CALIFORNIA

FOOD PROCESSING INDUSTRY

TECHNOLOGY ROADMAP

prepared by the

Food Industry Advisory Committee
&
California Institute of Food and Agricultural Research
University of California, Davis

for the

California Energy Commission
Sacramento, CA

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Preface:

A Food Industry Advisory Committee (FIAC) set the agenda for this roadmap. It met three times during the period of November 2001 through June 2002 and also communicated using electronic mail. A public workshop was held to discuss key issues on June 4, 2003 at UC Davis and further discussions were held in November 2003 and May 2004.

This document offers a vision, objectives and approach to an energy and resource efficient food processing industry in California. Adoption and integration of new emerging technologies into processing facilities will play a crucial role in achieving a globally competitive industry. The diverse nature of the industry requires a multi-prong approach to problem solving.

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Acknowledgements

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Table of Contents

I. **Executive Summary**

The California Food Processing Industry leads the nation and is an important, diverse and dynamic industrial sector in California's overall economy. Building upon the premier agricultural industry, food processing is a $50 billion dollar industry and the third largest industrial energy user in the state. California's great Central Valley is home to over 3000 factory sites and has the world's largest single factory sites for processing fluid milk (California Dairies Inc.), cheese (Hilmar Cheese Company), milk powder/butter (California Dairies, Inc.), wine (E & J Gallo), and poultry (Foster Farms). Over the past 20 years, increasing population and urbanization have brought on sharper competition for water, energy, greater regulatory requirements, and higher costs for operating older, inefficient factories. Co-production of wastes and its associated liabilities has become a significant cost factor, or limiting factor to growth of operations. The energy crisis and labor policies of the 1990's further exacerbated difficulties for food manufacturing firms in California. In combination, these factors resulted in factory closures (e.g. Del Monte Foods; San Jose; Hunt Wesson, Fullerton and Davis; and Tri Valley Growers, Modesto and Gridley) and general industry consolidation across the state. Some large newly constructed factories (Cheese and Protein International, Tulare; Brawley Beef, Brawley) and pilot plants (ConAgra, Irvine; Creative Research Management, Stockton) incorporate the most modern automated and energy efficient technologies to track and trace food at all points in the process.

The California Institute of Food and Agricultural Research (CIFAR) established a Food Industry Advisory Council (FIAC), comprised of industry and technology experts, to lead discussions in order to determine the state of the industry, to prioritize research needs, and develop a vision and plan for the future. CIFAR facilitated this process and subsequently, held several public forums and meetings to develop the California food processing roadmap. These outcomes supported California's Public Interest Energy Research Program.

The FIAC set an agenda for a research program and proposed a vision for the industry and a mission and target.

Vision: To continuously improve the global competitiveness of the diverse California food industry with respect to improving energy and productivity efficiencies and reducing water use.

Mission: To manage energy and other resources to meet or exceed all standards and benchmarks.

Target: To identify cost effective savings with payback within 2 years.

The committee met several times and further communicated over a period of three years to complete the industry-driven program and implementation plan. Eight priority research and development areas of need were identified, plus targets and possible approaches, aimed directly at improving energy and productivity efficiencies and reducing water use in California's food processing industry, were then developed.

Ranked Order of Priority
Research and Development Needs*

Optimize Equipment and Utilities
Validate Existing Technologies
Improve Thermal Efficiencies
Improve Power Quality
Improve Water Use Efficiency
Develop Total Raw Material Utilization
Ensure Food Safety and Security
Develop Seasonal Infrastructure

*as determined by the Food Industry Advisory Committee, 2002 and updated in 2004.

The overall recommendations and conclusions of the committee are the result of applying an overall systems approach whenever possible in order to incorporate multiple variables and efficiencies (e.g., power, water, raw materials, product, waste, and externalities) into a total integrated and process controlled operation. Updating or incorporating new pumps, motors, sensors, and separations plus having the ability to track, trace and partner to utilize all components of the raw materials and process additives, were found to be essential and highly recommended. Consistency and reliability in product quality and safety were likewise considered essential.

As a result of the roadmap exercise, nine near-to-medium term research and development projects were initiated in 2003:

1. **Energy Efficient Ultra Low NO_X Burner (ULNB) Control Technology**
2. **Topping Cycle for Optimization of Can Cooker/Cooler Operation**
3. **Infra Red Drying of Rice to Improve Energy Efficiency**
4. **Waste Heat Driven Adsorption Chilling**
5. **Integrated Benchmarking & Energy & Water Management Tool for the Wine Industry**
6. **Reduction of Heat Exchanger Surface Fouling**
7. **Thermally Driven Heat Pump for Process Heating and Cooling**
8. **Tartrate Stabilization of Wines using Electrodialysis**
9. **Energy Conservation in Refrigerated Warehouses**

The roadmap, and results of these projects, can be further used as leverage for additional funds for research, development and deployment of advanced sustainable and energy efficient technologies for food processing operations.

II. Introduction

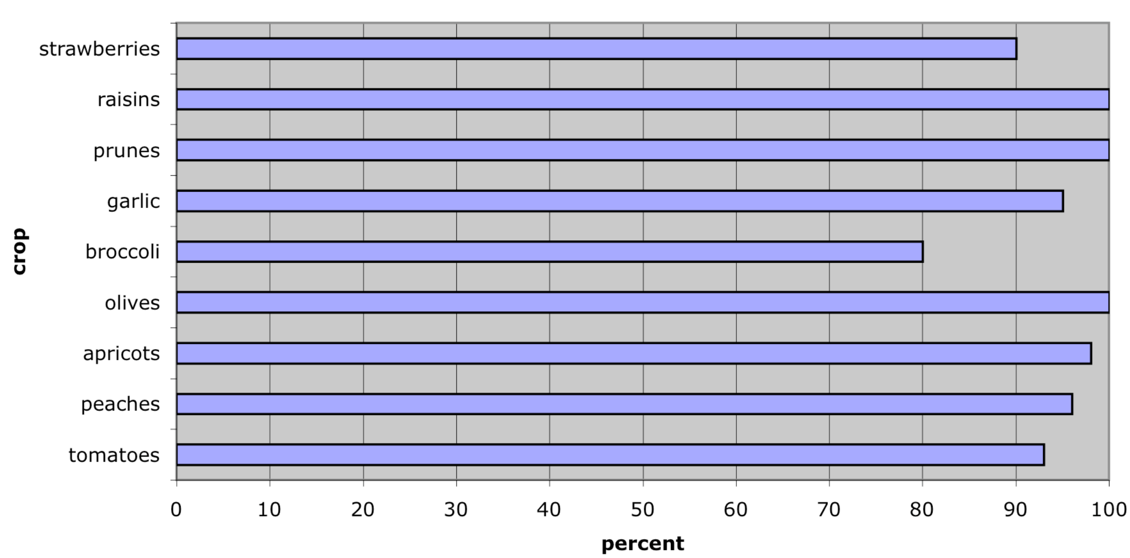
A. Overview of the Industry

The food and beverage industry in California is highly diversified. It is estimated to comprise over 3,000 plants processing commodities from over 88,000 farms. About 240 commodity and trade associations represent food and agricultural interests in California. The dynamic nature of the food processing industry has made its precise characterization difficult. However, some long-term trends within sectors of the industry are apparent.

California ranks 5th in the world in agricultural production (at $27.6 billion in 2002), and first in the U.S. for total food processing output, when defined as total value of shipments at $41.8 billion dollars and greater than $50 billion dollars in 2002 (Sullivan, 1999, CLFP and personal communications, 2004).

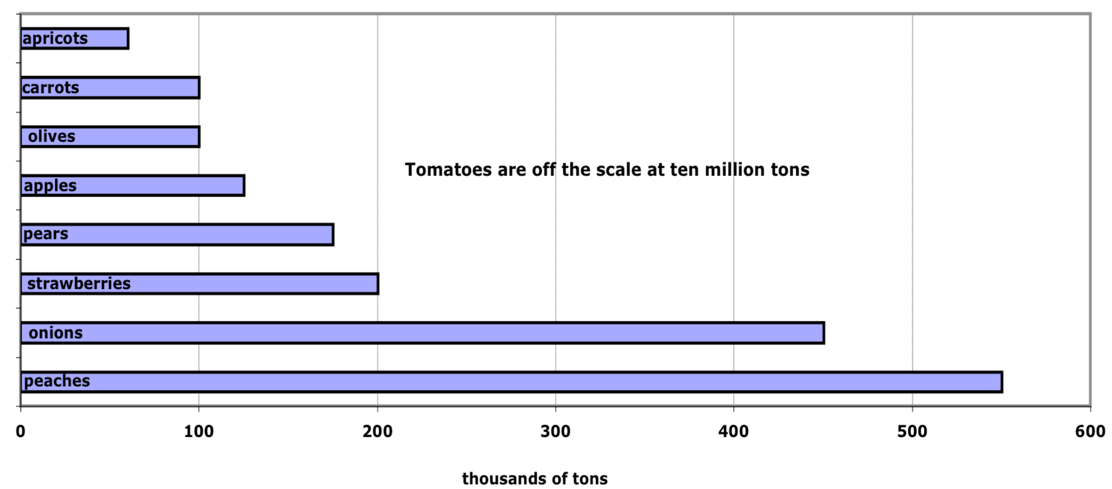
California is first in the nation in production of milk, milk powder/butter, fruits, vegetables, wine, and almonds; second in cheese; fifth in meat; and tenth in grains (CDFA, 2002). It accounts for 20% of U.S. production of milk at 35 billion pounds, 50% of milk powder and butter, and more than 40% of processed fruits and vegetables, with individual commodity rankings for tomatoes, 95%; black ripe olives, 100%; fruit cocktail, 100%; pears, 40%; prunes, 100%; raisins, 100%; strawberries, 90%; almonds, 100%; and pistachios, 100% (CLFP data, 2001 and Figure 1).

Figure 1. Percent of US Production of Selected Fruits and Vegetables from California



Tomato processing is the most dominant category within the fruit and vegetable sector, comprising over 80% of the output in tons (CLFP data, Figure 2).

Figure 2. Annual California Production of Selected Fruits and Vegetables



U.S. production of almonds and pistachios is 100% from California, and almonds are the top agricultural export crop in California, representing 13% of the total export value in 2002 (data from CDFA and UC Davis).

The diversity of California's agriculture across all sectors of food operations is reflected in the range in size of the processing facilities. They include all types and sizes, from the "Mom and Pop" shops to the largest single site operations in the world. California is home to the world's largest single-site manufacturing plant for cheese (Hilmar Cheese, Hilmar); tomato products (Morningstar Packing, Williams); poultry (Foster Farms, Livingston); and wine (E & J Gallo, Livingston). A list of the major food processors with plants in California is given in Appendix 1. This report includes only those broad sectors of food processing that require the most water and energy namely: fruits and vegetables; dairy (cheese, milk powder/butter); meat (beef, poultry); and wine.

The usual way of expressing the value of these sectors is in terms of unprocessed food commodities. In this report, we want to emphasize the impact of value-added processing and thus show both the total value of the top unprocessed food commodities (Table 1) and the added value of processing these commodities (Table 2). The values shown in Table 2 were determined by organizations representing specific sectors and should be regarded as minimum values. Even though the only major energy-use sectors are considered in the list in Table 2, the added value for processed commodities was found to be $63.9 billion, more than twice that of the original commodity value. This is in the same range as the total value for all processed commodities determined in 1996 by the census bureau to be $41.4 billion, and reflects the growth since 1996.

Table 1. The Value of California's Top Food Commodities*
(CDFA data, expressed in millions of dollars)

1	Milk and Cream	$3,812
2	Grapes, All	$2,579
3	Lettuce, All	$1,278
4	Cattle and Calves	$1,229
5	Almonds	$1,190
6	Strawberries	$ 991
7	Tomatoes, All	$ 926
8	Oranges, All	$ 559
9	Broccoli	$ 488
10	Carrots	$ 460
11	Chickens, All	$ 452
12	Avocados	$ 358
13	Pistachios	$ 336
14	Potatoes, All	$ 307
15	Walnuts	$ 305
16	Lemons	$ 287

*The values represent commodity values

Table 2. Estimated Value Added for Food Processing in California

Food Processing Sector	**Value (in billions)**
Fruits & Vegetables[1]	$10
Dairy[2]	$35
Beef and Poultry[3]	$8.5
Wine[4]	$9.9
Rice[5]	$0.5
Total	**$63.9**

[1]CLFP data, 2003, post harvest only and does not include irrigation water.
[2]N. Fletcher, 2003, Dairy Issues Forum
[3]Personal Communications. California Beef Council, 2002 ($5B); Bill Mattis, California Poultry Federation, 2004, ($3.5B)
[4]Wine Institute, 2003
[5]California Rice Commission, 2004

The food processing industry consumes an enormous amount of water and expensive energy resources available to the State of California. The amount of water and energy (electricity and natural gas) used by major food processing sectors were estimated on an annual basis, employing a variety of sources with verification by representatives of the dominant processing facilities within each sector (Table 3).

Table 3: Estimated Annual Water and Energy Use of Major Food Processing Sectors in California

Food Processing Sector	Water (Million Gallons)	Gas (Million Therms)	Electricity (Million KWH)
Fruits & Vegetables[1]	30,000	300-400	600-800
Dairy			
Cheese[2]	600	43	583
Milk Powder/Butter[3]	360	33	130
Meat			
Beef[4]	1200	5	88
Poultry[5]	2000	40	360
Wine[6]	2900	23	406
Rice[7]	Negligible	41	316
Refrigerated Warehouses[8]	Negligible	Negligible	1000

[1]CLFP data, 2003, post harvest only and does not include irrigation water.
[2]Personal communication, T. Struckmeyer, Hilmar Cheese, 2004, (does not include water and energy for production of raw milk but does include whey processing, which is an integral part of cheese making)
[4]Personal communication. J. Gomes, California Dairies, Inc., 2004
[4]Personal communication, Jim Oltjen, UC Davis, 2004 (608gal/animals slaughtered) and Cattle Buyers Weekly, Dec 2003 (# animals slaughtered), and personal communication, J. Maxey, Beef Packers, Fresno. numbers reflect slaughtering plants only.
[5]Personal communication. Bill Mattis, California Poultry Federation, 2004
[6]Alcohol, Tobacco, Tax and Trade Business, Dec. 2001 (574 M gal wine produced), and Wine Institute report (5 gal water per gal wine), (does not include water inputs to production of grapes)
[7]Pernsonal communication, J. Mannapperuma, 2003 (drying only)
[8]Personal communication, International Association of Refrigerated Warehouses, and World Food Logistics Organization, 2004.

From this table it is clear that the food industry in general, and fruit and vegetable processing in particular, requires significant amounts of water for their operations. In a processing season, many California fruit and vegetable plants use 0.5 to 3 million gallons per day. On average for fruit, vegetables and wine, about 88% of the water used in operations becomes effluent water and so, water management is very important. Thus, fruit and vegetable processing generates the most effluent water by far when compared to the other major energy intensive sectors (Table 4).

Table 4: Estimated Total Annual Effluent Water Discharge within Major Food Processing Sectors in California

Food Processing Sector	Total Water Discharge (Billion Gallons)
Fruits & Vegetables[1]	29
Dairy	
Cheese[2]	2.1
Milk Powder/Butter[3]	1.0
Meat	
Beef[4]	1.0
Poultry[5]	1.2
Wine[6]	2.5

[1]Personnal communication, Ed Yates, CLFP, 2004 (estimated as 88% of water use)
[2]Personal communication, T. Struckmeyer, Hilmar Cheese, 2004
[3]Personal communication. J. Gomes, California Dairies Inc., 2004
[4]Personal communication, J. Maxey, Beef Packers, Fresno. 2004
[5]Personal communication. Bill Mattis, California Poultry Federation, and Dr. Jurgen Strasser, Process and Equipment Technology, 2004
\[6]Estimated as 88% of water use

With such high levels of effluent generated, many fruit and vegetable operations have examined technologies that might reduce their effluent volume and further allow in-plant reuse of this water stream. Separation of suspended and dissolved solids from the effluent water has been found to reduce the effluent load (BOD, COD) that is discharged from the plant to water treatment plants and has offered alternative uses for the separated solids. Technologies, such as membrane filtration, in combination with pre- and post-treatment have proven useful (e.g. Sunkist, Bakersfield).

In addition, many process operations are becoming constrained because of their effluent levels that is discharged into local municipal waste treatment plants. Increasing demand for water treatment by all sources, especially in urban areas, has saturated the ability of these municipal facilities to handle needs and thus, they allocate maximum allowable levels per plant. Petaluma Poultry Processors is an example of a food operation that was limited in plant capacity because it had reached a maximum level of effluent that could be processed by the City of Petaluma municipal treatment facility.

While energy use is significant in food processing operations, energy efficiency has not been a priority until the past five years when greater competition for limited resources and the resultant higher prices have brought significantly higher operational costs. Of greater concern for the food processing industry has been the quality and reliability of available power, since any interruptions in utility service can result in significant production losses and can also impact the safety of the product.

A profile of energy use between electricity and natural gas is given in Table 3 and 5. The values and percentages are estimates, as there is a wide range in types of plants within each category. Within the fruit and vegetable sector, tomato processing is the dominant operation with energy going mostly to thermal processing. This is in contrast to dairy and wine processing where pumping and refrigeration are the dominant uses of energy.

Table 5: Estimated Distribution of Energy (%) within Major Food Processing Sectors in California

Food Processing Sector	Pumps Motors Fans Conveyors Lighting	Pasteurization Heating Systems Evaporators Dryers Sterilization	Cooling Freezing Refrigeration	Sanitation Clean in Place
Fruits & Vegetables	10	70	15	5
Dairy				
Cheese	35	40	20	5
Milk Powder	25	55	15	5
Meat				
Beef	30	20	40	10
Poultry	30	20	40	10
Wine	50		40	10
Rice (drying)	20	80		
Refrigerated Warehouses	15		80	5

B. Specific Characteristics of Industry Sectors

Fruit and Vegetable: California is the leading producer of fruit and vegetables in the United States and their processing is the largest food manufacturing industry in California, creating about $50 billion of added value a year. This sector includes 184 companies that operate 229 factories to produce $10 billion of processed fruits and vegetables a year (20% of the nation's total). This is $1 billion more production than that of the next two states combined. This sector produces over 500 million cases of canned products and over 1.8 billion pounds of frozen products every year (CLFP, 2002).

Energy costs for this sector are increasing and large processors are looking for ways to improve efficiencies as well as to ensure reliability of supply of high quality power. The costs for electricity in 2001 were about $70 million but are expected to escalate significantly to about $140 million. Prior to 2000, the annual cost for natural gas was around $90 million, in 2000 it was $135 million, and in 2001 it dropped to $100 million. The fruit and vegetable industry's energy use is highly seasonal, with 80% of natural gas and 60% of electricity being consumed during the peak summer processing season of mid-July to mid-October (CLFP, 2002). Demand-side energy management is increasing, driven by incentives, rebates and rate increases. As the steps that can be taken to affect the supply side become more limited, companies are mainly focusing on the demand side of managing energy costs. This industry sector also used the most water by far compared to other food processing sectors in the state.

It should be noted that the fresh-cut produce category has not been included with traditionally processed fruits and vegetables, although it involves washing, cutting, conveying, mixing, controlled atmosphere packaging and refrigeration. Three plants in the Salinas area dominate this category, Fresh Express, Dole Packaged Products, and River Ranch. The sector is growing at a rate of about 11% (IFPA data, 2002) constrained only by regulatory issues related to water and air. The numbers for energy and water use plus effluent water disposal given in the tables would be higher if fresh-cut were to be included.

Dairy: California's significant dairy industry is based on 1.5 million milking cows that delivered 35 billion pounds of milk in 2002 with 75% of the available milk solids being processed into cheese, milk powder and butter products. The state's milk production has grown by almost 12 billion pounds since 1993 and, in 2002, growth in production of milk (5%), cheese (5%), milk powder (9%) and butter (11%) set new records compared to the previous year (Cheese Reporter, 2003). Milk production (80%) is largely controlled by four major dairy cooperatives: California Dairies, Inc. (Artesia, CA); Land O' Lakes (Tulare, CA); Dairy Farms of America (Modesto, CA); and Humboldt Creamery Association (Fortuna, CA).

In 2003, a situation occurred that slowed the rate of growth in California's dairy industry. Low milk prices at farm level reflected an imbalance between supply and demand for milk and dairy products. A new program called "Cooperatives Working Together" (CWT) was formed to reduce supply and stabilize the industry. Prices rose and production growth slowed in 2003 to a 1% growth in production of milk compared to the previous year, with cheese, powder and butter leveling off also. Milk is produced in 37 counties, although only five of these counties make up 68% of the production: Tulare, Merced, Stanislaus, San Bernardino, and Kings. (Cheese Reporter, 2003)

A significant amount of electricity is required to operate water and vacuum pumps for milking, and refrigeration for cooling. The incorporation of variable frequency drives in pumps for milking and refrigeration, and the use of premium high efficiency motors, has been shown to improve energy efficiency (PG&E report, 2002).

The two largest cheese plants in California are Hilmar Cheese Company (Hilmar) and Leprino Foods (Tracy). In addition, a large cheese-whey processing plant (Cheese & Protein International, CPI, Tulare - joint venture between Land O'Lakes and Mitsui Inc.) was completed in 2002. CPI incorporates the latest equipment for efficient separations, and water and energy use. Across the board, the large cheese processors have modern facilities that have incorporated new technologies to keep costs down and ensure safety.

California Dairies Inc. produces about 50% of the milk powder/butter with Land O'Lakes, Challenge and Humboldt Creamery producing most of the remaining butter. The bulk of milk powder is bagged and sold to the government.

Food safety and security, together with environmental and energy issues, are the primary issues of concern in the dairy industry. The U.S. dairy industry is recognized as a national security concern to be protected from incidents, intended or accidental. In addition, large dairies (so-called mega-dairies) are having difficulty in getting operating permits because of environmental issues. There are further constraints on growth because of regulatory issues associated with air and water quality. Energy has become an important factor in their business because of uncertain rate structures and high costs. Processors feel there are few options for favorable future contracts for electricity and natural gas.

Meat: Meat processing plants inspected by the USDA in California in 1999 were estimated at 726, a number that has not varied more than 5% since 1995 when there were 772 plants. The plants inspected include egg, poultry, beef, lamb, pork and tallow processing facilities including rendering. Non-commercial entities such as prisons and university meat labs are also included in this number. Meat products from California include meat snacks, fresh cut meat and poultry, and prepared foods such as soups, frozen dinners, and canned meats. Some meat processors, such as Campbell Soup (Sacramento) and Kraft (Buena Park) use meat as a food ingredient. Beef and poultry represent the bulk of meat processing in California.

Beef: The California beef industry has a capacity of more than 2 million beef cattle per year. Beef Packers, Inc. (Fresno) is the largest beef packing plant west of the Rocky Mountains, and it continues to expand with new construction, including its own wastewater treatment plant. The second largest plant in California is newly constructed Brawley Beef of Imperial Valley that is utilizing irradiation to ensure safety of its products. Three other beef processors complete the big five that dominate the beef industry: Harris Ranch Beef Company (Selma), Central Valley Meat Company (Hanford, CA) and Hallmark Meat Packing (Chino). Energy use is primarily associated with provision of refrigeration and sanitation.

Poultry: The poultry industry is significant and processes on average 250 million birds a year (California Poultry Federation, 2004). The largest single poultry plant in the world is Foster Farms (Livingston) where about 0.5 million birds per day are processed. Foster Farms and Zacky Farms (Fresno) represent the largest plants in California, Petaluma Poultry Processors (PPP, Petaluma) represents a medium sized processor that has incorporated technology to minimize chemical inputs and maximize energy and water use efficiencies in plant operations. PPP has replaced chlorine with chlorine dioxide as a sanitizer. Temperature regulation and refrigeration are the primary uses for energy in the plant and between 7-10 gallons of water are used per bird.

Wine: California ranks 4th in the world in wine production after Italy, France and Spain and produces 90% of all U.S. wine, producing over 444 million gallons of wine in over 847 commercial wineries, valued at $2 billion a year (1998 data, Wine Institute). E & J Gallo is the largest wine producer and wine supplier in the U.S., having fully integrated energy and water efficient systems plus waste utilization on their plant sites, (Food navigator.com, 2004)

Refrigerated Warehouses: There are 77 reported cold storage units in California that require at least 1000 million KWH of electricity per year. This sector is an important service category of California's food industry and it is growing. The warehouses are networked through two organizations: The International Association of Refrigerated Warehouses (ARW) and the World Food Logistics Organization (WFLO). The members of ARW are from public refrigerated warehouses (as distinct from warehouses owned by the owners of the stored material; i.e. onsite stores)

C. Trends:

Food product reformulation or co-packing is a growth segment of California's food industry, as indicated by the significant number of small food reformulation facilities that have been established recently. About two-thirds of the food processing plants belong to this sector at present. Mexican foods, salsa, pasta, are some of the products manufactured with most of the plants being located close to population centers.

Commodity processing is being consolidated into more central and automated plants, resulting in closure of many smaller and older plants. This is most apparent in facilities for fruit and vegetable canning (e.g., tomato, asparagus and artichoke canning). Most new construction and expansion of plants is located in areas where environmental compliance is easily achievable (cheese processing; e.g. CPI, Leprino Foods). A number of pilot facilities have emerged recently (e.g. Creative Research Management, National Food Laboratory) demonstrating the value of applying new processing and packaging technologies (e.g., electron beam, x-ray, aseptic line, pulsed electric field, high pressure) to food operations.

New processing methods are being employed with the increase in multicultural food production, based upon ingredients provided by a wide range of sources. The trend to use automated processing equipment and sensors is reducing overall energy use by making the process more efficient with less human error, resulting in less re-work and waste.

Complete and better byproduct utilization in processing operations has become increasingly important to profitability. California agriculture-based processing industries will further benefit from better utilization of materials that go to waste and/or animal feed. These materials often contain useful nutraceutical components that are not being recovered because appropriate technologies needed for their cost effective recovery have not yet been developed. Creative Research Management in Stockton is focused on developing cost effective technologies for this purpose.

A food distribution system using supply chain infrastructure and management is essential to cost effective delivery of food from the farms to the consumer and is of increasing importance in our need to ensure safety and security of the system for delivery at any time and to any location of an incredibly wide range of product categories. Essential components to such a system are illustrated in Figure 3.

Figure 3: Supply Chain Management

The importance of closely networked systems embraces all components of the supply chain on a real-time basis. The components of the supply chain must include high speed communications, "track and trace", appropriate temperature and moisture controls, transportation systems to originate from a multitude of suppliers and deliver through many intermediate points to a multitude of retailers and consumers. Water and waste management systems are integrated into the supply chain to support sustainable and cost effective operations. There is also increasing pressure on producers and processors to implement socially responsible strategies (e.g., animals, environment). The consumers want to know where their food is coming from and that the process of making it is consistent with their values.

Water supply, energy supply, and sewage removal are essential to most food and beverage facilities. These services, once inexpensive and taken for granted, have become expensive and sometimes unreliable, placing California food processors at a serious disadvantage in the face of intense competition from both domestic and foreign producers For example, the impact of the availability of foreign fresh and processed food imports, including peaches, garlic, apples and rice, has devastated some of California's fresh and processed food markets. The industry has responded to these challenges with improved conservation, relocation, selfreliance and many other innovative approaches to water supply, energy supply and sewage removal.

Food safety is still a top issue for consumers with animal disease, pest outbreaks and food-borne illness escalating worldwide. Much of the discussion of food safety continues to focus on the pathogen jump from animals to humans so that the meat industry has been particularly impacted. Future concerns will likely revolve around toxins in the food supply (e.g. in grain storage). The increase in microbial counts in the air has led many processors to think about practices such as conveying products in open areas, and bulk packaging products for shipment. Biomonitoring will increasingly be used to track the consequences of environmental pollutants on health.

Food safety and security are areas of intense recent attention and discussion, with increased levels of concern over bio-terrorism and the need to secure facilities, as well as ensure safety of food and food ingredients from foreign sources. Our vulnerabilities to terrorism are adding a new wrinkle of insecurity and are re-defining food production and processing practices. The need for secure facilities is expected to increase energy use and sensitivity to power quality, for example the use of time clocks with biometrics to sense personal identity.

III. Background

The development of a Roadmap for the California Food Processing Industry is an important step in demonstrating that food processing is a major contributor to our State's economy and well being, a major user of electricity, natural gas and water, and a generator of effluents that can influence the quality of the environment. The roadmap will show further that there are major issues that cut across this diverse industry that can be helped or solved by further research, development and demonstration of existing and new technologies. The above characteristics fit with the goals of the Public Interest Energy Research Program

A. Project Objective

To create a food processing roadmap that defines a current baseline for energy, water use, and practices as well as water and air quality considerations, and that points to key needs and directional targets that are dependent on research, development and demonstration which, if studied and implemented could significantly increase energy and water efficiency plus minimize negative environmental impacts.

B. Report Organization

This report is organized into several sections to address the project objectives.
The Introduction Section provides an overall snapshot of California's diverse food processing industry, but selectively concentrates on the sectors that have the most impact on energy and water. Current data and trends are presented to ensure that this report reflects today's needs.

The Project Outcomes section provides a detailed account of the priority research needs and targets that cut across the various food industry segments and presents the research needs in terms of a roadmap to ensure the FIAC vision, mission and target.

Vision - To continuously improve the global competitiveness of the diverse California food industry with respect to improving energy and productivity efficiencies and reducing water use.

Mission - To manage energy and other resources to meet or exceed all standards and benchmarks.

Target - To provide cost effective savings with payback within 2 years.

The conclusions and recommendations section leads into the first phase of implementation projects.

IV. Project Approach

The roadmap was generated through the combined efforts of the membership of the Food Industry Advisory Committee (FIAC) and the process was facilitated by the California Institute of Food and Agricultural Research at the University of California, Davis. From the starting point of the 1998 technical report, the impact of the energy crisis to the California food processing industry was evaluated in meetings in November 2001 and February 2002. The revised issues were presented at a public meeting June 4, 2002 at UC Davis, and comments were incorporated into the document. The results provide guidelines for PIER's short-term RD&D investments and related activities.

In addition, several roadmaps prepared for other purposes, were examined during the preparation of this document. They include

Beyond the Molecular Frontier: Challenges for Chemistry and Chemical Engineering. 2003. National Academies, National Academies Press, Washington, DC.

21st Century Agriculture: A Critical Role for Science and Technology. 2001. U.S. Department of Agriculture, Washington, D.C.

Electricity Technology Roadmap: Powering Progress. 1999. Electric Power Research Institute, Pleasant Hill, CA.

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V. Project Outcomes

A. A Vision for the Future of the California Food Industry

The FIAC set the vision and agenda for California's food processing industry. The proposed vision is to continuously improve the global competitiveness of the diverse California food industry with respect to improving energy and productivity efficiencies and reducing water use.

This vision builds upon the supply into, and infrastructure surrounding, California's 64 billion dollar food processing industry (based on major energy using industry sectors only, Table 3). California is fortunate to have an extensive supply of, and diversity in, raw materials for processing to food, feed and beverages, and some of the most advanced, processing and packaging manufacturing and pilot plants in the U.S. California regulations in food and beverages are often used as a model for national FDA and USDA regulations and policy. In addition, California's food and agricultural system has extensive support network of government-, industry- and university-based groups to help ensure its health as a strong industry.

California's growing, increasingly urban population and somewhat anti-business climate have brought new challenges to achieving the above-stated vision. Important "drivers" that have and continue to influence shifts and consolidation in the industry are given in Table 6.

Table 6. Key Drivers

Global competition
Safety and security
Energy quality, reliability and cost
Water availability, quality and cost
Waste reduction and liability
Air quality issues
Residue analysis
Cost of labor

The "drivers" stated in Table 6 are the principle factors influencing competitiveness of the food industry across all sectors.

1. **Global competition** is a given but must be kept in balance with domestic needs. There must be balance and similar standards for all countries or there is a need to adjust the price and availability of imported products. Standards need to be identified and put in place with special consideration to safety and security issues.

2. **Safety and security** across all sectors is the number one issue facing the food industry. The need to "track and trace" at all point sources within the food chain is redefining processing in favor of automated, controlled systems whenever possible, including the use of appropriate on- and off-line sensors and detectors.

3. **Energy**, its quality, reliability and cost, is an important driver in retaining and growing the food processing industry in California. The energy crisis and its fallout have prevented manufacturing operations from changing energy suppliers and contracts until the debt is paid off. This restriction, and its underlying uncertainty, is negatively influencing decisions for investment and growth. Also, reliability in power is essential to processing food as the least perturbation in power can have dramatic effects on the cost and safety of the products. Thus, appropriate back-up generators must be in place.

4. **Water,** its availability, quality and cost, is a significant component in processing food, especially fruits and vegetables. All modern facilities are conscientiously incorporating practices and systems that ensure a high quality of water (sometimes further processing water coming into the plant from city supplies) and maximizing in-plant use and re-use through the use of technologies such as membrane filtration systems. Since a controlling factor in the size of plants is the amount of effluent water that can be discharged to municipal treatment facilities, there are increased incentives to reduce this amount by finding ways to clean and re-use the water in the plant.

5. **Waste** reduction is a key driver for the industry with most facilities examining ways to reduce cost and liability of its solid and liquid waste. Larger operations are separating and concentrating waste streams for use on their property (fertilizer), finding new uses (nutraceuticals, color, flavor) or developing partnerships for co-products (Morningstar Packing tomato paste operation in Los Banos providing Kagome with a co-tomato stream that is then concentrated and bulk packed for shipment to Japan.) Land application is becoming less desirable due to the potential for groundwater contamination and associated liability.

6. **Air quality** issues are huge in the dairy industry where there is a need to develop standard methods for measuring ammonia and other compounds in dairies and reducing odor. Microbial counts in fungi and bacteria have been found to be at much higher levels in the air in recent years. This results in more food processing facilities using closed conveyer systems and/or packaging in the plant, rather than relying on their customers to individual package the product. In general, the less open the system and the less human contact, the better.

7. **Residue analysis** for certain pesticides, herbicides and other chemicals that could be present in raw materials and throughout processing has been mandated for food processing operations. Increased regulation in this area is driving the use of automated processing and control systems for data acquisition, analysis and management.

8. The cost of **labor** is a sensitive and important issue that directly impacts profitability. The availability of cheap labor in other countries is driving some processing operations out of California (and into Mexico and China) which can have a long term negative impact, if not taken into account in import taxes, etc. The high cost of workman's compensation compared to other states is also a noteworthy observation that is negatively contributing to expansion of this industry in California.

The FIAC set a mission to manage energy and other resources to meet or exceed all standards and benchmarks, followed by a target to provide cost effective savings with payback within 2 years. Table 7 provides a summary of the most significant goals and benchmarks. This is followed in the next section by specific issues, including targets and approaches recommended for implementation in order to achieve the mission.

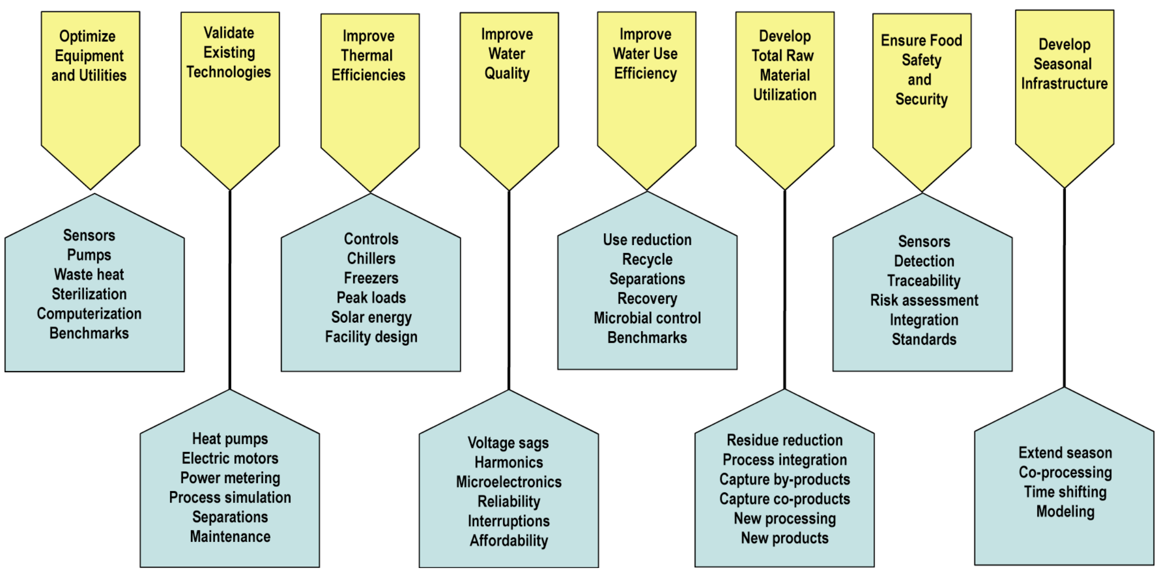
Table 7. Goals and Benchmarks

Goals	**Benchmarks**
Efficient use of energy distributed power and flexible fuel plants microprocessor-based control systems, where applicable integrated unit operations capture and re-use low grade power	Reduce energy use (KWh) per SKU by 35%
Efficient use of water resources capture and re-use water in plant	Reduce water use per SKU by 40%
Total material utilization	95+% of materials utilized; reduced costs and liability and increased profitability.
Safe and secure food supply track and trace (on-line) smart cards, RFID	"seal of safety" enhances consumer confidence and ensures profitability
Environmental steward	"sustainable" label enhances consumer loyalty and hence profitability

B. Major Research Needs and Targets

The FIAC set the detailed research agenda aimed directly at improving energy and productivity efficiencies and reducing water use in California's food processing industry by identifying eight research areas of need (priority ranking from left to right, Figure 4), plus corresponding targets and approaches.

Figure 4: Needs and Priorities for California's Food Processing Industry



The following provides a list of research needs, targets and possible approaches.

1. Industrial Optimization of Process Equipment and Plant Utilities

Objective: To optimize overall process equipment efficiency

Effective implementation of industrial optimization practices offers food processors opportunities for increased efficiency, reduced costs and improved product quality. Industrial optimization facilitates management's ability to make essential operating decisions that translate to a more efficient use of energy and other resources. Industrial optimization practices (software and control equipment) use these data to characterize process equipment. Design curves are interpreted within the system to generate mathematical representations. The appropriate design data are used to construct a detailed computer model of the equipment used to generate the performance indicators under current operation.

The real benefits from using optimization practices come from the frequent evaluation of equipment performance based on real data. Data can be downloaded onsite or accessed remotely via web-based software. The processed data are applied to the software calculation engine to generate the performance indicators and provide the equipment results. Knowing the operating performance of plant or process equipment will assist operators in troubleshooting problems early, remotely and at low cost. Thus, comprehensive data on plant operational parameters allows for a wide-ranging comparison of effectiveness and efficiency of different installations, and therefore will greatly influence the next cycle of investment decisions.

Targets

- To identify investments in energy efficiency etc. which, through cost savings, will have a payback in two years.
- To increase plant performance, productivity and throughput by identifying optimal equipment design and maintenance schedules.
- To improve product quality.
- To improve maintenance/management decisions and implementation.
- To optimize the integration of components into systems that provide for maximum energy efficiency, resource use, and production.

Possible Approaches

- Overall computer-assisted and systems-based approach; develop appropriate computer monitoring programs.
- Evaluate all process equipment according to design/guarantee conditions to determine if still within specification. Specifically examine power consumption, throughput, pressure ratio, etc, as well as operating points, showing expected operational parameters at "normal", "min" and "max" conditions.
- Recommend new equipment and/or monitoring systems as appropriate.
- Conduct educational and training classes.

2. Technology Validation

Objective: Validate and transfer emerging and existing technologies in a new process setting.

There is considerable technology used outside the food industry with potential for use in food operations if cost effectiveness is established (e.g., new types of power, fuel cells, membrane filtration, ozonation, and aseptic processing). In addition, automation resulting in more precise temperature control and more efficient utilization of raw materials, bio-based processing technologies, such as the use of enzymes and beneficial microbes to replace the use of mechanical energy are some potent examples of how technology can reduce energy use. In many cases, the demonstration and validation of a technology to different situations can accelerate its adoption. There is a need for a systematic process of assessment of current developments in technology, sort of a "consumer reports" for industry. DocuLabs is one example of a technology assessment service agency (http://www.doculabs.com/). Often a promising technology will require further development in order to be applied in new ways.

Targets

- Demonstrate technology.
- Apply technologies that are currently used in other industries (e.g., new types of power, fuel cells, membrane filtration, ozonation, aseptic processing, and biobased processing).
- Establish training and education programs.
- Transfer industry experiences and expertise.

Possible Approaches

- Establish or utilize a central screening and demonstration facility for technology demonstration, optimization and transfer to industry.
- Adapt equipment through interactions with suppliers, manufacturers.
- Provide cost/benefit indices to industry for new and existing technologies and equipment.
- Conduct life-cycle analysis of operation.
- Develop recovery processes for low-quality energy (e.g. heat pumps).
- Communicate state-of-the-art motor technology.
- Leverage state and federal funding and utility incentives to advance new technology.
- Inform food processors of new technologies by providing them with specific information through mailings, forums, etc.

3. Food Processing Thermal Efficiencies
Objective: Improve energy efficiency in heating, cooling and drying.

The California food processing industry is undergoing considerable change, in part because the older plants are grossly inefficient and have become too costly to operate. Many older food processing plants could no longer compete with more modern operations or foreign operations and have closed. Of particular concern is global competition from China, which has lower energy costs and has become the world's largest fruit producer. In addition, China's less stringent environmental regulation and lower labor costs make for more economical operation. Owners and operators of newer plants have to pay close attention to overall efficiencies and resource allocations, such as hot and cold water use, pumping, monitoring and waste. Life cycle analysis is proving to be a useful tool to determine optimal efficiency. In addition to the economics of processing, attention should be given to the distribution chain, as there are clear issues to do with energy management and product maintenance still to be solved. For example, currently approximately 27% of products are lost in retail due to improper temperature control. It has been stated that the "energy consumption of refrigerating systems could be reduced by at least 20% in the short term and an objective of 30-50% reduction, depending on applications, by 2020 is a goal which could be achieved" (International Institute of Refrigeration, 2003).

A segment of the food processing industry currently under severe energy-linked pressures is the produce dehydration sector. Currently, in the great Central Valley of California, over 3000 driers and dehydrators operate, with energy costs accounting for up to 60% of the cost of the final dried product. The process is often inefficient, employing outdated technologies. Often production is seasonal, associated with only one commodity. More flexible, strategically located, and portable equipment could provide better utilization of capital. Also, new energy efficient dehydrators and driers could be introduced.

Targets

- Develop standard methods for process control.
- Improve temperature control: in cold chain, transport refrigeration and distribution, retail chillers, freezer operations.
- Integrate heating and cooling operations to capture waste heat.
- Improve and maximize energy efficiency of dryers.
- Improve and maximize utilization of capital investment of process equipment.
- Optimize process by focusing on process control (e.g., moisture sensors).

Possible Approaches

- Develop standard methods and monitor results.
- Develop and use control sensors for temperature, humidity and time in process operations and in transport and storage facilities.
- Adopt automatic control devices and monitoring systems.
- Improve facility design by improving efficient, multi-stage cooling.
- Maximize use of off-peak power.

- Utilize waste heat.
- Adopt software to facilitate integration and optimization of container equipment.
- Retrofit existing equipment.
- Develop highly efficient refrigeration systems (compressors, evaporators, new refrigerants) for heat removal (e.g. spiral configurations)
- Replace old chillers and ensure chillers are maintained at proper temperature.
- Maximize the use of lower air temperature, moisture recirculation and targeted air flow in tunnels used in dehydration.
- Consider the use of zone drying and heat pumps.
- Disseminate information in public forums.
- Assist in the transfer of promising new technology.

4. Power Quality and Reliability
Objective: Stable and reliable source of high quality power.

As the technology for managing electrical loads in food processing equipment advances, the sensitivity of food processing industries to power quality disturbances is increasing. Several factors have contributed to the growing importance of power quality for food processing industries. These include:

Microelectronic advances.
Automation increases.
Process changes from batch to continuous flow.
Electronic controls replacing electromechanical controls.
Computers moving from the computer room to office and processing floors.
Increased cost of downtime for food processing facilities that requires continuous round-the-clock operation without maintenance.

As these advances reshape the food processing industry in California, power quality concerns are becoming an important factor for productivity enhancement of California food processing industries. A food processing facility contains a number of unit processes that enable the facility to perform the work it was set up to do. These unit processes are comprised of industrial equipment that works with other equipment to create a system. Each individual component of the process is susceptible to power line variations. Instability in any of these sensitive devices can cause the process to fail, which can cost thousands of dollars per minute in downtime and lost product. Understanding the process is key to mitigating these types of problems. This knowledge also allows facility engineers to work together to identify weaknesses and critical components and recommend what can be done to harden the process.

Power supply reliability also is a critical requirement for food processors. Power interruptions cause not only a tremendous loss of revenue for the processing plant and an increase in waste disposal problems, but also potentially impact food safety. Production lost due to in-season downtime might be unrecoverable. In order to reduce the cost of power interruption; that can cost thousands of dollars per hour per system, such as in the case of an aseptic processing operation where large amounts of products must be reprocessed or destroyed as a result of power interruption, processors are opting for either an uninterruptible or firm power supply of their own. They are paying exorbitant rates to the local utility to ensure "firm" service. However, even with firm service, there are power quality aberrations that cause plant downtime and resulting food safety/quality issues. Power quality is an electricity supply chain issue on both sides of the meter: the utility AND the customer for their respective power quality mitigation investments. A separate grant awarded to Del Monte Foods for power quality (see Section V, D. Models for Strategy Implementation) funds Roadmap development for the California food industry with real time power quality monitoring and corrective action down to the cycle level. Also, power quality as well as general energy efficiency endeavors, need to be a combination of best practices energy management coupled with technical solutions in order to optimize efficiencies and cost.

Targets

- Ensure consistent power quality at both the utility and its customer.
- Broaden options for sources of power.
- Develop more adequate uninterruptible power supplies or back-up power systems.

Possible Approaches

- Monitor the power quality variations at a food processing facility.
- Identify technologies and engineering solutions to mitigate power quality problems.
- Develop advanced technologies to ensure high quality power.
- Develop alternative fuels (diesel, No. 6 oil, propane, biomass, coal, etc).
- Develop co-generation.
- Seek economic incentives for reducing electric load and off-peak use.
- Conduct public educational and technology transfer forums.

5. Reduce Water Effluent and Improve Recycling
Objective: Reduce water requirements.

During the processing season, each fruit and vegetable processing plant uses in the order of three to four million gallons of water per day. The availability of water and the costs associated with effluent treatment are becoming major issues as resources become tighter. In some cases, water is the limiting factor in manufacturing capacity. The ability to remove and recover suspended and dissolved solids in order to deliver reusable or sterile water and to reduce the amount of wastewater has been demonstrated. There are several examples of membrane cross-flow filtration being implemented in food processing operations to make them more energy and water efficient, and to reduce wastes. Capturing low grade thermal energy from water effluent for reuse is important, since cost benefit analyses show that minimizing heating and cooling of water, and recovering the cost of waste treatment and disposal, can make the industry more self-reliant.

Targets

- Reduce fresh water use.

- Separate dissolved and suspended solids from process effluent water by incorporating separation technologies at front end point sources (preferred) or at the end of the pipe as combined streams (much less efficient).

Possible Approaches

- Examine the benefit of redirecting water and bypassing municipal facilities and applying treated water directly to agriculture. Need to consider microbial implications and water quality standards.

- Evaluate membrane filtration technologies alone, and in combination with pre- and post-treatment technologies.

- Develop more efficient membrane designs to integrate water and energy and recover valuable solids and reuse water within the plant.

- Evaluate ozonation to augment the use of chlorine for microbial control and increase feasibility of water reuse.

- Develop more versatile membrane modules for water effluent treatment that operate under conditions of high pressure, high pH, high solids, and are of low cost.

- Remove and recover total suspended solids (TSS) & total dissolved solids (TDS) in process water and reuse water within the processing plant or sell residual solids as a product. Evaluate markets for these byproducts.

- Identify quality of water streams by further characterizing wash-water.

- Employ water stream "segregation" of dissolved and particulate solids.

- Increase investment in wastewater treatment facilities (e.g. 200,000–300,000 acre feet of water could be freed up if water bypasses municipal treatment and goes directly to agriculture or wetlands. The publicly owned treatment works could be avoided if this is a short cycle. Need to evaluate risks.

- Use methane from waste decomposition in low energy activities.

- Recover low-grade heat.

6. Issue: Supply Chain Waste Reduction Between Producer and User.
Objective: Develop total raw material utilization.

Food processing operations can greatly improve profitability through better integration of their operations toward minimizing waste and use of resources (energy, water, land, air). Many manufacturers are using life cycle assessments for measuring the economics and environmental and societal impacts of their operations. Energy, water and air contributions are being taken into account in the environmental (resource) part of the analysis. Companies such as Cargill, Dow, Dupont, and Roche, to name a few, are using this approach to market their products under a sustainability label. The importance of assessment and monitoring raw material and other inputs can significantly influence profitability of the plant. Energy from by-products can be generated in-plant and also through cooperatives, a trend that is receiving increasing attention. The dynamics of each operation require plant-by-plant real time assessments of specific products. Better utilization of materials, other than use in animal feed, for biomass energy, or as a "waste stream", may be realized. These materials often contain useful "bioactive" components that are not being recovered because appropriate technologies needed for their cost effective recovery have not yet been developed. Generalized computer models are now available to aid in these assessments but they still require refinement for a given plant operation.

Targets

- Re-design plant operations to minimize waste and recover by-products.

- Re-examine processes with attention to waste utilization systems approach.

- Improve separations of liquid-liquid and liquid-solid streams.

- Develop new uses for byproducts.

Possible Approaches

- Perform life cycle analyses using various existing and new processing scenarios. Quantify energy, product, environmental, and social criteria. Use computer models.

- Determine composition of by-product streams and identify potential value components.

- Examine potential for isolating, separating and/or extracting food/feed components and pharmaceutical components from byproducts by highlighting functionality of co-products.

- Develop new processes and uses for by-products.

- Integrate new and cost effective separations with applications of byproducts.

- Evaluate equipment used in processing on basis of energy, water and waste.

- Reduce volume of wastes by solid-liquid separation and fractionation.

- Evaluate use of incineration for energy generation after considering all other options for re-capturing chemical energy of biomass.

- Utilize and/or develop new software to manage new inventory/replacements.

- Establish training and education programs.

- Demonstrate transfer of technology.

- Expand CA Integrated Waste Management Board Resource report/publicize.

7. Maintenance of safety and security of food supply through changing practices and technologies.
Objective: Evaluate safety aspects of new technologies and develop appropriate certification technologies to ensure safety and security of food supply.

Food safety is a key issue with global sourcing of food and ingredients, new practices and technologies in processing. Handling of food can be problematic and new standards are being introduced that need to be evaluated and incorporated into certification programs. The threat of bioterrorism adds new emphasis on safety and security of food operations. Impacts on energy, added waste and other resource needs could be significant. Alarms leading to extensive market recall of product with need for subsequent reprocessing or safe disposal are expensive and wasteful. New and automated processing lines with sensors and automatic controls are being introduced (e.g. aseptic processing, pulsed electric field, high pressure processing, ultraviolet and electron beam). Efficient removal systems for ethylene in closed environments, and replacement of certain chemicals, such as chlorine and certain refrigerants, with other more benign choices are being implemented.

<u>Targets</u>

- Integrate post-harvest treatment and management of food supply to assure its protection from insects, rodents and microbial pathogens (fungi, bacteria, viruses and parasites).

- Incorporate electronic reporting systems to catalogue levels of specific compounds in food materials at all stages in the food chain from farm to table.

- Develop system for ethylene removal. Current systems are not efficient and need to remove ethylene from the enclosed environment.

- Replacement of ammonia refrigerants by safer, less toxic, energy efficient alternatives.

Possible Approaches

- Integrate pest management strategies to develop disease-resistant crops and insect-resistant crops so that less pesticide and herbicides are used and thus, carried over into processing.

- Develop computer software modules to track and trace pesticides and herbicides throughout process.

- Evaluate consequences (re: safety and security) of using new processing technology (e.g., aseptic, high pressure, pulsed electric field, UHT and microwave) and sanitation agents (e.g. ozone, hot water, ultraviolet, electron beam, X-ray and chlorine dioxide).

- Develop and validate alternative sterilization systems for operational efficiency and food safety.

- Conduct educational and training sessions.

8. Complexity and inefficiency of seasonal operations.
Objective: Address challenges of seasonal operations.

A significant part of California's food processing industry is characterized by seasonal processing varying from one to three months or less (e.g., wine, fruit and vegetable processing) to six months (e.g. nuts) as compared to year round industries (e.g., dairy, meat, poultry). The seasonal industry is highly dependent on energy and other resources during the processing season but is often characterized by lack of new investment in infrastructure and hardware (e.g. dehydration of fruits). Emerging partnerships between complementary-seasonal industries is an emerging trend (e.g., ski resort and fruit/vegetable processor).

Targets

- Consistently high quality seasonal products.

- Secure infrastructure that cost-effectively links energy management systems with hardware.

- Improve the efficiency (reduce cost and attain high quality products) of seasonal operations.

- Coordinate equipment and energy use between companies that operate at different times of the year.

Possible Approaches

- Utilize more flexible equipment to extend the process season, and handle a wide range of materials.

- Share facilities and equipment between operations to extend season.

- Link energy management with food and beverage processing.

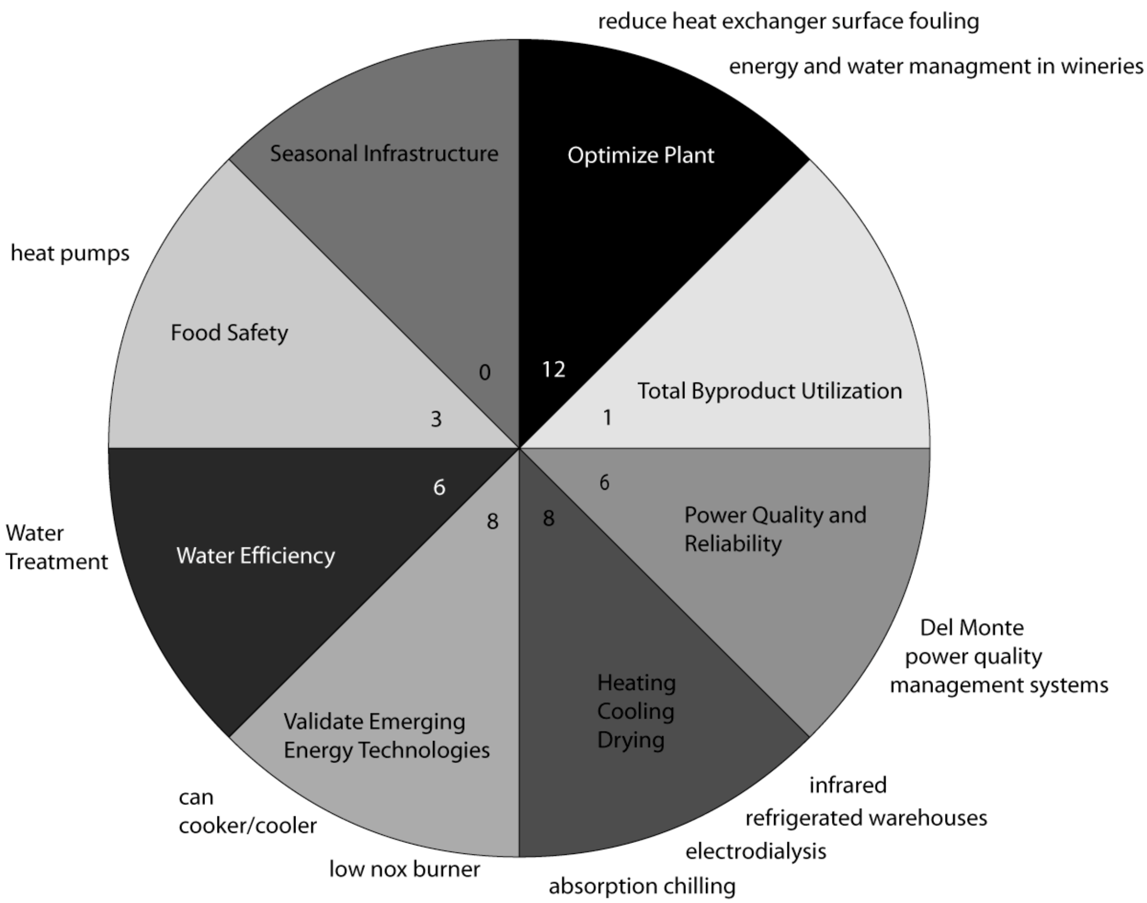
-
- Develop infrastructure to link energy management systems to hardware.

- Develop computer models to achieve consistent high quality product.
.
- Share generation of power with other seasonal industry (ski resort).

C. Research and Demonstration Projects

A call for proposals was initiated in 2003, based on the agenda and priority issues set by the Food Industry Advisory Committee. Nine near-to-medium term research and development projects were initiated in 2003 from forty-four proposals and the number of proposals submitted for each issue is noted in Figure 5.

Figure 5. Distribution of Proposals and Awarded Contracts as a Function of Priority Issues.



Food Industry Energy Research (FIER) Program of the California Energy Commission has launched several RD&D projects conducted at research institutions and in food plants. These projects listed below and referred to in abbreviated form outside the circle in Figure 5, address a broad spectrum of research and RD&D targets included in the roadmap.

1. Energy Efficient Ultra **Low NO_X** Burner (ULNB) Control Technology
2. Topping Cycle for Optimization of **Can Cooker/Cooler** Operation
3. **Infra Red** Drying of Rice to Improve Energy Efficiency
4. Waste Heat Driven **Adsorption Chilling**
5. Integrated Benchmarking & **Energy & Water Management** Tool for the Wine Industry
6. Reduction of **Heat Exchanger Surface Fouling**
7. Thermally Driven **Heat Pump** for Process Heating and Cooling
8. Tartrate Stabilization of Wines using **Electrodialysis**
9. Energy Conservation in **Refrigerated Warehouses**

The potential energy savings from implementation of these projects is summarized in Table 8.

Table 8. Potential Energy Savings with R& D projects

	Potential Energy Savings	
Project	**Million kWh**	**kTherms**
Heat Exchanger Fouling	15	6,300
Infrared Drying of Rice	128	11,800
Retort/Cooler Optimization	36	-470
Low NOx Burner	65	0
Benchmarking Wineries	75	4,600
Adsorption Refrigeration	75	0
Wine Electrodialysis	28	0
Heat pump	3	380

The roadmap, and results of these projects, can be further used as leverage for additional funds for research, development and deployment of advanced sustainable and energy efficient technologies for food processing operations.

D. Models for Strategy Implementation

A good example and model for leveraging stakeholders and funds for water and energy research is a two-year project that began in April 2004. California is a partner in this consortium, called the *State Technologies Advancement Collaborative (STAC).* The goal of the project is to develop a body of knowledge about the food processing industry's energy and water efficiency opportunities. STAC includes the development of energy-related Best Practices for the food industry as well as identification of new and emerging technologies. Stakeholders include the Oregon Department of Energy (Oregon), Washington State University (WSU) Energy Program, California Energy Commission (CEC), and Idaho Department of Water Resources Energy Division (Idaho), in cooperation with the Northwest Food Processors Association (NWFPA), the California League of Food Processors (CLFP), Northwest Energy Efficiency Alliance (Alliance), Lawrence Berkeley National Laboratory (LBNL), and Del Monte Foods. Funds principally come from federal sources (DOE, ASERTTI, and NASEO) through the *Western U. S. Food Processing Efficiency Initiative* that is being administered through the Oregon Department of Energy.

The expected outcome of this project is to substantially improve the energy and water use efficiency of the food processing industry in the Western states. At least six demonstration projects will be completed and an analysis and best practices portfolio will be assembled. Results will be disseminated via training and workshops. This will lay a foundation for the NWFPA and CLFP to establish and provide comprehensive efficiency services to all their members and other interested food processors. This work will leverage the expertise, interests, and resources of the Western states, the Alliance (a unique regional electric utility association), and LBNL (a national research laboratory). Partners will develop the definitive body of knowledge about food processing energy and water use efficiency opportunities and establish an effective framework for communicating that information.

This planning network and partnership, in conjunction with industry leaders, will have both forums and format to continue developing this resource and widen use within the national food and other interested manufacturing industry.

This network will serve as a "one stop" source for food industry energy-related information from U.S. DOE and state energy commissions. One of the outcomes of the proposal will be the development of Enterprise Energy and Asset Management (EAM) for energy that will be transferable to other U.S. manufacturing industries. Mr. Glen Lewis, of Del Monte Foods, who leads this effort also has communicated this model to leaders of the food processing industry form U.K. and follow-up collaborations are expected.

The STAC proposal has promised measurable energy savings and emissions reductions. Six or more demonstration projects will be completed with matching funds. Energy savings will exceed 7,300 million British thermal units (MMBtu) resulting from energy savings of 550,000 kilowatt hours per year and over 55,000 therms of natural gas.

Total project cost is $1,627,777 and funding granted is $730,652. Planned completion date is April, 2006.

VI. Conclusions and Recommendations

The roadmap agenda provides the basis for soliciting and evaluating proposals that will significantly impact energy and water efficiencies, and other important considerations, such as waste minimization, in California's food processing industry. Strengthening the industry should better protect it against unforeseen events, such as the black out that occurred on the eastern seaboard on August14, 2003 and caused untold economic damage to an unprotected process facility.

A. Commercialization Potential and Examples

1. Dehydrators (Addresses issue 1 and 3)
In one project, FIAC member Walter King found that refinements to dehydration tunnels can significantly reduce usage of natural gas. In a large raisin dehydration plant, King found that redirecting air, reducing fan speed, and measuring and controlling moisture for optimal recirculation resulted in 35% reduction in electrical use and 10% to 20% reduction in natural gas use. With energy incentives for up to 50% of costs, payback for modifications was 25 days (gas) and 50 days (electrical).

2. Forklifts (Addresses issue 1)
There are two projects currently being funded addressing energy efficient optimization for operation and maintenance of forklifts in a manufacturing plant setting. Del Monte Foods is testing new technology at their Modesto (STAC grant) and Hanford (EPRI grant) plants. The plant at Modesto will be part of the STAC demonstration project to monitor real time forklift energy activity via Internet in Enterprise Energy Management (EEM). This project will evaluate new AC forklift and fast charging technologies. Del Monte Foods is one of the first U.S. manufacturers to implement this advanced technology. EEM will be coupled with

Enterprise Asset Management (EAM), where EEM energy data feeds EAM as an input for predictive and preventive maintenance to ensure the equipment is maintained and operated in an energy efficient manner. Working capital investment for parts is minimized as well as labor manhours. The plant at Hanford will compare propane and AC vs DC voltage to fast-charge forklifts. They are currently in year two of a four-year project, and still to be done is photovoltaic charging on peak as well as AC forklift flow batteries and fuel cell development. The results are expected to significantly increase fuel efficiency and optimize forklift performance and maintenance.

3. In-plant Wastewater Treatment (Addresses issue 5 and 6)
Professor Ruihong Zhang, with funding from the California Energy Commission, will be demonstrating waste conversion and wastewater treatment technologies using a solids digester system. Her patent-protected integrated wastewater treatment technology will be used at pilot scale on the University of California at Davis campus, and at commercial scale at the City of Industry to demonstrate digestion of green and food wastes. The pilot digester is expected to process 3 tons per day waste beginning in late 2004. Additional wastewater digestor systems will be used to treat various wastewater streams, including meat processing wastewater. A new anaerobic digester, called Anaerobic Mixed Biofilm Reactor, has been shown to work well for treating wastewater, and is being applied to wastewater from Gills Onions and Norcal Waste Systems.

B. *Recommendations*

1. Distribute the roadmap to the California food industry.

2. Using the roadmap as a base, provide assessments on potential of energy and water efficient technologies to specific food processing operations as requested. Funds would need to be identified.

3. Support CEC, CDFA and specific California food processing industry support organizations with technical assistance as needed. Funds would need to be identified.

4. Host public forums to disseminate and further discuss results of funded research.

5. Publish and otherwise disseminate information on technology, which if implemented could mean significant savings in energy and water use and provide an environmentally sound direction.

C. Benefits to California

1. Outcomes of research projects will be shared and serve as a model for food processors to adapt to their own situations to improve production efficiencies and thereby enhance competitiveness of industry in California.

2. Research projects will provide energy and environmental benefits without direct costs to the industry partners (PIER program providing funding). See benefits, in terms of

possible energy savings from implementation of the nine PIER-funded projects, as summarized in Table 8.

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VIII. Glossary

Biomonitoring is a measure of living biological organisms of parts thereof.

BOD, Biological Oxygen Demand - a measure of the rate of use of oxygen by water borne microorganisms in removing organic compounds dissolved in the water.

Byproduct is a side product made during the manufacture of something else.

COD, Chemical Oxygen Demand - the quantity of oxygen used in biological and non-biological oxidation of materials in water; a measure of water quality.

Co-product is a product produced together with another product.

Effluent Water – water that flows out of a processing plant, sewer, or industrial outfall. Generally refers to wastes discharged into municipal treatment plants or on-site evaporation ponds.

Firm power supply refers to uninterruptible power.

A **kilowatt-hour (kWh)** equals 1000 watt-hours and is a measure of electrical energy. A watt-hour equals the amount of energy transferred when a current of one watt flows for one hour. A watt equals the amount of energy transferred when a current of one ampere flows under a pressure of one volt.

PIER - Public Interest Energy Research - supports public interest energy research, development and demonstration (RD&D) that will help improve the quality of life in California by bringing environmentally safe, affordable and reliable energy services and products to the marketplace. The PIER Program annually awards up to $62 million to conduct the most promising public interest energy research by partnering with RD&D organizations including individuals, businesses, utilities, and public or private research institutions.

Power Quality refers to any occurrence manifested in voltage, current, or frequency deviations that results in failure or misoperation of industrial plant equipment. May occur inside or outside of the metered circuit.

Power Reliability - the more frequent the loss of power the lower the reliability.

Acronyms

ARW - The International Association of Public Refrigerated Warehouses

ASERTTI - Association of State Energy Research and Technology Transfer Institutions

CDFA - California Department of Food and Agriculture

CEC - California Energy Commission

CLFP - California League of Food Processors

EAM - Enterprise Energy and Asset Management

EEM - Enterprise Energy Management

EPRI – Electric Power Research Institute

DOE - Department of Energy

IFPA - International Fresh-cut Produce Association

LBNL - Lawrence Berkeley National Laboratory

NASEO - National Association of State Energy Officials

NFPA - National Food Processors Association

NWFPA - Northwest Food Processors Association

PG&E - Pacific Gas and Electric Company

RD&D - Research, Development and Demonstration

SKU - Stock Keeping Unit

STAC - State Technologies Advancement Collaborative

WFLO - World Food Logistics Organization

WSU - Washington State University

IX. List of Figures

X. List of Tables

XI. Appendices

Appendix I

Locations of Selected Major Processing Sites within Each Sector

Fruit and Vegetable Thermal Processors (Canned and Aseptic Preservation)

Bell Carter Foods, Corning
Campbell Soup Supply Company, Sacramento, Dixon
DeFrancesco & Sons, Inc., Firebaugh
Del Monte, Modesto, Hanford
Escalon Premier Brands, Escalon
Gallo, Fresno
H.J. Heinz
Ingomar Inc., Los Banos
Kagome, Inc, Los Banos
Knudsen, Chico
Los Gatos Tomato Products, Huron
Lyons Magnus, Fresno
Morningstar Packers, Williams and Los Banos
Musco Family Olive Co., Tracy
Pacific Coast Producers, Woodland
Rio Bravo Tomato Company, Buttonwillow
Signature Fruit, Modesto
SK Foods, Williams
Smucker Fruit Processing Company, Oxnard
Stanislaus Food Products, Stanislaus
Sunkist, Tipton
Toma-tek (Neil Jones Food Company), Firebaugh
Unilever-Best Foods, Stockton (tomato)

Dehydrated Foods

Sunsweet Dryers, Yuba City
SunMaid Growers, Kingsburg
Conagra Foods, Gilroy
Mariani, Winters
Wilbur Packing Company, Yuba City
Traina Dried Fruit, Patterson
Valley Sun Products, Newman
Mooney Farms, Chico

Frozen Fruit and Vegetable Processing

J.R. Wood, Modesto
Patterson Frozen Foods, Patterson
Wawona Frozen Foods, Clovis
J.R. Wood, Atwater
Superb Farms

Fresh-Cut (minimally processed)
Bolthouse, Bakersfield (carrots)
Dole, Soledad
Fresh Express, Salinas
Gills Onions, Oxnard
Grimmway Farms, Bakersfield (carrots)
Naturipe Berry Growers, Salinas
River Ranch, Salinas

Dairy Processing Plants (compiled from the Top 100 list of Dairy Foods Magazine published August 2003) and other direct sources. Number represents national rank by sales, 2002)

Bongrain, (Advanced Food Products/Land O'Lakes), City of Industry, Los Angeles, Visalia (33)
California Dairies Inc., Artesia, Fresno, Los Banos, Tipton, Turlock (17)
Carvel Corporation, Commerce (55)
Cheese and Protein International, (Land O'Lakes/Mitsui), Tulare
Crystal Cream and Butter, Sacramento (63)

Dairy Farmers of America, Modesto, Corona, Willows, Petaluma, Turlock, Ventura (9)
Dean Foods, Buena Park, Hayward, City of Industry, Fullerton, San Leandro,

Southgate, Tulare (1)

Dreyer's Grand Ice Cream, City of Commerce, Union City (11)
Foster Farms, Modesto, Fresno (47)

Gossner Foods Inc., El Centro (80)
Hilmar Cheese Company, Hilmar (30)
Humboldt Creamery Association, Humboldt, Fortuna
Ice Cream Partners, USA (Nestle/ Dreyers), Bakersfield, Tulare (27)
Joseph Farms, Atwater
Kraft and Kraft-Knudsen, Tulare, Visalia, (cold storage: Stockton, Ontario) (2)
Kroger, Compton (7)

Lactalis/Sorrento, San Jose, Turlock (22)
Land O' Lakes, Tulare, Orland (3)
Leprino Foods, Tracy and Lemorre East and West (10)

Producer's Dairy Foods, Fresno (79)
Safeway, Los Angeles, San Leandro (23)
Santee Dairies Inc, City of Industry (59)
Stremicks Heritage Foods, Cedar City, Riverside, Santa Ana (41)
Superstore Industries (Sunnyside), Sacramento and Cordelia (51)
Westfarm Foods, Los Angeles (14)

Meat and Egg Processing (Source: top 100 meat processors, Stagnitos, 2003, Numbers after processors indicate company's national ranking in size by net sales where known)

Beef Processors
Beef Packers, Fresno (slaughter site)
Brawley Beef, Imperial Valley (slaughter site)
Bridgeford Foods Corp, Anaheim (73)
Central Valley Meat Company, Hanford (slaughter site)
Excel Corportion, Marysville (beef & pork) (2)
Golden State Foods, City of Industry (MacDonald's burgers)
Hallmark Meat Packing, Chino (slaughter site)
Harris Beef Company, Selma (slaughter site) (56)
Randall Foods, Vernon (42)
United Food Group, Vernon (49)

Poultry
Foster Farms, Livingston and Fresno (14)
Petaluma Poultry Processors, Petaluma
Zacky Farms, Fresno

Pork
Clougherty Packing Co. (Farmer John), City of Industry (slaughter site) (38)
Ito Cariani Sausage Co., Hayward (98)

Lamb
Superior, Dixon (62)

Eggs
NuLaid, Ripon

Wineries
Bronco Winery, Ceres, Escalon, Napa, Sonoma
Canandiagua (Constellation Wines, US), Lodi
Franzia Winery, Ripon, Sanger
Gallo, Livingston

Aseptic Packaged Drinks and Soups (co-packers)
California Natural Products, Lathrop (rice dream, soups)

Creative Research Management
Pacific Choice Brands, Fresno

Nuts
Blue Diamond Almond Growers, Sacramento
Paramount Farms, Los Angeles (head offices)
Diamond of California, Stockton (walnuts)

Refrigerated Warehouses
77 locations in California (data from International Directory of Refrigerated Warehouses and Distribution Centers. 2003. International Association of Public Refrigerated Warehouses, Paris, France)