Most food consumed in the United States is processed. Food is processed to extend its edible shelf life, make it more convenient to prepare, make foods edible that are otherwise unpalatable, produce new food forms, and create ingredients for use in further food processing. To accomplish these tasks, food processors rely heavily on energy in the form of heat and mechanization.

Major energy used in the food processing industry comes from fossil fuels. The goal of this chapter is to take up current and future energy use in food and fiber processing, marketing, and distribution. The discussion will include an energy-accounting method that is an essential component of energy conservation technologies.

In the last few decades the food industry has grown rapidly. All indicators point toward continuing growth in the future. In 1977, the total food marketing bill was $123.5 billion. The food processing sector consumed $35.8 billion or 29 percent of the total. The other major sectors were wholesaling, $18.5 billion; retailing, $32.1 billion; public eating places, $27.2 billion; and transportation, $9.9 billion.

Several socioeconomic factors affect domestic demands for processed foods. Demands for convenience foods and food consumed outside the home continue to increase as more spouses are employed and family size decreases. It is expected the food processing industry will maintain a key role in meeting needs of the U.S. consumer.

Besides domestic needs, worldwide needs for food are expected to continue to grow, as illustrated by Chancellor and Goss (1976). Their study estimated that: a) the world population will increase to between 6.0 and 7.1 billion in the year 2000; and b) world requirements for food calories in the year 2000 will be nearly double those in 1970.

The United States has maintained its leadership in exporting agricultural goods. The agricultural

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The United States is the leader in exporting agricultural goods like this grain being loaded on the Missouri River near Kansas City. To maintain this leadership and meet domestic needs of food, the food processing industry will require a reliable energy source.

Trade showed a positive net balance of payments of about $12 billion for each year from 1974 to 1976. To maintain the export market leadership and meet domestic needs of food, the food processing industry will require a reliable supply of energy.

Several studies have focused on determining energy consumption by the food sector. These findings, summarized by the Federal Energy Administration (1976), provide a perspective of energy use in the U.S. food system.

Of the total U.S. energy consumption, about 2.9 percent was used for farm production, 4.8 percent for food manufacturing (processing), 4.3 percent for in-home food preparation, 2.8 percent for out-of-home preparation, 0.5 percent for wholesale food trade, and 0.8 percent for retail food trade.

These values include direct, indirect, capital and transport costs in energy use.

**Energy Need After Food Is Produced**

Substantial energy is expended after food leaves the farm gate. Only 18 percent of the energy in the food system is spent in food production, with the remaining 82 percent used to process, market, and prepare it for consumption. The largest share of that 82 percent is used by the food processing segment.

A study by Development Planning Research Associates, Inc., reported by Unger (1975), provides comparison of energy use within the leading energy-intensive manufacturing industries.

The food and kindred products industry group (Standard Industrial Classification 20) ranks sixth in terms of gross energy use after primary metals, chemical and allied products, petroleum and coal.
The meat-packing industry uses more than 99 trillion Btu's a year, making it the highest energy-consuming industry in the food and kindred products group.

The food industry, however, relies heavily on the other five industrial groups for goods and services. Within the same group of industries the food and kindred products industry ranks first in terms of total employment, value added, and the total value of shipments.

Of the 14 leading energy-consuming food and kindred products industries, meat-packing ranks as the highest energy consumer. Because of their volume, the meat-packing, prepared animal feeds, and fluid milk industries are the leading energy consumers.

Ranking based on energy used per dollar value of shipment indicates beet-sugar processing to be the most energy-intensive followed by wet-corn milling.

Cost of energy use in the food system is low in terms of per unit product cost. Doering et al. (1977) presented information on energy cost per unit of final product. Energy embodied in packaging is not included. Based on 1974 costs, the energy cost divided by market cost was less than 10 percent for most common food items. As energy costs rise, the energy cost per unit market cost will also increase.

The type of energy source used in the food sector varies among different segments. The processing industry uses all fuel types, whereas other segments, such as transport or home preparation, are overly dependent on a single source.

Most warehouse and retail establishments rely heavily on electricity for distribution. Considerable energy derived from liquid fuels is used by medium-
size transport vehicles such as route trucks and step vans weighing 8,000 to 14,000 lbs.

**Flexibility With Fuels**

The processing sector has greater flexibility in substituting one fuel source for another. Since a voluntary energy-conservation program was adopted in the food processing industry, these trends have been observed.

For example, the National Food Processors Association reports that the canned fruits and vegetables industry has relied increasingly on fuel oil, moving away from natural gas. The natural gas consumption for this industry decreased from 63 percent of total energy used in 1972 to 50 percent in 1978, while oil use increased from 20 percent of total energy consumption to 35 percent (Department of Energy, 1979).

In the past, energy has been a relatively under-priced resource. Although future energy prices are uncertain and subject to unpredictable political and even military events, energy prices may go higher— even substantially higher.

The supply of some sources of energy may be unreliable, as evidenced in the Midwestern States in the winter of 1976. This problem may be aggravated by political problems in oil-producing nations.

In view of these uncertainties it is important to recognize the need for timeliness of the energy supplies to certain food processing industries. For example, most fruit and vegetable canning plants operate during only 6 to 12 weeks of the year; an energy curtailment during that period would seriously affect the industry.

Short-term stockpiling of coal and fuel oil for processing plants in urban areas poses difficult logistical problems.

The most convenient supply of energy to the processing plant has been clean-burning natural gas brought through pipes. In contrast, shipment and storage of coal or fuel oil at or near the plant location could create serious problems. Plants in urban areas would require considerable expenditure to maintain a reliable energy-handling and delivery system. In addition, the industry will have to address the environmental impact of burning coal to general energy at plant locations.

A voluntary energy conservation program instituted by the Department of Energy (DOE) requires major energy-consuming firms to report on their energy efficiencies. Using 1972 as a base year, the goal for the food and kindred products industry was to improve efficiency by 12 percent by 1980.
In a recent survey of selected food industries (DOE, 1980), it is reported that the food industry improved its energy efficiency by 17 percent by 1978 over 1972 through installing steam traps and automatic controls on heating devices, eliminating excessive lighting, improving boiler efficiency, and other housekeeping measures.

No major effort has been directed towards energy-saving modifications of process equipment.

All major food processing operations have a potential for energy conservation. Equipment used in processing foods was designed during the era of plentiful energy supplies. Previous emphasis on equipment has been on capacity, product quality, and reduced labor requirement. With little or no concern about energy use, most present equipment consumes more energy than necessary.

Improving efficiencies of energy use in process equipment offers considerable challenges. It will be unrealistic to expect the industry to discard current equipment overnight in favor of newly designed energy-efficient equipment. The more practical approach is to modify current equipment and operating procedures.

New energy-saving equipment can be introduced gradually as other equipment becomes obsolete. Unfortunately, reliable data on energy use by processing equipment are not available.

A question often raised is how to initiate an energy-conservation program. Energy accounting is the first step toward any major energy-related improvements in the food industry.

An energy-accounting method useful in developing energy conservation technologies for the food industry was outlined by Singh (1978). The method involves the following steps.

**Decide on Objective.** If the analysis objective is to determine the feasibility of improving the thermal energy use efficiency of a process, only thermal energy sources (such as steam or heated air) need be accounted for. All energy types must be accounted for when determining total energy use of a process or a plant.

**Choose a System Boundary.** Selecting a correct system boundary requires experience and the ability to visualize the process completely. Several attempts may be needed to determine important energy inputs. This is more difficult when analyzing a large system. But selecting a system boundary is relatively simple for an energy analysis of food processing equipment.
**Draw Flow Diagram.** Energy used by different processing equipment during a certain base time can be presented concisely on the flow chart, and energy used in the system per unit product can be calculated.

**Identify Mass, Energy Inputs.** All mass and energy flows (steam, heated air, or electrical energy) that cross the system boundary must be correctly identified.

**Measure Inputs.** If the analysis involves a piece of processing equipment, measurement will involve such items as steam flow, product flow, or electricity. Repeated trials are needed to observe energy-use variation, if any, in relation to time and different product flow rates.

**Identify Outputs.** All energy outputs from the system and product flow across the system boundary must be included in the analysis. Certain forms of energy output may not be obvious in the first trial.

**Measure Outputs.** Measure product flow and energy outputs from the system, including any increase in energy in the product, such as increased product temperature.

Once the information outlined in the above steps is systematically obtained, energy accounting can be carried out easily. The energy-accounting method presented above is a powerful tool to obtain quantitative information on energy use in food processing systems. The method permits determination of the relative importance of different processing operations in terms of their energy use.

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**Substantial Payoff Seen**

The energy-accounting method is useful in finding energy use efficiencies of various equipment. It should be recognized that the method requires installing energy-sensing instruments followed by monitoring and analysis of data. Initially, such costs could be substantial for a large-scale accounting study. However, substantial payoffs are possible.

Using an energy-accounting diagram for canning whole-peeled tomatoes which shows the quantity and type of energy consumed at various locations in a processing plant, Singh *et al.* (1980) identified major energy-intensive unit operations that should be further examined in tomato processing plants.

A similar study conducted on an atmospheric retort used to sterilize canned foods helped develop modifications that showed a 50 percent reduction in energy. Such modifications, with payback periods of about one season, are already being implemented in the canning industry to conserve energy and reduce the impact of increasing energy costs (Griffith *et al.*, 1979).
Comparison of energy costs of different types of processing methods has been a subject of few research studies. The research data are still too meager to draw final conclusions. However, certain trends can be observed.

In canning food products the major area of energy consumption is manufacturing the package, namely the metal can. The energy cost of a can may be as much as 190 percent of the energy used to process the product. Similarly for frozen foods, large amounts of energy are used in retail, wholesale and the home for low-temperature storage — up to 340 percent of energy used to process the food.

Rao (1980) has computed the energy consumption per 2.9 oz. serving of corn kernels from fresh refrigerated, frozen, and canned as 2937, 2541, and 2875 Btu respectively. These values account for energy consumed by various steps after harvest and before in-home preparation. It should be stressed that there is considerable variability in the data used to obtain the above values.

It is expected that as more data become available it will be possible to make better comparisons between different processing modes. In such comparisons, the influence of other factors — such as food quality and rates of processing capacity — cannot be overlooked.

Efficient use of solar energy in food processing has been limited to a few processes such as drying grapes for raisins and drying apricots. Recently, through Federal funding, several feasibility studies have been initiated to examine the use of solar energy.

For example, solar ponds are being investigated for preheating water for a food processing plant in Alabama. During the day, water in six 181' x 16' ponds collect solar energy. The hot water is then pumped to the plant for use in processing. The project is anticipated to supply 7 percent of the plant's total energy requirement.

Solar collectors on the roof of a cannery in Sacramento, Calif., have been used for heating water to 198° F. The hot water is used in can-washing lines.

A food dehydration plant in Gilroy, Calif., is drying onions and garlic by air heated with solar collectors. Water heated to 200° F in the collectors is pumped through a heat exchanger to heat air for use in the driers. The project is designed for dehydrating 250 million pounds of onions and garlic annually.
Due to the high cost of solar collectors and their poor efficiencies, the payback periods for such installations are currently not attractive. As the cost of collectors becomes more reasonable and as costs of conventional energy sources increase, more use of solar energy is expected.

Use of geothermal energy in food processing is obviously limited by geographical locations. A plant in Ontario, Oreg., is investigating the use of geothermal energy to supply energy to blanchers and peelers for processing potatoes.

Certain food processors are re-examining plant wastes that were earlier discarded. Biomass wastes such as walnut shells, rice hulls, almond hulls, peach and cherry pits contain large amounts of energy. If properly harnessed, the wastes can be used as an energy source for the processing plants.

A canning plant in Modesto, Calif., is burning peach pits in the boilers to generate steam. The company expects fuel savings of approximately $190,000 per year.

Cogeneration is also being seriously considered by processing plants. Since many plants use both electricity and low pressure steam, the cogeneration principle allows much better efficiencies in energy generation.

Alternate technologies are expected to gain considerable importance in coming years as energy costs rise. Payback periods for adapting several of these technologies will decrease with increasing costs of fossil-fuel based energy sources.

Processing of Fibers

In the recent past there has been considerable interest in examining energy use in processing agricultural fibers such as cotton and its comparison with synthetic fibers.

For cotton, the major operations after harvest are ginning, processing or weaving followed by dyeing or finishing. According to Winkle et al. (1978), 100 pounds of baled cotton lint require 29 kWh of energy. For manufacturing cloth the energy requirements are estimated to be 6.5 kWh/square yard, while shirt manufacture consumes another 1 kWh/square yard.

The analysis of Winkle et al. (1978) shows that in order to manufacture cotton shirts the energy requirement is less than the energy required for polyester/cotton blends. However, when energy consumption is compared on the basis of lifetime use — thus accounting for washing, drying and ironing — the energy requirement for polyester/cotton blends is more favorable than for 100 percent cotton.
Considering production, processing and lifetime use, energy-intensive maintenance of a cotton shirt is 115.5 kWh compared to 72.4 kWh for the 65/35, polyester/cotton blend.

This analysis clearly shows the importance of careful system analysis when energy use is examined. Certain products or processes may appear very frugal in their energy use when considered alone. However, the overall system may yield surprisingly different results.

**Summing Up**

The time for energy conservation and use of alternate energy technologies has arrived. The food processing industry has a considerable potential in realizing large energy savings through modifications of equipment and processes. As discussed in this chapter, the industry has already become more energy conscientious.

Judicious use of energy should help a processing plant in maintaining a competitive edge over others, in addition to keeping the price of food from increasing due to costly energy.

**Further Reading:**


Energy Utilization in the Leading Energy Consuming Food Processing Industries, S. G. Unger, 1975, Food Technology, December, p. 34.

External Heat Exchangers on Retorts Save TVG $59,000/Yr., H. E. Griffith, A. Malvick and K. Robe, 1979, Food Processing, May, p. 156.