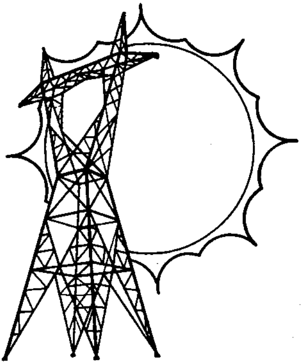
DSM Pocket Guidebook



Western Area Power Administration
Energy Services

Volume 3: Agricultural Technologies

DSM Pocket Guidebook

Volume 3: Agricultural Technologies

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Contract DE-IA65-90WA07253 with
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Contract DE-AC02-83CH10093 with
U.S. Department of Energy
Washington, D.C.

SERI/TP-254-4098C ■ APRIL 1991
DE91002155

Printed in the United States of America
Available from National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Price: Microfiche A01 / Printed Copy A07

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issue of the following publications which are generally available in most libraries: *Energy Research Abstracts (ERA); Government Reports Announcements* and Index (*GRA* and I); *Scientific and Technical Abstract Reports (STAR);* and publication NTIS-PR-360 available from NTIS at the above address.

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ACKNOWLEDGMENTS

The National Food and Energy Council (NFEC) with its allied organizations—the National Rural Electric Cooperative Association (NRECA) and the Edison Electric Institute (EEI)—has been instrumental in advancing research in energy efficiency for the agricultural sector. The Electric Power Research Institute (EPRI) has been an active sponsor of their work. Several NFEC documents are cited extensively in this volume of the *DSM Pocket Guidebook* and deserve special mention here.

- McFate, K. L., and B. A. Stout, eds., *Electrical Energy in Agriculture,* 1989, Amsterdam, Elsevier.
- NFEC, 1986, *Agricultural Technical Brief Notebook,* Pub. 8609, Columbia, MO.
- NFEC, 1986, *Electric Farm Equipment Guide,* Pub. 8610, Columbia, MO.

The NFEC can be contacted directly if you have any questions about these publications. Their address is 409 Vandiver West, #202, Columbia, MO 65202. Their telephone number is (314) 875-7155.

FOREWORD

In previous years of low-cost energy, many demand-side management (DSM) technologies simply were not cost effective. Today, however, with rising energy prices and the mandate to conserve, utility DSM programs and advanced energy-efficient technologies offer utilities significant opportunity for economic means to reduce operating costs and shift or defer load growth. Furthermore, recent developments in DSM technologies have improved energy quality and reduced customer maintenance costs.

This series of guidebooks is intended as a tool for utility personnel involved in DSM programs and services. Both the novice and the DSM expert can benefit from the information compiled.

Efficient energy utilization through DSM applications helps Western meet one of its primary objectives—elimination of wasteful energy practices and adoption of conservation programs that meet customer needs in an era of diminished resources and increased environmental concerns.

PREFACE TO THE DSM POCKET GUIDEBOOK

INTRODUCTION

It has been estimated that if electricity were used more efficiently with commercially available end-use technologies, 24%–44% of the nation's current demand for electricity could be eliminated. Almost all major electric utilities in the west are investigating such demand-side management (DSM) opportunities. In some service territories, for example, improved efficiency could soon produce as much power as that from new coal-fired plants (Figure P-1) and produce it at a lower cost (Figure P-2). Even utilities that currently have excess capacity are finding that DSM offers an opportunity to build efficient end-use stock to help them meet their future load shape objectives.

Utility DSM programs typically consist of several measures designed to modify the utility's load shape (for example, innovative rate structures, direct utility control of loads, promotion of energy-efficient technologies, and customer education). The coordinated implementation of such measures requires planning, analysis of options, engineering, marketing, monitoring, and other coordination activities (Figure P-3). This guidebook addresses one facet of an overall DSM program: selection of end-use technologies within the electrical utilities.

TECHNOLOGY SELECTION

All facets of a utility's DSM program, including technology selection, must be planned with the utility's overall objectives in mind. Selected technologies must make the utility better able to serve its customers by providing low-cost reliable power. Yet the utility must also be able to recover its fixed and operating costs. In

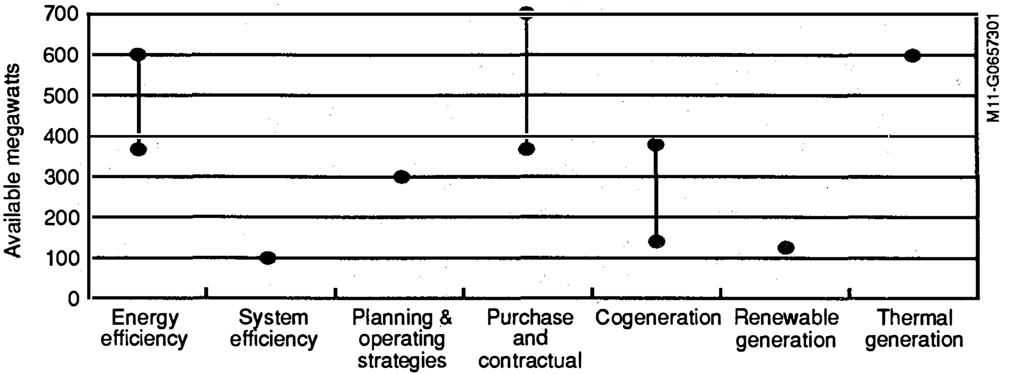

Figure P-1. Source: "Planning for Stable Growth, Pacific Power and Utah Power Resource and Market Planning Program, Volume 1—Summary Report" (Nov. 1989).

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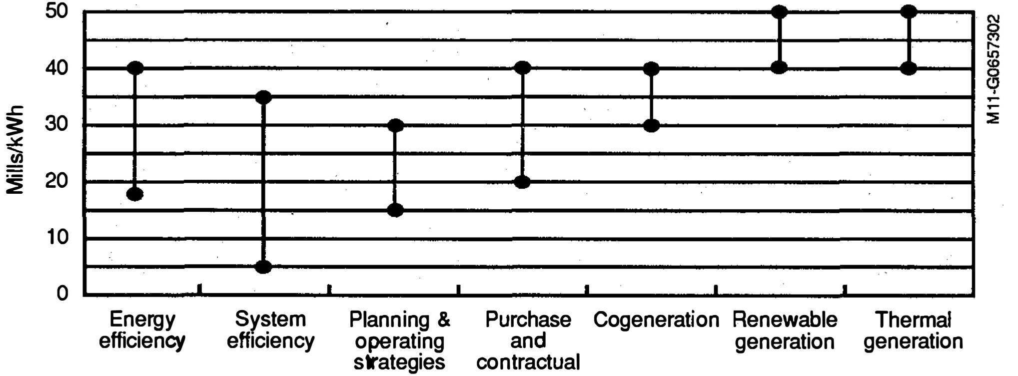

Figure P-2. Source: "Planning for Stable Growth, Pacific Power and Utah Power Resource and Market Planning Program, Volume 1—Summary Report" (Nov. 1989).

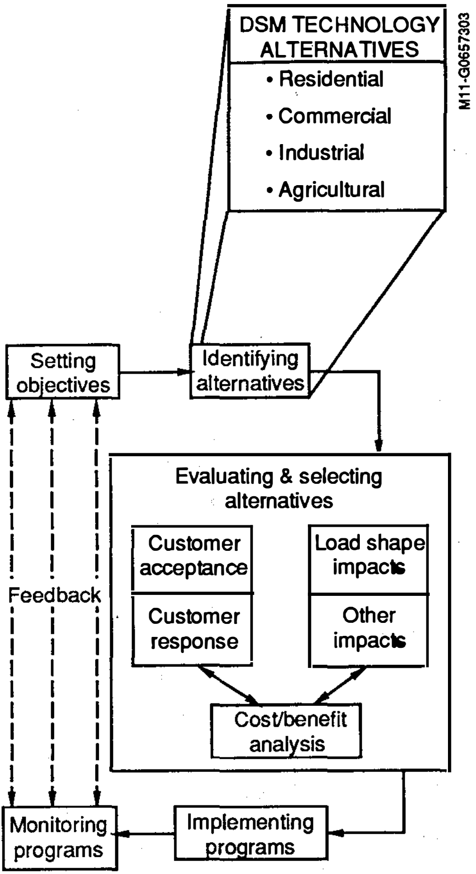

Figure P-3. DSM technology alternatives—position in the overall DSM program process. Source: Electric Power Research Institute, "DSM Technology Alternatives," EPRI EM-5457 (Oct. 1987).

practice, this usually means that the technology must provide the same or expanded cost-effective energy service to the customer while also smoothing out the utility's load curve and delaying the need for additional power plants. This guidebook directly addresses these requirements by estimating the simple payback (to the end user) for energy-efficient end-use technologies and their impacts on the utility's load curve.

A number of additional factors must be considered in technology selection. Primary among these are customer acceptance of different end-use technologies, the type of marketing effort required to promote each, and the potential impact on the utility's revenues. These are not addressed in this guidebook.

INTENDED AUDIENCE

This guidebook is intended to be a quick reference source both for utility field representatives in their customer interactions and for utility planners in the early stages of developing a DSM program. It is designed to allow a quick screening of commercially available electric end-use technologies with emphasis on the residential, commercial, and agricultural sectors. Only a limited number of technologies applicable to industrial processing (motors, adjustable-speed drives) are included because industrial customers usually are better informed about their energy options, they have more resources and incentive to investigate such options in detail, and the full range of industrial processes is beyond the scope of this guidebook.

Finally, this guidebook is directed primarily at small municipal utilities and rural electric cooperatives within the Western Area Power Administration (Western) service area (see Figure P-4). Large utilities with more abundant resources may find the guidebook useful as only a starting point. Their technology selection process will undoubtedly also include review of other source documents and detailed system and engineering analyses of the options.

Figure P-4. Western Area Power Administration area map

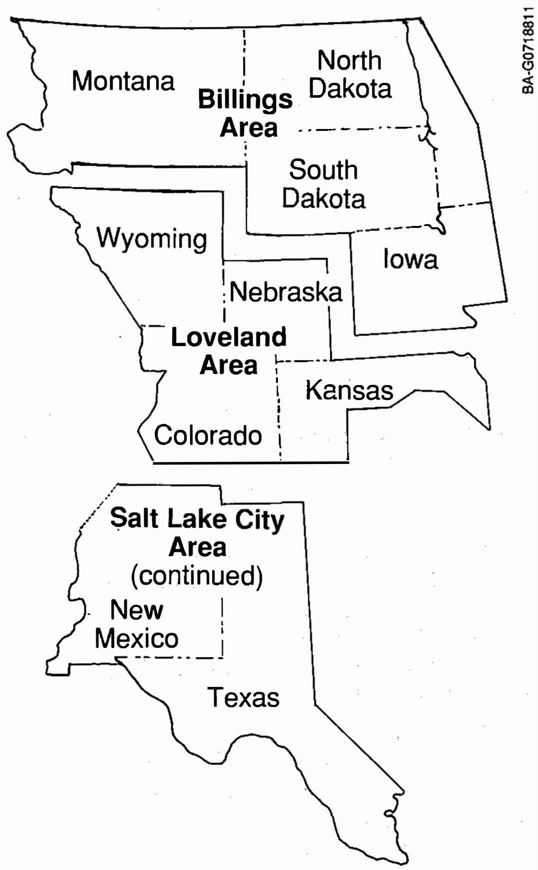

Figure P-4 (continued). Western Area Power Administration area map

METHODOLOGY/DATA

For each technology the guidebook presents a short numbered "technology brief"—text that describes the option, its relevant applications, and its potential impact on the utility's load duration curve. Each brief also includes a summary table (usually not specifically referred to by number) with quantitative estimates of initial costs, energy savings, and simple payback to the customer. All costs are expressed in 1990 dollars. For most technologies, capital cost and energy savings are estimated for one or more energy-efficient options and a reference case—usually an electric technology.

Where sufficient data exist, payback (to the end user) for the energy-efficient option is also compared to that for the reference case. Payback is determined by dividing the capital cost (incremental over the reference case) by the annual dollar savings (relative to the reference case). For simplicity, regional utility variations in electricity prices are ignored; the payback calculations use electricity prices of $0.08/kWh, $0.07/kWh, and $0.07/kWh in the residential, commercial, and agricultural sectors, respectively. To estimate payback using actual local electricity prices, multiply the payback by actual electricity price in dollars per kilowatt hour/assumed electricity price in dollars per kilowatt hour. For technologies such as replacement windows or insulation in which payback varies based on the climate, a payback range is given or the energy savings and payback are calculated for more than one climate.

Demand charges generally are not included in the payback calculations, because demand rates and possible reductions vary widely by region and utility, and for most of the options demand savings is small. For those technologies that have a large impact on demand (e.g., commercial building cool storage), a range of demand savings is presented and included in the payback calculations.

In almost all cases, the quantitative estimates of costs and energy savings have been taken from existing literature, including documentation of completed utility DSM programs, field studies and experiments, manufacturers' data, laboratory experiments, and computer simulation and analysis. The sources used varied depending primarily on the availability of data and the complexity of the technology. For example, manufacturers' data were used for several cost estimates, but only rarely for performance estimates, and then only in conjunction with data from field studies or simulations. On the other hand, for more complex technologies such as passive solar home design, the data were drawn from field studies and simulations to capture all the interactions that occur between building components and the local climate.

As might be expected, cost and performance values drawn from different sources are frequently inconsistent. (The reasons for such variations and the resulting uncertainties in the guidebook data are addressed later in this preface.) To reconcile such inconsistencies, the reports were first examined in detail and, in many cases, their authors contacted to identify the higher-quality studies and/or reasonable causes for the differences. For some technologies, we eliminated conflicting sources, either because the system or climate was not like the one being described in the guidebook, or because one analysis was clearly superior. If no clear distinction could be made between the analyses, the guidebook presents either a range of values or an average value.

Because of the condensed nature of this guidebook and our desire to keep it simple, we have provided only limited references for the source materials and computations. The guidebook is not intended to substitute for a detailed analysis, but rather to point the reader toward those technologies most likely to benefit both the end user and the utility. For more details, the reader should consult the references (in sections titled "For More Information") at the end of each brief.

■ *DATA VARIABILITY AND UNCERTAINTY*

A problem with guidebooks like this is that the data can at best present only a simple overview of each technology. Yet hundreds of volumes have been written describing the application of these technologies. Consequently, the cost and performance estimates presented here should be used with a clear understanding of the sources of variability and uncertainty.

Variations in performance occur with climate and with the technology's design and configuration, the system within which it is applied, and the way it is used. Cost varies with the quality or brand of an individual component, the size (e.g., cost per ton for large commercial air conditioning systems is less than for small unitary systems), the quantity ordered (e.g., cost per lamp for a major commercial retrofit will be less than the retail purchase price of a single lamp), and/or the time of purchase (inflation and technological improvements change costs over time). Generally, the only variation quantified in this guidebook is the range in performance with different climatic conditions.

Similarly, there are significant sources of uncertainty in the cost and performance data. The uncertainties, which largely result from drawing cost and performance statistics from a number of different sources, include

- Lack of complete documentation of the assumptions, data, and methods used in many of the studies
- Lack of statistically valid generalizations because of small sample sizes (i.e., results in the referenced studies are frequently based on only a few applications or systems)
- Reference study results based on simulations and limited testing, not field testing
- The use of multiple studies or sources for the cost and performance values of a single technology.

Where possible, we have avoided such problems by identifying excellent sources. However, as might be expected, we are more confident of some of the results than others. Thus for many technologies, we have included a rough measure (high, medium, low) of our confidence and the extent of the data variability and uncertainty. We expect that future revisions of this guidebook will provide the opportunity to reduce some of these uncertainties.

ORGANIZATION AND USE OF THE GUIDEBOOK

The guidebook consists of three pocket-sized volumes, each introduced by this preface. The first volume considers end-use technologies for the residential sector. The second volume includes technologies for the commercial sector as well as motors and variable-speed drives applicable to the commercial, industrial, and agricultural sectors. The third volume discusses energy-efficient technologies for the agricultural sector with an emphasis on the central and western United States (see area map in Figure P-4).

A number of technologies (e.g., energy-efficient windows) apply to more than one end-use sector. Where applicable, cross references are provided in the briefs. They are also summarized in Table P-1.

Each volume contains two sets of matrices to allow a quick screening of the technologies. One matrix addresses payback values, and the other identifies the most likely impact of each technology on the utility load duration curve (see Figure P-5). A utility planner who has identified the types of load changes desired and the appropriate end-use sectors can use the matrices to quickly identify candidate technologies. The text in the briefs provides background information.

Table P-1. Cross-Sector References

	End-Use Sector / Volume Number		
Technology	Residential 1	Commercial 2	Agricultural 3
Insulation	1,3	■	
Windows	4,5,6	1	
Weatherstripping	7	■	
Duct leaks	15	■	
Passive solar	8	2	
Heat pumps	9	9	
Efficient air conditioners	13	8	
Energy management	■	10	■
Hot water efficiency	17	16	7
Solar hot water	19	■	■
Fluorescent lamps	21	11	
Cooking	25	18	
Swimming pools	26	■	
Motors		19–28	■

Each number refers to a written brief that describes the technology. A solid box (■) indicates that the technology is of interest in the sector, but is not written up. For example, see Vol. 1 (residential), technology brief #17, for a thorough discussion of hot water efficiency. See Vol. 2 (commercial), technology brief #16, or Vol. 3 (agricultural), technology brief #7, for additional information. If you are interested in motors in the agricultural sector (Vol. 3), the black box directs you to consult technology briefs #19–#28 in Vol. 2 (commercial).

Load Shifting
Example: Cool storage

Peak Clipping
Example: Direct control of air conditioning units

Valley Filling
Example: Thermal energy storage

Strategic Load Growth
Example: Heat pumps

Flexible Load Shape
Example: Direct control of residential water heaters

Strategic Conservation
Example: Weatherization and efficient appliances

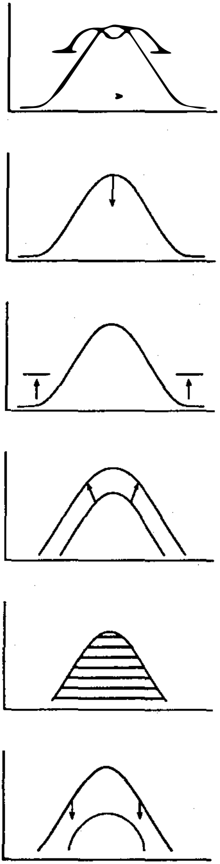

Figure P-5. Typical load shape changes resulting from selected demand-side alternatives. Adapted from Clark W. Gellings, highlights of a speech presented to the 1982 Executive Symposium of EEI Customer Service and Marketing Personnel.

AGRICULTURAL

INTRODUCTION

Electricity accounts for 9% of total United States farm energy use. Although this value appears low, it can have a large impact on many small, rural electric utility systems. Of special interest to all utilities is the impact on peak demand, particularly in arid and semi-arid regions, during the summer growing season when irrigation and other agricultural demands are the greatest. For example, Utah Power and Light's irrigation use is only 3% of annual sales, but comprises 15% of the system peak. Agricultural usage in California accounts for about 4% of sales, but 10% of peak demand.

The two largest uses of electricity in the U.S. agricultural sector are irrigation pumping (30.8%) and dairy farming (18.6%). Together, they represent about 50% of electricity use on farms. The remaining uses include livestock (27.9%), nonirrigated farm crops (16.7%), and poultry (6%). Figures A-1 and A-2 show the top five crops (in terms of cash receipts) in the midwest and the southwest.

Agricultural customers are a highly diverse group. This characteristic makes it hard to generalize energy use patterns or to estimate the effects of load management. Some customers use electricity only a few hours per year and others operate year round. For irrigation, some customers have nearly constant electrical demands between April and October. Others, like dairies, greenhouses, and crop processing operations, have many different electric uses and have highly variable loads. Also, there are important factors influencing agricultural electrical demands that are beyond the customer's control. These include limitations on water supply by an irrigation district, changes in weather conditions, variations in construction and efficiency of equipment, and moisture content of crops.

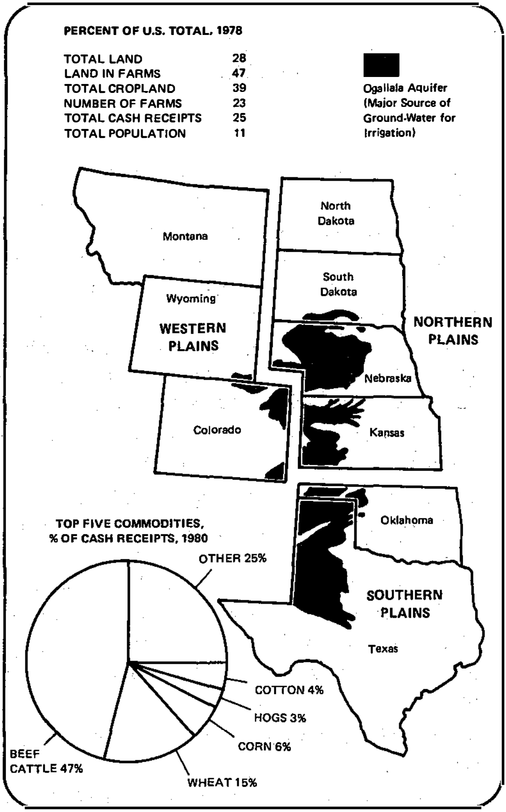

Figure A-1. The Great Plains: agricultural characteristics

Each electrical farm application is unique and is often decided largely on non-energy related issues like water consumption, crop yield, and livestock growth. Therefore, cost/benefit analyses for agricultural equipment and operations are generally too site specific

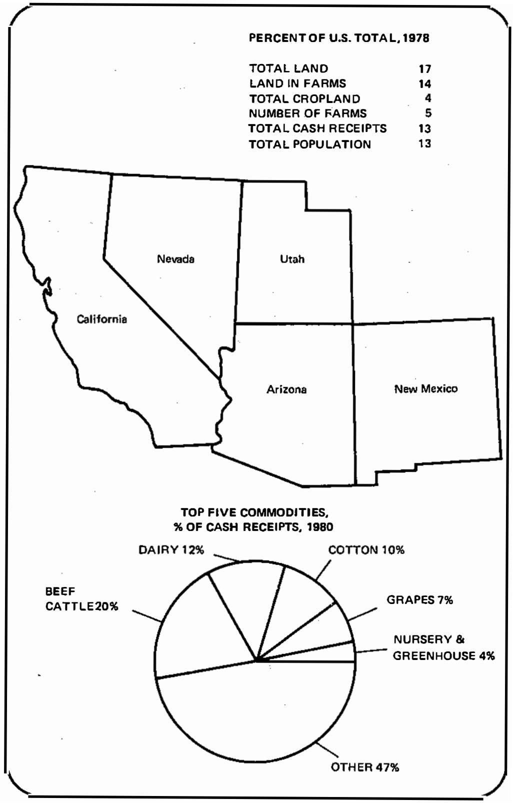

Figure A-2. The southwest: agricultural characteristics (includes Hawaii)

to fit into a quick reference manual. Instead, in this volume, various equipment and operations are described and a comparison between alternate technologies is made whenever applicable.

Performance-related information about the equipment or operation is presented as electricity use per year per animal or as a unit of production so that the electricity use can be scaled to the energy use of specific operations found on individual farms.

FOR MORE INFORMATION

Battelle Press, 1983, *Agriculture 2000, A Look at the Future*, pp. 36, 40.

Each technology discussed in this guidebook contributes to one of six demand-side management (DSM) objectives. The matrix of agricultural measures with these DSM objectives is shown in Table A-1.

Table A-1.
Agriculture: Demand-Side Management Strategies

	PC*	VF*	LS*	SC*	SG*	FLS*
IRRIGATION						
1. Alternative irrigation systems				■	■	
2. Irrigation load management	■			■		
3. Pumping plant efficiency improvement				■	■	
4. Automation of irrigation	■			■		
DAIRY FARM MEASURES						
5. Ice-bank vs. direct-expansion milk cooling	■		■			
6. Partial in-line coolers or precoolers	■					
7. Water heating				■		
8. Waste heat recovery	■			■		
9. Vacuum pump				■		
10. Ventilation				■		
MATERIALS HANDLING						
11. Grain conveyance						
12. Feed processing	■			■		
13. Electric chore vehicles		■			■	
CROP DRYING						
14. Grain drying with low-temperature electric		■		■		
15. Grain drying with unheated air	■			■		
16. Controlled aeration for quality grain	■	■				
17. Hay drying		■			■	
LIVESTOCK MEASURES						
18. Electric brooding—poultry		■			■	
19. Dual fuel for livestock/brooding	■	■			■	
20. Waterers				■	■	
21. Earth-tube heat-exchange ventilation systems	■			■		
22. Controlled ventilation				■		
23. Evaporative cooling systems		■		■		

* PC = peak clipping; VF = valley filling; LS = load shifting; SC = strategic conservation; SLG = strategic load growth; FLS = flexible load shape

Sources: National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO. National Food and Energy Council, 1988, *Residential Commercial and Agricultural Technology*, Columbia, MO.

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IRRIGATION

IRRIGATION

■ ■ ■

Not only is irrigation one of the primary uses of electricity in agriculture, but it represents one of the best opportunities for electric energy conservation and peak demand reduction. The principal measures that can be used to achieve such reductions include the proper selection of an irrigation system and improvements in pumping system efficiency.

A variety of irrigation systems are in use throughout the United States. Energy consumption is one of several important factors in the selection of an irrigation system. In many western arid and semi-arid regions where water supply is limited, the efficiency with which the irrigation system applies water to the roots of the crop is the driving factor. Other factors that frequently play an important role include land slope, soil characteristics, crop type, fertilizer requirements, and capital and labor costs.

Nonetheless, electric power requirements and costs can be significant in the pumping and distribution of irrigation water. These requirements vary dramatically with the type of system selected. For example, the electric power requirements of a precision application system can be three to four times less than that of a high-pressure center-pivot sprinkler system used in the same field on the same crop. This section of the *DSM Pocket Guidebook* presents an overview of the trade-offs that must be considered in terms of costs, application efficiency, and power requirements for the principal irrigation systems. Although the data presented are representative, individual irrigation system costs and performance vary significantly from site to site.

(continued)

Unless the irrigation system is gravity fed, water must be pumped from the well to the distribution system. Improvements in electric motor efficiency are discussed in Volume 2 of this guidebook. Concerns that are unique to irrigation pumping efficiency include crop water requirements and irrigation timing, the effect of pumping efficiency of changes in the water table, conversions of an irrigation system to another type, addition or deletion of pumps, friction losses in extended distribution piping, and motor selection. Proper design of an agricultural pumping system should result in a performance of about 135 kWh used per acre foot of water per 100 feet of lift. Performance improvements of 25%–50% are possible with proper maintenance.

The following definitions and terms are used in this section: (1) *Application efficiency:* The ratio of the amount of water stored in the crop root zone to the amount of water applied to the field. (2) *Pumping plant efficiency:* The ratio of the water power output (flow times head) to the electrical power input, also called "wire-to-water" efficiency. (3) *Conveyance efficiency:* The ratio of water delivered to a farm or field in comparison to the amount of water diverted from its source. Conveyance efficiency reflects the water lost to seepage, evaporation, or spilling between the point of diversion and the point of delivery. (4) *Pumping plant performance:* The energy (in kilowatt hours) required to lift one acre foot of water 100 feet. Measurements that are needed to calculate performance are pumping lift in feet, content pumping rate in gallons per minute, and energy (kWh) input during a 24-hour period. Table A-6 shows potential energy savings for efficiency improvements in these units for different lift heights.

$$\text{Performance} = \frac{22{,}600 \times \text{kWh}}{\text{gpm} \times \text{Lift}}$$

Terms: gpm is pumping rate in gallons per minute. Lift is pumping lift in feet. kWh is energy in kilowatt hours. 22,600 is a conversion factor.

ALTERNATIVE IRRIGATION SYSTEMS

DESCRIPTION

Most irrigation systems fall into three general categories: gravity, sprinkler, and drip systems. Table A-2 shows that in the southwestern United States, gravity systems consume the highest fraction of electricity used for irrigation. See Table A-3 for the application efficiency, pressure, and energy requirements for each of the principal system types. Advantages and disadvantages are discussed below for each general system type.

DRIP A drip irrigation system consists of the pump to draw water from the source, the main line and lateral pipes to supply water to individual plants, and the emitters to control the rate of water flow to each plant. Advantages of drip irrigation include extremely low water usage, automated fertilizer and chemical application, high application efficiency, moderate delivery pressure, and suitability for rocky or steep slopes. Its disadvantages include high initial costs, clogging, salt accumulation near plant, and potential for water-stressed root development.

GRAVITY FLOW These systems use gravity to transport water at low pressure to the field. With furrow irrigation water is delivered to individual furrows, whereas the entire field is flooded in flood irrigation.

FURROW Advantages of furrow irrigation include low-pressure transfer, low energy usage, and very low delivery pressure requirements. Disadvantages include the requirement for a 2% natural slope or less, possible need for expensive grading, large quantities of water required, high labor costs due to placement of siphon tubes or piping, and very low application efficiency.

FLOOD Advantages include low-pressure transfer, low energy usage, and very low delivery pressure requirements. Disadvantages include its suitability for level fields only, the possible need for expensive grading, the need for large quantities of water, imprecise application, and low application efficiency.

SURGE Surge irrigation is the intermittent application of water to furrows. The flow of water is alternated between two sets of furrows on either side of a surge valve installed in a gated pipeline. When the gates are opened, water is delivered in pulses or surges to each set of gated pipe on either side of the valve.

The surge method saves water. Its advantages include fast advance and uniform distribution of water down the furrow, smoothing of soil as the water infiltrates, the lack of deep percolation at the furrow head, and low delivery pressure. Disadvantages include the possible need for additional pipe and expensive grading and the cost of surge valves.

SPRINKLER Sprinkler irrigation consists of systems that transfer water to the crop through pressurized piping and sprinkler heads to spray water over crops.

CENTER PIVOT Suitable for large acreages, the center-pivot system has several advantages. Water is distributed properly and land grading is not required (the system can operate over rolling land). It is easily automated and little labor is required; application efficiency is high compared to flood or furrow irrigation. Its disadvantages include some water loss from evaporation, high energy requirements for pumping and lateral movement, and the need for high delivery pressure (although lower-pressure systems are available).

LINEAR MOVE In this system, suitable for rectangular fields, water is distributed properly and no land grading is required. Application efficiency is high compared to flood or furrow irrigation. Its disadvantages include some water loss from evaporation, high energy requirements for pumping and lateral movement, and the need for high delivery pressure (although adaptation to low-pressure nozzles is easily accomplished).

TRAVELING GUN In this system water is properly distributed, land grading is unnecessary, and labor requirements are low. However, water is lost to evaporation, energy requirements are high for pumping and cart movement, application efficiency is low, and very high delivery pressure is required.

Table A-2. Predominant Irrigation Systems by State[1]

	Sprinkler					Gravity		Total
	Center Pivot	Traveling Gun	Drip	Linear Move	Other	Open Ditch	Gated Pipe	
Arizona	3.9	0.0	0.2	1.4	2.3	92.2	0.0	100
Calif	1.9	0.2	3.0	3.5	30.7	29.2	31.6	100
Colorado	46.0	0.1	0.0	1.7	1.7	41.0	9.6	100
Kansas	43.4	2.0	0.0	1.0	0.0	5.4	48.2	100
Montana	4.1	0.0	0.0	0.8	0.0	95.1	0.0	100
Nebraska	49.1	2.1	0.0	10.9	0.4	7.3	30.2	100
Nevada	10.6	0.0	0.0	0.0	3.4	79.8	6.2	100
New Mexico	17.3	0.0	0.1	0.6	0.4	24.5	57.1	100
Oklahoma	29.2	4.4	0.1	23.9	6.3	7.4	28.8	100
Texas	16.4	2.7	0.2	13.9	6.1	44.3	16.4	100
Utah	6.1	0.4	0.0	23.0	13.9	50.9	5.7	100

1 Expressed as a percent of irrigation energy used in each state

Source: Broehl, J. H., et al., 1986, *Demand-Side Management for Rural Electric Systems*, EPRI-EM-4385, p. 26.

Table A-3. Irrigation System Efficiencies and Energy Usage: Costs and Benefits

Irrigation System	Application Efficiency[1]	Conveyance Efficiency[2]	Discharge[1] Pressure (psi)	Capacity[2] (cfm)	Capital Cost ($/acre)	Energy Use[1] (kWh/acre in.)
Drip/trickle	0.9	0.95–1.0	40	2–160	825	38
Furrow	0.6	0.65–1.0	10	11–640	100–950[4]	60
Flood	0.7	0.65–1.0	5	11–640	100–1050[4]	40
Center pivot, high pressure	0.82	0.95–1.0	90	6–6400	500–600	70
Center pivot, medium pressure	0.85	0.95–1.0	60	6–6400	"	52
Center pivot, low pressure	0.88	0.95–1.0	40	6–6400	"	40
Linear move, medium pressure	0.85	0.95–1.0	50	6–6400	125–1200	47
Traveling gun	0.75	0.95–1.0	100	6–6400	—	89
LEPA[3]	0.95-0.98	—	10	—	35–120[5]	35

Source: Whittlesey, N., 1986, *Energy and Water Management in Western Irrigated Agriculture*, Westview Press, Boulder, CO, pp. 38–40.

1 Data from the University of Arkansas. Energy requirements based on 100-ft lift and pump/motor efficiency of 65%.

2 Source: McFate, Kenneth W., ed., *Electrical Energy in Agriculture*, 1989, Amsterdam, Elsevier, p. 228.

3 Hamon, Carrol, 10 July 1990, Internal Memorandum, Colorado Office of Energy Consortium, Longmont, CO (based on 300-ft lift).

4 Includes the cost of grading.

5 Incremental cost for modifying a center pivot or linear system. Source: EPRI EM-5457.

IRRIGATION LOAD MANAGEMENT

DESCRIPTION

Irrigation load management controls can be used to reduce peak demands in both arid and semi-arid regions of the country. The utility offers irrigators one or more control options at reduced rates. The irrigator selects control options based on crop needs, cost savings, irrigation system flexibility and capacity, and management abilities. Savings resulting from the reduction in peak demand are shared by the irrigator and the utility. Irrigators reduce operating costs, and utilities pay for the load management control system through savings in demand costs. Care must be taken to avoid crop losses, a possible result of untimely irrigation. For more information on load management, see technical brief #10 on energy management in Volume 2 of this guidebook.

APPLICABILITY

CLIMATE Semi-arid to arid areas benefit most. The greatest potential for irrigation load control and utility electrical demand reductions depends upon irrigation systems that have adequate water supplies, soils that have minimum water holding capacities of 1.5 inches per foot of soil depth, and automated irrigation systems. **DEMAND MANAGEMENT OBJECTIVES** Strategic conservation, peak clipping

COSTS AND BENEFITS

Costs for individual controllers are about the same as for controllers used with water heaters and air conditioners; however, installation costs are higher. Although fewer units are needed to control large demands, more transmission equipment is needed to send signals to the controllers than is needed by water heaters or air conditioners.

■ *FOR MORE INFORMATION*

National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO, p. AT-107.

PUMPING PLANT EFFICIENCY IMPROVEMENT

DESCRIPTION

Although the maximum theoretical efficiency for a pumping plant is about 75%, results of most pumping tests show that the average pumping plant efficiency falls between 50% and 60%. To ensure maximum efficiency, all three principal components of the irrigation pumping plant—motor, drive shaft, and pump assembly—must be designed to fit the system and must be kept in good repair. Figure A-3 shows the sources of pumping plant losses for a well tuned (71.5% efficient) plant.

Regardless of the distribution system, conveyance efficiency, and pressure requirements of various irrigation systems, it is still necessary to pump water to the distribution system. Much of this water is pumped from wells, especially in the midwest where water tables have declined. Table A-4 shows the range of water table depths for midwestern and southwestern states.

If you know the pumping lift and distribution system pressure requirements, you can use Table A-5 to estimate the electrical energy required per acre foot of water.

Many electric utilities offer pumping plant efficiency testing for their customers. A simple test that takes about an hour can determine water discharge rate (gpm), discharge pressure (psi), power requirements (hp), energy consumption (kWh), and water pumping level. Then, an estimate of potential savings can be made.

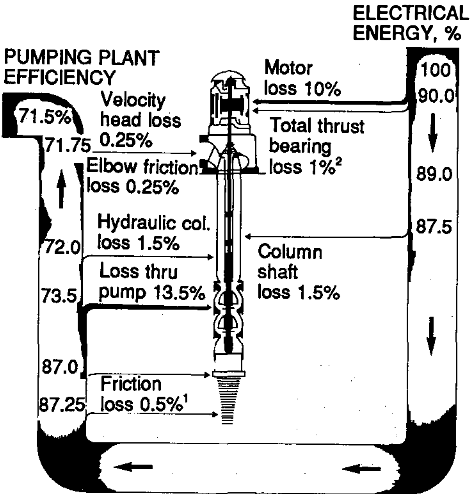

Figure A-3. Typical large pumping plant system efficiency losses—from deep well turbine input to distribution components. Courtesy P.G. & E.

Table A-4. Pump Lift Ranges for Major Groundwater-Irrigated States in the West

State	Pumping Lift (feet)
Arizona	75–535
California	75–300
Colorado	175–270
Kansas	175–250
Nebraska	25–250
New Mexico	75–225
Oklahoma	200–275
Texas	75–225

Source: Whittlesey, Norman K., ed., 1986, *Energy and Management in Western Irrigated Agriculture*, Boulder, CO: Westview Press, p. 105.

Table A-5. Pumping Energy Requirements for Different Lifts and Delivery Pressures

	Energy Requirements (kWh/acre foot)		
Lift	Delivery Pressure		
(feet)	40 psi	60 psi	80 psi
50	260	350	440
100	350	440	525
200	525	610	700
300	700	790	875
400	875	960	1050
500	1050	1140	1230

Source: *Doane's Agricultural Report*, 1977.

■ *APPLICABILITY*

All crop irrigation systems.

DEMAND MANAGEMENT OBJECTIVES Strategic conservation, strategic load growth

■ *COSTS AND BENEFITS*

Table A-6 provides a quick estimate of potential savings given present pumping efficiency and present annual acre-inch requirements assuming a final efficiency of 65%. To use the table find your present pump efficiency in the top row and select the entry for the given lift. Now apply your $/kWh rate and acre-inch requirements to the figures to determine yearly savings. The cost for efficiency testing of equipment ranges from $2,000 to $4,000 and is about $200 per test.

Savings calculation: Present efficiency (tested) 40%; final system efficiency (assumed) 65%; lift 200 ft; $/kWh $0.04; annual water requirement 1500 acre-ft. From Table A-6: Savings = 16.4 kWh/acre-in.; annual savings = (16.4) (0.04) (1500 x 12) = $11,800.

■ *FOR MORE INFORMATION*

National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO, p. AT-108.

Table A-6. Pumping System Efficiency: Costs and Benefits[1]
(kilowatt hours per acre-inch pumped)

	Present Pump Efficiency (%)							
Head (ft)	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**
50	10.5	7.7	5.6	4.1	2.9	2.0	1.2	0.5
100	21.0	15.3	11.2	8.2	5.8	3.9	2.4	1.1
150	31.5	23.0	16.9	12.3	8.7	5.9	3.6	1.6
200	42.0	30.6	22.5	16.4	11.7	7.8	4.8	2.2
250	52.5	38.3	28.1	20.5	14.6	9.8	6.0	2.7
300	63.0	45.9	33.7	24.6	17.5	11.8	7.2	3.3
350	73.5	53.6	39.4	28.7	20.4	13.8	8.4	3.8
400	84.0	61.2	45.0	32.8	23.3	15.7	9.5	4.4
450	94.5	68.9	50.6	36.9	26.2	17.7	10.7	4.9
500	105.0	76.6	56.2	41.0	29.2	19.7	11.9	5.5

1 Assumes 65% efficiency after improvement

Source: Walker, Lloyd, 1988, *Energy Managment, Irrigated Agriculture Production Systems*, Longmont, CO, Energy Conservation for Colorado, p. 12.

AUTOMATION OF IRRIGATION

DESCRIPTION

This brief covers computerized irrigation control and scheduling. In computer irrigation control, an on-farm computer remotely controls irrigation pumps and sprinkler systems. Software permits four major management functions. Monitoring allows the irrigator to detect mechanical failures quickly. Remote control allows for quick changes to the system in response to management needs. Irrigation scheduling responds to weather conditions. Load interruption automatically allows for peak shifting. In some areas, water and energy savings amount to 30%.

Compared to simpler timing devices, computer control allows for an interruption sequence based on the amount of water that is needed and available. Furthermore, monitoring protects against yield loss caused by undetected breakdown. For the utility, a predetermined amount of load can be shed. If you know your seasonal water usage (inches) and irrigated area (acres), you can use the last column in Table A-3 to estimate annual energy requirements.

In computerized scheduling, real-time weather data are used to estimate evapotranspiration (crop water use) and to forecast the next time for irrigation. Water budgets are calculated by adding rainfall and irrigation, then subtracting evapotranspiration, surface runoff, and drainage below the root zone. Forecasts for the water budget are based on climate averages for the previous few days. Weather data are obtained from state networks or from on-site weather stations.

Savings of water and energy is between 10% and 30%. Crop production is usually increased by more timely irrigations. The cost of scheduling is often offset by a decrease in operating costs and an increase in crop sales. Table A-7 shows some representative annual per-acre savings for low (10 in./season) and high (60 in./ season) water use crops for different irrigation systems assuming 10% and 30% savings from the control system. These figures do not represent the corresponding savings in water.

APPLICABILITY

CLIMATE Weather data and soil moisture content must be available.

DEMAND MANAGEMENT OBJECTIVES Strategic conservation, peak clipping

COSTS AND BENEFITS

The cost of a radiotelemetry system for computer control varies depending on the number of units served by one computer, the sprinkler interfacing required, and customization of sensors and software. A system serving between 10 and 20 sprinklers costs $3000–$4000 per control point. Assuming 100 acres per point, paybacks range from 8 years for 10% savings in low water usage applications to less than 6 months for 30% savings in high water usage applications. See Table A-7 for more information.

The cost for software for scheduling irrigation varies widely between $500 and $5,000 per unit. Some government agencies provide such software free. On-site weather stations cost about $2,500; however, information from local weather networks usually can be obtained inexpensively. Paybacks are similar to those for irrigation control strategies.

FOR MORE INFORMATION

National Food and Energy Council, 1986, *Agricultural Technical Briefs Notebook*, Columbia, MO, p. AT-112.

Table A-7. Automation of Irrigation: Costs and Benefits

Irrigation System	Base Energy kWh/acre in.[1]	Savings per Acre ($) Low Water Usage 10 in./acre/season 10% Saved	Low Water Usage 30% Saved	High Water Usage 60 in./acre/season 10% Saved	High Water Usage 30% Saved
Drip/trickle	38	2.66	7.98	15.96	47.88
Center pivot, high pressure	70	4.90	14.70	29.40	88.20
Center pivot, medium pressure	52	3.64	10.92	21.84	65.52
Center pivot, low pressure	40	2.80	8.40	16.80	50.40
Linear move, medium pressure	47	3.29	9.87	19.74	59.22
Traveling gun	89	6.23	18.69	37.38	112.14

1 Data from the University of Arkansas.

Source: National Food and Energy Council, 1983, *Farm Energy Analysis*, Columbia, MO, p. E22.

DAIRY FARM MEASURES

■ ■ ■

The three major electrical energy uses on dairy farms are milk cooling, water heating, and vacuum pumping. In addition to these uses ventilation, lighting, feed processing, and other electrical equipment significantly affect electricity use and demand.

Electrical energy use per cow or per unit of milk produced varies with dairy farm size, climate conditions, and management practices. Decisions on what, how, and when dairy farm operations take place can greatly influence electricity use and the cost of production.

ICE-BANK VS. DIRECT-EXPANSION MILK COOLING

DESCRIPTION

Most milk is cooled in bulk coolers. Direct-expansion milk coolers and ice-bank milk coolers are the two most commonly used bulk coolers in the United States. Cooling in cans with mechanical refrigeration is no longer common. Regardless of the method used to cool milk, all methods must meet FDA standards set for cooling requirements. Milk must be cooled to 45°F or less within two hours after milking. The blend temperature in the bulk tank after the first and subsequent milkings must not exceed 50°F. Maintaining the blend temperature usually requires more refrigeration than the initial cooling.

The most common method used to cool milk is direct expansion. This method uses a storage tank with a refrigerated jacket. In the jackets are evaporator plates that contain a freon refrigerant that expands and absorbs heat from milk. The milk is in direct contact with the stainless steel tank liner and must be stirred in the tank so that it makes contact with the refrigerated surface. Evaporator plates and condensing units must be sized carefully to meet industry standards. A 3-hp condensing unit with a direct-expansion system will cool about 600 pounds of milk per hour to 45°F. Large dairies usually require two large condensing units with a large bulk tank and extensive evaporator surface.

Another means of cooling milk is through the use of an ice bank. An ice-bank milk cooling system uses ice that is frozen during the utility's off-peak hours. Chilled water is circulated through the ice to an in-line heat exchanger that cools the milk to 38°F as it is being transferred to the bulk storage tank. No further cooling is required in the storage tank. Ice-bank systems are most applicable on large dairy farms where milk is produced at high rates over several hours twice a day. In an ice-bank system, blend temperatures are not a problem and overall milk quality is improved, because all milk is introduced into the storage tank at the required temperature and little agitation is required. Peak electrical loads can be reduced because condensing units can be sized to produce ice during off-peak hours. Overall energy use is about 25% greater than direct expansion because of standby losses in the ice bank and storage tank as well as colder milk temperatures (around 38°F rather than 45°F).

APPLICABILITY

Direct expansion is most applicable for small to medium-sized dairies with low to moderate (up to 1500 lb/h) milk-loading rates. Milk will be cooled with up to 25% less electricity than when ice-bank systems are used. For large dairies, however, condenser horsepower may be high, which could add a large electrical load to the system peak, creating high year-round demand charges. Also, larger tanks have a smaller condenser surface area--to--volume ratio requiring excessive stirring, which can lower the quality of the milk.

Dairies with high milk-loading rates coupled with electric demand meters or time-of-day meters can benefit significantly from ice-bank systems. The peak load will be less and milk cooling and quality problems are reduced.

DEMAND MANAGEMENT OBJECTIVES (for an ice bank): peak clipping, load shifting

FOR MORE INFORMATION

National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO, p. AT-116.

Table A-8. Ice-Bank vs. Direct-Expansion Milk Cooling: Costs and Benefits

Equipment or Load	Electricity Used kWh/year/cow	Comments
Direct-expansion bulk tank with precooler	95	Mid-sized dairies (500–1500 lb/h)
Direct-expansion bulk tank without precooler	143	Mid-sized dairies (500–1500 lb/h)
Direct-expansion bulk tank		
with condenser	82	550-cow herd
heat exchanger	112	140 cwt/year/cow
		6.36 t/year per cow
Direct-expansion	154	Alternate day pickup
bulk tank without	147–163	60-120-cow herds
condenser heat exchanger	151	140-cow herd
Ice-bank cooler	182–278	140 cwt/year
without condenser		6.36 t/year/cow
heat exchanger	142	550-cow herd
Can cooler	160	Small herd

Source: McFate, Kenneth L., and B. A. Stout, eds., 1989, *Electrical Energy in Agriculture*, Chapter 7, "Electricity Used in Farmstead Operations," K. L. McFate. Amsterdam, Elsevier, pp. 129, 130.

Note: The cost of both direct-expansion and ice-bank cooling systems varies directly with the milk storage capacity requirements. For example, a 600-gallon direct-expansion system costs up to $10,000, whereas a 1500- to 2000-gallon system costs $20,000 or more. Ice-bank systems cost more than direct-expansion systems, but load management and milk quality benefits make ice-bank systems more cost effective for large dairies.

PARTIAL IN-LINE COOLERS OR PRECOOLERS

DESCRIPTION

Partial in-line coolers are used to precool milk before it enters the bulk tank by transferring the milk's heat to well water. For example, this process will cool one gallon of milk to 70°F from 90°F while raising two gallons of well water from 55°F to 65°F. Although some electrical energy is needed to run the water circulation pump, it is considerably less than that required to operate the compressor motor to provide equivalent cooling capacity. However, energy savings alone will not pay for a partial in-line cooler except in large dairies. The energy savings combined with increased milk cooling capacity may justify partial cooling, especially if the spent tempered water can be used for some additional purpose such as cleanup, prepping cows, flushing floors, or animal consumption. The potential annual energy savings for partial in-line cooling is shown in Table A-9. Note that the savings figures do not account for use of the tempered water for some other purpose.

APPLICABILITY

Large dairies; retrofits to expand present system capacity; dairies with unconstrained well water supply and need for warm nonpotable water.

DEMAND MANAGEMENT OBJECTIVE Strategic conservation, peak clipping

Table A-9. Partial In-Line Coolers or Precoolers: Costs and Benefits

Daily Milk Production	Annual Energy[1] Cost of Refrigeration		Annual Savings from In-Line Cooling		Cost[2]	Simple Payback
1000 lb	kWh (1000)	$	kWh (1000)	$	$	yr
5	14.6	1022	5.4	378	1500	3.9
10	29.2	2044	10.8	756	2307	3.0
20	73.0	5110	27.0	1512	3923	2.6
30	87.6	6132	32.4	2268	5538	2.4
40	116.8	8176	43.2	3024	7154	2.4
50	146.0	10220	54.0	3780	8769	2.3
60	175.0	12250	64.7	4529	10385	2.3
70	204.4	14308	75.6	5294	12000	2.3

1 Milk is cooled from 90°F to 36°F. In-line cooler reduces milk temperature from 90°F to 70°F (or about 37% of cooling energy requirements). Warm water is not used (no displaced water heating requirement calculated). Assumes an efficiency of 8 kWh/1000 lb (or a refrigeration coefficient of performance of about 2) of milk and electricity priced at $0.07/kWh.

2 Cost are representative of plate-type heat exhangers.

Source: Adapted from Bizzarro, A. B., 1979, *NRAES, Agricultural Energy Management, In-Line Milk Cooling on the Farm*, NFEC, Farm Energy Analysis Program.

WATER HEATING

■ *DESCRIPTION*

Water heating accounts for up to 40% of the electrical energy consumed on a dairy farm. The two principal uses of hot water on a dairy farm require different temperatures. Washing of milking equipment requires a temperature of 160°F, and washing cows' udders before milking requires water with a temperature of 100°F. Other typical uses for warm water is for consumption by the cows, which increases their intake and production, and for filling flush tanks for parlor washing.

There are two major types of milking equipment. Pipeline systems, generally employed for herds of more than 40 cows, require a larger quantity of water for washing than a non-pipeline system. The volume of water used in a pipeline system can be measured and will remain relatively constant over a period of time. Typically, a pipeline system requires 2.4 gallons per day per cow of water at 160°F.

Non-pipeline milking systems, sometimes called bucket systems, use less hot water for sanitation than pipeline milking systems. Although the amount of water used is difficult to measure, when it is determined the amount remains relatively constant for each milking.

Farm water heating energy and demand requirements can be reduced in four ways:

- Waste heat recovery
- Insulation
- Efficiency improvements
- Load management.

The reader should consult the section on residential water heating (in Volume 1 of this guidebook) for possible insulation and efficiency improvements (e.g., heat pumps). These are essentially the same for all hot water requirements. The additional requirements for high temperatures and long pipe runs found in dairy farms make tank and pipe insulation even more cost effective. Load management for dairy farm water heating is facilitated by the regularity with which hot water is required for udder washing and the cleaning of milking equipment. Demand control options are discussed in Volume 1, brief #20 (water heating cycling control) and in Volume 2, brief #10 (energy management systems).

Energy for water heating on dairy farms averages around 160 kWh per cow annually. This usage can be reduced by waste heat recovery methods described in the next brief.

APPLICABILITY

DEMAND MANAGEMENT OBJECTIVE Strategic conservation

FOR MORE INFORMATION

McFate, Kenneth, L., and B. A. Stout, eds., 1989, *Electrical Energy in Agriculture*, Chapter 7, "Electricity Used in Farmstead Operations," K. L. McFate. Amsterdam, Elsevier, p. 130.

WASTE HEAT RECOVERY

INTRODUCTION

There are several sources of heat from a refrigeration unit. One is the heat removed from the milk to cool it from 90°F to 40°F. Another is the waste heat from the compressor and motor. Most of the heat is contained in hot gas that comes from the compressor. Typically, condenser coils and fans are used to reject this heat to the atmosphere.

Heat from the refrigeration system can be recovered in the form of hot water by using either an add-on heat exchanger or a heat exchanger built into the condenser. Depending on the type of heat exchanger that is used, a 75% reduction in water heating energy requirements can be realized.

ADD-ON HEAT EXCHANGERS (DESUPERHEATERS)

Add-on heat exchangers are installed in series, along with a water storage tank and a circulating pump, between the discharge side of the cooling system compressor and the existing air-cooled condenser (Figure A-4). Because these units capture only refrigerant superheat, only 15%–50% of the available heat is recovered. Some of the heat is lost through the condenser. Therefore, the air-cooled condenser must remain in the system when the add-on heat exchanger is installed. Water temperatures of 90°F–110°F result, with a reduction in water heating costs of 30%–40%. Add-on heat exchangers cannot capture as much of the available heat as complete condensing heat exchangers, but they are much less expensive.

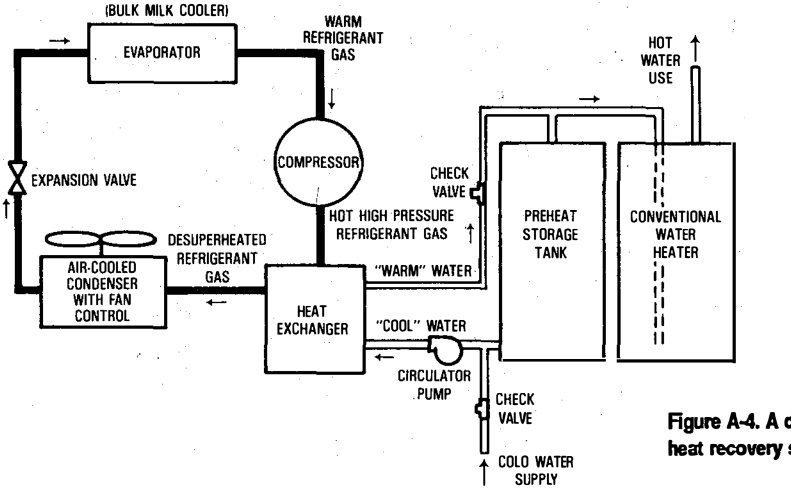

Figure A-4. A desuperheating (add-on) heat recovery system. Courtesy NFEC.

COMPLETE CONDENSING HEAT EXCHANGERS The complete condensing heat exchanger is a special water-cooled condenser unit instead of the typical air-cooled condenser (Figure A-5). Depending on the heat-transfer efficiency and the rate at which hot water is removed, condensing heat exchangers are capable of heating water up to 180°F, because nearly all refrigeration heat as well as heat produced by the compressor and motor is transferred. However, typical complete condensing heat exchangers produce water temperatures between 120°F and 150°F. Water heating costs are reduced by 60%–85%. Complete condensing units are added when a water heating system is installed or replaced. Proper sizing of the storage tank is important to ensure a constant supply of cold water to the condenser. If the inlet water temperature to the condenser gets too high, refrigeration efficiency is decreased. Some units dump excess heated water when the temperature rises too high; other systems have a back-up condenser coil and fan.

APPLICABILITY

New or retrofit dairy water heaters.

DEMAND MANAGEMENT OBJECTIVES Strategic conservation, peak clipping

COSTS AND BENEFITS

See Table A-10 for the annual savings possible with a complete condensing heat exchanger that recovers 90% of the heat from the refrigerant. Add-on heat exchangers cost between $1000 and $1600. Complete condensing units are much more expensive, because refrigeration compressors are frequently included.

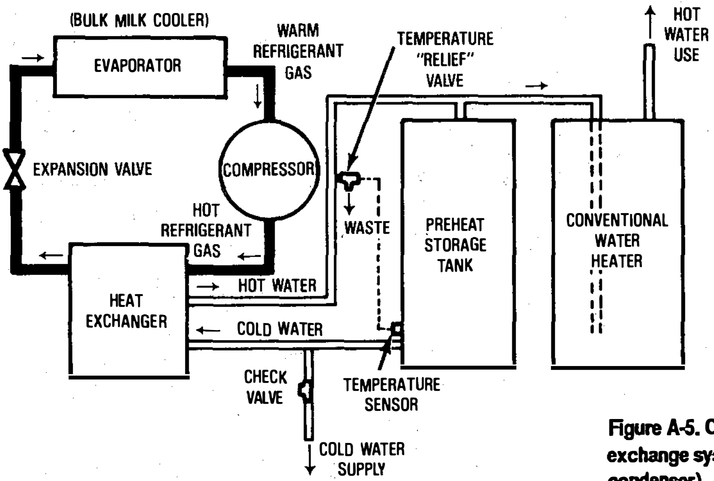

Figure A-5. Complete condensing heat exchange system (with no air-cooled condenser). Courtesy NFEC.

Table A-10.
Waste Heat Recovery: Costs and Benefits[1]

Daily Milk Production (1000 lbs)	140°F Water Produced Daily (gallons)	Annual Savings Electricity at $0.07/kWh	Cost of System ($)	Payback (yr)
5	432	1217	2000	1.6
10	864	2433	2846	1.2
20	1728	4886	4538	0.9
30	2592	7299	6231	0.9
40	3456	9732	7923	0.8
50	4331	12165	9615	0.8
60	5198	14598	11308	0.8
70	6064	17031	13000	0.8

1 Based on complete condensing exchanger recovering 90% of heat from refrigerant gases. Savings based on using 50% of the hot water produced. This is possible if water is used for flush tanks and cow watering. In general, complete condensing units produce more hot water than can be used. Annual displaced water heating based on 107°F temperature rise.

Source: Adapted from Peterson, R., and R. Koelsen, 1979, "Dairy Farm Heat Exchangers for Heating Water," *Northeast Regional Agricultural Engineering Service*, p. 3.

VACUUM PUMPS

DESCRIPTION

The average vacuum pumping requirement on a dairy farm is about 150 kWh/cow/year, which puts it on par with milk cooling and water heating energy requirements. Because vacuum pumps on most dairy farms are operated many hours each day, the cost of operating a pump with a motor that is larger than necessary can be costly. Although motors for vacuum pump systems vary from about 1 to 10 kW, the motors should be no larger than necessary. Industry guidelines for a pipeline milking system require about 1.2 kW of electric motor capacity for each milker unit with accessory components. Typical vacuum flow requirements are shown in Table A-11.

The most common type of vacuum pump used on dairy farms is a rotary vane type. For larger farms, a water-sealed or ring-seal type of pump is available which can be used to recover the heat of compression in a flush tank. Both types of pumps have about the same efficiency. The ring-seal type is more reliable and more expensive.

Savings in vacuum pumping results from proper sizing and maintenance of the electric motor attached to the pump. See the section on motors in Volume 2 of this guidebook for more information.

Table A-11.
Vacuum Flow Requirements for Milking Systems at a Vacuum Level of One-Half Atmospheric Pressure (7.34 psi)

Pipeline System Component	cfm[1]/unit
Milker unit	6
Vacuum-operated release	5
Pulsated vacuum line per 10 ft of length	1
Vacuum bulk tank	0
Milk meter	1
Sanitary couplings per 20	1
Inlets per 10	1
Reserve for regulator	3

1 Bucket type milking system—4 cfm/bucket unit.

Source: McFate, Kenneth L., and B. A. Stout, eds., 1989, *Electrical Energy in Agriculture*, Chapter 6, "Electric Energy Management on Dairy Farms," L. A. Brooks. Amsterdam, Elsevier, p. 96.

VENTILATION

DESCRIPTION

Both natural and mechanical ventilation are used for dairy farm barns, milking parlors, and milkhouses. Natural ventilation depends on wind pressure, building orientation and construction, and differences between indoor and outdoor temperature to provide air movement. A dairy farmer who uses electrically powered fans for air movement has much greater control over the environment. Although the power demand for a ventilation system is based upon the hottest and coldest weather of the year, in the interest of economy it is not necessary to design the system for only a few hours of extreme weather. Dairy farm animals can tolerate less than ideal conditions for short periods of time.

Milkhouses usually use positive-pressure fans to avoid drawing in dusty air and odors from the milking parlor or barn. Typical ventilation energy requirements are listed in Table A-12. For more information on ventilation efficiency improvements, refer to brief #22 on controlled ventilation under livestock. Recommended ventilation rates for dairy animals are shown in Table A-13.

Table A-12.
Electricity Used for Ventilation on Dairy Farms

Equipment or Load	Electricity Used kWh/year/cow
Ventilation: Fans for stanchion barn	21
Ventilation: Fans for milk/parlor room	22
Milk parlor/milk room (winter heating)	10–20

Source: McFate, Kenneth, L., and B. A. Stout, eds., 1989, *Electrical Energy in Agriculture*, Chapter 7, "Electricity Used in Farmstead Operations," K. L. McFate. Amsterdam, Elsevier, p. 131.

Table A-13.
Recommended Dairy Barn Ventilation Rates[1]

Age or Size		Ventilating Rate per Animal[2] Cold Weather (cfm)	Mild Weather (cfm)	Hot Weather (cfm)
Calves	0–2 months	15	50	100
Heifers	2–12 months	20	60	130
	12–24 months	30	80	180
Cows	(1400 lb)	50	170	470

1 Although this table of values is used widely throughout the central U.S. from Wisconsin to Oklahoma, more often the rate of ventilation would be one-half to two-thirds of the levels listed. Ventilation adjustments should be made to meet local housing and climate conditions.

2 An alternative cold-weather rate is one-fifteenth of the building volume. An alternative hot weather rate is the building volume divided by 1.5.

Source: McFate, Kenneth L., and B. A. Stout, eds., 1989, *Electrical Energy in Agriculture*, Chapter 6, "Electric Energy Management on Dairy Farms," L. A. Books. Amsterdam, Elsevier, p. 110.

MATERIALS HANDLING

■ ■ ■

Grain conveyance and feed processing are two primary uses of electricity for materials handling. These, together with electric chore vehicles, a load growth opportunity, are discussed in this section.

GRAIN CONVEYANCE

The two most widely used conveyors for moving grains on farms are augers and bucket elevators. There are other specialty conveyors for different kinds of livestock and poultry feeding systems. For example, belt conveyors are energy efficient but are more expensive than augers and cannot move materials up steep slopes.

When choosing a conveyance system, consider factors that affect the efficient use of electricity: the amount of moisture in the grain, the relative location of storage and feed-processing structures, and the method of unloading storage structures.

TERMS AND DEFINITIONS

AUGER The most widely used type of conveyor on farms is the auger. The auger is a screw conveyor and is used to move shelled corn, small grains, and ground feed. It is inexpensive and portable and may be used for many purposes. Its low efficiency tends to be offset by its low first cost. Moving corn with a high moisture content (25%) requires more power to drive the auger because the flow characteristics differ from those for dry corn.

BUCKET ELEVATOR The vertical bucket elevator is more energy efficient and more readily adaptable than the auger to high-volume grain- and feed-handling systems. Bucket systems often move grain to great heights so that the grain flows by gravity into the drying system. Bucket systems can be as much as 65% more efficient than augers on a per ton/ft of lift basis.

COSTS AND BENEFITS

Typical ranges for efficiencies are shown below:
Bucket system 0.0015–0.002 kWh/ton/ft of lift
Auger system 0.0049–0.0055 kWh/ton/ft of lift
For example, lifting and filling a 30-foot-diameter bin to a depth of 8 feet (~5000 bushels assuming 40 lb/bu) with a 40-foot lift would require up to 8 kWh with a bucket system and up to 22 kWh with an auger.

FEED PROCESSING

DESCRIPTION

Two automatic farm feed-processing systems are commonly used to mix and process feed for farm livestock and poultry. The hammer mill is usually used to process feed into finely ground grain for poultry and hogs. Both the hammer and the roller mill are used for processing feed for dairy or beef cattle. Because the electrical demand of an automatic electric feed-processing system is directly related to the size of the power unit, the smallest unit possible should be chosen.

HAMMER MILL The most popular mill is the hammer mill, because it is simple in construction, grinds different grains well, and is easily adapted to automatic control. It consists of three rows of free-swinging steel blades that are attached to an electric motor shaft. These blades force or "hammer" the grains through openings in a circular screen. The size of openings in the screen (usually between one-eighth and one-half inch) determines the size of the grind. The energy consumption is higher for mills with smaller screens, which produce more finely ground products. Table A-14 shows typical energy requirements for different grains and screen sizes.

Typically, four to six different grains are introduced into the grinding chamber of the hammer mill. The grains are measured by volume, most often using an auger.

The hammer mill is available in sizes between 2 and 10 horsepower and in single-phase or three-phase power units.

ROLLER MILL Compared to a hammer mill, a roller mill reduces grain size less. It is often used to crush high-moisture corn. It consists of two rollers of equal diameter spaced to give the desired crushing effect.

Table A-14.
Electricity Used for On-Farm Hammer-Mill Operation

Task or Operation	Primary Loads (kW)	Electricity Used (kWh/ton) 1/2" screen	1/8" screen
15% corn	2.24	1.6	6.6
25% corn	2.24	2.2	11
Dry oats	2.24	1.8	20
12.5% grain sorghum	2.24	1.4	5.0

Source: McFate, Kenneth L., and B. A. Stout, eds., 1989, *Electrical Energy in Agriculture*, Chapter 7, "Electricity Used in Farmstead Operations," K. L. McFate. Amsterdam, Elsevier, p. 139.

One roller might be set for wheat or oats and another for shelled corn or milo. When more than one grain is crushed, either augers or fluted wheels are used to meter the volume of flow. Unlike in the hammer mill, ingredients do not flow into a common crushing chamber. Instead, mixing takes place in a separate compartment after each grain has been crushed. A disadvantage of the roller mill is that it cannot be started under a load. The principal advantage of the roller mill is its lower energy requirements on a per-ton basis. See Table A-15 for more information.

■ *APPLICABILITY*

All sizes of operations for dairy, swine, and poultry farms.

DEMAND MANAGEMENT OBJECTIVES Strategic conservation, peak clipping

■ *COSTS AND BENEFITS*

Typical swine and poultry systems cost between $12,000 and $25,000 for a turnkey operation.

Table A-15. Energy Requirements for Roller-Mill Operation (kWh/Ton)

Feed Type	Moisture (%)	Clearance (inches)	Grooves per inch	kWh/Ton Energy Requirements Rate lb/min 10	20	30	40	50
Corn	29.7	0.100	6	1.12	0.68	0.54	0.47	0.42
Corn	10.4	0.075	6	1.99	1.55	1.37	1.24	1.19
Corn	10.2	0.075	12	1.99	1.55	1.37	1.24	1.19
Corn	24.8	0.080	12	1.74	1.24	1.12	0.93	0.80
Oats	11.3	0.020	6	1.62	1.06	0.91	0.81	—
Oats	12.3	0.028	12	1.74	1.12	0.95	0.87	—
Wheat	12.8	0.046	12	1.74	1.24	1.04	0.93	0.85

Source: National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO, p. AT–123.

ELECTRIC CHORE VEHICLES

DESCRIPTION

Farm chores that can be done using a tractor, feed cart, or forklift account for 24% of total agricultural vehicle energy use. A shift from liquid fuel to electricity for such tasks represents a significant load growth potential. This load growth potential is further enhanced by the opportunity for off-peak (valley filling) battery charging at low rates. Initially, electric-powered vehicles may cost more than their internal combustion–powered counterparts, but they have some attractive features. Two electric-powered vehicles currently in use are the electric lift truck and the battery-powered chore tractor.

Many California growers are using electric lift trucks in refrigerated storage buildings because of new battery designs that allow their operation in an eight-hour shift. Furthermore, compared to propane-powered trucks, electric lift trucks cost less to maintain, do not produce carbon monoxide, make less noise, and do not produce as much waste heat.

In refrigerated storage facilities, propane-powered units produce nearly three times as much waste heat as electric-powered units. This heat must be removed by the refrigeration system. Although the electric vehicle requires energy for charging the batteries, the electrical consumption for battery charging occurs during off-peak hours. The added cost of removing the heat produced by the propane unit is balanced by the battery-charging costs. The net effect is that the energy savings and the maintenance cost benefits will pay for the higher initial costs of the electric vehicle over its life. An electric lift truck costs approximately $23,000, or 60% more than a propane truck. Operating costs for electric vehicles are estimated at $1.00 per hour compared to $2.50 per hour for propane trucks. Table A-16 presents a comparison

Table A-16.
Electric Chore Vehicles: Costs and Benefits

	Electric/Direct[1]	Electric/Battery	Diesel
Energy costs ($)	$0.10/kWh	$0.05/kWh	$1.14/gal
Efficiency (%)	77%	33%	10%
Cost at axles ($/kWh)[2]	13	25	28
Initial costs ($)[3]	40,000	50,000	40,000
Lifetime (years)	10	10	7
Total annual costs ($)[4]	13,500	14,525	16,390

1 The direct-powered vehicle is assumed to be operated on peak, the battery-powered vehicle to be charged off peak.
2 Includes cost of battery replacement for the electric/battery option.
3 60 kW (80 hp) 4WD or equivalent tractor.
4 Includes capital, energy, and maintenance costs.
Source: Adapted from McFate, Kenneth L., and B. A. Stout, eds., 1989, *Electrical Energy in Agriculture*, Champter 11, "Electric Vehicles in Agriculture," L. L. Christianson et al. Amsterdam, Elsevier, pp. 216, 217.

of the annual cost of operation for diesel and electric chore vehicles.

Battery-powered tractors using a DC electric motor and lead/acid materials are similar in size to conventional tractors with a diesel engine and a fuel tank. Electric tractors with high clearance and farm implements are commercially available in sizes ranging from 40 to 80 hp. They are designed for operating feed wagons, handling manure in outdoor lots, feeding and loading hay and silage, removing snow and debris, and hauling. They can be equipped with a trencher, wire reel, and platform loader. The battery capacity is typically adequate to operate approximately four hours daily.

APPLICABILITY

The electric lift truck is applicable for refrigerated storage facilities, greenhouses, dairy farms, and materials handling. Battery-powered chore tractors are applicable for short-term farmstead use, heavy-use farm jobs, dairy farms, confinement livestock, and feedlots.

DEMAND MANAGEMENT OBJECTIVES Strategic load growth, valley filling

FOR MORE INFORMATION

Roberts, W., 1988, "Electric Powered Vehicles for Storage and Production Facilities," *Long Island Horticulture News*, Long Island, NY, p. 3.

National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO, p. AT-101.

McFate, Kenneth, L., and B. A. Stout, eds., 1989, *Electrical Energy in Agriculture*, Chapter 11, "Electric Vehicles in Agriculture," L. L. Christianson et al. Amsterdam, Elsevier, p. 209.

CROP DRYING

■ ■ ■

The purpose of grain drying is to remove enough moisture so that mold does not grow in any part of the stored grain. Grain drying is done on cash crop farms as well as on dairy and poultry farms. Although fossil fuels, solar energy, or electric heat may be used for drying, electricity is the predominant energy source for moving the air through the grain. Factors to consider for grain drying include moisture content of the grain, fan characteristics, power required, the amount of air to be moved, and the conditions of the drying air. Where grain is dried in high-temperature (180°F–240°F) batch processes, the primary heat source is LPG.

A typical structure for drying grain is a round, all-metal bin on a concrete base with a perforated metal floor above the concrete base. The space between the concrete and the metal, called the plenum, is used to contain the direct air, from electrically powered fans, that moves through the grain. The roof must have openings to exhaust the most air. The overall efficiency of various all electric grain drying methods is summarized in units of kilowatt hours per bushel of corn per percent moisture removed:

Low-temperature air	0.1–0.2	kWh / bu / %
Unheated air	0.25–0.3	kWh / bu / %

High-temperature batch grain drying systems have the lowest efficiency in terms of Btu per percent moisture removal. They are also the most labor intensive.

For more information, see National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO, pp. AT-102, AT-103.

GRAIN DRYING WITH LOW-TEMPERATURE ELECTRIC

DESCRIPTION

Low-temperature crop drying uses a combination of air that is heated a few degrees above ambient fall temperatures and air that is flowing at the rate of 1 to 3 cubic feet per minute to dry a bushel of grain. Resistance heaters are used to raise the temperature 3°F to 5°F. Because the heat is precisely controlled, energy efficiency is good and the grain quality is better than when high temperatures are used. Because low-temperature drying is a long-term process, fans operate continuously from the time that wet grain enters the bin until it is dry 30 to 60 days later. Heat is best used during periods of high humidity, which often exist at night and on foggy or rainy days. Typical fan size is 1 to 2 hp per 1000 bushels of grain. The electric heater should be sized at 1 to 1.5 kW per fan horsepower. The drying system should start to operate when the average daily temperature reaches 50°F to 55°F and run until the grain is dry or the average daily temperature reaches about 30°F.

Benefits to the utility system include a good load factor during the drying season, com and sorghum drying that does not add to the summer or winter peak load, and an interruptable load. For the consumer, advantages include lower energy use and cost and a higher-quality product less susceptible to breaking than grain dried at high temperatures.

APPLICABILITY

All types of drying bins and crops.

CLIMATE Preferably dry climates

DEMAND MANAGEMENT OBJECTIVES Valley filling, strategic load growth, strategic conservation

■ *COSTS AND BENEFITS*

Electric heaters cost between $20 and $40 per kilowatt. Cost of fan motor units ranges from $100 to $200 per horsepower. Centrifugal fans cost more than axial fans. Fans powered with three-phase motors cost less than fans powered with single-phase motors. Installation, wiring and building modifications are additional expenses.

■ *FOR MORE INFORMATION*

National Food and Energy Council, 1986, *Agricultural Technical Briefs Notebook*, Columbia, MO, p. AT-103.

GRAIN DRYING WITH UNHEATED AIR

DESCRIPTION

Drying grain with unheated air, sometimes called natural air drying, uses the air's natural capacity for absorbing moisture. Air with a relative humidity of 60%–70% dries grain to a moisture level that is safe for long-term storage at 15% moisture content. Although high-humidity air removes little moisture, the heat of compression caused by the moving air raises the temperature between 1°F and 3°F, thereby reducing the relative humidity. Drying time, from several days to a few weeks, depends on air flow and weather conditions. Unlike batch or continuous-flow systems, unheated air drying usually takes place in grain storage bins equipped with perforated floors. Air-flow rates from 1 to 3 cfm/bushel used to dry grain of 20% to 26% moisture require 1 to 3 hp for each 1,000 bushels of grain. Grain depth should not exceed the static pressure limit of the fans.

Advantages to the customer include low energy requirements for grain drying and high-quality grain.

The utility benefits from a steady electrical load during October and November. Grain drying is a load that can be interrupted during daily peaks for short periods of time without harming the quality of grain.

APPLICABILITY

Farms with adequate storage; cereal grain, wheat, and soybean farms.

CLIMATE Moderate

DEMAND MANAGEMENT OBJECTIVES Strategic conservation, strategic load growth, peak clipping

COSTS AND BENEFITS

Cost of fans is between $100 and $200 per horsepower. Centrifugal fans cost more than vane axial fans. Fans powered with three-phase motors are less expensive than fans powered with single-phase motors. Electrical wiring and installation are additional costs.

FOR MORE INFORMATION

National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO, p. AT-102.

CONTROLLED AERATION FOR QUALITY GRAIN

DESCRIPTION

Controlled aeration is the circulation of air through grain after normal drying to prevent spoilage. Because grain that is stored during early fall is warmer than grain stored during winter months, there is a temperature gradient in the stored grain. As cold air is warmed, it picks up moisture and moves upward, where the moisture condenses and falls on the top layers of the grain, and a crust forms there. Thus, moisture migrates unevenly through the mass of grain to unbalance the previously dried grain. The purpose of controlled aeration is to automatically equalize and maintain the temperature of grain at a level that prevents moisture migration and reduces biological and insect activity. The grain temperature should be constant within 10°F to 20°F of the coldest storage month. The grain should not be aerated below 32°F.

Aeration requires an air-flow rate of one-tenth cfm per bushel of grain to make a complete temperature change within 120 to 200 hours. Larger-horsepower drying fans decrease the amount of time needed to completely change the temperature. Computerized sensing and control units can ensure accuracy as well as continuous monitoring. Table A-17 shows the results of a simulation that indicates that controlled aeration of grain can improve by 74% the pounds of moisture removed per hour of fan use.

Table A-17. Controlled Aeration for Quality Grain: Costs[1] and Benefits

Fan Control	Fan, Continuous	Expert Control
Average final moisture % wet basis	20.35%	22.92%
Hours fan on	335	59
Storage life remaining, top layer, %	27.2	65.4
Average temperature of grain on October 14	56°F	42°F
Moisture removed pounds/hr of fan use	45.8	79.8

Source: National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO, p. AT–130.

1 The cost varies. One basic control system that will monitor and control up to 12 bins costs about $3000. Sensing probes are about $70 to $100 per bin for each unit. Data are based on simulation studies.

APPLICABILITY

On-farm commercial grain storage.

DEMAND MANAGEMENT OBJECTIVES Valley filling, strategic conservation, peak clipping

FOR MORE INFORMATION

National Food and Energy Council, 1986, *Agricultural Technical Briefs*, Columbia, MO, p. AT-128.

HAY DRYING

DESCRIPTION

High-quality alfalfa hay contains about 80% moisture. The moisture level for safe storage is about 15%. When alfalfa is allowed to dry in the field, many of the high-protein leaves shatter and are lost. To avoid the loss of nutrients in the shattered leaves, hay must be cut at the proper stage of maturity and allowed to partly dry in the field. Then, when the moisture content is about 40%, the hay should be baled or chopped to a length of 4 to 6 inches. This procedure reduces field drying time to about 50% of normal and, consequently, reduces losses from intense sun or severe thunderstorms. This partly cured hay may be placed in a permanent structure where it is completely dried.

Hay drying systems that use large quantities of heat are usually batch type and dry the hay in one to two days. Natural air drying requires a minimum of 2.5 cfm of air for each cubic foot of hay to be dried and takes 5 to 12 days for a six-foot layer of hay. Drying time depends on the initial moisture content of the hay, air-flow rate, temperature and humidity of the air, and the type of equipment used for drying.

Benefits to the farmer of hay drying include better quality feed and up to 20% greater profit when marketed. Utilities benefit from a greater use of electricity.

APPLICABILITY

Dairy and specialty farms; for market sale.

DEMAND MANAGEMENT OBJECTIVES Strategic load growth, valley filling

COSTS AND BENEFITS

Costs vary. In Missouri studies, 62 kWh per ton were used to dry 35% to 40% moisture chopped hay with a slotted floor system during a normal summer.

FOR MORE INFORMATION

National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO, p. AG-129.

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LIVESTOCK MEASURES

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Together, poultry and livestock production account for approximately 34% of the electricity consumed by the agricultural sector. Brooding and watering represent major uses of electricity for poultry, swine, and beef production. In addition, electrical equipment for lighting, feeding, ventilation, and other uses significantly affects the cost of a livestock operation.

ELECTRIC BROODING

DESCRIPTION

Today, both poultry and swine brooding are frequently done with electricity in well-constructed, well-insulated buildings. Baby chicks are confined to a brooding area for the first 25–28 days of their lives. Similarly, newborn swine lie on floors heated as high as 95°F for several weeks, after which they can be transferred to the nursery, where floors are heated to about 55°F or 60°F. To allow for efficient use of electricity, brooding can be confined to only a small area of a building (partial house brooding). A large mass of concrete or water, sometimes both, can be heated during the power supplier's off-peak hours to supply the heat needed for brooding throughout the day.

In an in-floor electric heat system, the cable used to heat the concrete requires a heat density of 4–5 W per square foot for a well-constructed building. One study in a mild climate showed that a concrete floor without insulation on the underside lost only 4.9°F when the heat was turned off for twelve hours after reaching 88°F. Another common brooding system uses, instead of a heated floor, heat lamps directed at the animals.

The lack of accumulated moisture caused by using electric rather than fossil-fuel heat reduces the cost of ventilation. For comparison, one pound of moisture is produced for each pound of liquid petroleum that is burned. Other advantages include both lower mortality and better feed conversion due to climate control. On the other hand, care must be taken with electric heating to avoid overheating newborn chicks and pigs. Typical energy consumption for swine and poultry brooding is shown in Table A-18.

Table A-18.
Electricity Used for
Swine and Poultry Brooding

Load or Area Involved	Electricity Used	Comments
SWINE BROODING		
Cable, in floor 400W per pen	50–100 kWh per sow litter	Lower use in fall, higher use in winter
Cable, in floor 300W per pen	19 kWh per sow litter	Southern climate
Commercial pads 300W per pen	40–120 kWh per sow litter	Lower use in fall, higher use in winter
Heat lamps 250W per pen	6 kWh/day per sow litter	Units on continuously
POULTRY BROODING		
1560 hover units	18–44 kWh per 100 birds	Spring–summer broods, poor housing
	25-60 kWh per 100 birds	Fall–winter broods, poor housing
	46 kWh per 100 birds	November–January broods, insulated housing
Quartz heat brooders	34 kWh per 100 birds	Well-insulated (R-13) windowless test house
Space heaters (supplemental)	5 kWh per 100 birds	Well-insulated (R-13) windowless test house

Source: McFate, Kenneth L., and B. A. Stout, eds., 1989, *Electrical Energy in Agriculture*, Chapter 7, "Electricity Used in Farmstead Operations," K. L. McFate. Amsterdam, Elsevier, pp. 133, 136.

APPLICABILITY

CLIMATE Mild winter climates; colder winter climates where an overall U value of 0.1 Btu/h-ft^2-°F is met by the building shell.

DEMAND MANAGEMENT OBJECTIVES Valley filling, strategic growth

FOR MORE INFORMATION

National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO, p. AT-124.

Table A-19.
Electric Brooding: Costs and Benefits

Brooding System	Annual Cost[1] ($)
Conventional gas LP	2550
Conventional electric	6470
Electric cable in-floor (off peak)	1290
PVC in-floor	1180
PVC on-floor	1230

1 Source: National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO, p. AT-124.

Note: Assumes five broods per year and a 20,000-bird capacity. Electric cost $0.08/kWh, $0.04/kWh off peak, 85 cents/gal LPG. Actual cost data for in-floor systems are limited. The projected cost is about $12 per 100 birds for an electric cable system and about $17 per 100 birds for a PVC system. The cost for a PVC system laid on the floor is about $11 per 100 birds. These costs exclude labor, extra insulation, and added electrical service equipment.

DUAL FUEL FOR LIVESTOCK BROODING

DESCRIPTION

Dual fuel means that two fuels are used to provide heat for brooding. Electricity is the primary energy source used during off-peak hours 80%–95% of the time. LP gas is the usual secondary fuel used during on-peak hours about 5%–20% of the time. The objective is to avoid paying demand prices for electricity. Switching between systems can be remotely controlled by the utility using radio or power-line carrier systems. Well-constructed and well-insulated brooding houses are required.

More opportunity for dual fuel exists for swine production than for poultry production (located primarily in the warm southeastern U.S.), although one Minnesota turkey producer reduced electricity costs by 30%–44% using dual fuel and saved $700 during 1986. See Table A-20 for savings obtained by three Minnesota farms.

APPLICABILITY

CLIMATE Winter weather conditions

DEMAND MANAGEMENT OBJECTIVES Peak clipping, valley filling, strategic load growth

Table A-20. Dual Fuel for Livestock Brooding: Costs[1] and Benefits

Type of Operation	System Type	Annual Use (kWh)	Annual Savings ($)[2]	Payback (yr)
Farrow to finish 500 hogs	Hot water in-floor system electric/LPG	42,000	861	1.5–3
Feeder to finish 200 hogs	Hot water in-floor system electric/LPG			
Farrow to finish 1600 hogs	Electric in-floor, LPG space heat	75,150	1579	1
Farrow and nursery 2000 hogs	Electric in-floor, LPG space heat	60,410	1329	2–2.5

Source: McFate, Kenneth L., and B. A. Stout, eds., 1989, *Electrical Energy in Agriculture*, Chapter 4, "Electric Heating Applications on Farms," D. R. Price. Amsterdam, Elsevier, p. 45.

1 The cost varies with each system, but one system cost $2200 in a Minnesota farrowing house.

2 Off-peak energy costs are about $0.04/kWh, or half the on-peak energy costs.

WATERERS

DESCRIPTION

The amount of water consumed by livestock directly affects their health, ability to digest feed, body tissue building, and body heat regulation. In Iowa, researchers found that hogs with ice-free water gained 0.24 lbs more per day than those in pens where water was not readily available. Also, Iowa studies showed that dairy cows with access to automatic waterers drank 18% more water and produced 3.5% more milk than cows watered twice a day. When livestock is fed modern rations that include high protein, an increased water intake is necessary for good health. In warm to hot climates, livestock (including poultry) use more than the usual amount of water to regulate body temperature. Not only do waterers improve production, but they also reduce mortality. Typical energy consumption for livestock waterers is shown in Table A-21.

Although the size and shape of waterers varies depending upon the type of livestock, the basic design principles remain the same. One way to prevent water from freezing is to apply electric heat. For example, heating elements on some waterers are immersed in the drinking water storage chamber so that heat is transferred directly to the water. Outside waterers must be well insulated with 1.5 inches or more of insulation to prevent freezing. Adjustable temperature control will minimize energy use because water should not be overheated. The water surface must be readily available to livestock, but hinged lids or lightweight floats on the water surface may be used to reduce heat loss. Hogs can use a fountain-type waterer that delivers water on demand and eliminates the standby losses of trough systems.

Table A-21.
Electricity Used for Livestock Watering

Load or Area	Electricity Used	Comments
Outside location	5–10 kWh per hog marketed	100–200 lb hogs
Inside location	2–3 kWh per hog marketed	100–200 lb hogs
Pumping distribution	3 kWh per hog marketed	One 2,000-hog farm
Cattle waterer (outside)	6–7.5 kWh/cow/year	
Pumping/distribution	0.35 kWh per 220 lbs	Four-farm average

Source: McFate, Kenneth L., and B. A. Stout, eds., 1989, *Electrical Energy in Agriculture*, Chapter 7, "Electricity used in Farmstead Operations," K. L. McFate. Amsterdam, Elsevier, pp. 131, 132, 134.

Another method to prevent livestock water from freezing uses continuous-flow waterers that either recirculate water or dispose of the excess water in a nonrecirculating system. In this method, heating elements are not immersed in the drinking bowl or cup. Electricity uses include circulating pumps, electric heaters to heat the supply tank, and electric trace heaters to prevent pipe freezing.

APPLICABILITY

CLIMATE All climates, especially in cold winter climates where freezing is likely to occur

DEMAND MANAGEMENT OBJECTIVES Strategic conservation, strategic load growth

AGRICULTURAL BRIEF #21

EARTH-TUBE HEAT-EXCHANGE VENTILATION SYSTEMS

DESCRIPTION

Earth-tube heat-exchange ventilation systems use the relatively uniform temperature of the earth at depths of 6–12 feet to supplement heating in the winter and cooling in the summer for livestock buildings. During the year, the temperature at a depth of 6 feet varies only about 10°F and at a depth of 12 feet it varies only about 6°F. Studies have shown that after passing through the heat-exchanger tube, the winter outside air will enter a building 25°F to 30°F warmer, and in the summer 25°F to 30°F cooler, than ambient temperatures.

Actual design of an earth-tube heat exchanger depends on ventilation requirements, the area free for pipe burial, and soil characteristics. Earth-tube heat exchangers perform best in wet clay soil because of their high heat conductivity. Success of systems in deep sandy soils is questionable. When the earth-tube heat-exchange system is used with electric heating for livestock facilities, peak demand is reduced.

APPLICABILITY

Livestock confinement.

DEMAND MANAGEMENT OBJECTIVES Strategic conservation, peak clipping, strategic load growth

FOR MORE INFORMATION

National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO, p. AT-126.

Table A-22. Earth-Tube Heat-Exchange Ventilation Systems: Costs and Benefits

Design temperature rise	25°F
Design outdoor temperature	30°F
Ventilation rate	50 cfm/animal
Equivalent days of design operation per winter	50 days
Annual heating savings	496 kWh/animal
Annual savings ($0.07/kWh)	$35/animal
Cost per animal (i.e., 500-cfm design)	$150/animal ($3 per cfm)
Payback	4.3 yr

Source: Adapted from National Food and Energy Council, 1986, *Agricultural Technical Brief Notebook*, Columbia, MO, p. AT–126.

CONTROLLED VENTILATION

Controlled livestock ventilation uses propeller fans with electric motors to exchange normally clean outside air with dust-, moisture-, and odor-laden air in a livestock building. During cold periods, heat must be added to this process. During warm weather, air exchange is used to control the temperature rise in buildings that is caused by accumulation of livestock body heat.

In livestock structures, it is recommended that a combination of small and large fans be used to provide moisture and odor control in the winter as well as to cool during warmer months. During the coldest weather, the ventilation system must remove most of the moisture produced but as little heat as possible. Air-to-air heat exchangers are available to recover heat from the warm moist air exhausted from the building. With efficiencies in the 50%--70% range, these units have five-year paybacks.

The four basic components for livestock ventilation systems are air inlets, air inlet controls, motor-driven fans, and fan motor controls. Although the driving force is the electrically powered fan, the air inlets must be carefully controlled to evenly distribute the fresh air. Controls are used to keep the amount of inlet opening matched to the number of fans running. For direct-drive fans, a 10 to 12 cfm/W performance is good; for belt-drive fans, 18 to 29 cfm/W is considered good. Both 115-V and 230-V single-phase power are commonly used; the higher voltage is preferred to reduce wiring cost and line loss. Three-phase power is less expensive than single-phase power, but it is only available to a limited number of farmsteads.

Advantages to the utility's customer include reduced labor requirements; lower heat bills; healthier livestock and less medication; more intense facility use; faster weight gains; and increased production of meat, eggs, and milk. Also, the utility can expect predictable loads. One disadvantage to the utility is the peak demand created after a power outage. Fans should be reactivated in stages to reduce this peak.

■ *APPLICABILITY*

Dairy barns and milking rooms; other livestock confinement.

DEMAND MANAGEMENT OBJECTIVES Strategic conservation

■ *COSTS AND BENEFITS*

Costs vary. In one example, a system with a 200-pig nursery would cost about $2000; 50% of this cost would be for fans and fan controls. Costs vary depending on quality of components, whether or not corrosion-resistant components are required, sophistication of controls, and transportation requirements. Air-to-air heat exchangers cost $2–$6 per cfm.

■ *FOR MORE INFORMATION*

National Food and Energy Council, 1986, *Agricultural Technical Briefs*, Columbia, MO, p. T-106.

Northeast Regional Agricultural Engineering Service, 1979, "Choosing and Maintaining Ventilation Fans," Cornell University, NY, FS 21.

EVAPORATIVE COOLING SYSTEMS

DESCRIPTION

In areas of relatively low humidity, evaporative cooling systems use heat from ambient air to vaporize water and thus cool the air. With the trend toward tightly insulated, well-constructed livestock buildings, environmental control is necessary. Evaporative cooling helps to reduce poultry mortality caused by heat in major broiler- and egg-producing areas. Swine producers also cool structures with evaporative coolers.

For a utility, evaporative cooling of livestock buildings is a strategic load growth opportunity. One northeastern structure used 82 kWh/year per 100 birds for ventilation. For the customer, reduced mortality can result in a payback that varies from a few days to several years depending on high summer temperatures.

APPLICABILITY

Poultry and swine operations.

CLIMATE Summer months, dry climates

DEMAND MANAGEMENT OBJECTIVES Valley filling, strategic load growth

COSTS AND BENEFITS

The cost is variable. In one southeastern poultry operation, cost was about $0.35 per bird housed. Because of high pressure against which fans must operate and the extra energy used by the water circulation pump, the cost of operating the evaporative cooling system may be as much as 25% greater than dry air ventilation systems during high-temperature periods.

FOR MORE INFORMATION

National Food and Energy Council, 1986, *Agricultural Technical Briefs Notebook*, Columbia, MO, p. AT-135.

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