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# Energy Usage Survey of Dairies in the Southwestern United States

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***Abstract.*** *A survey of 14 dairies in Texas and California was conducted to determine their total energy use on an annual basis. The goal of the survey was to evaluate the effect of production and management processes on energy consumption. The total energy used on facilities varied widely with the type of operation; e.g., pasture, open lot, or hybrid (a combination of open-lots and free-stall) systems, as well as with the relative age of the facility. The on-farm energy supply sources included electricity, gasoline, diesel, propane, and natural gas. Total energy usage ranged from as low as 464 kWh per year per animal (kWh/yr·a) for a pasture dairy in Northeast Texas, to as high as 1,637 kWh/yr·a for a hybrid facility in Central Texas. The electricity usage at the dairies was allocated to four main energy sinks, the milking parlor, the animal housing areas, feeding, and waste management, where possible. Generally, milking and housing components dominated the electrical usage for hybrid dairies with the milking parlor being the primary consumer of energy for the open-lot facilities.*

**Keywords.** Dairy, electricity, propane, free-stall, open lot, alternative energy.

## Introduction

Increasing energy costs across the country have led to significant interest in the use of alternative sources of energy that may already be available at an animal feeding operation (AFO) such as manure or other biomass for power generation. There are three major forms of energy consumed on dairies in the southwestern United States: electricity, liquid fuels (diesel and gasoline), and gaseous fuels (propane and natural gas). The liquid fuels are typically used in vehicles for transportation and delivery of feed and equipment while the gaseous fuels are primarily used for heating water during winter months. The array of fuel sources, all with a different energy content, are typically acquired from different suppliers creating a challenge for operators to accurately quantify the total amount of energy used at a facility.

Ryan and Tiffany (1998) estimated energy usage on dairies in Minnesota to determine the impact of carbon taxes on the industry. They reported an annual usage of diesel, electricity, propane and gasoline on a 100 lb-weight of milk basis along with the average milk production and heard size allowing for conversion to other units. Annual energy expenditures were estimated at 779 kWh per year per animal (kWh/yr·a) for diesel, 628 kWh/yr·a for electricity, 377 kWh/yr·a for propane, and 114 kWh/yr·a for gasoline. There was no discussion of the uses of the different energy sources on the dairy; however, the estimates were specifically for dairy operation only and did not include any agronomic farming operations. Electricity use is generally assumed to be for milking operations including cooling of milk. The primary use of propane is for heating buildings and water; this is assumed to be a significantly larger requirement in the much colder climate of Minnesota than dairies in the mild southwest climate.

Minott and Scott (2001) reported fuel use on a 500 cow, free-stall dairy in the state of New York. The analysis was conducted as part of a feasibility study for implementation of a fuel cell for energy conversion using lagoon biogas as the fuel source. They reported electricity and propane usage on an annual basis. The total electricity consumption was 413,869 kWh resulting in energy usage of 828 kWh/yr·a. They reported a detailed breakdown of the ultimate use of energy across the facility. Ventilation fans, operated on a continuous basis, were the highest consumer of electricity resulting in approximately 27% of the total energy usage. The next largest consumer of power was the vacuum pump used for milking operations, with 26% of the total energy consumption. Annual propane usage was reported as 18,570 liters or 214 kWh/yr·a. The only uses of propane were reported as building and water heating.

Both studies described above were for dairy facilities in the Northern regions of the United States that experience significantly different climactic conditions than the southwestern United States. Therefore, the main objective of this research was to assess energy usage on dairies in the southwestern United States. In this study we quantified energy usage using information available at the facility-wide level and then compared the energy usage between dairies with different management styles, relative age, and location.

## Review of Dairy Management Systems in Texas and California

Dairy management systems in the southwest are based on the type of housing used for the cattle. Two main types of housing are used, free-stalls and open lots. Free-stalls consist of open air barns with paved floors and individual stalls for the cattle. Open lot facilities consist of earthen pens with a paved feed lane and small shade structures for the cattle. However, most dairies consist of either a completely open lot facility or a combination of free-stalls and open-lots, known as a hybrid facility. Additionally, a small number of operations exist where dairy cows are housed on pastures.

Free-stall housing structures provide increased comfort for animals by providing full shade and relatively dry bedding area. Fans and water dripping systems operated in free-stalls during warm months cool cattle. Conversely, open lot facilities have shelters for shade but do not have any other cooling systems in the housing area.

The dairies included in this study were located in three regions of Texas and in the San Joaquin Valley of California. Texas regions were Central, the Panhandle, and Northeast Texas. Table 1 shows the types and locations of the dairies surveyed in this study along with the types of energy used. The dairies in Central Texas consisted of one open lot and three hybrid dairies. Two dairies were selected for sampling in the Panhandle of Texas; one was an open lot dairy while the other was a hybrid system. The dairies surveyed in the Northeast region consisted of small pasture dairies. Therefore, these dairies were expected to have significantly less energy usage than other types. The dairies in California were all located in the San Joaquin Valley. Dairies W1 through W5, located in the Modesto area, were owned and managed by a single company. The other two dairies in California were located in the Central San Joaquin Valley and were managed by a single company as well. All California dairies included in this study were hybrid facilities, which is the prevalent type of dairy operation in the region.

Table 1. Management system, size (number of dairy cattle), and types of energy used at the dairies surveyed.

| | Dairy | Size | Management | Electricity | Liquid Fuels | | Gaseous Fuels | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Diesel | Gasoline | Propane | Natural Gas |
| Texas | C2 | 2200 | Hybrid | ✓ | ✓ | | ✓ | |
| | C3 | 2100 | Open Lot | ✓ | ✓ | | ✓ | |
| | C5 | 550 | Hybrid | ✓ | ✓ | | ✓ | |
| | C7 | 990 | Hybrid | ✓ | ✓ | ✓ | ✓ | |
| | P1 | 7000 | Hybrid | ✓ | ✓ | | ✓ | |
| | P5 | 6000 | Open Lot | ✓ | ✓ | | | ✓ |
| | E1 | 180 | Pasture | ✓ | ✓ | | | |
| California | D1 | 2400 | Hybrid | ✓ | ✓ | | ✓ | |
| | D2 | 3500 | Hybrid | ✓ | ✓ | | ✓ | |
| | W1 | 735 | Hybrid | ✓ | ✓ | ✓ | ✓ | |
| | W2 | 1180 | Hybrid | ✓ | ✓ | ✓ | ✓ | ✓ |
| | W3 | 850 | Hybrid | ✓ | ✓ | ✓ | ✓ | |
| | W4 | 1190 | Hybrid | ✓ | ✓ | ✓ | ✓ | |
| | W5 | 1780 | Hybrid | ✓ | ✓ | ✓ | ✓ | |

## Methods

Each dairy provided varying levels of information for the survey. For example, some dairies kept a detailed record of electricity usage on a monthly basis for every meter billed while others only had billing statements for a winter month and a summer month. Ultimately, utility companies were contacted to provide actual annual usage recorded by the various meters at a given dairy. The variation in available data was true for all three energy sources.

### *Electrical Usage*

Total annual electrical energy consumption for each dairy was obtained from billing information obtained from each dairy or from the utility company with the dairy's permission. Total electrical usage was subdivided according to use for milking, housing, waste management, feeding, and fresh water pumping. The most complete data for electrical energy usage was the availability of monthly bills for each meter installed at a dairy, with each meter dedicated to a specific process or operation. However, this detailed information was not available for all dairies surveyed, so alternative methods for estimating electrical energy usage from incomplete data were evaluated.

For Method 1, it was assumed that a bill for one of the winter months (December or January) represented usage for half the year and a bill for one of the summer months (June or July) represented usage for the other half of the year. The average of these two bills then represented the average monthly usage over the entire year and was used to calculate annual usage on a per-animal basis.

For Method 2, a portion of the year covering both summer and winter months was used to calculate an average monthly usage during that period. Total usage for the period was calculated by subtracting the starting meter reading for the period from the ending meter reading for the period. Total usage was divided by the number of months in the period to get an average monthly usage. This average was then used to calculate the annual usage on a per-animal basis.

For Method 3, the difference in starting meter readings for bills from the same month one year apart were used to estimate annual usage. One problem with both the second and third methods was estimating the number of times the meter reset to zero as it cycled past 100,000 kWh during the usage period.

USDA Farm Energy Calculator

The USDA has developed an energy estimator for animal housing to help operators estimate possible savings from changes in their operations (USDA, 2008). Inputs for the calculator include the region where the facility is located, the number of cattle, and milk production. Additionally, types of equipment used and operating parameters for the major consumers of electrical energy are specified by the user. The output includes estimates of the energy used for long-day lighting, air circulation, milk cooling, water heating, and milk harvest.

Results from the energy estimator provide an approximation of the energy used by some of the major systems on a dairy. However, direct comparison of the energy usage estimated by this calculator with results from the energy survey is difficult because the USDA energy estimator doesn't take into account the use of electricity for pumping of fresh water and operations such as offices and break rooms that are present on most facilities.

### *Liquid Fuels*

Liquid fuels were used to power all mobile equipment on the dairies as well as generators for backup power in emergency situations. The primary use of these fuels was to power the equipment used for feeding and for general use around the dairy facility. No liquid fuel use values could be assigned to individual operations because the fuel was bought and stored in bulk. One dairy operator in the San Joaquin Valley actually kept records as to how much fuel was consumed by individual vehicles, but the vehicles were used at all dairies operated by the management company making it difficult to determine liquid fuel used by an individual dairy. Typically, dairies use liquid fuel on an as needed basis without assigning it to specific uses (feeding, scraping etc.). However, all dairies surveyed were able to separate fuel usage for farming from that used for dairy operations.

### *Gaseous Fuels*

Gaseous fuels are typically used in only a few locations on dairies. The primary uses of gaseous fuels were for heating the water used for cleaning operations and heating buildings. Dairies thoroughly clean all milking equipment and keep a clean working area while milking, resulting in large amounts of energy used for water heating. The annual usage of these fuels was obtained from all facilities by compiling consecutive monthly bills for one year.

## Results

### *Electrical Usage*

Because the availability of data for electrical usage varied among the dairies, it was important to evaluate different methods developed to estimate annual usage. To determine the differences among the estimating methods, they were applied to data for dairies C2 and C3 for which complete records were obtained. These dairies were selected for analysis because they represented the two primary types of dairies in the southwest, hybrid and open lot, and they were located in the same region of Central Texas. Results from applying these methods to estimate electrical consumption for various energy sinks at the dairies are shown in Table 2.

Table 2. Comparison of electrical energy usage on dairies C2 and C3 calculated using different estimation methods with actual usage (kWh/yr·a).

| | Dairy C2 | | | | Dairy C3 | | | |
|---|---|---|---|---|---|---|---|---|
| Method: | Actual | 1 | 2 | 3 | Actual | 1 | 2 | 3 |
| Milking | 312 | 306 | 296 | 309 | 495 | 564 | 537 | 496 |
| Housing | 149 | 175 | 164 | 151 | 0 | 0 | 0 | 0 |
| Waste Management | 151 | 147 | 91 | 153 | 15 | 8 | 11 | 14 |
| Feeding | 13 | 8 | 8 | 11 | 5 | 5 | 5 | 5 |
| Water | 98 | 59 | 94 | 46 | 52 | 48 | 50 | 51 |
| Total | 723 | 695 | 652 | 670 | 566 | 625 | 602 | 566 |

The data in the "Actual" columns represent the electrical energy usage for an entire year as reported by the utility company for the period from March, 2006, through February, 2007. Method 1 assumed that the average monthly electrical usage was equal to the average of a winter (December or January) bill and a summer (June or July) bill. This average was then used to calculate annual consumption per animal. For Method 2, a summer bill was selected to provide a starting meter reading and a winter bill for an ending reading. For example, the bill covering the usage period from June 28, 2006, to July 29, 2006, for diary C2 was selected to provide a starting meter reading and the bill covering usage from January 28, 2007, to February 28, 2007, provided an ending meter reading. The average monthly electrical usage for this period was then used to estimate annual usage. To apply Method 3, meter readings from bills one year apart, e.g., the starting meter reading for March, 2006, and ending meter reading for February, 2007. Annual usage was estimated by taking the difference between these readings. A drawback of both Methods 2 and 3 is that the number of times each meter resets to zero as it passes 100,000 kWh must be estimated to calculate usage during the period.

## Texas Dairies

Ultimately, complete annual electrical usage data were obtained for all dairies except Texas dairies C5 and C7. Only data for one winter and one summer month were available for those dairies, so Method 2 was used to estimate annual usage. Table 3 shows the results of this analysis.

Table 3. Texas dairy electrical usage on an annual per animal basis (kWh/yr·a).

| | Texas Dairies | | | | | | |
|---|---|---|---|---|---|---|---|
| | C2 | C3 | C5 | C7 | P1 | P5 | E1 |
| Milking | 312 | 495 | 312 | 525 | 161 | 241 | 217 |
| Housing | 149 | 0 | 58 | 62 | 48 | 15 | N/A |
| Waste Management | 151 | 15 | 21 | 82 | 0 | 9 | 63 |
| Feeding | 13 | 5 | N/A | 13 | 6 | 2 | N/A |
| Water | 98 | 52 | 14 | 9 | 83 | N/A | N/A |
| Total | 723 | 566 | 406 | 692 | 299 | 268 | 280 |
| Source[1] | A | A | 2 | 2 | A | A | A |

[1] "A" indicates actual data reported, and a number indicates which method was used to estimate values for that dairy.

Dairy C2 was a hybrid facility that used water to flush manure from the free-stall barns. This method consisted of pumping lagoon water into large storage tanks that subsequently released large volumes of water to remove the manure from the free-stalls. The water was then collected in a holding basin, pumped through a solids separation system, and drained back into the lagoon. The separated solids were stored for later composting. Additionally, this dairy had a rotary milking parlor built in 2003 that used a variable frequency drive vacuum pump that consumes less energy than the traditional constant speed pump. The feeding component of the electrical usage on this dairy was primarily attributed to a small feed grinding facility that was used occasionally.

Dairy C3 was an open lot dairy located in the same region and operated by the same owner as dairy C2. This facility had an older milking parlor that did not use a variable frequency drive pump or scroll compressors. Therefore, dairy C3 used approximately 59% more energy on a per animal basis for milking than dairy C2. However, being an open lot dairy, it used no electrical energy for housing. Additionally scraping manure from open lots with a tractor compared to flushing free-stalls in a hybrid dairy saved considerable amounts of electricity on an annual basis. Therefore, the total energy usage on a per animal basis at dairy C3 was less than that at a similar size free-stall dairy.

Dairy C5 used a vacuum system to collect manure from its free-stalls which was applied to fields in close proximity to the dairy. This dairy did not use a solids separation system for effluent flowing to the lagoon which resulted in lowered electrical usage. Additionally, the use of the vacuum system required significantly less pumping of water for flushing the free-stalls. Hence, the electrical usage of dairy C5 was lower than either dairy C2 or C3 on a per animal basis.

Dairy C7 was a unique dairy in this study because it contained an experimental covered lagoon biogas digester designed to use the methane produced to power an electric generation unit. The resulting electrical energy was designated to aerate the effluent from the digester to accelerate solids settling leading to lower nutrient loading rates in the aerated effluent applied to the surrounding land. However, the digester operation was halted due to technical difficulties but the aeration system continued operation by using electricity supplied by the local utility company. This resulted in a 34% increase in the total electrical energy usage of dairy C7.

Dairies P1 (hybrid) and P5 (open lot) located in the Panhandle of Texas between Amarillo and Lubbock, had similar herd sizes and experienced similar climatic conditions. Both dairies used less electricity than the dairies located in Central Texas having similar management and housing systems.

Dairy P1 used significantly less electricity than all the comparable Central Texas facilities for several reasons. First, this dairy scraped manure lanes with tractors instead of flushing them with water or using a vacuum system. Additionally, a high capacity pre-cooler for milk that used well water to pre-cool the milk prior to its storage drastically reduced electrical usage but increased electrical usage for pumping water compared to other hybrid dairies in Table 3.

The open lot dairy P5 used electrical energy primarily for milking. Security lights in open lots, feeding operation, and irrigation of wastewater to crop and hay fields contributed to far less electrical energy use as compared to milking.

Dairy E1 was a pasture dairy in Northeast Texas with approximately 180 cattle. The dairy only milked twice daily as compared to three times a day by hybrid or open lot dairies, decreasing its electrical usage. There were no housing structures for the cattle resulting in no electrical usage. The waste management system consisted of pumping wash water from the milking parlor to a wastewater storage structure that was higher in elevation than the milking parlor. Hence, milking and waste management were the only electrical usage components for the dairy.

## California Dairies

Table 4 shows the electricity usage for California dairies. The water and housing usage for all dairies was included in the milking center electrical usage as it was recorded on a common meter. Dairies labeled D1 and D2 were operated by the same owner with dairy D1 being the older of the two. Dairy D2 had newer pumps that were more appropriately sized for the milking parlor which accounts for the difference in electrical usage for milking. Dairy D2 pumped lagoon effluent a greater distance to flush free-stalls than dairy D1 and so consumed more electrical energy for waste management. The electrical usage for feeding was negligible on an annual per animal basis.

Dairies W1 through W5 were operated by one company with different site specific managers. All five dairies were located within a 5 mile radius in the Northern San Joaquin Valley. Like the other California dairies, these dairies recorded their water, housing and milking electrical usage on a common meter. Feeding operations were shared among them and are shown in Table 4 as the same average value for each dairy. The differences in electrical usage by dairies W1 through W5 were attributed to variable worker skills, pumping requirements and waste management systems among the dairies.

Table 4. California dairy electrical usage on an annual per animal basis (kWh/yr·a).

| | California Dairies | | | | | | |
|---|---|---|---|---|---|---|---|
| | D1 | D2 | W1 | W2 | W3 | W4 | W5 |
| Milking<br>Housing | 383 | 314 | 686 | 492 | 413 | 576 | 550 |
| Waste Management | 28 | 65 | 102 | 207 | 245 | 255 | 262 |
| Feeding | 0 | 0 | 4 | 4 | 4 | 4 | 4 |
| Water | - | - | - | - | - | - | - |
| Total | 411 | 379 | 792 | 700 | 658 | 832 | 812 |
| Source[1] | A | A | A | A | A | A | A |

[1]Actual data were available for all dairies.

### *USDA Farm Energy Calculator*

The USDA farm energy calculator was used to estimate electrical usage for a theoretical 1000 cow dairy in College Station, TX. Two cases were evaluated, a baseline scenario using the worst case assumptions and a peak efficiency scenario assuming the lowest energy usage. Equipment for the dairy included mercury vapor long-day lighting, fans that are not cleaned in both the free-stall and milking parlor, no pre-cooler or scroll compressor used for milk cooling, and constant speed drive for the vacuum pump. Daily milk production was assumed to be 29.5 kg/d·a (65 lb/d·a). Results for these two scenarios are presented in Table 5.

Table 5. Electrical usage at a dairy in Central Texas estimated using the USDA farm energy calculator for both the highest and lowest efficiency options.

| | Energy Usage (kWh/yr·a) | |
|---|---|---|
| | Baseline | Peak Eff |
| Housing (lighting, air circulation) | 291 | 116 |
| Milking (milk cooling, milk harvest) | 427 | 220 |
| Total | 718 | 336 |

In comparing these values to those obtained from the Central Texas dairies in the survey, the estimated usage for housing is somewhat higher but that for milking is comparable. This calculator does not estimate energy used for waste management and therefore, the total electrical usage cannot be directly compared.

Figure 1 shows electrical consumption by process on each dairy included in the study. Values for total usage estimated using the USDA calculator are included as horizontal lines on the figure. The housing and milking usage total for all the dairies except the two Panhandle dairies, the Northeast Texas dairy and one California dairy are within the range estimated by the USDA calculator.

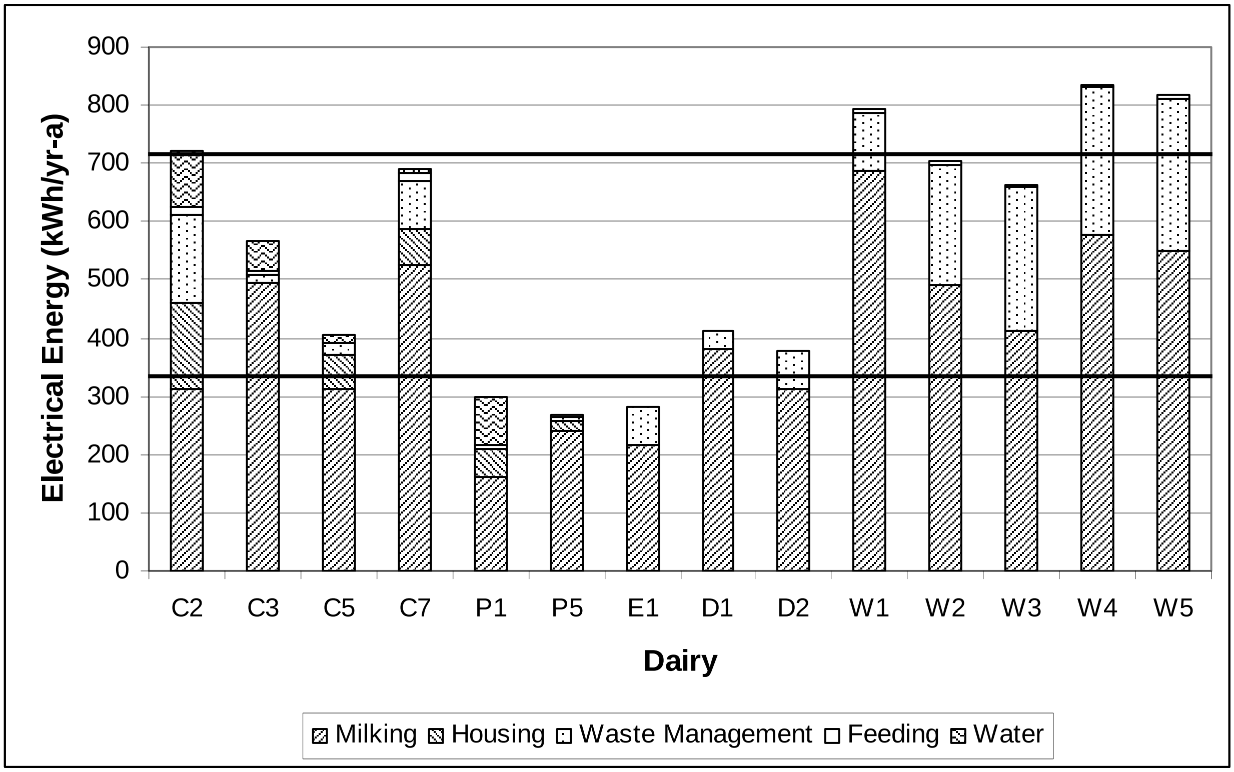


Figure 1. Total electrical energy usage for each dairy in the study subdivided according to different parts of the operation. Horizontal lines indicate the range of total electrical energy usage values estimated using the USDA farm energy calculator.

### *Liquid Fuels*

Annual usage of liquid fuels on a kWh/yr·a basis for each dairy surveyed is shown in Table 7. The reason for higher fuel usage at diary C2 (hybrid with flush lanes) versus dairy C3 (open lot with scraped manure removal) was due to a large on-site composting operation at this dairy. Allocating fuel usage between dairy and composting operations was not possible. Dairy C7 had significantly lower fuel usage than others in the Central Texas region, but no specific reasons for this could be identified. Dairy P1 was a large operation that had numerous vehicles, some of which were assigned to several workers. This may have resulted in use of some fuel for non-dairy operations. Dairy E1, with cows on pasture, had the lowest fuel usage per animal due to the lack of activities that used such fuel. Dairies D1 and D2 were operated similarly by the same owner. The feed storage and mixing facility was adjacent to dairy D1 resulting in possible comingling of fuel usage between the dairies. Dairy D2 was further away resulting in the fuel used on this facility being strictly for the facility and nothing else. The five ‘W’ dairies were operated by a single company with a centralized fuel storage facility. Consequently, the fuel usage was tracked on a per vehicle basis and allocated to farming, calf raising, and dairy operations. Unfortunately, the fuel usage was not itemized on a per dairy basis. This resulted in dividing the total fuel usage reported equally among all the five dairies (Table 7).

Table 7. Liquid fuel usage for all dairies (kWh/yr·a).

| Dairy | Liquid Fuel | | Total |
|---|---|---|---|
| | Diesel | Gasoline | |
| C2 | 800 | 0 | 800 |
| C3 | 569 | 0 | 569 |
| C5 | 776 | 0 | 776 |
| C7 | 103 | 192 | 295 |
| P1 | 619 | 0 | 619 |
| P5 | 242 | 0 | 242 |
| E1 | 122 | 61 | 183 |
| D1 | 636 | 0 | 636 |
| D2 | 394 | 0 | 394 |
| W1 | 275[1] | 78[1] | 353 |
| W2 | 275[1] | 78[1] | 353 |
| W3 | 275[1] | 78[1] | 353 |
| W4 | 275[1] | 78[1] | 353 |
| W5 | 275[1] | 78[1] | 353 |
| Average | 454 | 110 | 487 |
| Std Dev | 260 | 71 | 222 |

[1]Liquid fuels were from a centralized storage facility and could not be allocated to each dairy separately so usage was divided evenly.

### *Gaseous Fuels*

All dairies provided information on gaseous fuel purchases for one year for this survey except dairy E1 which did not report this type of fuel use. Operations that provided fuel usage as one sum across all processes and operations were treated as using the fuel equally for those processes and operations on a per animal basis. Table 6 shows the gaseous fuel use on a kWh/yr·a basis for all the dairies.

Overall, the energy expenditure for water heating was similar for all dairies on a per animal basis. The main variation in this value was for dairies P1 and P5, the newest dairies in the sample set equipped with heat exchangers that actually feed the heated water to the water tanks and not just to the watering troughs for the cattle. Dairy W4 had a higher energy usage because the propane storage was shared with a calf raising operation near the dairy. There was no information available to separate usage by the calf raising facility from that for the dairy, so the usage was divided evenly with 50% applied to the dairy. This resulted in significantly higher energy usage for this dairy.

Table 6. Gaseous fuel usage on all dairies (kWh/yr·a).

| Dairy | Gaseous Fuel | | Total |
|---|---|---|---|
| | Propane | Natural Gas | |
| C2 | 114 | - | 114 |
| C3 | 134 | - | 134 |
| C5 | 192 | - | 192 |
| C7 | 168 | - | 168 |
| P1 | 56 | - | 56 |
| P5 | - | 41 | 41 |
| E1 | N/A[1] | N/A[1] | N/A[1] |
| D1 | 135 | - | 135 |
| D2 | 131 | - | 131 |
| W1 | 168 | - | 168 |
| W2 | 53 | 71 | 124 |
| W3 | 182 | - | 182 |
| W4 | 306[2] | - | 306[2] |
| W5 | 79 | - | 79 |
| Average | 143[3] | 56 | 127[3] |
| Std Dev | 69[3] | 21 | 48[3] |

[1]Dairy E1 did not report gaseous fuel use.
[2]Gaseous fuel use reported by dairy W4 included usage by a calf ranch that was combined with the dairy.
[3]Does not include dairies E1 and W4.

### *Total Energy Usage*

Total energy usage subdivided according to energy source for each of the dairies involved in this survey is summarized in Table 8 and Figure 2. The maximum energy usage was 1637 kWh/yr·a on a free-stall dairy in Central Texas. This older dairy was undergoing expansion at the time of the survey which may have contributed to its higher energy usage. The lowest energy usage was 464 kWh/yr·a at the pasture dairy in Northeast Texas for which information on gaseous fuel usage was not provided. However, even if the higher end of gaseous fuel usage were added to the total for this dairy, it would still be one of the lowest energy users among those surveyed.

Making accurate comparisons of fuel use efficiencies across all dairies was difficult due to the broad range of management characteristics at dairy operations. Dairies C3 and P5 were both open lot facilities, but their total energy consumption varied by a factor of 2.3 (1269 versus 551 kWh/yr·a). This difference was evident across all categories of energy usage and was most likely due to dairy P5 being a much newer facility.

Table 8. Total energy usage for all dairies (kWh/yr·a).

| Dairy | Electricity | Liquid Fuels | Gaseous Fuels | Total |
|---|---|---|---|---|
| C2 | 723 | 800 | 114 | 1637 |
| C3 | 566 | 569 | 134 | 1269 |
| C5 | 406 | 776 | 192 | 1374 |
| C7 | 692 | 295 | 168 | 1155 |
| P1 | 299 | 619 | 56 | 974 |
| P5 | 268 | 242 | 41 | 551 |
| E1 | 280 | 183 | N/A | 464 |
| D1 | 411 | 636 | 135 | 1182 |
| D2 | 379 | 394 | 131 | 905 |
| W1 | 792 | 353[1] | 168 | 1314 |
| W2 | 700 | 353[1] | 124 | 1177 |
| W3 | 658 | 353[1] | 182 | 1193 |
| W4 | 832 | 353[1] | 306 | 1185 |
| W5 | 812 | 353[1] | 79 | 1244 |
| Average | 558 | 487 | 127[2] | 1165[2] |
| Std Dev | 210 | 222 | 48[2] | 268[2] |

[1]Liquid fuel usage was reported as an aggregate value for the five "W" dairies and so was simply divided evenly among them.
[2]Average and standard deviation values for gaseous fuel and total usage do not include E1 since no usage was reported for that dairy and W4 since the reported value included usage by a calf ranch.

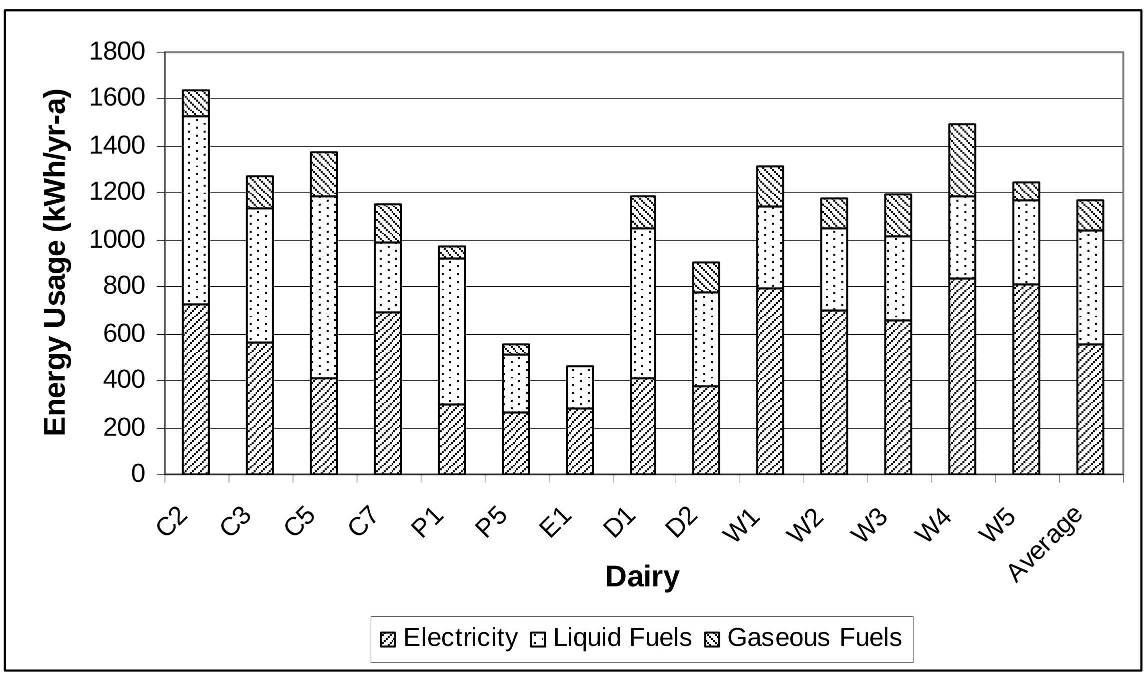


Figure 2. Total energy usage for each dairy in the study subdivided according to type of energy. The last column represents the average value for each type of energy across all dairies.

In general, newer dairies consumed less total energy per animal than comparable older dairies due to newer and more energy efficient equipment and facility design. Free-stall facilities typically used more energy than comparable open lot dairies because of the energy expended inside the free-stalls for flushing, cooling fans and lights.

## Conclusion

Energy usage on 14 dairies surveyed in the southwestern United States was highly variable due to different housing systems, ages of facilities and energy efficiency of equipment used for milking, pumping wastewater and heating clean water. The greatest amount of energy used at all dairies was electrical, followed by liquid and gaseous fuels. Generally, newer dairies were more efficient in electrical energy use than their older counterparts, indicating that a significant amount of energy might be saved by upgrading facilities with new, more energy efficient equipment.

While this study looked broadly at dairy energy usage, more useful information can be gained by an intensive survey of energy usage for specific processes and operations at dairies. For example, installing energy consumption meters on specific motors in the milking parlors or specific fans in the housing structures would furnish process-specific information on energy use efficiency. The wide variation in energy usage on these dairies suggests that any dairy could benefit substantially from an energy audit of its facilities to identify potential areas for upgrading equipment or implementing energy conservation. An energy audit would be particularly important for facilities considering development of an onsite alternative energy system to match potential types of energy production to usage.

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