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TIME-OF-USE RATES AND ELECTRICITY COSTS OF REPRESENTATIVE NEW YORK DAIRY FARMS

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ABSTRACT

Electric utilities throughout the Nation are experimenting with strategies to reduce total electricity consumption or to alter the timing of electrical power use by their customers. This report focuses on one such strategy, time-of-use (TOU) electric rates, and the likely effect of this pricing option on the New York dairy sector. The purpose of the study is to assess the change in farm electrical energy costs when power is sold to dairymen at higher rates for periods of peak power demand and at substantially lower rates for off-peak periods.

This study is based on the results derived from a farm-level, computer decision model which calculates farm energy consumption by major end uses--such as milk cooling and feeding--and by time of day. The model differentiates power use on farms depending on the type of electrical equipment and the timing of its use.

Results show that, in the case of the TOU rates now being implemented by Niagara Mohawk, moving from flat rates to TOU rates has only marginal effects on electric energy costs incurred by dairy farmers. For the 28 representative farm businesses considered, larger farms have the most significant cost savings under the new rate (just over 12 percent), with smaller dairy operations approximately breaking even when electric power is purchased at TOU rates.

These results also show that initial concerns over abrupt increases in power costs under new energy pricing schemes were misplaced. While power costs clearly increase during the summer and winter when rates increase to reflect peak power use, dairy farmers receive a concomitant windfall gain when purchasing power at relatively lower rates off-peak.

The authors are Professor, Associate Professor, former Research Support Specialist, and former Graduate Research Assistant, respectively, in the Department of Agricultural Economics, Cornell University. This report is based on research supported by Niagara Mohawk Power Corporation.

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TIME-OF-USE RATES AND ELECTRICITY COSTS OF REPRESENTATIVE NEW YORK DAIRY FARMS

INTRODUCTION

The demand for electric power in the State of New York, as elsewhere in the country, has grown steadily for the past several decades. During seasonal peak periods, demand has sometimes approached the limit of available generating capacity. In response, the State's electric utilities have added generating capacity where possible. In recent years, however, new generating capacity has become increasingly costly due to general inflation and because of more stringent environmental and safety standards. For these reasons, utilities have placed greater emphasis on discouraging the continual growth of electricity demand, thereby avoiding or delaying the higher costs and environmental and health risks. Some efforts focus on decreasing the overall level of demand (conservation), while others, attempt to shift demand from peak to off-peak periods (load shifting). Both conservation and load shifting are important examples of what utilities refer to as demand side management (DSM).

One important DSM program involves making adjustments to rate schedules for billing electricity customers. Raising rates during times of peak demand to reflect the higher marginal cost of electricity generation (and lowering them during off-peak periods) has been shown to shift demand from peak to off-peak periods (e.g., EPRI,1979; Granger et al., 1979; and Hendricks et al., 1979). These time-of-use rates (TOU), as they are called, differ by time of day and by season according to when a utility's peak and off-peak periods of consumer demand occur. By smoothing out fluctuations in demand over the course of a day or season, TOU rates permit more efficient generation of electric power, reduce the likelihood of energy shortages during peak demands and delay the need for the construction of new power plants.

Under order of the New York Public Service Commission (Order 88-23), New York utilities are currently implementing these rates for their residential customers consuming large amounts of electricity annually. For example, Niagara Mohawk Power Corporation's (NMPC), residential customers who consume more than 30,000 Kwh annually are being shifted from the current flat rate (SC-1) to a TOU rate (SC-1C). Since the electrical service for many farming operations is connected to the same meter as the residence on the premises, a substantial portion of the customers affected by the TOU rate are family-operated farms.

This new rate may have a noticeable effect on the energy bills of these residential customers. Currently, there is considerable debate in the farm community over the potential effects on the cost of electricity to that group of farms using electricity during daily peak periods. Dairy farmers in New York are a major component of this group because dairying is energy intensive, it's electricity consumption is centered around a fixed milking schedule, and it is the dominant agricultural enterprise in the State.

This bulletin is one of a series of reports that examines the effects of Niagara Mohawk's mandatory residential time-of-use rate (SC-1C) on the New York farm sector. The purpose here is to evaluate the effects of NMPC's TOU rate on dairy farms, controlling for differences in milking technology and farm size. Earlier reports have reviewed the TOU rate and NMPC's plans for implementation and, in a general way, described the possible implications of new rate making for the New York dairy sector (Middagh et al., 1991; Bills et al., 1991). The research reported here provides initial quantitative estimates of the changes in farm electricity bills by moving to the new rate.

To make this evaluation, we use information from a variety of sources, including two large data sets, the 1987 Farm Management and Energy Survey and the 1988 Rural Household and Farm Energy Survey. Both were funded by Niagara Mohawk Power Corporation. These data are used to construct three sets of representative farms which differ by energy consumption as measured by Kwh/year. Although the farm groups are those used by NMPC in their three-phase implementation plan and were developed in part for NMPC's administrative convenience, they also reflect significant differences in numbers of cows and yearly milk production.[1] In this sense, the groups provide a useful way of comparing the implications of moving to the TOU rate across small, medium and large farms.

The comparative analysis is conducted through a farm-level, spreadsheet-based computer decision model which calculates farm electric energy consumption by major end use and distributes it by season and time of day. We differentiate among farms based on clusters of electrical equipment. The model incorporates coefficients from regression

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[1] Niagara Mohawk is implementing the new rate in three separate phases, beginning with the residential customers who are the largest users of electricity. Phase I customers are those consuming over 60,000 Kwh/year; Phase II use 40,000-60,000 Kwh/year; and Phase III customers consume 30,000-40,000 Kwh/year. The implementation of this TOU rate began in January, 1990.

equations, end-use indices from engineering studies and algorithms that closely fit data from previous research projects. To calculate yearly electricity consumption, estimates of electricity consumption by end use and time of day are annualized and summed. NMPC's flat and TOU rates are built into the model so that differences in annual costs between the two rate schedules can be computed.

The report is organized into several sections. The next section contains a discussion of how survey data are combined to provide profiles of dairy farm customers in NMPC's service territory. This is followed by discussions of the important components of the computer decision model and characteristics of the representative farms. Next, there is an analysis of the differences in utility bills when farm customers move from the flat rate to the TOU rate. The relative importance of major end uses to the overall level of electricity consumption is highlighted. This report concludes with a summary and discussion of the implications of our results for both Niagara Mohawk Power Corporation and its farm customers.

THE FARM MANAGEMENT ENERGY SURVEY DATA

To place the comparative analysis of flat and TOU rates in a useful context, we have developed a profile of dairy farm customers in the NMPC service territory and delineated a sub-set of farm customers likely to fall in each size group. The grouping was based on the 1988 Rural Household and Farm Energy Survey. The sampling frame for this mail survey was rural NMPC customers served by the SC-1 rate. There were 3,958 usable records; approximately 1,550, or 39 percent, of the customers responding to the March 1988 survey said they were actively engaged in a farming operation. Of these, 1,310 were classified as dairy farms. We have information on farm electrical equipment clusters, milking technology, and the volume of products produced for each of these farms. The farm survey data are matched to NMPC billing data.

Developing a Usable Sample

For this analysis, we have eliminated cases that do not meet certain criteria (see Table 1). Each criterion was imposed to eliminate anomalous observations and gain sharper registration with our farm-based decision model. This procedure, and the adjustments that result, are reasonable on several grounds. First, we eliminated some cases for which there was no response to certain questions, e.g., type of milking technology or amount of milk

Table 1. Screening Criteria for Survey Dairy Farms

Item	Critical Value	Cases passing	Percent of total
Milk per cow	Between 5,000 and 25,000 lbs annually	968	73.9
Months in production	milk at least 10 months out of year	1,194	91.1
Implied flat rate per Kwh	$.06-$.10	1,272	97.1
Total Kwh/year	Between 30,000 and 125,000 Kwh	934	71.3
No. of billing days	300 or more	1,302	99.4
Number of cows	20 or more	1,229	93.8
Acres of farmland	20 or more	1,275	97.3
Milking system	Parlor, Pipeline or Buckets	1,156	88.2
Annual Kwh per cow	200 or more	1,159	88.5
Annual production of milk (lbs)	More than 0	1038	79.2
All combinations		671	51.1
Total		1,310	100

Source: 1988 Rural Household and Farm Energy Survey.

produced on the farm. Second, there were some incomplete billing records supplied by NMPC for our survey farms. Finally, some records were "outliers" that could not be explained easily, but probably are due to reporting errors by the respondent. Parameters for milk production are most restrictive; nearly one quarter of all cases were rejected based on calculated production per cow. However, while some of these restrictions would invalidate the same records, others are particular to only a single farm. Thus, about 51 percent or 671 of the total dairy farms in the 1988 data set met the 10 criteria in Table 1. These 671 records provided the data base on which the representative farms for each size group are constructed.

Although the data for these 671 farms were judged to be suitable for analysis, one nagging problem remained. The 1988 data set contained no information on the timing of electrical equipment use on the farm needed to model electricity use by time of day and season. To overcome this limitation of the more streamlined mail survey, we accessed data from the 1987 Farm Management and Energy Survey. This latter data base includes records for about 750 dairy farmers throughout the upstate New York area and contains exhaustive information on the timing of equipment use. Starting times and durations of equipment use reported in this survey were assumed to be representative for farms in our core 1988 data base. This assumption seems reasonable if one first controls, as we did, for annual Kwh use, herd size, and milking technology.

Features of the Study Farms

Using the 671 dairy farms defined for the study, nearly 15 percent of the farms use between 30,000 and 40,000 Kwh and fall in the smallest size group (Phase III farms). In the NMPC service territory, these farms are estimated to have nearly 320 acres of farmland and a herd of 49 cows on average (Table 2). Farms in the other two groups constitute about 22 percent (Phase II farms) and 63 percent (Phase I farms) of the total; they are also quite a bit larger, with acreage averaging about 380 and 550, respectively, and herds averaging 65 and 106 cows. Annual milk production per cow on the larger Phase I farms is over 2,500 pounds above that of the smaller Phase III farms. Higher productivity combined with the larger herds, is primarily responsible for the fact that annual electricity use on the Phase I farms is more than two and a quarter times higher than for Phase III farms.

As expected, most of the operators of the smaller farms (Phase III) milk cows in stanchion barns. Unlike farms in the other two groups, there is nearly an even split on the use of bucket and pipeline technology in these stanchion set-ups. Some of the farms using buckets probably employ a dumping station, but we have no data on rate of occurrence. Herd size does vary with type of milking technology; farms with parlors have 17 more cows on average than do the farms with stanchion technology. On farms with parlors, average milk production per cow is 824 pounds per year (or 6 percent) higher than the 12,941 pound

Table 2. General Characteristics of Dairy Farms in NMPC Service Territory

Parameter	Kwh/year Phase III (30,000 to 40,000)	Phase II (40,000 to 60,000)	Phase I* (60,000 +)
# Farms in sample	98 farms	149 farms	424 farms
Percent of farms**	14.6	22.2	63.1
Average farm size	316 Acres	382 Acres	554 Acres
Milk production/herd	641,801 lbs.	916,032 lbs.	1,622,619 lbs.
Milking system			
Stanchion barn	94%	90%	64%
(buckets)	(49%)	(21%)	(4%)
(pipeline)	(45%)	(69%)	(60%)
Parlor	6%	10%	36%
Average herd size	49 cows	65 cows	106 cows
Stanchion barn	48 cows	62 cows	92 cows
(buckets)	(48 cows)	(59 cows)	(93 cows)
(pipeline)	(47 cows)	(62 cows)	(92 cows)
Parlor	66 cows	90 cows	129 cows
Average production/cow	12,992 lbs.	14,202 lbs.	15,500 lbs.
Stanchion barn	12,941 lbs.	14,206 lbs.	15,568 lbs.
(buckets)	(11,926 lbs.)	(13,732 lbs.)	(15,316 lbs.)
(pipeline)	(14,048 lbs.)	(14,348 lbs.)	(15,584 lbs.)
Parlor	13,765 lbs.	14,175 lbs.	15,380 lbs.
Annual electricity use	34,991 Kwh	48,021 Kwh	79,835 Kwh
Stanchion barn	34,851 Kwh	48,069 Kwh	76,589 Kwh
(buckets)	(34,551 Kwh)	(46,792 Kwh)	(77,783 Kwh)
(pipeline)	(35,178 Kwh)	(48,453 Kwh)	(76,514 Kwh)
Parlor	37,140 Kwh	47,594 Kwh	85,468 Kwh
Annual electricity bill***	$2,440	$3,328	$5,447

Source: 1988 Rural Household and Farm Energy Survey.

* 60,000 - 125,000 Kwh/year.

** This distribution of farms is slightly different from that found in the historical billing data from NMPC's farm customers, where 18.6%, 33.2% and 48.2% were in Phase III, Phase II, and Phase I, respectively.

*** Includes taxes and other miscellaneous charges.

average for those with stanchions. The average yearly Kwh use for farms with parlors is also higher by about 7 percent than for farms with stanchions.

MODELING ELECTRICITY COSTS

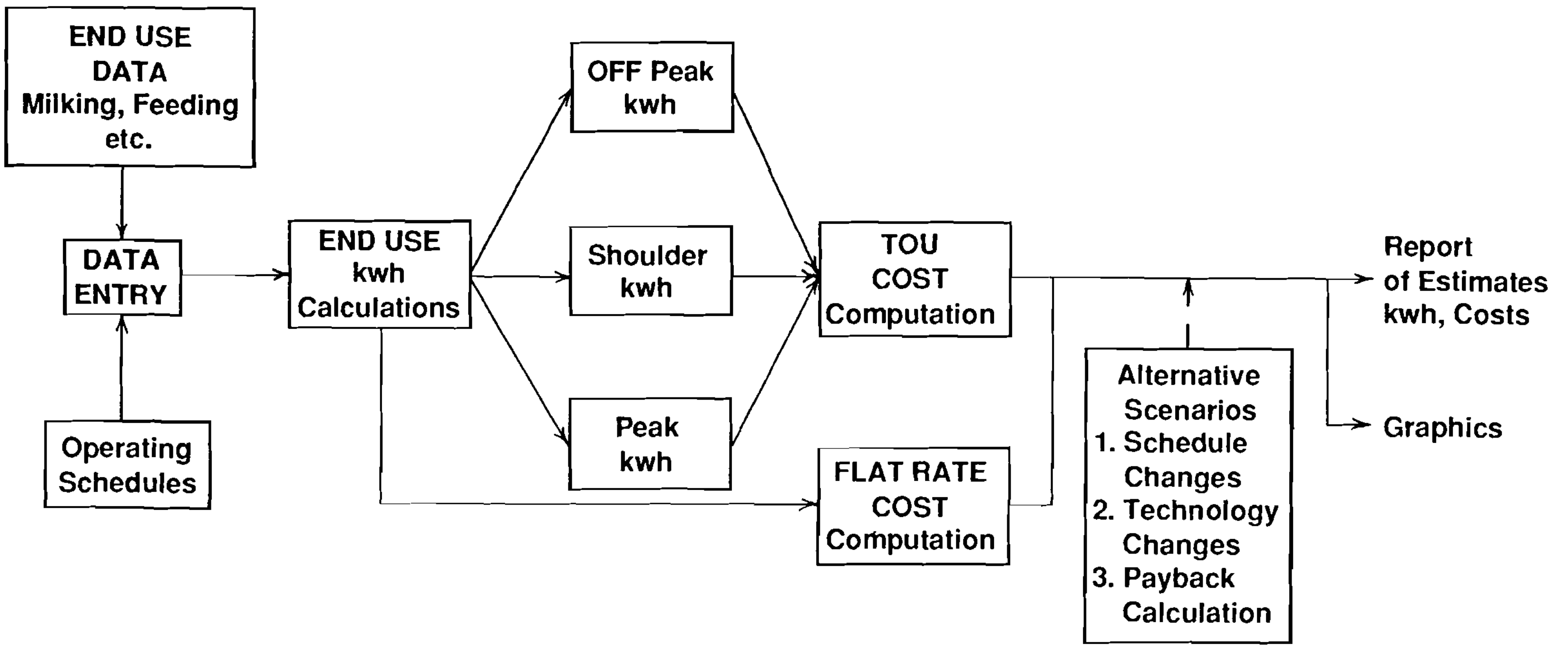
The methodology needed to estimate individual farm electricity costs under flat and TOU rates is straightforward. The spread-sheet model is designed to operate in several steps (Figure 1). First, it calculates energy consumption for the seven major electrical end uses found on most dairy farms. End-use Kwh consumption figures for all farm electrical equipment associated with these end uses are calculated from regression models, end use indices or other algorithms that closely fit data collected from previous research. Second, estimates of end-use electricity consumption are distributed by season and time of day using survey data on the timing of equipment operation for the representative farms so the TOU rate can be applied. Third, the consumption figures by end use and TOU category are annualized and summed to provide a yearly energy consumption. Finally, the kilowatt hour consumption in each category is multiplied by its corresponding rate (in cents/Kwh) to determine the energy cost for each of the time-of-use categories. Total annual Kwh consumption is also multiplied by the current flat rate so that annual cost differences between time-of-use rate and flat rate prices can be compared.

The model has been developed using LOTUS 1-2-3, Version 3.0. Currently, the model does have the capacity to examine the effects of limited load shifting on the differential electricity bills, but this is in the context of a "what if" mode. There is nothing in the model that would determine the optimal load shifting due to the TOU rate. Future versions of the model will have the capacity to evaluate the desirability of investments to conserve energy, or to shift load to off-peak periods. This feature should help evaluate the desirability of rebates and other incentives by utilities to induce farmers to make such investments.

Assumptions and Algorithms for End-Use Consumption Estimates

Cornell University has extensive data on New York farm electric energy use, equipment clusters and timing of operations, but no large-scale study of metered end-use and daily electricity load shape data exists. Therefore, data from a variety of sources were used to estimate end-use electric power consumption and distribute it by time of day. One important source is a set of meter data from a study of small-to-medium sized dairy farms conducted by a Wisconsin utility. In this research, 25 family-operated dairy farms from

Figure 1. FARM ENERGY ANALYSIS MODEL



Iowa, Minnesota and Wisconsin were studied to estimate their daily energy consumption patterns. The data base for each farm contained 27 months of hourly metered data consisting of total energy use, as well as data for two major end uses, the milk cooler and water heater. Electricity use in the farm residences was excluded from these data, but each farm provided information on herd size, equipment use and milking and feeding schedules (Dairyland Power Cooperative, 1987). By assuming that these midwestern dairy farms are comparable to many family farms located in New York State, these data provided the basis for modeling end-use consumption by time of day.

The specific algorithms used to model energy consumption by time of day and end use were derived from the information in the survey and other previous research as well. The most important relationships are as follows: Each dairy farm is assumed to have no major electricity using activities unrelated to the dairy operation. All farms are assumed to milk twice daily and at the same times each day of the year.[2] Parlors and stanchion/pipeline configurations are equipped with conventional pipeline transfer and pumping systems. With bucket technology, hand carrying, rather than a milk dumping station, is assumed.

Vacuum Pump: The vacuum pump is used for all milking and also operates during the wash/sanitation cycle for pipeline and parlor configurations. For bucket milking systems, the vacuum pump is assumed to run only during actual milking times. For pipeline systems, additional pump time is added for pre-milking pipe sanitation and post-milking cleanup. The pump is needed to move these liquids through the lines. An additional 30 minutes per milking is added to pump operation time under this scenario.

The equations used to estimate annual electricity requirements for the vacuum pumps are given below (Farmer, 1991):

(1) $PKwh_{B1} = 365 * (VPHP * 0.75 * (DMT)/60)$

(2) $PKwh_{P1} = 365 * (VPHP * 0.75 * (DMT + (30*DM))/60)$

(3) $PKwh_{P2} = 365 * (VPHP * 0.65 * 0.75 * (DMT + (30*DM))/60)$

where PKwh is equal to annual vacuum pump Kwh; B is for a bucket system; P is for parlor or pipeline and subscripts 1 and 2 refer to a one- or two-pump system. VPHP is the vacuum

[2] Another key dimension is the use of three daily milkings on larger dairy farms. Future refinements in the model will incorporate the ability to alter the frequency of daily milking.

pump horsepower and DMT is daily milking time in minutes for both milkings. DM is the number of daily milkings.

When information about the horsepower of the vacuum pump is not available, it is estimated by the following equation:

$$(4) \qquad VPHP = 2.97 + 0.0004 * CWT - 1.54 * PD$$

where VPHP is vacuum pump horsepower; CWT is milk produced, measured in hundred weight; and PD is a dummy variable that takes on a value of unity if milking takes place in a parlor and zero otherwise. The parameters of this equation were estimated using the data from Dairyland Power Cooperative (1987). The R^2 for this equation is 0.498, while the t-ratios for the estimated coefficients on the variables are 2.745, 4.434, and -1.624, respectively.

Milk Cooling: The milk cooler is assumed to be a standard variety of modern design and made of stainless steel. Coolers are assumed to be less than 15 years old. Two separate estimates of annual milk cooler Kwh are used, the first one is for a system with a well water precooler (Farmer et al., 1988):

$$(5) \qquad MC_{wp} = 0.5 * CWT$$

where MC is annual milk cooler Kwh and the subscript wp is for a well water precooler. CWT is annual milk production measured in hundred weight. The equation for a standard bulk tank was estimated using data from the Dairyland Power Cooperative (1987) and is given below:

$$(6) \qquad MC_{sb} = -40.257 + 0.754 * CWT + 73.048 * CHP + 2092.5 * D_{ib}$$

where the subscript sb refers to standard bulk tank; CHP is cooler horsepower; and D_{ib} is a dummy variable for an ice bank precooler. This variable takes the value of unity if there is an ice bank precooler; it is zero otherwise. The R^2 for this equation is 0.926 and the t-ratios on the coefficients, beginning with the constant term, are -0.059, 0.464, 14.178, and 3.451, respectively. Where unknown, the compressor horsepower for bulk coolers is taken from the data in Table 3.

Water Heating: The heater element is assumed to be rated at 4500 watts. An automatic washing system is assumed for both pipeline and parlor technologies. For bucket technology, equipment is assumed to be washed by hand. The annual electricity used by an electric water heater is given by:

Table 3. Bulk Cooler Horsepower by Capacity of Cooler

Cooler Capacity (Gallons)	Horsepower
100-200	1-2
300-500	3-4
600	4
800	5
1,000	5 or two 3's
1,250-1,500	two 3's or two 4's
2,000	two 4's or two 5's
3,000-4,000	two 4's or 5's
5,000-6,000	15-20
7,000	30

Source: Brochure from Dari-Kool Bulk Milk Cooling Systems, DEC International, Madison, Wisconsin and personal conversation with Mr. Bryce Johnson, Refrigeration Engineer.

$$(7) \qquad WKwh = e^{(2.63 - 0.464 * D) + 0.278 * \ln(CWT * COWS) + 0.237 * \ln(CA - WT)}$$

where WKwh is annual electricity consumption for water heating; e is the base for natural logarithms; D is a dummy variable that takes on a value of unity if there is a heat transfer system and zero otherwise; CWT is hundred weight of milk; COWS is the number of cows being milked; CA is the capacity of the hot water tank; and WT is the rating of the heating element in watts. This equation was estimated (in log-linear form) from data from the Dairyland Power Cooperative (1987). The R^2 is 0.634 and the t-ratios on the coefficients are 2.131, -3.234, 3.441, and 2.063, respectively.

Feeding: All motors used in the handling and conveyance of livestock feed are evaluated together using total aggregate horsepower. Applying basic electromagnetic relationships, a simple estimator of kilowatts used in the feeding process can be created and is represented by (McFate, 1989):

$$(8) \qquad FKwh = \left(\frac{TFHP * 750}{1,000}\right) * \left(\frac{FMW}{60}\right) * 185 + \left(\frac{TFHP * 750}{1,000}\right) * \left(\frac{FMS}{60}\right) * 180$$

where FKwh is annual electricity consumption for feeding; TFHP is total aggregate motor horsepower dedicated to feeding; FMW is total daily feeding minutes for winter months; and FMS is total daily feeding minutes for summer months.

This algorithm is in this fashion so that differences in summer and winter feeding schedules can be accommodated. The winter portion of the algorithm is set at 185 days, while the summer portion is set at 180 days. This algorithm was generated in-house.

Waste Handling: Waste handling Kwh is estimated in a manner similar to feeding:

$$(9) \quad WHKwh = \left(\frac{TWHP * 750}{1{,}000}\right) * \left(\frac{WMW}{60}\right) * 185 + \left(\frac{TWHP * 750}{1{,}000}\right) * \left(\frac{WMS}{60}\right) * 180$$

where WHKwh is annual electricity consumption for waste handling; TWHP is total aggregate horsepower dedicated to waste handling; WMW is total daily winter waste handling minutes; and WMS is total daily summer waste handling minutes. Winter and summer days are 185 and 180 days, respectively.

Ventilation: Estimating kilowatt hours for ventilation fans is more complicated, due in large part to the variability of fan size and performance, weather conditions, and the type of setup found on a given dairy farm.

The general algorithm for electricity consumption from ventilation fans is:

$$(10) \quad VKwh = (Fans_s * Kwh_s) * Time_h$$

where VKwh is ventilation kilowatt hours per year, $Fans_s$ is the number of fans of size s; Kwh_s is average hourly electricity consumption for fans of size s; and $time_h$ is annual operating time in hours (Ford, et al., 1991).

The model assumes that fans operate during milking hours (for barn and parlor fans) unless other operating times are specifically entered. Electricity use for the fans is calculated by using a Lotus lookup table containing consumption estimates for four different fan sizes. These estimates are in Table 4.

Barn Lighting: Barn lights are assumed to be operated throughout the year during milking times. An additional 30 minutes of operation are added before and after each daily milking to account for preparation and clean-up activities in the milk room and parlor. The equation used to estimate annual electricity consumption for lighting the barn and milking area, measure in Kwh (BMLKwh), is given by:

$$(11) \quad BMLKwh = (ABWB/1000) * [MHY + NMD * 365]$$

Table 4. Electricity Use by Fans

Fan Diameter	Kilowatts Per Hour
18"	0.422
24"	0.513
36"	0.628
48"	1.136

Note: Figures are derived as averages of comparably sized fans tested at the University of Illinois (Ford, et al., 1991). Fan tests were conducted at 0.10 inches of static pressure, a situation commonly observed in livestock buildings.

where ABWB is the total wattage of all light bulbs in the barn and milking area; and NMD is the number of milkings per day; and other variables are as defined above. An additional 60 minutes are added before and after each milking to the stanchion barn and free stall area to account for other daily chore activities.

Outdoor Lighting: Outdoor or security lights are assumed to operate 12 hours per night throughout the year. The equation to estimate annual electricity consumption by the outdoor night lights, measured in Kwh (NLKwh), is given by:

(12) $$NLKwh = (ABWN/1000) * 12 * 365$$

where ABWN is the total wattage of outdoor night lights.

Miscellaneous: Water pumps, welding machines, tractor block heaters, grain dryers and other electrical uses fall in this category. Miscellaneous use of electricity is assumed to be five percent of total Kwh used by all dedicated end use activities. This percentage can be manually changed within the model by the user to simulate higher or lower levels of miscellaneous equipment use.

Total miscellaneous electricity consumption is apportioned across time-of-use rates as follows: Off-season is 50 percent, off-peak is 25 percent, shoulder is 12.5 percent and peak is 12.5 percent. These percentages are based primarily on the distribution of days in the various time-of-use rate categories throughout the year and some assumptions about the timing of daily use for miscellaneous equipment.

Farm Residence(s): In individual applications of this model where estimates of household electricity consumption are available, it is distributed across the different periods by the following percentages: Off-season is 50 percent, off-peak is 32 percent, shoulder is 11 percent, peak is 7 percent. These percentages are based on preliminary results of metered "bucket data" from Niagara-Mohawk Power Corporation (correspondence with M. Piper, 5/92). In this application, no estimates of household consumption are available; in interpreting the results below, it is important to remember that household consumption is not included.

Representative Farms

A number of representative farms were constructed for each of Niagara Mohawk's three implementation phases. Within each phase, the representative farms differ by size, as measured by herd size, and by milking. Two milking technologies, bucket and pipeline, are available in stanchion barns. There are also farms with milking parlors, but as noted above, these farms are concentrated in Phase I (Table 2).

The number of farms needed to represent a particular implementation phase and milking technology is a function of the variation in herd size within each group, as measured by the standard deviation (Table 5). For most groups there are at least three representative farms.[3] In the case where exactly three farms seemed sufficient, one group was formed by averaging the characteristics of farms whose herd size ranged between plus or minus 1/2 a standard deviation from the mean. A second farm is developed by averaging the characteristics of those farms with herd sizes between minus 3/2 standard deviations from the mean (or the smallest herd size, whichever is lower) and minus 1/2 standard deviations from the mean. A third farm is developed by averaging the characteristics of those farms with herd sizes between plus 1/2 and plus 3/2 standard deviations from the mean (or the largest herd size, whichever is larger). In the remaining situations where it seemed advisable to construct more than three representative farms, a similar procedure was followed, but the herd size ranges over which the groups are formed were often based on plus or minus 1/4 standard deviations, rather than 1/2 standard deviations.

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[3] In the case where there are only a small number of farms with a given technology in a particular implementation phase, only one representative farm is constructed. A good example of this is Phase I farms with bucket technology (Table 6). There are only 16 of these farms in the sample; the only representative farm has a mean herd size of 93. All other characteristics of this representative farm that could be obtained from the 1988 survey are averages across these 16 farms. Similarly, there are only 12 and 6 sample farms with milking parlors in Phase II and Phase III, respectively (Tables 7 and 8). Thus, there is only one representative farm developed for each of these groups.

The number of sample farms that were used in constructing the representative farms, along with the herd size ranges represented in the groups are given in Tables 6, 7, and 8. The average number of cows, the annual milk production and electricity consumption (estimated from actual billing data from Niagara Mohawk Power Corporation which include consumption for the farm residence) are also reported for each farm. In total, there are 28

Table 5. Dispersion of Cow Numbers for Defining Representative Farms

Phase/Technology	$-\frac{3}{2}\sigma\rightarrow$	$\leftarrow -\sigma\rightarrow$	$\leftarrow -\frac{1}{2}\sigma\rightarrow$	$\leftarrow \bar{X}\rightarrow$ (σ)	$\leftarrow \frac{1}{2}\sigma\rightarrow$	$\leftarrow +\sigma\rightarrow$	$\leftarrow +\frac{3}{2}\sigma$
Phase I							
Buckets (4%)	39	57	75	93 (36)	111	129	147
Pipeline (60%)	20	44	68	92 (48)	116	140	164
Parlor (37%)	56	80	105	129 (49)	154	178	203
Phase II							
Buckets (21%)	35	43	51	59 (16)	67	75	83
Pipeline (69%)	35	44	53	62 (18)	71	80	89
Parlor (10%)	8	35	63	90 (55)	118	145	173
Phase III							
Buckets (49%)	26	33	41	48 (15)	56	63	71
Pipeline (45%)	31	37	42	47 (11)	53	58	63
Parlor (6%)	30	42	54	66 (24)	78	90	102

Source: The 1988 Rural Household and Farm Energy Survey.

Note: $\bar{X}$ is the mean number of cows on farms and the numbers in the other columns of the table are cow numbers at plus or minus the indicated number of standard deviations (σ) from the mean. The numbers in parentheses are the percentages of farms in each phase using the milking technology; the detail may not add due to rounding.

Table 6. Characteristics of Representative Phase I Farms

	Farm Name: Bucket Milking Technology
	BI1
Cows	93
Milk/Yr. (1000 lbs)	1,434
Kwh/Yr. (1000's)	78
# Sample Farms	16
Herd Size Range	40-165

	Farm Name: Pipeline Milking Technology					
	PLI1	PLI2	PLI3	PLI4	PLI5	PLI6
Cows	49	67	91	113	139	271
Milk/Yr. (1000 lbs)	841	1,073	1,372	1,716	2,069	4,065
Kwh/Yr. (1000's)	66	72	77	80	95	101
# Sample Farms	13	91	88	37	12	10
Herd Size Range	31-55	56-79	80-103	104-127	128-151	152-560

	Farm Name: Parlor Technology					
	PAI1	PAI2	PAI3	PAI4	PAI5	PAI6
Cows	77	103	127	151	180	226
Milk/Yr. (1000 lbs)	1,205	1,657	1,954	2,286	2,560	3,341
Kwh/Yr. (1000's)	75	81	88	92	93	97
# Sample Farms	32	41	37	16	8	21
Herd Size Range	57-91	92-116	117-140	141-165	166-189	190-330

Note: The characteristics of representative farms from the 1988 Farm Energy Survey are averages across the number of farms in the herd size range.

Table 7. Characteristics of Representative Phase II Farms

	Farm Name: Bucket Milking Technology		
	BII1	BII2	BII3
Cows	43	62	78
Milk/Yr. (1000 lbs)	614	792	1,064
Kwh/Yr. (1000's)	46	45	50
# Sample Farms	12	10	9
Herd Size Range	30-50	51-66	67-92

	Farm Name: Pipeline Milking Technology			
	PLII1	PLII2	PLII3	PLII4
Cows	46	61	79	101
Milk/Yr. (1000 lbs)	657	897	1,097	1,385
Kwh/Yr. (1000's)	47	49	49	51
# Sample Farms	33	44	14	10
Herd Size Range	35-52	53-70	71-88	89-125

	Farm Name: Parlor Technology
	PAII1
Cows	71
Milk/Yr. (1000 lbs)	959
Kwh/Yr. (1000's)	47
# Sample Farms	13
Herd Size Range	42-100

Note: The characteristics of representative farms from the 1988 Farm Energy Survey are averages across the number of farms in the herd size range.

Table 8. Characteristics of Representative Phase III Farms

	Farm Name: Bucket Milking Technology		
	BIII1	BIII2	BIII3
Cows	36	48	70
Milk/Yr. (1000 lbs)	409	562	959
Kwh/Yr. (1000's)	34	35	34
# Sample Farms	20	18	10
Herd Size Range	26-40	41-55	56-100
	Farm Name: Pipeline Milking Technology		
	PLIII1	PLIII2	PLIII3
Cows	36	48	60
Milk/Yr. (1000 lbs)	486	672	854
Kwh/Yr. (1000's)	34	35	36
# Sample Farms	15	14	15
Herd Size Range	30-41	42-52	53-65
	Farm Name: Parlor Technology		
		PAIII1	
Cows		66	
Milk/Yr. (1000 lbs)		915	
Kwh/Yr. (1000's)		37	
# Sample Farms		6	
Herd Size Range		40-100	

Note: The characteristics of representative farms from the 1988 Farm Energy Survey are averages across the number of farms in the herd size range.

representative farms, 13 for Phase I, 8 for Phase II, and 7 for Phase III. For Phase I, the representative farms range in size from 49 cows to 271 cows; milk production ranges from 841 thousand pounds to just over 4 million pounds per year. Phase II farms range in size from 43 to 101 cows, while Phase III farms range from 36 to 70 cows. Only three of the Phase II farms have annual milk production over a million pounds; the maximum annual milk production for the representative farms in Phase III is about 950 thousand pounds.

ANALYSIS OF REPRESENTATIVE FARMS

To analyze the implications of moving to TOU rates for representative farms from the three implementation phases, data on herd size and production for each representative farm were entered into the computer model described above, along with information from Tables A1 through A3 on the timing of milking and other farm operations. Additional information is added for lighting and ventilation, according to average types of systems and the number of lights and fans used. These data are in Tables A4 through A6 and were computed from the 1987 Farm Management and Energy Survey, as were the assumptions made with regard to water heater and milk cooler specifications.

It is important to remember in the analysis below that the modeling runs and the resulting cost estimates exclude any electricity consumption at the farm residence. The electricity charges used are Niagara Mohawk's SC-1 residential rate (a flat-rate charge of $0.07196 per Kwh) and the SC-1C residential time-of-use charge, but exclude any state and local taxes and any periodic rate adjustments authorized by the Public Service Commission due to fluctuations in fuel costs (Figure 2).[4] The monthly service charges are $5.85 and $32.20 for the flat and TOU rates, respectively. The estimates also assume that there are no adjustments in energy use to off-peak times as a result of the TOU rate. Assuming that there are some opportunities to move consumption off-peak, the estimates reported below represent an upper bound on the size of the TOU bill.

Comparisons of Annual Electricity Bills

The results of running the model for the 28 representative farms are given in Tables 9, 10 and 11. Annual electricity bills across the representative farms assuming a flat rate range from a high of $9,033 for the largest Phase I farm with a milking parlor to a low of

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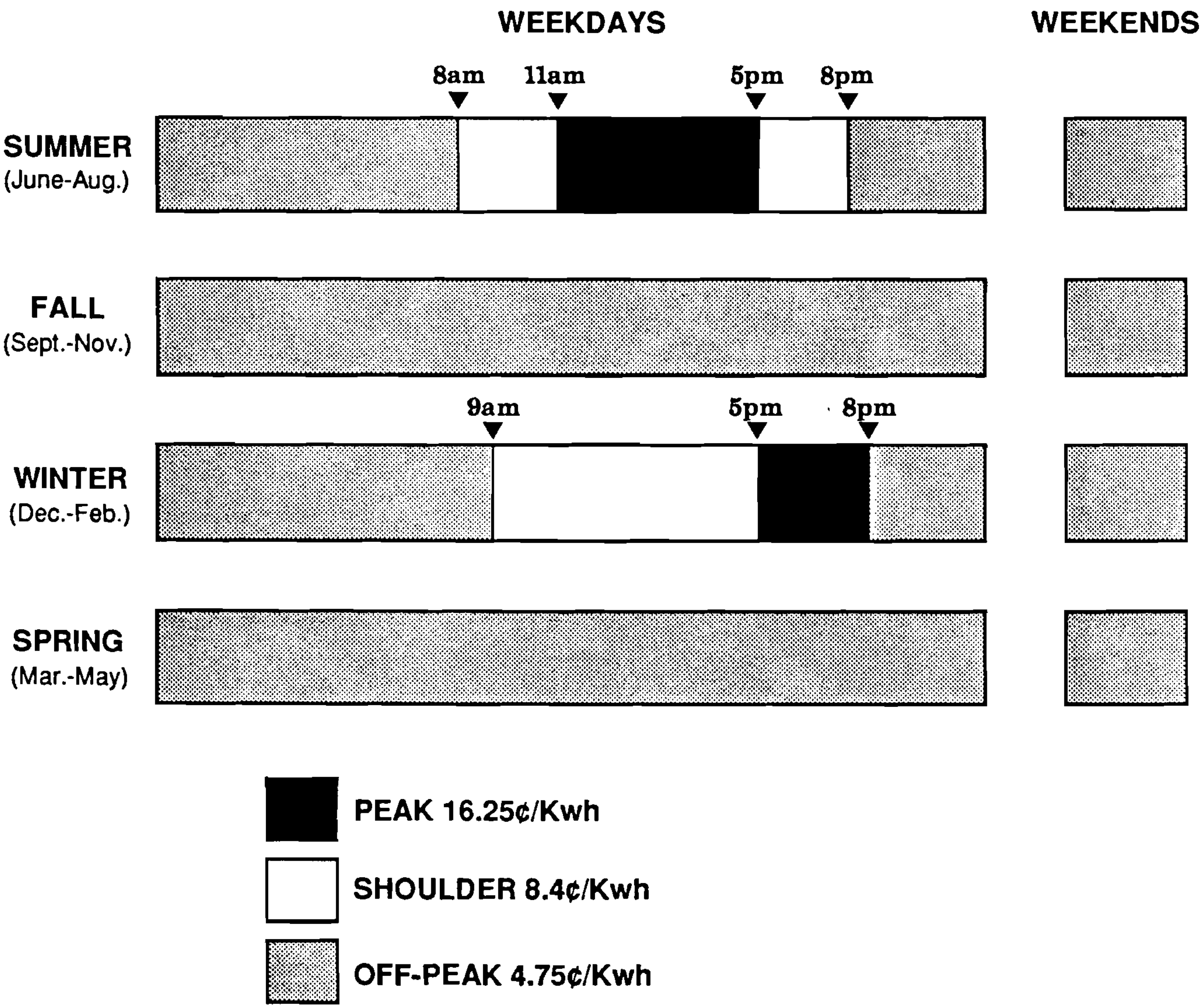
[4]For the TOU rate, months during the spring and summer are called off-season, but the cost of electricity during these months are charged at the off-peak rate.

Figure 2
NIAGARA MOHAWK TIME-OF-USE ELECTRIC RATE



CUSTOMER CHARGE: $32.20/month

FLAT RATE	**7.196¢/Kwh**
CUSTOMER CHARGE	**$5.85/month**

Table 9. Estimated Electricity Bills and Energy Charges for Phase I Representative Farms

Representative Farm	Estimated Bill		Bill Comparisons		Energy Charge		Charge Comparisons	
	Flat Rate	TOU Rate	$ Change	% Change	Flat Rate	TOU Rate	$ Change	% Change
Bucket Technology								
BI1	$3,601	$3,321	-280	-7.8	$3,531	$2,934	-597	-16.9
Pipeline Technology								
PLI1	2,805	2,666	-138	-4.9	2,735	2,280	-455	-16.6
PLI2	3,513	3,253	-260	-7.4	3,443	2,866	-576	-16.7
PLI3	3,875	3,598	-276	-7.1	3,805	3,212	-593	-15.6
PLI4	5,530	4,963	-566	-10.2	5,460	4,577	-883	-16.2
PLI5	5,921	5,326	-596	-10.1	5,851	4,939	-912	-15.6
PLI6	8,942	7,878	-1,064	-12.0	8,872	7,492	-1,381	-15.6
Parlor Technology								
PAI1	3,641	3,366	-275	-7.6	3,571	2,979	-592	-16.6
PAI2	4,403	4,024	-379	-8.6	4,333	3,638	-695	-16.1
PAI3	5,060	4,624	-437	-8.6	4,990	4,237	-753	-15.1
PAI4	5,810	5,241	-570	-9.8	5,740	4,854	-886	-15.4
PAI5	5,768	5,210	-558	-9.7	5,698	4,824	-874	-15.3
PAI6	9,033	8,089	-944	-10.5	8,963	7,702	-1,260	-14.1

Note: See Table 6 and the tables in Appendix A for descriptions of representative farms. Estimates are for 12 months exclusive of the farm residence. The data are rounded to the nearest dollar.

Table 10. Estimated Electricity Bills and Energy Charges for Phase II Representative Farms

Representative Farm	Estimated Bill: Flat Rate	Estimated Bill: TOU Rate	Bill Comparison: $ Change	Bill Comparison: % Change	Energy Charge: Flat Rate	Energy Charge: TOU Rate	Charge Comparison: $ Change	Charge Comparison: % Change
Bucket Technology								
BII1	$2,236	$2,192	-44	-2.0	$2,166	$1,806	-360	-16.6
BII2	2,818	2,653	-166	-5.9	2,748	2,266	-482	-17.5
BII3	3,345	3,136	-209	-6.3	3,275	2,750	-526	-16.1
Pipeline Technology								
PLII1	2,592	2,485	-107	-4.1	2,522	2,099	-423	-16.8
PLII2	3,233	3,035	-198	-6.1	3,163	2,648	-515	-16.3
PLII3	3,397	3,170	-227	-6.7	3,327	2,784	-543	-16.3
PLII4	4,873	4,418	-455	-9.3	4,803	4,032	-771	-16.1
Parlor Technology								
PAII1	3,262	3,050	-212	-6.5	3,192	2,663	-529	-16.6

Note: See Table 7 and the tables in Appendix A for descriptions of representative farms. Estimates are for 12 months, exclusive of the farm residence. The data are rounded to the nearest dollar.

Table 11. Estimated Electricity Bills and Energy Charges for Phase III Representative Farms

Representative Farm	Estimated Bill		Bill Comparison		Energy Charge		Charge Comparison	
	Flat Rate	TOU Rate	$ Change	% Change	Flat Rate	TOU Rate	$ Change	% Change
Bucket Technology								
BIII1	$1,863	$1,877	+15	+0.8	$1,793	$1,491	-302	-16.8
BIII2	2,325	2,274	-51	-2.2	2,255	1,888	-367	-16.3
BIII3	3,155	2,948	-208	-6.6	3,085	2,561	-524	-17.0
Pipeline Technology								
PLIII1	2,391	2,328	-63	-2.6	2,321	1,941	-379	-16.4
PLIII2	2,601	2,483	-119	-4.6	2,531	2,096	-435	-17.2
PLIII3	3,110	2,927	-183	-5.9	3,040	2,540	-500	-16.4
Parlor Technology								
PAIII1	3,162	2,968	-194	-6.1	3,092	2,581	-510	-16.5

Note: See Table 8 and the tables in Appendix A for descriptions of representative farms. Estimates are for 12 months, exclusive of the farm residence. The data are rounded to the nearest dollar.

$1,063 for the smallest farm in Phase III (the one with bucket technology). These same farms also have the highest and lowest annual electricity bills under the TOU rate: $8,089 and $1,877, respectively.

Niagara Mohawk Time-of-Use Electric Rate

Electricity bills under the TOU rate are ranked the same across the 28 farms as for the flat rate. Despite the higher monthly service charges under the TOU rate, the bill is lower under the TOU rate in all cases, except for farm BIII1, but the savings are not proportional. The largest savings is $1,064 (over 12 percent) for the largest Phase I farm with a parlor, while the smallest ($44 or 2 percent) is for the next to the smallest Phase II farm with bucket technology.[5] (The smallest Phase III farm would experience less than a one percent increase in cost.) Although there are a couple of exceptions, the percentage savings generally rise with the size of the farm (as measured by the number of cows) and rise as one moves from bucket to pipeline to parlor technology.

A comparison of the energy charges (the electricity bill less the monthly fixed charges) leads to slightly different results (Tables 9, 10 and 11). Since the fixed monthly charge is higher under the TOU rate than it is under the flat rate, it should be no surprise that estimated energy charges are lower for all representative farms as well. Savings range from a high of $1,381 for the largest Phase I farm with a pipeline to $302 for the smallest Phase III farm with bucket technology. On a percentage basis, the savings range from a high of 17.5 percent (farm BII2) to a low of 14.1 percent (PAI6). However, in contrast to the situation for the entire electricity bill, percentage savings on the energy costs alone tend to be slightly higher for smaller farms using a particular milking technology and increase slightly as you move from Phase I to Phase III.

The fact that percentage reductions are somewhat higher for smaller farms is because energy costs abstract from any fixed charges which are naturally a larger fraction of the total electricity bill for small farms. The fact that the TOU energy charges are consistently lower for all farms is because most current electricity use on dairy farms occurs at off-peak times (Middagh et al., 1991) when rates are well below the flat rate level. Not only are many

[5] The results in this report focusing only on Phase III farms differ slightly from those in an earlier unpublished report to Niagara Mohawk Power Corporation because the characteristics of the representative farms have been changed somewhat and the simulation model has been refined, particularly in the way it calculates energy use for water heating and lighting (Bills et al., 1991).

operations scheduled at off-peak times during the day, it is important to remember that peak and shoulder prices are only in effect for six months of the year.

It is also informative to examine the cost savings realized in moving to a TOU rate on a Kwh basis. This information, along with estimates of energy use, is given in Tables 12, 13 and 14. The estimated annual energy use (excluding the farm residence) ranges from a high of just under 124,000 Kwh (farm PAI6) to a low of approximately 25,000 Kwh for farm BIII1.

Table 12. Cost Savings on Phase I Farms in Moving to TOU Rates

Representative Farm	Savings/1000 Kwh: Electricity Bill	Savings/1000 Kwh: Energy Charge	Estimated Kwh
Bucket Technology			
BI1	$5.71	$12.16	49,065
Pipeline Technology			
PLI1	3.64	11.97	38,001
PLI2	5.43	12.05	47,841
PLI3	5.23	11.21	52,873
PLI4	7.46	11.63	75,866
PLI5	7.32	11.22	81,308
PLI6	8.63	11.20	123,295
Parlor Technology			
PAI1	5.55	11.93	49,625
PAI2	6.29	11.55	60,211
PAI3	6.30	10.86	69,345
PAI4	7.14	11.11	79,770
PAI5	7.04	11.04	79,175
PAI6	7.58	10.12	124,550

Note: See Table 6 and the tables in Appendix A for descriptions of representative farms. The savings are calculated from data on Table 9 and the Kwh figures on this table.

In general, the savings in the total electricity bill per 1,000 Kwh in moving from the flat rate to the TOU rate increases with farm size (Tables 12, 13, and 14). The average savings in Phase III is $2.86 per 1000 Kwh. It rises to $4.30 and $6.40 per 1000 Kwh for Phases II and I, respectively. Within each phase, the cost savings also rise in general as one moves from the smallest to the largest farms within a given milking technology.

The situation is somewhat different when looking only at savings in the energy charge (Tables 12, 13, and 14). Here the cost savings per 1000 Kwh are nearly the same across phases, averaging $11.39 for Phase I, $11.89 for Phase II, and only slightly more, $11.98, for Phase III farms. There is no clear relationship between farm size and the savings level within a given milking technology. The fact that some smaller farms within a given milking technology have larger energy charge savings per 1000 Kwh than do the larger farms, again highlights the importance of the fixed charge when comparing total electricity bill savings with just the savings due to the energy charge.

Table 13. Cost Savings on Phase II Farms in Moving to TOU Rates

Representative Farm	Savings/1000 Kwh		Estimated Kwh
	Electricity Bill	Energy Charge	
Bucket Technology			
BII1	$1.45	$11.96	30,095
BII2	4.34	12.62	38,189
BII3	4.60	11.55	45,514
Pipeline Technology			
PLII1	3.04	12.07	35,043
PLII2	4.51	11.71	43,955
PLII3	4.91	11.75	46,234
PLII4	6.81	11.55	66,742
Parlor Technology			
PAII1	4.78	11.92	44,354

Note: See Table 7 and the tables in Appendix A for descriptions of representative farms. The savings are calculated from data on Table 10 and the Kwh figures on this table.

Table 14. Cost Savings on Phase III Farms in Moving to TOU Rates

Representative Farm	Savings/1000 Kwh		Estimated Kwh
	Electricity Bill	Energy Charge	
Bucket Technology			
BIII1	-$0.60	$12.11	24,909
BIII2	1.62	11.72	31,337
BIII3	4.85	12.23	42,875
Pipeline Technology			
PLIII1	1.95	11.76	32,245
PLIII2	3.37	12.37	35,170
PLIII3	4.34	11.83	42,242
Parlor Technology			
PAIII1	4.51	11.88	42,963

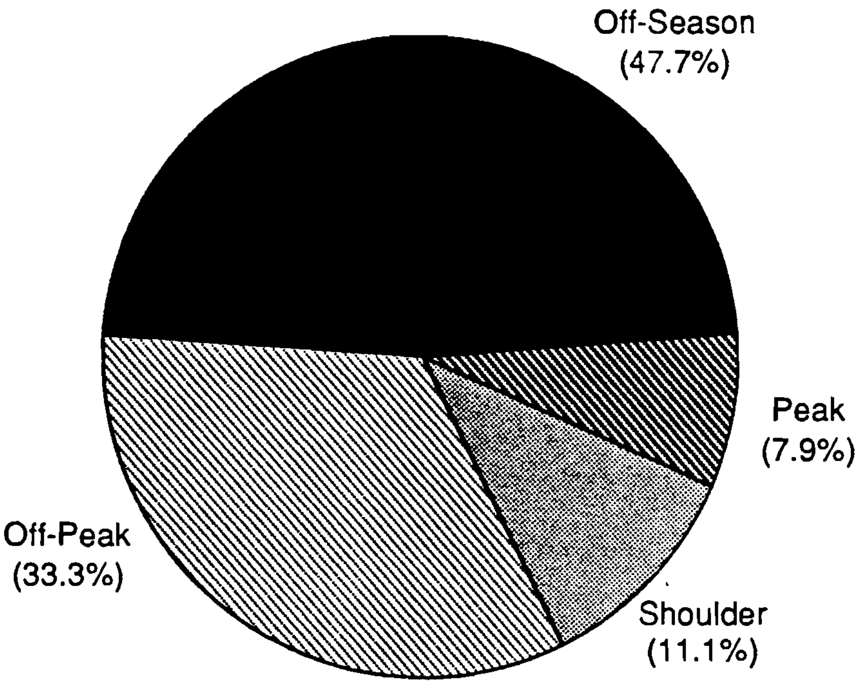
Note: See Table 8 and the tables in Appendix A for descriptions of representative farms. The savings are calculated from data on Table 11 and the Kwh figures on this table.

Distribution of Electricity Use On and Off Peak

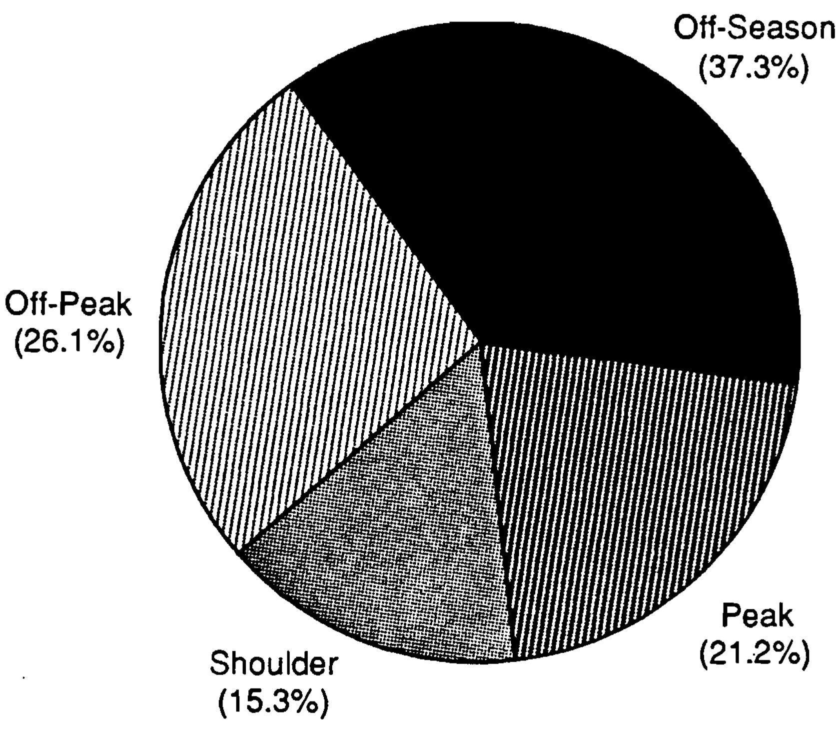
Although there are some differences in the energy charge cost savings per 1000 Kwh across the representative farms, they are not terribly large. This is not difficult to explain after examining the distribution of energy use across peak, shoulder, off-season, and off-peak periods. The average distribution of energy use by TOU period for the representative farms is in Figure 3; details for each farm are in the tables in Appendix B. For all representative farms, about 33 percent of electricity use is off-peak, the range being only 31.4 percent for farms BI1 and BII3 to 35 percent for farms PLI5 and PLI6. Use during the shoulder period ranges from a low of 10 percent to 12 percent. Because peak rates are in effect only six months of the year, and then only for a small number of hours a day, only between 7

Figure 3. Distribution of KWH and Energy Charges by Rate Period

KWH Distribution by Rate Period
Total Farm Kwh Consumption



Cost Distribution by Rate Period
Energy Charge



percent and 9 percent of energy is used during peak periods. Off-season use ranges from 46 percent to 49 percent of total energy utilization.[5]

Obviously, the proportion of TOU energy charges occurring in the peak and shoulder periods is substantially higher than the proportion of energy use because the rates are higher in peak and shoulder periods than they are in the off-peak. The TOU energy charge for the shoulder period is about half again as large in percentage terms as is the energy use during the period (Figure 3 and Tables B1-B3). For the peak, the energy charge is nearly three times as important as it is for energy use; it ranges between 20 percent and 24 percent of the total TOU energy charge. Despite this fact, given the nature of the current distribution of energy use, it is probably safe to conclude that the potential for further cost savings or reductions by merely shifting production off peak is somewhat limited. This does not mean, however, that savings can't be made through conservation efforts.

Distribution of Electricity Use by End Use

A complete discussion of additional savings due to load shifting or investments in conservation efforts at the farm level would require that the additional costs be weighted against the savings. These issues are to be the subject of a future research report. However, most investments to conserve energy or shift load affect energy consumption by major end use on the farm. Table 15 contains summary information on this distribution of energy use and costs by major end use. The distribution of Kwh by end use for each representative

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[5]Because the implementation of Niagara Mohawk Power Corporation's TOU rate is not complete, there is limited information on the actual energy use by peak, shoulder and off-peak periods. As part of the research accompanying this implementation, the Research Triangle Institute is analyzing data from the customers for which the TOU meters have already been installed. To date, there are data only for several hundred Phase I farms, 223 of which are farms also included in the 1988 Rural Household and Energy Survey mentioned in Table 2.

For these farms, the annual Kwh consumption estimated from the billing date provided by NMPC is 79,100 Kwh. This would have been for the year 1987. For these same farms, the most recent annual consumption (as measured on the TOU meters) is 80,500 Kwh. According to the TOU meters, 81 percent of the Kwh consumption occurred at off-peak and off-season, 12 percent on the shoulder and the remaining 7 percent on peak. This distribution is remarkably similar to that estimated by the farm simulation model used in this study. These data, however, do include the farm residence. A more complete validation of the model will have to wait until TOU meter data for farms in the other two phases become available and better estimates of household consumption are obtained.

Table 15. Average Percentage Distribution of Kwh and Energy Costs for All Representative Farms

End Use	Mean	Standard Deviation	Maximum	Minimum
	------------------% of Kwh/Year------------------			
Milking	20.4	3.7	30.6	16.0
Milk Cooling	18.3	3.3	25.3	12.2
Water Heater	23.9	5.5	31.6	13.1
Feeding	9.3	2.5	15.0	5.0
Waste Handling	1.2	0.5	2.2	0.3
Ventilation	5.0	1.1	7.6	3.6
Lighting	17.3	3.3	27.0	7.1
Miscellaneous	4.8	0.0	4.8	4.8
	-----------% of Flat Rate Energy Charge-----------			
Milking	20.4	3.7	30.6	16.0
Milk Cooling	18.3	3.3	25.3	12.1
Water Heater	23.9	5.5	31.6	13.1
Feeding	9.3	2.5	15.0	4.9
Waste Handling	1.2	0.5	2.1	0.3
Ventilation	5.0	1.1	7.6	3.6
Lighting	17.3	3.3	27.0	7.1
Miscellaneous	4.8	0.0	4.8	4.8
	----------% of TOU Rate Energy Charge----------			
Milking	20.5	3.5	30.6	16.2
Milk Cooling	18.6	3.5	25.7	12.1
Water Heater	21.8	5.2	28.9	11.6
Feeding	9.5	2.5	15.1	5.2
Waste Handling	1.1	0.5	2.2	0.3
Ventilation	5.5	1.2	8.3	4.0
Lighting	17.9	3.4	27.9	7.6
Miscellaneous	5.2	.04	5.3	5.1

Note: Calculated from detailed results of the simulation runs for all representative farms.

farm is given in Appendix C. Because of the similarity in the distribution of costs to the distribution of Kwh, the detailed costs by end use are not reported.

Of the eight end uses reported, it is not surprising that, on average, the three largest users of electricity are water heating (23.9 percent), milking (20.4 percent) and milk cooling (18.3 percent). Lighting is not far behind. For all end uses, the standard deviations in these percentages are small relative to the means.

In general, the percentage of Kwh consumption for those end uses associated most directly with milk production (milking and milk cooling) rises in moving from the smaller farms to the larger ones. The percentage consumption of electricity for feeding also rises as herd size increases.

In contrast, the proportion of total electricity use for water heating falls as farm size increases within a given phase and given milking technology. This suggests that the demand for hot water for cleaning etc. is less dependent on the number of cows and milk output than are these other uses. The same can be said for lighting and ventilation.

DISCUSSION AND CONCLUSIONS

Electric utilities throughout the Nation are experimenting with strategies to reduce total electricity consumption or to alter the timing of electrical power use by their customers. This report focuses on one such strategy, time-of-use (TOU) electric rates, and the likely effect of this pricing option on the New York dairy sector. The purpose of the study is to assess the change in farm electrical energy costs when power is sold to dairymen at higher rates during periods of peak power demand and at substantially lower rates during off-peak periods. Such pricing schemes have initially proven to be controversial in the farm community, with dairy farmers concerned with escalating electric bills because power use on a dairy farm is centered on a fixed milking schedule.

This study is based on the results derived from a farm-level, computer decision model which calculates farm energy consumption by major end uses--such as milk cooling and feed handling--and by time of day. The model differentiates power use on farms depending on the configuration of electrical equipment and the timing of its use. Many of the parameters in the model, as well as the characteristics of a number of representative farms studied, are based on extensive data sets developed to assess the use of electricity on New York farms.

To illustrate the effects of moving to new TOU electricity rates, electric power rates charged by the Niagara Mohawk Power Corporation (NMPC) are incorporated into the analysis. NMPC serves farm customers in all or parts of 32 upstate New York counties. Many NMPC farm customers purchase power at residential rates; those residential customers purchasing over 30,000 Kwh each year are being shifted from a flat rate to a TOU rate. Farm customers on the flat rate purchase electricity at about $0.07 per Kwh, before any applicable state and local taxes or periodic fuel cost adjustment charges. The new NMPC rate for larger residential customers features rates that range from just over $0.16 per Kwh during peak periods to just under $0.05 per Kwh during off-peak periods. There is also a shoulder rate of just over $0.08 per Kwh. The peak and shoulder periods apply to certain hours of the day during the summer and winter. All hours are at off-peak rates during the fall and spring. The TOU rate is also designed to be revenue neutral for NMPC for this class of customers. To accomplish this purpose, the fixed monthly service charge is increased from $5.85 to $32.50 per month.

Electricity use on a dairy farm fluctuates with herd size and with the technology used to husband and milk dairy stock. To capture a significant amount of this variability in New York, we developed estimates of power use by time of day for each of 28 representative farms. The farms differentiate herd size, stanchion or loose housing, and milking technology, and the timing of electrical equipment use. Both bucket and pipeline technologies are considered. For this analysis, it is assumed that no adjustments in management are made--either in the timing of milking, feed handling or waste handling, or in the configuration/size of electrical equipment--as a result of the new TOU rate. These procedures allow the effect of rate changes to be isolated and set the stage for more detailed analyses of load-shifting techniques farm operators might use to alter the amount or timing of electric power use.

Results show that, in the case of the TOU rates now being implemented by NMPC, moving from flat rates to TOU rates has only marginal effects on energy costs incurred by dairy farmers. For the 28 representative farm businesses considered, annual electricity bills range from $1,863 to just over $9,000 under the flat rate, but change to a range of $1,877 to about $8,089 under the new TOU rate. The largest projected cost savings amounts to over 12 percent; larger farms have the most significant cost savings under the new rate, with smaller dairy operations approximately breaking even when power is purchased at TOU rates.

These results also show that initial concerns over abrupt increases in power costs under new energy pricing schemes were misplaced. While power costs clearly increase during the summer and winter when rates increase to reflect peak power use, dairymen receive a concomitant windfall gain when purchasing power at relatively lower rates off-peak and off-season. Off-peak power use is significant on some farms and, regardless of the timing of equipment use, all producers can buy power at low flat rates during the fall and the spring. In fact, analysis has shown that the bulk of all electricity use on a dairy farm occurs off-peak if one makes reference to the new NMPC rate. For the farms studied here, an estimated 80 percent of all power use is off-peak under the NMPC rate. Actual outcomes across New York State, of course, will depend on the timing of milking operations and the rate design selected by the utility who supplies the dairy operation with electric power.

Although the New York dairy industry will welcome stability or even decreases in power costs under new rates, our results may seem anomalous from the broader perspective of energy pricing and the general issue of incorporating pricing strategies into efforts to affect power use via demand side management. Namely, rates are changed, but customers seem unlikely to realize cost savings in addition to those mentioned above of sufficient size to induce them to alter behavior significantly. Other things equal, dairy farmers are not likely to shift large amounts of electricity consumption from peak to off-peak in response to TOU prices.

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APPENDIX A

MILKING, FEEDING AND GUTTER CLEANING TIMES FOR REPRESENTATIVE FARMS

APPENDIX B

ENERGY USE AND CHARGES ON REPRESENTATIVE FARMS BY TOU PERIOD

APPENDIX C

PERCENTAGE DISTRIBUTION OF Kwh BY END USE FOR REPRESENTATIVE FARMS

Table A1. Milking, Feeding and Gutter Cleaning Times for Phase I Farms

	Farm Name: Bucket Milking Technology
	BI1
Milking	
AM Start	5:46
Duration (min.)	117
PM Start	4:51
Duration (min.)	115
Feeding	
1st Start	7:36
2nd Start	4:43
Gutter Cleaning	
AM Start	9:11

	Farm Name: Pipeline Milking Technology					
	PLI1	PLI2	PLI3	PLI4	PLI5	PLI6
Milking						
AM Start	5:29	5:53	5:36	5:22	5:22	5:27
Duration (min.)	92	113	120	147	159	149
PM Start	5:13	4:53	4:38	3:50	3:56	4:12
Duration (min.)	93	111	119	147	152	145
Feeding						
1st Start (AM)	7:22	7:25	7:55	6:43	6:15	6:51
2nd Start (PM)	4:51	3:38	3:59	2:56	4:50	4:17
Gutter Cleaning						
AM Start	9:40	8:23	8:22	9:10	7:32	7:18

	Farm Name: Parlor Technology					
	PAI1	PAI2	PAI3	PAI4	PAI5	PAI6
Milking						
AM Start	5:22	5:07	5:00	5:05	4:47	4:03
Duration (min.)	141	161	189	184	193	241
PM Start	4:13	4:02	3:39	3:32	2:52	2:34
Duration (min.)	139	155	177	178	182	228
Feeding						
1st Start (AM)	6:27	6:57	6:05	6:13	6:30	6:09
2nd Start (PM)	3:50	4:33	4:32	3:56	4:18	3:51
Gutter Cleaning						
AM Start	6:35	11:00	8:45	8:20	7:40	6:55

Note: These characteristics of the representative farms are from the 1987 Farm Energy Survey. The milking times are averages across the number of farms in the herd size range from Table 6, whereas other times are from subsets of farms in that herd size range that feed twice a day and clean gutters once a day.

Table A2. Milking, Feeding and Gutter Cleaning Times for Phase II Farms

	Farm Name: Bucket Milking Technology			
	BII1	BII2	BII3	
Milking				
AM Start	5:56	5:44	5:35	
Duration (min.)	103	122	131	
PM Start	5:14	5:01	3:29	
Duration (min.)	102	119	128	
Feeding				
1st Start (AM)	8:14	7:02	9:00	
2nd Start (PM)	4:33	5:00	4:00	
Gutter Cleaning				
AM Start	9:30	9:43	8:34	
	Farm Name: Pipeline Milking Technology			
	PLII1	PLII2	PLII3	PLII45
Milking				
AM Start	5:54	5:56	5:53	5:25
Duration (min.)	91	108	119	132
PM Start	5:07	5:03	4:56	4:08
Duration (min.)	92	107	116	132
Feeding				
1st Start (AM)	7:14	7:36	7:17	7:38
2nd Start (PM)	4:49	3:49	4:13	3:15
Gutter Cleaning				
AM Start	9:23	9:03	8:13	8:37
	Farm Name: Parlor Technology			
		PAII1		
Milking				
AM Start		5:22		
Duration (min.)		137		
PM Start		4:21		
Duration (min.)		137		
Feeding				
1st Start (AM)		7:11		
2nd Start (PM)		4:30		
Gutter Cleaning				
AM Start		7:44		

Note: These characteristics of the representative farms are from the 1987 Farm Energy Survey. The milking times are averages across the number of farms in the herd size range from Table 7, whereas other times are from subsets of farms in that herd size range that feed twice a day and clean gutters once a day.

Table A3. Milking, Feeding and Gutter Cleaning Times for Phase III Farms

	Farm Name: Bucket Milking Technology		
	BIII1	BIII2	BIII3
Milking			
AM Start	5:57	5:46	5:42
Duration (min.)	96	114	128
PM Start	5:21	4:58	4:28
Duration (min.)	94	114	125
Feeding			
1st Start (AM)	7:47	8:34	7:15
2nd Start (PM)	4:36	4:41	4:56
Gutter Cleaning			
AM Start	9:33	9:37	9:08

	Farm Name: Pipeline Milking Technology		
	PLIII1	PLIII2	PLIII3
Milking			
AM Start	5:51	5:58	5:55
Duration (min.)	88	92	106
PM Start	5:21	5:02	5:05
Duration (min.)	90	92	105
Feeding			
1st Start (AM)	6:49	7:18	7:41
2nd Start (PM)	4:49	4:49	3:48
Gutter Cleaning			
AM Start	9:05	9:34	9:10

	Farm Name: Parlor Technology
	PAIII1
Milking	
AM Start	5:25
Duration (min.)	134
PM Start	4:26
Duration (min.)	135
Feeding	
1st Start (AM)	7:10
2nd Start (PM)	4:33
Gutter Cleaning	
AM Start	7:44

Note: These characteristics of the representative farms are from the 1987 Farm Energy Survey. The milking times are averages across the number of farms in the herd size range from Table 8, whereas other times are from subsets of farms in that herd size range that feed twice a day and clean gutters once a day.

Table A4. Lighting, Ventilation and Cooling Equipment for Phase I Farms

	Farm Name: Bucket Milking Technology
	BI1
Lighting (Watts)	
Barn	2,005
Milk Room	286
Total	2,291
Outdoor	
No. of Bulbs	0
No. of Vent Fans	2
Milk Cooler (gal.)	600

	Farm Name: Pipeline Milking Technology					
	PLI1	PLI2	PLI3*	PLI4	PLI5*	PLI6*
Lighting (Watts)						
Barn	2,303	2,386	2,748	3,011	3,571	4,803
Milk Room	259	289	280	393	294	495
Total	2,562	2,675	3,028	3,404	3,865	5,298
Outdoor						
No. of Bulbs	1	1	1	2	2	3
No. of Vent Fans	2	2	3	5	5	5
Milk Cooler (gal.)	600	1,000	1,000	1,250	2,000	1,500

	Farm Name: Parlor Technology					
	PAI1	PAI2*	PAI3*	PAI4*	PAI5*	PAI6*#
Lighting (Watts)						
Barn	1,274	1,348	1,604	2,256	438	3,031
Milk Room	267	189	297	251	352	214
Parlor	587	588	752	634	419	967
Total	2,128	2,125	2,653	3,121	1,209	4,212
Outdoor						
No. of Bulbs	1	2	2	2	2	3
No. of Vent Fans	2	2	2	3	3	4
Milk Cooler (gal.)	800	1,000	1,000	1,500	2,000	3,000

Note: These characteristics of the representative farms are from the 1987 Farm Energy Survey. The milking times are averages across the number of farms in the herd size range from Table 6. All outdoor lights are 175 watts.

* These farms have heat transfer systems that use heat given off by milk cooling to help heat water.
\# These farms have a precooler in front of the bulk tank.

Table A5. Lighting, Ventilation and Cooling Equipment for Phase II Farms

	Farm Name: Bucket Milking Technology			
	BII1	BII2	BII3	
Lighting (Watts)				
Barn	1,619	2,062	2,254	
Milk Room	309	337	220	
Total	1,928	2,399	2,474	
Outdoor				
No. of Bulbs	1	1	1	
No. of Vent Fans	2	2	2	
Milk Cooler (gal.)	400	625	1,000	
	Farm Name: Pipeline Milking Technology			
	PLII1	PLII2	PLII3*	PLII45
Lighting (Watts)				
Barn	2,294	2,298	2,472	3,122
Milk Room	242	304	275	322
Total	2,536	2,602	2,747	3,444
Outdoor				
No. of Bulbs	1	1	1	1
No. of Vent Fans	2	2	3	5
Milk Cooler (gal.)	600	1,000	1,000	1,000
	Farm Name: Parlor Technology			
		PAII1		
Lighting (Watts)				
Barn		1,361		
Milk Room		237		
Parlor		524		
Total		2,112		
Outdoor				
No. of Bulbs		1		
No. of Vent Fans		2		
Milk Cooler (gal.)		1,000		

Note: These characteristics of the representative farms are from the 1987 Farm Energy Survey. The milking times are averages across the number of farms in the herd size range from Table 7. All outdoor lights are 175 watts.

* These farms have heat transfer systems that use heat given off by milk cooling to help heat water.

Table A6. Lighting, Ventilation and Cooling Equipment for Phase III Farms

	Farm Name: Bucket Milking Technology		
	BIII1	BIII2	BIII3
Lighting (Watts)			
Barn	1,532	1,747	2,254
Milk Room	312	314	268
Total	1,844	2,061	2,522
Outdoor			
No. of Bulbs	1	1	1
No. of Vent Fans	2	2	2
Milk Cooler (gal.)	400	500	600

	Farm Name: Pipeline Milking Technology		
	PLIII1	PLIII2	PLIII3
Lighting (Watts)			
Barn	2,966	1,984	2,297
Milk Room	212	256	306
Total	3,178	2,240	2,603
Outdoor			
No. of Bulbs	1	1	1
No. of Vent Fans	3	2	2
Milk Cooler (gal.)	500	600	1,000

	Farm Name: Parlor Technology
	PAIII1
Lighting (Watts)	
Barn	1,329
Milk Room	243
Parlor	513
Total	2,085
Outdoor	
No. of Bulbs	1
No. of Vent Fans	2
Milk Cooler (gal.)	1,000

Note: These characteristics of the representative farms are from the 1987 Farm Energy Survey. The milking times are averages across the number of farms in the herd size range from Table 8. None of these farms has either a precooler for the bulk tank or a heat recovery system. All outdoor lights are 175 watts.

Table B1. Energy Use and Charges on Phase I Farms by TOU Period

Representative Farm	Off-Season Energy Use	Off-Season Energy Charge	Off-Peak Energy Use	Off-Peak Energy Charge	Shoulder Energy Use	Shoulder Energy Charge	Peak Energy Use	Peak Energy Charge	KWH
	Percentage Distribution								
Bucket Technology									
BI1	49	38	31	25	12	17	7	20	49,065
Pipeline Technology									
PLI1	48	38	33	26	11	16	7	20	38,001
PLI2	48	38	32	25	11	16	8	21	47,841
PLI3	48	37	32	25	12	16	8	21	52,873
PLI4	46	36	35	27	11	15	8	21	75,866
PLI5	46	36	35	27	11	15	8	22	81,308
PLI6	47	37	34	27	11	15	8	21	123,295
Parlor Technology									
PAI1	48	38	32	26	11	15	8	21	49,625
PAI2	48	38	34	27	10	14	8	21	60,211
PAI3	48	37	33	26	11	16	8	21	69,345
PAI4	47	37	34	26	11	15	8	22	79,770
PAI5	47	37	34	26	11	15	8	22	79,175
PAI6	47	36	34	26	10	14	9	24	124,550

Note: See Table 6 and the tables in Appendix A for descriptions of representative farms. Detail may not add due to rounding.

Table B2. Energy Use and Charges on Phase II Farms by TOU Rate Period

	Percentage Distribution								
	Off-Season		Off-Peak		Shoulder		Peak		
Representative Farm	Energy Use	Energy Charge	Energy Use	Energy Charge	Energy Use	Energy Charge	Energy Use	Energy Charge	KWH
Bucket Technology									
BII1	48	38	33	26	12	17	7	20	30,095
BII2	48	38	33	27	11	15	7	20	38,189
BII3	48	38	31	24	12	17	8	21	45,514
Pipeline Technology									
PLII1	48	38	33	26	11	16	8	20	35,043
PLII2	48	38	32	25	12	16	8	21	43,955
PLII3	47	37	34	27	11	15	8	21	46,234
PLII4	47	37	33	26	11	16	8	21	66,742
Parlor Technology									
PAII1	48	38	33	26	11	15	8	21	44,354

Note: See Table 7 and the tables in Appendix A for descriptions of representative farms. Detail may not add due to rounding.

Table B3. Energy Use and Charges on Phase III Farms by TOU Rate Period

Representative Farm	Percentage Distribution								KWH
	Off-Season		Off-Peak		Shoulder		Peak		
	Energy Use	Energy Charge	Energy Use	Energy Charge	Energy Use	Energy Charge	Energy Use	Energy Charge	
Bucket Technology									
BIII1	47	37	34	27	12	16	7	20	24,909
BIII2	48	38	33	26	12	17	8	21	31,337
BIII3	48	38	32	26	11	15	8	21	42,875
Pipeline Technology									
PLIII1	47	37	34	27	11	15	8	21	32,245
PLIII2	48	38	33	26	11	16	7	20	35,170
PLIII3	48	38	32	25	12	16	8	20	42,242
Parlor Technology									
PAIII1	48	38	33	26	11	15	8	21	42,963

Note: See Table 8 and the tables in Appendix A for descriptions of representative farms. Detail may not add due to rounding.

Table C1. Percentage Distribution of Kwh by End Use for Phase I Farms

End Use	Farm Name: Bucket Milking Technology
	BI1
Milking	19
Milk Cooling	23
Water Heater	30
Feeding	5
Waste Handling	1
Ventilation	4
Lighting	15
Miscellaneous	5

	Farm Name: Pipeline Milking Technology					
	PLI1	PLI2	PLI3	PLI4	PLI5	PLI6
Milking	19	20	22	20	23	25
Milk Cooling	17	18	20	18	20	25
Water Heater	28	26	17	23	15	15
Feeding	8	10	12	10	11	9
Waste Handling	1	1	2	1	1	1
Ventilation	4	4	5	7	7	5
Lighting	19	17	18	16	18	16
Miscellaneous	5	5	5	5	5	5

	Farm Name: Parlor Technology					
	PAI1	PAI2	PAI3	PAI4	PAI5	PAI6
Milking	20	23	26	26	31	29
Milk Cooling	19	21	22	22	25	23
Water Heater	27	18	17	16	18	13
Feeding	12	15	10	10	8	9
Waste Handling	1	0.5	1	0.5	0.4	0.3
Ventilation	4	4	4	5	6	6
Lighting	14	14	15	16	7	16
Miscellaneous	5	5	5	5	5	5

Note: The characteristics of the representative farms are given in Table 6 and the tables in Appendix A. Detail may not add due to rounding.

Table C2. Percentage Distribution of Kwh by End Use for Phase II Farms

	Farm Name: Bucket Milking Technology		
	BII1	BII2	BII3
Milking	17	18	19
Milk Cooling	16	16	19
Water Heater	31	29	28
Feeding	5	7	6
Waste Handling	2	1	2
Ventilation	5	5	4
Lighting	19	20	18
Miscellaneous	5	5	5

	Farm Name: Pipeline Milking Technology			
	PLII1	PLII2	PLII3	PLII4
Milking	18	19	21	19
Milk Cooling	15	16	19	16
Water Heater	27	26	18	24
Feeding	9	11	12	11
Waste Handling	2	1	2	1
Ventilation	4	4	6	8
Lighting	20	18	18	17
Miscellaneous	5	5	5	5

	Farm Name: Parlor Technology
	PAII1
Milking	18
Milk Cooling	17
Water Heater	27
Feeding	12
Waste Handling	1
Ventilation	5
Lighting	15
Miscellaneous	5

Note: The characteristics of the representative farms are given in Table 7 and the tables in Appendix A. Detail may not add due to rounding.

Table C3. Percentage Distribution of Kwh by End Use for Phase III Farms

	Farm Name: Bucket Milking Technology		
	BIII1	BIII2	BIII3
Milking	16	17	18
Milk Cooling	13	14	17
Water Heater	32	30	28
Feeding	5	6	7
Waste Handling	1	1	1
Ventilation	6	6	5
Lighting	22	20	19
Miscellaneous	5	5	5
	Farm Name: Pipeline Milking Technology		
	PLIII1	PLIII2	PLIII3
Milking	17	18	19
Milk Cooling	12	15	16
Water Heater	26	28	26
Feeding	6	11	11
Waste Handling	1	2	1
Ventilation	6	4	4
Lighting	27	18	18
Miscellaneous	5	5	5
	Farm Name: Parlor Technology		
		PAIII1	
Milking		18	
Milk Cooling		17	
Water Heater		27	
Feeding		12	
Waste Handling		1	
Ventilation		5	
Lighting		16	
Miscellaneous		5	

Note: The characteristics of the representative farms are given in Table 8 and the tables in Appendix A. Detail may not add due to rounding.

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