POTENTIAL FOR ENERGY, PEAK DEMAND, AND WATER SAVINGS IN CALIFORNIA TOMATO PROCESSING FACILITIES

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ABSTRACT

Tomato processing is a major component of California's food industry. Tomato processing is extremely energy intensive, with the processing season coinciding with the local electrical utility peak period. Significant savings are possible in the electrical energy, peak demand, natural gas consumption, and water consumption of facilities.

The electrical and natural gas energy usage and efficiency measures will be presented for a sample of California tomato plants. A typical end-use distribution of electrical energy in these plants will be shown. Results from potential electrical efficiency, demand response, and natural gas efficiency measures that have applications in tomato processing facilities will be presented. Additionally, water conservation measures and the associated savings will be presented.

It is shown that an estimated electrical energy savings of 12.5%, electrical demand reduction of 17.2%, natural gas savings of 6.0%, and a fresh water usage reduction of 15.6% are achievable on a facility-wide basis.

INTRODUCTION

According to the University of California Vegetable Research & Information Center, canned tomatoes processed in California comprise over 90% of the total tomato consumption of the United States and approximately 35% of the total tomato consumption of the world (7). In 2011, the amount of California processed tomatoes was approximately 12 million tons, with the main areas of cropland focused in Fresno, Yolo, and Kings County (14). While farm prices for processed tomatoes are fairly stable when compared to other agricultural commodities, processers carry much more risk and price volatility (1).

For tomato processors, energy costs comprise approximately 6% of a facility's total expenses (15). Thus, energy efficiency is a critical component in maintaining a tomato processor's profitability in the global market. BASE Energy, Inc. has performed detailed energy audits, calculation assistance, and wastewater treatment assessments at several major California tomato processing plants. The Industrial Assessment Center (IAC) at San Francisco State University has also performed detailed energy audits at a few California tomato processing plants. Together, this represents over 30% of all the tomato processors in California, forming a strong basis for energy savings and water conservation potential. The presented data are mainly based on the results of the facility-wide audits.

PROCESS

Tomato processing occurs from late July to early October, with most processing seasons lasting between 90 and 100 days (approximately 2,300 hours per year). The most common end forms of processed tomatoes are paste and diced tomatoes, although purée and whole tomatoes are also processed. Other major materials used in this process include packaging containers and fresh water. Figure 1 shows a typical tomato process from raw material receiving until final product storage. Please note that this is considered "in-container processing", while "aseptic processing" has the cooking, sterilization, and cooling stages prior to packaging (12).

<u>Bulk Dump (*All Tomatoes*)</u>

Tomatoes are trucked in from the fields to the facility. Samples from the trucks are inspected based on their quality and aesthetic appeal prior to dumping. A typical plant will receive approximately 400 trucks per day during the season. The highest quality tomatoes are designated to become whole or diced tomatoes, while the remaining tomatoes are designated for the paste and purée lines.

The raw tomatoes are washed out of the truck trailers into water flumes, which serve two purposes: the flumes will transport the tomatoes to either the peeling area or the crushing area, and they will clean the tomato surfaces of excess debris (stones, insects, vines, etc.). Typically, there will be multiple stages of flumes, with the last stage chlorinated to disinfect the tomato skins.

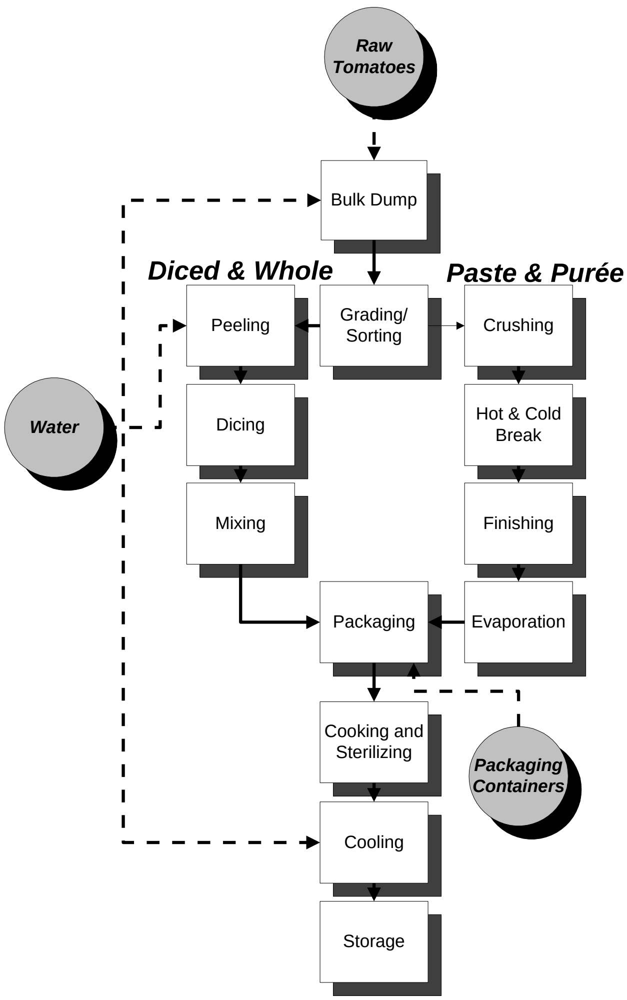

Figure 1 - Typical Tomato Canning Process

<u>Grading/Sorting (*All Tomatoes*)</u>

Grading and sorting are typically performed differently at each facility. The main goal of sorting is to remove sub-par tomatoes from the diced & whole lines to be sent to the paste & purée lines.

Typical practices include using skilled operators to visibly inspect the tomatoes, pneumatic ejectors with photosensitive sensors to sort the tomatoes based on color, rotary screens to sort the tomatoes based on size, and other types of specialized sorting equipment.

<u>Peeling (*Diced & Whole Tomatoes*)</u>

There are three main methods used for peeling tomatoes: mechanical, chemical, and steam. A fourth method, infrared peeling, is currently in the research and development stages at U.C. Davis.

Mechanical peeling involves either placing a rotating tomato through stationary blades or by letting it tumble across abrasive rollers. This is the least used method, as it will typically involve a significant loss of product (25%, compared to 8-18% with steam) (9).

Chemical peeling involves preheating the tomatoes with injected steam, before a caustic solution (Typically sodium hydroxide, 12 - 18% solution, 185– 212 ^{o}F) (8) strips the skin from the tomatoes, and the tomatoes are rinsed before continuing to the next stage of the process. The finish of the tomatoes is the best with chemical peeling, and this method will typically remove more of the peel when compared to steam (8). The main drawback to chemical peeling is that the caustic solution waste stream is difficult to treat, representing a very high pH solution that needs to be neutralized.

Steam peeling involves feeding the tomatoes into a rotating cage, while low pressure steam (24 – 27 psig) (8) strips the skins from the tomatoes. Steam peeling is the most common type of peeling used by tomato processors in California. With steam peeling, the total tomato yield is typically greater than caustic peeling, but less skin is removed (8).

Infrared peeling is in the research and development stage at University of California, Davis as a part of a grant from the California Public Interest Energy Research (PIER) program (13). Infrared peeling is a non-water and non-chemical process. Natural-gas fuelled infrared heaters heat the skins, a vacuum chamber cracks the skins, and mechanical rollers separate the skins from the rest of the tomato. It has been shown in a laboratory setting that IR heating reduced the product loss by 9% and resulted in a firmer product when compared to chemical peeling (11), and is expected to have lower energy usage when compared to steam peeling (13).

Typically, all peeled tomatoes will be checked for blemishes, discolorations, or poor peeling one more time before being sent to the next stage of the process.

<u>Dicing (*Diced Tomatoes*)</u>

Whole tomatoes will be sent to dicers, which are rotating blades in predetermined arrangements to cut the tomatoes into nearly any sized cubes. The diced tomatoes are sent to shaker tables to remove excess juice before being sent to the mixing and filling lines.

Mixing (*Diced & Whole Tomatoes*)

Diced and whole tomatoes are typically mixed with preservatives, such as citric acid for acidity control and calcium chloride for product firming, prior to being canned.

Crushing (*Paste & Purée*)

Whole tomatoes designated for paste and purée production are sent to crushing machines, which turn the tomatoes into a coarse pulp. The pulp is then sent to either a hot break or a cold break, depending on the desired finished product.

Hot Break & Cold Break (*Paste & Purée*)

Hot breaks and cold breaks deactivate enzymes in the tomatoes, both of which are significant consumers of steam. A hot break will hold the tomato pulp at 210 ^{o}F. This deactivates pectic enzymes, inhibits breakdown of pectin in the product, and results in a thicker, more consistent paste. A cold break will hold the tomato pulp at 150 ^{o}F, which will destroy pectin and result in a thinner, brighter product. After the hot or cold break, the tomato pulp is sent to the finishing lines.

Finishing (*Paste & Purée*)

The finishers essentially act as screens, removing skins, seeds, and pulp from the product. The screen size will determine the end finish of the product, and sizes typically range from 0.25" (very coarse, for thick sauce) to 0.02" (very fine, for soup and juices) (10).

Evaporation (*Paste & Purée*)

Evaporation is used on tomato pastes and purées to increase the percent of sugar content, or percent soluble solids, designated by ^{o}B (degrees Brix). Raw juice will enter the evaporators at 5 – 7 ^{o}B, and leave the evaporators at various paste concentrations. The USDA classifies light concentration as 24 – 28 ^{o}B, medium concentration as 28 – 32 ^{o}B, heavy concentration as 32 – 39.3 ^{o}B, and extra heavy concentration as greater than 39.3 ^{o}B (17). Typically, there will be pre-evaporators for low ^{o}B tomato paste, and thicker pastes will be sent to higher density evaporators. Generally, the evaporators are kept under vacuum (18).

There are three main types of evaporators: Multiple-Effect evaporators, Thermal Vapor Recompression (TVR), and Mechanical Vapor Recompression (MVR).

Multiple-effect evaporators operate by pumping the product in a counter-flow arrangement from input steam through multiple tanks, or effects. Higher pressure steam is input to the final evaporation stage (highest ^{o}B product) and enters each subsequent effect at lower pressures (and lower ^{o}B product). In each effect, product will be recirculated or sent to the next higher density effect. In practice, evaporators will typically be between 2 effects and 5 effects, with the ideal steam economies ranging from one unit of steam evaporating 2 units of water from tomatoes (2-effect) to one unit of steam evaporating 4 units of water (4-effect) (6).

TVR evaporators operate by using a steam ejector to mix the tomato water vapor exiting the evaporator with high-pressure steam from the boilers before reintroducing it into the evaporator. Steam is condensed out of the evaporator itself to maintain a mass balance in the system. The steam economy for a double-effect TVR evaporator is approximately 4 units of water evaporated from the tomatoes for every 1 unit of steam input to the system (6).

MVR evaporators operate by compressing the tomato water vapor exiting the evaporator before recirculating the higher pressure steam back into the evaporator. The compressor can be either steam driven, if the facility has a use for the low pressure steam that would exit the turbine, or electrically driven through a motor. The steam economy for MVR systems can be as high as 20 units of water evaporated from the tomatoes for every one unit of steam into the system (6). MVR provides the most heat recovery from the evaporated tomato vapor, but is also more capital intensive to implement when compared to TVR (18).

Packaging (*All Tomatoes*)

Processed tomatoes are canned or aseptically sealed in other containers to preserve their freshness throughout the year. The cans are typically made of tin, with an enamel lining to protect the can from the acidity of the tomatoes. Other types of packaging include glass and plastic bags or jars. Containers are usually cleaned before packaging by hot water, steam, or blasts of pressurized air (9).

For all tomatoes, mechanical filling lines will volumetrically measure the amount of product into the packaging material to over 90% filled (9), exhaust the air to create a vacuum, and mechanically or thermally seal the package. Whole and diced tomatoes are usually topped with tomato juice or very thin purée prior to the filling/exhausting/sealing unit. In some cases, nitrogen gas is added to the container prior to sealing to displace any oxygen remaining in the container.

Cooking and Sterilizing (*All Tomatoes*)
Packaged tomato products are not stored in refrigerated warehouses. Thus, the U.S. Department of Agriculture requires that the canned products be sterilized to prevent bacterial growth within the cans (16). Cooking and sterilization can occur either before or after the packaging process.

Aseptic in-line sterilization typically occurs before flash cooling. Steam is injected into the line carrying the tomato paste or purée, rapidly raising the temperature and sterilizing the tomatoes. Aseptic sterilization can also be performed through the use of tube-in-tube heat exchangers.

In-container sterilization occurs by submerging the packages into ambient or low-pressure (about 3 psig) steam baths. The exact temperatures and durations of sterilization depend on the product and geometry of the package.

Cooling (*All Tomatoes*)
There are several methods for cooling, depending on the process. Flash cooling systems occur after the evaporation stages, tube-in-tube cooling systems occur after the sterilization stage, and submerged cooling tower water or chilled water systems occur after the packaging stage. Flash cooling systems provide a higher quality product and do not have significant capacity constraints, but tube-in-tube systems provide more reliable sterilization (12).

For flash cooling systems, the product is flash cooled after evaporation by injection into a vacuum chamber. This rapidly lowers the product temperature to approximately 98 ^{o}F – 105 ^{o}F, and slightly increases the solids content of the paste or purée.

Tube-in-tube systems are typically single units which perform the heating/sterilization in earlier tubes, with cooling in the later tubes.

Storage (*All Tomatoes*)
Packaged tomatoes are stored in ambient temperature warehouses, and shipped to various customers throughout the year on request.

ENERGY USAGE
BASE and the Industrial Assessment Center at San Francisco State University have performed integrated energy audits of seven tomato processors in California. Figures 2 through 4 show the level of annual electrical energy consumption, peak electrical demand, and annual natural gas energy consumption for each plant.

As shown in these figures, there is significant variation in the electrical energy consumption between the plants mainly due to the production capacity. However, there is little variability between the electrical energy consumption and peak demand for each plant, which shows that each plant operates at maximum capacity throughout the season. Figure 5 shows that Plants A and B are more natural gas energy intensive, relative to their electrical energy consumption, when compared to the other plants. We suspect that this is mainly due to the use of steam turbines to drive large pumps for the evaporators.

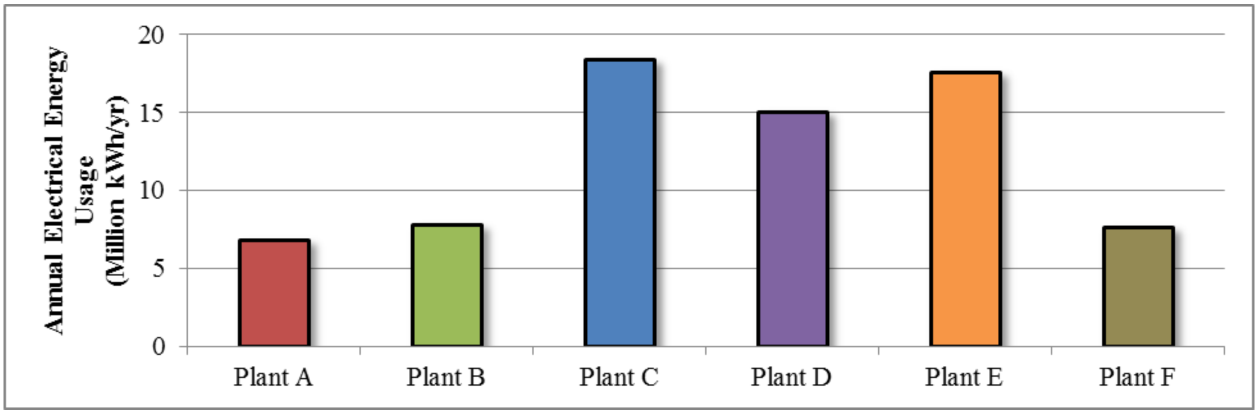

Figure 2 - Annual Electrical Energy Consumption for Various Plants

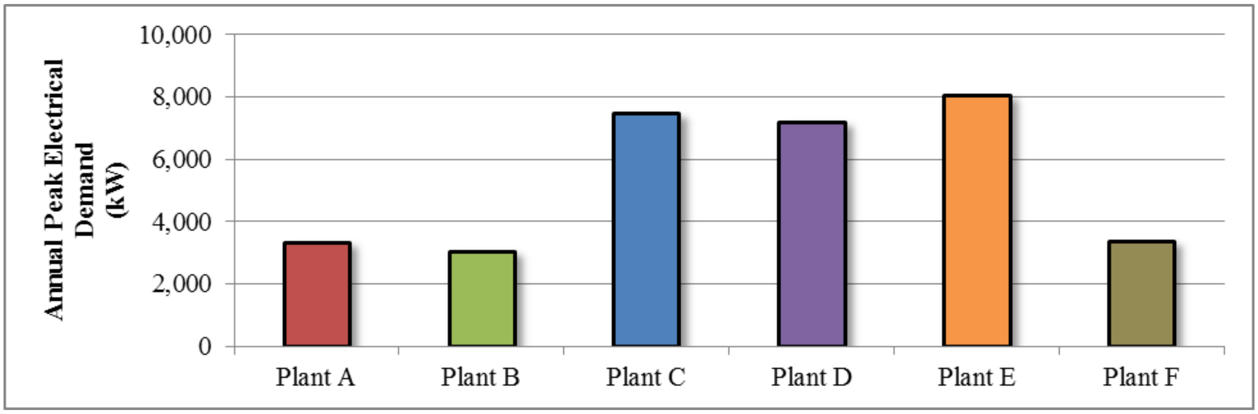

Figure 3 - Peak Electrical Demand for Various Plants

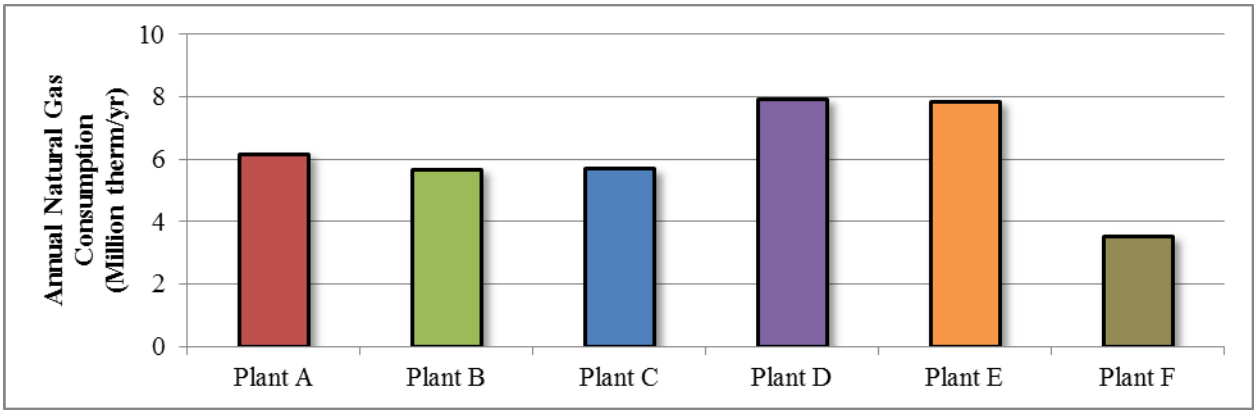

Figure 4 - Annual Natural Gas Consumption for Various Plants

Tomato processors are seasonal in operation, and typically operate over a 90 – 100 day period. Figures 5 through 7 show the monthly profile of electrical energy consumption, peak demand, and natural gas consumption, respectively. These figures show that production begins ramping up at the end of July, operates at full capacity throughout August and September, then finishes production in mid-October. Figure 8 shows a typical electrical demand profile for a week while the processing facility is in season. This figure shows that the electrical demand is nearly constant while the facility is processing tomatoes; the demand varies by only 5%.

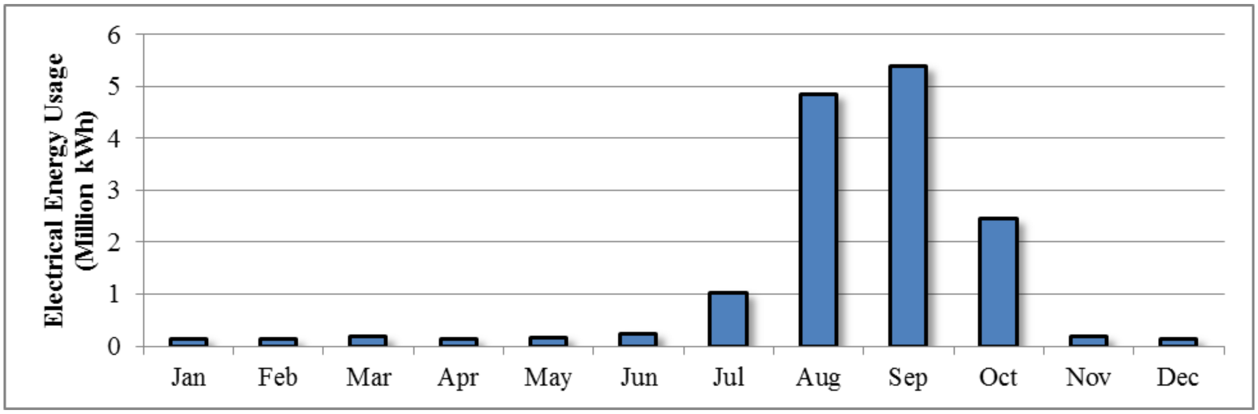

Figure 5 - Monthly Electrical Energy Consumption for a Typical Plant

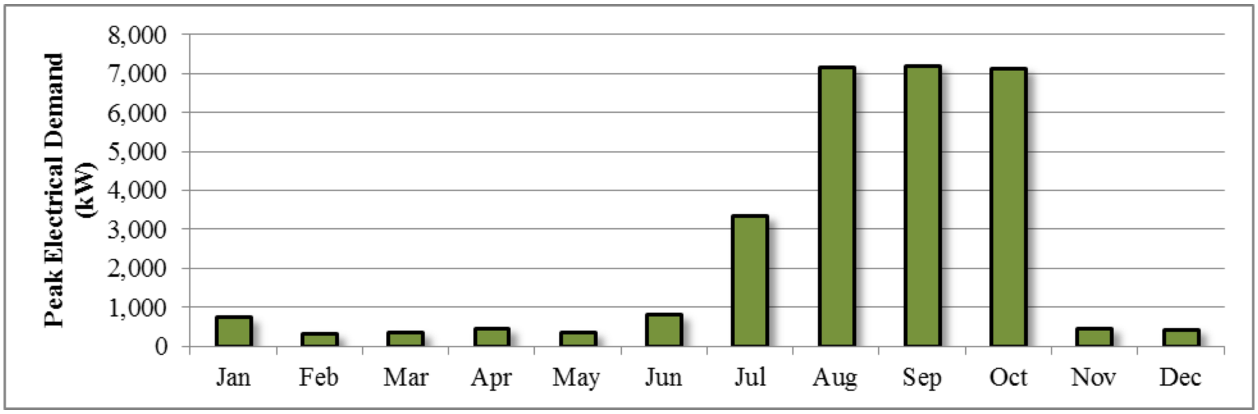

Figure 6 - Monthly Peak Electrical Demand for a Typical Plant

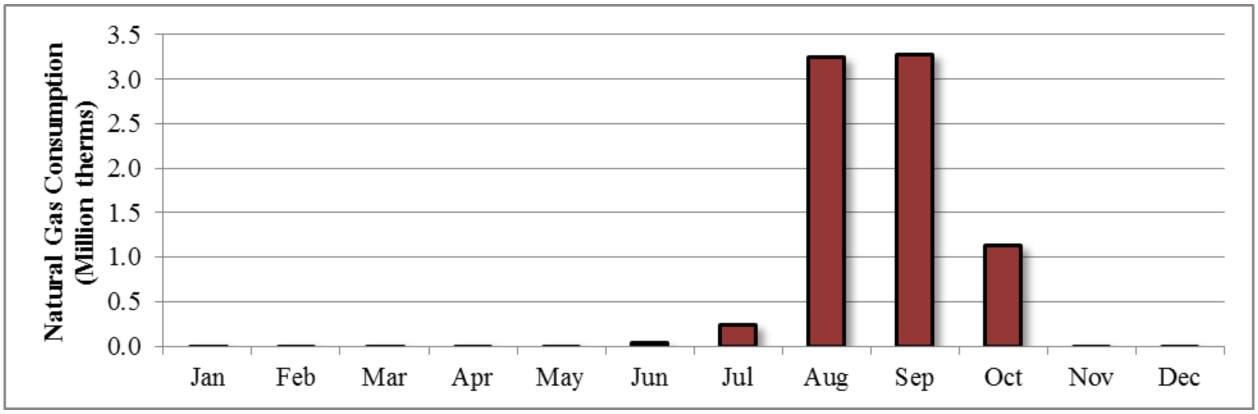

Figure 7 - Monthly Natural Gas Consumption for a Typical Plant

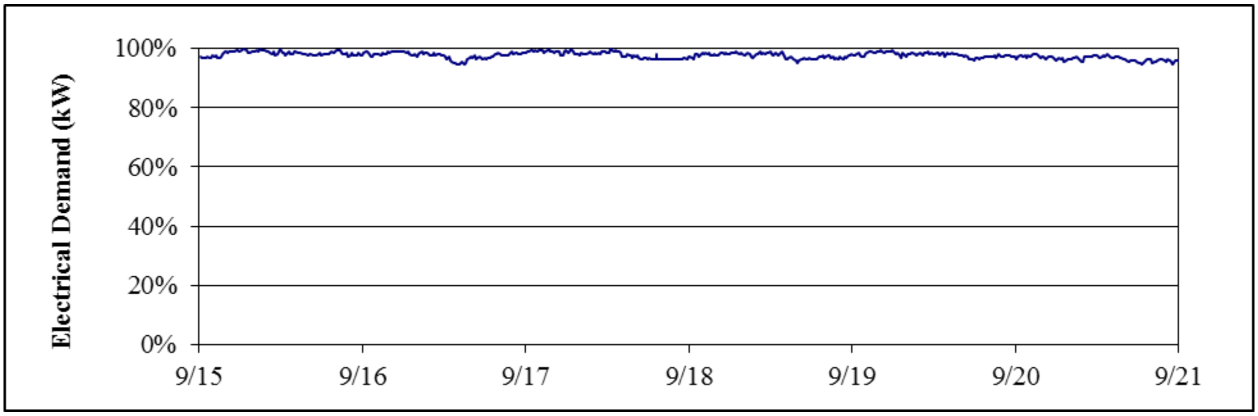

Figure 8 – Weekly Electrical Demand Profile for a Typical Plant

Figure 9 shows the typical distribution of electrical energy consumption in a tomato processing plant. The cooling towers, hot breaks, and evaporators are the most significant consumers of electrical energy in the plant. This is mainly due to paste/purée recirculation in the evaporators and product cooling. Other significant consumers are the steam boiler combustion blowers, boiler feedwater pumps, facility lighting, and air compressors. Table 1 summarizes the range of electrical energy consumption for major end uses in the audited tomato processing facilities.

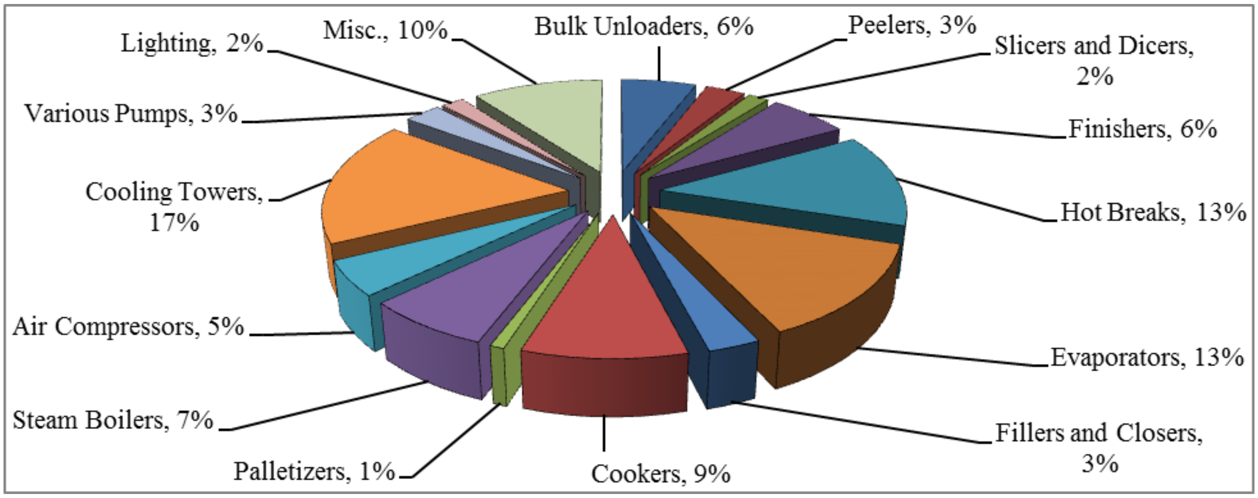

Figure 9 - Distribution of Electrical Energy Consumption in a Typical Plant

Table 1 - Range of Major Electrical Energy End-Uses

Evaporators & Breaks	19.5% - 47.0%
Lighting	1.8% - 11.5%
Boilers	3.5% - 17%
Compressed Air	3.0% - 3.5%
Cooling Towers	11.4% - 17.4%

The vast majority (95 – 98%) of natural gas consumption in tomato processing plants is in the steam boilers. The heat energy from the steam is also significantly greater than the heat required at the source (10,339 Btu of natural gas consumed at source for each kWh consumed on site) to generate the electrical energy used at the plant (3). For the plants audited, natural gas energy is 75 – 90% of the total energy usage at the plant. The major consumers of steam energy are the evaporators and hot/cold breaks, cookers, sanitizing equipment, and CIP operations.

OPPORTUNITIES IN ENERGY EFFICIENCY

Tomato processing facilities are extremely production oriented. On-site engineers typically do not have time to optimize the performance of their equipment during the short harvest season for tomatoes; thus, many opportunities for energy efficiency are available for both electrical and natural gas consuming equipment. This section will describe various identified measures, as well as the relative amount of savings compared to the total system consumption. All inspections were performed during the processing season.

Table 2 at the end of this section summarizes each measure, the relative system energy savings that can be achieved in a tomato processing facility, and the expected simple payback period for these measures. A brief description of the recommended energy efficiency measures for tomato processing facilities follows.

Steam Systems

Steam boilers at a tomato processing facility are the largest energy consuming equipment by a large margin. Therefore, any comprehensive energy efficiency audit should include this equipment. Tomato processors typically use several large water-tube boilers producing steam from 150 psig up to 500 psig. Combustion efficiencies for these boilers range from 72% - 86%, based on flue gas analyses performed by site personnel.

Repair Steam Leaks and Failed Steam Traps

Steam leaks and failed steam traps are fairly easy to identify, and represent a significant loss of thermal energy and potentially a safety risk if left unchecked. Steam leaks should be tagged at the beginning and end of the harvest season and repaired to reduce the natural gas consumption of the steam boilers.

On average, diligently repairing steam leaks can save 0.5% of the steam boiler's natural gas consumption, but can be up to 2.1% for sites with a significant number of leaks. Lawrence Berkley National Laboratory (LBNL) estimates that natural gas savings up to 10% can be achieved by implementing a steam leak repair program. This is an extremely low-cost measure to implement, with payback periods less than a year.

Return Condensate to the Main Condensate Return

There are various reasons that condensate may not be returned to the steam boilers. Failed steam traps may cause condensate to build up in the lines, and bypass valves or relief valves will be opened by maintenance personnel to prevent water-hammering (liquid plug of condensate hammering against a pipe bend at high velocity). Returning condensate also saves water, as well as boiler makeup water treatment costs and blow down losses.

Typically, tomato processors will already have extensive condensate return systems installed, but there may still be opportunities for condensate return. Natural gas savings for the steam boilers range from 0.02% of the total system consumption to as high as 3.6% for plants with a significant number of condensate points that drain to the wastewater system. Tomato processing facilities are fairly compact, and condensate return distances between the major steam users and the boiler room will not be very long; payback periods for this measure are typically less than a year.

Install an O_2 Trim System on the Boilers

Water tube boilers can operate at excess air levels up to 79% during part load conditions. Too much excess air will result in inefficient operation of the boiler. Excess air can be introduced to the combustion chamber through infiltration, a decrease in the ambient air temperature (increasing air density), fuel and air linkage misalignments, air leaks, and defects in the combustion blower dampers or burner management systems (2).

Installing an O_2 trim system can reduce the natural gas consumption of the steam boilers up to 0.8%. This measure also results in combustion blower electrical energy savings. The implementation of this measure is usually low-capital, and will pay back in less than a year.

Reduce the Operating Pressure of the Boilers

High pressure steam (380 - 420 psig) is usually needed to run backpressure steam turbines for pumping applications. Some boilers may produce a much higher pressure steam than what it is required by the processes, which reduces heat transfer rate and efficiency inside the boilers.

Reducing the discharge pressure of the steam boilers from 500 psig to 450 psig to better match the turbine demand and avoid pressure reduction in a pressure reducing valve (PRV) can result in a 1% increase in efficiency for the system. It is relatively simple for a boiler technician to adjust the pressure setpoint of the boiler system, and the payback for this measure is less than a year.

Insulate Various Hot Surfaces

Due to the steam usage intensity of tomato processors, there are many equipment surfaces that could benefit from the installation of insulation. This equipment includes condensate tanks and lines, deaerator tanks, boiler feed lines, boiler ends, product tanks feeding into the evaporators, hot or cold breaks, and sterilizers, cookers, heat exchangers, and others. Typically, fiberglass blankets are used as the insulation type, but there have been recent developments in commercially available thin-film spray-on insulation for surfaces up to 400 ^{o}F.

Application of insulation on uncovered surfaces can save 0.2% to 1% of the steam boilers' natural gas consumption. Simple payback periods for this measure range from 1 year to 2.6 years, depending on the difficulty of insulation application and temperature of the surface.

Replace or Repair Failed Economizers on the Boilers

Over time the economizers on boilers will fail, and boiler feedwater will be bypassed. Repairing these economizers can save a significant amount of energy.

Repairing failed boiler economizers can save up to 2.7% of the boiler's natural gas consumption, with a typical simple payback period of approximately 2 years.

Convert Existing Evaporator into an MVR System

A Mechanical Vapor Recompression (MVR) evaporator is the most efficient and most capital intensive type of evaporator. Steam from the evaporated tomato paste is recompressed and sent to earlier stages in the evaporator.

Installing an MVR system can save 5% to 11% of the boilers' natural gas consumption. It requires a significant capital investment, but typically has a simple payback of 2.2 to 5.5 years.

Install an Additional Effect on the Evaporator

Evaporator stages, or effects, operate at a lower pressure than the previous effect so that the evaporated tomato vapor heat can be used. Each additional effect on an evaporator increases the steam economy of the system.

Installing an additional effect on the evaporator can save approximately 3.7% of the boilers' natural gas consumption. This is a capital intensive measure, with a simple payback of approximately 10 years.

Electrical Systems

Tomato processors are large consumers of electrical energy. Due to their seasonal operation at the end of summer and the concentration of facilities in Fresno, Yolo, and Kings County (hot climate), tomato processors contribute significantly to the local utilities' peak electrical demands. There are many opportunities for electrical energy savings in nearly every stage of the process.

Repair Compressed Air Leaks

Compressed air is used in instrumentation throughout the plant. During production, lines can come loose at the fittings or form holes, forming leaks. Compressed air leaks can represent significant losses of energy.

Implementing a compressed air leak repair program at the beginning and end of the season can save up to 10% of the compressors' energy consumption. The annual cost savings for this measure will exceed the cost required to implement an inspection and repair program.

Use VFD-Controlled Air Compressors as Trim Units

Rotary screw air compressors are used to provide instrumentation compressed air at tomato processing facilities. In some cases, compressed air is also used in mechanical conveyance, air knife dryers, and the wastewater system. Often, one or more air compressors will be operating at part load, which is inefficient for screw compressors. It is recommended to install air compressor controls so all constant-speed compressors are nearly 100% loaded, and only the VFD-compressor part-loads as the trim unit.

Controlling the VFD compressor as the trim unit can save up to 4% of the electrical energy of the compressed air system. Implementation costs for this type of control system is low, and payback periods are less than a year.

Replace Compressed Air with Blower Air

Compressed air is used in some applications, such as package flattening, drying, or mechanical conveyance, when high pressure blower air would be an acceptable and an efficient alternative. Compressed air is typically produced at about 120 psig, while the air pressure for certain applications can be as low as 3 psig. Rotary lobe blowers can easily produce this pressure of air.

Implementation of this measure can save up to 2.3% of the compressed air energy usage, with a simple payback period of approximately 3.3 years.

Install Variable Frequency Drives on Water and Product Pumps

Water is used for many different purposes at a tomato processing facility; unloading flumes, product washing, equipment cleaning processes, heating and cooling circulation, and makeup water to cooling towers and boilers. Often, these pumps will be oversized and throttled or bypassed in order to control the flow and pressure. Installing Variable Frequency Drives (VFDs) and pressure or level sensors on these pumps can save a significant amount of energy and peak demands.

Installing VFDs on pumps at tomato processing facilities can save 16% to 80% of the electrical energy and up to 80% of the peak demand of these pumps. Simple payback periods range from less than a year to 6.4 years, depending on how far each pump is throttled or bypassed.

Install VFDs on Cooling Tower Fans

Cooling towers are used extensively in tomato processing facilities for cooling product exiting the peelers, evaporators, and sterilizers. Reducing the fan flow through a VFD when the ambient wet-bulb temperature is below design conditions can save significant amounts of energy.

Implementation of this measure can save 42% to 63% of the cooling tower fan energy consumption. There is no demand savings for this measure, as the utility peak period coincides with the peak ambient wet-bulb and dry-bulb temperatures. Implementation of this measure can be fairly capital intensive, and payback periods range from 1.8 years to 4.1 years.

Install VFDs on the Boiler Combustion Blowers

Typically, the airflow rate for boiler combustion blowers will be controlled by inlet vanes or dampers. Removing or completely opening the vanes/dampers and controlling the blower flowrate with a VFD will result in significant energy savings.

Energy savings for this measure range from 44% to 73% for the combustion blowers, with peak demand savings from 33% to 44% of the damper controlled boiler combustion blowers. Simple payback for this measure ranges from less than a year to 1.6 years.

Replace Hydraulic Drives with Electric Drives

Hydraulic pumping systems are an inefficient method of pumping and application for speed control. Often, hydraulic systems would be used so the equipment they were actuating would be simple to wash down without causing electrical shortages. However, this is no longer necessary because of totally enclosed stainless steel "wash-down" motors. Replacing hydraulic drives with electric drives can result in a significant amount of electrical energy and peak demand savings.

Installing electric drives in place of hydraulic drives can result in an electrical energy savings and peak demand reduction up to 57% compared to the hydraulic drive consumption. Simple payback periods are approximately 1.2 years.

Install High Efficiency Lighting

Typical processing areas will be lit with high-bay high-wattage metal halide lamps. Other support areas may be lit by inefficient T12 lighting. Replacing these lamps with T5, T8, light-emitting diode (LED), or induction lighting can result in significant electrical energy savings and reduce the peak electrical demand. Additionally, full spectrum high efficiency lighting can possibly reduce the occurrence of manual sorting errors (5), and increase productivity, decrease accidents, and morale among night shift workers (4).

High efficiency lighting can save from 38% to 80% of the fixtures electrical energy consumption and peak demand. Depending on the hours of operation, simple payback periods range from less than a year up to 4.7 years.

Install Lighting Controls

Office buildings and warehouses at tomato processing facilities will often be unoccupied for extended periods of time, or have sufficient daylight available where the lights will not be needed.

Installing lighting motion sensor and daylight sensor controls can save 24% to 75% of the fixture's energy consumption and reduce the peak demand by up to 75%. Simple payback periods for this measure range from 1.0 years to 3.2 years.

Use Steam Turbines Instead of Electric Drives

Often at tomato processing facilities, steam will be generated at a much higher pressure and temperature than what some processes, such as the tomato paste evaporators, can use. This steam will be throttled to a lower pressure through the use of a pressure reducing valve (PRV). Often, there are large electrically driven pumps near these processes that can be replaced with steam backpressure turbine driven pumps, both producing mechanical work and lower pressure steam. This measure is especially effective for evaporator circulation pumps, because the mechanical work and low pressure steam is used in the same piece of equipment.

Savings for this measure can be from 28% to 47% of the evaporator process electrical energy consumption and peak demand. Implementing this measure will slightly increase the natural gas consumption of the boiler system. Simple payback periods for this measure are approximately 5 years.

Table 2 - Summary Energy Efficiency Measures and Typical Savings for Tomato Processors

Energy Efficiency Measure Description	**Typical Range of System Energy Savings Comparison**	**Typical Range of Simple Payback**	**No. Facilities Recommended**
Steam Boilers			
Repair Steam Leaks and Failed Steam Traps	0.5% - 2.1%	< 1 year	5
Return Condensate to the Main Condensate Return	0.02% - 3.6%	< 1 year	3
Install an O_2 Trim System on the Boilers	0.8%	< 1 year	2
Reduce the Operating Pressure of the Boilers	1.0%	< 1 year	1
Insulate Various Hot Surfaces	0.2% - 1.0%	1 – 2.6 years	2
Replace Failed Economizers on the Boilers	2.7%	2 years	1
Convert Existing Evaporator into an MVR System	5% - 11%	2.2 – 5.5 years	2
Install an Additional Effect on the Evaporator	3.7%	10 years	1
Electrical Systems			
Repair Compressed Air Leaks	10%	< 1 year	1
Use VFD-Controlled Air Compressors as Trim Units	4%	< 1 year	1
Replace Compressed Air with Blower Air	2.3%	3.3 years	1
Install VFDs on Water and Product Pumps	16% - 80%	1 year – 6.4 years	2
Install VFDs on Cooling Tower Fans	42% - 63%	1.8 years – 4.1 years	3
Install VFDs on Boiler Combustion Blowers	33% - 44%	1 year – 1.6 years	2
Replace Hydraulic Drives with Electric Drives	57%	1.2 years	1
Install High Efficiency Lighting	38% - 80%	4.7 years	5
Install Lighting Controls	24% - 75%	1 year – 3.2 years	5
Use Steam Turbines Instead of Electric Drives	28% - 47%	4.6 years – 5.1 years	2

OPPORTUNITIES IN DEMAND RESPONSE

Most tomato processing facilities in California are concentrated in Fresno, Yolo, and Kings County. Additionally, because the tomato harvest season is in late summer, the peak demand of these facilities coincides with the local utility peak demand.

Tomato processors are so highly production oriented that it is difficult to enact demand response programs. However, in some cases there are site-specific measures that can be used to reduce the facility's load on the grid. Table 3 on the next page summarizes these measures and the relative site demand reduction that can be achieved. A brief description of the recommended demand response measures for tomato processing facilities follows.

<u>Turn Off Warehouse Lights</u>

Most tomato processors have large ambient temperature warehouses to store the seasonal product year-round until a customer places an order. If the warehouses have skylights, the lighting can be turned off during a peak demand response event. Turning off the warehouse lighting can reduce a tomato processor's peak demand by approximately 0.3% with negligible implementation costs.

<u>Charge the Forklift Batteries During the Off-Peak</u>

Often, a facility will have multiple forklifts to transport product to and from the warehouses. Charging the forklifts during the off-peak utility period can reduce the peak demand, as well as save costs by consuming energy during a low-rate period. Charging the forklifts during the off-peak period can reduce a tomato processor's peak demand by approximately 2%. The facility may need to purchase additional chargers, batteries, and timers in order to implement this measure. Note that some processors will use propane-fuelled forklifts; this measure only applies to battery-powered forklifts.

<u>Shut Down Packaging Lines</u>

Some tomato processors have multiple packaging lines, and it would be feasible to shut down one or more lines during a demand response event. This process may include conveyors, product pumps, sanitation and cooling equipment, and filler/sealer units. In some plants, shutting down a packaging line could reduce a facility's peak demand by 11% with negligible implementation costs.

OPPORTUNITIES IN WATER CONSERVATION

During the harvest season, tomato processors are significant consumers of water. Most producers will pump water from the aquifer, use the water internally, then discharge the effluent to land application. The facilities audited consumed between 129 and 532 million gallons per year. Table 4 summarizes the recommended water conservation measures. Please note that the measures listed in this table may be applied to multiple areas in a facility. A brief description of the recommended water conservation measures for tomato processing facilities follows.

<u>Repair Water Leaks</u>

Valves, hoses, and water storage tanks can all spring leaks due to normal wear and tear. Implementing a maintenance program to repair these leaks can significantly reduce the amount of fresh water that a facility purchases from the city or pumps from the aquifer. Repairing water leaks can save approximately 0.7% of a facility's water consumption.

<u>Prevent Overflow of Cooling Tower Water</u>

Cooling tower makeup water pumps may be improperly controlled and cause significant overflow rates by continuously supply water to the cooling tower sump after it has already been filled. Installing a level control system on the cooling tower makeup water pump can save up to 1.7% of a facility's total water consumption. Implementation of this measure will often pay back within a year.

<u>Cascade Water in the Flume System</u>

Water jets are used to unload tomatoes from trucks, which are then conveyed into the processing facility by a series of flumes. Water can be recovered from the last stages of the flume, filtered, and sent to former stages counter-current to the flow of the product. Recovering water from one flume and using it in another flume can save between 1.3% and 3.8% of a facility's total fresh water consumption, and will typically pay back in less than a year.

<u>Reuse Single Pass Cooling Water</u>

In tomato processing facilities, pump seal cooling water and product cooling water is often drained. It is recommended to reroute this water back into the cooling tower or flumes to offset fresh makeup water. Reusing single-pass cooling water can save between 1.7% and 5.0% of a facility's total fresh water consumption. This measure will pay back between one year and 4.8 years, depending on the amount of collection points.

<u>Recycle Evaporator Condensate</u>

If the condensate from the evaporated tomatoes is relatively pure, condensate water can be used in the cooling towers, unloading flumes, and other low-grade facility applications (9).

Table 3 - Summary of Demand Response Measures and Typical Demand Reduction for Tomato Processors

Demand Response Measure Description	Typical Range of Site Demand Reduction	Typical Range of Simple Payback
Turn Off Warehouse Lights	0.3%	< 1 year
Charge the Forklift Batteries During the Off-Peak	2.0%	< 1 year
Shut Down Packaging Lines	11.3%	< 1 year

Table 4 - Summary of Water Conservation Measures and Typical Savings for Tomato Processors

Energy Efficiency Measure Description	Typical Range of Site Water Savings	Typical Range of Simple Payback
Repair Water Leaks	0.7%	< 1 year
Prevent Overflow of Cooling Tower Water	1.7%	< 1 year
Reuse Flume Water in Former Stages	1.3% - 3.8%	1 year – 4.8 years
Reuse Single Pass Cooling Water	1.7% - 5.0%	1 year – 4.8 years
Recycle Evaporator Condensate*	N/A	N/A

*There is no range of savings or payback period for this measure, because it is referenced from the Lawrence Berkeley National Laboratory (LBNL).

CONCLUSIONS

Tomato processing is an extremely energy intensive industry, with approximately 6% of the total costs of operation spent on energy. California tomato processors supply 35% of the world's packaged tomato consumption. Thus, it is important to help reduce this bottom line for tomato processors in California through the use of conservation practices.

It is possible to reduce the electrical energy consumption, peak demand, natural gas energy consumption, and water consumption significantly and cost effectively. On a facility-wide basis, up to 12.5% of the total electrical energy consumption, 17.2% of the total peak demand, and 6.0% of the total natural gas consumption can be conserved through energy efficiency and conservation measures, as well as demand response measures. This represents a total cost savings of approximately $480,000 per year. Additionally, water conservation measures can result in a 15.6% facility-wide reduction of fresh water usage, representing approximately $30,000 per year in electrical energy costs. If all energy conservation and water conservation measures are considered together, payback periods for these facilities are between 1.2 years to 3.6 years.

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