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Energy Efficiency in New York State Agriculture: Summary of Energy Efficiency Programs and Research Opportunities

Final Report

June 2015

Report Number 15-14

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Energy Efficiency in New York State Agriculture: Summary of Energy Efficiency Programs and Research Opportunities

Final report

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NYSERDA Report 15-14 NYSERDA Contract 40347 June 2015

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Acronyms and Abbreviations

AEEP	Agricultural Energy Efficiency Program
ASABE	American Society of Agricultural and Biological Engineers
CO2	carbon dioxide
CHR	compressor heat recovery
EEV	electronic expansion valve
FEAT™	Farm Energy Audit Tool
ft2	square feet
GHG	greenhouse gas
GWh	gigawatt-hour
kW	kilowatt
kWh	kilowatt hour
LED	light-emitting diode
MW	megawatts
NASS	National Agricultural Statistics Service
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
MMBtu	million British thermal units
mtCO2e	metric tons of carbon equivalents
REDC	Regional Economic Development Council
TEV	thermal expansion valve
USDA	United States Department of Agriculture
VFD	variable frequency drive
W	watts

Executive Summary

Agriculture is a major economic sector in New York State (NYS), generating $5.4 billion in revenue in 2012.[1] NYS has a long standing commitment to the energy efficiency of farms, notably through energy efficiency programs such as NYSERDA's Agriculture Energy Efficiency Program (AEEP). Despite the success of this program, untapped opportunity exists to secure additional energy savings from NYS' farms. Additional savings can be achieved from deeper penetration for agricultural sectors that have not historically participated in NYSERDA's energy efficiency programs, and from underutilized technologies that show promise but need further research to demonstrate true potential. EnSave developed this report with three major analyses to help NYSERDA better understand how NYS' agricultural sector can contribute to overall energy efficiency and greenhouse gas (GHG) reduction goals. The report is organized as follows:

- Section 1 – The range of baseline energy use for each major farm type with electricity or natural gas as a predominant energy source and a summary of energy efficiency program success to date.
- Section 2 – Identification of underutilized measures within NYS's agriculture.
- Section 3 – A description of technologies meriting additional research, including prioritization based on level of commercialization, energy savings potential, and other factors.

Section 1 includes data on 782 applicants to the AEEP, 762 energy audits performed as part of the AEEP or other NYSERDA energy efficiency programs, and from EnSave's audits for farms with similar geographic and demographic characteristics (i.e., New England, Mid-Atlantic, and upper Midwestern United States). Data were compared with statistics from the United States Department of Agriculture (USDA) Census of Agriculture database to better understand the overall characteristics of agriculture in NYS and the extent to which NYSERDA program participants mirror the state's overall demographics. Summary statistics for all farm types participating in AEEP provide energy and GHG savings to date.

1 USDA-NASS Census of Agriculture. 2012. http://www.agcensus.usda.gov/Publications/2012

Section 2 was based on an analysis of implementation data from AEEP beginning in January 2011. In total, 1,094 energy efficiency measures have been installed, approximately 75-85% of which were installed on dairy farms. Based on the type and frequency of measures installed through AEEP combined with market experience, 10 underutilized energy efficiency measures were identified, including occupancy sensors, thermostatic controls, compressed air leak detection, radiant tube heaters, shade curtains, bench heating systems, well pump variable speed drives, evaporator fan controls, thermostatically controlled outlets, and engine block heater timers.

Section 3 was developed based on market knowledge and experience as a designer and implementer of agricultural energy efficiency programs. In total, nine energy efficiency measures that merit further research are identified, including ozone laundry, light emitting diode (LED) lighting for greenhouses, variable frequency drives (VFDs) for ventilation fans, conductive cow cooling, evaporative cooling, electronic expansion valves, geothermal heat pumps, outside air economizers, and dynamic temperature control for greenhouses. A review of the level of commercialization, prior research, barriers to adoption, potential GHG savings and estimated cost is provided for each of these measures.

This report identifies the following points that NYSERDA may want to consider when developing future agricultural programs and identifying technologies with research and development potential:

- AEEP has been successful in engaging dairy producers to participate, particularly larger (greater than 500 herd size) farms. Despite this success, there is still significant opportunity for smaller dairies (particularly in the 100 to 500 herd size range) to improve energy efficiency and avoid GHG emissions, and all dairies may benefit from the emerging agricultural technologies identified in Section 3.
- Other farm types, such as vineyards, orchards, greenhouses, and poultry have low participation rates in AEEP and other NYSERDA programs despite having significant energy use and economic presence in NYS. Opportunity exists for increasing the engagement of these farms in energy efficiency.
- NYS agriculture can likely benefit from emerging technologies that are not widely used in agriculture but are better established in other sectors. Before farms are ready to adopt these measures; however, more research is needed to ensure that these technologies are appropriate for agriculture and do not negatively impact production efficiency.

1 Baseline Energy by Sector

Understanding baseline energy use is a critical step toward maximizing the results of energy efficiency efforts and cost-effectively targeting farms based on opportunity. Baseline energy usage is characterized by understanding average energy usage on a per-farm basis, by season, and for aggregate energy usage by farm type. Three sources of data (Appendix A) are used to address these questions, including farm data from the AEEP, the USDA National Agricultural Statistics Service (NASS) 2012 Census of Agriculture, and data from EnSave's Farm Energy Audit Tool (FEAT™). This section provides a basic overview of NYS' agricultural sector, followed by an analysis of baseline energy use by farm type.

1.1 Overview of NYS' Agricultural Sector

Agriculture is a major contributor to NYS' economy, generating over $5.4 billion in sales in 2012.[2] The State has a large agricultural output per capita and is ranked among the top 10 states for production of fluid milk, grapes, maple syrup, orchard crops, and vegetables.[3] Table 1 provides an overview of NYS' standing as compared with other top-producing states for its top 10 agricultural subsectors.

2 USDA-NASS Census of Agriculture. 2012. http://www.agcensus.usda.gov/Publications/2012.

3 Ibid.

Table 1. NYS Subsector Size and State Rankings

Source: USDA-NASS Census of Agriculture 2012

Subsector	Total Size	Top 3 States by Production	Ranking of NYS
Milk Cows	610,712 cows	California, Wisconsin, New York	3rd
Grapes	39,216 acres	California, Washington, New York	3rd
Maple Syrup	358,603 gallons	Vermont, Maine, New York	3rd
Orchard	93,661 acres	California, Florida, Washington	9th[4]
Vegetables	135,997 acres harvested	California, Idaho, Washington	9th[5]
Eggs	5,208,831 laying birds	Iowa, Ohio, Indiana	19th
Cattle and Calves	1,419,365 cattle and calves	Texas, Nebraska, Kansas	21st
Grains and Oilseeds	960,602 acres harvested	Iowa, Illinois, North Dakota	26th
Hog	337,333 hogs sold	Iowa, North Carolina, Minnesota	29th
Chickens (Meat)	2,062,445 birds sold	Georgia, Alabama, Arkansas	29th

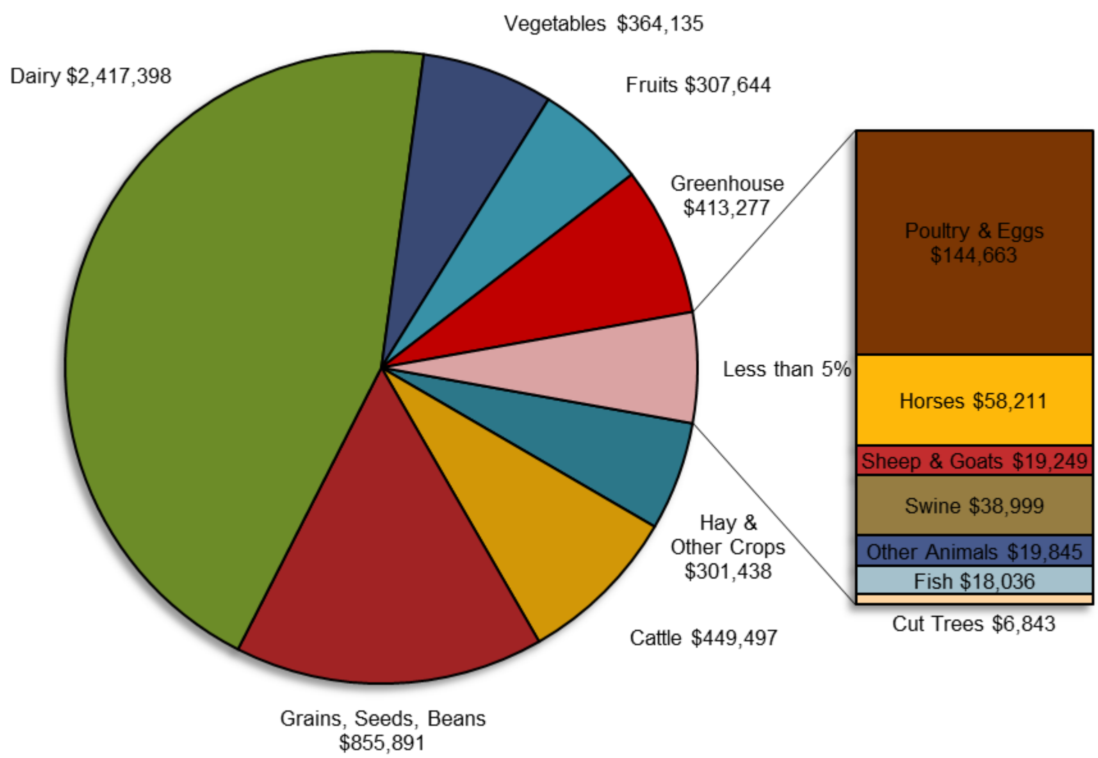
Dairy represents the most prominent subsector in NYS, accounting for almost 45% of the total annual sales, followed by grain and oilseed, cattle, nursery, and vegetable production (Figure 1).

4 NYS is third for apples.

5 NYS is first for pumpkins and cabbage.

Figure 1. Value of Sales in NYS by Subsector

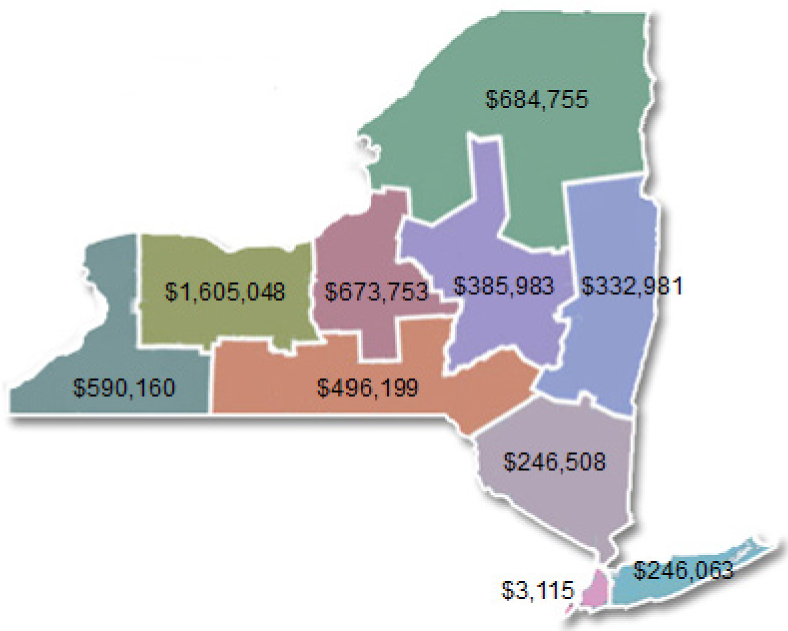
Source: USDA-NASS Census of Agriculture 2012



According to Figure 2, the largest concentration of agriculture by market sales is in the Finger Lakes area, but this area accounts for only 30% of all agricultural sales within the State. The Mid-Hudson, Long Island, and New York City regions, while considered heavily urbanized, produced approximately $500 million in market sales in 2012.

Figure 2. Agricultural Market Sales by Regional Economic Development Council (REDC) Region (in $1,000)

Source: USDA-NASS Census of Agriculture 2012. Background map source: http://regionalcouncils.ny.gov



This report focuses on major farm types that use electricity and natural gas as predominant energy sources. The analysis provided in this report is proportional to the amount of historical energy usage data and farm energy audit data available. Subsectors with a longer history of energy efficiency initiatives, such as dairy farms, have a larger pool of data from which to draw on for analysis.

Total estimated electricity, natural gas and GHG savings for the AEEP across all farm types in NYS are calculated for all applicants to the program (Table 2). Data for each unique farm type are provided with the respective farm type discussion in this report. Overall all farm types, the most commonly installed energy efficiency measures are lighting, pumps and motors, and cooling technologies. The greatest GHG emissions avoidance opportunities have been realized with lighting and ventilation improvements.

Table 2. Summary of Energy and Greenhouse Gas Savings for All AEEP Applicants (n=780)

Source: NYSERDA AEEP; Compiled by EnSave, Inc.

Recommended Measure Category	Percentage of Applicants Approved6	Electricity Savings (kWh)	Natural Gas Savings (MMBtu)	Greenhouse Gas Savings (mtCO2e)
Lighting: Excluding LED Projects	32.9%	7,388,892	0	2,126
Vacuum Pump VFDs and Motor Replacements	20.4%	1,730,173	0	498
Pre-coolers and Milk Transfer Pump VFDs	19.6%	2,130,034	0	613
Refrigeration or Cold Storage	17.7%	1,600,948	0	461
Ventilation of Air (Circulation, Exhaust, and Tunnel)	15.3%	5,448,640	0	1,568
Lighting: LEDs (Full and Partial Projects)	5.9%	2,955,586	0	850
Water Heating: Compressor Heat Recovery	5.3%	437,390	210	137
Air Heating, Air Cooling, and Building Environment	3.3%	688,830	2,094	308
Electric Motors and Pumps Not Used in Milk Production	1.9%	610,060	0	176
Water Heating: Replacement Heaters and Pipe Insulation	1.9%	63,643	7	19
Stock Watering	1.5%	150,736	0	43
Dishwashers, Clothes Washers, Dryers	0.9%	11,580	0	3
Engine Block Heater Timers	0.4%	5,160	0	1
Outside Air Economizers	0.1%	41,680	0	12
All Other Measures[7]	2.6%	417,310	87	125
Total		**23,680,662**	**2,398**	**6,940**

1.2 Dairy

Milk production is NYS's most prominent agricultural activity, accounting for over $2.4 billion in milk sales in 2012[8]. In total, approximately 5,247 dairy farms (610,712 cows) operate in the State[4]. The population of milk cows is well distributed throughout the northern and western sections of NYS (Figure 3). All Regional Economic Development Council (REDC) regions north of the Mid-Hudson region have a significant dairy presence.

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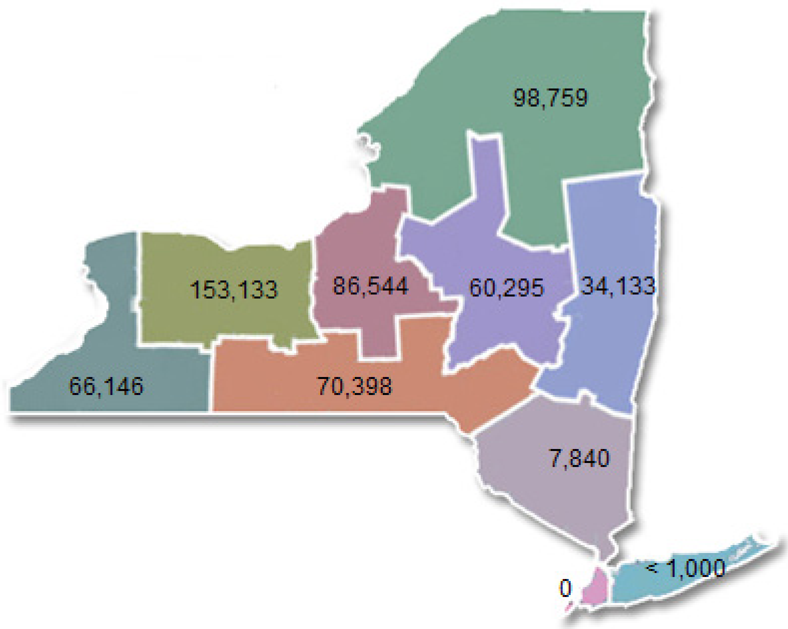
6 This column represents the percentage of applicants for which at least one measure in the category was approved for installation by AEEP program representatives. It does not reflect whether or not the applicant has since installed that measure.

7 This row represents more site-specific and unique measures not limited to but including HVAC changes, suction line insulation, vending machine controls, timers not used for engine block heaters, and grain dryers. Most items in this row were recommended only once.

8 Ibid.

Figure 3. Milk Cow Distribution in NYS by REDC Region

Source: USDA-NASS Census of Agriculture 2012. Background map source: http://regionalcouncils.ny.gov



Dairy farms represent approximately 71% of AEEP applicants and provide the most robust data set of any farm type. Table 1 provides a comparison between the number of AEEP dairy applicants and the total percent of applicants received from each dairy herd size category based on USDA NASS data, along with total number of milking cows.

Table 3. AEEP Dairy Farm Applicants Compared With USDA NASS 2012 Dairy Farm Counts

Source: USDA-NASS Census of Agriculture 2012, NYSERDA AEEP Data, Compiled by EnSave Inc.

Average Number of Milking Cows	USDA NASS 2012 Number of Dairy Farms	NYSERDA AEEP Number of Dairy Applicants	Percent of Total Dairy Farms with Applications to AEEP	USDA NASS 2012 Total Number of Cows
N / A	-	11	-	-
1 - 49	2,589	45	2%	60,354
50 - 99	1,676	165	10%	111,547
100 - 499	916	213	23%	168,688
500 - 999	143	64	45%	100,295
1,000 - 2,499	91	52	57%	129,622
2,500+	12	6	50%	40,206
Totals	5,427	556	10%	610,712

Participation in AEEP has been largely skewed toward dairies with 500 cows or more (Table 3); this is a common profile for energy efficiency programs in the United States. Larger farms consume more energy and thus have greater opportunities for implementing energy efficiency measures that may not be economically feasible for smaller operations. Larger dairy operations often receive more individualized attention from utility account managers, equipment vendors, and the extended agricultural community due to their size, which may contribute to higher participation rates in energy efficiency programs.

Total estimated electricity, natural gas, and GHG savings for NYS dairies that participated in AEEP indicate significant savings from technologies within 14 categories (Table 4).

Table 4. Summary of Energy and Greenhouse Gas Savings, NYSERDA AEEP – Dairy Applicants (n=555)

Source: NYSERDA AEEP; Compiled by EnSave, Inc.

Recommended Measure Category	Percentage of Applicants Approved[9]	Electricity Savings (kWh)	Natural Gas Savings (MMBtu)	Greenhouse Gas Savings ($mtCO_2e$)
Lighting: Excluding LED Projects	29.5%	4,293,497	0	1,235
Vacuum Pump VFDs and Motor Replacements	24.3%	1,310,383	0	377
Pre-coolers and Milk Transfer Pump VFDs	24.1%	1,339,774	0	386
Refrigeration or Cold Storage	16.8%	841,515	0	242
Ventilation of Air (Circulation, Exhaust, and Tunnel)	15.9%	4,050,334	0	1,165
Water Heating: Compressor Heat Recovery	6.7%	411,120	55	121
Lighting: LEDs (Full and Partial Projects)	6.5%	2,363,300	0	680
Water Heating: Replacement Heaters and Pipe Insulation	2.2%	60,343	0	17
Electric Motors and Pumps Not Used in Milk Production	1.6%	416,720	0	120
Air Heating, Air Cooling, and Building Environment	1.1%	29,380	31	10
Dishwashers, Clothes Washers, Dryers	0.9%	8,190	0	2
Stock Watering	0.7%	29,446	0	8
Engine Block Heater Timers	0.4%	4,630	0	1
All Other Measures[10]	1.6%	237,820	0	68
Total		**15,396,452**	**86**	**4,435**

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9 This column represents the percentage of applicants for which at least one measure in the category was approved for installation by AEEP program representatives. It does not reflect whether or not the applicant has since installed that measure.

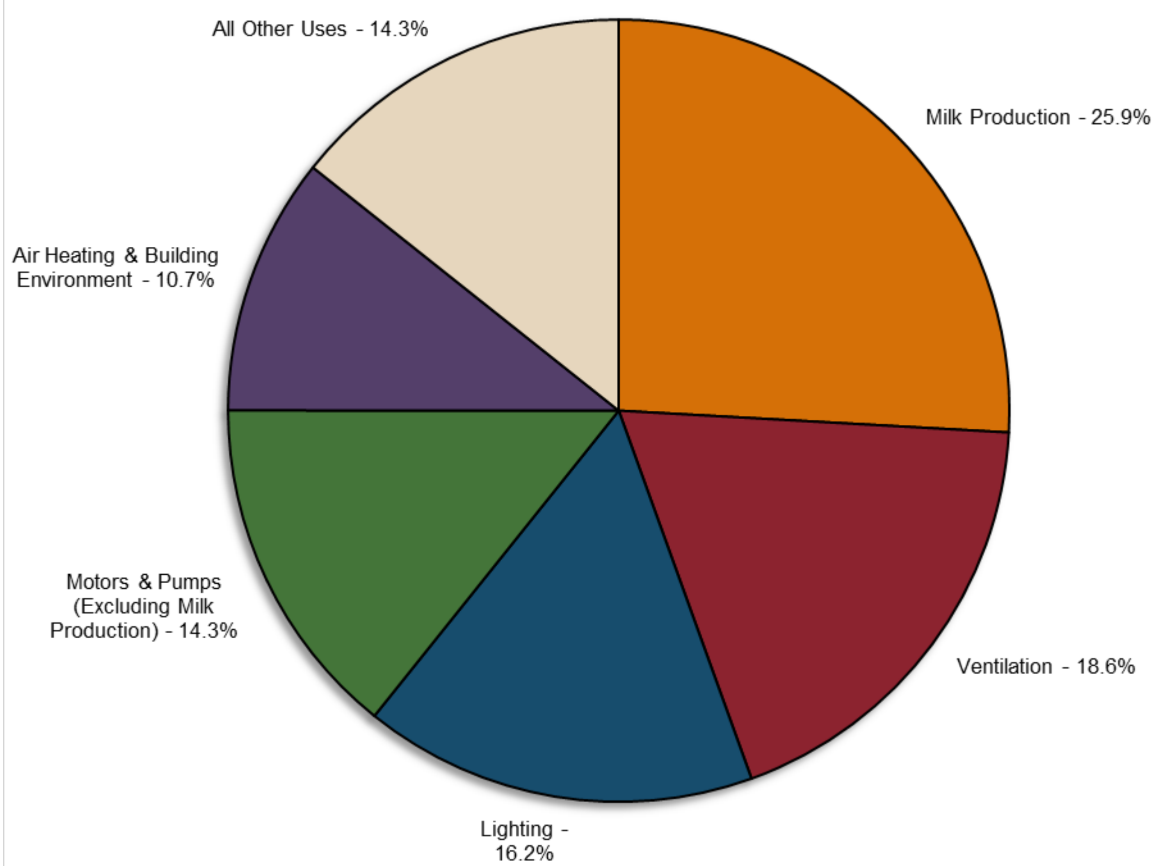
10 This row represents more site-specific and unique measures not limited to but including HVAC changes, suction line insulation, vending machine controls, timers not used for engine block heaters, and grain dryers. Most items in this row were recommended only once.

1.2.1 Baseline Energy Use

Although energy use typically accounts for only approximately 5 to 10% of a dairy farm's operational expense, it represents an area where optimization can be made in a cost- and time-efficient manner. Dairy farms use energy for various on-farm functions (Figure 4) including milk harvest, milk cooling, water heating, lighting, ventilation, manure separation, and lagoon pumping.

Figure 4. Average Annual Electricity and Heating Fuel Use by Dairy Operation, FEAT Dairy Dataset (n=48)

Source: EnSave, Inc.

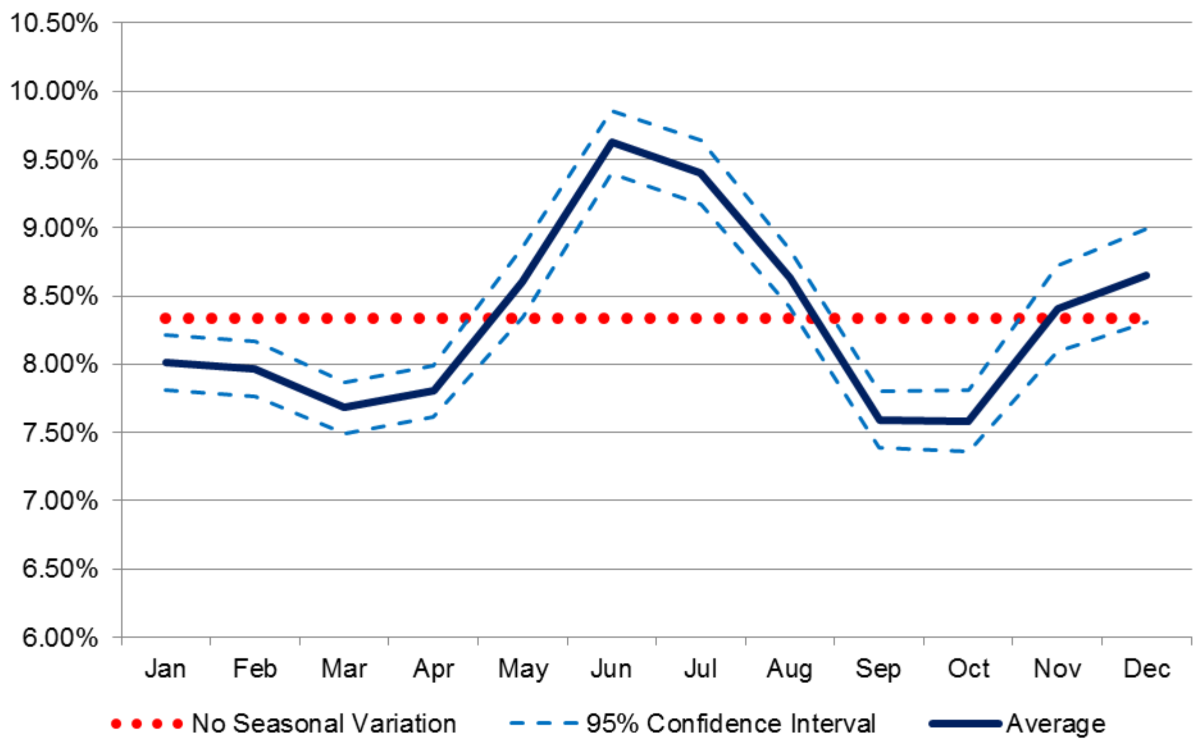


The majority of energy used on dairy farms is devoted to equipment that uses electricity, including compressors, pumps, lighting, motors, and fans. Propane and diesel are typically used for space and water heating on NYS dairy farms; natural gas is not a common heating fuel due to limited availability. Among AEEP applicants, 41 of 556 dairy applicants (7%) reported using natural gas as a heating fuel, most of which were located in the regions where natural gas is available (see Appendix B for more information regarding natural gas distribution in NYS). The precise breakdown of heating fuel use on dairy farms in NYS is not known; however, it is estimated that over 85% of the farms use propane as their primary fuel for space and water heating followed in decreasing order by electricity, fuel oil, and natural gas.

Figure 5 presents how much electricity on average is used by a dairy farm during a given month, expressed as a percentage of that farm's total electricity use. This analysis is based on 436 dairy audits as part of AEEP containing utility information from October 2006 through January 2014. The dashed blue lines indicate the upper and lower bounds of a 95% confidence interval[11] for the average, and the red dotted line represents a hypothetical scenario in which energy use remains constant through the year.

Figure 5. Percent Annual Total Electricity Consumed Monthly by Audit: NYSERDA Dairy Audits (n=436)

Source: NYSERDA audits data, compiled by EnSave, Inc.



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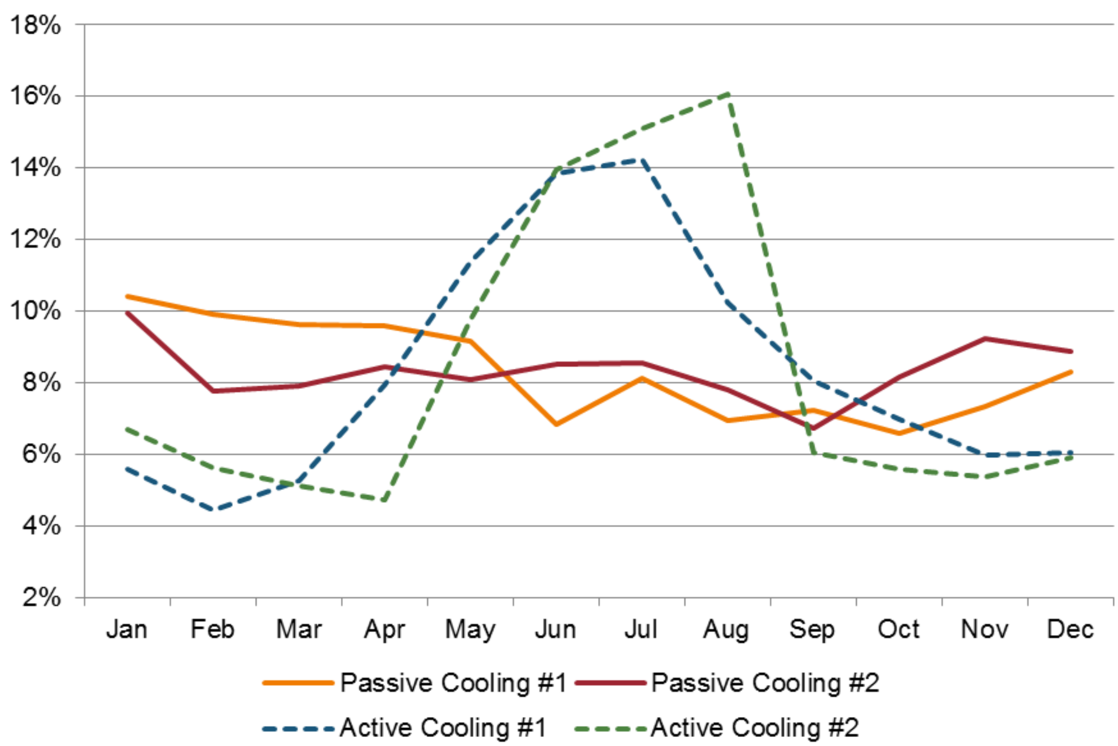
11 Electricity consumption values for NYS's agricultural operations are assumed to be log-normal. See Appendix B: Methodology for more information on log-normal distributions.

Two prominent seasonal peaks in electricity use are evident (Figure 5). In general, the major peak in electricity use occurs in the summer (May and early August), and a minor peak in electricity use in the winter months (November to late December). This pattern does not describe all dairy farms in NYS but it is representative of the average farm. Among the 436 farms used in this analysis, 26 (6%) did not show significant peak electric use in summer or winter, and 84 (19%) audits had a more prominent peak in electric use in winter than summer.

In general, electricity usage peaks in summer coincide with increased refrigeration and cow cooling loads, whereas winter peaks are related to higher lighting requirements and heating loads. Based on analysis of dairy farms using active ventilation systems versus passive ventilation systems (i.e., no fans), it is evident that ventilation is a major contributor to summer peak electric demand. Figure 6 provides a comparative analysis of four dairy farms in the Northeastern United States, two of which are using active ventilation and two of which are using passive ventilation. The peak electric demand for farms using active ventilation closely corresponds with the average summer electric usage peak (Figure 5).

Figure 6. Percent Annual Total Electricity Consumed Monthly by Audit: FEAT Selected Audits

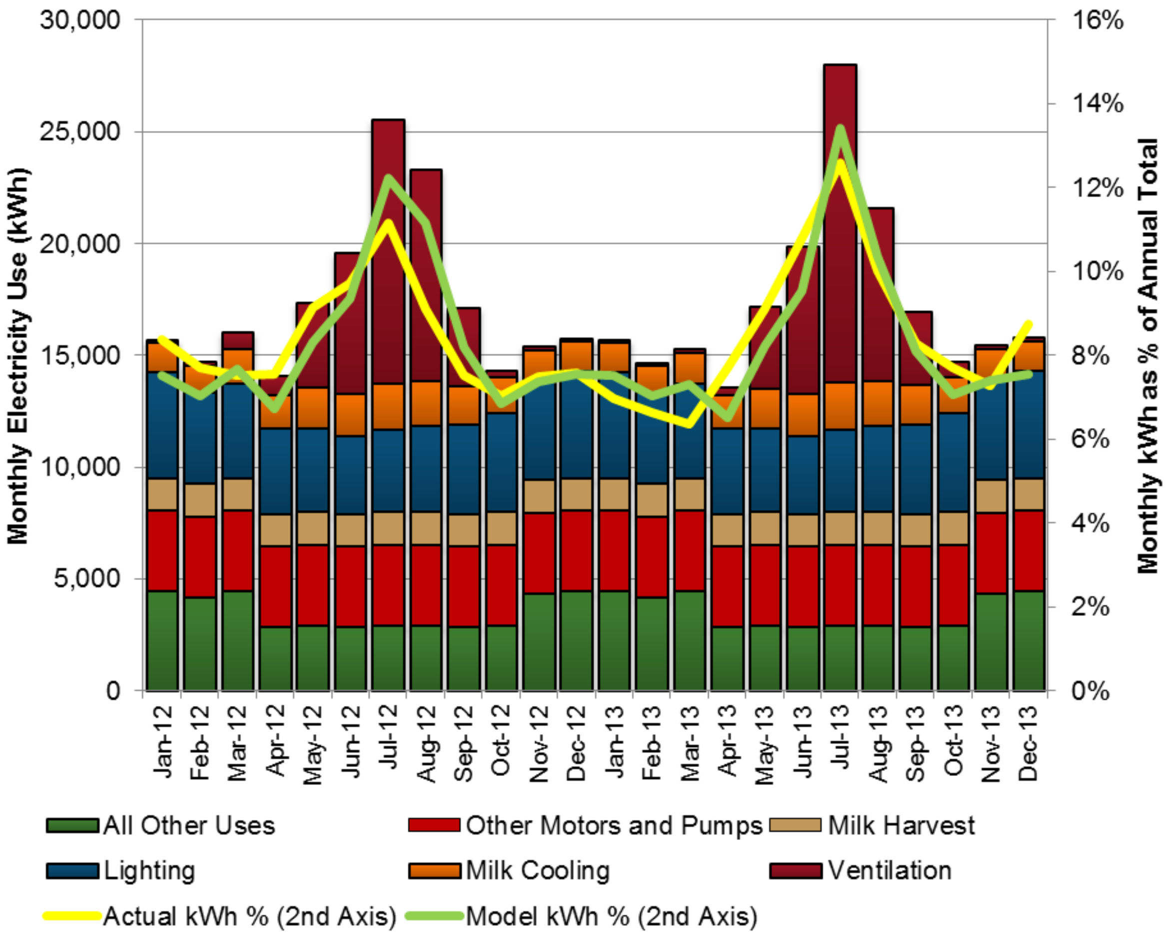
Source: EnSave, Inc.



Analyzing seasonal electrical usage for all equipment on dairy farms provides further insight into dairy farm energy usage patterns. Figure 7 is based on data for 48 dairy farms located in NYS and New England outside of AEEP between 2012 and 2013. (Appendix C provides a more detailed description of the methodology used to develop this model.)

Figure 7. FEAT Model of Average Seasonal Electricity Use, Northeastern Dairy Farms

Source: EnSave, Inc.



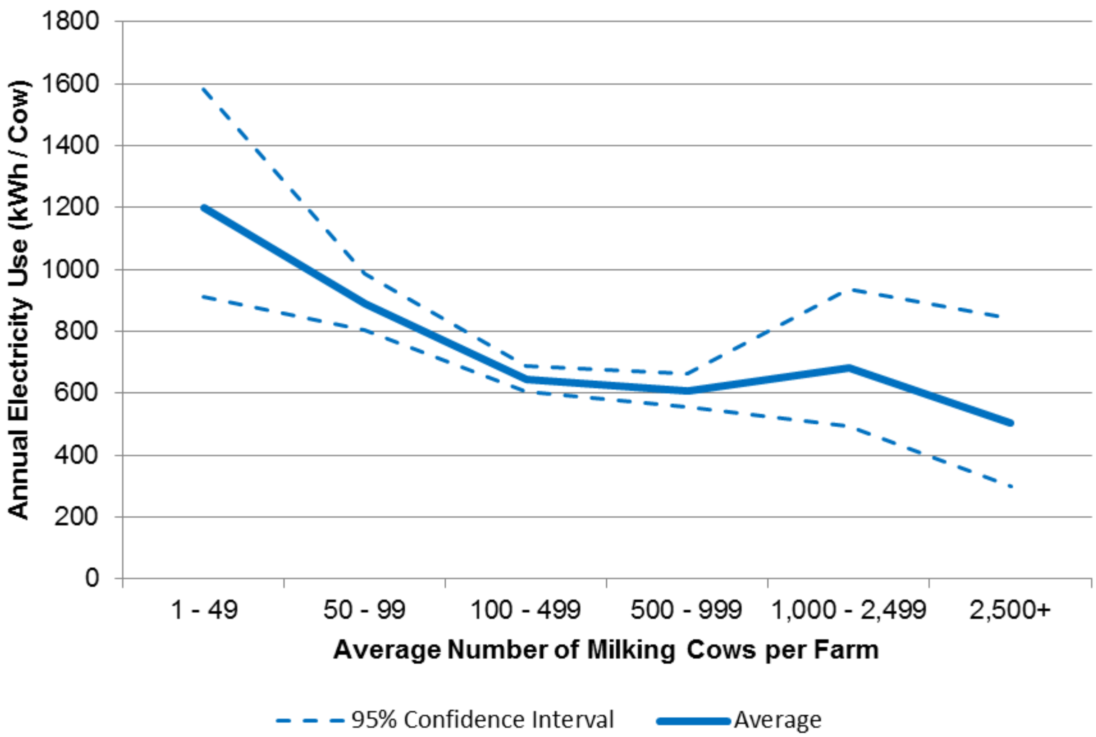
The above model results provide a clearer picture of the factors contributing to seasonal electric usage peaks. The majority of the summer peak is attributable to ventilation and cow cooling. The source of increased electricity use in winter months is less certain but is likely due to a combination of factors including increased lighting demand, increased use of engine block heater timers, and increased shop usage.

1.2.2 Average Baseline Energy Use per Farm

In general, there is a positive correlation between farm energy efficiency and farm size. The average dairy farm in NYS consumes between 174,537 and 212,281 kWh annually or approximately 729 and 794 kWh per cow milked (Figure 8). For comparison, NYSERDA reports the average residence in NYS consumes approximately 6,600 kWh annually.

Figure 8. Estimated Annual Electricity Use per Cow, All NYS Dairy Farms (n=5,427)

Source: EnSave, Inc.



Variability in electricity use between dairy operations is high; it is common for an individual dairy operation in NYS to consume electricity at a rate different than the average. Within the data sets used to develop this report, natural gas usage data was only available for 14 farms; given this minimal sample size, the average consumption of natural gas per dairy farm is estimated.

1.2.3 Summary of Findings

Fluid milk production for NYS dairies is responsible for the majority of energy consumption, primarily as electricity. In total, these farms consume between an estimated 379 and 542 gigawatt hours (GWh) annually. The electricity is not consumed at a regular rate throughout the year. During the major summer peak in electricity use, dairy farms in NYS consume between 36 and 52 GWh. At the individual farm level, the average dairy farm in NYS is expected to consume between 174,537 and 212,281 kWh annually and between 16,808 and 20,443 kWh during the summertime peak.

So far, AEEP has approved measures for energy efficiency on NYS dairy farms that are estimated to save 15,396,452 kWh; 86 MMBtu of natural gas; and 4,435 metric tons of carbon dioxide equivalent. Dairy farms account for approximately 71% of applicants to the AEEP program and the approximately 75 to 85% of energy efficiency measures installed.

Participation in the AEEP program is dominated by dairies with 500 cows or more; significant opportunity remains to target smaller dairies (50 to 499 cows). Approximately 94 to 151 GWh of energy savings potential remains for NYS's dairy farms of all sizes, based on average savings identified in energy audits conducted through the AEEP and the current estimated application and approval rates. Expressed in terms of GHG emissions those additional savings represent between 27,000 and 43,000 metric tons of carbon dioxide equivalent.[12]

Additionally, based on seasonal energy usage patterns (Figure 5), significant opportunities remain for demand reduction in summer and winter months beyond the estimated 94 to 151 GWh previously outlined. Opportunities also exist to utilize new and emerging technologies such as ozone laundry, conductive cow cooling, and electronic expansion valves may provide opportunities to achieve greater savings, though more research is needed to validate these technologies (see Section 3).

1.3 Vegetables

Vegetable production is the fifth largest agricultural subsector in NYS by market value, and was responsible for generating over $364 million in revenue in 2012. Approximately 136,000 acres of vegetables are harvested for sale annually, almost 54% of which is concentrated in the Finger Lakes region (Figure 9).

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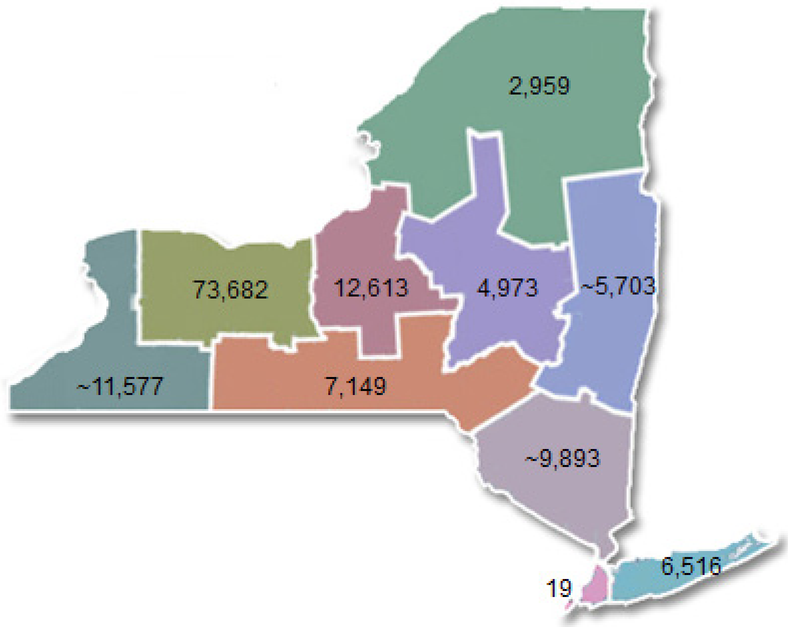
12 For more information on how greenhouse gas emissions savings are calculated, see Appendix D.

Figure 9. Acres of Vegetables Harvested for Sale by REDC Region

Source: USDA-NASS Census of Agriculture 2012. Background map source: http://regionalcouncils.ny.gov



At present, there are 67 AEEP applicants who reported growing vegetables as part of their operation. Of these applicants, 19 (30%) operations were devoted solely to vegetable production. These applicants were primarily concentrated into the Finger Lakes/Central NYS and Mid-Hudson/Capital regions. A total of 7,306 acres of vegetable production have been reported by AEEP applicants, representing approximately 5% of the total acreage devoted to vegetable production in the State. The size of vegetable operations varies widely in NYS, ranging from less than an acre to several thousand acres. Table 5 reports the total acreage associated with the top 10 vegetable crops produced in NYS in 2012 and the total acreage of all other vegetable crops.

Table 5. Acres of Vegetables Harvested for Sale in NYS, 2012

Source: USDA-NASS Census of Agriculture 2012

Crop Type	Acres Harvested
Sweet Corn	28,586
Snap Beans (Bush and Pole)	27,927
Potatoes	21,865
Cabbages (Head)	11,320
Onions (Dry)	7,958
Green Peas	7,691
Pumpkins	6,273
Winter Squash	4,120
Beets	3,372
Tomatoes	3,005
All Other Vegetable Crops	13,880
Totals	135,997

Total estimated electricity, natural gas, and GHG savings for NYS vegetable farms that participated in AEEP indicate significant savings from technologies within 13 categories (Table 6). Improvements in building temperature controls, lighting, refrigeration or cold storage, and ventilation achieved the highest energy and GHG savings. Note that 28 of the 67 vegetable applicants also operated greenhouses, and savings from these applicants is counted toward both subsectors.

Table 6. Summary of Energy and Greenhouse Gas Savings, NYSERDA AEEP – Vegetable Applicants (n=67)

Source: NYSERDA AEEP; Compiled by EnSave, Inc.

Recommended Measure Category[13]	Percentage of Applicants Approved[14]	Electricity Savings (kWh)	Natural Gas Savings (MMBtu)	Greenhouse Gas Savings ($mtCO_2e$)
Lighting: Excluding LED Projects	25.4%	326,600	0	94
Ventilation of Air (Circulation, Exhaust, and Tunnel)	14.9%	64,911	0	19
Air Heating, Air Cooling, and Building Environment	11.9%	635,690	462	207
Refrigeration or Cold Storage	11.9%	129,750	0	37
Lighting: LEDs (Full and Partial Projects)	4.5%	97,266	0	28
Water Heating: Replacement Heaters and Pipe Insulation	3.0%	2,090	7	1
Vacuum Pump VFDs and Motor Replacements	3.0%	11,880	0	3
Pre-coolers and Milk Transfer Pump VFDs	3.0%	3,590	0	1
Dishwashers, Clothes Washers, Dryers	1.5%	3,120	0	1
Stock Watering	1.5%	2,700	0	1
Water Heating: Compressor Heat Recovery	1.5%	9,080	0	3
Electric Motors and Pumps Not Used in Milk Production	1.5%	50,880	0	15
All Other Measures[15]	3.0%	15,860	0	5
Total		**1,353,417**	**469**	**414**

1.3.1 Baseline Energy Use

Energy use associated with vegetable production is primarily from field activities, cold storage, packing, and warehouse operations. It is difficult to make generalizations regarding baseline energy use due to the variability of growing, storage, and packing requirements for different vegetable crops. Even among farms growing the same crop type, there are substantial differences in energy utilization depending upon

13 Several categories involve technologies used for a dairy rather than a vegetable operation; these applicants were running both a vegetable operation and a dairy and are represented in both tables.

14 This column represents the percentage of applicants for which at least one measure in the category was approved for installation by AEEP program representatives. It does not reflect whether or not the applicant has since installed that measure.

15 This row represents more site-specific and unique measures not limited to but including HVAC changes, suction line insulation, vending machine controls, timers not used for engine block heaters, and grain dryers. Most items in this row were recommended only once.

the level of crop processing requirements, process automation, and commodity end-use. As an illustration, Table 7 provides an electricity usage and management comparison of four AEEP applicants located in the same REDC region producing onions.

Table 7. Comparison of Four AEEP Applicants Producing Onions in the Same Region

Source: NYSERDA AEEP Data, Compiled by EnSave Inc.

Farm Number	kWh / Acre Harvested	Dehumidifiers for Crop Storage	Conveyor Belt Motors	Ventilation Fans	Efficient Lighting
1	930	Yes	25-50	Yes	No
2	1,087	No	50-75	Yes	No
3	141	No	1-25	No	No
4	144	No	1-25	Yes	Yes

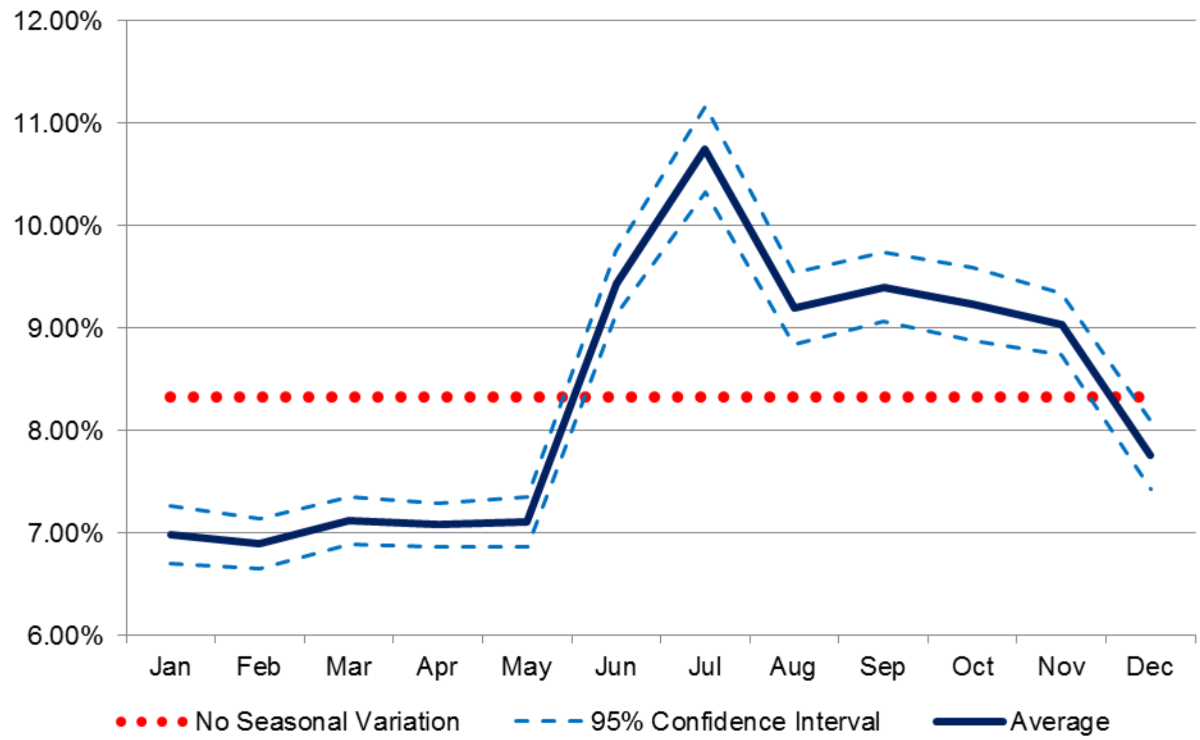
The wide range of energy usage and post-harvest processing methods used as an example in Table 7 illustrates the difficulty in benchmarking the baseline energy use of vegetable operations compared with other farm types (such as dairy) which have more consistent production requirements. Within the AEEP applicants themselves reporting vegetable production, the range of average kWh use is between 84,890 and 107,203 kWh, but the small population of audits (54 producers versus the 3,467 identified in the Census of Agriculture) combined with the observed variability inhibits application of these numbers to the general population of vegetable operations in NYS.

Despite the variability associated with vegetable farms, there are discernible patterns that emerge when analyzing energy usage data. Figure 10 illustrates annual electricity consumed on a monthly basis by vegetable farms in NYS. This analysis is based on 54 vegetable audits that contained utility information from August 2007 through April 2013. The dashed blue lines represent upper and lower bounds of a 95% confidence interval[16] associated with the average, and the red dotted line represents a hypothetical scenario in which energy usage remains constant through the year.

[16] Electricity consumption values for New York's agricultural operations are assumed to be log-normal. See Appendix C for more information on log-normal distributions.

Figure 10. Percentage of Annual Electricity Consumed Monthly by Audit: NYS Vegetable Audits (n=54)

Source: NYSERDA audit data, compiled by EnSave, Inc.



In general, electricity use peaks in summer from June through July and begins to decline gradually in September before dropping more substantially in the winter months. This usage pattern corresponds with the commencement of field operations with the long decline in use due to cold storage and packaging operations following vegetable harvest. Note that the confidence interval widens considerably in the fall months, which is likely attributable to the diversity in processing and management requirements associated with different vegetable crops. The role of irrigation in electricity consumption is unclear; while it is reasonable to assume that increased water pumping is a factor during the growing season, the audits generally did not provide direct evidence that irrigation was a major factor in the electricity peak. Natural gas usage is typically minimal on vegetable farms and primarily used for heating warehouses.

1.3.2 Summary of Findings

Vegetable production is among the most diverse agricultural subsectors in NYS, and as such presents a challenge in terms of benchmarking baseline energy usage. If the 54 audits conducted on vegetable operations in AEEP could be considered representative of the whole industry in NYS, then the average operation consumes between 84,890 and 107,203 kWh annually. However, there are sampling and variance concerns that prevent applying those averages to the subsector in NYS as a whole.

Despite this diversity, several energy usage patterns emerged in the analysis of audit data. Energy use peaks in summer during the growing season, and tail off slowly into the fall months. The peak corresponds with field operations while the slow drop is attributed to processing and cold storage. Section 3 provides an overview of several technologies that may present opportunities for reducing energy associated with vegetable cold storage in NYS, including electronic expansion valves and outside air economizers.

So far, AEEP has approved measures for energy efficiency for vegetable operations that are estimated to save 1,353,417 kWh, 469 MMBtu of natural gas, and 414 metric tons of carbon dioxide equivalent. Based on the limited number of vegetable operation energy audits analyzed as part of this report, substantial energy savings opportunities within the vegetable production sector exist. If similar savings opportunities seen by AEEP applicants exist for vegetable operations that have not applied to AEEP then there is 85 GWh and 26,000 MMBtu of savings potential available with currently recommended measures. These savings numbers are preliminary; further research is necessary to provide more accurate estimates of potential energy savings.

1.4 Greenhouses

NYS has approximately 2,322 greenhouse, nursery, and floriculture farms that produced approximately $401 million in annual revenue (Table 8).

Table 8. Revenue from Crops Grown or Started in Greenhouses in NYS

Source: USDA-NASS Census of Agriculture 2012

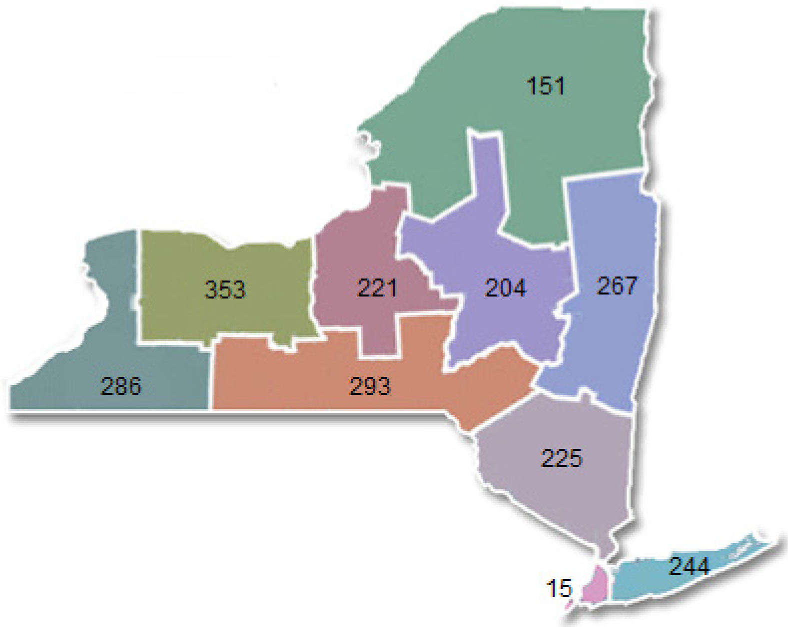
Crop Type	Revenue
Floriculture Crops[17]	$211,375,256
Nursery Stock Crops	$138,727,418
Greenhouse Vegetables and Fresh Cut Herbs	$27,421,938
Cuttings, Seedlings, Liners, and Plugs	$19,102,883
Mushrooms	$1,628,080
Vegetable Transplants	$1,474,942
Vegetable Seeds	$856,848
Aquatic Plants	$614,143
Greenhouse Fruits and Berries	$446,390
Bulbs, Corms, Rhizomes, and Dry Tubers	$193,510
Flower Seeds	$41,248

Greenhouse and nursery operations are distributed throughout NYS and collectively account for over 39 million square feet of agricultural space under glass or other protection (Figure 11).

[17] Floriculture crops include bedding/garden plants, cut flowers and cut florist greens, foliage plants, and potted flowering plants.

Figure 11. Greenhouse, Nursery, Floriculture Operations REDC Region

Source: USDA-NASS Census of Agriculture 2012. Background map source: http://regionalcouncils.ny.gov



Participation by greenhouse operators in AEEP has been fairly limited. Among all AEEP applicants, 51 (6.5%) are listed as having at least one greenhouse. Table 9 provides a summary of greenhouse size metrics based on data reported from 30 applicants to the AEEP.

Table 9. Statistics on Greenhouse Area as Reported by AEEP Applicants

Source: NYSERDA AEEP data, compiled by EnSave Inc.

Applicants that reported area of greenhouses	30
Total area of greenhouses reported by all applicants	1,020,985 ft^2
Greatest area of greenhouses reported by a single applicant	130,680 ft^2
Lowest area of greenhouses reported by a single applicant	2,000 ft^2
Number of greenhouse operations with area less than 2,500 square feet	1
Number of greenhouse operations with area between 2,500 and 8,000 square feet	4
Number of greenhouses operations with area between 8,000 and 22,000 square feet	10
Number of greenhouses operations with area between 22,000 and 62,000 square feet	12
Number of greenhouse operations with area greater than 62,000 square feet	3

Total estimated electricity, natural gas and GHG savings for NYS greenhouses that participated in AEEP indicate significant savings from technologies within nine categories (Table 10). Improvements in building temperature controls, lighting, ventilation, and refrigeration or cold storage achieved the highest energy and GHG savings. Note that 28 of the 52 greenhouse applicants also listed vegetables as a subsector, and savings from these applicants is counted toward both subsectors.

Table 10. Summary of Energy and Greenhouse Gas Savings, NYSERDA AEEP for Greenhouse Applicants (n=52)

Source: NYSERDA AEEP; Compiled by EnSave, Inc.

Recommended Measure Category[18]	Percentage of Applicants Approved[19]	Electricity Savings (kWh)	Natural Gas Savings (MMBtu)	Greenhouse Gas Savings ($mtCO_2e$)
Lighting: Excluding LED Projects	25.0%	375,850	0	108
Air Heating, Air Cooling, and Building Environment	17.3%	623,460	794	221
Ventilation of Air (Circulation, Exhaust, and Tunnel)	11.5%	41,761	0	12
Refrigeration or Cold Storage	9.6%	20,330	0	6
Water Heating: Replacement Heaters and Pipe Insulation	3.8%	2,090	7	1
Vacuum Pump VFDs and Motor Replacements	1.9%	5,700	0	2
Dishwashers, Clothes Washers, Dryers	1.9%	3,120	0	1
Stock Watering	1.9%	2,700	0	1
All Other Measures[20]	5.8%	25,960	0	7
Total		**1,100,971**	**801**	**359**

18 Several categories involve technologies used for a dairy rather than a greenhouse; these applicants were running both a greenhouse and a dairy and are represented in both tables.

19 This column represents the percentage of applicants for which at least one measure in the category was approved for installation by AEEP program representatives. It does not reflect whether or not the applicant has since installed that measure.

20 This row represents more site-specific and unique measures not limited to but including HVAC changes, suction line insulation, vending machine controls, timers not used for engine block heaters, and grain dryers. Most items in this row were recommended only once.

1.4.1 Baseline Energy Use

Similar to vegetable operations, greenhouses are variable in the types of crops they produce and their production requirements. Greenhouse crop selection dictates important management and growth parameters that impact baseline energy use, including optimal greenhouse temperature, irrigation, harvest cycles, and cold storage requirements. In general, energy use in greenhouses is devoted to a combination of space heating, lighting, ventilation, cold storage, and irrigation. An analysis of 29 Northeastern greenhouse operations in EnSave's database[21] revealed that each operation included at least one heated greenhouse, 26 (89%) used ventilation, 10 (34%) had some form of cold storage, and none used supplemental lighting for plant growth (although 3 of the 51 greenhouse AEEP applicants reported using supplemental lighting). Additional energy is sometimes consumed in the operation of on-site retail outlets associated with greenhouse operations.

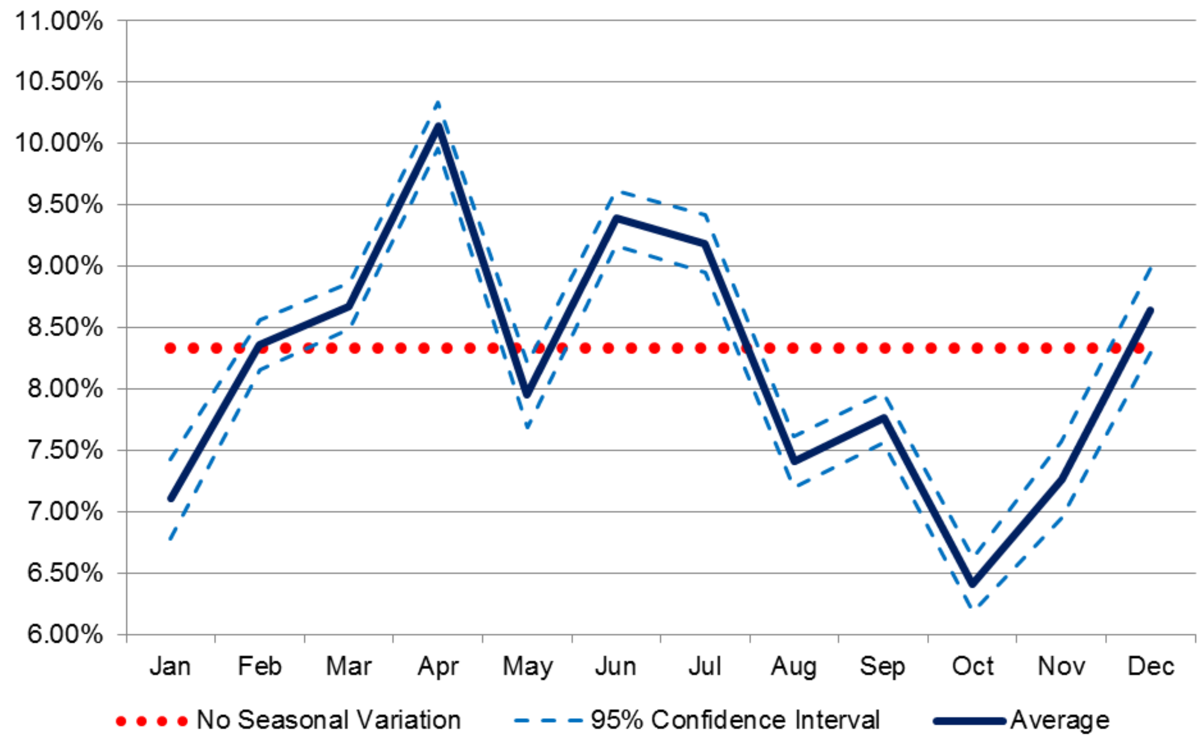
Figure 12 shows seasonal analysis of electricity use for greenhouse operations from NYSERDA's collection of audit reports. This analysis is based on 40 audits that contained fuel usage history from August 2007 through January 2013. The dashed blue lines in Figure 12 represent upper and lower bounds of a 95% confidence interval[22] for the average, and the red dotted line represents a hypothetical scenario in which energy usage remains constant through the year.

21 This FEAT dataset contains greenhouse operations from New York, Vermont, Connecticut, Massachusetts, and New Hampshire with audit reports completed between December 2009 and August 2013.

22 Electricity consumption values for New York's agricultural operations are assumed to be log-normal. See Appendix B: Methodology for more information on log-normal distributions.

Figure 12. Percentage of Annual Total Electricity Consumed Monthly by Audit: Greenhouse Audits (n=40)

Source: NYSERDA audits data, compiled by EnSave, Inc.



No seasonal peak in electricity use is identified based on the limited greenhouse energy usage data used available for NYS. The minimum sample size needed to estimate average energy use is approximately 296. However, even with a sufficient dataset, greenhouse energy analyses must account for crop varieties grown, since this is a major factor in energy usage patterns. Further research is needed to quantify the baseline energy use and potential savings associated with greenhouses.

1.4.2 Summary of Findings

So far, AEEP has approved measures for energy efficiency for greenhouse operations that are estimated to save 1,100,971 kWh, 801 MMBtu of natural gas, and 359 metric tons of carbon dioxide equivalent. Determining baseline energy use, seasonal patterns, and savings potential for greenhouses is particularly challenging given the diversity of greenhouse operations and the paucity of data. Although the participation rate of greenhouses in AEEP has been low, significant opportunities for energy reduction likely exist, as the population of likely candidate sites in NYS that have greenhouses but have not applied to AEEP is over 2,000 operations.

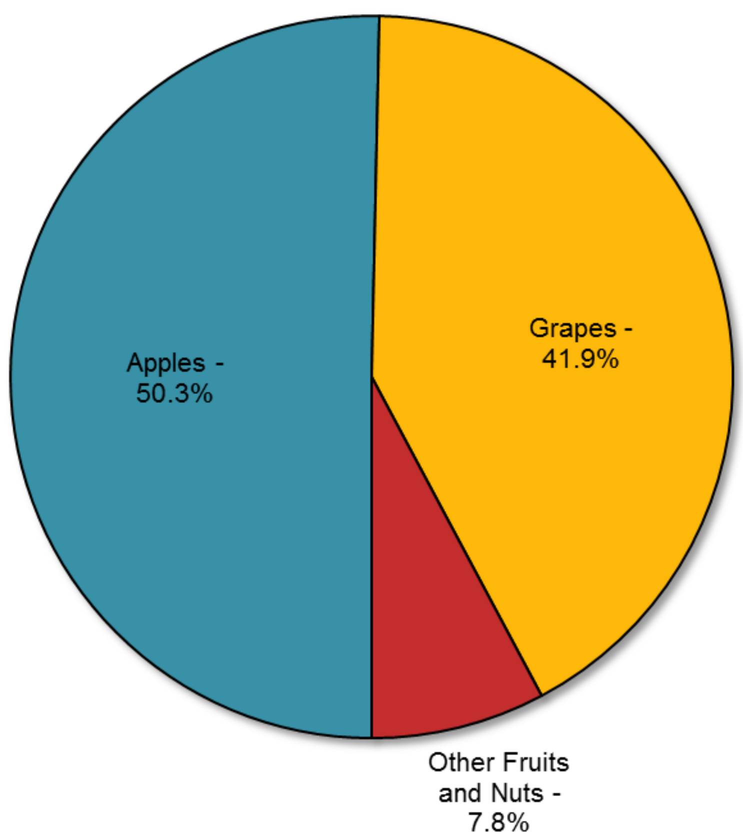
Section 3 explores several technologies that may hold promise for enhancing greenhouse energy efficiency, including LED lighting, geothermal heat pumps, and dynamic temperature control.

1.5 Orchards and Vineyards

According to the Census of Agriculture, NYS ranks third in grape production and ninth in orchard production nationwide. NYS has approximately 2,598 fruit and nut orchards, of which 1,392 (53%) grow apples and 1,365 (52%) grow grapes.[23] From the perspective of acreage, over 91% of the land devoted to fruit and nut production in NYS is currently devoted to apples and grapes (Figure 13). Collectively, orchards and vineyards contribute over $307 million to the State's economy annually.

Figure 13. NYS's Orchard and Vineyard Crops by Acreage

Source: USDA-NASS Census of Agriculture 2012

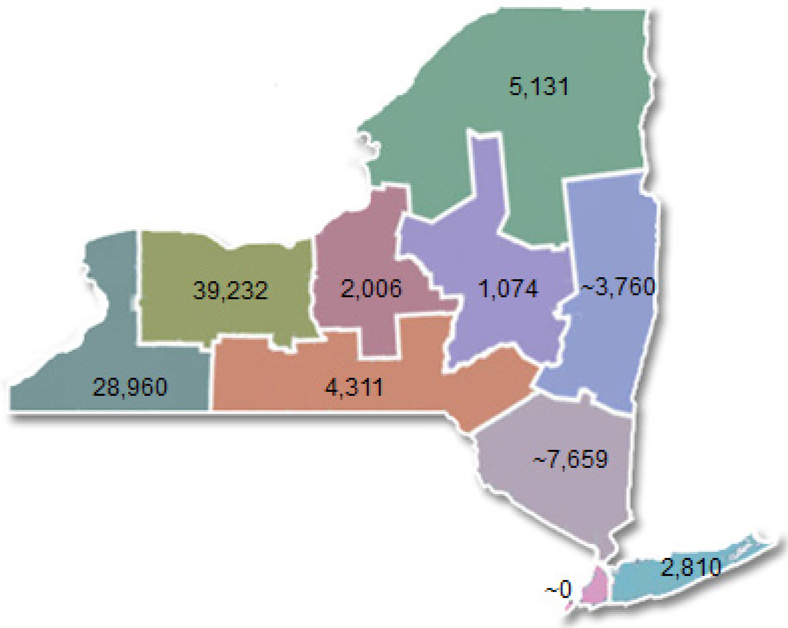


[23] A small number of operations grow both apples and grapes; The Census of Agriculture does not present its data in a manner where the overlap can be identified.

Orchards and vineyards are concentrated in the Western NYS and Finger Lakes regions, where twice as many acres devoted to orchards and vineyards than all other regions combined (Figure 14).

Figure 14. Acres of Orchards and Vineyards by REDC Region, 2012

Source: USDA-NASS Census of Agriculture 2012. Background map source: http://regionalcouncils.ny.gov



Relatively few orchard and vineyards are represented in AEEP. Of the 780 total applicants, 54 (7%) reported acreage devoted to either orchard or vineyard production. Of these applicants, 17 (31%) exclusively operated orchards, and 19 (35%) exclusively operated vineyards; the remaining 66% were diversified farms.

Total estimated electricity, natural gas, and GHG savings for NYS orchards and vineyards that participated in AEEP indicate significant savings from technologies within 11 categories (Table 11). Improvements in refrigeration or cold storage, lighting, building temperature controls, and ventilation achieved the highest energy and GHG savings.

Table 11. Summary of Energy and Greenhouse Gas Savings, NYSERDA AEEP – Orchard and Vineyard Applicants (n=55)

Source: NYSERDA AEEP, Compiled by EnSave, Inc.

Recommended Measure Category[24]	Percentage of Applicants Approved[25]	Electricity Savings (kWh)	Natural Gas Savings (MMBtu)	Greenhouse Gas Savings ($mtCO_2e$)
Refrigeration or Cold Storage	18.2%	260,110	0	75
Lighting: Excluding LED Projects	16.4%	107,850	0	31
Air Heating, Air Cooling, and Building Environment	7.3%	21,580	85	11
Ventilation of Air (Circulation, Exhaust, and Tunnel)	3.6%	20,931	0	6
Vacuum Pump VFDs and Motor Replacements	3.6%	11,880	0	3
Pre-coolers and Milk Transfer Pump VFDs	3.6%	3,590	0	1
Lighting: LEDs (Full and Partial Projects)	1.8%	2,066	0	1
Dishwashers, Clothes Washers, Dryers	1.8%	270	0	0
Water Heating: Compressor Heat Recovery	1.8%	9,080	0	3
Electric Motors and Pumps Not Used in Milk Production	1.8%	54,000	0	16
All Other Measures[26]	3.6%	4,050	0	1
Total		**495,407**	**85**	**147**

1.5.1 Baseline Energy Use

Orchards and vineyards demonstrate several significant areas of energy use including refrigeration, controlled-atmosphere storage, lighting, ventilation, processing, and heating. Among these areas, refrigeration and controlled- atmosphere storage are the most energy intensive. Orchards often use cold storage to preserve crops after harvest as well as controlled-atmosphere storage, which maximizes shelf life by controlling temperature; humidity; and levels of oxygen, nitrogen, and carbon dioxide. Other

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24 Several categories involve technologies used for a dairy rather than a orchard; These applicants were running both a orchard and a dairy and are represented in both tables.

25 This column represents the percentage of applicants for which at least one measure in the category was approved for installation by AEEP program representatives. It does not reflect whether or not the applicant has since installed that measure.

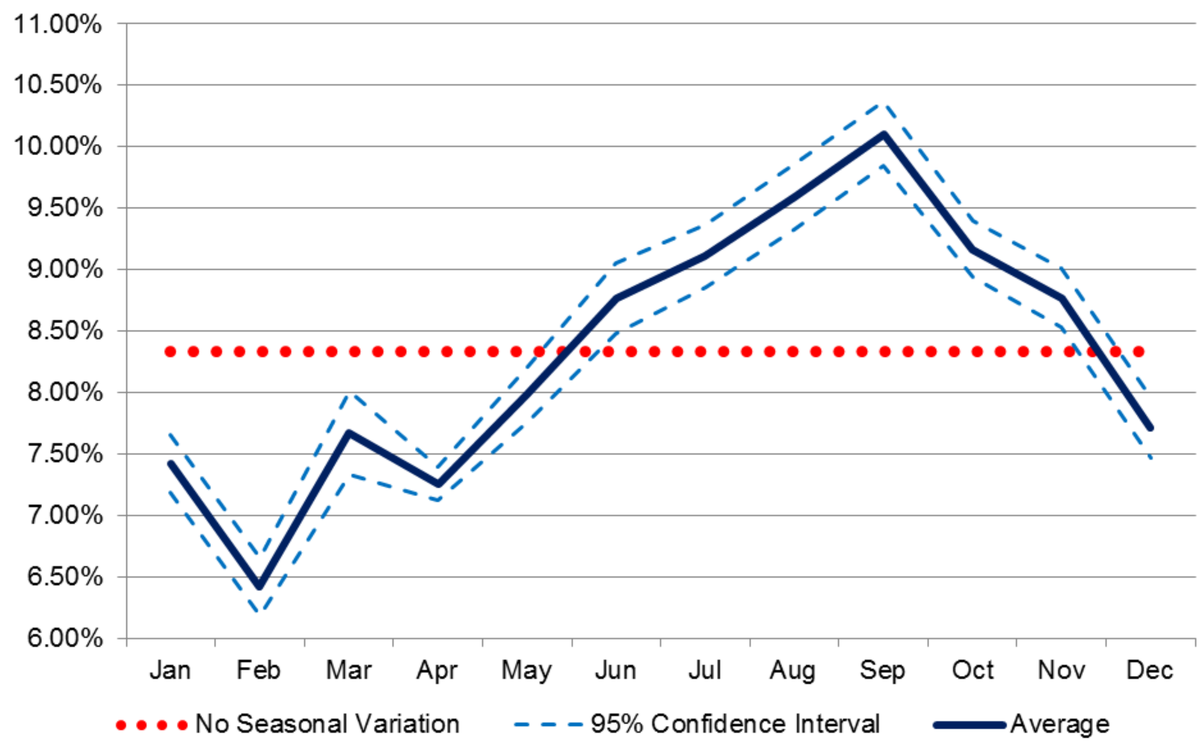
26 This row represents more site-specific and unique measures not limited to but including HVAC changes, suction line insulation, vending machine controls, timers not used for engine block heaters, and grain dryers. Most items in this row were recommended only once.

electricity usage is typically associated with warehouse operations including processing and packaging as well as operating retail spaces and tasting rooms. Heating fuel is commonly used for space heating in warehouses and retail spaces, and occasionally for dehydrating fruits or nuts. Additionally, fuel is consumed during the growing season for field operations and irrigation.

Among NYSERDA audits, 32 have been conducted for orchards and 14 for vineyards. Figure 15 shows an analysis of monthly electricity use for orchard and vineyard operations from this set of 46 audit reports. Audits contain fuel usage history from August 2007 through January 2013. The dashed blue lines in Figure 15 represent upper and lower bounds of a 95% confidence interval[27] for the average and the red dotted line represents a hypothetical scenario in which energy usage remains constant through the year.

Figure 15. Percentage of Annual Electricity Consumed Monthly by Orchards and Vineyards

Source: NYSERDA audits data, compiled by EnSave, Inc.



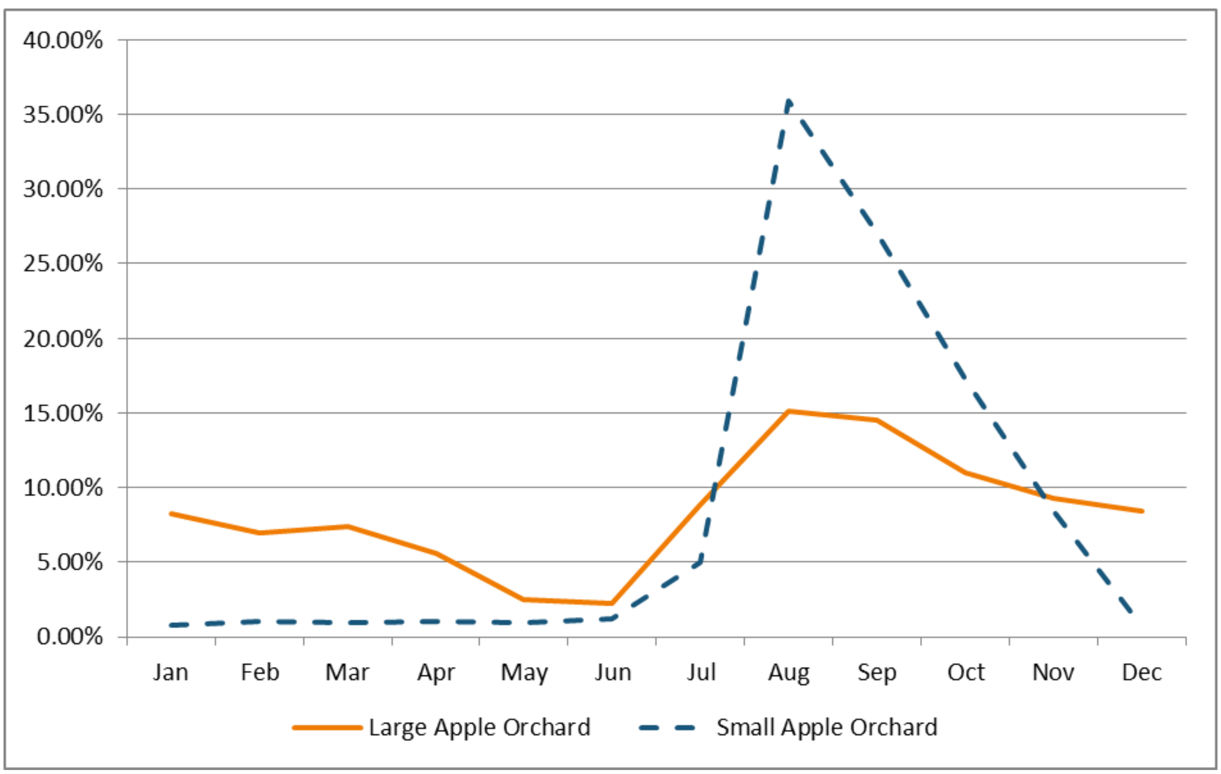
27 Electricity consumption values for New York's agricultural operations are assumed to be log-normal. See Appendix C for more information on log-normal distributions.

Based on the sample of 46 audits analyzed, electricity usage for orchards and vineyards typically peaks in September and October following harvest, declines steadily through the winter and spring, and begins rising again in early spring. This pattern of energy usage is more constant for orchards, and more variable with vineyards. Additionally, the electricity usage increases in March, where a small spike can be seen in Figure 15. However, this spike is partly attributable to three orchards that also produce maple syrup and consumed additional electricity for sugaring operations and does not appear to be directly attributable to orchard and vineyard operations.

Figure 16 highlights the monthly electricity use for two Northeast orchards audited by EnSave. One orchard covers approximately 500 acres and has extensive cold storage facilities and atmospheric control, and the other covers approximately 40 acres and has a small cold storage facility.

Figure 16. Percent Annual Total Electricity Consumed Monthly by Audit: FEAT Selected Audits

Source: EnSave, Inc.



Both orchards have peak electricity use in August and September corresponding to the apple harvest in the Northeast, similar to the pattern observed in the NYSERDA audit data set (Figure 17). After the harvest, the small orchard's electricity use drops sharply, but the larger orchard declines more gradually. The larger orchard has a bigger harvest and greater cold storage demand. Energy usage associated with cold storage declines as apples are sold and cold storage is decreased; the larger orchard's inventory is sold more gradually than the smaller orchard.

The larger orchard likely receives a higher demand charge in August, but it is smaller relative to its overall usage whereas the smaller orchard sustains a much larger demand charge in August relative its overall usage. Significant cost savings potential exists for these operations in technologies and practices that reduce peak demand.

1.5.2 Average Baseline Energy Use per Farm

Based on the number of orchards and vineyards currently registered in NYS, energy usage data from approximately 252 orchards and 254 vineyards would be necessary to accurately calculate baseline energy usage. With data available from only 46 combined orchard and vineyard audits, it is difficult to accurately quantify baseline energy usage of these operations. However, based on audits conducted on AEEP applicants, the average annual electricity use is between 167,529 and 219,843 kWh per farm. Whether or not these averages are applicable to the whole subsector in NYS cannot be determined without conducting more audits. It is likely these audits represent larger operations and the true average is much lower. From the Census of Agriculture the average acreage of apple orchards per operation is approximately 34 acres and the average vineyard has approximately 28 acres of grapes. Most AEEP applicants reporting orchards or vineyards report over 50 acres in cultivation.

1.5.3 Summary of Findings

In contrast to vegetable and greenhouse operations, orchards and vineyards have more constant and predictable energy usage patterns. In general, electricity use is primarily devoted to cold storage and climate control, peaking between August and October following fruit harvest and steadily declining through winter as the volume of produce under cold storage decreases. Additional energy is used for the operation of retail outlets, processing fruits (e.g., washing, packing, drying, fermenting, etc.), field operations, and general warehouse operations. Based on their relative uniformity, orchards and vineyards represent an opportunity for baseline energy usage benchmarking and development of energy best management practices. Section 3 provides an overview of several technologies that may present opportunities for reducing energy associated with cold storage in NYS, including electronic expansion valves and outside air economizers.

If the 46 audits conducted on orchard and vineyard operations in AEEP could be considered representative of the whole industry in NYS, then the average operation consumes between 167,529 and 219,843 kWh annually. It is likely, however that the true average is lower because larger farms are overrepresented in AEEP audits.

In AEEP, approved measures for energy efficiency for orchards and vineyards are estimated to save 495,407 kWh, 85 MMBtu of natural gas, and 147 metric tons of carbon dioxide equivalent. Based on the limited number of energy audits analyzed as part of this report, energy savings opportunities are likely at orchards and vineyards that have not applied to AEEP. The amount of potential savings cannot be accurately quantified, but is expected to be significant given the size of the sector and the type of equipment and processes required.

2 Underutilized Energy Efficiency Technologies

NYS' agricultural sector is among the most advanced in the nation in terms of energy efficiency and implementation of innovative technologies. Despite this, there is always room for improvement through early adoption of emerging technologies, as well as identifying areas where measures are underutilized based on information gathered from agricultural communities in other parts of the country and world. This section provides a summary of potentially underutilized energy efficiency measures for NYS farms. Section 3 complements this analysis and provides a more thorough overview of technologies meriting further research.

In attempting to identify underutilized energy efficiency technologies within NYS' agricultural sector, it is important to consider the engagement of each agricultural subsector in pursuing and implementing energy efficiency measures. Dairy farms represent the vast majority of both applicants and implementers in AEEP, accounting for approximately 75-85% of the 1,094 measures installed. Due to the disproportionately high participation rate of dairies, any strategy to address underutilized energy efficient measures within NYS should also take into account less-represented agricultural subsectors.

The technologies in Table 12 were identified through an analysis of energy efficiency measures installed through the AEEP program. A list of all measures approved over the course of the AEEP was compiled, and the frequency of each measure was determined. The most commonly installed measures were lighting and ventilation, followed by vacuum pump VSDs, scroll compressors, transfer pump VSDs, compressor heat recovery, and milk pre-coolers. Of the remaining measures, approximately 30 technologies were identified, and each was evaluated to determine the degree to which they are underutilized based on frequency of installs from farm energy audits. Due to the lack of case studies for these technologies, as well as the variability inherent in agricultural operations, it is difficult to provide accurate estimates of potential energy savings on a per-farm or per technology basis. However, based on analysis of farm energy audits conducted through AEEP, it appears that the technologies listed in Table 12 are viable and underutilized within New York's agricultural sector. They were not frequently approved by the program, but they were also not seen to be already present on the farm or recommend as part of the audit report.

Table 12. Underutilized Energy Efficiency Technologies in NYS Agriculture

Source: NYSERDA AEEP; Compiled by EnSave Inc.

Energy Efficiency Measure	Applicable Agriculture Types	Percentage of AEEP Applicants Approved
Engine block heater timers	Any operation with mobile diesel equipment	0.4%
Occupancy sensors	Dairy, cold storage	< 0.1%
Thermostatic controls	Greenhouses	< 0.1%
Thermostatically controlled outlet	Dairy, greenhouse	< 0.1 %
Compressed air leak detection	Dairy	0%
Radiant tube heaters	Dairy, poultry	0%
Shade curtains	Greenhouse	< 0.1%
Bench heating systems	Greenhouse	< 0.1%
Well pump variable speed drives	Vegetable production, orchard and vineyard	0%
Evaporator fan controls	Dairy, cold storage	< 0.1%

Based on analysis of audit data and market knowledge, it appears that there is significant energy efficiency and GHG savings potential associated with greenhouses, nurseries, smaller dairies, and farms with cold storage, and that these populations have not applied to the AEEP at a level reflective of their presence in NYS. A targeted marketing approach that actively encourages these sectors of agriculture to apply for funding would generate additional energy savings from the AEEP and ensure a more equitable distribution of program funds to high-energy-use agricultural operations.

In addition to the measures in Table 12, there are a number of emerging technologies within the agricultural sector that merit further research and may prove to be underutilized. These technologies are covered in Section 3.

3 Technologies Meriting Additional Research

This section provides a basic overview of energy efficiency technologies meriting further research to determine their applicability, feasibility, and potential energy and GHG savings within NYS's agricultural sector. A review of the level of commercialization, prior research, barriers to adoption, and implementation cost is provided for each of the technologies selected. Although most technologies are applicable to more than one agricultural subsector, the most promising emerging technologies are relevant to dairy farms, greenhouse, and cold storage facilities. Most of these technologies are firmly established in other industries but are relatively new to agriculture, thus necessitating the need for further research (Table 13).

Table 13. Energy Efficiency Technologies Meriting Additional Research by Agriculture Type

Energy Efficiency Measure	Applicable Agriculture Types
Ozone laundry	Dairy, vineyard
LED lighting for plant production	Greenhouse
VFDs for ventilation fans	Dairy, swine, poultry, greenhouse
Conductive cow cooling	Dairy
Evaporative cooling	Dairy, swine, poultry, greenhouse
Electronic expansion valves	Dairy, vegetable, orchard, vineyard
Geothermal heat pumps	Dairy, greenhouse
Outside air economizers	Vegetable, orchard, vineyard
Dynamic temperature control	Greenhouse

3.1 Ozone Laundry

Ozone laundry has been widely used in the commercial laundry sector since the 1980s but is relatively new in the agricultural sector. Ozone washers work by cleaning and disinfecting laundry using ozone rather than heat and detergents. Research has demonstrated that ozone laundry can be more effective than traditional laundering methods in eliminating bacteria and viruses (Cardis et al. 2007, Rice et al. 2013), as well as significantly reducing energy and water inputs (Rice et al. 2007, Rice et al. 2010, Riesenberger 2001). Energy and GHG savings are primarily achieved by avoiding the need for hot water for sanitizing, and instead infusing water with ozone which acts as a potent oxidative agent (Rice et al. 2010). Existing washers can be retrofitted with ozone laundry systems, which typically consist of an ozone generator, oxygen concentrator, and ambient ozone monitoring device.

Ozone laundry is primarily applicable to dairy farms where it has multiple potential applications. For sanitation purposes, it is necessary to wash each cow's udders by hand with a wash cloth prior to milking (up three times per day). This procedure can produce considerable quantities of laundry needing to be sanitized on a daily basis. Ozone laundry systems can greatly reduce chemical detergents and hot water used during the washing process, while simultaneously improving sanitation. Additionally, ozone sanitation technology has potential applications as a clean-in-place method for sterilizing milking lines and equipment rather than using hot water. This technique is gaining popularity in beverage and food industries and also has potential to significantly reduce energy usage, water usage, and chemical inputs (Aline et al. 2010). Estimated energy and associated GHG emission reductions derived from reduced hot water demand ranges from approximately 50% to 90%. Water usage reduction estimates range from 30% to 45%, with up to 75% with a closed-loop ozone laundry system (Cadis et al. 2006).

While significant opportunities exist for implementing ozone laundry technology in NYS' agricultural sector, further research is needed to quantify potential energy savings, understand potential implementation challenges, and determine the potential viability of ozone technology for CIP applications on farms. Presently, the level of commercialization of ozone technology within the State's agricultural sector is minimal. The primary barrier to adoption is a lack of awareness; there are few companies actively advertising this technology to farmers, and few case studies have been conducted. The cost of ozone laundry systems varies with the size of the farm, and typically ranges from $4,500 to $9,000.

3.2 Light Emitting Diode Lighting for Greenhouses

Although light emitting diode (LED) lighting has been commercially available for several decades, it is becoming more widely used in agricultural operations due to declining costs. LEDs have applications in all agricultural subsectors, both for interior and exterior lighting. The benefits of LED lighting over more conventional lighting technologies such as high intensity discharge, incandescent, and fluorescent include longer effective useful life (typically rated at 50,000 to 100,000 hours), greater control over spectral composition by mixing diode wavelengths and intensity, potentially higher luminous efficacy (typically measured in photopic lumens emitted per watt of input power), and improved safety due to lower operating temperatures and no mercury content.

The energy efficiency benefits and cost effectiveness of LEDs have been well researched within nonagricultural sectors; however, far less research has been conducted to evaluate the effects of LEDs on animal and plant production. Research pertaining to effects of LEDs on animal behavior and production has been primarily concentrated within the poultry industry, and results have been generally favorable, resulting in a rapidly rising adoption rate of LEDs among poultry farmers. An important outcome of this research was determining the optimal light wavelength to stimulate production and achieve desired animal behavior. However, little research has been conducted to determine the effects of LED lighting on dairy production, which represents the largest opportunity within NYS' agricultural sector. Despite the lack of research within the dairy industry, EnSave has worked with numerous dairy farmers throughout the country who have implemented LED lighting in their barns and/or milking parlors.

Aside from dairy farms and other smaller confined animal operations, the most notable opportunity for LEDs is in the greenhouse industry. Numerous studies have demonstrated the advantages of LED lighting over conventional lighting sources, and have concluded that the primary barrier to adoption is price (Morrow 2008, Tamulaitis et al. 2005). During each decade since their commercialization, LEDs prices have fallen by a factor of 10 while performance has increased by a factor of 20 (Steigerwald et al. 2002), indicating that the economics of LEDs will soon become competitive with conventional greenhouse lighting technologies in the high-intensity discharge family (e.g., high pressure sodium and metal halide). A significant body of research exists to validate the merits of LED lighting, but further research is needed to establish optimal wavelengths and light levels for different crops as well as clarify best management practices.

The primary barriers to implementing LEDs on farms include up-front cost, a lack of awareness of this technology, lack of access to LEDs suitable for agricultural operations, and a lack of research on the effects of this technology on animal production. Prices for LEDs designed for commercial and industrial applications currently range from approximately $2 to $4 per Watt, which is significantly higher than the cost of any other mainstream lighting technology. However, economic benefits derived from energy savings, labor reduction, and possibly productivity increases can help to offset high up-front costs. More research is needed to quantify these benefits and present them in a clear and concise manner to more effectively educate the agricultural community on LED lighting.

3.3 Variable Frequency Drives for Ventilation Fans

Variable frequency drives (VFDs for fans save electricity by automatically adjusting the operating speed of fans based on the difference between the current air temperature and the desired air temperature. If the ambient temperature is close to the set point temperature, VFDs will reduce the demand of electricity by the fan motor by lowering fan speed. Conversely, if the ambient temperature is greater than the desired temperature, VFDs will raise fan speed, and electrical consumption will vary based on affinity laws. VFDs can be installed on existing ventilation systems, or installed as an integrated component of individual fans, and they can be used to control individual fans or multiple fans. While VFDs for ventilation fans have been commercially available for some time, they have not been widely implemented in the agricultural sector. As of the time of writing this report, roughly 20 AEEP applicants had installed VFDs for ventilation fans on their operation compared to 111 who had approved ventilation projects that did not include VFDs.

The primary barrier to implementation for fan VFDs is the high initial install cost. VFDs for single fans typically range in price from $300 to $600, and VFDs designed to control multiple fans (typically 10 or more) can range in price from $4,000 to $8,000 depending on the required ventilation system load. While some VFDs can run on single-phase power, larger VFDs may require three-phase power, which may not be readily available at the farm. If three-phase power is not available, then a phase converter would be required, adding roughly $3,000 to $6,000 to the install cost. Additionally, if existing fan motors are not VFD rated, it may be necessary to upgrade them before installing a VFD. A secondary barrier to implementation is a lack of consensus regarding energy savings and effects on animal comfort. More research is needed to quantify energy and GHG savings, optimal VFD configuration (e.g. controlling fans individually versus in sequence), and any potential effects on animal health and production efficiency. Fan VFDs are potentially applicable to dairy, swine, poultry, and greenhouse operations, although the greatest potential for NYS likely lies with dairies.

3.4 Conductive Cow Cooling

Conductive cow cooling (CCC) is a technology designed to enhance cow comfort and temperature regulation through the use of heat exchangers embedded under cow bedding. The heat exchangers used in CCC generally consist of plastic beds with channels for a cooling fluid (typically ground water or glycol) to pass through. Contact between the heat exchanger and cow bedding creates heat transfer through conduction, effectively drawing the heat from the cow through the bedding and into the cooling fluid.

Closed loop CCC systems can reduce electricity consumption by lowering the demand on ventilation fans by reducing runtimes during peak load periods (i.e., hot summer days) and potentially reducing water consumption used for cow cooling through recirculation, particularly in cases where CCC is replacing misting or evaporative cooling systems (Gebremedhin 2014).

CCC is still largely in the research and development stage, and is not yet widely available on the commercial market. However, numerous studies have been conducted to vet this technology, and preliminary results are promising. One study demonstrated that conductive cooling can alleviate heat stress during hot and humid weather, even when conventional fan-based systems cannot (Mondaca et al. 2013). A recently concluded study at Cornell University and funded by NYSERDA found that CCC resulted in increased feed consumption and lowered rectal temperatures, skin temperatures, and respiration rates of cows, but did not have a significant effect on milk production levels (Perano 2014). EnSave is currently conducting a measurement and verification study in collaboration with the leading manufacturer of CCC systems to determine effects on energy usage, GHG emission reductions, water usage, and milk production.

The primary barrier to adoption of CCC technology is the lack of commercial availability. Commercial systems are expected to be more widely available in the next one to two years, and the anticipated installation cost (materials and labor) will range from approximately $300 to $500 per stall, based on market research. Although preliminary research has already been conducted, further research is needed to verify potential energy, GHG, and water savings as well as any potential effects on milk production.

3.5 Evaporative Cooling

Evaporative cooling is a well-established technology that uses moisture to absorb heat in the air in order to reduce heat stress on livestock. There are three primary methods of evaporative cooling: direct, indirect, and direct-indirect. Direct evaporative cooling is the most common form used in agriculture and works by blowing air across wet media (typically an evaporative cooling pad), causing water to evaporate. This process cools air and increases its humidity, although it is possible to cool air without increasing humidity through the use of indirect evaporative cooling systems. Because drier air is able to absorb more water than humid air, evaporative cooling systems perform best in arid climates. Evaporative cooling is most commonly used in barns that are enclosed, where tunnel exhaust fans are used to pull air through evaporative cooling pads. For this reason, evaporative cooling is used more extensively in the poultry and swine industries than dairy. However, stand-alone units are becoming increasingly available any may accelerate the adoption of this technology.

Estimating the implementation cost for evaporative cooling systems is difficult given that the project scope can vary widely depending on existing building construction (e.g., solid versus enclosed sidewalls), existing ventilation configuration, and building size. Rocky Mountain Power recently compiled a list of commercial evaporative cooling projects completed between 2010 and 2013 with their associated energy savings and simple payback periods, which ranged from less than a year to 5.7 years for direct evaporative cooling systems installed in warehouses, schools, office buildings, and medical facilities (Rocky Mountain Power 2013); however, these costs could be considerably higher for agricultural operations.

Barriers to adoption of evaporative cooling primarily relate to a lack of awareness, uncertainty over the economic benefits, and incompatibility with existing buildings. Numerous studies have demonstrated positive effects of evaporative cooling on livestock comfort and well-being (Ryan et al. 1992; Chaiyabutr et al. 2008; Berman 2006; Stinn and Xin, 2014). However, little research has been conducted on the energy savings associated with this technology. More comprehensive research is needed to quantify the performance and market potential of evaporative cooling (both integrated and stand-alone) in the dairy industry, particularly as it compares with conductive cow cooling. Additionally, evaporative cooling may have applications in greenhouse cooling. EnSave is aware of one greenhouse in NYS that has used this technology to supplement ventilation, although the performance results are not known. More research is needed to determine the utility of this technology in greenhouse environments.

3.6 Electronic Expansion Valves

Electronic expansion valves (EEVs) are an alternative to thermostatic expansion valves (TEVs) and are the primary method of implementing floating head pressure control. TEVs are widely used mechanical devices designed to regulate the injection of refrigerant liquid into the evaporator and maintain a constant evaporator superheat (Farquharson 2013). EEVs are more sophisticated and use an electronic controller to measure temperature and pressure at critical points within the refrigeration system to regulate the flow of refrigerant more precisely than a conventional TEV, thus resulting in energy savings (Lazzarin et al. 2009, Farquharson 2013). Within the agricultural sector, this technology has applications primarily on dairy operations and for vegetable and fruit cold storage.

EEVs have been available for commercial and industrial refrigeration systems for some time, and have been gaining popularity as an alternative to TEVs in recent years. Few case studies are available that explicitly quantify potential energy savings, however one study conducted in Italy found potential energy savings of between 18.5% and 22% for supermarket display cabinets through the use of EEVs, depending on the location (Lazzarin et al. 2009). Another study quantified reductions in energy losses at refrigeration unit start-up and found that EEVs resulted in a maximum inefficiency of 8% versus 23% on a 20-kW refrigeration unit (Carel Industries 2013).

Despite the favorable results of the limited studies conducted in commercial and industrial applications, there is little to no research available investigating this technology in an agricultural context. EEVs likely have direct transferability with cold storage facilities, but it is unclear how they will perform on dairy farms. One potential complication on dairies is the use of compressor heat recovery (CHR) systems. CHR is a technology that allows the dairy to utilize waste heat derived from refrigeration compressors to pre-heat water for sanitization. Installing an EEV in a dairy refrigeration system would result in less waste compressor heat available to supply the CHR unit, resulting in the need to offset this deficit with heating fuel or electricity. One possible solution would be to utilize renewable energy (e.g., in the form of solar thermal panels) to pre-heat water rather than a CHR, though this would likely be a far more costly alternative. More research is needed to determine how EEVs perform on dairies, particularly in conjunction with CHR units. Additionally, because dairy refrigeration systems are typically oversized to cool milk quickly, opportunities may exist to save energy by allowing the refrigerant system to switch between milk cooling and milk storage modes through the use of an EEV.

The primary barrier to adoption of EEVs is a lack of awareness, and general lack of information in the marketplace. Additionally, implementation cost data for EEVs is difficult to obtain. One supermarket study determined that the total cost (materials and labor) to install EEVs was $445 per unit, and that initial costs would be recovered in a period of approximately 1.4 years (Lazzarin et al. 2009). However, more research is needed to determine the average implementation cost and energy savings for this technology within an agricultural context. Additionally, EEVs require more highly specialized technicians, resulting in higher maintenance costs as compared with TEVs.

3.7 Geothermal Heat Pumps

Geothermal heat pump systems utilize the relatively constant temperature of the earth and groundwater to offset heating and cooling loads. This technology is well-established and researched, and has been widely implemented throughout NYS. However, the use of geothermal heat pump systems by agricultural facilities is uncommon and further research is required to better understand the feasibility, economics, and potential energy savings associated with this technology. Research is also needed to determine the most appropriate form of geothermal technology for different agricultural operations. Several types of geothermal heat pump system configurations exist; depending on site characteristics, one system may work more effectively than the others. The four basic geothermal system designs are:

- Horizontal Closed-Loop System – uses horizontal trenches in the ground for heat exchange).
- Vertical Closed-Loop System – uses vertical drilled channels in the ground for heat exchange).
- Open-Loop System – uses ground or surface water for heat exchange; the water is circulated using a pump system, and after use it is pumped back into the ground).
- Pond Closed-Loop System – uses a body of surface water as the thermal source/sink).

Although geothermal heat pumps may have applications in a wide variety of agricultural subsectors, the primary opportunities within NYS likely are dairy farms and greenhouses. Dairy farms may be particularly good candidates for this technology given their substantial heating and cooling needs, and many dairies already utilize geothermal technology in their operation of well-water plate coolers. In addition to utilizing geothermal technology for aiding with milk cooling, geothermal heat pumps have been proposed as a way to offset dairy hot water heating loads. A study funded by the Colorado Department of Agriculture (Baer et al. 2013) concluded that substantial opportunities exist for utilizing geothermal heat pumps in dairies, and that these systems could be designed to replace compressor heat recovery systems, thereby simplifying the overall complexity and cost of heating and cooling systems. An analysis of a proposed 6-kW dairy ground source heat pump system conducted as part of this study estimated that the installed the system would achieve a 54% reduction in heating costs and 71% reduction in cooling costs, and that the simple payback period would be approximately three years for a $160,000 system. Despite these favorable estimates, there is a lack of installed systems to clearly validate the economic viability of geothermal heat pumps on dairies.

In addition to potential applications on dairy farms, geothermal heat pumps may present significant opportunities for greenhouses. This application of geothermal technology is well-researched, and has become more widely accepted as an alternative system in recent years. Rafferty & Boyd (1997) provide a comprehensive overview of greenhouse heating with geothermal technology and describe six different potential geothermal systems for heating and cooling greenhouses, along with cost estimates. Additionally, Panagiotou (1996) provides a thorough overview of geothermal greenhouse design. Few recent peer-reviewed studies have been conducted on geothermal applications for greenhouses in climates similar to New York State; however, an economic analysis on a solar greenhouse integrated with solar assisted geothermal heat pump systems conducted in Turkey demonstrated that this technology was economically preferable to conventional heating and cooling systems (Ozgener and Hepbasli 2005).

Despite the maturity of this technology, little research is available providing analysis of potential energy savings. One comprehensive study concluded that open-loop geothermal heat pump systems show considerably more favorable economics than closed-loop systems, but that the feasibility of greenhouse heating with both closed- and open-loop systems is strongly dependent on the cost of alternate fuels (Chiasson 2005). The same study determined that it would be economically feasible to install an open-loop system costing up to $600/ton at a natural gas price of $0.80/therm, which would be capable of handling approximately 80% of total annual heating demands (Chiasson 2005). It is important to note that greenhouse crops should be determined prior to installing a geothermal heat pump system given that the crop dictates the heating demands and consequently the required capacity of the system (Panagiotou 1996).

Pricing for geothermal systems vary widely depending on system type, system size, and characteristics of the farm including bedrock depth, soil type, available land area for ground loops, and access to deep water. Generally speaking, most average sized agricultural operations would likely require an investment of $30,000 to $200,000 to implement a geothermal heat pump system, although this number could easily be exceeded. Chiasson (2005) provides a chart depicting the economic sensibility of greenhouse geothermal heating based on natural gas cost and installation cost, which ranges from $200 to $1,000 per kW for open loop systems. Installation costs will vary with site characteristics such as bedrock depth and soil type. More research is needed to determine the suitability of geothermal heat pumps for NYS dairy farms and to provide up-to-date estimates on potential energy savings and payback periods.

3.8 Outside Air Economizers

Outside air economizers (OAE) systems (also called air-side economizers or free coolers) use cold outside air to offset cooling and refrigeration loads, thereby reducing compressor runtime and reducing energy usage. This technology has existed for decades, but has not been widely adopted within the agricultural industry. Existing refrigeration systems can be retrofitted with OAEs to draw outside air when the appropriate outside temperatures are reached. This technology is particularly well suited to climates with cold winters, and manufacturers have reported that customers in the New England area are able to utilize OAEs up to 130 days per year. Producers of eggs, dairy products, potatoes, vegetables, and fruit crops within NYS could potentially benefit from using outside air economizers.

The relatively high cost-to-savings ratio of OAEs makes them best suited to larger-scale operations. In general OAEs are cost effective when the refrigerator box volume is greater than 1,000 cubic feet, and best suited to walk-in style coolers. Efficiency Vermont estimates that OAEs can reduce compressor energy usage by 10 to 30% and result in savings of approximately 2,500 to 7,000 kWh annually per 5-horsepower compressor (EfficiencyVermont 2013). An economic feasibility study conducted as part of the Massachusetts Farm Energy Program for a yogurt production facility concluded that the simple payback period would be 8.6 years for 1,920 cubic foot cooler (Callahan 2013). In 2011, EnSave conducted an evaluation for an OAE system for cold storage facilities on a potato farm in Massachusetts. The installation cost was approximately $24,000 each for two refrigerated spaces of 108,000 cubic feet and 84,000 cubic feet. The energy savings from refrigeration were 28% and 35% respectively for each of these spaces, respectively, and in both instances the simple payback period was less than four years. In both instances, evaporative fan controllers were installed, which increased the energy savings value.

There are several potential barriers to adoption; however it is unclear why OAEs are not more widely pursued. The primary barrier to adoption is likely a lack of awareness. Although OAEs are a fairly mature technology, they may not be readily available or marketed throughout NYS, thus inhibiting their adoption. Additionally, OAEs may in some cases present challenges in terms of maintaining optimum humidity for produce storage. Further research is needed to understand the barriers to adoption, more accurately quantify potential energy savings, and determine the potential applications of OAEs within the dairy industry.

3.9 Dynamic Temperature Control of Greenhouses

The automation of greenhouse production systems has the potential to significantly reduce energy consumption. There are four basic types of controls available for aiding in the automation of greenhouse: thermostats and timers, analog “step” controllers, computer zone controllers, and integrated computer controls. Each of these control types offers varying degrees of ability to automate greenhouse processes including heating and cooling, ventilation, artificial lighting, CO_2 concentration, irrigation, etc. Among the more advanced techniques for energy conservation in greenhouses using computerized control systems is dynamic temperature control, a technique which is utilized more widely in Europe, but it still relatively new in the United States.

Dynamic temperature control of greenhouses uses an environmental control computer and software to lower heating set points when the outside air temperature and incoming solar radiation are low, and increase set points when the opposite is true (Blanchard and Runkle 2011). In one trial, dynamic temperature control demonstrated heating cost savings of approximately 6 to 14% (Runkle and Both 2011). Another study conducted in Denmark demonstrated that it is possible to reduce energy usage by between 25% and 48% without affecting plant quality and production time by using a control system that regulates temperate and CO_2 concentration based on outdoor photosynthetic photon flux density and photosynthesis models (Ottosen et al. 2006, Vox et al. 2010).

Numerous barriers exist that prevent more widespread adoption dynamic temperature control in greenhouses. Given the sophistication of these controls and their integration with greenhouse HVAC systems, the complexity and cost of implementation can escalate quickly. More research is needed to determine the feasibility and economics of retrofitting existing greenhouses with computerized controls to achieve dynamic temperature control. Additionally, further measurement and verification of energy savings associated with computerized greenhouses in the Northeast would be beneficial in accelerating the adoption of advanced greenhouse climate control strategies including dynamic temperature control. One of the best examples from NYS is Gotham Greens, which operates three greenhouse facilities in New York City, each of which utilizes state-of-the-art climate control technology. These facilities could provide useful test beds for measurement and verification of energy savings to establish performance benchmarks for other greenhouses throughout NYS.

4 Supporting Observations

In addition to identifying opportunities to enhance energy efficiency efforts within NYS' agricultural sector through analyzing baseline energy data, identifying underutilized measures, and supporting research on emerging technologies, there are a number of important program elements that can contribute to the success of future agricultural energy efficiency programs within NYS. The following sections address the value of energy audits and considerations in developing incentive structures for energy efficiency programs.

4.1 Energy Audits

Energy audits are an important part of a comprehensive agricultural energy efficiency program. Farmers may receive information about energy efficient equipment from their vendors or through discussions with other producers in their industry. However, these anecdotal recommendations do not include a context for which measures are most cost-effective for a particular farm, and which specifications are most energy efficient. An energy audit helps prioritize the decisions for the farmer by including an objective analysis of energy efficiency recommendations on the farm, presented with information about initial cost, energy savings, expected useful life, and simple payback period. An energy audit also includes information about quality standards and specifications that should be included when installing the equipment, to assist the farmer in making an educated equipment selection that will achieve the projected energy savings. Without these specifications, farmers can too easily purchase lower-quality equipment that may not meet recommended efficiency standards and result in inferior performance and disappointment. An agricultural energy audit that meets American Society of Agricultural and Biological Engineers (ASABE) Type II standards does two things: quantifies the savings for the program participant, and provides the farmer with a tool for prioritizing future energy efficiency investments based on payback and total savings for all fuels used on the farm.

4.2 Incentivizing Energy Efficiency Technologies

Various methods are used to incentivize the adoption of energy efficiency measures. The most common incentives provide direct subsidies, low-interest loans, and establishing mandatory efficiency standards. Although numerous factors determine the efficacy of these strategies, research conducted in both the residential and commercial markets strongly indicates that direct subsidies programs far outperform loan programs and the establishment of standards in promoting measure implementation and the installation of measures with higher performance standards (Stern et al. 1986, Train and Atherton 1995, Walls 2014). Research also indicates that in addition to financial incentive structure, program delivery and implementation strategy are important factors in determining the success of energy efficiency programs (Stern 1992).

The Missouri Agricultural Energy Saving Team—A Revolutionary Opportunity (MAESTRO) program, which was implemented between May 2010 and March 2013, provides a clear example.[28] The following quote from the U.S. Department of Energy's website summarizes the effect of loans versus grants in the performance of the MAESTRO program (US DOE 2013):

> When MAESTRO was first established, it focused on creating low-interest loans for farmers. After a few months and only one interested party, the program talked with stakeholders and found that another loan was the last thing farmers wanted. 'The extended agricultural community was telling farmers not to take on more debt in order to sustain themselves,' according to Tony Stafford, Executive Director of the Missouri Agricultural and Small Business Development Authority. 'Once we changed the program to include incentives of up to $12,000 and lowered the prices of the Energy Management Plans and Home Audits, we dramatically increased program interest.'

Direct subsidies also appear to be a major factor contributing to high participation and measure installation rate for the AEEP. The program delivery strategy, which includes utilizing industry-specific knowledge and experience of third-party contractors, subsidized energy auditing, and robust marketing and outreach, is a critical component of the program's success.

[28] The MAESTRO program was funded by the American Reinvestment and Recovery Act of 2009, and was a collaborative effort by the Missouri Department of Agriculture, Missouri Agricultural and Small Business Development Authority, University of Missouri, and EnSave, Inc.

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Appendix A: Data Sets

EnSave used data from three distinct datasets to perform this analysis: NYSERDA's own applicant and audit data from AEEP, USDA-NASS 2012 Census of Agriculture, and FEAT™, which is EnSave's repository of agricultural energy efficiency audits.

A.1 NYSERDA's Program Applicant and Audit Data

NYSERDA has a history of funding energy efficiency programs for agriculture. AEEP is the program targeted for agriculture and active from 2011 through 2014. During this time, 782 farmers have applied for incentive funds for equipment replacement. NYSERDA contracts with EnSave to administer AEEP. Overall responsibilities include marketing, enrollment, technical review, incentive approval, reporting, tracking, and verification. In administering this program, EnSave has received and aggregated data for all farms that have applied.

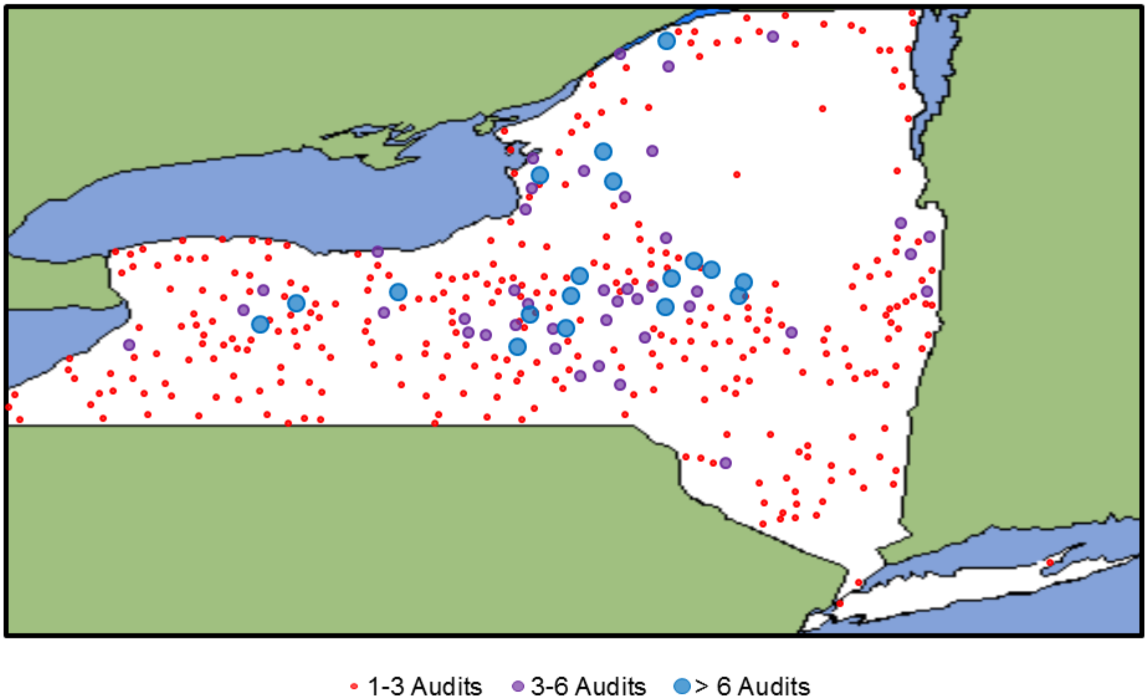
AEEP data contains both demographic and energy information regarding NYS's farms, but AEEP's data cannot be considered a random sample of agricultural operations in NYS. As a product of an ongoing program, AEEP's data represents agricultural producers who are interested in and seek out energy efficiency.

A.1.1 Demographics

Agricultural operations from across NYS have applied for funding via AEEP offered by NYSERDA. Figure 17 shows the distribution of AEEP applicants within NYS. Applicants are represented in most major agricultural areas statewide. Areas with little or no representation by the program correspond to urban areas, mountainous regions, or are not part of a utility territory eligible for the program.

Figure A-1. NYSERDA Applicants by Postal Code as of August 2014

Source; NYSERDA AEEP; Compiled by EnSave Inc.



A.1.2 Data Elements

The AEEP application submitted by farmers requests information about the applicant's operation, such as location, type of agriculture, and farm size. The AEEP program data also includes energy efficiency measures considered and installed. AEEP also provides access to an energy audit conducted by NYSERDA's FlexTech Program contractors. These audits meet the ASABE Type II standard, which means they involve a site visit and contain a comprehensive evaluation of all equipment at the operation and analyze all fuels used on the farm. NYSERDA In total, there are 762 audit reports from NYSERDA available for analysis (Table A-1).

Table A-1. Data Elements from NYSERDA Used in Analysis

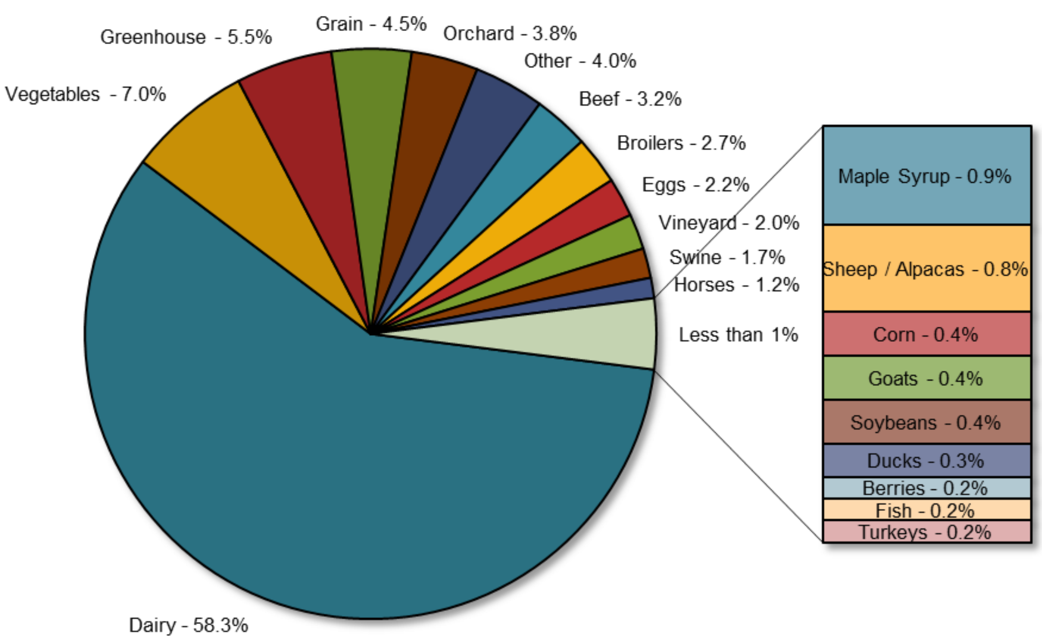
Source: EnSave, Inc.

Document Type	Data Element	Description
AEEP Application	Location of Operation	The county and REDC where the operation was located.
AEEP Application	Commodity	The agricultural product or products that the operation produces for sale. A operation may produce and sell multiple commodities.
AEEP Application	Operation Size	The size of the operation, generally expressed in numbers of livestock or in acres of fields worked.
Farm Energy Audit	Monthly Electricity Use Data	The consumption of electricity as reported by the operation's utility. This information is collected as part of the audit.
AEEP Measures Summary	Energy Efficiency Measures Considered and Installed	Energy efficient equipment or changes considered by the farmer. NYSERDA may provide incentives for installation, if the measure qualifies.

Applicants to AEEP produce a wide variety of commodities in several agricultural subsectors. Figure A-2 shows the subsector counts for AEEP applicants. Applicants can participate in multiple subsectors.

Figure A-2. NYSERDA AEEP Applicant Subsector Count

Source; NYSERDA AEEP; Compiled by EnSave Inc.



Applicants who report dairy as their subsector comprise the bulk of NYSERDA applicants. In addition, 97% of applicants who listed dairy did not list any other subsectors; non-dairy applicants were more likely to report more than one subsector. For example, 51% of the greenhouse applicants also reported another subsector, like vegetables or orchards.

A.2 USDA's 2012 Census of Agriculture

Every five years the USDA's National Agriculture Statistics Services (NASS) conducts a full census of agriculture in the United States. The latest census data year is 2012, and USDA released the findings from this census on May 2, 2014. The Census of Agriculture data provides a broad, comprehensive look at all segments of NYS's agriculture, including size and revenue numbers.

A.2.1 Demographics

As a census rather than a survey, the Census of Agriculture intends to count and record the contribution of every agricultural operation in the United States and Puerto Rico. In doing so, it has a very inclusive definition of an agricultural operation. NASS defines a farm as any entity producing more than $1,000 in revenue annually from agricultural products. By using such an inclusive definition, raw farm counts from Census data tend to be very large, and usually have to be qualified with some measure of size (e.g., average milking herd, area under glass, etc.).

A.2.2 Data Elements

The 2012 Census of Agriculture contains state and county level data on the number of farms, the commodities they produce, the size of the operation, market value, and other demographic and economic factors. The Census does not collect any data directly related to energy use, such as annual consumption. , Visit the NASS webpage at www.agcensus.usda.gov/index.php for more information on the data elements contained in the Census of Agriculture.

One other key consideration regarding Census of Agriculture data is that data are released fully aggregated with no individual census responses available. NASS protects individual farms' identities by withholding information if that information could be identified with a specific farm. This identification can occur often when data at the county level is used in analysis. In this report, where county-level data from the Census of Agriculture is used, sometimes that data will be reported with a "~" meaning "approximately" (e.g. "~5,000" for "approximately 5,000"). This notation means that the Census withheld some county-level information to protect the identity of an individual farm.

A.3 FEAT™ and EnSave's Energy Efficiency Audit Data

EnSave has been providing agricultural energy efficiency consulting services since 1991. This consulting has included conducting energy audits of farms in 47 of 50 states, plus Puerto Rico. In addition, EnSave has contracted with NYSERDA to deliver energy efficiency in NYS since 1999.

In 2011, EnSave launched FEAT™, its software tool for audit tracking, calculation, and analysis. FEAT provides the capability to track data and outcomes from hundreds of farm energy audits performed by throughout the United States and Puerto Rico. Although the Census of Agriculture data provides the broad look at agriculture in NYS and AEEP's data provides insight into the farms and farmers seeking energy efficiency in NYS, FEAT's data provides detailed information on baseline energy use in agriculture.

A.3.1 Demographics

FEAT is a repository of thousands of audits. To perform this analysis for NYSERDA, EnSave pulled subsets of audits that were demographically similar to farm populations being studied. Most audits were full ASABE Type II audits conducted by EnSave auditors.

Like AEEP data, the data in FEAT is not random, but from operations who have sought out energy efficiency, either through national programs like USDA's Environmental Quality Incentive Program (EQIP) or various state, local, and utility energy efficiency programs that EnSave has operated.

A.3.2 Data Elements

Because in many cases FEAT is used by EnSave to generate these audit reports, many data elements are available for analysis, including utility bill history, equipment inventories, and quantifiable elements of farm operation, like milking herd sizes or flocks of poultry processed. All of these items can be aggregated and used to produce a bigger picture of farm operation practices within a state or region (Table A-2).

Table A-2. Data Elements from FEAT Audits Used in Analysis

Source: EnSave, Inc.

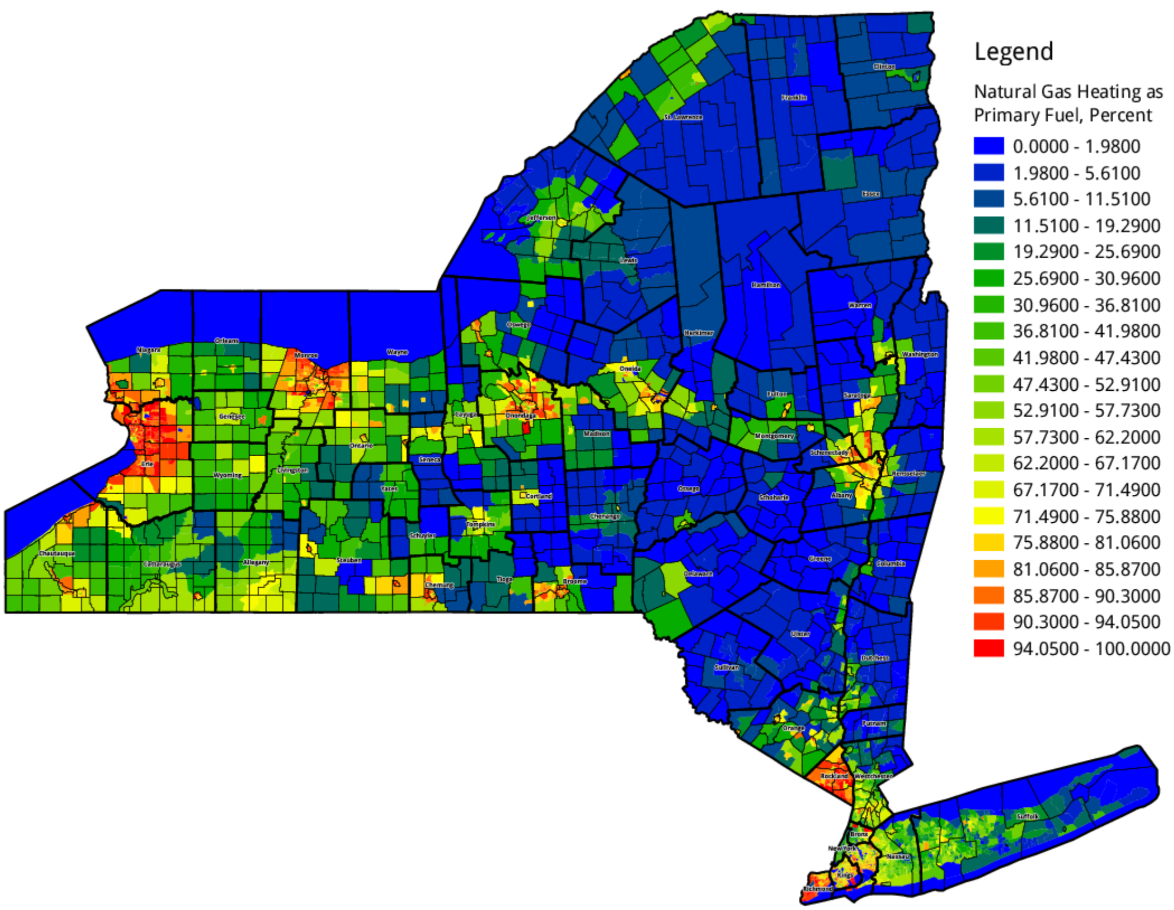
Data Element	Description
Location of Operation	The county and state where the operation was located.
Commodity	The agricultural product or products that the operation produces for sale. A operation may produce and sell multiple commodities.
Operation Size	The size of the operation, generally expressed in numbers of livestock or in acres of fields worked.
Monthly Electricity Use Data	The consumption of electricity as reported by the operation's utility. This information is collected as part of the audit.
Heating Fuel Use Data	The consumption or delivery of heating fuel as reported by the operation's utility. This information is collected as part of the audit. The most common heating fuels are propane, #2 fuel oil, and natural gas.
Milk Production Equipment Inventory	Specifications of all equipment used in milk production, such as manufacturer and model, size, capacity, run hours, and estimated annual energy use.
Greenhouse Equipment Inventory	Specifications of all equipment used in greenhouses, such as manufacturer and model, size, capacity, run hours, and estimated annual energy use.
Orchard and Vineyard Equipment Inventory	Specifications of all equipment used on orchards and vineyards, such as manufacturer and model, size, capacity, run hours, and estimated annual energy use.
Lighting Equipment Inventory	Specifications of all lighting used on the farm, such as bulb type, wattage, number of fixtures, location of fixtures, run hours, and estimated annual energy use.
Ventilation Equipment Inventory	Specifications of all equipment used in ventilation, such as manufacturer and model, diameter, rated airflow or thrust, run hours, and estimated annual energy use.
Electric Motor Equipment Inventory	Specifications of all electric motors not used in the above categories, such as manufacturer and model, what the motor is used for, efficiency rating, run hours, and estimated annual energy use.
Equipment Inventory for Other Aspects of the Operation	Specifications of all equipment used by the operation that does not fall in the above categories, such as heaters and stock watering, refrigerators, washers, and dryers.

Appendix B: Natural Gas Distribution in NYS

Agriculture in NYS relies on a variety of heating fuels. Where available, natural gas is a popular choice for farms with a significant heating load. However, many agricultural areas do not currently have access to natural gas because the lower population densities in these areas make building out natural gas infrastructure less economically feasible.

Figure B-3. Natural Gas Heating as Primary Fuel, NYS

Source; http://andyarthur.org/new-york-state/ny-census/ny-census-energy/map-natural-gas-as-primary-fuel.html



Regarding agriculture, most operations that can take advantage of natural gas infrastructure are west of Syracuse. East of Syracuse, operations need to be located within or at the edge of a major population center, such as Albany or New York City.

Appendix C: Methodology

C.1 Averages and Variance

Energy use data has a very high variance, making a simple average an inaccurate representation. Even operations that share common characteristics (such as crop/livestock type, acreage/herd size, and location within NYS) often have very different energy use profiles. Out of the 462 dairy audits, 36 were for farms with milking herd sizes between 90 and 110 cows. Although similar in many respects, these audits electricity consumption per milking cow ranged from a low of 267 kWh per cow up to 1,157 kWh per cow.

C.2 Energy Use and Log-Normal Distributions

One way to mitigate high variance within a data set is to establish the distribution of its values. If this distribution follows certain rules, then established statistical methods can help provide additional context to the data that the high variance obscures.

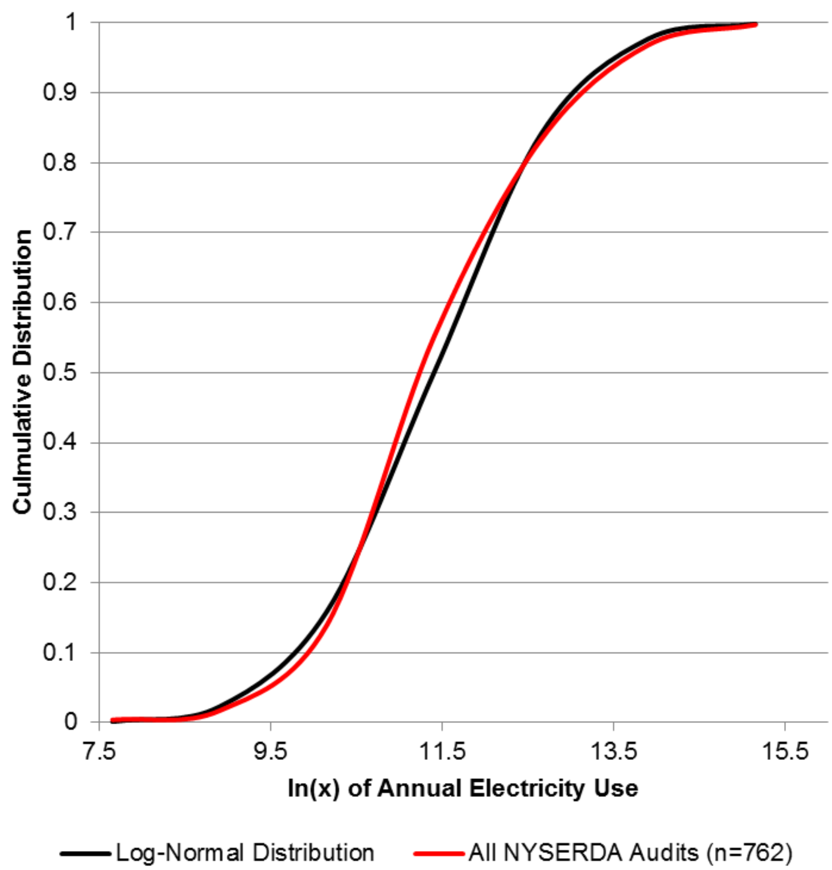
The most common of these distributions is the normal distribution. If the distribution of electricity use on dairies follows the bell curve, then a variety of established statistics formulas can help provide context and ranges to the data. The annual energy use data used in the analysis performed for Section 1 fails a basic test for the normal distribution since the standard deviation is greater than the mean. Under these circumstances, a normal distribution would predict negative annual energy use, which is not valid.

Although the energy use data analyzed for this report is not normally distributed, there is evidence that it may be log-normal.[29] A log-normal distribution is one in which the logarithms of a variable follow a normal distribution. Figure C-1 shows the results of a visual test for the log-normal distribution for annual electricity use in the 762 available audit reports collected by NYSERDA.

29 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 C-1. Cumulative Distribution Chart, Natural Logarithms of Annual Electricity Use, All NYSERDA Audits

Source; NYSERDA audits, compiled by EnSave, Inc.



This visual test suggests that the NYSERDA audit data set follows a log-normal distribution. Tests related to electricity use in subsets of the audits data suggest the log-normal distribution holds as well. With the log-normal assumption in place, established analytical methods can be utilized to provide confidence intervals for averages and calculate the necessary minimum sample sizes for analysis.

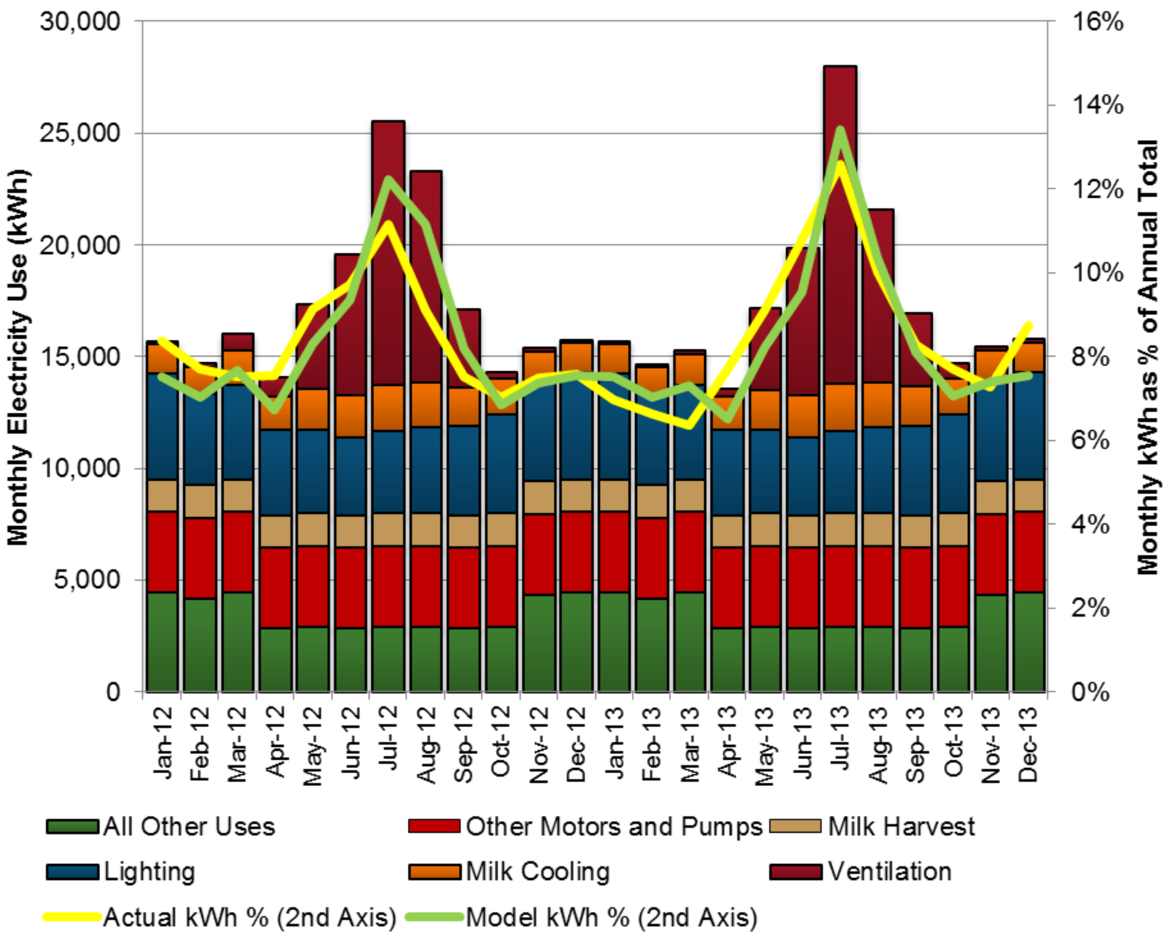
C.3 “Average Dairy” Seasonal Use Model

As seen in Section 1, Figure C-2 displays a model of seasonal electricity use compiled from 48 farms in EnSave’s FEAT dataset. The model highlights the years 2012 and 2013, which is the timeframe where the data set has the most overlap between farms. 2012 was the warmest year on record for Albany, NY since 1820. 2013 was close to average.

The model leverages the overlap to create audit reports FEAT uses to store many elements related to electricity use on a dairy farm. FEAT is used to understand the equipment used and how much energy is consumed annually by that equipment. FEAT provides a consistent manner of analysis, as equipment of the same type is evaluated the same way across audits. All audit deliverables are available for analysis along with a summary of all annual energy consumption. For each farm in the 48-farm dataset, FEAT provides an estimate of how much electricity is consumed annually by lights, fans, motors, in milk production, etc. If the data from FEAT is combined with seasonal information, such as temperatures and daylight availability, the result is the seasonal model of electricity use.

Figure C-2. FEAT Model of Average Seasonal Electricity Use, Northeastern Dairy Farms

Source; EnSave, Inc. KALB weather data from degreedays.net



Model components include the following:

- Weather Data – The weather data used in this model was compiled using heating and cooling degree days as calculated by www.degreedays.net from the weather station at Albany International Airport (KALB). These degree days were used to calculate proportions of electricity use. For example, if a certain month received 20% of the total degree days for the year, then the related component of use was designated 20% of its total towards that month.
- Milk Production
    - Milk Harvest – All 48 farms in the data set report milk production throughout the year. The model therefore assumes all electricity devoted to milk harvest is spread evenly throughout the year.
    - Milk Cooling – Since milk harvest is assumed to occur consistently throughout the year, the need for milk cooling is likewise spread evenly throughout the year. Electricity use devoted to milk cooling has two components. The first is not related to weather, but the amount of electricity needed to cool milk from the temperature that it is pumped from the cow (roughly 98° F) to the holding temperature of the milk (roughly 38° F). The second component is related to weather, based on the assumption that compressors have to work harder in warmer weather, and that component is based off of the cooling degree days at KALB for 38° F during the timeframe of the model.
    - Water Heating – Most of the farms in the sample did not use electricity for heating water, but because this model creates a composite farm, a small amount of electricity in the model was allocated to water heating. This electricity is treated as occurring consistently throughout the year and has been rolled into the “All Other Uses” component.
- Lighting – Roughly 23% of all lighting inventoried in the audits had no seasonal component. These were primarily interior lights that were on both during daylight and nighttime hours. These lights are assumed to have been used consistently throughout the year. The remaining 77% of lights are assumed to have a seasonal component and are only on during nighttime hours. The seasonal component is modeled by taking into account how much daylight is available each month at the latitude of Albany International Airport (42.76N).
- Ventilation – 4% of all fans inventoried in the audits had no seasonal component. These fans are modeled as running consistently throughout the year. The remaining fans are modeled based on of the proportion of cooling degree days at KALB for 65° F during the timeframe shown in the model. This temperature was selected as it is the temperature above which cows begin to feel stressed from the heat.
- Other Motors and Pumps – Motors and pumps in this category are assumed to be running consistently throughout the year and have no seasonal component.
- All Other Uses
    - Most items in the “All Other Uses” category do not have a seasonal component and are assumed to run consistently throughout the year.
    - The one equipment item in the “All Other Uses” category that is modeled seasonally is engine block heaters for tractors. It is assumed that engine block heaters are run from mid-to-late November to early March, irrespective of weather during those months.

Appendix D: Greenhouse Gas Emissions Calculations

EnSave calculates GHG emissions in terms of metric tons of carbon dioxide equivalent (mtCO_2e). This calculation takes into account three designated greenhouse gasses: carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). The calculation uses emissions in metric tons and multiplied by their associated Global Warming Potential (GWP) factor. The GWP factors used for these emissions are the factors published as part of the Intergovernmental Panel on Climate Change (IPCC)'s Fourth Assessment Report (AR4). The AR4 factors are listed in Table D-1.

Table D-1. Relevant Global Warming Potential (GWP) Factors

Source: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-errata.pdf

Greenhouse Gas	GWP
Carbon Dioxide (CO_2)	1
Nitrous Oxide (N_2O)	298
Methane (CH_4)	25

EnSave obtains the emissions factors for electricity generation from the EPA's Emissions & Generation Resource Integrated Database (eGRID) dataset, specifically eGRID2010 v1.1.[30] eGRID data breaks emissions down in several ways; EnSave uses the State-level emissions factors for all calculations in this report. According to eGRID, 1 megawatt of electricity generated for NYS produces approximately 0.2877 mtCO_2e.

Note that NYS' electricity generation is relatively clean. From eGRID, NYS ranks tenth in the nation in GHG emissions rate, which is approximately half of the national average. The practical result is that energy efficiency projects that save electricity have less of an impact on GHG emission reductions in NYS than the same size project in most other states.

For natural gas and other heating fuels, EnSave uses emissions factors derived from two U.S. government sources. The first is the EIA's "Voluntary Reporting of Greenhouse Gases" program.[31] The second is the EPA's "Compilation of Air Pollutant Emissions Factors," known generally by its reference number AP-42.[32]

30 Information on eGRID can be found at the EPA's eGRID page, http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

31 http://www.eia.gov/oiaf/1605/

32 http://www.epa.gov/ttn/chief/ap42/index.html

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