The Food Processing Industry at a Glance

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ABSTRACT

The food processing industry is the fourth largest consumer of energy in the U.S. industrial sector. Food processors use nearly 1,200 trillion Btu of energy per year (DOE/EIA 1994). The industry is composed of more than 21,000 processing plants (DOC 1997). Together they comprise a $400 billion industry (Food Engineering 1999). While energy represents on average between 1 and 2 percent of total operating costs, in some industry sub-sectors energy makes up as much as 20 percent. Major energy end uses include drying, refrigeration, process heating and cooling, and machine drives.

In the spring of 2000, E SOURCE documented a variety of energy end uses in the industry, surveyed 148 plant managers by telephone and conducted in-depth interviews with 8 corporate energy managers (Adams et. al. 2000). We asked the plant managers to respond to a variety of questions on topics such as decision-making, plant energy use, electricity and deregulation, natural gas use, energy services and outsourcing, energy efficiency, and plans for plant renovations and new construction. In our interviews with the corporate energy managers, we explored their current strategies for purchasing energy and energy services and asked them what they expect to do in the future.

This paper provides some of the key findings from this report, including an overview of industry challenges, key energy end uses and innovations, and valuable insights from energy managers on the energy issues that food processors face.

Introduction

Today's food processors are under the gun to produce cleaner, more convenient, cheaper, and just plain more products for a demanding public. Even as they are driven to incorporate new technologies, they are facing intense competition that forces them to cut costs and increase output. Only processors that can adapt and follow market trends are likely to survive.

Consumers' demands for more convenient and novel packaging and for new products are also driving changes in the manufacturing infrastructure. Production lines will have to become more flexible so that food plants can adapt to fluctuations in product demand. Automation is also likely to become more important as a means of controlling constantly changing manufacturing requirements. As Ken Battista, vice president of business development for the Power Group, has noted, "'Three meals a day with the family' consumption patterns are virtually nonexistent. In the future people are going to eat when they're hungry, not when the clock on the wall tells them to. This means that the methods of delivering the food (packaging) must be more convenient, portable, and consumer friendly"(Adams et. al. 2000).

In an effort to unravel the complexities of this industry and its energy use patterns and efficiency opportunities, E SOURCE surveyed nearly 150 food processing companies and conducted eight in-depth interviews with energy managers. E SOURCE focused its study on six key subsectors: bakery products, meats, dairy, preserved fruits and vegetables, beverages, and grains (Table 1). The interviews were conducted during the spring of 2000, prior to the energy price increases that began at the end of that year, so these results indicate what today may sound like a conservative approach to energy efficiency. Nonetheless, the findings point to an industry that is concerned about energy use and efficiency but is still a hard sell when it comes to actually purchasing energy services or changing production practices.

Table 1. Key Data Describing the Respondents to the E SOURCE Survey

	Number of Respondents	Average Number of Plants per Company	Average Sales Volume ($ millions)	Average Total Number of Plants per Company	Average Number of Employees per Company
Bakery Products	26	25	117	1,457	229
Meats	25	6	44	198	179
Dairy	25	32	29	104	101
Preserved Fruits and Vegetables	25	6	269	1,290	210
Beverages	25	26	178	1,003	208
Grains	22	16	121	414	129
Overall Average		19	140	824	177

How Important Is Energy?

Most of the corporate energy managers E SOURCE spoke with claim that energy costs represented between 1 to 2 percent of operating costs. With a few exceptions in individual subsectors across the industry, energy issues generally don't get as much attention from corporate decision-makers as do production matters. Production equipment always comes first. One energy manager told E SOURCE, "If a plant needs a blow-mold machine to make plastic milk jugs, and I want a generator, the blow-mold will win, even if the return on investment is the same" (Adams et. al. 2000).

Additionally, food processors and their affinity groups are coping with so many pressing industry issues that even larger energy issues like restructuring aren't likely to be addressed. Regulatory matters like waste disposal, genetically modified organisms (GMOs), and product sanitation, as well as industry trends including mergers and acquisitions and the need to serve niche food markets, are more than enough to distract most food processors from energy concerns.

Despite these factors, E SOURCE's survey of food plant managers found that more than half of the companies plan to renovate or add new plants over the next two years. Although more companies are planning renovations than new construction, 18 percent indicate that they intend to add plants. On a regional basis, more companies in the Northeast are likely to renovate plants. However, the Midwestern companies that intend to renovate are actually planning to upgrade a higher number of plants than companies in other regions. More companies in the Midwest and West are expecting to undertake new construction (Adams et. al. 2000).

Energy Use And Spending

Electricity is the predominant source of energy. It makes up 58 percent of the energy used by food processors. Natural gas accounts for 32 percent. The remaining 10 percent is spent on such alternatives as diesel and fuel oil (DOE/EIA1994). The high reliance on electricity is due in part to the widespread use of refrigeration in many of the subsectors. Only Grains and Beet Sugar Refining do not require some type of cooling to ensure that products are properly preserved.

Looking at energy expenditures on a per plant basis, Fats and Oils manufacturers have the highest energy expenditures (Figure 1). When looking at the subsectors as a whole, Grains turns out to have the highest total energy expenditures at $1.1 billion. With respect to other operating expenses, the Meats subsector takes first place for labor costs ($11.1 billion) and for cost of materials excluding energy ($77.8 billion) (DOE/EIA1994). The total annual energy bill for the food processing subsectors covered in this study amounts to almost $5.3 billion (Adams et. al. 2000). Looking at expenditures on a regional basis, Midwestern plants of all sizes annually spend around $1.7 billion on energy—quite a bit more than the other regions. Western and Southern plants (which both spend around $1.3 billion on energy) qualify for second and third place (Adams et. al. 2000).

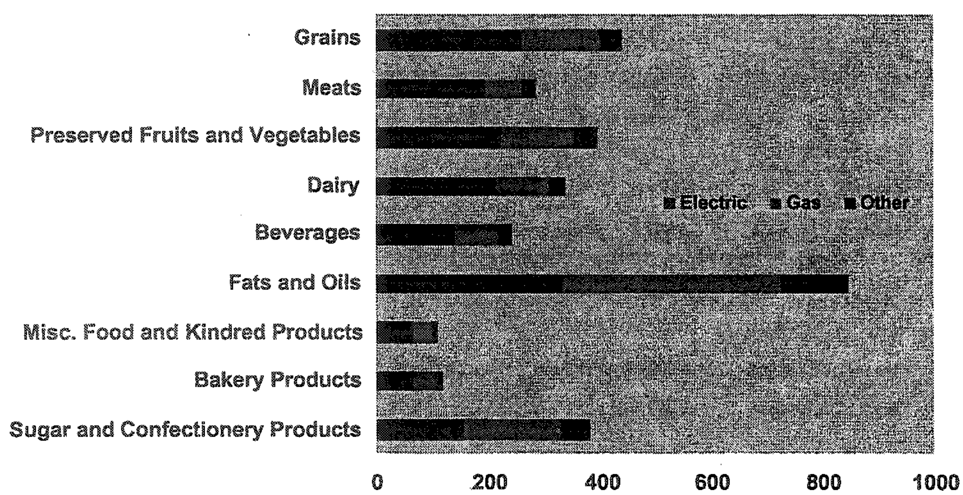

Figure 1. Energy Expenditures Per Plant Among Food Processing Subsectors (in thousands of dollars)

Energy End-Use Technologies

Although the processes used in the food industry are unique to each product, there are some basic functions that are common to many processes. They include heating and drying, cooling and refrigeration, and mechanical processes (for squeezing, extruding, pressing, mixing, and separating) (Adams et. al. 2000). These processes are continually becoming more automated and more efficient.

Today, new product lines are constantly being introduced—especially in the snack and convenience foods industries—and those changes often require new processes. Despite the pressures to innovate, because energy-using equipment is so closely tied to production and product quality, the food industry is relatively slow to implement new processes or energy efficiency measures, for fear that product quality may be compromised (Adams et. al. 2000).

Fortunately, advances in metallurgy, the availability of better construction materials, and new manufacturing methods have contributed to significant improvements in the design and quality of process equipment. Better equipment has helped create more consistent quality and reduced contamination and spoilage, and it has resulted in less downtime for maintenance while extending equipment life (Adams et. al. 2000). For the basic processes described here, the yield refers to amount of final product per unit of raw materials used, and the throughput is defined as total amount of final product per unit of time.

Heating and Drying

In the food industry, heating and drying techniques vary depending on the process, the ingredients, and the desired final product. But no matter what approach is used, it probably falls into one of two general categories: direct heating and drying (applying heat directly to a product) or indirect heating and drying (applying heat to a medium that then transfers heat to the product) (Adams et. al. 2000). Heat transfer media include water for boiling and oil for frying.

Heat is used for warming or cooking food products, cleaning, and sterilizing tanks and process equipment. It may also be used in evaporators; pasteurizers; reaction vessels; and for cooking, blanching, proofing, and drying food products. In fact, up to 10 percent of the total energy consumed by this sector is used for drying (Adams et. a.l. 2000).

The choice of technology for drying is driven more by concerns about product quality and safety of operations than by energy savings potential. If a specific color and texture are desired, food processors will usually sacrifice yield or product throughput. Common technologies range from water immersion and steam heating to forced-air gas or electric heating and drying and microwave ovens (Adams et. al. 2000).

An example of an innovative heating and drying technology is low-inertia heaters utilizing flat radiant panels. The low-inertia heaters replace the furnace refractory lining with flat radiant panels, isolating the combustion products from the protective gas atmosphere while increasing the radiating surface area. This approach provides uniform temperature and a larger radiating surface, improving product quality. The radiant panel's self-recuperating feature cools the burner surface and increases thermal efficiency to better than 70 percent, compared with about 30 percent for conventional ovens (Adams et. al. 2000).

Cooling and Refrigeration

Preserved Fruits and Vegetables, Meats and Dairy are the most refrigeration-intensive subsectors of the ones we looked at. Only Grains and Beet Sugar Refining do not require some type of cooling to ensure that products are properly preserved. Two types of refrigeration systems are commonly used in the food processing industry: absorption systems and vapor-compression systems. Absorption refrigeration is generally more expensive than vapor compression refrigeration unless there is a cheap source of heat, like a cogeneration system. The trick with absorption refrigeration is the affinity between two compounds, such as ammonia and water, such that the refrigerant "dissolves" into the absorbent (Adams et. al. 2000).

Gas-driven refrigeration is a new approach to cooling. According to *Gas Technology*, about 3.8 million horsepower (hp) of refrigeration equipment is installed in U.S. food processing and cold storage warehouses. Vapor-compression refrigeration systems driven by electric motors can represent a significant portion of a beverage processor's electrical load. And it's a load that tends to peak during the daytime and in the summer, when electricity costs and demand charges are highest. Because gas has usually been less expensive than electricity during these peak hours, using a gas-powered engine to drive refrigeration systems can reduce energy costs. A facility might gain more efficiency by combining a gas engine with a heat recovery system. The recovered heat from the gas engine can be used to produce hot water up to 225° Fahrenheit (F) or low-pressure steam at 15 pounds per square inch gauge (psig). Gas engines operating at variable speeds can also provide higher partial-load efficiencies than electric motors (Gas Technology 1999). Combined with absorption cooling, energy savings can increase by an additional 25 percent to enhance energy savings by more than 75 percent (Martin et. al. 2000).

Thermal storage is not a new approach but one that may be on the rise due to high peak demand costs. Thermal storage uses ice, made during nonpeak hours, to keep food cold during times of peak energy demand. Food processing companies interested in taking advantage of utility load management programs that allow companies to sell energy back to the grid at near wholesale prices may be particularly interested in thermal storage (Martin et. al. 2000).

Boilers

The boilers used in the food processing industry are smaller than conventional industrial and utility boilers (Adams et. al. 2000). Although different types of boilers that run on a variety of fuels are used to produce steam at food processing plants, natural gas is the primary fuel, with fuel oil as a backup. Electric boilers and electric hot water heaters are far less common in this industry. Boilers are the largest energy users in the food processing industry (DOE/EIA 1994).

Boilers and hot water heaters are used for process functions and for indirect heating and cleaning. Many food processes require ingredients to be mixed with water at above ambient temperatures. For example, hot water is used in the milling of corn starch, in the cooking and canning of fruits and vegetables, in malt brewing, and in baking processes. Steam from boilers is used for sterilization as well as for pasteurization of dairy products and fruit juices. It may also be used to flush or clean products or machinery to eliminate food pathogens and bacteria (Adams et. al. 2000).

Machine Drives and Product-Handling Equipment

Machine drives are used in mechanical work—such as cutting, grinding, chopping, extracting, and centrifuging—and for moving raw and packaged food through the process lines. Machine drives are also used for the complex operations involved in bottling, canning, and other types of packaging; for fitting, closing, and sealing; and for preparation for storage or shipping. The primary source of energy for machine drives is electricity. Adjustable- or variable-speed motors have become very popular for machine drives in the food processing industry (Adams et. al. 2000). An adjustable-speed drive (ASD) makes it possible to vary the operating speed of an induction motor by providing power to the motor at varying frequencies (Howe et. al. 1999). This flexibility allows food processors to control a production line based on just-in-time raw materials inventories or on demand for finished product. They can also make adjustments for assembly-line bottlenecks without shutting down the entire process (Adams et. al. 2000).

Lighting

Food plants tend to be very concerned about lighting—more so than many other types of manufacturing plants. That's because some foods can age faster when exposed to light. For example, a dairy product like milk will lose essential vitamins if exposed to direct light. In some processes, infrared lights are used because they don't interfere with product quality.

The heat that lighting generates is also a concern in the food processing industry. Refrigerated rooms where food is stored have a minimal amount of lighting to reduce the cooling load and keep energy costs down. For example, most meat processing is done at 45° to 55°F, so targeted illumination is used in the work areas to minimize the cooling load. The need to avoid waste heat from lighting in refrigerated areas creates an opportunity for high-efficiency lighting. Another option might be remote-source lighting, in which the light source (and its waste heat) is located outside the refrigerated space and light is distributed to the space via fiber optics, light tubes, or other means. Some forms of lighting may also provide sanitation benefits. For example, ultraviolet lighting is used in processing areas to minimize bacterial growth and to eliminate surface pathogens on food products prior to packaging (Adams et. al. 2000).

Heating, Ventilation, and Air Conditioning Equipment

In the food industry, HVAC is process- and product-specific. Typical requirements for HVAC are governed by the U.S. Occupational Safety and Health Agency's (OSHA's) requirements for air quality and for the safety of process line workers. These systems are closely tied to the temperature at which the food processing must be carried out. For example, in meat processing plants, the air temperature is kept close to 40°F to minimize aging and prevent spoilage (Adams et. al. 2000).

What We Heard From Energy Managers About Energy Efficiency And Supply Opportunities

Although the E SOURCE study didn't investigate companies' willingness to trade off one set of benefits or services for another, the following presents some insights gleaned from the study into the energy needs and management strategies of food processing companies:

- Energy equipment maintenance and repair are high on the list of managers' energy service needs across all the subsectors we investigated.
- The Preserved Fruits and Vegetables and the Dairy subsectors show the most interest in outsourcing energy services.
- The Meats subsector shows the greatest concern for power quality and reliability.
- The Preserved Fruits and Vegetables subsector shows the highest percentage of interest (40 percent) in cogeneration or on-site generation.
- Around 44 percent of Dairy subsector respondents believe that it is very important to be viewed as an energy efficient company.
- Across all the subsectors, lighting systems and packaging equipment are the most popular targets for upgrades and replacements. Refrigeration equipment and machine drives took second and third place.

When asked about the barriers to energy efficiency, across all subsectors, around 28 percent of the respondents whose companies had not implemented energy efficiency programs in the past year identified capital expense as the biggest roadblock to making improvements. Because of the intensity of energy consumption in corn processing, energy equipment purchases claim a higher place on the decision-makers' radar screens at those plants.

When asked about the greatest opportunities for energy efficiency improvements, the highest priority by far (about 53 percent) is cooling and refrigeration equipment (Figure 2). Equipment for heating and drying, machine drives, and lighting systems are clustered in second place (at around 35 percent).

Cogeneration and On-Sight Generation Opportunities

In our survey of food processors for this study, cogeneration and on-site generation services drew the second highest overall interest among a range of energy services. About 10 percent of the plant managers say they are "very interested" in cogeneration and on-site generation. (Turnkey equipment services took first place with 11 percent.) In a separate E SOURCE survey conducted in the first quarter of 1999, food processors indicated an 18 percent overall interest in purchasing backup generators (Adams et. al. 2000).

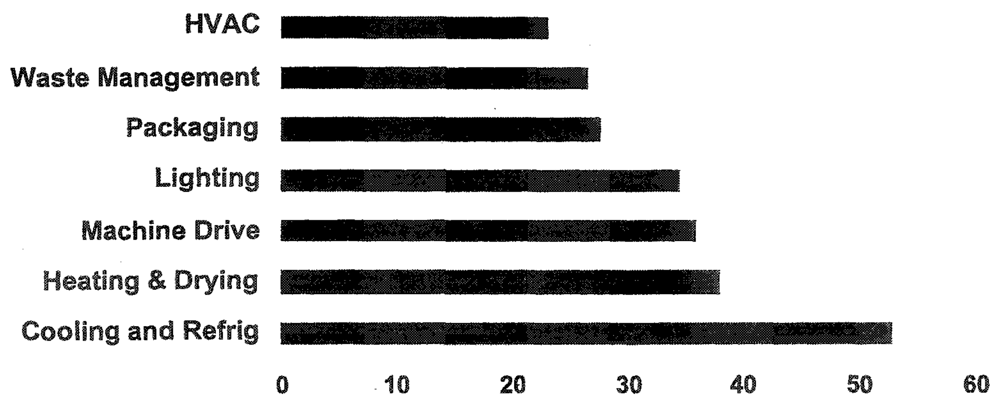

Figure 2. Greatest Opportunity for Energy Efficiency (percent agreeing)

E SOURCE found the most interest in such services among plant managers in the Preserved Fruits and Vegetables (40 percent) and Beverages (36 percent) subsectors. Corn refineries and breweries, that use high amounts steam, have the greatest opportunities for cogeneration. More than 75 percent of the plant managers we spoke with do not now have on-site electricity generators or other backup power equipment at their plants. Among the 29 plants that do have some type of power generation or backup capabilities, the most common type of equipment is a diesel generator (Adams et. al. 2000).

Concerns About Voltage Fluctuations and Power Outages

Around 35 percent of facility managers in the Bakery Products subsector and 28 percent of managers in the Dairy subsector say that power quality problems like voltage fluctuations constitute a serious challenge for their businesses. Looking at responses on a regional basis, we find that plant managers in the West and Northeast are most likely to view these kinds of power quality issues as a serious concern.

With respect to more disruptive power quality issues such as outages, plant managers in the Dairy, Bakery Products, and Beverage subsectors are more likely than their counterparts in other food sectors to express serious concern. Regionally, plant managers in the West and Northeast cite power outages as a serious problem. Overall, more than one-third of the respondents said that power outages are not a serious problem for their plants (Adams et. al. 2000).

In the Words of the Plant Manager

As energy supply issues become more prevalent, E SOURCE expects that power outages will move more to the forefront of energy managers' concerns. Here are some excerpts from one-on-one interviews conducted for the E SOURCE Multi-Client Study "Reliability in the Emerging Electricity Marketplace: The End-User Perspective" that describe what food processors face when there is a power outage (LeBlanc et. al 1999)).

Potato starch modification plant manager. A reliable, high-quality electrical power supply is critical to our operations, and I expect 100 percent reliability. A typical outage is about 2 seconds in length, but no level of outage is acceptable, because it costs money (in downtime and lost product) and makes us lose customers. Agitators constitute our primary equipment. If an outage of 1 second or more occurs, the 15 motor starters on the agitators stop, and the starch turns to concrete. If the outage is only momentary, we have to quickly restart each of the motors when power is restored to prevent this from happening. If the outage lasts for more than 1 minute, we turn on gasoline engines that are hooked up directly to the agitators.

Our flash dryer is also very dependent upon reliable power. Even with an outage of only 2 seconds, everything in the dryer plugs up. All the product that was in it is wasted, and it takes about 1 hour to clean the dryer. The other main problem caused by an outage is a safety issue. We have emergency lighting, but it goes off as soon as the power is restored. Because all our lighting is mercury halide, it takes about 15 minutes for the lights to come back on. We're a 24-hour-a-day facility, so outages during the nighttime hours cause safety problems during this 15-minute window.

Vegetable processing facility manager. An outage happens instantaneously. Even if the power flickers, the plant is shut down, causing approximately 40 minutes of downtime. The number of outages is minimal, and most are weather-related. Electricity is less reliable than all other services—we have never had to shut down for any other service.

Sausage factory facility manager. Our utility scales back the power to businesses on the weekends, which puts a glitch in the power. We've tried to put isolation transformers on all the important equipment in the plant. This cost us about $100,000, which is a lot of money for us. We justified the expense based upon potential lost production.

Packed frozen foods plant manager. The cost of being down for a day could be astronomical. We don't have any backup power today, and that scares me. I wouldn't accept a slight decrease in reliability for any amount of savings; that might be okay in a home, but not in a business.

Conclusions

The food processing industry is extremely diverse. Average energy expenditures on a per plant basis range from $830,000 annually for fats and oils manufacturers to $300,000 annually for meat processing plants. Although energy represents on average between 1 and 2 percent of total operating costs, in some industry subsectors, such as Grains, energy can make up as much as 20 percent. Food processing companies face a broad array of energy efficiency opportunities. Innovative technologies and approaches are emerging that can significantly reduce energy use and enhance production.

The E SOURCE survey of energy managers revealed that companies do plan to renovate or add new plants over the next two years, which will increase the opportunities for deploying new approaches and technologies. The study shows that cooling and refrigeration represent the greatest opportunities for energy efficiency, followed by heating and drying, machine drives, and lighting. Power quality problems are a significant issue for this industry.

Peak demand shortages during the summer months of 2001 could drive more companies to consider on-site generation and peak-shaving strategies such as thermal cooling.

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