ON-FARM ENERGY USE CHARACTERIZATIONS

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Abstract

This report characterizes the national and several state agriculture sectors in terms of on-farm energy use. Agriculture represents 1.8% of the national gross domestic product (GDP), and energy costs represent up to 6% of farm production costs, costing the nation's farmers $10 billion in energy bills a year. Results show that energy use is highly dependant on farm-type and region, and can be specific to both. Nationwide, the largest on-farm energy uses include motors (with irrigation being the largest motor application), lighting, and onsite transportation. Individual states, while showing some variation, have the same general large energy uses. Further research is required to refine these estimates, as the estimates reported here include significant expert judgment.

Introduction

Agriculture is an important part of the U.S. economy and culture. Many agencies and programs are working to preserve, improve, and grow a healthy agricultural economy. This report and its companion *Potential Energy Efficiency Savings in the Agriculture Sector* (Brown and Elliott 2005) identify the opportunities for energy efficiency within the sector. A third report, *Energy Efficiency Programs in Agriculture: Design, Success, and Lessons Learned* (Brown, Elliott, and Nadel 2005) identifies current programs available in energy efficiency for the agriculture sector and provides recommendations on gaining maximum benefit from those and future programs. Through the course of the three reports, the available data has been identified, and data gaps have become clear.

Background of Energy Use in Agriculture

The total value of sales for agriculture has been steadily increasing historically. In 1997, agriculture income was $196 billion, nearly doubling from 1978. Although this amount equaled only 2% of the GDP (BEA 2004), millions of Americans depend on agriculture for food and livelihood. Further, agriculture is a cultural mainstay, representing the American ideal of self-reliance, hard work, and a connection with the land. Continuation of a strong agricultural sector is imperative to the future of the United States. Nationwide, an average of 6% of farm production expenses are directly energy related (USDA 1999). This number varies depending on the type of farming, the geographic location of the farm, and the type of products and processes used on the farm.

Agriculture, a typically resilient sector, has been hard hit disproportionately by the recent energy price increases due to energy's relatively high share of costs and the inability of farmers to pass along these costs. Energy use, previously thought of as a fixed cost, is now beginning to be viewed as a controllable cost through demand-side energy efficiency and onsite and renewable energy production. Energy efficiency is the streamlining of energy use through technology and behavior in a way that minimizes energy use and cost while maximizing productivity.

In the past, programs addressing energy efficiency on the farm were piecemeal: specific to the needs of a farm or group of farms, but resulting in different farms re-inventing the (efficiency) wheel at a high cost (Brown, Elliott, and Nadel 2005). Several developments over the last few years have increased interest in quantifying, monitoring, and promoting efficient energy use on the farm on a large scale.

First, increasing energy prices and volatility over the last decades have increased interest in energy use patterns. Concurrently, profit margins on farms (especially small farms) have continued to shrink, leading to an interest in minimizing expenses. Further, until recently electricity prices in most states were regulated. The price volatility that has resulted from restructuring in states like California and Pennsylvania encouraged many in the population, including farmers, to take a closer look at how they use energy. These changes in the market have made farmers realize that controlling energy use can have an impact on profit margins.

Second, the current delivery infrastructure for fuel and electricity were completed in the 1950s. Delivery system difficulties include the lack of natural gas availability to most rural areas, but primarily refer to the aging electricity grid. Recent years have seen reduced investments in grid maintenance and modernization, manifested by brownouts, blackouts, and voltage problems. Maintaining the grid has become a significant cost in rural areas (often termed the "last mile" cost problem) and as a result, it may be less expensive for the government to encourage efficiency and renewable energy options to delay or negate the need to upgrade and modernize rural grid infrastructure.

Third and finally, as interest in renewable energy and on-farm energy production increase, efficient use of energy is required to minimize the capacity of large, capital-intensive onsite energy generators. Efficiency is a necessary precursor to renewable energy, as renewable systems are still expensive (even in the face of rising energy costs).

Increasing energy efficiency in every sector has broad financial benefits for American society. It decreases fuel use without sacrificing productivity, reducing reliance on international fuel markets. This decreased fuel use reduces pollution emitted from electric generation plants at the local, regional, and national levels. Energy efficiency also relieves stress on the electricity grid and can delay grid infrastructure upgrades, not just in rural areas, but also all along the transmission grid.

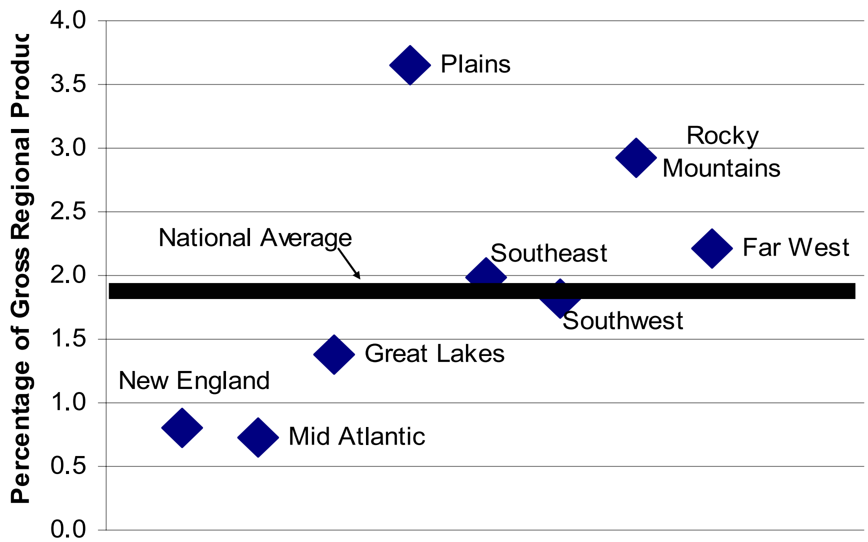
States for which agriculture is a large part of the economy are starting to look more seriously at energy costs as a controllable production cost on farms. Farmers have found that energy efficiency changes also promote production efficiency or capacity building. More than just being able to save energy and cost to the individual farmer, energy efficiency reduces pollution and dependence on foreign oil. These ancillary benefits, plus the ones mentioned in the previous paragraph, can be used to justify larger-scale energy efficiency programs.

This report is motivated by this increased interest in quantifying, monitoring, and encouraging efficient energy use on the farm. Through national and several state-level examples, we characterize agricultural energy use. We only target direct on-farm energy use while acknowledging that indirect farm energy use (e.g., fertilizer and agricultural chemicals) may be a significant energy cost or potential area of savings associated with some farm-types. On-farm energy production is not covered. The results reflect a lack of accessible data regarding on-farm energy use. This presented a significant challenge in determining the potential for energy efficiency (addressed in detail in the companion report of Brown and Elliott 2005). In the final sections of this report, we address the data issues and suggest specific needs and relative priorities.

Methodology

National level data (EIA 2000; USDA 1999) was used to determine the primary agricultural end-uses of energy at the national and state level. Not all state data were available for energy use in agriculture, and several options for determining that data were reviewed. The first was straight extrapolation based on the state contribution to the national economy and the state contribution to the national agricultural economy. That model would only hold, however, if there was little variation between agricultural production and energy use based on region, farm-type, and fuel type. By comparing the national agricultural contribution to the economy with various state contributions to the gross state product, we can see that the agricultural sector varies in economic impact depending on region (see Figure 1).

Figure 1. Variation of Agricultural Gross Regional Product



Source: BEA 2004

For a more realistic (but also more time-consuming) reflection of agricultural energy use at the state level, we used state-level data collected by the U.S. Department of Agriculture (USDA) to show variation among several sample states: California, Florida, Kansas, New York, North Carolina, Vermont, and Wisconsin. While this analysis does not cover all states, these states represent a wide variety of climates and primary farm-types, as well as reflecting the differing focuses on agriculture as an economic driver among the states.

Data Sources

The 1997 Census of Agriculture (USDA 1999) is a census run by the National Agricultural Statistical Service (NASS) of the USDA every five years. At the time of this research (summer/fall 2004), the 1997 Census of Agriculture was the most recent complete volume available. USDA released supplemental tables for the *2002 Census of Agriculture* (USDA 2003b) in the fall of 2004. Aside from the timing difficulties in using the 2002 data as the primary data, there were also changes to the sorting of data in the 2002 survey, making the data unusable for many of the analyses.[1] Notwithstanding, the 2002 data was used as a check for changes in the agriculture sector. Where available, state-prepared data was also used to augment and check the national data.

[1] The 2002 survey collected data only on total utility costs to the farm, not individual fuels as the previous surveys had done. No methods for estimating the electricity and other fuel costs from the total utility data were found to be acceptable.

The 1997 Census of Agriculture (USDA 1999) lists national, state, and county data. Our report uses the data at the national and state levels for value of shipments (VOS) in the agricultural sector by North American Industrial Classification System category (NTIS 2002), number, and size of farms.

However, state data was primarily used to determine how energy is used on different types of farms. Other data sources used for determining energy by fuel and end-use include previous ACEEE research on energy end-uses, individual state data, and national energy use data.

Agriculture Sector Energy End-Use Characterization

This section presents summary characterizations for energy use in the agricultural sector. The national characterization is followed by an overview of the sample state characterizations outlining the role of agricultural energy use within states and in the nation. Resource restrictions allowed us only to characterize six states along with the national picture. We believe these states to be as representative as possible of their regions. The states also represent a wide variety of primary farm-types, showing together the variation among regions, even in the same farm-type.

USA

Overview

The agricultural sector of the U.S. economy provides upwards of $200 billion in VOS in every type of agriculture from grain to soybeans and cattle to aquaculture. Agriculture and farming services represent about 1.8% of the total GDP. Total agricultural production costs, including seed or livestock purchased, fertilizer, chemicals, fuel, labor, rent, taxes, and any other associated cost, is just above $150 billion. Energy ranks sixth out of the total production expenses (6%) and accounts for over $9 billion in expenses a year (EIA 2000; USDA 1999).

Table 1 lists the largest farm-types in the United States by the largest VOS and energy expenditures as a percentage of total production expenditures. Oilseed and grain farming (NAICS code 1111) represents the largest product category, comprising almost a quarter of the national value of agricultural VOS (22%). The energy expenses by percentage of total production expenses on oilseed and grain farms are the highest (9%) of the represented NAICS codes nationwide, indicating that this would be a large potential target for energy efficiency projects. The remaining farm shipments are distributed throughout the other farm-types.

When speaking about effectively identifying large energy use farm-types, broad generalizations fail to describe adequately the agricultural sector in the states, or even in regions. For example, as mentioned above, nationwide, agriculture represents 2% of the GDP. Figure 1 shows why extrapolating that all regions would have agriculture making up 2% of their gross regional product does not effectively represent the regions. It would greatly minimize the importance of agriculture as an economic driver in the plains and Rocky Mountain States, while exaggerating agriculture's economic importance in New England and the Mid-Atlantic. Analyzing the state-level data for the largest VOS shows the variation that exists between the national averages and the state-level data.

Table 1. National Agricultural Farm-Types by VOS and Energy Use

NAICS Title*	% Agriculture VOS	% Energy Expenditures of Total Production Expenditures
Oilseed and Grain Farming	23	9
Poultry and Egg Production	12	3
Dairy Cattle and Milk Production	11	6
Cattle Feedlots	10	2
Other Crop Farming	10	9
Beef Cattle Ranching and Farming	9	7
Hog and Pig Farming	7	4
Fruit and Tree Nut Farming	6	6
Greenhouse Nursery and Floriculture	6	7
Animal Aquaculture	2	7
Sheep and Goat Farming	<1	7

*NAICS is a United States Government Classification System (NTIS 2002)
Source: ACEEE analysis of USDA 1999

Table 2 provides a data summary of the largest energy-using agriculture subsectors in the United States and sample states. Not only does it show that primary farm-types are often different, but it reflects the varying economic (and, by extension, political) importance of agriculture. Figure 2 shows national energy use by fuel-use and end-use for all farm-types.

Table 2. State Comparison of Primary Farm-Type (PFT) and Energy Expenditures

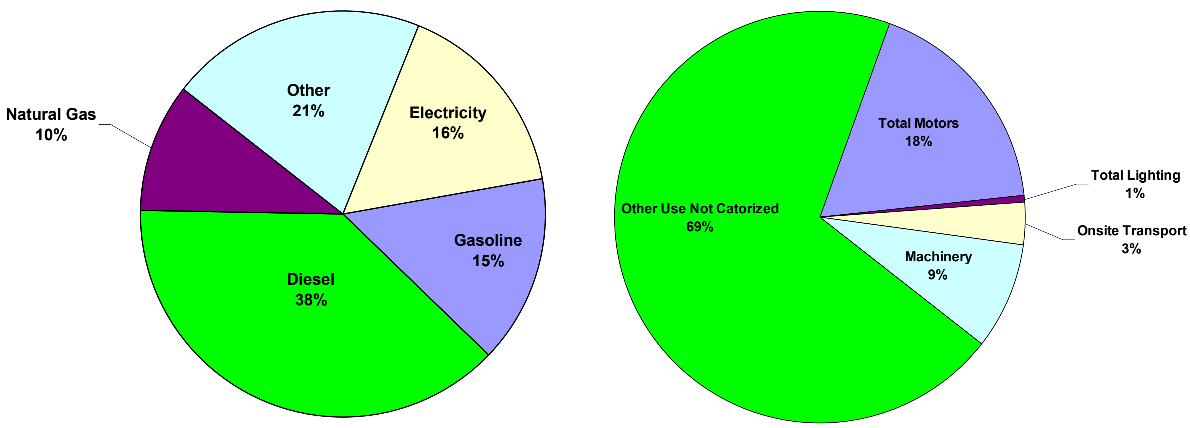
	USA	California	Florida	Kansas	New York	Vermont	Wisconsin
Ag. Product (% GDP or GSP)*	1.8	2.2	1.9	3.8	0.5	2.7	2.7
Primary Farm-Type (PFT) by VOS**	Oilseed/ Grain	Fruit/ Tree Nut	Fruit/ Tree Nut	Cattle Feedlots	Dairy Cattle/Milk	Dairy Cattle/Milk	Dairy Cattle/Milk
State Portion of United States VOS**	100%	62%	12%	20%	8%	2%	15%
PFT Energy Expenses (% Total Expenses)**	9	6	3	1	7	6	7
% National Average Energy Expenses for State PFT**	9	6	6	2	6	6	6

*BEA 2004; ** USDA 1999

Notwithstanding the difficulties of generalizing about end-use energy use in the agriculture sector, it does give a useful overview of national energy usage in the sector and provides a context for state-level characterizations. Figure 2 presents two categorizations of agriculture energy use that are particularly helpful: by fuel and by major end-use. The fuel picture shows that gasoline and diesel are by far the largest uses in the sector, making up 75% of agriculture fuel use all together. The end-use picture extends this notion, showing the dominance of machinery and transport, but also indicating that gasoline and diesel are likely used to fuel a portion of the motors as well. Indeed, as Table 3 shows, 141 of the 167 trillion Btus used nationwide for motors are used in the form of gasoline and diesel. The remaining end-uses for the fuels are onsite transport and machinery.

Motors also comprise much of the known end-use for the remaining fuels. A discussion of the specific end-uses is located in the "Major End-Uses" section on page 14 of this report. Figure 2 and Table 3 also identify a data gap issue. The non-categorized end-uses are much larger than those categorized. In other words, while we can say from available data that motors are the primary end-use for many fuels, data collection focused on on-farm energy uses may identify other end-uses to be of equal importance. Specific recommendations are presented beginning on page 15 of the report on how to best address this data gap situation.

Figure 2. Total National Energy Use in Agriculture by Fuel and Major End-Use



Note: End-use numbers include only available information. Other end-uses, such as drying and curing, for which there was little data availability, are not included. Detailed tables can be found in the appendix.

From a data gap perspective, Table 3 also shows that the problem is less pervasive at the farm-type level. Far less uncategorized fuel use is seen in the individual farm-types. This is the result of more focused research being found for these farm-types, allowing for more in-depth analysis of the end-uses. Narrowing the target either regionally or to a specific farm-type allows us to use the data that we have to its greatest extent. The following state-specific sections identify in more depth where the high energy-using farms types are and how energy is used on the farm. For more details as to the fuel uses within each of the farm-types, both nationally and at the state level, please see the appendix.

Table 3. End-Use Energy Use in the United States (in trillion Btus)

	Total Motors	Total Lighting	Onsite Transport	Machinery	Other Not Categorized	Total
Total — All Farm-Types						
Gasoline	134	—	2	1	5	142
Diesel	7	—	28	77	249	361
Natural Gas	2	—	—	—	94	98
Other	15	2	—	2	169	195
Electricity	9	3	—	—	136	153
Total Petroleum	158	2	30	80	517	796
Total Energy	167	5	30	80	653	949
Poultry — Total Energy	12	1	1	1	1	17
Dairy — Total Energy	12	0	1	13	2	31
Greenhouse/Nursery — Total Energy	8	0	1	4	2	15
Cattle Feedlots — Total Energy	37	3	3	29	2	74
Oilseed and Grain Farming — Total Energy	49	1	11	12	6	78
Fruit and Tree — Total Energy	8	0	2	4	0	15
Hog and Pig — Total Energy	7	1	1	1	0	10

California

Overview

The state of California contributes 12% of the nation's value of agricultural sales, making it the largest agricultural producer in the United States. In 1997, about half of California's 75,000 farms are listed as fruit and nut farms (NAICS 1113) and they produce 33% of the total agricultural VOS from the state. These farms produce 62% of the U.S. fruit and nut farm crop and shoulder 66% of the total fruit and nut farming energy costs nationwide. In 2000, according to the California Department of Food and Agriculture, fruit and nut gross receipts were increasing in the state (CEC 2004). Within the state, fruit and nut farmers are responsible for 6% of total agricultural energy expenditures.

California also produces 39% of the national VOS in vegetables and melon farming (NAICS 1112). Within the state, vegetable and melon farms contribute to 22% of the VOS. The state spends about 38% of the country's total agricultural energy expenditure for the NAICS code. This type of farming is responsible for 7% of the total agricultural energy expenditures in the state.

The third largest contributor to national value of sales from California is greenhouse and nursery farms: 20% of the national greenhouse and nursery value of sales comes from California. Greenhouse and nursery farms contribute 10% of the total value of agricultural products in the state. Twenty percent of the money spent on energy in these types of farms nationwide is spent in California. Seven percent of the state's agricultural expenditures on energy are spent on these farms.

On-Farm Energy Use

Table 4 identifies the major end-uses by farm-type and fuel in California. More detailed farm-type fuel data can be found in the appendix. The California Energy Commission reports that the largest energy use in crop farming (both fruit and nut and vegetable types) in California is electricity used for pumping water for irrigation (CEC 2003). Our findings and the 1997 Census of Agriculture data corroborates, indicating that over 85% of California's farm land is irrigated (USDA 2003a). California's arid climate and large agricultural output also logically connect high energy use with irrigation. The California Energy Commission found that crops from California required 2,996 million kWh of electricity to get to market in 2000 (CEC 2003).

Onsite transportation also factors in as a large energy end-use in California. The top three production subsectors (fruit and nut farming, vegetables and melons, and greenhouse and nursery) all require large expanses of land, and moving farm labor (the largest production expense in California agriculture) and irrigation technicians uses a lot of energy. In 1997, 3% of farm production expenses were attributed to gasoline (USDA 1999). The second largest use of gasoline, irrigation, was dominated by electricity as a pumping fuel, with gasoline representing less than 1% and diesel only 14% (USDA 2003a).

Table 4. Summary End-Use Energy Use in California[2] (in trillion Btus)

	Total Motors	Total Lighting	Onsite Transportation	Machinery	Other Not Categorized	Total
Total — All Farm-Types						
Gasoline	1	—	1	0.1	—	2
Diesel	4	—	3	3	—	10
Natural Gas	0.383	—	—	—	1	2
Other	0.001	0.023	—	0.05	0.4	0
Electricity	4	2	—	—	—	6
Total Petroleum	5	0.02	4	3	2	14
Total Energy	9	2	4	3	2	19
Dairy — Total Energy	2	0.1	0.1	1	0.22	3
Greenhouse/Nursery — Total Energy	3	0.2	0.2	1	1.00	6
Cattle Feedlots — Total Energy	1	0.1	0.1	0.4	0.01	1
Oilseed and Grain Farming — Total Energy	0.5	0.0	0.3	0.3	0.04	1
Fruit and Tree — Total Energy	5	0.4	1.7	3	0.36	11

[2] Detailed tables are found in the appendix.

Florida

Overview

The state of Florida contributes 3% of the national agricultural value of sales and spends 2% of the nation's agricultural energy expenditures. In 2002, the Florida Department of Agriculture and Consumer Services released a report stating that the fruit and nut industry alone had a value-added of $2.9 billion and that the overall agriculture and natural resources industries in Florida provided almost 500,000 jobs for Floridians (Hodges and Mulkey 2002).

Florida produces 13% of the national VOS from greenhouse and nursery farming, while expending only 8% of the national energy expenditures for that farm-type. Very little energy end-use work has been done in the greenhouse sector. The most notable research has been carried out in New Zealand, where energy costs represent between 6 and 27% of production expenses for greenhouse crops. In the United States, that number is lower, averaging around 6% (4% in Florida) for a variety of reasons including climate, energy prices, delivery systems, process energy use, and different technology uses (e.g., insulation) between the U.S. and the New Zealand markets. The research, however, can be used as a helpful background piece for general energy use within the greenhouse farm-type.

Fruit and tree farming (NAICS 1112) is also prominent in Florida, presenting 24% of the total agricultural VOS for the state (while only 12% of the national VOS for that NAICS code). These farmers are expending 3% of the total state agricultural production expenses, but 8% of the total national energy expenditure for this type.

The final large piece of Florida's agricultural VOS is vegetable and melon farms, which produce 23% of the state's agricultural output and 11% of output for that farm-type nationwide. Energy expenditures comprise 4% of Florida's total agricultural production expenses for this farm-type, but 6% of the national total agricultural production expenses. It is likely that the energy expenditures are lower in Florida because the warm, wet, climate is hospitable to growing vegetables and melons, and there is less need for irrigation relative to the rest of the country.

On-Farm Energy Use

On-farm energy use in Florida is presented in Table 5. Aside from natural gas, which is not used as a primary fuel in Florida agriculture, the fuels are used about equally. Although there is certainly available data regarding motors, there is a significant amount of energy going to unknown or unmeasured end-uses in Florida. Despite the fact that the total energy use is smaller than average for specific farm-types, still fully half the energy used on those farm-types is uncharacterized.

Table 5 identifies the major farm-types in Florida as greenhouse/nurseries and fruit and nut types. In contrast to other citrus and vegetable farming-focused states, like California, the Census reports that only 45% of Florida farmland is irrigated and there is little difference between energy use on irrigated versus non-irrigated land (USDA 1999). While it is not a large amount of energy relative to other states, Florida-specific literature regarding its citrus fruit industry indicates that irrigation may represent up to a third of the energy production costs for that farm-type (Harrison 1992). Another notable difference between Florida and other irrigating states is that over half of Florida's irrigation is pumped with diesel fuel, and irrigation comprises most of the use of that fuel (USDA 2003a, 2003b). More detailed Florida data by farm-type can be found in the appendix.

In data regarding on-farm energy use for greenhouses, no Florida-specific data could be found. A New Zealand Ministry of Agriculture and Forestry (MAF) reported, however, that the primary direct energy use in greenhouses was for heating, ventilation, and cooling (HVAC) (Barber 2003). While climatic and market differences change the impact of HVAC system energy use in Florida, the Barber study points to a variety of complications stemming from this finding, not the least of which being the energy and productivity performance of different insulators of greenhouses. He found that while plastic greenhouses had better energy performance, the improvements were overshadowed by vegetable production decreases. We found no quantitative support for this finding, however, so it is not included in the quantitative analysis.

Table 5. End-Use Energy Use in Florida (in million Btus)

	Total Motors	Total Lighting	Onsite Transportation	Machinery	Other Not Categorized	Total
Total — All Farm-Types						
Gasoline	577,297	—	628,913	62,891	3,200,130	4,469,231
Diesel	281,335	—	208,866	563,938	4,165,779	5,219,918
Natural Gas	144	—	—	—	149,184	149,328
Other	3,185	53,581	—	107,162	3,957,675	4,121,602
Electricity	887,638	297,197	—	—	2,777,797	3,962,633
Total Petroleum	861,962	53,581	837,779	733,991	11,472,767	13,960,079
Total Energy	1,749,599	350,778	837,779	733,991	14,250,564	17,922,712
Greenhouse/ Nursery — Total Energy	1,598,605	61,172	124,488	530,460	2,797,001	5,111,725
Fruit and Tree — Total Energy	1,056,749	92,963	226,077	394,718	4,139,843	5,910,351

Kansas

Overview

Kansas produces 5% of the total U.S. agricultural VOS and purchases 0.2% of the total energy expenditures nationwide. (This is not a small number; Kansans spend $345 million on energy used in agriculture every year.)

The largest contributor to national VOS in Kansas is cattle feedlots. Twenty percent of the nation's VOS for this farm-type originates in Kansas, and the feedlots make up 43% of total agricultural VOS from Kansas. In Kansas, energy use in this farm-type is 1% of all production expenses. That's smaller than the nationwide average of 2%.

Literature reflects that direct energy use expenses on cattle feedlots is small, while the indirect energy uses of feed production (on irrigated land) and transportation to monitor and transport the animals uses most of the fossil fuel energy associated with cattle feedlots (University of Arizona 2002). This evidence is supported by the Census, which reports that in Kansas, less than 1% of the total production expenditures for cattle feedlots are from energy.

The Census also reports that over a third of the value of crops shipped in Kansas in 1997 were oilseed and grain (NAICS 1111). While still beneath the national average of 9% for energy-based production expenses, 7% of the farm-type expenses are energy related. Because the cattle industry is so regulated by USDA for health and safety reasons, energy has not been the focus of cost reductions, and few studies have approached energy use from an energy efficiency (as opposed to production efficiency) perspective.

On-Farm Energy Use

On-farm energy uses for cattle feedlots differ from crop farm energy uses. Machinery and onsite transportation are the major uses of energy for ranching (University of Arizona 2002). In Kansas, the major fuel for onsite transport is diesel (see Table 6). Grain farming creates the feed for these cattle, and it is not surprising to see these two subsectors partnered within a state. Grain farming is generally irrigated in Kansas, and the fuel preference for Kansans is natural gas (70% of irrigation expenses).

Table 6. End-Use Energy Use in Kansas (in million Btus)

	Total Motors	Total Lighting	Onsite Transportation	Machinery	Other Not Categorized	Total
Total — All Farm-Types						
Gasoline	283,528	—	62,887	31,443	4,760,913	5,138,772
Diesel	3,102,907	—	1,414,272	2,616,403	10,098,247	17,231,828
Natural Gas	1,561,060	—	—	—	11,061,417	12,622,476
Other	27	8,182	—	16,365	2,702,906	2,727,481
Electricity	285,611	128,124	—	—	3,857,061	4,270,795
Total Petroleum	4,947,522	8,182	1,477,158	2,664,211	28,623,483	37,720,557
Total Energy	5,233,133	136,306	1,477,158	2,664,211	32,480,544	41,991,352
Cattle Feedlots — Total Energy	1,700,177	100,725	104,609	1,594,591	5,758,505	9,258,608

New York

Overview

New York's agriculture VOS makes up only 1% of the national agricultural VOS. In several specific farm-types, the state makes up a larger part of the national VOS for that farm-type. In Dairy Cattle and Milk Production (NAICS 11222), for example, New York is responsible for 8% of the national VOS within the type.

On average, over all types of farms, New York's farmers spend 8% of their production expenses on energy, about 2% more than the national average. In all farm-types, New York is about 1% above the national average for expenditures on energy.

NAICS 11222 provides 56% of the total agricultural VOS for the state (and 0.8% of the national VOS for agriculture). State-specific energy expenditures for this farm-type amount to $87 million, or approximately 8% of total farm production expenses.

On-Farm Energy Use

As can be seen from Table 7, dairy accounts for the majority of energy use and motor energy use in the state. In 2003, the New York Research and Development Authority (NYSERDA), the public benefits fund administrator for the state of New York, commissioned a summary of dairy farm energy audits (Ludington and Johnson 2003). The report looked at 38 energy audits from both milk parlor- and tiestall-type dairy farms in New York and summarized the findings. The audits showed that energy end-uses on dairy farms include milk cooling, vacuum pumps, lighting, ventilation, electric water heating, feeding equipment, and manure handling. The study also reported on what types of efficiency measures the farms had in place, finding that over two-thirds of the farms had at least one of the following already installed: energy-efficient lights, refrigerator heat recovery, plate coolers, a variable speed drive (VSD) vacuum pump, and/or a VSD milk pump. Most of the savings on these farms was the result of VSD vacuum pumps.

Table 7. End-Use Energy Use in New York (in million Btus)

	Total Motors	Total Lighting	Onsite Transportation	Machinery	Other Not Categorized	Total
Total — All Farm-Types						
Gasoline	163,223	—	179,529	17,953	2,000,207	2,360,912
Diesel	1,014,788	—	442,592	774,536	3,625,256	5,857,172
Natural Gas	5,514	—	—	—	751,287	756,801
Other	47,301	40,063	—	80,126	3,316,256	3,483,746
Electricity	486,662	182,827	—	—	2,377,624	3,047,112
Total Petroleum	1,230,827	40,063	622,121	872,615	9,693,006	12,458,632
Total Energy	1,717,489	222,890	622,121	872,615	12,070,630	15,505,744
Dairy — Total Energy	1,093,687	26,196	44,771	1,187,519	4,395,940	7,189,113

Vermont

Overview

Vermont represents 0.2% of the nation's agricultural VOS, at just over $400 million in 1997. The vast majority of Vermont's agricultural income comes from dairy cattle and milk production (79%), and the state's production provides 2% of the nation's milk shipments. Vermont matches the national average percentage for energy expenditures for most farm-types, including dairy and milk production. For this farm-type, the total agricultural expenditures were $18.5 million in 1997.

On-Farm Energy Use

Dairy farms are a critical part of the Vermont economy, and as such have been the focus of many energy efficiency initiatives in the state, as shown in Table 8. Vermont farms function, like other farms around the country, on a small profit margin, and the state has taken the perspective that energy is a variable cost and decreasing it increases a farm's chance of survival. The dairy farm-type has very similar energy end-uses nationwide, and so the energy end-uses in Vermont are very similar to those in New York, including motors and lighting.

Table 8. End-Use Energy Use in Vermont (in million Btus)

	Total Motors	Total Lighting	Onsite Transportation	Machinery	Other Not Categorized	Total
Total — All Farm-Types						
Gasoline	3,032	—	3,311	331	125,094	131,769
Diesel	533,190	—	165,100	165,100	607,789	1,471,178
Natural Gas	—	—	—	—	—	—
Other	7,877	5,175	—	10,350	494,105	517,507
Electricity	66,007	28,575	—	—	406,726	501,308
Total Petroleum	—	—	—	—	1,226,988	1,226,988
Total Energy	610,106	33,750	168,411	175,781	1,633,714	2,621,762
Dairy — Total Energy	55,641	5,992	1,550	548,486	1,339,921	1,951,590

Wisconsin

Overview

Wisconsin represents 3% of the total national agricultural VOS, with crops having a market value of $5.5 billion. Energy expenses associated with these crops neared $300 million in 1997, 7% of the total Wisconsin production expenditures and 3.1% of the national agricultural production expenditure.

Over half (56%) of Wisconsin's VOS originates from dairy cattle and milk production (NAICS 11222). Energy production expenditures for this farm-type are slightly higher than the national average, at 7% rather than 6%. Regional differences contribute to this difference between Wisconsin and New York and Vermont. Fifteen percent of the national dairy VOS comes from Wisconsin.

Wisconsin's second largest VOS crop falls into the oilseed and grain farming category (NAICS 1111), comprising 12% of state VOS and 1% of the national VOS for this farm-type. Nationally, energy use on this farm-type represents 9% of the total farm production expenditures. In Wisconsin, energy represents only 6% of the total production expense for this type of farm.

On-Farm Energy Use

Like in California and Vermont, the bulk of energy use on dairy farms in Wisconsin is the cost of motors, primarily for pumping. Table 9 shows the dominance of motors as end-uses in Wisconsin, although it is important to note the amount of energy not identified with a specific end-use. Data from Canada filled some of the data holes for Wisconsin, as that country has done a lot of research on oilseed and grain farming in climates similar to Wisconsin's.

In Canada, energy use research on oilseed and grain farms has found that the primary energy end-use is for farm machinery (e.g., tractors and trucks) (Khakbazan 2000). This farm-type is a major feeder (no pun intended) to the large cattle ranching industry. Energy reduced in this basic farm-type will decrease energy costs for the many different farm-types that depend on it.

Table 9. End-Use Energy Use in Wisconsin (in million Btus)

	Total Motors	**Total Lighting**	**Onsite Transportation**	**Machinery**	**Other Not Categorized**	**Total**
Total — All Farm-Types						
Gasoline	193,112	—	212,785	21,279	2,891,128	3,318,304
Diesel	1,986,930	—	1,242,557	952,627	6,169,971	10,352,085
Natural Gas	21,829	—	—	—	1,781,960	1,803,789
Other	3,561	35,228	—	70,455	4,294,201	4,403,444
Electricity	1,155,525	413,738	—	—	4,426,944	5,996,207
Total Petroleum	2,205,432	35,228	1,455,342	1,044,360	15,137,260	19,877,622
Total Energy	3,360,957	448,966	1,455,342	1,044,360	19,564,204	25,873,829
Dairy — Total Energy	2,435,673	65,128	88,941	2,298,031	9,104,785	13,992,558
Cattle Feedlots — Total Energy	426,710	75,931	27,453	274,719	1,197,340	2,002,153

Major End-Uses

From the sample states in this report, it is clear that despite regional and farm-type differences, there are themes to energy use on the farm based on the available data. This section uses the national and state characterizations to outline three cross-cutting areas that use the largest amounts of on-farm energy: motors, lighting, and space conditioning.

Motors

Motor energy use is the primary use of energy for all farm-types that use irrigation because of the energy it takes to pump water to and through the system. California fruit and vegetable farming is the largest user of irrigation. Florida fruit and vegetable farmers also use irrigation, but because of the magnitude of the California market, the real energy use of the Florida market is much smaller. Where it might not be economical to design and promote an energy efficiency program for irrigation motors in Florida, designing a program in California and then transferring that program to Florida for more savings with less upfront cost for government agencies may be worthwhile.

Dairy farm-types are another candidate for motor energy efficiency programs due to their large use of pumps on the farm. Because dairy farms are the agricultural livelihood of many states in which they are prominent, many dairy energy efficiency programs have already been implemented in states such as New York, Vermont, and Wisconsin (Brown, Elliott and Nadel 2005). Continuing to quantify the end-uses of energy in the sector will allow a more accurate calculation of program-related energy and cost savings, as well as potential for savings in these and other states.

Lighting

On-farm lighting includes residential lighting as well as larger-scale lighting in barns, such as hog and pig farms, and area lighting. Lighting has long been known as a major electricity user in both the residential and commercial sectors. In these sectors, cross-cutting programs have introduced compact fluorescent lighting to the general public residential sector, efficient lighting fixtures and designs to the commercial sector. Similar programs could be designed and applied to almost all farm-types.

Energy-efficient lighting in these applications, however, must be carefully tested and designed. Research in North Carolina found that changing lighting to the most energy efficient type in hog, pig, and poultry farms had decreased the productivity of the animals (Elliott 1993). Productivity and other primary foci of agriculture must be incorporated into any effective energy efficiency program.

Space Conditioning

The final cross-cutting energy efficiency end-use is heating and cooling systems. Because of the diverse climatic regions that the agricultural sector covers and the varying requirement of different operations, heating and cooling systems offer a large market for energy efficiency programs. Hog and pig, poultry, and greenhouse farm-types have large cooling and heating loads.

Additional Data Needs

Determining on-farm energy use is complicated from a data collection standpoint because USDA has historically compartmentalized programs by farm output as opposed to farm processes. While it would be mildly unrealistic to expect USDA to change the priority of its agricultural programs based solely on the needs of energy efficiency, it may be possible to incorporate end-use data collection through the current USDA infrastructure—for example, through the agricultural census.

The first priority for data collection is to understand better the end-uses within different regions and farm-types. States and utilities are in a good position to carry out this research, as states have an understanding of important end-uses (more so than national data collectors), and utilities have a unique access to farmers, as they have the primary and sometimes only contact with the farmer regarding energy use on the farm. More clarity regarding what happens to energy on the farm also stands to aid the utilities in infrastructure and program planning.

Through the course of our research, we identified several end-uses that were widely accepted as using large amounts of energy, but we found little or no quantitative evidence usable for the characterization. While the magnitude of the end-use will vary with region and farm-type, these are end-uses that may be a large expense for large groups of farmers and therefore could be good opportunities for targeting energy efficiency programs. We recommend that the following qualitatively identified as important end-uses be the priority for data collection:

- Drying and Curing
- Heating, Ventilation, and Air Conditioning
- Water Heating (residential numbers were used for this study)

Even end-uses for which we had quantitative data could be solidified through improved or expanded data collection. Onsite transportation, for instance, is only vaguely defined, lacking clarity as to when onsite transportation transitions into freight transportation away from the farm. Because freight transportation is thought to be a large portion of energy use in food production, the distinction becomes important. Further, with data being collected by a variety of different agencies, this is just one example of data that needs to be better clarified.

To summarize, we recommend two steps for increasing data availability and usefulness:

1. Individual end-uses be identified and their energy use quantified. We recommend that this be done at the state or local level, by the state or the utility service, as both those agencies will gain from the knowledge as well as the farmers.
2. Definitions for farm-types and end-uses need to be clarified in order to more accurately reflect reality. We recommend that this be done at the national level because it is at the national level that the data could later be compiled and used to identify large-scale national cost-saving energy efficiency opportunities.

Conclusion

In the growing and constantly economically streamlining agricultural sector, energy has emerged as a variable cost. Energy efficiency offers an opportunity to minimize energy costs to the farmer, decrease pollution, delay the need for electric grid infrastructure improvements, and increase productivity. Although plentiful, available agriculture data is not ideal for measuring energy by end-use, thereby making it difficult to predict where the largest opportunities for energy efficiency are. Estimates in this report are accurate enough to reflect variation among states and regions regarding the economic importance of energy use among different regions and states. This characterization is sufficient for general policy development, including identification of the greatest energy needs and reasons to pursue them. Brown and Elliott (2005), the companion report to this one, although accurate enough to show that there are large opportunities in the agriculture sector for energy savings, would be greatly improved by better baseline data on energy end-use.

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Appendix: In-Depth Data Tables

Table A-1. End-Use Energy Use by Farm-Type and End-Use USA (in trillion Btus)

	Total Motors	Total Lighting	Onsite Transport	Machinery	Other Not Categorized	Total
Total —All Farm-Types						
Gasoline	134	—	2	1	5	142
Diesel	7	—	28	77	249	361
Natural Gas	2	—	—	—	94	98
Other	15	2	—	2	169	195
Electricity	9	3	—	—	136	153
Total Petroleum	158	2	30	80	517	796
Total Energy	167	5	30	80	653	949
Poultry						
Gasoline	3	—	0	4	0	7
Diesel	0	—	0	1	5	6
Natural Gas	0	—	—	0	10	10
Other	2	0	0	3	28	33
Electricity	5	1	—	6	6	18
Total Petroleum	6	0	1	7	44	58
Total Energy	12	1	1	13	49	63
Dairy	—	—	—	—	—	—
Gasoline	8	—	0	1	0	9
Diesel	1	—	—	12	22	34
Natural Gas	0	—	—	—	2	2
Other	1	—	—	—	11	14
Electricity	3	0	—	—	20	23
Total Petroleum	10	—	0	13	35	59
Total Energy	12	0	0	13	54	83
Greenhouse/Nursery						
Gasoline	6	—	0	1	0	7
Diesel	0	—	—	3	5	8
Natural Gas	0	—	—	—	16	16
Other	1	0	—	0	7	8
Electricity	1	0	—	—	6	7
Total Petroleum	7	0	0	4	28	39
Total Energy	8	0	0	4	34	46
Cattle Feedlots						
Gasoline	33	—	0	3	1	38
Diesel	1	—	—	25	39	65
Natural Gas	0	—	—	—	8	8
Other	2	0	—	0	21	24
Electricity	0	3	—	—	17	20
Total Petroleum	37	0	0	29	69	136
Total Energy	37	3	0	29	87	156

	Total Motors	Total Lighting	Onsite Transport	Machinery	Other Not Categorized	Total
Oilseed and Grain Farming						
Gasoline	43	—	0	4	2	50
Diesel	1	—	7	7	23	38
Natural Gas	0	—	—	—	22	23
Other	4	1	—	1	46	52
Electricity	0	0	—	—	0	0
Total Petroleum	49	1	8	13	93	163
Total Energy	49	1	8	13	93	163
Fruit and Tree						
Gasoline	8	—	0	1	0	9
Diesel	0	—	1	3	7	11
Natural Gas	0	—	—	—	2	2
Other	0	—	—	0	4	4
Electricity	0	0	—	—	10	11
Total Petroleum	8	—	1	4	12	26
Total Energy	8	0	1	4	23	37
Hog and Pig						
Gasoline	3	—	0	0	0	4
Diesel	0	—	0	1	7	8
Natural Gas	0	—	—	—	2	2
Other	1	0	—	0	10	11
Electricity	3	1	—	—	2	6
Total Petroleum	4	0	0	1	19	25
Total Energy	7	1	0	1	21	31

Table A-2. End-Use Energy Use by Farm-Type and Fuel-Type in California (in trillion Btus)

	Total Motors	Total Lighting	Onsite Transportation	Machinery	Other Not Categorized	Total
Total — All Farm—Types						
Gasoline	1	—	1	0.1	10	12
Diesel	4	—	3	3	17	26
Natural Gas	0.383	—	—	—	10	11
Other	0.001	0.023	—	0.05	7.7	8
Electricity	4	2	—	—	13	19
Total Petroleum	5	0.02	4	3	44	56
Total Energy	9	2	4	3	58	75
Dairy						
Gasoline	0.85	—	0.05	0.05	0.03	1
Diesel	0.06	—	—	1.06	2.10	3
Natural Gas	0.01	—	—	—	0.46	0
Other	0.11	—	—	—	1.30	1
Electricity	0.63	0.06	—	—	2.69	3
Total Petroleum	1.04	—	0.05	1.11	3.89	6
Total Energy	1.67	0.06	0.05	1.11	6.58	9
Greenhouse/Nursery						
Gasoline	2	—	0.1	0	0.07	2
Diesel	0.06	—	—	1	1.95	3
Natural Gas	0.17	—	—	—	7.14	7
Other	0.12	0.004	—	0	1.35	1
Electricity	1	0.2	—	—	2.25	3
Total Petroleum	2	0.0	0.1	1	10.51	14
Total Energy	3	0.2	0.1	1	12.75	17
Cattle Feedlots						
Gasoline	1	—	0.0	0.0	0.03	1
Diesel	0	—	—	0.3	0.52	1
Natural Gas	0	—	—	—	0.00	0
Other	0	0.0	—	0.0	0.41	0
Electricity	0	0.1	—	—	0.42	1
Total Petroleum	1	0.0	0.0	0.4	0.96	2
Total Energy	1	0.1	0.0	0.4	1.39	3
Oilseed and Grain Farming						
Gasoline	0.4	—	0.0	0.0	0.01	0
Diesel	0.0	—	0.3	0.3	1.02	2
Natural Gas	—	—	—	—	—	—
Other	0.0	0.0	—	0.0	0.33	0
Electricity	0.0	0.0	—	—	0.47	1
Total Petroleum	0.5	0.0	0.3	0.3	1.37	3
Total Energy	0.5	0.0	0.3	0.3	1.84	3

	Total Motors	Total Lighting	Onsite Transportation	Machinery	Other Not Categorized	Total
Fruit and Tree						
Gasoline	4	—	0.2	0	0.15	5
Diesel	0	—	1.3	3	7.37	12
Natural Gas	0	—	—	—	2.36	2
Other	0	0.0	—	0	2.36	3
Electricity	0	0.4	—	—	7.51	8
Total Petroleum	5	0.0	1.6	3	12.24	22
Total Energy	5	0.4	1.6	3	19.74	30

Table A-3. End-Use Energy Use by Farm-Type and End-Use in Florida (in million Btus)

	Total Motors	Total Lighting	Onsite Transportation	Machinery	Other not Categorized	Total
Total — All Farm-Types						
Gasoline	577,297	—	628,913	62,891	3,200,130	4,469,231
Diesel	281,335	—	208,866	563,938	4,165,779	5,219,918
Natural Gas	144	—	—	—	149,184	149,328
Other	3,185	53,581	—	107,162	3,957,675	4,121,602
Electricity	887,638	297,197	—	—	2,777,797	3,962,633
Total Petroleum	861,962	53,581	837,779	733,991	11,472,767	13,960,079
Total Energy	1,749,599	350,778	837,779	733,991	14,250,564	17,922,712
Greenhouse/Nursery — Total Energy						
Gasoline	1,353,805	—	124,488	77,805	—	1,556,098
Diesel	44,016	—	—	440,310	1,716,491	2,200,817
Natural Gas	—	—	—	—	—	—
Other	37,986	6,173	—	12,345	418,317	474,821
Electricity	162,798	54,999	—	—	662,192	879,989
Total Petroleum	—	—	—	—	2,134,809	2,134,809
Total Energy	1,598,605	61,172	124,488	530,460	2,797,001	5,111,725
Fruit and Tree — Total Energy						
Gasoline	855,799	—	59,021	59,021	9,837	983,677
Diesel	29,444	—	88,362	206,179	1,148,231	1,472,217
Natural Gas	1,612	—	—	—	147,044	148,656
Other	156,383	25,412	—	50,825	1,722,172	1,954,793
Electricity	13,510	67,550	—	—	1,269,948	1,351,008
Total Petroleum	—	—	—	—	3,027,284	3,027,284
Total Energy	1,056,749	92,963	147,383	316,024	4,297,232	6,710,330

Table A-4. End-Use Energy Use by Fuel and Farm-Type in Kansas (in million Btus)

	Total Motors	Total Lighting	Onsite Transportation	Machinery	Other Not Categorized	Total
Total — All Farm-Types						
Gasoline	283,528	—	62,887	31,443	4,760,913	5,138,772
Diesel	3,102,907	—	1,414,272	2,616,403	10,098,247	17,231,828
Natural Gas	1,561,060	—	—	—	11,061,417	12,622,476
Other	27	8,182	—	16,365	2,702,906	2,727,481
Electricity	285,611	128,124	—	—	3,857,061	4,270,795
Total Petroleum	4,947,522	8,182	1,477,158	2,664,211	28,623,483	37,720,557
Total Energy	5,233,133	136,306	1,477,158	2,664,211	32,480,544	41,991,352
Cattle Feedlots — Total Energy						
Gasoline	1,487,373	0	104,609	104,609	13,033	1,709,624
Diesel	72,617	0	0	1,489,982	2,068,261	3,630,860
Natural Gas	68,186	0	0	0	1,772,005	1,840,190
Other	59,690	2,238	0	0	686,438	748,367
Electricity	12,311	98,486	0	0	1,218,769	1,329,566
Total Petroleum	0	0	0	0	4539737	4539737
Total Energy	1,700,177	100,725	104,609	1,594,591	5,758,505	9,258,608
Oilseed and Grain Farming —Total Energy						
Gasoline	2,358,649	0	165,887	165,887	20,667	2,711,091
Diesel	234,013	0	2,400,774	2,400,774	6,665,084	11,700,645
Natural Gas	354,269	0	0	0	9,206,683	9,560,952
Other	122,172	4,581	0	0	1,404,981	1,531,735
Electricity	19,226	57,677	0	0	1,903,331	1,980,234
Total Petroleum	0	0	0	0	17297416	17297416
Total Energy	3,088,329	62,258	2,566,662	2,566,662	19,200,747	27,484,657

Table A-5. End-Use Energy Use by Fuel and Farm-Type in New York (in million Btus)

	Total Motors	Total Lighting	Onsite Transportation	Machinery	Other Not Categorized	Total
Total — All Farm-Types						
Gasoline	163,223	—	179,529	17,953	2,000,207	2,360,912
Diesel	1,014,788	—	442,592	774,536	3,625,256	5,857,172
Natural Gas	5,514	—	—	—	751,287	756,801
Other	47,301	40,063	—	80,126	3,316,256	3,483,746
Electricity	486,662	182,827	—	—	2,377,624	3,047,112
Total Petroleum	1,230,827	40,063	622,121	872,615	9,693,006	12,458,632
Total Energy	1,717,489	222,890	622,121	872,615	12,070,630	15,505,744
Dairy						
Gasoline	640,283	—	36,798	36,798	22,079	735,957
Diesel	65,896	—	—	1,120,363	2,108,553	3,294,812
	901	—	—	—	61,729	62,631
Other	124,644	—	—	—	838,542	1,314,371
Electricity	261,962	26,196	—	—	1,403,369	1,781,343
Total Petroleum	831,724	—	36,798	1,157,161	3,030,903	5,407,770
Total Energy	1,925,411	26,196	73,596	2,314,321	4,434,272	8,773,796

Table A-6. End-Use Energy Use by Fuel and Farm-Type in Vermont (in million Btus)

	Total Motors	Total Lighting	Onsite Transportation	Machinery	Other not Categorized	Total
Total — All Farm-Types						
Gasoline	3,032	—	3,311	331	125,094	131,769
Diesel	533,190	—	165,100	165,100	607,789	1,471,178
Natural Gas	—	—	—	—	—	—
Other	7,877	5,175	—	10,350	494,105	527,857
Electricity	66,007	28,575	—	—	406,726	501,308
Total Petroleum	544,098	5,175	168,411	175,781	1,226,988	2,130,804
Total Energy	610,106	33,750	168,411	175,781	1,633,714	2,632,112
Dairy						
Gasoline	—	—	1,550	2,325	73,241	77,117
Diesel	—	—	—	546,161	535,339	1,081,500
Natural Gas	—	—	—	—	—	—
Other	—	—	—	—	342,440	409,559
Electricity	55,641	5,992	—	—	388,901	471,078
Total Petroleum	—	—	1,550	548,486	951,020	1,568,175
Total Energy	55,641	5,992	1,550	548,486	1,339,921	2,039,253

Table A-7. End-Use Energy Use by Farm and Fuel-Type in Wisconsin (in million Btus)

	Total Motors	Total Lighting	Onsite Transportation	Machinery	Other Not Categorized	Total
Total — All Farm-Types						
Gasoline	193,112	—	212,785	21,279	2,891,128	3,318,304
Diesel	1,986,930	—	1,242,557	952,627	6,169,971	10,352,085
Natural Gas	21,829	—	—	—	1,781,960	1,803,789
Other	3,561	35,228	—	70,455	4,294,201	4,403,444
Electricity	1,155,525	413,738	—	—	4,426,944	5,996,207
Total Petroleum	2,205,432	35,228	1,455,342	1,044,360	15,137,260	19,877,622
Total Energy	3,360,957	448,966	1,455,342	1,044,360	19,564,204	25,873,829
Dairy						
Gasoline	1,508,363	—	88,941	133,411	3,035	1,733,750
Diesel	120,227	—	—	2,164,619	3,726,502	6,011,348
Natural Gas	3,654	—	—	—	220,893	224,547
Other	158,214	—	—	—	1,819,464	1,977,679
Electricity	645,215	65,128	—	—	3,334,891	4,045,235
Total Petroleum	1,790,458	—	88,941	2,298,031	5,769,894	9,947,324
Total Energy	2,435,673	65,128	88,941	2,298,031	9,104,785	13,992,558
Cattle Feedlots						
Gasoline	372,469	—	27,453	27,453	749	428,125
Diesel	11,998	—	—	240,020	347,885	599,903
Natural Gas	2,089	—	—	—	126,247	128,336
Other	36,224	3,622	—	7,245	405,714	452,806
Electricity	3,930	72,309	—	—	316,744	392,982
Total Petroleum	422,780	3,622	27,453	274,719	880,596	1,609,170
Total Energy	426,710	75,931	27,453	274,719	1,197,340	2,002,153