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CC343 Energy Efficiency in Food Processing

R. C. Anantheswaran

D. W. Macke

R. D. Grisso

Nebraska Cooperative Extension Service CC 343

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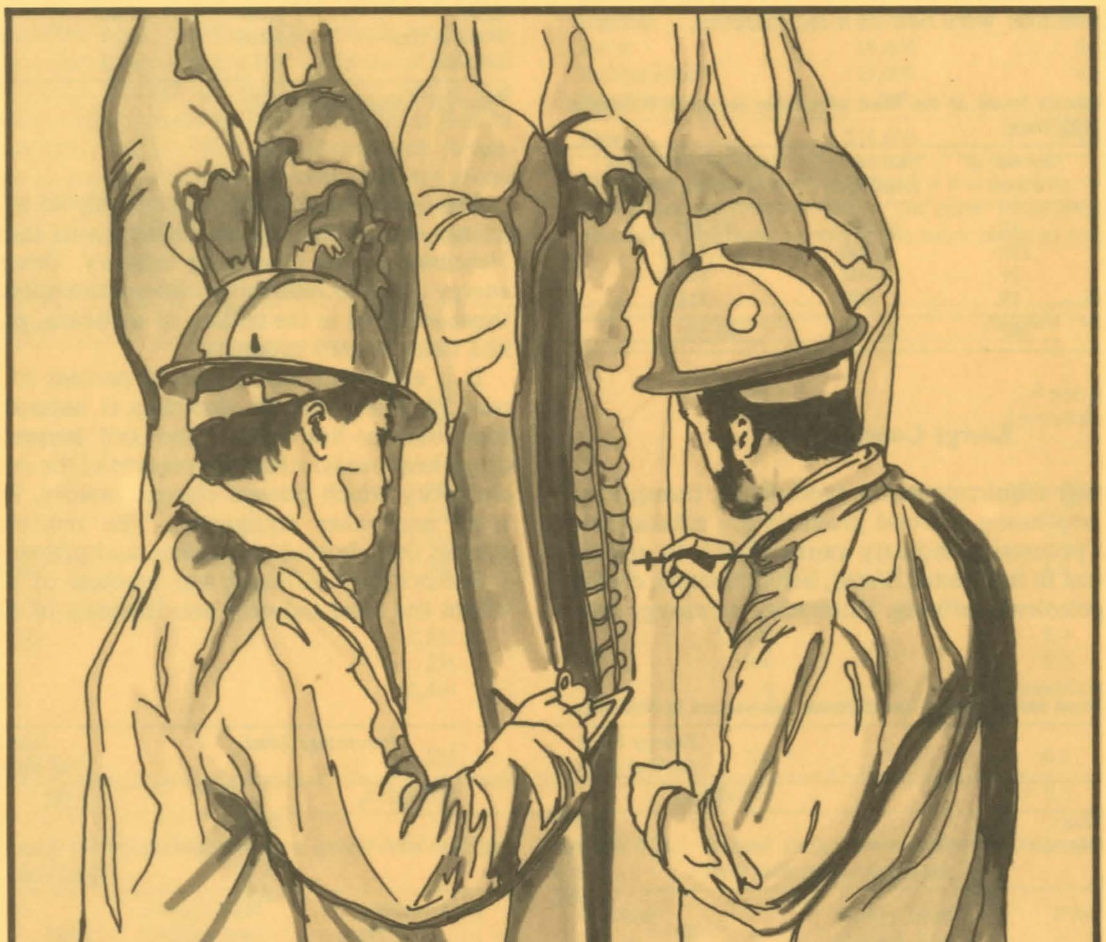
R. C. Anantheswaran, Food Process Engineer
D. W. Macke, Consultant
R. D. Grisso, Extension Agricultural Engineer



Food processing is a very important industry for Nebraska.

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The food processing sector accounts for over 60 percent of the value of shipments of manufactured goods from Nebraska.

In 1985, this sector shipped products valued at $8.4 billion, which roughly accounts for 55 percent of Nebraska's manufacturing output. The food processing sector also contributed up to 45 percent of the state's total foreign exports, valued at $332 million.

The four important food processing sectors in Nebraska are meat processing, milled grain, dairy, and fat and oil products, which are linked to the type of production agriculture prevalent in the state. These four sectors account for up to 95 percent of the value of food processing shipments sent out of Nebraska. Meat packing alone accounts for nearly 70 percent of the value of food processing shipments.

Table 1 summarizes the relative activity levels of the four important food processing sectors within Nebraska. Meat products dominate in terms of value of shipments. Of the $6.9 billion in meat-related shipments, about $6.5 billion were tied to meat packing.

Table 1. Activity levels of the food processing sector in Nebraska (1982 Data)

Sub-sector	*Number of Firms*	*Number of Employees*	*Value of Shipments in millions of $$$*
Meat	96	15,000	$6,887.2
Grain	121	3,700	1,118.0
Dairy	31	1,400	326.0
Fats and Oils	19	600	411.5
Totals	267	20,700	$8,742.7

Energy Consumption

The energy requirements for production, transportation and processing of food products are substantial. The food processing industry ranks fourth in energy consumption in the United States, behind metals, chemicals and petroleum refining. Estimating the energy consumption used by the various segments of the food industry is complex. Nevertheless, the information is useful in implementing energy conservation programs and in monitoring energy use efficiency.

Tables 2 and *3* summarize the total energy consumed, by energy source and the subsector, respectively, by the food processing sector in Nebraska. Estimated total energy consumption by the food processing sector is 23.6 trillion Btu, or roughly one-fourth the energy used in the production of raw agricultural commodities in the state.

Table 2. Energy sources used by the food processing sector in Nebraska

Energy Source	*Annual Energy Used (Billion Btu)*	*Percentage Used*	*Intensity[a] of Energy Use*
Electricity	4,720	20.0%	500
Petroleum	1,133	4.8	120
Coal	1,180	5.0	125
Natural Gas	16,496	69.9	1,749
LP Gas	71	0.3	8

[a]Btu per dollar of shipment

Meat-packing accounts for roughly 45 percent of all energy use in this sector, reflecting its importance to Nebraska's food processing industry. Other leaders in energy usage include those who process animal fats, and those involved in the milling of soybeans, grain milling, and dairy related products.

It is estimated that about 70 percent of the energy used by this sector in Nebraska is natural gas which fuels boilers, hot water tanks and burners for other direct heat needs. About 20 percent of the energy used is electricity which powers electric motors, refrigeration units and other equipment. The remaining energy sources include coal, petroleum and propane.

Factors that influence the amount of energy used within the food industry are: intensity of plant opera-

Table 3. Annual energy use by the different sub-sectors in Nebraska

Sub-Sector	*Energy Used (Billion Btu)*		*Percentage Used*		*Intensity[a] of Energy Use*	
Meats	10,546		44.7%		1,532	
Meat Packing		9,717		92.14		1,369
Prepared Meats		400		3.79		1,416
Poultry		159		1.51		2,310
Eggs		222		2.11		2,528
Dairy	628		2.7%		1,926	
Cheese		406		64.7		2,323
Fluid Milk		223		35.5		1,631
Milled Grain	2,471		10.5%		2,210	
Flour		400		16.2		2,028
Cereal		512		20.7		2,372
Pet Food		473		19.1		2,294
Prepared Feeds		1,090		44.1		2,201
Fats and Oils	2,962		12.6%		7,203	
Soybeans Mills		1,463		49.4		5,219
Animal		1,494		50.4		16,947
Remaining Sectors	6,993		29.6%			
Totals	23,000		100.00			2,502

[a]Btu per dollar of shipment

tion, type of food processing operation, degree of primary versus downstream processing, plant operation and management practices, plant layout and organization, level of technology and equipment efficiency.

Within the food processing sector there is considerable diversity of activity, ranging from meat slaughtering operations to egg cracking plants to the distillation of vegetable oils from grains. The relative energy use per unit value or pound of product varies with the type of operation. For example, the energy consumption per dollar value of shipments varies greatly between the subsectors within the food processing sector:

Meats	1,532Btu/$
Milled Grain	2,210
Dairy	1,926
Fats & Oils	7,203
Sector Average	2,502 Btu/$

The sector average for energy consumption per dollar value of shipments in Nebraska is very close to that of the most dominant subsector, which is meat products. Even within a particular subsector, various types of activities have varying energy use to value-produced relationships as illustrated below for meat products and fats and oils.

Meat-Packing	1,369 Btu/$
Prepared Meats	1,416
Poultry	2,310
Eggs	2,528
Soybean Processing	5,219
Animal Fats	16,947

Management and operational practices marginally affect energy usage from one plant to the next. Two identically-sized plants with similar processes can have somewhat different energy usage patterns and levels based on simple factors such as housekeeping practices. The design of a new plant, or the layout or organization of an existing plant, can affect the flow of materials and people. For example, if finished commodities have to be moved several times prior to shipment, energy usage levels are higher.

The underlying level of technology present in the plant has a substantial bearing on energy usage relative to per dollar of goods produced. Plants with "state-of-the-art technology" and with energy efficient designs and equipment consume less energy than older plants or plants not retrofitted for energy efficiency.

Energy Conservation

A considerable proportion of the total production cost in food processing is spent on energy used in the manufacturing plant. While energy requirements are directly related to product throughput, potential for energy savings exists in almost all plants. An analysis for a typical meat-packing plant, small to medium in size, processing beef at the rate of 100,000 carcasses a year and employing around 50 people, is discussed here. *Tables 4a* and *4b* list the total consumption and energy used by end-use, respectively, for this meat-packing plant. Direct heat requirements, sanitation and refrigeration represent the major energy end-use areas.

Table 4(a). Annual energy consumption by a typical meat-packing plant

*Energy Source**	*Energy Used (Billion Btu)*	*Percentage Used*
Petroleum	1,000	10.0%
Natural Gas	6,000	60.0
Electricity	1,400	14.0
Coal	1,300	13.0
Other	300	3.0
Totals	10,000	100.0%

*Many plants will not use all these fuels, but may rely on gas for the boiler fuel or coal exclusively. The disaggregation reflects a composite usage of these energy sources by the various plants.

Table 5 summarizes the potential energy savings for this typical smaller-sized meat-packing plant, and *Table 6* describes the necessary procedures to realize these energy savings.

Regular tungsten-halogen incandescent lamps have an efficiency of around 40 lumens/watt, whereas the fluor-

Table 4(b). Annual energy consumption by end-use in a typical meat-packing plant

End-Use	*Energy Used (Million Btu)*		*Percentage Used*	
Boiler	7,600		76.0%	
Losses		1,980		19.8
Food Processing		910		9.1
Hot Water		1,900		19.0
Boiler Feed Water Heat		1,140		11.4
Rendering		1,900		19.0
Electricity	1,400		14.0%	
Direct Heat for Processing		310		3.1
Refrigeration		510		5.1
Air Conditioning		60		0.6
Lighting		200		2.0
Mechanical Rooms		320		3.2
Other	1,000		10.0%	
Space Heating		200		2.0
Processing		800		8.0
Totals	10,000		100.0%	

escent lamps operate at a much higher efficiency of around 70 lumens/watt. Because of their higher efficiency, fluorescent lamps or hi-intensity discharge lamps are recommended.

To avoid having to pay a premium in the form of demand charges for the use of electricity during peak hours, some of the processing operations should be moved to off-peak hours. Installation of demand controllers can help shed loads of less priority, such as fans and water heaters, when a designated peak load is established. Factors such as high efficiency transformers and electrical supply connections of good quality can minimize the amount of electrical energy used.

Strategies for increasing boiler efficiency are aimed at complete combustion of the fuel and minimization of heat losses. Periodic cleaning will ensure that the injection system is working properly without any blockages.

The air to fuel ratio should be checked to ensure complete combustion of the fuel. Preheating combustion air can increase the efficiency of fuel usage. This can be accomplished by recirculating the ceiling air from the boiler room to the combustion chamber. A substantial amount of energy savings can be attained by insulating the boiler. Accessories also are available to minimize radiation losses.

Losses from excessive blow down and from discarded condensate can be recovered with a heat exchanger. Using water softeners to treat feed water, and periodic maintenance of boiler tubes to prevent fouling, will minimize energy losses during operation.

Installation of a heat exchanger in the ammonia refrigerant line, between the compressors and the condensers, will recover the heat from ammonia which can be used to heat water for sanitation and plant use.

Table 5. Potential energy savings in a typical meat-packing plant

Efficiency Measure	*Annual Energy Savings (Million Btu)*	*Percent Saved*
Lighting		
Install New Lighting	66	33.0%
Turn off Unneeded Lights	5	2.5
Boiler		
Boiler Maintenance	675	8.9
Stop Steam Leaks	500	6.6
Insulate Lines, etc.	1,192	15.7
Refrigeration		
Insulate Refrigerator Lines	13	4.2
Hot Boning	168	33.0
Heat Recovery	101	19.9
Hot Water		
Reduce Hot Water Temp	168	8.8
Recover Boiler Heat	477	25.1
Totals	3,365	33.7%

Table 6. General procedures to reduce energy usage in a typical meat-packing plant

Lighting

Replace present lighting with high-efficiency lighting systems.
Adopt adequate lighting levels and turn off unneeded lighting.

Load Management

Prioritize operations during peak hours to avoid excessive demand charges.

Boiler Operation

Do periodic cleaning of burners and injection systems, and optimize air to fuel ratio. Also maintain steam traps.
Repair all steam leaks.
Insulate boiler, all steam lines, condensate return, boiler feed water line, etc.
Recover heat from the boiler blow down steam using a heat exchanger for use in producing hot water for sanitation and processing.
Recirculate the warmer ceiling air using ceiling fans during the heating season.

Refrigeration

Recover waste heat from refrigeration systems at condensers, and use it for generating hot water.
Insulate all refrigeration lines and valves.
Use door curtains in high traffic refrigerated area.
Adopt a hot-boning process which directly reduces refrigeration requirements.

Hot Water

Lower hot water temperature.
Use waste heat from the boiler and refrigeration systems to provide most of the hot water needs for the plant.
Use high pressure low volume pumps to supply hot water.

Energy storage systems, in the form of an insulated storage tank that can hold hot water from the heat recovery systems, also are recommended. This heated water can be pumped later for use in processing or clean-up operations. Insulating the refrigeration rooms and reducing the infiltration losses also can result in substantial energy savings.

Based on a typical plant analysis, approximately *one-third of the energy currently used in small to medium-size plants could be saved.* If these savings potentials are applicable to the entire meat industry, over four trillion Btu could be saved with energy efficiency measures. Primary savings center on boiler efficiency, electric motors, lighting systems, refrigeration units and hot water usage.

An economic analysis of such an energy management program is shown in *Table 7. Table 7a* outlines the capital investment associated with the prescribed energy efficiency measures, and *Table 7b* shows the life cycle cost analysis for these measures. For meat packing, capital investment opportunities with simple paybacks of five or less years range from a low estimate of around $12 million (only smaller to medium-size plants are retrofitted) to a high estimate of over $70 million (where all plants are retrofitted). With this investment range, energy dollar savings to the meat packing industry alone could run $5 to $30 million annually at current prices.

Similar measures also can be adopted for other food processing industries. *Tables 8* and *9* show an analysis for a small to medium fluid milk processing plant in Nebraska, processing about 60 million pounds of milk annually.

An energy efficiency analysis for a cheese production plant, small to medium in size and producing 3.5 million pounds of cheese, is shown in *Tables 10* and *11.* A substantial amount of energy can be recovered from the whey drying process by using heat recovery systems. Use of membranes for preconcentrating the whey before it is sent to the dryer will not only be more energy efficient, but also will result in the reduction of whey disposal costs.

Table 7(a). Capital investment requirements

Efficiency Measure	*Typical Investment for a Plant*	*Aggregate Investment[a] for the Subsector (Million $$$)*
Lighting	$3,400	$1.0- 3.4
Boiler	19,600	5.9-19.7
Refrigeration	15,600	4.8-47.7
Hot Water	700	0.2- 0.7
Totals	$39,650	$11.9-71.5

[a]The lower range investment estimate is based on only retrofitting the smaller and medium size plants. The upper range estimate assumes that there is potential to retrofit the larger plants as well.

Table 7(b). Life cycle cost analysis for a typical plant

Efficiency Measure	*Annual Savings*	*Investment*	*Payback (years)*
Lighting			
Retrofit	$ 1,188	$ 3,400	2.9 years
Operation	90	0	Immediate
Boiler			
Maintenance	1,755	0	Immediate
Steam Leaks	1,300	650	0.4
Insulation	3,099	13,000	4.2
Heat Recovery	1,240	6,000	4.8
Refrigeration			
Heat Recovery	2,301	15,000	6.5
Insulate	234	900	3.8
Hot Boning	2,484	0	Immediate
Hot Water			
Reduce Temperature	1,212	700	0.6
Aggregates	$15,600	$39,650	2.5

Table 8(a). Annual energy consumption by a typical fluid milk processing plant

Energy Source	*Energy Used (Million Btu)*	*Percent Used*
Petroleum	454	10.8%
Natural Gas	1,369	32.6
Electricity	2,302	54.8
Other	71	1.7
Totals	4,200	100.0%

Table 8(b). Annual energy consumption by end-use in a typical fluid milk processing plant

End-Use	*Energy Used (Million Btu)*		*Percent Used*	
Boiler	1,806		43.0%	
Pasteurization		53		12.7%
Hot Water for Cleaning		475		11.3
Boiler Losses		790		18.8
Electricity	2,302		54.8%	
Refrigeration		1,940		46.2
Homogenization/ Separation		181		4.3
Packing		84		2.0
Lighting		92		2.2
Space Heating	71		1.7%	
Totals	4,200			100.0%

Table 9. Potential energy savings in a typical fluid milk processing plant

Efficiency Measure	*Annual Energy Savings (Million Btu)*	*Percent Saved*
Boiler		
Maintenance	225	12.5%
Plug Steam Leaks	167	9.2
Insulate Lines, etc.	397	21.9
Heat Recovery	159	8.8
Lighting	22	23.9
Refrigeration Insulation	150	7.7
Totals	1,120	26.7%

Table 10(a). Annual energy consumption by a typical cheese production plant

Energy Source	*Energy Used (Million Btu)*	*Percent Used*
Petroleum	576	18.0%
Natural Gas	2,175	68.0
Electricity	256	8.0
Coal	96	3.0
Other	96	3.0
Totals	3,199	100.0%

Table 10(b). Annual energy consumption by end-use in a typical cheese production plant.

End-Use	*Energy Used*		*Percent Used (Million Btu)*	
Boiler	2,015		63.0%	
Losses		867		27.1%
Space Heating		96		3.0
Processing		749		23.4
Hot Water		304		9.5
Electricity	224		7.0	
Processing		96		3.5
Refrigeration		45		1.4
Lighting & Mechanical Rooms		67		2.1
Whey Drying	960		30.0	
Totals	3,199		100.0%	

Table 11. Potential energy savings in a typical cheese production plant

Efficiency Measure	*Annual Energy Savings (Million Btu)*	*Percent Saved*
Boiler		
Insulate the Evaporator	80	4.0%
Maintenance on the Boiler	225	11.2
Plug Steam Leaks	167	8.3
Insulate Lines, Boilers, etc.	397	19.7
Heat Recovery for Hot Water	159	7.9
Lighting	22	32.8
Whey Drying Efficiencies	336	35.0
Totals	1,386	43.3%

Summary

Food processing is Nebraska's single largest manufacturing industry, accounting for almost one half of the value of all manufactured output, and consuming over 23 trillion Btu of energy. Meat processing, milled grain, dairy, and fat and oil products are the four important food processing sectors in the state, and account for 70 percent of this energy usage.

Nebraska's meat packing industry is composed of a few large packing plants, many medium size packing plants, and a large number of smaller meat packing and processing plants. Estimating the sector-wide savings potential is difficult since limited information exists on the energy efficiency of the very large packers. Assuming that the typical plant analysis discussed is representative, it is estimated that around 4,000 billion Btu of energy can be saved in this subsector through the implementation of suggested efficiency measures.

Assuming that the savings identified for the typical plant could be realized in all of the fluid milk processing plants in Nebraska, out of the 223 billion Btu used in total subsector energy consumption for milk processing, nearly 60 billion Btu could be saved through cost effective, energy efficient measures. Similarly, the total energy savings in the cheese production industry could reach 150 billion Btu. Up to 40 percent of the total energy used currently could be saved using simple energy conservation measures.