDRESS ALL FUEL TYPES

Energy efficiency programs sponsored by investor-owned utilities have been active in Pennsylvania and many other states for several decades. These programs can drive significant reductions in electricity and natural gas use, but they do not address opportunities for reducing other fuels such as propane, diesel, and heating fuel, which can account for a large portion of a farm's energy use and cost. Therefore, an agricultural energy efficiency program should incentivize cost-effective reduction of any fuel used on the farm in order to make the greatest impact on the farms' energy use and costs and meet a need that is not addressed through utility programs.

6.1.4 THE AGRICULTURAL SECTOR IS HARD-TO-REACH AND UNDERSERVED

Farms are considered a hard-to-reach and underserved sector for energy efficiency program administrators. They are a distinct segment of Pennsylvania's business sector, yet they have different equipment needs than other businesses. Unlike many peers in the commercial sector, farms often don't have a facility manager dedicated to equipment maintenance and financial optimization. Farmers can benefit from access to an energy efficiency program that provides a combination of incentives and technical assistance to help them implement energy efficiency practices.

Because farmers are widely dispersed geographically, it can be more expensive to reach the agricultural sector than other types of businesses. With many competing demands for attention on the farm, farmers can be slow to respond and are not always available during core business hours because that is when they are busiest with active farm work. It is important to understand the seasonality of each agricultural subsector in order to maximize the impact of program marketing and outreach efforts. These challenges, coupled with the barriers identified in Section 4 above, are important to consider when crafting an agricultural energy efficiency program.

6.2 OPTIONS FOR DEP-SPONSORED ENERGY EFFICIENCY PROGRAMS

6.2.1 OPTION A: EDUCATION AND SUPPORT THROUGH DEVELOPMENT AND DISSEMINATION OF BEST PRACTICES AND DISSEMINATION OF FINANCIAL ASSISTANCE OPTIONS

6.2.1.1 BEST PRACTICES

This report recommends the development of outreach materials to educate Pennsylvania's agricultural sector about best practices to reduce energy use. Best practices materials can take several forms, such as a multi-page booklet, one-page handouts, educational videos, articles developed for the agricultural media, or an online information clearinghouse. Creation of best practices material as a companion to an energy efficiency incentive program is a cost-effective way to educate farmers about energy efficiency opportunities and can drive interest in implementing energy efficiency projects. The recommendations would include a combination of cost-effective capital investments as well as low-cost and no-cost activities. Best practices materials funded by DEP should be inclusive of all subsectors but emphasize opportunities in the dairy and poultry sectors given their prominence in Pennsylvania.

Technical information about specific energy efficiency practices and technologies can be used to educate farmers about targeted opportunities and help them in their decision-making. This technical information can take the form of flyers, fact sheets, videos, articles, and other media. Information on low and no-cost recommendations that farmers can implement on their own (such as cleaning fan blades and light covers, keeping tractor tires properly inflated, and implementing a maintenance schedule for equipment) can help many small farmers who might not be eligible for financial assistance programs or lack the resources to invest in new equipment.

Alongside the development of best practices materials, it is recommended that the DEP or program administrator implement an outreach and dissemination campaign to educate Pennsylvania producers about the practices. The best way to distribute information is to partner with organizations within the agricultural community to distribute the best practices through their existing communication channels (newsletters, blogs, social media, etc.) and through attendance at events serving the agricultural community. DEP can present best practices material to Pennsylvania farmers through workshops, informational tables at events and conferences, and webinars.

A comprehensive best practice guide would include all the measures included in Table 12. If the DEP wished to take a more targeted approach, the measures in Table 22 should be prioritized. Appendix C contains links to examples of best practices material developed by other states and programs. Funding has come from state-sponsored energy efficiency initiatives spearheaded by a Public Utilities commission, industry funding, and grant funding.

[40]6.2.1.2 PUBLICIZATION OF FINANCIAL ASSISTANCE PROGRAMS

A common refrain from current program administrators who responded to the survey (see Appendix B) is that farmers are not sufficiently aware of the financial assistance programs that could help them. Alongside the creation of best practices material, the DEP can create a simplified, user-friendly version of the program summary spreadsheet in Appendix B to inform farmers of the existing energy efficiency incentives, financing, and technical assistance available in Pennsylvania. This information can then be shared with farmers and the agricultural community using the same information channels used to disseminate best practices materials. This way, farmers are informed of the opportunities available so they can make an educated decision about what type of funding to pursue. With the up-front cost of the equipment being a primary impediment to installation of energy efficient equipment, farmers need as much assistance as possible to drive program participation.

To the extent practicable, it is recommended that the DEP or administrator designate a staff person or contractor to serve as an ombudsperson for farmers. This ombudsperson would develop familiarity with each program and could direct farmers to the appropriate funding source(s) based on the farm's needs. This service provides value because the funding sources have multiple deadlines, eligibility requirements, and application processes and can easily cause confusion for the farmer. Having a well-trained ombudsperson who can engage farmers directly to answer questions provides a better experience than providing a lengthy list of program options for farmers to sort out on their own.

A combination of best practices and referrals to existing programs would allow the DEP to drive adoption of energy efficiency measures and practices without having to fund its own program administration or incentive deployment activities.

6.2.2 OPTION B: DEEPER PROMOTION TO STEER FARMERS TO EXISTING ENERGY AUDIT AND INCENTIVE FUNDS

In Option B, the DEP would promote and fund delivery of energy audits to Pennsylvania agricultural producers while enhancing its promotion of existing energy efficiency programs. New York state currently funds delivery of agricultural energy audits through its Agriculture Energy Audit Program and then leverages external funding to provide farmers with incentive funds.

Investor-owned utilities and the federal government offer incentives for energy efficiency projects, but an energy audit or assessment is typically required to access these incentives. There are several entities in Pennsylvania that provide energy audits to farms and rural businesses through USDA Rural

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Development's Energy Audit and Renewable Energy Development Assistance (EA/REDA) grant. The DEP could work with existing administrators of these programs to help promote the availability of the agricultural energy audits and encourage farmers to implement energy projects post-audit through utility, state, or federal programs. Because the DEP is eligible to apply for EA/REDA funding, the DEP may also consider securing a grant to expand the number of audits available in the commonwealth.

The DEP currently receives funding from the U.S. Department of Energy's State Energy Program to fund industrial assessments for manufacturers. These assessments are currently delivered through the Pennsylvania State University's PennTAP and Northampton Community College's Emerging Technology Applications Center program. If possible, DEP can reserve some of its industrial assessment funds for agriculture so that farmers are eligible to receive these audits. The DEP administrator can also implement a marketing effort to educate farmers about the availability and benefits of these energy audits.

Energy audits provide a site-specific evaluation of the energy efficiency recommendations most appropriate for a farm. The energy audit analyzes where energy is used in the operation and evaluates the energy savings and cost-effectiveness of energy efficient alternatives. The audit serves as a decision support tool to help the farmer understand where energy is used, which energy efficient equipment should be considered, and how to prioritize energy efficiency investments based on payback period. Because an energy audit is tailored to the unique energy profile of each farm, it provides a more customized assistance than best practices material.

Energy audits can be provided as a stand-alone service and can also be a pre-requisite to accessing custom incentives or other program services. The American Society of Agricultural and Biological Engineers (ASABE) has established *Standard 612: Performing On-Farm Energy Audits*[41]. It is recommended that any energy audits provided through a DEP-sponsored program follow the standard of an ASABE "Type II" energy audit, as this standard is most commonly used for agricultural energy audits. Meeting this standard or the criteria of the USDA Natural Resources Conservation Service's *Conservation Activity Plan 128: Agricultural Energy Management Plan*[42] is required to access payments through the USDA Natural Resources Conservation Service.

In addition to a comprehensive energy audit that would evaluate all energy-using equipment on the farm, the DEP can also offer a pared-down audit that reviews just one or two measures. This targeted audit is commonly called an energy assessment or technical assistance report and is geared to farmers who want to evaluate a particular technology to determine its appropriateness for their farm. The energy audit can be provided at no cost to the farmer or the program can require the farmer to pay a portion of the cost. In EnSave's experience, there will be less demand for audits that require a partial payment from the farmer than audits that are provided at no charge. However, farmers who pay a portion of the audit's cost are more likely to implement a recommended energy efficiency project following the audit. A farmer cost

[41] The ASABE standard is not included in the appendix because it is accessible only to ASABE members.
[42] https://efotg.sc.egov.usda.gov/references/public/CO/FY17_CAP_128_Ag_Energy_Mgmt_Plan_Criteria.pdf

share of between 10-25% of the cost of the audit is typical, with most energy audits having an unsubsidized cost of between $2,000-$4,000.

The DEP's leveraging of audit funding would involve more one-on-one support to farmers receiving audits, as the administrator would follow up with audit recipients to review the available programs that can support installation of their recommended equipment. This follow-up is crucial to ensure that some portion of the energy audits lead to achieved energy savings.

While the focus of this study is energy efficiency, renewable energy should be considered alongside efficiency as a method to reduce energy costs and greenhouse gas emissions. Some state programs have offered renewable energy assessments to supplement the delivery of energy audits. There is value in the DEP contracting with a third-party consultant to conduct an assessment of the potential energy generation and cost-effectiveness of a farm's renewable energy project. This service can be more valuable than assessments from vendors who are trying to sell a product and therefore could have a conflict of interest when presenting the financial benefit of a project. Many farms lack the expertise to properly evaluate competing renewable energy proposals, and an independent third-party service can also assist farmers with evaluating vendor bids and determining whether the bid is appropriate for the site.

6.2.3 OPTION C: LOW-INTEREST REVOLVING LOAN FUND

A low interest revolving loan fund uses the interest and principal payments from existing loans to issue new loans. These loan funds can be relatively low-cost to administer. Below-market interest rates can spur interest in project implementation from farmers who might not otherwise invest in energy efficiency.

Low-interest loans to assist farmers with energy efficiency projects can be made available. Farmers have access to many forms of low-interest financing and some farms are reluctant to take on additional debt. However, some agricultural energy efficiency loan programs have been successful when the interest rate is below market rate. The Energize Delaware Farm Program offers 2-3% interest rates for energy efficiency and renewable energy projects and the program has delivered 34 loans since 2016 split between solar PV and energy efficiency projects. Delaware's financing funds projects where the value of the energy savings exceeds the debt service on the loan, a form of cash positive financing that is highly attractive to farmers when presented in a compelling manner.

The Coalition for Green Capital and the Nature Conservancy published two recent reports (2017) that provided a comprehensive evaluation of Pennsylvania's clean energy programs and recommended the creation of a "green bank" of public and private funding to finance clean energy projects. The reports point to the split between grants and loans in Pennsylvania's current and past financing programs (Alternative and Clean Energy Program, for example) as being over-reliant on grants and therefore unable to truly transform the market because the surge of clean energy activity spurred by grant funding only lasts as long as the grants are available. While this is true in the long-term, it is important to bear in mind that agriculture is not a mature market for energy efficiency in Pennsylvania.

Other states and other sectors of the economy have had longer-ranging grant and incentive programs, which could lead some policy-makers to wean the state's energy consumers from direct incentives and towards a market transformation approach.[43] In states with long-term energy efficiency incentives in place, it is worthwhile to consider transitioning to a market transformation model to drive continuous energy savings after incentive funds are exhausted. Notably, New York state is heavily focused on market transformation in its Reforming the Energy Vision initiative, but it also has a long history of comprehensive energy efficiency programs including agricultural programs. Without a broad-based, statewide effort focused on agricultural energy efficiency education and incentives, it would be premature to transition solely to a loan program as a vehicle for agricultural energy efficiency.

There may, however, be merit in the DEP promoting the availability of loans for energy efficiency projects that could benefit the agricultural community. Considering Pennsylvania already has a robust loan infrastructure in place through the utility loan funds and the state agencies, it may be appropriate for DEP to advocate setting aside a percentage of loan funds for agriculture and then implementing a marketing effort to educate farmers and trade allies about the availability of these loans. Given the lack of agricultural participation in the loans and the program administrators' opinion that there is a lack of awareness of these options, funding an outreach effort focused on agriculture will likely increase their participation in these loans. The DEP's administrator can lead the marketing and outreach effort to publicize the availability of these loans for farmers.

6.2.4 OPTION D: COMPETITIVE GRANT AWARDS FOR THE BEST ENERGY EFFICIENCY PROJECTS

A program design that is less expensive than a full-scale incentive program is a competitive grant program with awards for farmers who implement energy efficiency projects. Grant evaluation criteria could include a combination of total energy savings, project simple payback period, avoided greenhouse gas emissions, technological innovation, applicability of the technology to other sectors in Pennsylvania, and willingness of the producer to allow their farm to be used for a video, case study, or other showcasing.

Geared to under-commercialized technologies that are not widely used in Pennsylvania, this program element would award farmers who agree to have DEP publicize their farm and project to the agricultural community at-large. This effort is intended to reward innovation while also using real-life examples of farm energy efficiency to spur other farms to implement projects. It is recommended that the program focus heavily on dairy and poultry farmers who have the largest opportunity for energy savings and the largest number of peers with whom to share the benefits of an energy efficiency technology. The Maryland Energy Administration oversaw a competitive grant for Maryland agriculture which considered the ability to showcase the installed technology as a component of the evaluation criteria. Examples of farmer projects highlighted through that program are summarized in Appendix C.

[43] This article provides a definition and background of energy efficiency market transformation: https://www.utilitydive.com/news/market-transformation-moving-beyond-traditional-energy-efficiency-programs/557985/

A corollary of Option D is to also consider a competitive grant program for energy efficiency consultants or technology developers to demonstrate innovative or underutilized technologies. The New York Energy Research & Development Authority recently released an RFP soliciting ideas from technology developers or energy efficiency program administrators to demonstrate innovative technologies on the farm, which is shown in Appendix C. However, New York has had a longer history of delivering large-scale agricultural energy efficiency programs for farmers and has already incentivized many of the most cost-effective opportunities. This approach could make more sense once Pennsylvania has seen a greater penetration of best-practice energy efficiency technologies.

6.2.5 OPTION E: INCENTIVE DELIVERY PROGRAM

Option E is a comprehensive energy efficiency program offering many of the same services as options A-D coupled with DEP-provided incentives for energy efficient equipment. While the DEP has indicated it does not currently have the funding for a large-scale incentive program, this option should be considered for the future in order to have the widest impact on energy efficiency for Pennsylvania farms.

The most cost-effective option is to use DEP funding to pay for thermal efficiency projects not covered by utilities, or to serve electric cooperative customers who do not have access to Act 129 incentives. The DEP can also offer incentives to supplement Act 129 incentives by offering incentives on a broader range of agricultural measures or providing a more streamlined approach to funding custom energy efficiency projects.

In determining how to administer an incentive program, the DEP would want to consider its incentive structure. Incentives for some of the most common energy efficiency projects, such as lighting, can be offered on a prescriptive basis that offers a fixed incentive based on the type and quantity of units installed. Prescriptive incentives are reserved for projects that have an established and predictable amount of energy savings per unit. Lighting measures are likely to take up the bulk of energy savings within an energy efficiency program due to their high energy savings per unit and wide applicability to most farm types. Prescriptive incentives are also recommended for some of the most common dairy measures, such as variable speed drives, plate coolers, scroll compressors, and compressor heat recovery. Prescriptive incentives offer a streamlined participation process for farms with simplified calculations and documentation requirements. This option is attractive to farms and the program administrator because the incentives can be approved quickly.

A custom or calculated incentive is delivered based on the energy savings of the project and allows larger, more complex, or innovative projects to be considered for funding. An engineering review such as third-party calculations or an energy audit can be used to determine the energy savings. A pre- and post-installation site inspection or energy use metering may be necessary to verify the planned energy savings. Custom incentives require more administration and take longer to approve, but the energy savings of custom projects is more accurately calculated and often greater than prescriptive savings assumptions.

Another path to consider is offering incentives based on a percentage of the project cost as long as the project is cost-effective. The Energize Delaware Farm Program, the New York Agriculture Energy Efficiency

Program and Florida's Farm Energy and Water Efficiency Realization Program all offered incentives as a fixed percentage of a cost-effective project, as demonstrated through an energy audit or assessment and supported by an equipment quote attesting to the projected price of the project. Links to these programs are included in Appendix C.

To ensure funds are going to projects with the greatest amount of energy savings in relation to the cost, it is recommended that the DEP or the administrator set a cost effectiveness threshold for funded projects. Generally, a project that has a simple payback (total annual energy savings divided by initial cost) less than the effective useful life is considered cost-effective. The DEP may want to narrow the cost effectiveness threshold to a certain number of years based on funding availability. Similarly, measure with a simple payback of less than six months are sometimes excluded from energy efficiency programs because a project with such as short payback should be implemented solely on its own merits and should not need incentives. It is recommended to set a minimum payback period of six months and a maximum payback period that equals the expected useful life of the measure.

As a component of an incentive program, the DEP can supplement its offerings with giveaways of low-cost measures such as an engine block heater timer or LED bulb. These can be offered for free or at a substantial discount to farmers through the mail or via direct installation by a member of the program administrator's team. A giveaway provides immediate energy savings but also serves as a promotional and marketing tool to drive farmers' interest in the other offerings of the program. Once the farm has participated in the no-cost offering, the program administrator has established a relationship with the farm and has an entry point to discussions about other program offerings such as energy audits or incentives for energy efficient equipment. Giveaway measures should be inexpensive and widely applicable to a variety of farms. Prior programs promoting free engine block heater timers and/or LED bulbs to farmers have seen success in Vermont, New York, Minnesota, and Wisconsin with funding from utility commission-mandated energy efficiency programs. As these programs ended several years ago, information about them is no longer available online.

The DEP can consider adding a giveaway program as a component of a larger incentive program or as a stand-alone effort to build awareness of existing energy efficiency programs.

Another long-term strategy for the DEP to consider in a comprehensive incentive program is promotion of beneficial electrification. Beneficial electrification is the process of converting fossil-fuel powered equipment to electric-powered equipment in order to reduce greenhouse gas emissions. Electricity generally generates fewer greenhouse gas emissions than fossil fuels, and electricity generation is expected to reduce its emissions further over time with the introduction of more renewable and zero-emission generation. Beneficial electrification has captured a lot of attention in the energy efficiency industry as utilities and program administrators begin to look at greenhouse gas emissions overall rather than kilowatt-hours saved.

Some of the commercially available agricultural measures that can be converted from fossil fuel to electricity include irrigation pumps, water heaters, off peak thermal electric storage, heat exchangers, heat pumps, and maple sap evaporators. Other technologies, such as electric tractors, are very promising but are not yet commercialized[44]. The DEP may wish to consider incentivizing beneficial electrification for farms as a way to reduce greenhouse gas emissions.

7. RECOMMMENDED TIME-PHASED WORK PLAN TO IMPLEMENT POLICY RECOMMENDATIONS

The following work plan suggests a timeframe for the DEP to plan, procure and implement the top three program designs. The options are presented to run independently of each other, although in practice they may be combined or layered. This timeframe reflects the reasonable time period to develop RFPs and contracts without consideration for DEP's internal approvals and funding timelines, as these are not known to EnSave.

Table 21: Option A – Development and Dissemination of Best Practices Materials

Task	Timeframe
Commit to implementing Option A	Month 1
Determine whether outreach for best practices will be led by DEP staff or a contractor	Month 2
If choosing a contractor, draft and issue RFP for development and dissemination of best practices. If DEP will do the dissemination internally, draft and issue RFP for development of best practices only	Month 2- Month 4
Review proposals and select vendor for development of best practices material	Month 6 – Month 8
Best practices materials are developed	Month 8 – Month 13
Research venues to support with best practices (if DEP is doing outreach)	Month 2 – Month 3
Research venues to support with best practices (if contractor is doing outreach)	Month 8 – Month 10
Reach out to agricultural organizations to build relationships and discuss venues for distribution of materials (if DEP is doing outreach)	Month 3 – Month 5
Reach out to agricultural organizations to build relationships and discuss venues for distribution of materials (if contractor is doing outreach)	Month 8 – Month 10
Materials are disseminated throughout the agricultural sector	Month 13 – Month 25
Evaluate the program	Month 26

[44] Clark, Kyle. "Farm Beneficial Electrification: Opportunities and Strategies for Rural Electric Cooperatives," National Rural Electric Cooperative Association, October 2018.

Table 22: Option B – Promoting Energy Audit and Incentive Funds

Task	Timeframe
Commit to implementing Option B	Month 1
Determine whether to a) apply for EA/REDA funding b) partner with organization who already has EA/REDA funding, c) utilize DOE funding to fund audits, d) some combination of a-c	Month 1 – Month 3
Determine whether to hire an administrator to promote the audits and follow up with farmers post-audit, or do the work internally	Month 1 – Month 3
If selecting a contractor, develop and send an RFP	Month 3 – Month 5
Review responses and choose a contractor	Month 7 – Month 9
Submit proposal/funding request for additional or shifted audit funds, as applicable	Month 3- Month 13 (dependent on timeframe of funding agencies)
Deliver promotional effort to educate farmers about the opportunity for subsidized energy audits (if DEP is doing outreach)	Month 7 – Month 19
Deliver promotional effort to educate farmers about the opportunity for subsidized energy audits (if contractor is doing outreach)	Month 9 – Month 21
Follow up with participants to direct them to external funding for energy efficiency improvements	Month 7 – Month 21
If possible, follow up to learn which projects were implemented and what percentage of audited farms implement a project	Month 7 – Month 21
Evaluate the program	Month 22

Table 23: Option C- Low Interest Revolving Loan Fund

Task	Timeframe
Commit to implementing Option C	Month 1
Determine whether DEP can utilize existing in-state loan funds to reserve a portion of funding for agriculture	Month 1 – Month 3
Determine whether to hire an administrator to promote the loans, or to do the work in-house	Month 1 – Month 3
If selecting a contractor, develop and send RFP	Month 3 – Month 5
Review responses and choose a contractor	Month 7 – Month 9
Promote the low-interest loans (if DEP is doing outreach)	Month 3 – Month 15
Promote the low-interest loans (if contractor is doing outreach)	Month 9 – Month 21
Evaluate program	Month 22

Figure 3: Gantt Chart of Workplan

TASK TITLE	Month Work is Taking Place																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Option A																										
Commit to implementing Option A	■																									
Determine whether outreach for best practices will be led by DEP staff or a contractor		■																								
Draft and issue RFP for development and/or dissemination of best practices.		■	■	■																						
Review proposals and select vendor for development of best practices material						■	■	■																		
Best practices materials are developed								■	■	■	■	■	■													
Research venues to support with best practices (if DEP is doing outreach)		■	■																							
Research venues to support with best practices (if contractor is doing outreach)								■	■	■																
Reach out to agricultural organizations to build relationships (DEP)			■	■	■																					
Reach out to agricultural organizations to build relationships (contractor)								■	■	■																
Materials are disseminated throughout the agricultural sector													■	■	■	■	■	■	■	■	■	■	■	■		
Evaluate the program																										■
Option B																										
Commit to implementing Option B	■																									
Make determinations about who to partner with for audit delivery	■	■	■																							
Determine whether to hire an administrator to proote the audits	■	■	■																							
If selecting a contractor, develop and send an RFP			■	■	■																					
Review responses and choose a contractor							■	■	■																	
Submit proposal/funding request for additional or shifted audit funds, as applicable			■	■	■	■	■	■	■	■	■	■	■													
Deliver promotional effort (DEP)							■	■	■	■	■	■	■	■	■	■	■	■	■							
Deliver promotional effort (contractor)									■	■	■	■	■	■	■	■	■	■	■	■	■					
Follow up with participants							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
Learn which projects were implemented							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
Evaluate the program																						■				
Option C																										
Commit to implementing Option C	■																									
Determine whether DEP can reserve a portion of existing loan funds for agriculture	■	■	■																							
Determine whether to hire an administrator to promote the loans or do promotion in-house	■	■	■																							
If selecting a contractor, develop and send RFP			■	■	■																					
Review responses and choose a contractor							■	■	■																	
Promote the low-interest loans (DEP)			■	■	■	■	■	■	■	■	■	■	■	■	■											
Promote the low-interest loans (contractor)									■	■	■	■	■	■	■	■	■	■	■	■	■					
Evaluate program																						■				

8. CONCLUSION

Pennsylvania has a very diverse agricultural sector with farms of all sizes producing a wide variety of agricultural products. Given the overall importance of agriculture to the state's economy, farmers represent an important segment for participation in energy efficiency programs. Given that there are few programs specifically encouraging the adoption of energy efficiency measures within the agricultural sector, farmers likely have pent-up demand for financial and technical assistance that can assist with energy management.

Dairy and poultry farms are by far the largest energy users and have the greatest potential for energy savings. While a program focused on Pennsylvania's agricultural energy efficiency should tilt heavily to these two sectors, other types of farms also have ample opportunity to save energy. Energy efficient LED lighting is applicable to most sectors of agriculture and farm sizes, and therefore an energy efficiency program should heavily lean on lighting measures. A well-rounded program offering varying levels of incentives and technical assistance can ensure that smaller and less energy-intensive farms have an opportunity to increase their energy efficiency while still providing assistance to the energy-intensive farms that will make up the bulk of energy savings.

Ultimately, the recommendations within this report will help DEP and its stakeholders shape policy recommendations that will provide the greatest chance of success. The delivery of a comprehensive, statewide energy efficiency program will help secure Pennsylvania farmers' long-term sustainability and continued contributions to the state's economy and identity.

APPENDIX A: ENERGY USE AND SAVINGS METHODOLOGY

1. LIVESTOCK (DAIRY, BEEF, SWINE, POULTRY)

1.2 ENERGY USE AND ENERGY SAVINGS

EnSave conducts hundreds of agricultural energy efficiency audits annually across the United States. The outcomes of these audits are stored in FEAT™, which serves as EnSave's tool for data analysis. With FEAT, EnSave can use the audit data to provide trends and insights into how farms are using energy and how those farms can conserve energy.

For dairy, beef, swine, and poultry, the energy use and savings numbers by subsector used in this report were derived from audits conducted by EnSave and stored in FEAT where the farms matched characteristics of farms seen in Pennsylvania and surrounding states with a similar climate.

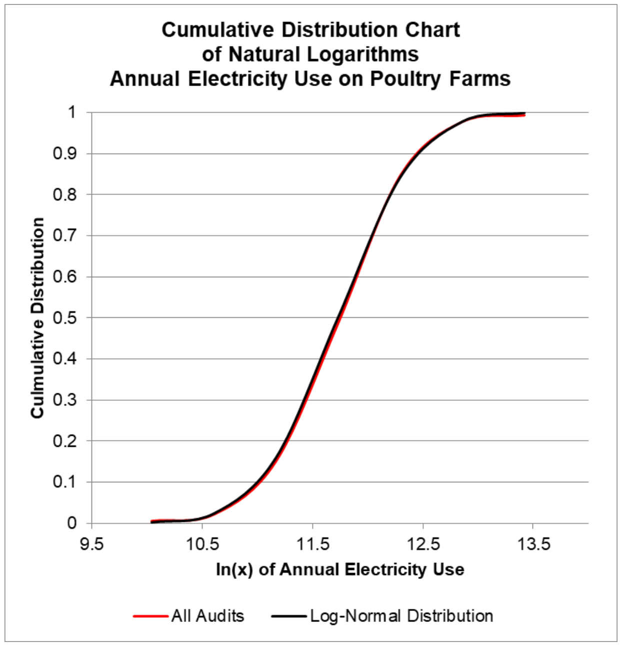
EnSave separated its audit data by subsector and then by the size range for each subsector. For each subsector, EnSave then calculated the mean energy use and mean energy savings numbers for each size range. Those numbers where then multiplied by the number of farms in that size range, and then they were added together to arrive at a total mean energy use and total mean energy savings.

1.3 STATISTICAL METHODOLOGY

EnSave's experience with agricultural use and savings numbers is that there is a high level of statistical variance, which can lead to difficulties in accurate predictions when applying mean numbers to large farm populations. To provide better context, EnSave calculates 95% confidence intervals for the means derived from audits in FEAT. This way, readers of this report can reasonably expect that the actual energy use and savings numbers exceed the lower bounds of the confidence interval.

Statistically, EnSave has found in this report and in others that energy use and savings data follow a log-normal distribution. That is, the distributions of these elements follow a certain common pattern, and because they do, EnSave can leverage standard equations developed for that pattern to produce the confidence interval. Wikipedia's article on log-normal distribution, at http://en.wikipedia.org/wiki/Lognormal_distribution, gives a good overview and explanation of the distribution and its properties. Figure A1 shows an example of this pattern in place for electricity use per poultry farm:

Figure A1: Cumulative Distribution Chart of Annual Electricity Use on Poultry Farms



The natural logarithms of electricity use of poultry/egg farms derived from the audits data (the red line) closely follows what would be expected for a log-normal distribution (the black line). As the data is assumed log-normal, 95% confidence intervals are calculated by Cox's method.

Sections 1.3.1.1 – 1.3.1.8 below provide the confidence intervals for energy use per farm and per sector for each type of livestock. EnSave utilized the mean value to determine the total energy use and savings per sector, which are highlighted in yellow in each example.

1.3.1.1 DAIRY CONFIDENCE BOUNDS PER FARM

Dairy Annual Average Electricity Use (kWh) by Farm Size					
	50 to 99	100 to 199	200 to 499	500 to 999	1000+
95% Upper	88,910	134,754	346,153	647,293	1,962,403
Mean	71,457	120,091	268,689	538,238	1,536,757
95% Lower	57,429	107,023	208,561	447,557	1,203,433

Dairy Annual Average Electricity Use (MMBtu) by Farm Size					
	50 to 99	100 to 199	200 to 499	500 to 999	1000+
95% Upper	302	459	1,180	2,208	6,695
Mean	243	409	916	1,835	5,242
95% Lower	195	364	711	1,526	4,105

Dairy Annual Average Electricity Savings (kWh) by Farm Size					
	50 to 99	100 to 199	200 to 499	500 to 999	1000+
95% Upper	20,775	26,855	65,698	124,353	190,200
Mean	15,584	19,166	39,839	89,791	116,210
95% Lower	11,690	13,678	24,158	64,835	71,003

Dairy Annual Average Heating Fuel Use (MMBtu) by Farm Size					
	50 to 99	100 to 199	200 to 499	500 to 999	1000+
95% Upper	214	650	614	1,614	2,138
Mean	141	327	368	990	1,260
95% Lower	93	164	221	607	742

Dairy Annual Average Heating Fuel Savings (MMBtu) by Farm Size	
	50+
95% Upper	114
Mean	61
95% Lower	33

1.3.1.2 DAIRY CONFIDENCE BOUNDS – ALL FARMS

Dairy Farm Size	Dairy Farm Counts								
			Dairy PA Annual Electricity Use (kWh) by Farm Size						
50 to 99	2626			50 to 99	100 to 199	200 to 499	500 to 999	1000+	Total
100 to 199	946		95% Upper	233,478,785	127,477,423	88,268,948	40,132,192	47,097,661	536,455,009
200 to 499	255		Mean	187,645,086	113,605,635	68,515,786	33,370,777	36,882,156	440,019,440
500 to 999	62		95% Lower	150,808,797	101,243,330	53,183,049	27,748,514	28,882,398	361,866,088
1000+	24								
Total	3,913		Dairy PA Annual Electricity Use (MMBtu) by Farm Size						
				50 to 99	100 to 199	200 to 499	500 to 999	1000+	Total
			95% Upper	794,013	434,010	300,919	136,869	160,673	1,826,485
			Mean	637,628	386,680	233,522	113,799	125,818	1,497,447
			95% Lower	511,943	344,499	181,206	94,616	98,523	1,230,787
			Dairy PA Annual Electricity Savings (kWh) by Farm Size						
				50 to 99	100 to 199	200 to 499	500 to 999	1000+	Total
			95% Upper	54,555,791	25,405,011	16,753,043	7,709,894	4,564,794	108,988,533
			Mean	40,923,167	18,130,750	10,158,850	5,567,053	2,789,040	77,568,860
			95% Lower	30,696,955	12,939,263	6,160,169	4,019,776	1,704,069	55,520,232
			Dairy PA Annual Heating Fuel Use (MMBtu) by Farm Size						
				50 to 99	100 to 199	200 to 499	500 to 999	1000+	Total
			95% Upper	561,904	615,151	156,612	100,094	51,302	1,485,062
			Mean	369,968	309,345	93,910	61,360	30,231	864,813
			95% Lower	243,288	155,329	56,270	37,606	17,811	510,304
			Dairy PA Annual Heating Fuel Savings (MMBtu) by Farm Size						
				50+					
			95% Upper	446,523			Total MMBtu use	2,362,260	
			Mean	239,386					
			95% Lower	127,502					

1.3.1.3 BEEF CATTLE CONFIDENCE BOUNDS PER FARM

Cattle Annual Average Electricity Use (kWh) by Farm Size		
	100+	
95% Upper	27,582	
Mean	21,142	
95% Lower	16,205	

Cattle Annual Average Electricity Use (MMBtu) by Farm Size		
	100+	
95% Upper	121	
Mean	89	
95% Lower	66	

Cattle Annual Average Electricity Savings (kWh) by Farm Size		
	100+	
95% Upper	7,653	
Mean	4,055	
95% Lower	2,148	

1.3.1.4 BEEF CATTLE CONFIDENCE BOUNDS- ALL FARMS

Cattle Farm Size	Cattle Farm Counts
100+	145

Cattle PA Annual Electricity Use (kWh) by Farm Size	
	100+
95% Upper	3,999,359
Mean	3,065,526
95% Lower	2,349,731

Cattle PA Annual Electricity Use (MMBtu) by Farm Size	
	100+
95% Upper	17,576
Mean	12,976
95% Lower	9,569

Cattle PA Annual Electricity Savings (kWh) by Farm Size	
	100+
95% Upper	1,109,739
Mean	587,935
95% Lower	311,453

1.3.1.5 POULTRY CONFIDENCE BOUNDS PER FARM

Poultry/Egg Annual Average Electricity Use (kWh) by Farm Size			
	100,000-199,999	200,000 to 499,999	500,000 or more
95% Upper	78,196	123,351	218,474
Mean	66,017	116,081	201,890
95% Lower	55,736	109,240	186,566

Poultry/Egg Annual Average Electricity Use (MMBtu) by Farm Size			
	100,000-199,999	200,000 to 499,999	500,000 or more
95% Upper	266	419	744
Mean	224	394	688
95% Lower	189	371	636

Poultry/Egg Annual Average Electricity Savings (kWh) by Farm Size			
	100,000-199,999	200,000 to 499,999	500,000 or more
95% Upper	27,873	31,508	74,391
Mean	14,496	24,232	51,891
95% Lower	7,538	18,637	36,196

Poultry/Egg Annual Average Heating Fuel Use (MMBtu) by Farm Size			
	100,000-199,999	200,000 to 499,999	500,000 or more
95% Upper	435	745	1,652
Mean	354	682	1,481
95% Lower	289	625	1,327

1.3.1.6 POULTRY CONFIDENCE BOUNDS- ALL FARMS

Poultry Farm Size	Poultry Farm Counts
100,000-199,999	348
200,000 to 499,999	253
500,000 or more	100
Total	701

Poultry/Egg PA Annual Electricity Use (kWh) by Farm Size				
	100,000-199,999	200,000 to 499,999	500,000 or more	Total
95% Upper	27,212,173	31,207,787	21,847,388	80,267,347
Mean	22,974,047	29,368,512	20,189,038	72,531,597
95% Lower	19,395,974	27,637,637	18,656,567	65,690,178

Poultry/Egg PA Annual Electricity Use (MMBtu) by Farm Size				
	100,000-199,999	200,000 to 499,999	500,000 or more	Total
95% Upper	92,501	106,102	74,444	273,047
Mean	78,041	99,808	68,785	246,634
95% Lower	65,832	93,887	63,557	223,276

Poultry/Egg PA Annual Electricity Savings (kWh) by Farm Size				
	100,000-199,999	200,000 to 499,999	500,000 or more	Total
95% Upper	9,699,770	7,971,513	7,439,102	25,110,385
Mean	5,044,503	6,130,751	5,189,103	16,364,358
95% Lower	2,623,385	4,715,040	3,619,620	10,958,046

Poultry/Egg PA Annual Heating Fuel Use (MMBtu) by Farm Size				
	100,000-199,999	200,000 to 499,999	500,000 or more	Total
95% Upper	151,432	188,483	165,200	505,116
Mean	123,324	172,651	148,071	444,045
95% Lower	100,420	158,146	132,716	391,283

1.3.1.7 SWINE CONFIDENCE BOUNDS PER FARM

Swine Annual Average Electricity Use (kWh) by Farm Size	
	200+
95% Upper	24,095
Mean	19,073
95% Lower	15,097

Swine Annual Average Electricity Use (MMBtu) by Farm Size	
	200+
95% Upper	81
Mean	64
95% Lower	51

Swine Annual Average Electricity Savings (kWh) by Farm Size	
	200+
95% Upper	1,073
Mean	624
95% Lower	362

Swine Annual Average Heating Fuel Use (MMBtu) by Farm Size	
	200+
95% Upper	439
Mean	260
95% Lower	153

1.3.1.8 SWINE CONFIDENCE BOUNDS- ALL FARMS

Swine Farm Size	Swine Farm Counts		Swine PA Annual Electricity Use (kWh) by Farm Size	
200+	617			200+
			95% Upper	14,866,647
			Mean	11,767,920
			95% Lower	9,315,049
			Swine PA Annual Electricity Use (MMBtu) by Farm Size	
				200+
			95% Upper	50,110
			Mean	39,537
			95% Lower	31,168
			Swine PA Annual Electricity Savings (kWh) by Farm Size	
				200+
			95% Upper	662,162
			Mean	384,737
			95% Lower	223,436
			Swine PA Annual Heating Fuel Use (MMBtu) by Farm Size	
				200+
			95% Upper	270,851
			Mean	160,144
			95% Lower	94,584

2. GREENHOUSES

2.1 NUMBER AND SIZE OF FARMS

The 2017 USDA Census of Agriculture reports that there are 689 farms growing food crops under glass or other protection on a total of 4.1 million square feet, not including mushroom crops. Table A1 provides a breakdown of these farms by size and sales, along with the percentage of sales and farms by size range.

Table A1: Pennsylvania Food Crops Grown Under Glass or Other Protection

Farm area	Farms	Area (ft2)	Sales	% of farms	% of sales
1 to 999 square feet	136	50,327	$206,792	20%	1%
1,000 to 1,999 square feet	79	113,991	$505,203	11%	2%
2,000 to 2,999 square feet	152	365,991	$1,497,417	22%	7%
3,000 to 3,999 square feet	92	303,672	$1,128,209	13%	5%
4,000 to 5,999 square feet	74	357,822	$1,156,912	11%	5%
6,000 to 9,999 square feet	58	426,989	$3,405,560	8%	16%
10,000 or more square feet	98	2,496,758	$13,687,118	14%	63%
Total	**689**	**4,115,550**	**$21,587,211**	**100%**	**100%**

It is important to note that a high percentage of the Pennsylvania farms growing food under glass or other protection are using seasonal high tunnel greenhouses, which typically use either no energy or a negligible amount of energy. The USDA Census of Agriculture does not differentiate between protected crop structure types (glass greenhouse, hoop houses, high tunnels, etc.), which required us to estimate the percentage of farms and protected crop area that should be excluded due to the absence of energy use.

Our energy analysis excludes farms under 2,000 square feet due to the high probability of these being seasonal hobby farms with little to no energy use (hoop houses and/or high tunnels). These farms account for only 3.3% of Pennsylvania's total protected crop sales. This results in an adjusted number of 474 farms growing crops on 3.95 million square feet. The USDA census further shows that tomato farms account for approximately 71% of the adjusted number of farms (338 farms), 59% of the adjusted growing area (2.34 million square feet), and 41% of the adjusted sales ($8.56 million).

Of the adjusted crop production area under protection, we estimate that 70% of production is taking place in high tunnels that have no opportunity for energy efficiency improvement. This estimate is based on a combination of satellite imagery and website surveys of Pennsylvania greenhouse companies, as well as email exchanges with Thomas Ford, Commercial Horticulture Educator for Penn State Extension. Mr. Ford has extensive experience working with Pennsylvania greenhouse and high tunnel growers and estimated that approximately 80% of growers using some form of protected culture are doing so with no heat or using portable heaters; the remaining 20% are growing in greenhouses with either forced hot air units or wood/coal-fired hot water boiler systems. Mr. Ford's 80% figure was adjusted to 70% due to the fact that we had already excluded all farms smaller than 2,000 square feet.

2.2 ENERGY USE

Baseline energy use for Pennsylvania's greenhouse operations was calculated based on a combination of energy benchmark studies and energy usage benchmarks derived from EnSave energy audits. Energy usage of greenhouse operations is notoriously difficult to estimate due to the high degree of variability among greenhouse operations, seasonal climate variability, and the variation in crop light and climate requirements for different crops. Our strategy to estimate baseline energy usage for greenhouses was to first calculate energy usage for greenhouse area producing tomatoes (which we assume accounts for approximately 60% of the total area, based on the USDA Census of Agriculture), and then extrapolate the energy usage of the non-tomato food crops.

Greenhouse tomato production is very energy-intensive versus other food crops due to high temperature and supplemental light requirements. Based on a study by North Carolina State University, tomato production requires approximately 0.78 gallons of liquid propane per square foot, which equates to 0.71 therms, or 71,500 Btus. Given that Pennsylvania has a slightly colder average climate than North Carolina, we assumed an average heating fuel energy use intensity of 0.8 therms/ft^2 for tomato production, which is within the range we would expect based on greenhouse energy audits conducted by EnSave. Electricity use in greenhouse tomato production is primarily used for supplemental lighting between October and April, and for ventilation during warmer months. Based on several studies, we found electricity usage benchmarks ranging from 5.2 kWh/ft^2 to 10 kWh/ft^2 and used a blended average of 8 kWh/ft^2.

Using the assumptions detailed above, we calculated the estimated annual heating fuel use for greenhouses producing tomatoes as follows:

2,338,987 ft^2 * 0.8 therms/ft^2 * 30% (year-round production area) = 561,357 therms

Baseline electricity use was calculated as follows:

2,338,987 ft^2 * 8 kWh/ft^2 * 30% (year-round production area) = 5,613,569 kWh

To calculate the energy use for non-tomato greenhouse crop production (accounting for an estimated 40% of year-round greenhouse crop production area), we assumed that non-tomato crops require, on average, 37.5% of the energy needed to produce tomatoes. This assumption is based on a weighted average that assumes 10% of the non-tomato greenhouse crops have the same energy intensity as tomatoes (e.g. peppers), 50% have an energy intensity equivalent to half that of tomatoes (e.g. leafy greens), and the remaining 40% of crops have an energy intensity equivalent to 1/16 that of tomatoes (e.g. culinary herbs with lower light requirements, or greenhouses that are under-illuminating their crops and/or not using supplemental lighting).

Non-tomato greenhouse crop production baseline estimated annual heating fuel use was calculated as follows:

> 1,612,245 ft^2 * 0.8 $therms/ft^2$ * 30% (year-round production area) * 37.5% (energy intensity adjustment) = 145,102 therms

Baseline electricity use for non-tomato greenhouse operations was calculated as follows:

> 1,612,245 ft^2 * 8 kWh/ft^2 * 30% (year-round production area) * 37.5% (energy intensity adjustment) = 1,451,021 kWh

The total estimated baseline energy use for the greenhouse sector equals the sum of the tomato and non-tomato operations:

> 561,357 therms + 145,102 therms = 706,459 therms
>
> 5,613,569 kWh + 1,451,021 kWh = 7,064,589 kWh

2.3 ENERGY SAVINGS

The estimated energy savings values assume an average potential savings of 25% per greenhouse operation. This estimate is based on industry experience, including results of past energy audits.

> 706,459 therms * 25% savings = 176,615 therms
>
> 7,064,589 kWh * 25% savings = 1,766,147 kWh

3. CROPS AND ORCHARDS

3.1 NUMBER AND SIZE OF FARMS

To estimate the number and size of crop and orchard farms, we used a combination of data from the 2017 USDA Census of Agriculture and the 2018 USDA Irrigation Water Management Survey (IWMS). According to the IWMS, there are 264 farms with energy expenses greater than or equal to $1,000. Based on the 2017 Census of Agriculture (Table 35), we estimate that 53.2% of irrigated farms are growing field crops within the scope of this study and that 7% are of irrigated farms are growing orchard crops. Applying these percentages to the 246 farms, we arrived at an estimated 140 irrigated farms growing field crops and 18 farms growing orchard crops.

3.2 ENERGY USE

Given that the IWMS provides data on irrigated farm energy expenses, we opted to use energy expenses as a proxy for farm size (versus acres) to calculate estimated baseline energy usage and energy savings. Using data from the IWMS, we calculated the estimated energy use intensity of irrigated farms using weighted averages for each fuel type (electricity, diesel, and gasoline). Weighted averages were calculated by multiplying the number of farms in each energy expense bracket by the median of the energy expense range, adding these figures, and dividing by the number of farms, as shown in Table A2.

Table A2: Weighted Average Energy Use Calculation for Electric-Irrigated Farms

Value	Farms with energy expense $1000-$1,999	Farms with energy expense $2,000-$4,999	Farms with energy expense $5,000-$9,999	Farms with energy expense $10,000-$19,999	Farms with energy expense $20,000-$49,999	Total
Median annual farm energy expense	$1,500	$3,500	$7,500	$15,000	$35,000	
Estimated average kWh use/farm	14,808	34,551	74,038	148,075	345,508	**616,979**
Number of farms	91	43	10	3	5	**152***
Farms * kWh use	1,347,483	1,485,686	740,375	444,225	1,727,542	**5,745,311**
Weighted average annual kWh use per farm	-	-	-	-	-	**37,798**

The estimated average kWh use per farm assumes an average electricity cost of $0.101/kWh. Note that the number of farms in this table is not adjusted to account for crops outside the analysis scope. In the case of electric-powered irrigated farms, the adjusted number of farms is 81 (152 farms * 53.2% = 81 farms). Using this same methodology, we calculated a weighted average energy use of 1,845 gallons of diesel per diesel-powered irrigated farm, and 1,129 gallons of gasoline per gasoline-powered irrigated farm.

The IWMS does not provide insight into energy expenses by crop type, so it is not possible to directly calculate the difference in irrigation pumping intensity for a field crop farm versus an orchard. For this reason, we relied on agronomic data to determine if the energy use intensity should be adjusted for orchards or field crops based on average farm size and/or crop water requirements. This analysis found that Pennsylvania's irrigated orchard farms are, on average, approximately 5.3% larger than irrigated field crop farms (8.16 acres versus 7.75 acres, respectively). Water use intensity is more difficult to estimate due to the lack of available information, but we estimate that orchards use a similar amount of water (within 6%) on average based on crop net irrigation water requirement estimates from the USDA NRCS National Engineering Handbook Irrigation Guide from neighboring New Jersey.

Due to the small number of irrigated orchard farms (18) and the minor or negligible increase in water usage requirements versus field crop operations, we determined that the energy usage benchmark of 169.38 MMBTUs per farm is a reasonable approximation for both irrigated orchards and field crop farms.

Table A3 provides overview of the baseline energy use calculations for field crops using the assumptions outlined above.

Table A3: Baseline Energy Usage Estimation for Irrigated Field Crops

Value	Estimated annual fuel use per farm	Percent of farms using fuel	Estimated number of farms	Estimated energy use	MMBTUs
Avg electricity use per irrigated farm (kWh)	37,798	57.6%	81	3,045,015	10,390
Avg diesel use per irrigated farm (gal)	1,845	30.7%	43	79,200	11,009
Avg gasoline use per irrigated farm (gal)	1,129	11.7%	16	18,554	2,301
Total			**140**		**23,700**

3.3 ENERGY SAVINGS

Energy savings for crop and orchard operations is associated with fuel-switching (converting from a diesel or gasoline motor to an electric motor), and improvements in water application efficiency and/or distribution efficiency. To estimate savings from fuel switching, we assumed an average internal combustion engine efficiency of 30% for diesel and gas engines, and a 90% efficiency for a replacement electric motor. The savings was calculated using the following formula: Savings = [Diesel/gas MMBtus] – ([Diesel/gas MMBtus] * (0.3/0.9)). These assumptions impute a fuel-switching energy savings of 66.7%.

To calculate energy savings potential for efficiency improvements to electric-powered irrigation systems, we assumed an average potential savings of 15%. This is a conservative estimate based on identified savings in past EnSave irrigation energy audits and is attributable to efficiency measures that include variable frequency drives (which are only applicable to electric motors), low-pressure sprinkler nozzles, conversion to drip irrigation, irrigation scheduling, and pumping plant tune-ups.

Fuel switching results in an overall energy savings (MMBTUs), but an increase in electricity use. To quantify the overall increase in kWh, we used the following formula:

> [kWh increase from fuel switching 100% of non-electric pumping plants * -1] + [15% kWh savings from pre-exisiting electric-powered irrigation systems] + [15% kWh savings from electric-powered irrigation systems after fuel switching]

For field crops, the result is:

> -1,300,212 kWh (new electric load from fuel switching) + 456,752 kWh (electric savings from existing electric-powered irrigation systems) + 195,029 (electric savings from fuel-switched irrigation systems) = -648,430 kWh

For orchards, the result is:

> -171,726 kWh + 60,236 kWh + 25,758 kWh = -85,642 kWh

MMBTU savings calculations for both field crops and orchards accounted for the displacement of fossil fuels in addition to the increased electricity usage. Table A4 provides an overview of the energy savings calculations for irrigated field crops, which shows a total estimated potential savings of 11,097 MMBTUs (10,432 MMBTUs from existing electric systems and fuel switching + 665 MMBTUs from electric savings post-fuel switching).

Table A4: Energy Savings Estimation for Irrigated Field Crops

Fuel type	Estimated baseline MMBTU usage	Estimated average potential savings	Total Savings (units of fuel)	Savings (MMBTUs)	kWh increase from fuel switching	Non-fuel switching savings opportunity assuming 100% fuel switching (MMBTUs)
Electric	10,390	15%	456,752	1,559		
Diesel	11,009	66.7%	52,800	7,339	1,075,454	550
Gasoline	2,301	66.7%	12,370	1,534	224,758	115
Total	**23,700**			**10,432**	**1,300,212**	**665**

APPENDIX B: PROGRAM ADMINISTRATOR SURVEY

1. SURVEY CONTENT

The DEP provided EnSave with a list of energy efficiency programs that could affect agriculture, along with contact information for the programs' administrators. This document is included as item 3 of Appendix B. EnSave developed a survey through a google form that was sent to program administrators in October 2019. EnSave sent a follow up email about the survey in early November and also called non-responsive administrators.

Below is the text of the email. Questions listed were included in the google form. The questions and survey responses are included in item 2 of Appendix B.

Hello,

My company, EnSave, is working under contract to the Pennsylvania Department of Environmental Protection to analyze the energy use and savings opportunities for Pennsylvania agricultural operations. We will also be making recommendations for state-level programs that can increase agricultural energy efficiency within the state.*

As part of this work, we are reviewing current programs that offer financial and technical assistance to Pennsylvania farms, and DEP has provided me with your contact information and some details about your program: Act 129 Incentives.

To help us better understand the current offerings, I would appreciate a few minutes of your time to fill out our survey about your program and the participation of agricultural producers.

The survey should about 10 minutes to complete. If you are listed as a contact person for multiple programs, you have received multiple emails. Please fill out the survey for each program that you administer. If you no longer administer the program, please forward this email along to the appropriate contact.

I invite you to contact me if you have any questions about the process! Thank you in advance for your time.

**Funding is provided through the U.S. Department of Energy's State Energy Program.*

2. Survey Responses

Name of your program	How long has the program been in existence (years)?	What is the typical funding available per farm or per customer, if known?	Approximately what percentage of the customer's project cost is covered by your program's funding?	Approximately how many total clients does your program serve in a typical year?
Small Business Avantage Grant	16	$4,900	10-25%	187
Pollution Prevention Assistance Account	16 years	75% of Project Costs, Up to $100,000	75-100%	3
Alternative Fuels Incentive Grant (AFIG)	15 years (since 2004)	Maximum grant awards of $300,000 for vehicles and $600,000 for fueling infrastructure most years. May vary from year to year, check current guidelines.	50-75%	35
Alternative and Clean Energy Program	11	Varies depending on loan proceeds and appropriations	25-50%	16
REAP grant energy assessments	numerous	upto $500,000 for grants with loans available too	10-25%	40
On Farm Energy Days	5 years	none	10-25%	0
Farm Energy IQ	5 years	0	10-25%	1
Emerging Technology Applications Center (ETAC)	25 years	not known	75-100%	12
West Penn Power Sustainable Energy Fund Act 129 Microloan Program	1	min $10K, max $50K	50-75%	2
Energy Assessment Program for Agricultural Producers and Small Businesses	in its current form since 2011; wind resource assessments (a component of the current program) since 2006	assessment cost covered by grant	75-100%	20
Sustainable Energy Fund	20 years	$250,000	75-100%	20
USDA REDA	3	Guaranteed loan with 25% available for grant	10-25%	10
PennTAP	52 years	25,000	10-25%	60
Met Ed/Penelec Sustainable Energy Fund	20	Up to $50,000	75-100%	15
PPL	Since 2009	Roughly $61 million per year	25-50%	Available to all PPL customers

2. Survey Responses

Name of your program	Of these, approximately how many are farms?	What are the typical agricultural energy efficiency or renewable energy technologies served by your program?
Small Business Avantage Grant	12	Lighting, Grain Dryers
Pollution Prevention Assistance Account	0	They have not applied
Alternative Fuels Incentive Grant (AFIG)	0. We have not historically received applications from farms, but they are eligible as a for-profit business.	We fund alternative fuels for transportation including biodiesel (B20 or higher blends), electric, compressed natural gas, liquefied natural gas, and propane.
Alternative and Clean Energy Program	1	Anaerobic Digesters
REAP grant energy assessments	half	lighting, motors, refrigeration
On Farm Energy Days	40	lighting, motors, refrigeration, pumps, irrigation, renewables
Farm Energy IQ	5	This is a train the trainer program. It hasn't been conducted in several years but could be
Emerging Technology Applications Center (ETAC)	1-2	process ee and photovoltaics
West Penn Power Sustainable Energy Fund Act 129 Microloan Program	0	We serve no agriculture currently. If they are eligible for Act 129 rebates through West Penn Power, they are eligible to apply. Typical projects involve lighting and HVAC upgrades.
Energy Assessment Program for Agricultural Producers and Small Businesses	10	primarily wind and solar assessments; we also provide details on biomass, geothermal, microhydro and efficiency
Sustainable Energy Fund	unknown	Anaerobic digesters
USDA REDA	70%	Lighting, solar, anything energy efficiency that can show a payback
PennTAP	10 %	E2 assessments, reverse osmosis for maple syrup, grain dryers, solar
Met Ed/Penelec Sustainable Energy Fund	0	Solar, geothermal, hydroelectric, LED lighting
PPL	Phase 2 (2013-2016) agriculture specific me	https://www.pplelectric.com/-/media/PPLElectric/Save-Energy-and-Money/ Page 99 of pdf, document page 91

2. Survey Responses

Name of your program	What do you believe are barriers that could prevent farms from accessing your program or participating to the fullest extent?	Do you have ideas on how these barriers could be overcome? If so, please share.
Small Business Avantage Grant	Matching Funds, Knowledge of the Program, Knowledge of Energy Efficiency	More Outreach, educate Ag members of EE benefits
Pollution Prevention Assistance Account	Low Interest Rate environment, Competing Programs, Knowledge of Program existence	Increase awareness of the program
Alternative Fuels Incentive Grant (AFIG)	First, marketing of the program. Many farms have probably not heard about our program. Also, lack of alternative fuel availability to fuel vehicles. In general, people are slow to change from fossil fuels (diesel and gasoline) for transportation vehicles. Another barrier we hear about is the lack of people/mechanics who know how to do the maintenance on the vehicles.	Increased marketing through ag-specific media outlets.
Alternative and Clean Energy Program	Competitive bidding, prevailing wage, and knowledge of other program requirements. Some projects are developed by one for a farm and the farmer may not be aware that they will be required to competitively bid or solicit proposals/quotes for the project.	Applicants are encouraged to read our guidelines in their entirety and contact DCED with any questions. To ease the RFP/bidding process for farms, there should be a list of companies that can provide design/build services for anaerobic digesters. PUC has a link to the Mid-Atlantic Renewable Energy Association's Directory for PA Solar Electric Installers. I have not come across anything similar for anaerobic digester installers to date.
REAP grant energy assessments	matching funds other priorities	better incentivies
On Farm Energy Days	scheduling, travel	hold more workshops in different locations
Farm Energy IQ	lack of interest	increased incentives
Emerging Technology Applications Center (ETAC)	Farms do not have the technical or financial resources.	Provide resources to identify ee opportunities and financial incentives to implement.
West Penn Power Sustainable Energy Fund Act 129 Microloan Program	.	.
Energy Assessment Program for Agricultural Producers and Small Businesses	not knowing the program exists; time to gather information needed for the assessment (i.e. electric bills and building dimensions)	Farmers having access to the spreadsheet like the one below is a great starting point.
Sustainable Energy Fund	Awareness	targeted marketing like the farm show
USDA REDA	not fully understanding the potential benefit of what can be discovered with a free energy assessment, participation may be due to cost of implementation of measures identified.	None at this time
PennTAP	Unaware of our program	Workshops, factsheets distributed, and presentations during ext
Met Ed/Penelec Sustainable Energy Fund	Lack of awareness	Hopefully, as a result of this survey, more farms will become aware of our competitive grant opportunity. We typically serve nonprofits and small businesses in economically distressed areas. Our application is available now and closes March 16, 2020.
PPL	Unknown	N/A

2. Survey Responses

Name of your program	Do you have other ideas for services or programs the Pennsylvania Department of Environmental Protection could provide to help PA farms reduce their energy use and serve a need that is not currently being met?	Please review this list of agricultural energy efficiency programs provided by the DEP. If you are aware of a technical or financial resource not on the list, please describe below or add to the list
Small Business Avantage Grant		I assisted in developing this list
Pollution Prevention Assistance Account	There are many other opportunities listed on the following list of programs.	I assisted with the development of this list.
Alternative Fuels Incentive Grant (AFIG)		None.
Alternative and Clean Energy Program	Is there a "boots on the ground" effort to get this information out to farms across Pennsylvania or are we strictly waiting for farms to contact us regarding potential projects? If not, is it possible to work with regional, county, or local organizations to educate farmers about these programs? There are various conferences and seminars for water and sewer, greenways, trails, infrastructure, etc. Are we seeing the same participation for agriculture? The Pennsylvania Association for Sustainable Agriculture is one example, and I do not see that DEP participated in the 2019 conference.	Solar Energy Program and Renewable Energy Program are absent from this list. They are both administered by DCED. Both are currently closed due to lack of funding, but they could provide financial resources for solar or wind projects on farms.
REAP grant energy assessments	load curtailment, shifting. Energy storage	You have everything I am aware of.
On Farm Energy Days	none	no
Farm Energy IQ	no	none
Emerging Technology Applications Center (ETAC)	Host energy efficiency webinars to reach a broader audience with ee measures.	I could not access the link.
West Penn Power Sustainable Energy Fund Act 129 Microloan Program		.
Energy Assessment Program for Agricultural Producers and Small Businesses		This is the most comprehensive list I've seen for farms in Pennsylvania. At this time I can't think of any others.
Sustainable Energy Fund	No	No
USDA REDA	None at this time	No
PennTAP	grants to implement energy efficient projects	Tax Credits
Met Ed/Penelec Sustainable Energy Fund		N/A
PPL	N/A	

3. Pennsylvania Agriculture Energy Efficiency Programs

AGRICULTURE ENERGY EFFICIENCY ASSISTANCE RESOURCES IN PENNSYLVANIA						
Program Name	**Organization**	**Brief description of services provided**	**Maximum Award**	**Cost to Farmers**	**Fact Sheet/Additional Info.**	**Type of Assistance**
Act 129 Incentives	Duquesne Light	Rebates for the installation of energy efficient equipment	Varies	Balance of project costs	Duquesne Light (Watt Choices) Act 129 Incentives We	Financial
Act 129 Incentives	First Energy	Rebates for the installation of energy efficient equipment	Varies	Balance of project costs	First Energy Agricultural Incentives Website	Financial
Act 129 Incentives	PECO	Rebates for the installation of energy efficient equipment	Varies	Balance of project costs	PECO Act 129 Incentives Website	Financial
Act 129 Incentives	PPL	Rebates for the installation of energy efficient equipment	Varies	Balance of project costs	PPL Act 129 Incentives Website	Financial
AgChoice Farm Credit Loans	AgChoice Farm Credit	Commercial bank specializing in agricultural loans as well as business consulting	Varies	Balance of project costs	AgChoice Farm Credit Website	Financial
Alternative and Clean Energy Program (ACE)	DCED	Grants and loans for the utilization, development and construction of alternative and clean energy projects in the state		50% matching investment	ACE Website	Financial
Alternative Fuels Incentive Grant	DEP	Grants for businesses and non-profits for alternative fuel vehicles including propane, electric, biodiesel, CNG, and LNG.Grants can also fund refueling infrastructure. Rebates are also available for individual residents.	Varies, maximum awards per vehicle are laid out in the grant guidelines each year	A portion of the incremental purchase cost	AFIG Website	Financial
Business Energy Investment Tax Credit (ITC)	IRS	Federal Tax Incentive available for renewable energy systems	10% to 30% tax credit for installation of solar technologies, fuel cells, small wind turbines, geothermal systems, and CHP systems	Balance of project costs	IRS Website	Financial
Community Foundation for the Alleghenies Grant Program	Community Foundation for the Alleghenies	Small grants in Bedford, Cambria, Somerset, and Indiana Counties	Grants in the $500-$5,000 range	Balance of project costs	Community Foundation for the Alleghenies Website	Financial
Compeer Financial Agriculture Financing (Formerly AgStar Farm Credit)	Compeer Financial	Financing for various agricultural expenses, from startups to equipment purchases and leases	Varies	Balance of project costs	Compeer Financial Website	Financial
Energy Assessment Program	NSSC (National Sustainable Structures Center)	On-site energy assessments for farms and rural small businesses, funded through USDA's REDA (Renewable Energy Development Assistance) Program	n/a	Free	NSSC Website	Assessments
Energy Assessment Program	St. Francis University Institute for Energy	On-site energy assessments for farms and rural small businesses, funded through USDA's REDA (Renewable Energy Development Assistance) Program	n/a	Free	St Francis University Website	Assessments
Energy Assessment Program	ETAC (Emerging Technologies Application Center)	On-site energy assessments for small to mid-sized manufacturers, including agri-related businesses (funded through DOE's State Energy Program)	n/a	Free	ETAC Website	Assessments
Energy Assessment Program	PennTAP (Pennsylvania Technical Assistance Program)	On-site energy assessments for small to mid-sized manufacturers, including agri-related businesses (funded through DOE's State Energy Program)	n/a	Free	PennTAP Website	Assessments
Energy Assessment Program	Penn State Ag Extension	On-site energy assessments for farms and rural small businesses, funded through USDA's REDA (Renewable Energy Development Assistance) Program	n/a	Free		Assessments

Environmental Quality Incentives Program (EQIP) for Energy Audits and Equipment Cost Sharing	NRCS	Financial assistance is available for the development of an Agricultural Energy Management Plan (AgEMP). The AgEMP, or energy audit, is completed by NRCS-certified Technical Service Providers.NRCS can also cost-share equipment upgrades that result from the audit.	Varies	Balance of project costs (NRCS typically cost sha	EQIP On-farm Energy Initiative Website	Audits & Financial
Farm Energy Day Workshops	Penn State Ag Extension	One day workshops that focus on the biggest energy opportunities for the ag sector in a particular geographic area (ex. Fruit producers, dairy producers)	n/a	Small registration fee, around $20	Penn State Extension Energy Workshops and Confere	Education
Farm Energy IQ Training	Penn State Ag Extension	3-day energy workshops focusing on energy efficiency, energy procurement, and renewables	n/a		Penn State Extension Energy Workshops and Confere	Education
Farm Service Agency Loans	USDA		Varies	Balance of project costs	Pennsylvania Farm Service Agency Website	Financial
Met-Ed Sustainable Energy Fund Grants	Met-Ed Sustainable Energy Fund at the Berks County Community Foundation	Grants for projects and programs that (a) support the development and use of clean energy technologies and energy efficiency or (b) support workforce development in the sustainable energy field in the Met-Ed or Penelec service territories.	Grants in the $2,000 to $50,000 range	Balance of project costs	Met-Ed/Penelec Sustainable Energy Fund Website	Financial
PA Industrial Development Authority First Industries Fund (FIF) Loans	DCED	Provides loan guarantees to nonprofit organizations and for-profit businesses to undertake projects relating to the promotion and development of agriculture in PA, including energy efficiency	Varies	Balance of project costs	FIF Fund Website	Financial
Penelec Sustainable Energy Fund Grants	Penelec Sustainable Energy Fund at the Community Foundation for the Allleghenies	Grants for projects and programs that (a) support the development and use of clean energy technologies and energy efficiency or (b) support workforce development in the sustainable energy field in the Met-Ed or Penelec service territories.	Grants in the $2,000 to $50,000 range	Balance of project costs	Met-Ed/Penelec Sustainable Energy Fund Website	Financial
PPAA (Small Business Pollution Prevention Assistance Account)	DEP	Low-interest, fixed-rate loans to small businesses undertaking projects which reduce waste, pollution or energy use	Maximum loan of $100,000		PPAA Loan Program Website	Financial
REAP (Rural Energy for America Program)	USDA (Rural Development)	Guaranteed loan financing and grant funding to agricultural producers and rural small businesses for renewable energy systems or to make energy efficiency improvements	Energy efficiency grant, max $250,000.Renewable energy systems grant, max $500,000.	Varies-75% cost share for grants only, 25% cost	REAP Fact Sheet	Financial
SBAG (Small Business Advantage Grants)	DEP, Small Business Ombudsman	Grants for P2 (pollution prevention) or E2 (energy efficiency) projects at eligible small businesses in PA including farms	$7,000	50% matching investment	SBAG Website	Financial
The Sustainable Energy Fund (PPL) Financing	The SEF (Sustainable Energy Fund)	Low interest loans available to ag businesses in PPL territory	Loans range from $5,000 to $1 Million	Balance of project costs	The SEF Website	Financial
West Penn Power Sustainable Energy Fund Financing	West Penn Power Sustainable Energy Fund	Loans and limited grant-making in the West Penn Power service territory for sustainable energy investments	Varies-loans typically in the range of $25,000 to $500,000. Grants typically capped at $25,000	Balance of project costs	WPPSEF Funding Website	Financial
West Penn Power Sustainable Energy Fund Act 129 Micro-Loan	Economic Growth Connection of Westmoreland	Micro-loans for energy efficiency projects	Loans up to $50,000	Balance of project costs	WPPSEF Micro Loan Application	Financial

APPENDIX C: PROGRAM EXAMPLES FROM OTHER STATES

Below, we have included links to information about other state programs or resources referenced within Section 6.2 of the report. Where known, we have also included information about the funding source for the program.

Funding for agricultural energy efficiency programs has typically come from public-benefits funds mandated by a state's public utilities commission (New York, Wisconsin), utility funds mandated by a public utility commission (California), or funding a state agency receives through a federal grant (common funders are the Environmental Protection Agency, the U.S. Department of Agriculture, and the Department of Energy). Other state agencies with limited funding for energy efficiency have also been able to fund energy efficiency through special initiatives such as the 2009 American Recovery and Reinvestment Act, 'leftover' funds from unsuccessful projects or grants, the Regional Greenhouse Gas Initiative, and special funds awarded to the agency as part of a settlement (for example, BP funds provided to the Florida Department of Agriculture and Consumer Services following the Deepwater Horizon oil spill).

OPTION A: EDUCATION AND SUPPORT THROUGH DEVELOPMENT AND DISSEMINATION OF BEST PRACTICES

Examples of agricultural energy efficiency best practices materials:

- Connecticut, sponsored by the Connecticut Farm Energy Program: https://ctfarmenergy.org/wp-content/uploads/2019/07/CT_BMP_July17_WEB-1.pdf
- Wisconsin, sponsored by Wisconsin Focus on Energy: https://focusonenergy.com/sites/default/files/Agriculture-Best-Practices_2016_web_0.pdf
- Dairy Industry, sponsored by the Innovation Center for U.S. Dairy: https://www.usdairy.com/~/media/usd/public/bestpracticesguideenergysavingsopportunitiesfordairy.pdf

Single-topic best practices:

- Pennsylvania: https://extension.psu.edu/top-10-ways-field-crop-farms-can-save-energy

The New York Energy Research & Development Authority (NYSERDA) recently released an RFP seeking contractors to develop and disseminate agricultural best practices. This RFP could serve as a useful guide if DEP were to consider soliciting bids for an administrator to deliver the best practices.

https://portal.nyserda.ny.gov/CORE_Solicitation_Document_Page?documentId=a0lt0000000X92qAAC

Examples of videos and case studies developed by grant recipients from Maryland's Kathleen A.P. Mathias Agriculture Energy Efficiency Program: https://energy.maryland.gov/business/Pages/incentives/mathiasag-2012.aspx

OPTION B:

NYSERDA Agriculture Energy Audit Program: https://www.nyserda.ny.gov/All-Programs/Programs/Agriculture-Energy-Audit

OPTION C: LOW-INTEREST REVOLVING LOAN FUND

- Coalition for Green Capital and the Nature Conservancy, Pennsylvania Clean Energy Market Report: http://coalitionforgreencapital.com/wp-content/uploads/2017/08/PA-Clean-Energy-Market-Report-8.15.17.pdf
- Coalition for Green Capital and the Nature Conservancy, Pennsylvania Energy Investment Partnership Report: http://coalitionforgreencapital.com/wp-content/uploads/2017/08/PA-Energy-Investment-Partnership-Report-7.19.17.pdf
- Energize Delaware Low Interest Loan Application: https://ensave.sharefile.com/d-s07041390fae42cc8

OPTION D: COMPETITIVE GRANT AWARDS FOR THE BEST ENERGY EFFICIENCY PROJECTS

NYSERDA's Advancing Agricultural Energy Technologies RFP: https://portal.nyserda.ny.gov/CORE_Solicitation_Document_Page?documentId=a0lt0000000K9K3AAK

OPTION E: INCENTIVE DELIVERY PROGRAM

- Energize Delaware Farm Program: https://www.energizedelaware.org/nonresidential/farm/
- Agriculture Energy Efficiency Program: https://www.nyserda.ny.gov/Business-and-Industry/Agriculture
- Farm Energy and Water Efficiency Realization Program: http://www.aceee.org/sites/default/files/publications/researchreports/u1807.pdf (see page 18)
- Wisconsin Focus on Energy Agribusiness Program: https://www.focusonenergy.com/business/agribusiness
- Pacific Gas & Electric Company: https://www.pge.com/en_US/small-medium-business/save-energy-and-money/rebates-and-incentives/industry-rebates/agriculture-and-food-processing.page
- Beneficial Electrification League: https://beneficialelectrification.com/

The maps below show the value of the seven sectors of agriculture per county as a percent of the total market value of agricultural products sold.

Figure 1: Dairy Market Value by Pennsylvania County

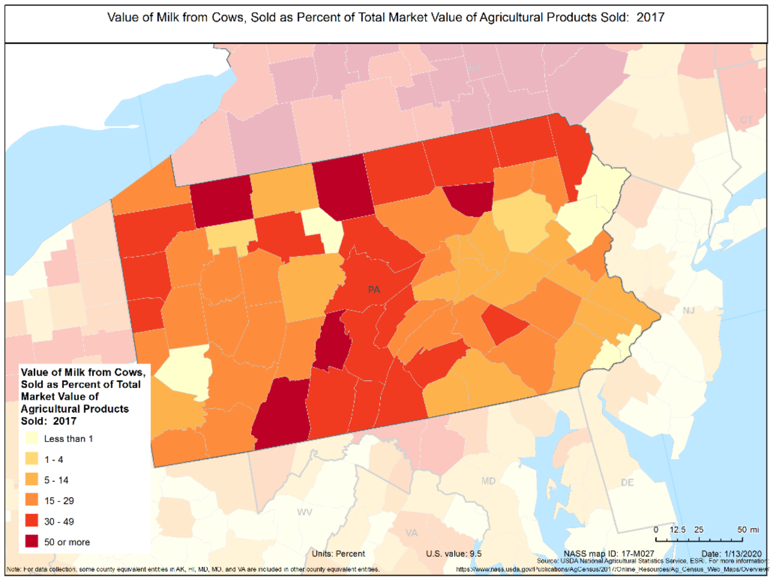


Figure 2: Beef Market Value by Pennsylvania County

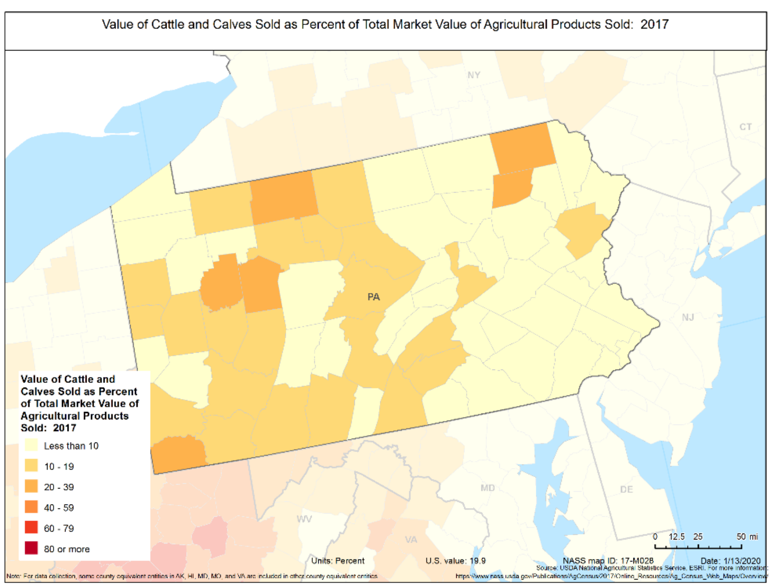


Figure 3: Poultry Market Value by Pennsylvania County

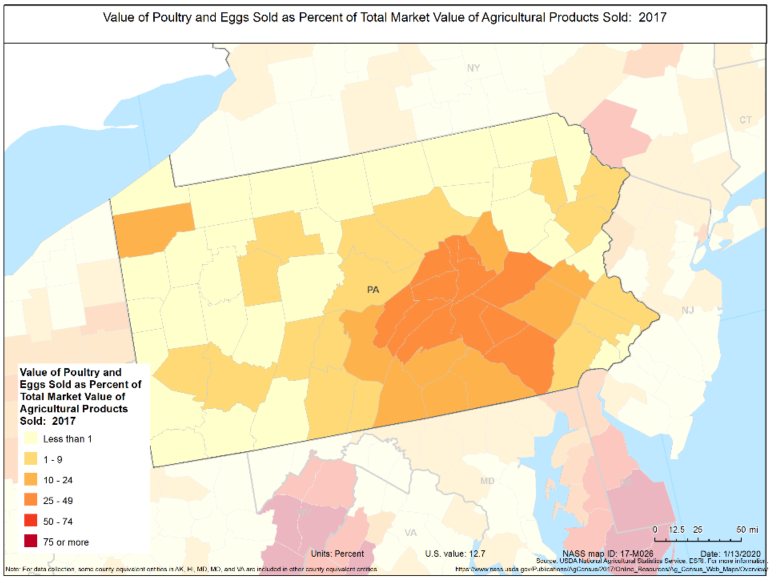


Figure 4: Swine Market Value by Pennsylvania County

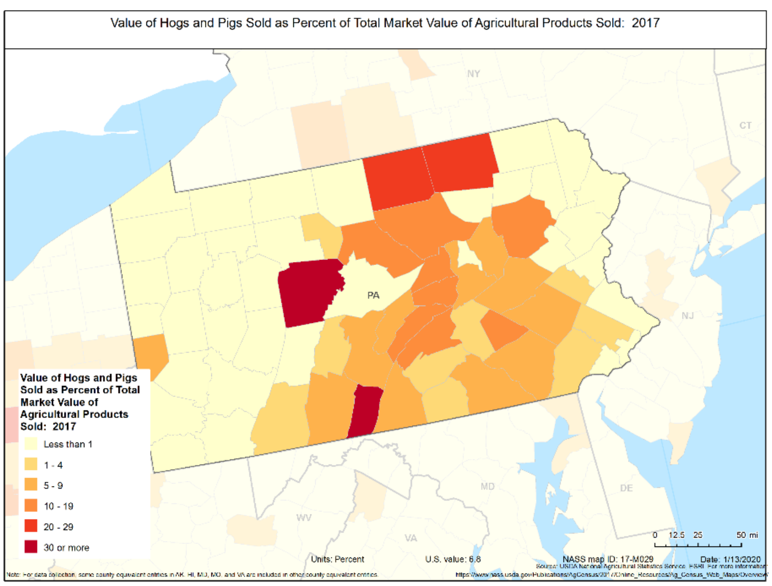


Figure 5: Orchard Market Value by Pennsylvania County

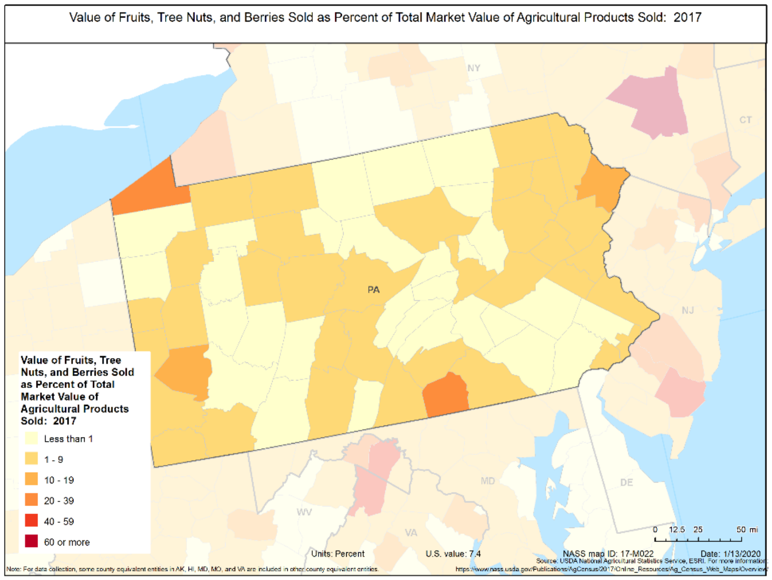


Figure 6: Greenhouse Market Value by Pennsylvania County

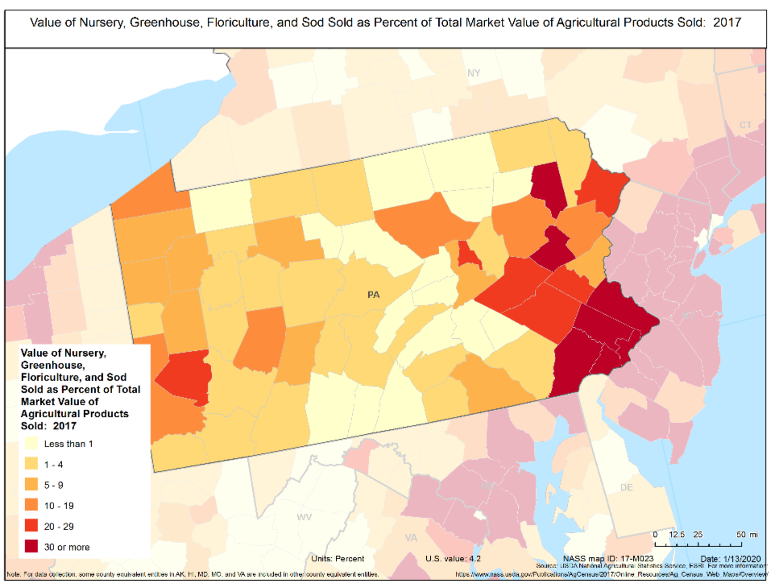


Figure 7: Crop Market Value (Grains, Oilseeds, Dry Beans & Peas) by Pennsylvania County

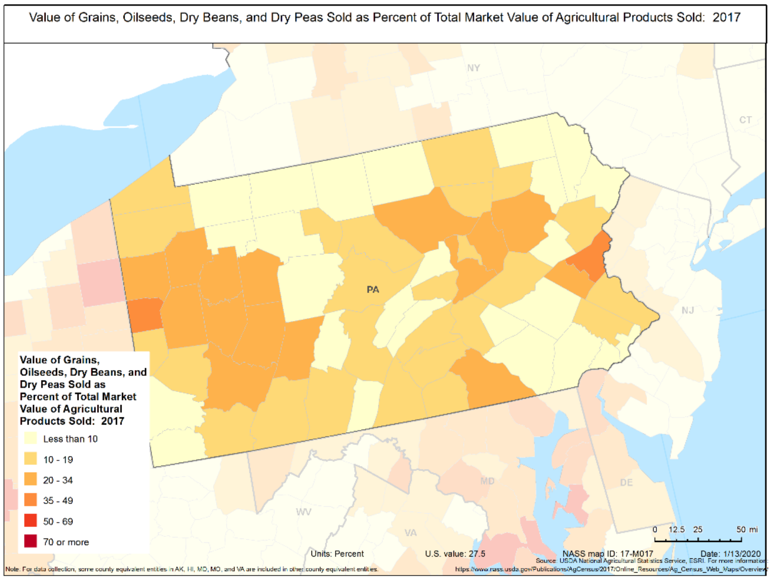


Figure 8: Crop Market Value (Vegetables, Melons, Potatoes, Sweet Potatoes) by Pennsylvania County