

**DEMAND-SIDE MANAGEMENT/ENERGY CONSERVATION
POTENTIAL FOR WISCONSIN DAIRY FARMS**

by

Ross W. Peebles
Douglas J. Reinemann, Ph.D.
Department of Agricultural Engineering
University of Wisconsin-Madison
Milking Research and Instruction Lab

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Summary:

A dairy farm energy model using the TRNSYS software package was expanded and used to model farms representative of those in Wisconsin. Electrical end uses, including water heating, milk cooling, lighting, ventilation, and the vacuum pump, were modeled for both an efficient and inefficient system with each case. These results, combined with current and projected dairy herd statistics and market penetration values for energy conserving technologies, were used to estimate both the current and 10 year projected energy use. From this, the potential energy savings from installing energy efficient equipment on dairy farms was determined.

Keywords:

Electrical Energy, Energy Savings, Electrical Demand, Energy Conservation,

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Farm Power Requirements, Dairy Herds

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DEMAND-SIDE MANAGEMENT/ENERGY CONSERVATION POTENTIAL FOR WISCONSIN DAIRY FARMS

R.W. Peebles and D.J. Reinemann

INTRODUCTION

Farm operations are continually increasing their use of electrical energy as farm size increases and more and more tasks become mechanized. Many applications formerly using other energy sources are also shifting to electrical energy. Farm energy use is highly correlated with utility peak demand and therefore makes up a larger percentage of statewide peak kW load than kWh consumption. This study was conducted to determine the impact of the dairy farm electric load on Wisconsin's statewide electrical demand and peak loads. The results are also of interest to dairy operators who wish to know which equipment options offer the greatest potential for reducing operating costs and energy use, while providing the greatest return on investment.

The TRNSYS simulation program developed by the University of Wisconsin, Solar Energy Lab was used as the basis for a dairy farm electrical energy use model. The model is composed of individual modules developed for each component of the system. These modules are connected together and scaled to the farm size to form a farm system for simulation. The effects of external factors, such as weather, as well as management strategies can also be examined.

The dairy energy model was used to analyze various energy conserving equipment options and develop demand curves for various farm sizes. The model currently includes modules for the major dairy electric end uses. Predominant types and configurations of equipment, management practices, and farm size have been modeled.

PREVIOUS WORK

Previous work has been presented by Peebles (1993) and Peebles et. al. (1993). Previously developed model components include modules for the Direct Expansion (DX) Bulk Tank Cooler, Heat Recovery Unit, Well Water Precooler, Water Heater, and Ice Builder/Cold Thermal Storage Unit, as well as supporting forcing function components.

Combinations of precooling, heat recovery, and cold thermal storage were compared

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with base case direct expansion milk cooling and electric resistance water heating. Scenarios for a 60 cow stanchion barn with both a 2 in. and 3 in. milk pipeline, a 200 cow farm with a double 6 milking parlor, and a 400 cow farm with a double 6 milking parlor were examined.

The initial study showed that for the smaller 60 cow farm, heat recovery was the best single equipment option for saving energy. Combined heat recovery and precooling offered the best option for the 200 and 400 cow farms, with precooling the best single component option. Over-sizing the milk pipeline resulted in excessive use of energy, water, and cleaning chemicals.

NEW TRNSYS MODULES

Additional modules developed include ventilation, lighting, the vacuum pump, and a chiller milk cooling unit. Refinements were also made to the DX Bulk Tank Refrigeration Unit, Ice Builder/Thermal Storage Unit, and Milk Flow Pattern Generator modules to conform with the standard TRNSYS format.

Vacuum Pump

The vacuum pump module uses the vacuum pump motor rating as an input parameter, with the total energy consumption calculation based on total run time. The vacuum pump is assumed to be either on or off, having a constant load and energy consumption rate when operating. The vacuum pump operates whenever there is milk flowing into the bulk tank, as specified by the milk flow pattern generator. For operation during the cleaning and sanitation cycles, the start time of each cycle is specified. A 15 minute sanitation cleaning cycle is assumed, with the vacuum pump running for 10 minutes during the cycle. The complete wash operation is assumed to take 1 hour, with the vacuum pump running 25% of the time (a total of 15 minutes) during this period.

Lighting

Lighting loads can be specified in either of two ways. The first method is to simply indicate a total lighting load in watts. With the second method, the lighting load is determined by the desired lighting level, lighting efficiency, and building size. Lighting is simply an on or off load. Lighting loads can be specified as constant, continuous, or controlled with a scheduling pattern. Several lighting modules can be used simultaneously (e.g. for the milking parlor, freestall barn, etc.).

Ventilation

Up to four ventilation levels can be specified in the ventilation module. These are considered the base, low, medium, and high ventilation rates. A thermostatically controlled operating range is specified for each level. The ventilation electric load is calculated from the desired ventilation rate specified in cfm, and fan efficiency in cfm/watt. Ventilation loads can also be scheduled by specifying daily on and off operating periods. This is used for modeling milking parlors and barns where the cows are let out to pasture. Data from a field study conducted by Wisconsin Public Service Corporation was used to verify the ventilation module.

Chiller Unit

An instant cooling chiller module was developed as this type of unit is commonly used in large dairy operations (>500 cows). The refrigeration system cools the a coolant solution, which then circulates through a heat exchanger to cool the warm milk. This module has not been verified nor has it been used to predict any system operating loads.

SIMULATION SCENARIOS

Simulations were run to estimate the range of energy use with four farms representative of the major size categories in Wisconsin. Energy use was determined for both an efficient and inefficient system with each farm size. The inefficient system included a direct expansion milk cooler, electric resistance water heater, standard size vacuum pump, medium efficiency fans, and incandescent lighting at 60% of the recommended illumination level. The efficient system included both heat recovery and precooling, an energy conserving vacuum pump, high fan efficiency, and fluorescent lighting at recommended lighting levels. Each scenario was run for a 30 cow farm, 60 cow farm, 200 cow farm, and 400 cow farm. Parameters used for each farm

Table 1: Modeled Farm Characteristics

	30 Cow Farm	60 Cow Farm	200 Cow Farm	400 Cow Farm
Milk Production, (lb/day)	1,480	2,960	9,865	19,725
Hot Water Use, (gal/day)	85	165	190	295
Milk Pipeline Size, (in.)	1-1/2	2	3	3
Milking Time, (h)	1-1/4	2	3	6
DX Size, (hp)	3	4	7-1/2	2 @ 4
Water Heater w/out Heat Recovery, (gal)	80	80	120	120
Water Heater w/Heat Recovery, (gal)	40	40	80	120
Heat Recovery Unit, (gal)	80	80	80	120
Agitator Motor, (hp)	1/3	1/3	2 @ 1/3	2 @ 1/3
Base Ventilation, (cfm)	2,000	3,000	1,200	1,200
Cold Weather Ventilation, (cfm)	5,500	10,000	-	-
Mild Weather Ventilation, (cfm)	10,000	30,000	4,800	4,800
Hot Weather Ventilation, (cfm)	60,000	60,000	48,400	48,400
Vacuum Pump, (hp)	3.6	3.6	7.5	10

are presented in Table 1.

The standard vacuum pump is sized according to current recommendations of the Milking Machine Manufacturers Council (MMMC, 1993). A vacuum pump consuming 50% less energy was used with efficient systems. Lighting levels were determined from Midwest Plan Service recommendations. Recommended lighting levels are 10 lum/ft² for stall barn milking, 20 lum/ft² for milking parlors, and 7 lum/ft for free stall housing (MWPS, 1992). Recommended levels were used with fluorescent lighting, but were reduced to 60% with incandescent lighting to more accurately reflect existing lighting levels typically found on farms. Milking center and parlor lighting was turned on 1/2 hour before milking and turned off 1/2 hour after milking. Barn lighting was also turned on 1/2 hour before milking, and remained on until 1 hour after milking for chores. For the stanchion barns, a 40 W bulb was turned on for the period between the evening and morning chores. With the free stall barns, a 150 W high pressure sodium lamp was left on at night.

Ventilation rates used for the stanchion barn or milking parlor are included in Table 1. Natural ventilation is assumed with the free stall barns used on the 200 and

400 cow dairies. The base, cold weather, and mild weather ventilation rates were based on recommendations from Midwest Plan Service (MWPS, 1990). Hot weather ventilation rate is based on wind tunnel design. For inefficient systems, the mild and hot weather ventilation rates used a fan efficiency of 17 cfm/watt. Efficient systems used a 20 cfm/watt fan efficiency. Ventilation thermostat controls used outdoor ambient temperature. Base load ventilation operated when outdoor temperatures were below 15 °F. Cold weather ventilation operated between 15 and 60 °F, mild weather ventilation between 35 and 60 °F, and hot weather ventilation whenever ambient temperature was above 60 °F. Milking parlor ventilation was turned off between milkings.

SIMULATION RESULTS

Efficient and inefficient systems were simulated for each farm size to determine the high and low electrical energy consumption limits. These high and low extremes define an operating range or "window" of expected energy use; energy use for various combinations of equipment and management options fall within this range. Annual and daily load curves were produced for each scenario. Annual load curves are presented in Figures 1 to 4. Daily load curves were calculated for both a January and July day to show the seasonal effect. Daily load curves are presented in Figures 5 through 12. Farm energy summaries are presented in Tables 2 through 6. Table 7 contains the maximum daily demand reduction between the efficient and inefficient systems.

Water heating, milk cooling, and vacuum pump use have traditionally been considered the three largest electrical energy consumers on dairy farms. Results in Tables 2 through 6 show that lighting and ventilation are potentially the largest users when assuming that recommended levels for ventilation and lighting are achieved. These results indicate that current lighting and ventilation levels are well below the suggested levels on many farms. Improved lighting and ventilation levels are, however, common renovations in existing facilities.

Wind tunnel design was used for modeling hot weather (high) ventilation rates. Ventilation becomes the largest electric load on the 30 and 60 cow farms when assuming that the desired ventilation rate is maintained and the cows remain indoors. Wind tunnel design is based on achieving a desired air velocity, with the building cross sectional area governing the ventilation rate (Faust and Holmes, 1991). Therefore, ventilation requirements are roughly the same for any given stall barn or parlor, regardless of the number of cows housed and milked. Energy use per cow decreases as the herd size increases. For example, fan energy use per cow on the 30 cow farm will be twice that of the 60 cow farm.

Estimated lighting loads are also quite high with recommended illumination levels. For modeling purposes, illumination was set at 60% of the recommended level for inefficient systems with incandescent lighting, as many farms have insufficient lighting. It was also assumed that lighting would be upgraded to suggested levels when installing efficient fluorescent lighting. Lighting energy use is especially high in the free stall barns on the 200 and 400 cow dairies due to the building size. Results show that significant savings are obtainable by changing incandescent lighting to fluorescent lighting, even when improving illumination.

The largest potential savings occurring between the inefficient and efficient systems on the 30 cow farm exist with lighting and water heating (Table 2), at about 3,000 kWh/yr for each option. When using heat recovery without precooling, as recommended for a farm of this size, savings in water heating energy increase to 4,900 kWh/yr. Savings between inefficient and efficient ventilation and vacuum pumps are approximately 1,700 kWh/yr each.

On the 60 cow farm using a 2 in. milk pipeline the ranking of potential energy savings categories are: lighting (5,800 kWh/yr), water heating (5,100 kWh/yr), milk cooling (3,800 kWh/yr), vacuum pump (2,500 kWh/yr), and ventilation (2,250 kWh/yr). When using heat recovery without precooling, as recommended, savings in water heating energy increase to 7,800 kWh/yr.

For the 200 cow farm with a parlor milking system the ranking of potential energy savings categories are: lighting (43,400 kWh/yr), milk cooling (12,000 kWh/yr), water heating (7,500 kWh/yr), and vacuum pump (7,200 kWh/yr). Savings in ventilation energy are insignificant, as mechanical ventilation is only used in the milking parlor. Lighting on this farm is the largest single end use. This assumes that recommended lighting levels are maintained in the freestall barns, and that lighting remains on during milking and chores.

For the 400 cow farm with a parlor milking system the ranking of potential energy savings categories are: lighting (81,000 kWh/yr), milk cooling (23,500 kWh/yr), and vacuum pump (17,000 kWh/yr).

Figure 1: 30 Cow Farm - Total Monthly Electrical Energy Use

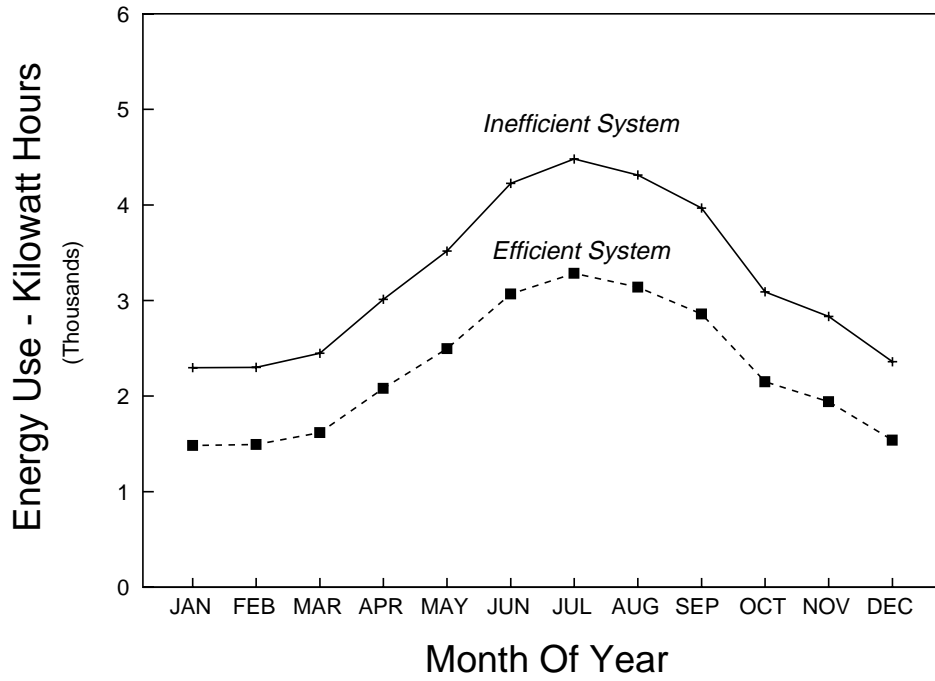


Figure 2: 60 Cow Farm - Total Monthly Electrical Energy Use

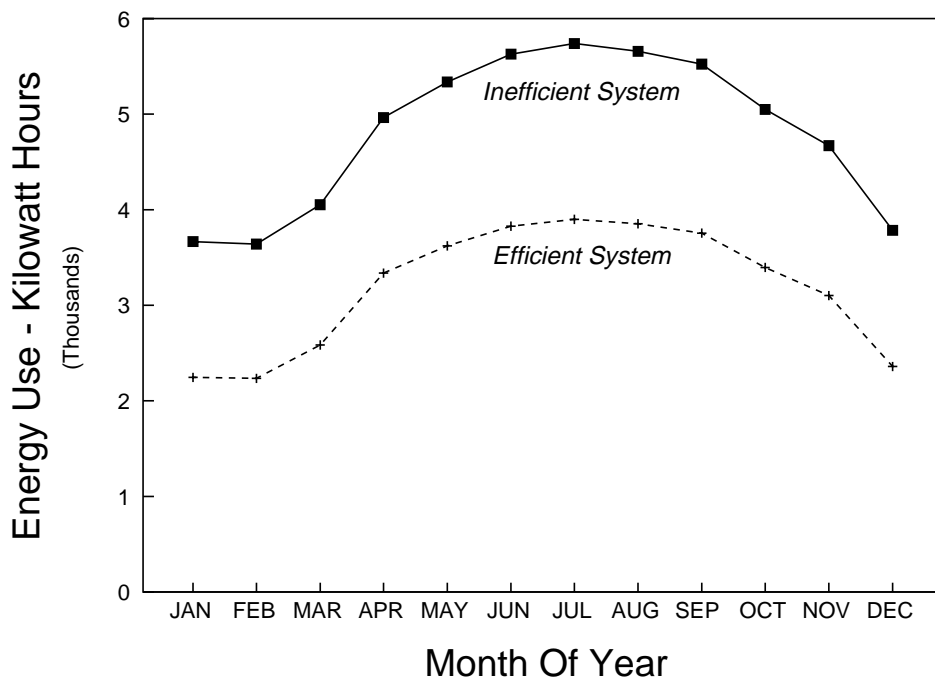


Figure 3: 200 Cow Farm - Total Monthly Electrical Energy Use

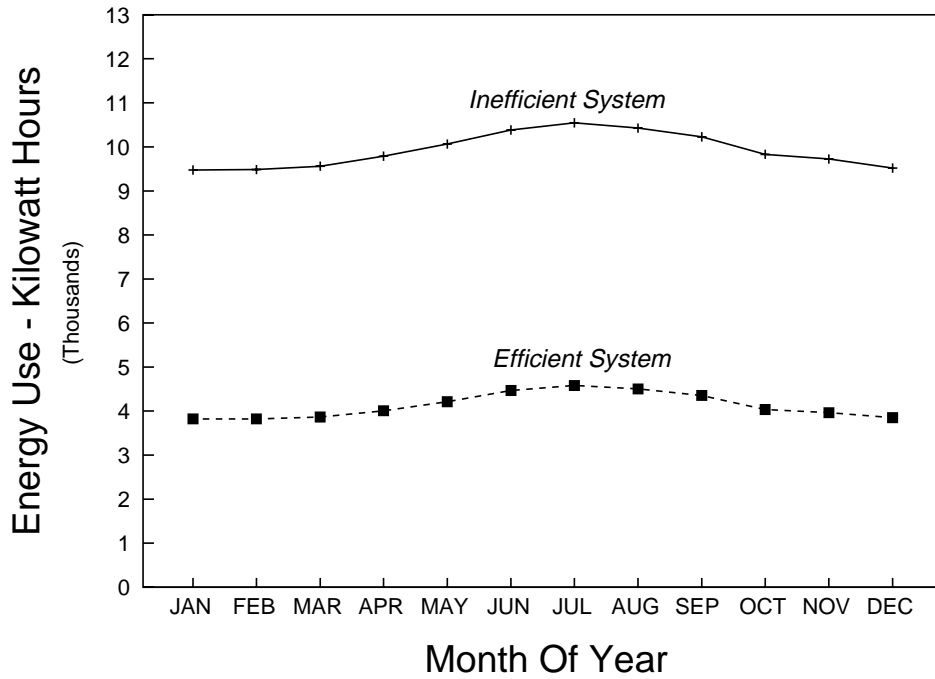


Figure 4: 400 Cow Farm - Total Monthly Electrical Energy Use

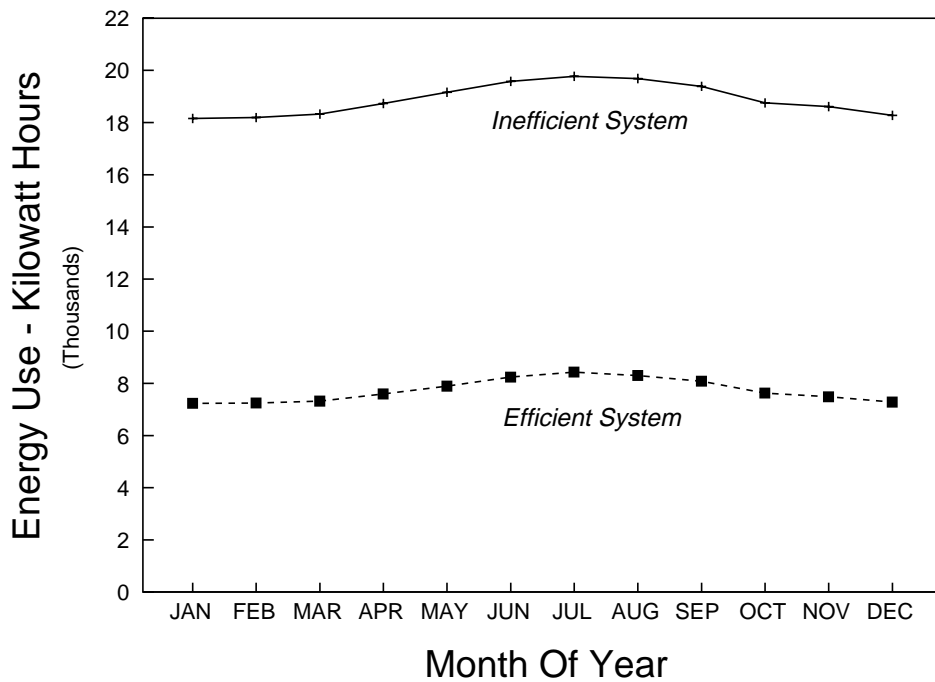


Figure 5: 30 Cow Farm - January Daily Load Curve

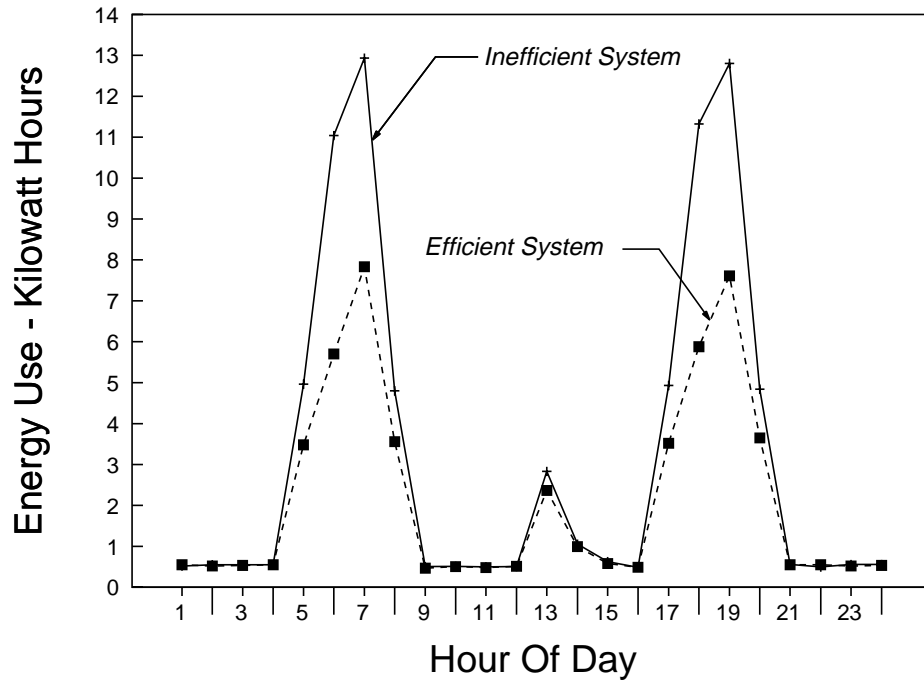


Figure 6: 30 Cow Farm - July Daily Load Curve

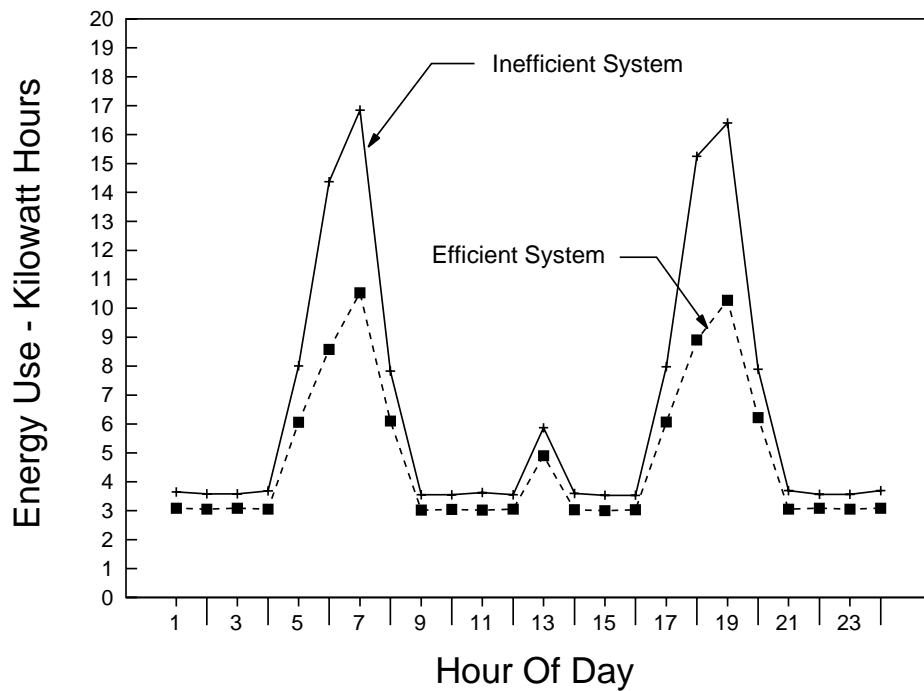


Figure 7: 60 Cow Farm - January Daily Load Curve

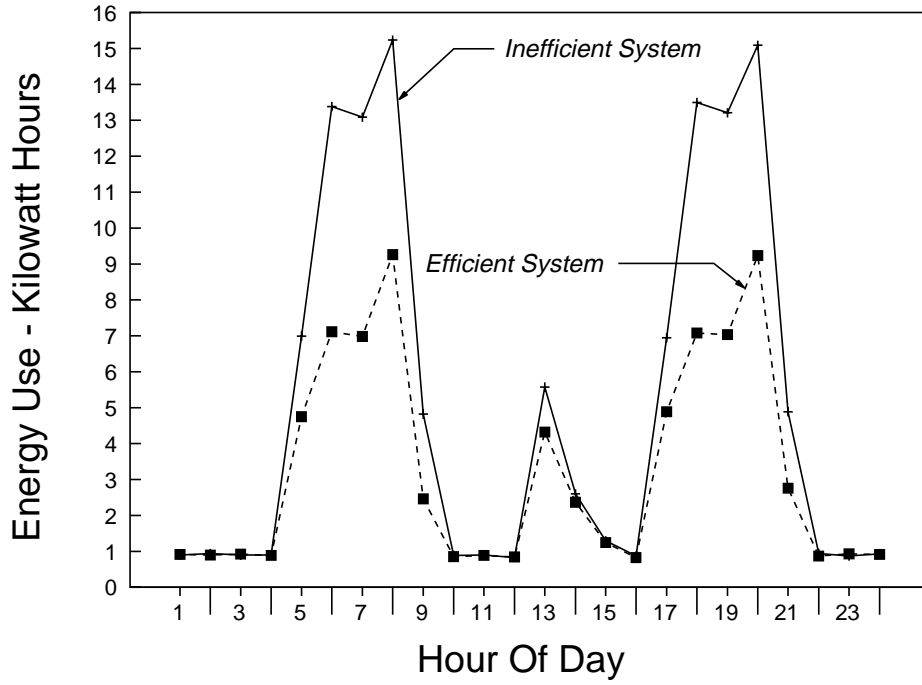


Figure 8: 60 Cow Farm - July Daily Load Curve

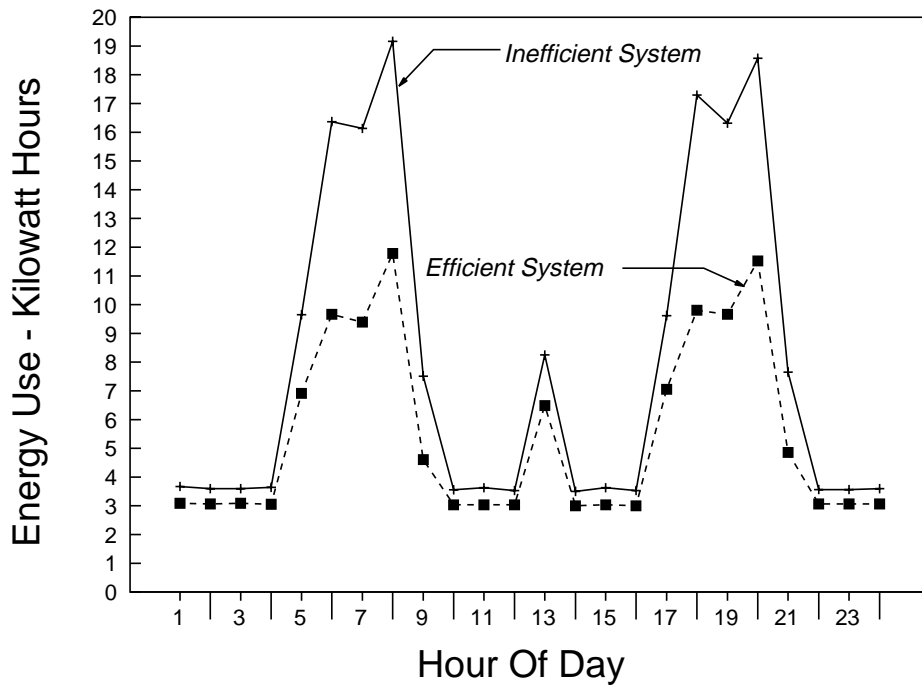


Figure 9: 200 Cow Farm - January Daily Load Curve

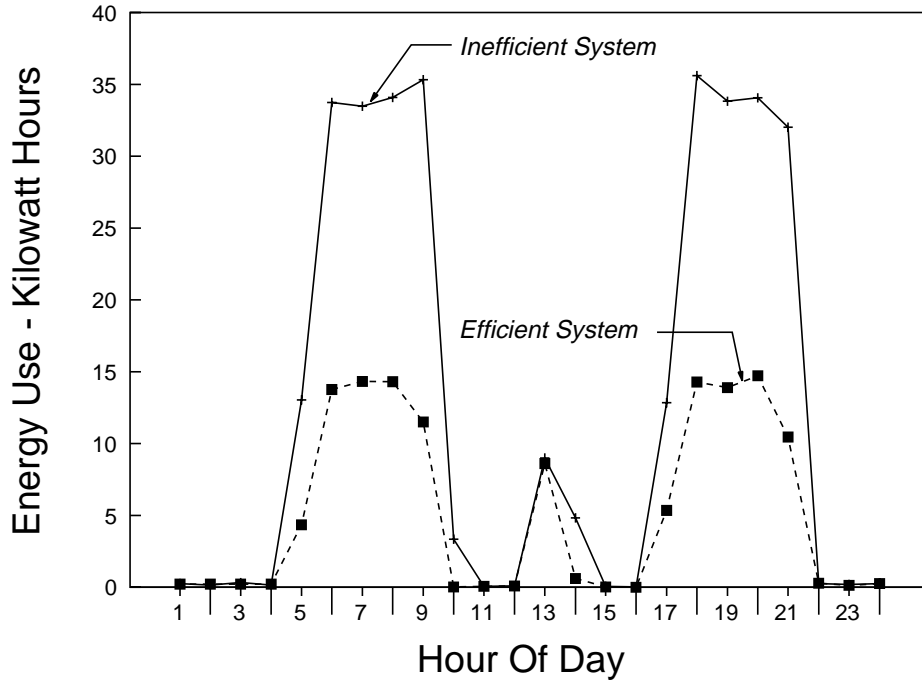


Figure 10: 200 Cow Farm - July Daily Load Curve

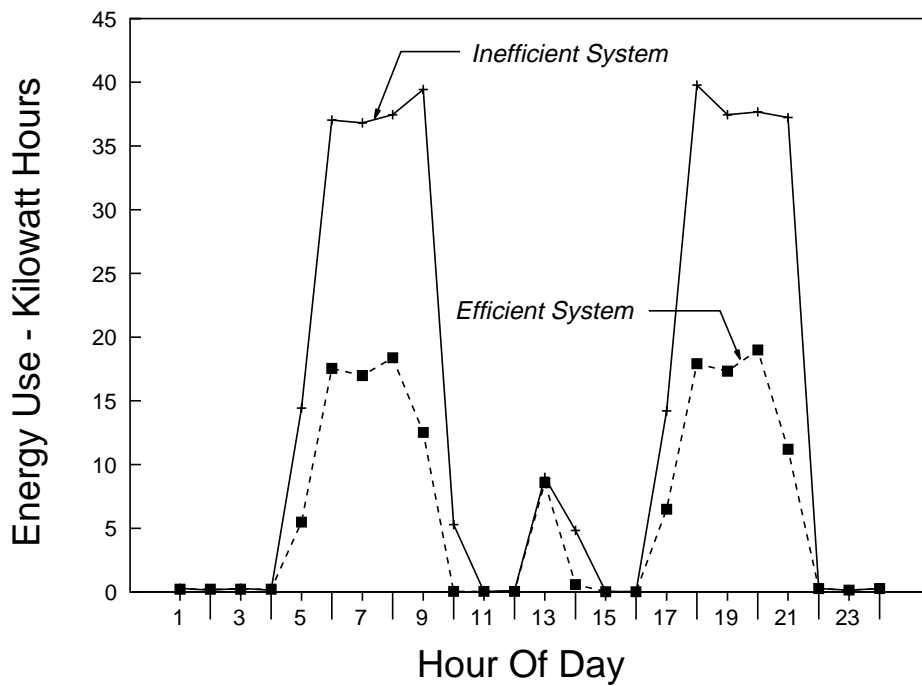


Figure 11: 400 Cow Farm - January Daily Load Curve

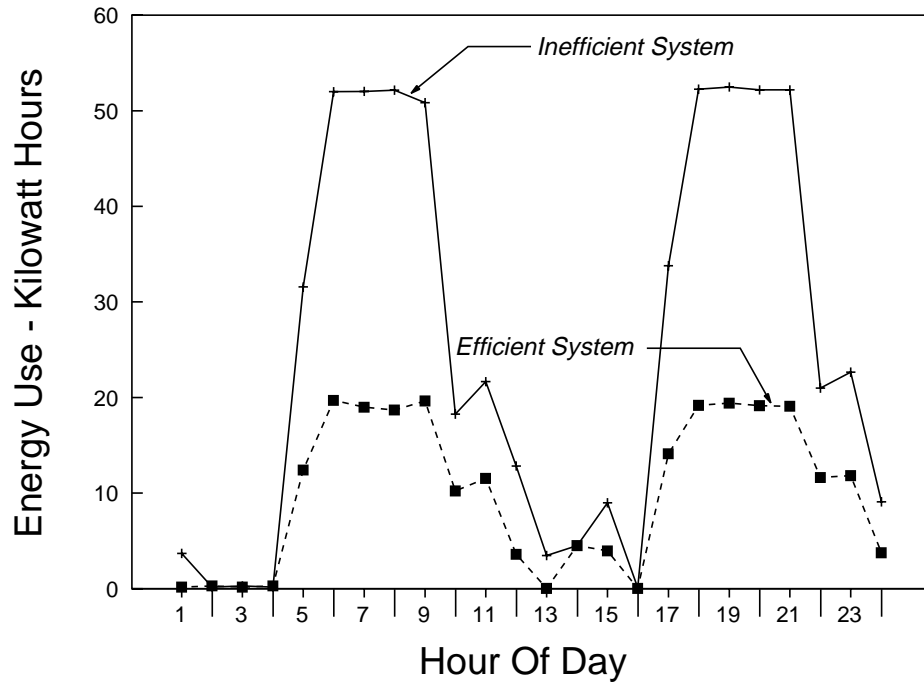


Figure 12: 400 Cow Farm - July Daily Load Curve

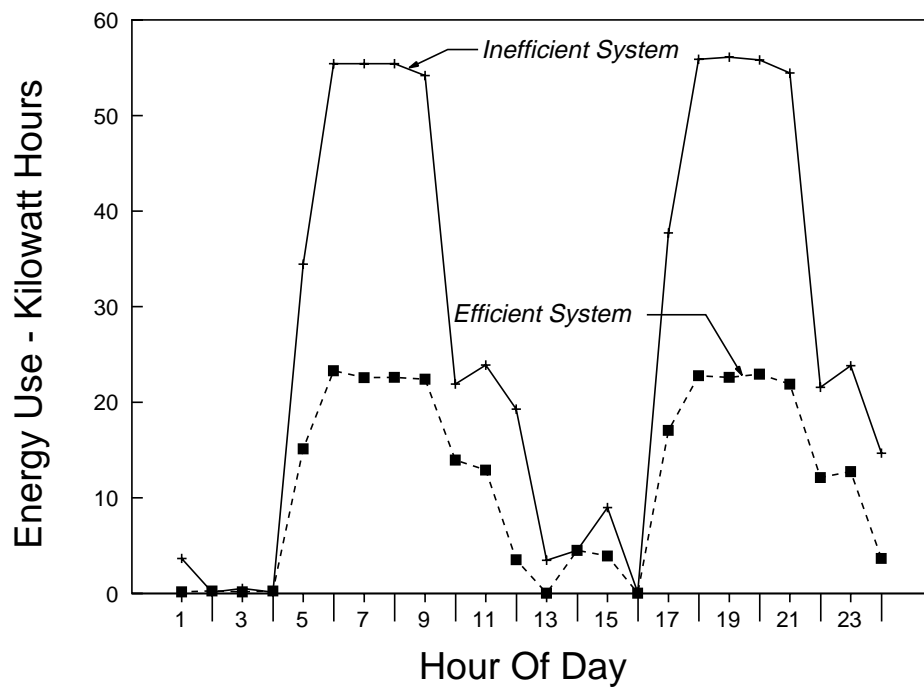


Table 2: Energy Comparison - 30 Cow Farm

WATER HEATING & MILK COOLING		Inefficient System	Efficient System	Savings	Percent Savings
Milk Cooling	Kwh/Cwt	0.83	0.42	0.41	49.4%
Water Heating	Kwh/Gal	0.26	0.20	0.07	25.6%
Milk Cooling	Kwh	4,405	2,228	2,176	49.4%
Water Heating	Kwh	11,421	8,499	2,922	25.6%
LIGHTING					
Fixed Barn	KWH	133	133	0	0.0%
Variable Barn	KWH	3,944	1,753	2,191	55.6%
TOTAL Barn	KWH	4,077	1,886	2,191	53.7%
Fixed Milking Center	KWH	0	0	0	0.0%
Var. Milking Center	KWH	1,139	281	858	75.3%
TOTAL Milking Center	KWH	1,139	281	858	75.3%
TOTAL	KWH	5,216	2,167	3,049	58.4%
VENTILATION					
Base Level	KWH	102	102	0	0.0%
Low Level	KWH	2,357	2,357	0	0.0%
Medium Level	KWH	1,629	1,385	244	15.0%
High Level	KWH	10,170	8,648	1,522	15.0%
TOTAL	KWH	14,260	12,490	1,770	12.4%
VACUUM PUMP					
VACUUM PUMP	KWH	3,543	1,772	1,771	50.0%
FARM TOTAL					
FARM TOTAL	KWH	38,845	27,157	11,688	30.1%

Table 3: Energy Comparison - 60 Cow Farm w/2" Milk Pipeline

WATER HEATING & MILK COOLING		Inefficient System	Efficient System	Savings	Percent Savings
Milk Cooling	Kwh/Cwt	0.73	0.37	0.36	49.2%
Water Heating	Kwh/Gal	0.26	0.17	0.09	34.4%
Milk Cooling	Kwh	7,781	3,953	3,827	49.2%
Water Heating	Kwh	14,832	9,733	5,099	34.4%
LIGHTING					
Fixed Barn	KWH	122	122	0	0.0%
Variable Barn	KWH	8,860	3,937	4,923	55.6%
TOTAL Barn	KWH	8,982	4,060	4,922	54.8%
Fixed Milking Center	KWH	0	0	0	0.0%
Var. Milking Center	KWH	1,620	720	900	55.6%
TOTAL Milking Center	KWH	1,620	720	900	55.6%
TOTAL	KWH	10,602	4,780	5,822	54.9%
VENTILATION					
Base Level	KWH	153	153	0	0.0%
Low Level	KWH	4,288	4,288	0	0.0%
Medium Level	KWH	4,887	4,155	732	15.0%
High Level	KWH	10,170	8,648	1,522	15.0%
TOTAL	KWH	19,500	17,250	2,250	11.5%
VACUUM PUMP					
	KWH	4,993	2,496	2,497	50.0%
FARM TOTAL					
	KWH	57,708	38,212	19,496	33.8%

Table 4: Energy Comparison - 60 Cow Farm w/3" Milk Pipeline

WATER HEATING & MILK COOLING		Inefficient System	Efficient System	Savings	Percent Savings
Milk Cooling	Kwh/Cwt	0.73	0.37	0.36	49.9%
Water Heating	Kwh/Gal	0.24	0.19	0.05	21.4%
Milk Cooling	Kwh	7,781	3,895	3,886	49.9%
Water Heating	Kwh	23,630	18,575	5,055	21.4%
LIGHTING					
Fixed Barn	KWH	122	122	0	0.0%
Variable Barn	KWH	8,860	3,937	4,923	55.6%
TOTAL Barn	KWH	8,982	4,060	4,922	54.8%
Fixed Milking Center	KWH	0	0	0	0.0%
Var. Milking Center	KWH	1,620	720	900	55.6%
TOTAL Milking Center	KWH	1,620	720	900	55.6%
TOTAL	KWH	10,602	4,780	5,822	54.9%
VENTILATION					
Base Level	KWH	153	153	0	0.0%
Low Level	KWH	4,288	4,288	0	0.0%
Medium Level	KWH	4,887	4,155	732	15.0%
High Level	KWH	10,170	8,648	1,522	15.0%
TOTAL	KWH	19,500	17,250	2,250	11.5%
VACUUM PUMP					
VACUUM PUMP	KWH	6,934	3,467	3,467	50.0%
FARM TOTAL					
FARM TOTAL	KWH	68,447	47,966	20,480	29.9%

Table 5: Energy Comparison - 200 Cow Farm

WATER HEATING & MILK COOLING		Inefficient System	Efficient System	Savings	Percent Savings
Milk Cooling	Kwh/Cwt	0.73	0.39	0.34	46.2%
Water Heating	Kwh/Gal	0.26	0.15	0.11	43.0%
Milk Cooling	Kwh	26,010	13,991	12,019	46.2%
Water Heating	Kwh	17,341	9,885	7,456	43.0%
LIGHTING					
Fixed Barn	KWH	405	405	0	0.0%
Variable Barn	KWH	50,800	13,550	37,250	73.3%
TOTAL Barn	KWH	51,210	13,960	37,250	72.7%
Fixed Parlor	KWH	0	0	0	0.0%
Variable Parlor	KWH	7,013	1,870	5,143	73.3%
TOTAL Parlor	KWH	7,013	1,870	5,143	73.3%
TOTAL	KWH	58,223	15,830	42,393	72.8%
VENTILATION					
Base Level	KWH	104	104	0	0.0%
Low Level	KWH	0	0	0	0
Medium Level	KWH	256	218	38	15.0%
High Level	KWH	2,663	2,264	399	15.0%
TOTAL	KWH	3,023	2,585	438	14.5%
VACUUM PUMP					
VACUUM PUMP	KWH	14,430	7,214	7,216	50.0%
FARM TOTAL					
FARM TOTAL	KWH	119026	49505	69521	58.4%

Table 6: Energy Comparison - 400 Cow Farm

WATER HEATING & MILK COOLING		Inefficient System	Efficient System	Savings	Percent Savings
Milk Cooling	Kwh/Cwt	0.71	0.38	0.33	46.4%
Water Heating	Kwh/Gal	0.25	0.14	0.11	43.9%
Milk Cooling	Kwh	50,671	27,185	23,486	46.4%
Water Heating	Kwh	27,024	15,152	11,872	43.9%
LIGHTING					
Fixed Barn	KWH	297	297	0	0.0%
Variable Barn	KWH	101,600	27,100	74,500	73.3%
TOTAL Barn	KWH	101,900	27,390	74,510	73.1%
Fixed Parlor	KWH	0	0	0	0.0%
Variable Parlor	KWH	8,766	2,337	6,429	73.3%
TOTAL Parlor	KWH	8,766	2,337	6,429	73.3%
TOTAL	KWH	110,666	29,727	80,939	73.1%
VENTILATION					
Base Level	KWH	140	140	0	0.0%
Low Level	KWH	0	0	0	0.0%
Medium Level	KWH	347	295	52	15.0%
High Level	KWH	3,800	3,229	571	15.0%
TOTAL	KWH	4,287	3,664	623	14.5%
VACUUM PUMP					
VACUUM PUMP	KWH	34,000	17,000	17,000	50.0%
FARM TOTAL					
FARM TOTAL	KWH	226,648	92,727	133,921	59.1%

**Table 7: Maximum Daily Demand Reduction
Between Efficient and Inefficient Systems**

Farm Size	Demand Savings (KW)	Percent Savings
30 Cow	6.4	37.9%
60 Cow w/2" Milk Pipeline	7.4	38.5%
200 Cow	26.9	68.3%
400 Cow	32.1	57.9%

WISCONSIN DAIRY PROJECTIONS

Current Wisconsin dairy farm statistics are provided in Table 8 (DATCP, 1993). Figure 13 shows the historical and projected number of total dairy herds. The distribution

Table 8: Current Wisconsin Dairy Farm Statistics

Herd Size	1 - 49	50 -100	100+	TOTAL
Total Farms	18,000	10,600	2,400	31,000
Percent Of Total Farms	58.1%	34.2%	7.7%	100%
Number Of Cows	599,100	699,600	347,300	1,646,000
Average Herd Size	33	66	145	53

of farms within each herd size classification is shown in Figure 14. Cow and herd number projections were extrapolated by fitting an exponential equation to historical data.

Currently, 58% of Wisconsin farms have herds of less than 50 cows, housed and milked with Round-the-Barn pipeline systems. Of the total herds, 24% have 30 head or less. This group has the highest age operators, with an average age of 56. Over 26% of the farmers in this group are of age 65 or over, which is almost double the number of any other herd size group. Many of these farmers have no intention of upgrading or expanding their facilities, nor do they foresee the operation continuing after their retirement. For these reasons, many of these farms will cease milking cows within the next 10 years. Many of the other farms in this group will either expand or rely on off-farm income. Although 100+ cow dairy herds only make up 8% of the total operations, this is the only growing segment. The growth rate is expected to continue or increase. This farm size category also has the lowest operator age of any group, with an average age near 46.

Figure 13: Total Wisconsin Dairy Farms Vs. Year

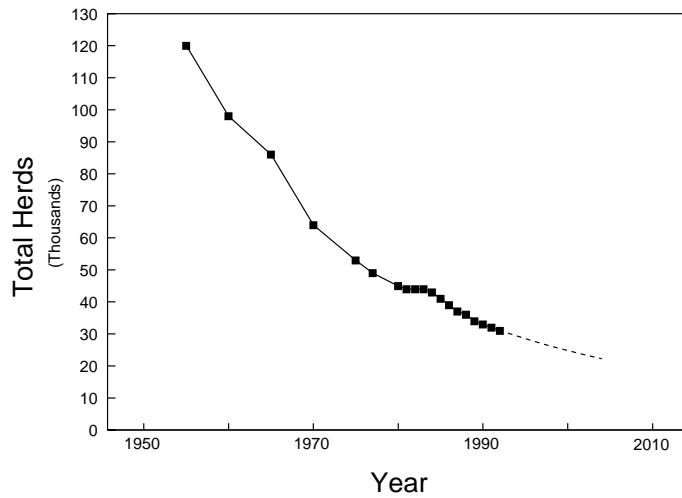
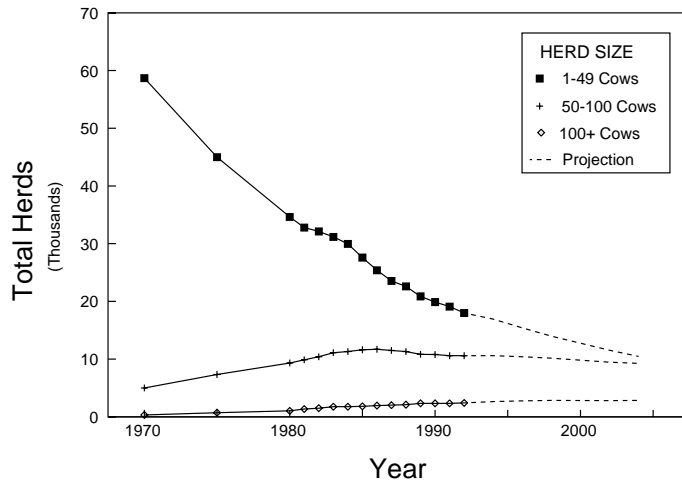


Figure 14: Annual Wisconsin Dairy Herd Makeup



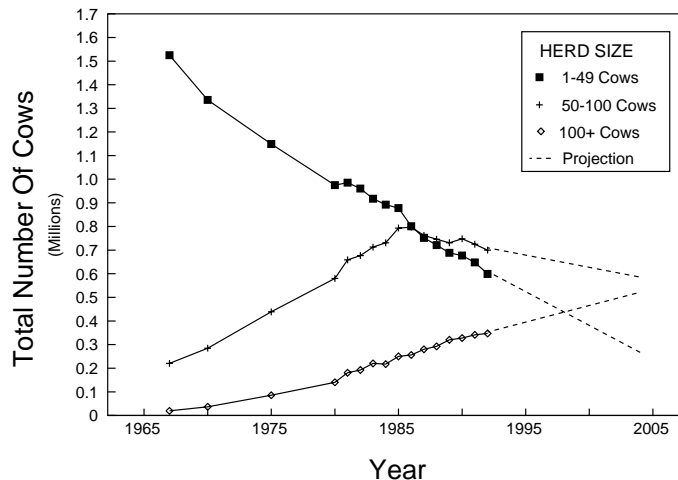
The continued trend over the next 10 years towards a higher percentage of larger farms is due to several factors. First, the total number of farms is expected to decrease, with a larger portion of smaller farms leaving the industry. Farm numbers are

Table 9: 10 Year Projected Wisconsin Dairy Farm Statistics

Herd Size	1 - 49	50 -100	100+	TOTAL
Total Farms	10,500	9,300	2,800	22,600
Percent Of Total Farms	46%	41%	12%	100%
Number Of Cows	272,500	596,000	531,000	1,400,000
Average Herd Size	26	64	190	62

projected to decrease from 31,000 to 22,600. Second, surviving farms will continue to expand, moving them into the next larger herd size category. A 10 year projection of Wisconsin dairy farm makeup is presented in Table 9. Total cow numbers are expected to decrease somewhat from the current 1.65 million, to a projected total of 1.4 million in 10 years. This will likely be accompanied by increased milk production per cow. The total number of cows within each herd size classification are plotted in Figure 15.

Figure 15: Total Cows Per Herd Group



The smallest dairy herds will likely be concentrated in the 20 to 40 cow range with single family owner/operators. Many will rely on off-farm income to supplement farm income. Herds of 50-100 cows are likely to be primarily single family operations with hired labor or multi-family partnerships. Larger farms with parlor milking systems will tend to be multi-family partnerships with hired labor. The average herd size of

Table 10: Technology Market Penetration

CURRENT MARKET SATURATION					
Herd Size	Heat Recovery	Precooling	Efficient Lighting	Efficient Fans	Efficient Vacuum Pumps
1 - 49	20%	5%	5%	10%	0%
50 - 100	50%	20%	15%	20%	0%
100+	80%	50%	50%	30%	0%
10 YEAR PROJECTED MARKET SATURATION					
Herd Size	Heat Recovery	Precooling	Efficient Lighting	Efficient Fans	Efficient Vacuum Pumps
1 - 49	20%	5%	5%	10%	0%
50 - 100	50%	20%	15%	20%	0%
100+	20%	13%	13%	8%	0%

freestall/milking parlor operations is expected to be 200 to 300 cows. While the distribution of farm labor will change with time and farm size, the number of people involved directly in farming operations is not expected to decrease significantly, following a pattern similar to total cow numbers.

CURRENT DAIRY SECTOR ENERGY USE

Table 10 shows both the current and projected market penetration values of various energy saving technologies for each farm class. These values were based on estimates from limited available data. Annual energy use was estimated for each farm class using these assumptions. The 30, 60 and 200 cow farm model scenarios were used to determine energy use for the 1-49, 50-100 and 100+ cow herd classes respectively. The previously stated model assumptions were used in each case. Total herd class energy consumption values were calculated by multiplying the total number of cows in each category by the energy use per cow predicted from the modeled case. These results are presented in Table 11. Ventilation is the largest end use on non-parlor/freestall farms, followed by water heating. This assumes implementation of wind tunnel ventilation systems. Lighting is the largest end use on large parlor/freestall farms, followed by milk cooling and vacuum pumps.

CURRENT DAIRY SECTOR ENERGY SAVINGS POTENTIAL

Table 11: Estimated Annual Energy Use

Farm Size	Water Heating (MWh)	Milk Cooling (MWh)	Lighting (MWh)	Fans (MWh)	Vacuum Pumps (MWh)	Total (MWh)
1 - 49	211,461	85,791	101,119	281,238	70,754	750,363
50 - 100	137,904	81,800	113,437	222,123	58,218	613,482
100+	22,831	34,731	64,297	5,021	25,058	151,937
TOTAL	372,197	202,321	278,853	508,382	154,030	1,515,782

Estimations for the current potential energy savings on Wisconsin dairy farms are provided in Table 12. These energy savings are calculated assuming that all energy saving technologies increase from present market penetration levels to 100% (i.e., all farms implement all recommended energy efficient technologies). Earlier work has

Table 12: Estimated Potential Annual Energy Savings

Farm Size	Water Heating (MWh)	Milk Cooling (MWh)	Lighting (MWh)	Fans (MWh)	Vacuum Pumps (MWh)	Total Savings (MWh)
1 - 49	109,420	5,109	57,838	31,812	35,367	239,546
50 - 100	47,893	1,999	57,702	20,988	29,115	157,698
100+	5,666	10,435	36,808	532	12,531	65,971
TOTAL	162,979	17,544	152,348	53,333	77,012	463,215

shown that heat recovery is preferred over precooling or a combination of the two on smaller dairies. Both precooling and heat recovery together are recommended for larger farms. These recommendations were used for estimating the potential energy use savings in Table 12, (e.g. only heat recovery was added to the farms in the <50 cow herd class, with the number of precoolers remaining unchanged).

The largest segment for potential savings is water heating in the <50 cow herd class, at 109,000 MWh, followed by lighting in the same class at 58,000 MWh. Lighting (58,000 MWh) and water heating (48,000 MWh) in the 50-100 cow herd class are the next two largest savings categories. These are followed by efficient lighting in the 100+ cow herd class, at 37,000 Mwh.

Even though the total categorical savings are smallest on the largest farms, savings per farm are much higher and the benefit-to-cost ratio for installing energy saving technologies is usually much higher on large farms.

PROJECTED DAIRY SECTOR ENERGY USE

Table 13: 10 Year Projected Estimated Annual Energy Use

Farm Size	Water Heating (MWh)	Milk Cooling (MWh)	Lighting (MWh)	Fans (MWh)	Vacuum Pumps (MWh)	Total (MWh)
1 - 49	96,359	39,093	46,078	128,155	32,241	341,928
50 - 100	117,483	69,687	96,638	189,230	49,597	522,635
100+	43,324	64,907	139,950	7,933	38,312	294,426
TOTAL	257,166	173,688	282,667	325,318	120,150	1,158,989

Table 13 contains the estimated energy use for Wisconsin dairy operations 10 years from now. These results are based on the projected herd size and market penetration values in Tables 9 and 11. Market penetration values for energy efficient technology were assumed to remain the same as the current values for farms in the <50 and 50-100 cow herd classes. The market penetration values in Table 10 for the largest farm class are lower because many of these facilities have not yet been constructed. Therefore, the potential for installing energy efficient equipment on farms in this class is high.

Total current energy use for all farms is estimated at 1.5 million MWh. This is expected to decrease to 1.2 million MWh in 10 years. Much of the expected decrease is due to changes in farm numbers and the farm size distribution. Energy use in the <50 cow herds will decrease by roughly 50% and energy use in the 100+ cow herd class will almost double. The 50-100 cow herd class will replace the <50 cow herd class as the largest energy consuming herd group. The largest projected end use is ventilation in 50-100 cow herds (189,000 MWh), followed by lighting in the 100+ cow herds (140,000 MWh), ventilation in <50 cow herds (128,000 MWh), and water heating in 50-100 cow herds (117,000 MWh).

PROJECTED DAIRY SECTOR ENERGY SAVINGS POTENTIAL

Projected energy savings potential in the dairy sector are shown in Table 14. The total potential energy savings is 400,000 MWh per year, with 100+ cow herds offering the greatest possible savings. Many of these 100+ cow facilities will be built in the next 10 years. As with any technology, installation at the time of construction is more cost effective than retrofit later. A need exists for education and recommended system designs so that new facilities install energy efficient equipment. The economics of installing these devices are not considered here, and have to be

evaluated in order to determine their practicality in different situations.

Table 14: 10 Year Projected Estimated Potential Annual Energy Savings

Farm Size	Water Heating (MWh)	Milk Cooling (MWh)	Lighting (MWh)	Fans (MWh)	Vacuum Pumps (MWh)	Total Savings (MWh)
1 - 49	49,861	2,328	26,356	14,496	16,116	109,157
50 - 100	40,801	1,703	49,157	17,880	24,804	134,345
100+	17,079	27,761	97,921	1,070	19,158	162,990
TOTAL	107,740	31,793	173,435	33,446	60,078	406,492

Efficient lighting in freestall housing is the largest categorical savings at 97,900 MWh, followed by water heating in <50 cow herds and efficient lighting in 50-100 cow herds at 49,000 MWh each. Heat recovery and efficient lighting will continue to be important in reducing future dairy energy use. The promotion of heat recovery equipment on both small and large farms is highly desirable, since savings in water heating energy offers the largest potential savings when considering all farms. Furthermore, heat recovery is an attractive economic option on almost any farm.

Efficient lighting also offers large potential savings and should be installed whenever upgrading lighting or building new facilities. Even if recommended illumination levels are not presently met in a facility, significant energy savings are still possible by replacing incandescent lighting with fluorescent lighting meeting suggested light levels. Savings from installing efficient fans in wind tunnel ventilation systems are also significant.

Efficient vacuum pumps offer high potential energy savings when considering the smallest herd size class as a whole. Energy efficient vacuum pumps and new recommendations for vacuum system design and sizing should be available within the next several years. It is questionable whether new technology will be economically feasible on many of the existing farms, except when replacing worn out equipment, but it should be promoted for all new facilities.

SUMMARY AND CONCLUSIONS

New components have been developed for the TRNSYS dairy farm model for ventilation, lighting, vacuum pumps, and an instant milk chiller. All new modules except the chiller unit assume loads which are either on or off. Their accuracy depends on setting the proper load levels and typical scheduling practices. More information is needed to determine the differences between load levels existing in the typical installation and the recommended values, which were used for modeling. The chiller unit has not been compared with field data.

Efficient and inefficient systems were modeled for several farm size categories and simulated. Equipment options included heat recovery, precooling, fluorescent lighting, efficient vacuum pumps, and efficient fans. Daily and annual load curves were developed for the inefficient and efficient systems. The results provide a lower and upper limit for energy use on each farm, defining a range or "window" of energy consumption in which the typical dairy farm should operate.

Results show that lighting and ventilation are potentially the largest end uses when achieving recommended lighting and ventilation levels. While many installations are currently under lighted and ventilated, this is a common upgrade to existing facilities. Energy efficient lighting provides significant savings over incandescent lighting, even when improving lighting levels.

Currently, there are 31,000 dairy farms in Wisconsin. This number is projected to decrease to 22,600 in 10 years. Total cow numbers are projected to decrease from 1.65 to 1.4 million cows. Of the total existing farms, 58% have less than 50 cows, 34% have herds between 50 and 100 cows, and 8% have herds with 100 or more cows. The number of herds ceasing production will be greatest in the smallest herd size class and the average herd size is expected to continue to increase.

Market penetration values were estimated for energy conserving technology in each herd size category. Total energy use and potential energy savings were estimated for each farm size category. In the 10 year projection, the greatest energy conservation potential will be on newly built freestall/milking parlor dairy operations. Therefore, a need exists for development of energy efficient system design recommendations and the education of dairy operators and supporting agricultural suppliers, so that new facilities install energy efficient equipment.

Promotion and installation of heat recovery equipment on both small and large farms remains a highly desired option. Efficient lighting also offers large potential savings, and should be installed whenever upgrading lighting or building new facilities. Efficient fans are beneficial in ventilation systems meeting wind tunnel design specifications. Substantial energy savings should also result from the use

of energy efficient vacuum systems. In general, the larger the farm, the greater the economic benefit from installing a given option.

REFERENCES

Bowe, D.A., 1994.

Wisconsin Public Service Corporation
Personal Communication.

DATCP, 1993.

Dairy Facts 1993.
Department of Agriculture, Trade and Consumer Protection, Madison, WI.

Faust, J. and B.J. Holmes, 1991.

Wind Tunnel Ventilation For Dairy Cows.
Dairy Profit Report. 4(5): 1-3,7.
Dairy Science Department, University Of Wisconsin-Madison.

MMMC, 1993.

Maximizing the Milk Harvest: A Guide for Milking Systems and Procedures.
Milking Machine Manufacturers Council of the Equipment Manufacturers Institutes,
Chicago, IL.

MWPS, 1992.

Farm Buildings Wiring Handbook.
Publication MWPS-28.
Midwest Plan Service, Iowa State University, Ames IA.

MWPS, 1990.

Heating, Cooling, and Tempering Air for Livestock Housing.
Publication MWPS-34
Midwest Plan Service, Iowa State University, Ames IA.

Peebles, R.W. and D.J. Reineman, 1994.

Agricultural Demand Side Management Strategies Analysis.
Report presented to Wisconsin Center For Demand Side Research, Madison WI.

Peebles, R.W., D.J. Reinemann, and R.J. Straub, 1993.

A Modular Computer Model For Milking Center Energy Use.
ASAE Paper No. 93-3534

Peebles, R.W., 1993.

Modeling Dairy Farm Milk Cooling And Water Heating Systems.
Unpublished M.S. Thesis. University Of Wisconsin - Madison, Madison WI.