Three California Industries Under the Energy Efficiency Microscope

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ABSTRACT

Setting policies and programs to improve efficiency in the industrial sector is challenging because of the diversity and complexity of these businesses. This study took a step toward addressing that by making a deep, tailored exploration of three key California industries: Electronics Manufacturing, Chemical Manufacturing, and Food Production. The study, which was sponsored by the California Public Utilities Commission (CPUC), identified energy efficiency opportunities and barriers through interviews with facility managers, equipment vendors catering to these industries, and other industry experts from academia and the U.S. Department of Energy (DOE) research labs, as well as a literature review. The study identified which energy efficiency technologies have the greatest future savings potential for these industries and estimated the current market saturation of these technologies. Its exploration of barriers to energy efficiency covered not only traditional ones -- such as first cost and fears of production disruption -- but also newer ones such as competition with energy efficiency for capital funds from solar and other distributed generation technologies. It also explored the involvement of these industries in demand response programs.

Background and Objectives

This paper summarizes the findings from a 2021 California industrial/agricultural market saturation study.[1] The study, which was sponsored by the CPUC, focused on six prioritized California industrial and agricultural subsectors. This paper will focus on the three industrial subsectors that were studied: chemical manufacturing, electronic manufacturing, and food production. The research objectives for this study included:

- Quantifying the market saturation of selected technologies/systems in each subsector that have the greatest potential for future energy savings.
- Collecting other information about these selected technologies/systems useful for the industrial/agricultural component of the California Potential and Goals (PG) Study model, including:
    - Average energy savings.
    - Proportion of facility energy consumption impacted by these energy-efficient technologies/systems.
    - Percent of applications in the facility where the energy-efficient technology/systems might not be suitable.
- Determining factors that prevent the wider adoption of the energy-efficient technologies/systems including whether customers opt for other energy investments such as self-generation

[1] While the study report was published in 2021, the data collection occurred in the second and third quarters of 2020.

- Collecting other information about industrial customers, such as their willingness to adopt energy-efficient technologies with and without program interventions, and their interest in demand response programs

How the Industries Were Selected

California's industrial subsectors are so numerous and diverse that it would have been impossible to study them both broadly and deeply within the study's budget limits. The market study team instead chose to do a deeper exploration of three key industrial subsectors. The main criterion for selecting these subsectors was their contribution to California's future energy consumption. The following table shows the top five California industrial subsectors based on their average share of forecasted electric and gas consumption over the 2020-2030 period. The forecasts come from the California Energy Commission's (CEC's) Integrated Energy Policy Report (IEPR) model.[2]

Table 1: Top Five California Industrial Subsectors
Based on Forecasted 2020-2030 Electric and Gas Consumption

Subsector	Percent of California Industrial Electric Consumption	Percent of California Industrial Gas Consumption
Petroleum	19%	52%
Food Services/Production	16%	18%
Chemical Manufacturing	10%	11%
Electronics/Semiconductor	13%	1%
Stone-Glass-Clay	7%	6%

Source: CEC IEPR projections

The market study team chose to focus on three of the top five of these subsectors: Food Services/Production, Chemical Manufacturing, and Electronics/Semiconductor. While the Petroleum subsector was the largest, COVID-19-related impacts on the industry concerned the team since they would be studying the subsector when it was not operating normally. For example, petroleum end users might discount the importance of energy efficiency more than they would in a normal year because their industry faced more immediate, daunting challenges from pandemic-related impacts. If petroleum facilities were doing furloughs due to the drop in gasoline consumption, it might be more difficult to reach end users for interviews. The team chose not to study the California aerospace industry due to the impacts of the pandemic on reduced air travel and the severe economic impacts this had on the industry.[3]

How the Energy Efficient Technologies Were Selected

Once the market study team had selected the three California industrial subsectors to focus on, the next step was to identify the three most promising energy-efficient technologies/systems for each of the three subsectors. The team conducted both a literature/database review and in-depth interviews with 38 subsector experts[4] to identify:

[2] IEPR: 2017 Ag-Com-Ind 6-digit North American Industry Classification System data by IOU from the CEC.

[3] During the subsector scoping process, the market study team and the CPUC both considered the California aerospace industry for study because it was one of the top five employers in California.

[4] These subsector experts included energy efficiency program evaluators and implementers, specialists from the federal energy labs, California university professors who study energy efficiency, and representatives from the California utilities who help deliver energy efficiency programs in the targeted subsectors.

1. Which technologies/systems use the most energy in these industrial/agricultural subsectors

2. Which technologies/systems have the greatest potential for future energy savings

The following table shows the selected energy efficiency technologies/systems along with the justifications for selecting them.

Table 2: Summary Table of Recommended Industrial EE Measures

Measure	Justifications
Food Services/Production	
Refrigeration System Optimization[5]	• Single largest electric energy consuming end use • Highest response from expert interviews • A top 10 recommended energy efficient measure for this subsector by Industrial Assessment Center (IAC) database • Legacy refrigeration systems not designed for efficient application and likely in need of control system upgrades
Heat Recovery	• High energy consuming end use for gas • This measure was among the most mentioned in the expert interviews • A top 10 recommended energy efficient measure for this subsector by IAC database
VSDs on Fans and Pumps	• Motors account for a substantial share of electric consumption in this subsector • Among the most mentioned in the expert interviews • A top 10 recommended energy efficient measure for this subsector by IAC database • Fluctuations in motor load • Cost-effectiveness has increased for smaller motors sizes
Chemical Manufacturing	

Heat Recovery	• Most frequently cited by interviewed experts
	• Sector has many processes and equipment that generate significant amounts of excess heat. Strategies include:
	  • Heat recovery from stack gases
	  • Recovery or reuse of low-pressure steam and condensate
	  • Heat recovery from compressors and exothermic processes

Advanced Automation and Optimization	• Second-most-cited efficient measure by interviewed experts • Typically, energy and cost savings are around 5 percent or more for many industrial applications of monitoring and control systems • Plant-wide monitoring and automated control systems
Variable Speed Drives (VSDs)	• Third-most-cited measure by interviewed experts • High potential for energy saving per IAC database • Replacing constant speed drives with variable speed drives where practical

[5] Includes a variety of smaller measures to improve the energy efficiency of refrigeration systems mostly through controls. These include head pressure adjustments, adjustment of suction pressure, sequencing of refrigeration compressors, temperature adjustments, improving insulation, adding VFDs to compressors and the installation of new more EE compressors.

Measure	Justifications
Electronics Manufacturing	

Optimize air change rates with VSDs in cleanroom spaces[6]	• Most frequently mentioned measure in the literature reviewed and expert interviews
	• This measure saves electrical energy in semiconductor fabrication facilities, specifically in the HVAC end-use of that subsector; this is important because:
	  • The DOE's Manufacturing Energy Consumption Survey (MECS) data shows that semiconductor manufacture facilities account for 72 percent of the energy usage in the electronics manufacturing subsector in the Western region of the US
	  • The MECS data shows that the largest end-use at semiconductor facilities is HVAC

Low-Cost O&M Retrocommissioning (RCx)	• Measures, such as RCx, that have short payback periods (1-2 years) are more likely to be implemented • Each semiconductor facility is unique and has different opportunities, RCx by nature is tailored to identify savings opportunities in a customized setting and can occur at any facility, impact any system, and result in both electricity and gas savings
Low pressure drop High Efficiency Particulate Air (HEPA)/Ultra Low Particulate Air (ULPA) filters in cleanroom spaces	• Reducing HVAC consumption in semiconductor facilities is important because, as noted, such facilities account for nearly three quarters of the energy usage in the West Coast electronic manufacturing subsector and HVAC is the largest end use at semiconductor facilities

Estimating the Market Saturation of EE Technologies/Systems

To estimate the California market saturation of these selected energy-efficient technologies/systems, the market study team used two different information sources. First it asked companies who sold these technologies/systems in California to estimate what percent of the end use customers in the three industrial subsectors were using them. The study completed 48 interviews with these equipment vendors.

The market study team also interviewed a small sample of 28 end users from these three industrial subsectors to find out what percent of them were using these energy-efficient technologies. Table 3 compares the market saturation estimates from the end users with those from the equipment vendors. It shows that, with one exception (refrigeration system optimization), the end user and vendor measure saturation estimates were reasonably close (within 20 percentage points of each other).

[6] This measure was later replaced by chiller plant optimization when in-depth interviews revealed that many electronics manufacturers might be reluctant to adopt it due to concerns about sensor costs, concerns about quality control process costs, and risk aversion to new technologies.

Table 3: Market Saturation of Selected EE Technologies/System

Subsector	EE Measure	End User Estimates	Vendor Estimates	Average Estimate
Electronics Manufacturing	Chiller plant optimization[7]	6%	24%	15%
	Retro-commissioning (RCx)	44%	No estimates provided	44%
	Low pressure drop cleanroom filters	39%	36%	38%
Food Production	Refrigeration system optimization	62%	24%	43%
	Boilers and heat recovery	19%	11%	15%
	VFDs on pumps and motors	68%	No estimates provided	68%
Chemical Manufacturing	Heat recovery	30%	12%	21%
	Advanced automation and optimization	29%	33%	31%
	VFDs	40%	51%	46%

Estimating Energy Savings for the EE Technologies/Systems

One of the most important inputs to the California PG Study model is the unit energy savings, defined as the average energy savings as a percentage of the end use energy consumption for a typical installation of the selected energy efficiency measure. The market study team asked equipment vendors to estimate the average energy savings for the equipment or services they sell. Table 4 shows the average of their savings estimates for the selected EE measures. Vendors reported average end use energy savings estimates over 30 percent for two of the selected measures and average energy savings estimates over 20 percent for four others. All nine measures for which the vendors provided savings estimates had double-digit levels of end use energy savings.

[7] As noted, this measure replaced optimizing air changes rates in cleanrooms with VFDs. Chilled water plant optimization consists of adding or updating hardware and control sequences to an existing chilled water system to reduce energy consumption associated with the chiller plant as a whole, which can consist of chillers, pumps, and cooling tower fans. Measures that can be categorized under chilled water plant optimization include but are not limited to: changing chiller plant configuration (e.g., from primary-secondary to variable primary); installing new, more efficient chillers; installing VFDs on pumps or cooling tower fans; installing deeper cooling coils with more rows to increase temperature drop across coils to reduce pumping energy, optimizing chiller, pump, cooling tower staging; Incorporating reset control logic on chiller/condenser water temperatures and pressures; and Incorporating or tuning of waterside economizer operation.

Table 4: Average End Use Energy Savings for the Selected EE Measures

Subsector	EE Measure	Average End Use Energy Savings	End Use or Equipment Type
Electronics Manufacturing	Chiller plant optimization	19%	Chiller plants
	RCx	11%	Facility operations which can benefit from RCx[8]
	Low pressure drop filters in cleanroom spaces	31%	HVAC systems used for the cleanrooms
Food Production	Refrigeration system optimization	29%	Refrigeration systems
	Boilers and heat recovery	18%	Boilers/Water heaters providing the heat which the scavenged waste heat is replacing
	VFDs on pumps and motors	33%	Pumps or motors
Chemical Manufacturing	Heat recovery	20%	Boilers/Water heaters providing the heat which the scavenged waste heat is replacing
	Advanced automation and optimization	25%	Facility operations which can benefit from advanced automation[9]
	Mechanical drives/VSDs	29%	Pumps or motors

Barriers to Energy Efficiency Adoption

The in-depth interviews and the literature review revealed several barriers to energy efficiency implementation in these three industrial subsectors.

Food Production

- *Lack of energy efficiency knowledge among subsector operators and management:* Experts observed that while larger, more sophisticated companies are using advanced controls for motor system optimization, other facilities lack the knowledge to implement these optimization strategies. Some experts claimed that there are not enough technical educators who can convince key decision makers of the benefits of current best practices. They noted that many operators in the Food Production subsector do not have the time to learn about energy efficiency opportunities.
- *Seasonal/episodic production schedules complicate the economics of energy efficiency investments:* Research revealed that the Food Production subsector is susceptible to seasonality changes and the run hours of process equipment varies greatly throughout the year. For example, it is common to have only 4 months of operation for vegetable processing. These lower hours-of-use can make

[8] The vendors estimated, on average, that 69 percent of a facility's operating systems could benefit from RCx.

[9] The vendors estimated, on average, that 55 percent of a facility's operating systems could benefit from advanced automation.

owners hesitant to upgrade to more EE systems because of longer payback periods and reduced cost effectiveness.

- *First cost barriers, especially for smaller companies:* Experts observed that many smaller facilities (micro-breweries or small wineries) do not have the capital resources to invest in EE upgrades of equipment. The replacement of large refrigeration systems is cost-prohibitive for companies of many sizes.
- *Large refrigeration systems require customized solutions:* The research found that refrigeration systems in the Food Production subsector are often old and built-up with equipment from various vendors over the years. One-size-fits-all remedies are usually not feasible and customized solutions are needed. However, some operators in this subsector are reluctant to pursue custom projects because they are expensive to develop and are subject to a higher level of scrutiny than more prescriptive measures.
- *The challenge of scheduling maintenance so as not to interrupt production:* Food facilities often operate 24/7 while in production and so are reluctant to halt production and lose revenue during these periods for EE-related maintenance. Companies must determine the right time to conduct maintenance so it will have the least impact on revenue. One expert proposed enhanced sensors and building empirical computer models to determine when these maintenance repairs should be made.
- *Reluctance to change out familiar equipment:* Some experts also said that many operators do not want to make changes to the systems and components they are accustomed to using with known results.
- *Lack of time to plan and implement EE projects:* Some experts noted that even when operators in the Food Production subsector are knowledgeable about energy efficiency opportunities, they often lack the time to plan and implement the energy efficiency projects.

Chemical Manufacturing

- *Competition for capital especially from process-related projects:* Some experts noted that most chemical companies are investor-owned and so they do not want to spend capital for energy efficiency gains that may be minimal, especially if it means they will accrue debt or lose out on more lucrative opportunities that will generate profit for their investors such as process-related improvements. It is likely that the lack of end user understanding of the benefits of energy efficiency mentioned below contributes to energy efficiency projects losing out to process-related ones in the capital funding cycle.
- *Low energy costs:* While chemical manufacturing is an energy-intensive industry, experts observed that energy costs are still cheap, so shutting down plants for incremental efficiency gains or optimizing their plants beyond the required levels to meet demand is not attractive to most operators.
- *Other barriers:* Other barriers revealed by the expert interviews and literature review included: concerns over lost production due to the downtime required to install and commission more energy efficient systems, concerns about possible negative impacts of energy efficient technology on product quality or yield, and decision makers' lack of understanding of the benefits of energy efficiency.

Electronics Manufacturing

- *Concerns about disrupting production:* All three groups of interviewees (experts, vendors, and end users) cited concerns about disrupting production, especially for measures that impacted

cleanrooms, as a factor that would limit installation of energy efficient measures. “Facility folks do not want to jeopardize the process,” said one subsector expert. “A breach in cleanliness would be very costly, so facility folks will not make any changes unless directed to do so from top management.”

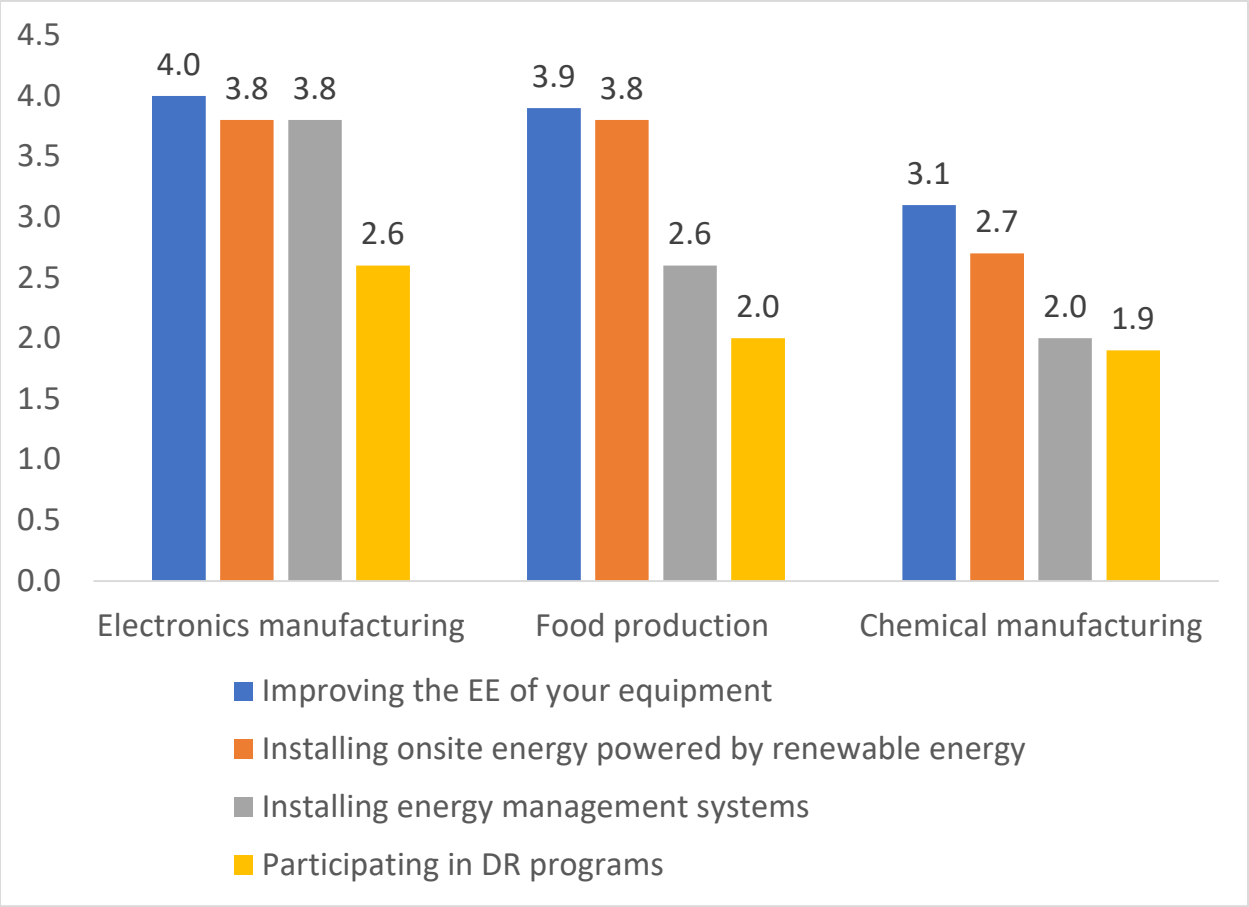
- *Concerns about the initial cost of energy efficiency:* All three groups also identified concerns about the initial cost of energy efficient measures as a factor. When asked why they had not installed an energy efficient measure that they were aware of, one end user said, “Primarily cost. We have to be cash conservative at this point.” Another end user said, “Our company is in a ramp-up cash-tight phase.” One of the vendors said the popularity of RCx stemmed from its low cost. “You have finite amount of funding, that is why RCx is so attractive, because typically it doesn't need that much money to make good energy savings happen,” they said.

- *Energy savings not being a priority:* The subsector experts and the end users mentioned energy savings not being a priority as a factor that would limit energy efficient measure installation. "Energy is not a priority at these [electronic manufacturing] facilities, production is, and energy is just an afterthought,” said one subsector expert. “There is a tendency to rely on status quo- not wanting to make a change, since that could affect production negatively, and cost a lot of money.”

Competition from Other Energy-Related Projects

The CPUC was interested in knowing whether other energy-related projects such as distributed generation and demand response might be competing with energy efficiency for capital funds. The market study team asked the industrial end users to rate the relative importance of various energy management options using a five-point scale where 5 equaled “very important” and 1 equaled “not important at all.” The following figure shows that while energy efficiency was the most important option for all three industrial subsectors, renewable energy is close to matching energy efficiency in importance.

Figure 1: The Relative Importance of Energy Management Options



The market study team also asked the industrial end users if they had onsite generation and, if they did, what type it was. Table 5 shows that the percent of end use customers who reported having solar installations was low for all three subsectors.

Table 5: Solar Saturation by Industrial Subsector

Subsector	% of End Users with Solar Installations
Electronics Manufacturing	10%
Food Production	36%
Chemical Manufacturing	14%

Finally, the market study team asked the end users if they had participated in a demand response program. Table 6 shows that participation was low for all industrial subsectors.

Table 6: Demand Response Participation by Subsector

Subsector	% of End Users Participating in DR Programs
Electronics Manufacturing	10%
Food Production	18%
Chemical Manufacturing	18%

Summary of Key Findings and Recommendations

Key findings from the Industrial/Agricultural Market Saturation Study include the following:

- **Selected measures offer the promise of significant energy savings:** The market study team asked equipment vendors to estimate the average energy savings for the equipment or services they sell. Vendors reported average end use energy savings estimates over 30 percent for two of the selected measures and average energy savings estimates over 20 percent for four others.
- **Opportunities for improved customer education:** With respect to the energy efficient technologies most relevant for their industries, only 20 percent of the chemical manufacturing end users were familiar with the advanced automation and optimization measure and only 40 percent of the electronics manufacturing end users were familiar with the chiller-plant optimization measure.
- **Sizable opportunities for EE improvements exist in the industrial and agricultural subsectors:** In the market saturation estimates from the end users and the vendors five of the nine measures had saturation levels below 40 percent and only one measure had market saturation levels above 50 percent.
- **Common factors/barriers constraining energy-efficient measure implementation:** The most common factors/barriers across all the subsectors were concerns about disrupting production, concern about the initial cost of energy efficient measures, and lack of knowledge of energy efficient measures and benefits. The market study team also asked the equipment vendors whether the investments their customers make in energy efficiency compete with other energy management decisions or technologies. Most of the vendors said there was competition, but they had differing opinions as to the degree of competition.

While this study focused on three specific industries, many of the study findings are applicable to a broader range of industries. Some common themes include the opportunity for substantial energy savings from industry-specific technologies and the challenges to energy efficiency projects posed by low industrial rates, competition for capital from process improvements, risk aversion given process complexity, and lack of industrial customer knowledge of the economic benefits of energy efficiency.

This last challenge – lack of customer knowledge of energy efficiency benefits – is the most significant for it leads to energy efficiency projects being undervalued when competition for capital is already stiff. Customer education can help, but it will require cooperation from both energy efficiency program representatives with specialized knowledge of the target industries and vendors of energy efficiency equipment who can customize their products to suit the industries' unique needs.

References

Industrial/Agricultural Market Saturation Study, 2021 Potential and Goals Study, prepared for the California Public Utilities Commission, submitted by DNV and Guidehouse, February 9, 2021.