

2025 Process Loads TPM Final Report

ET25SWE0003



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Abbreviations, Acronyms, and Glossary of Terms

Acronym	Meaning
AC	Alternating current
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
BRO	Behavioral, Retro-commissioning, and Operational
CalMTA	California Market Transformation Administrator
CARB	California Air Resources Board
CEH	Controlled environment horticulture
CPUC	California Public Utilities Commission
EE	Energy efficiency
ET	Emerging technology
eTRM	Electronic Technical Reference Manual
GHG	Greenhouse gas
HVAC	Heating, ventilation, and air conditioning
HVAC/D	Heating, ventilation, air conditioning, and dehumidification
IOU	Investor-owned utility
IT	Information technology
LBNL	Lawrence Berkely National Laboratory
PCM	Phase change material
PEI	Pump Energy Index
PG&E	Pacific Gas and Electric Company
SCE	Southern California Edison
SME	Subject matter expert

Acronym	Meaning
TPM	Technology Priority Map
TSB	Total System Benefit
WH	Water heating

Glossary Term	Meaning
Technology Category	One of six broad technology categories (e.g., Whole buildings, HVAC, water heating, lighting, plug loads and appliances, process loads, and portfolio enhancements).
Technology Family	Functional grouping that provides description of program role, opportunities, barriers.
Research Initiatives	New initiative in place of both subgroups and knowledge indices.
Research Initiatives Key	Visual aid that explains if each research initiative is at a level of high understanding, ranked on a low, medium, or high scale.
Rankings	Future Needs: Covers items that are not yet ready for consideration or due to having high needs in validation and market analysis. Programs should not be discouraged from submitting proposals for research initiatives with a “Future Needs” classification but instead focus on making a strong argument for how the project outcomes can help fill in the missing gaps for validation or market analysis. Low: Covers items that have lower industry interest and/or impacts for Total System Benefit (TSB) due to having an expansive data set or information readily available or not being pertinent to the research initiative. Medium: Covers items that are an evolution of or offer promise to existing and common technologies for TSB. This can be in the form of needs that are currently being addressed with existing projects or needs that may exist but are not critical to the objectives of meeting TSB metrics. High: Covers items that have high industry interest and high impacts for TSB.
Definitions	Narrative to provide additional clarification on the technology family scope.
Opportunities	Description of potential impacts and potential research areas.
Barriers	Description of key barriers and potential barriers research.
CalNEXT Role	Describes general level of engagement by CalNEXT SMEs. <i>Note: Roles will change as research is completed.</i>
Lead Collaborate Observe	Lead: CalNEXT expects to take on most or all of the work and cost burden. Collaborate: CalNEXT is interested in collaborating and co-funding projects. Observe: CalNEXT will track progress but encourage external

Glossary Term	Meaning
	programs to take lead in unlocking these opportunities.
CalNEXT Priority	Communicates an expected level of focus by CalNEXT SMEs. <i>Note: Priorities will change as research is completed.</i>
High	High: CalNEXT SME team has highlighted this technology family as having high impacts within the technology category.
Medium	Medium: CalNEXT SME team determined this technology family has moderate overall impacts within the technology category.
Low	Low: CalNEXT SME team has highlighted this technology family as having low relative impacts within the technology category.

Introduction

The Technology Priority Maps (TPMs) provide the CalNEXT program with a framework to externally communicate priorities of the program, clearly define the central focus areas of the program, and assist with project screening. They also document the impact potential, programmatic research needs, and market readiness of all technology families across each of the end-use technology areas and drive product ideation while informing project selection. This Final Report covers the revision process for the 2025 Process Loads TPM.

2025 TPM Changes

The Process Loads category has been revised to further clarify and expand the program definitions and priorities for prospective participants. The team revised current technology family definitions, opportunities, and barriers where appropriate for every technology family in this TPM. Notable drivers include passage of the Inflation Reduction Act of 2022, which will continue to provide additional market support over the next decade in the form of tax credits and state-administered incentive programs. Additionally, the continued need for programs to transition to the Total System Benefit (TSB) metric has implications for demand flexibility.

One of the key lessons the project team learned by was to consider overlaps between technology families, which prompted us to consolidate this year where appropriate. By looking at incoming proposals, the team made sensible consolidations, such as consolidating refrigeration to a single commercial and industrial technology family. We also culled TPM areas that did not have much traction and rolled them into adjacent TPMs, such as combining water systems with pumping systems, as all water system proposals were related to pumping efficiencies rather than water treatment. Going forward, this will simplify the process through which stakeholders select and propose topics. Furthermore, the cross-partner collaboration on technology families—such as controlled environment horticulture (CEH), where TRC runs the agricultural program for Pacific Gas and Electric Company (PG&E)—was helpful from a stakeholder feedback perspective.

As for the 2025 TPM update, the CalNEXT program team established a robust process for continuation of the TPM development and revisions. This year, we incorporated a stronger outreach push to ensure feedback, directly targeting potential deemed measure stakeholders from the California Public Utilities Commission (CPUC), San Diego Gas and Electric (SDG&E), the California Market Transformation Administrator (CalMTA), and others. The project team is made up of representatives from each of the program team partners: VEIC, AESC, TRC, UC Davis, and Energy Solutions. The Process Loads SME Team represents members that collectively support an array of energy efficiency (EE) programs using technologies covered by the Process Loads TPM; these emerging products are then contextualized into the priority maps through a markets and solutions lens.

Additional rankings now replace the icons under each of the categories, which are divided into two technology-driven criteria—Performance Validation and Market Analysis—and two market-driven criteria—Measure Development and Program Development. These rankings indicate if the research initiative is at the low, medium, or high stage. The new ranking table design, with its visual elements,

is intended to help a potential submitter quickly understand what research topics are of most need within a given technology family and record the current state of progress and understanding.

The summaries are intended to offer a clear representation of where the technology family stands in the portfolio, along with what remaining research is needed. The research initiatives tables describe the three to five most important technology areas, with the current version providing a simplified ranking view for easier use and external understanding of where the Process Loads portfolio stands. To date, most research projects take place within a handful of technology families across Process Loads, which was a large driver in how the technology families were chosen in 2025.

Table 1: Rankings and their meanings.

Icon	Meaning
 Future Needs	Covers items that are not yet ready for consideration due to having high needs in validation and market analysis. Programs should not be discouraged from submitting proposals for research initiatives with a “Future Needs” classification but instead focus on making a strong argument for how the project outcomes can help fill in the missing gaps for validation or market analysis.
 Low	Covers items that have lower industry interest and/or uncertain impacts for TSB due to having an expansive data set or information readily available or not being pertinent to the research initiative.
 Medium	Covers items that are an evolution or offer promise to existing and common technologies for TSB. This can be in the form of needs that are currently being addressed with existing projects or needs that may exist but are not critical to the objectives of meeting TSB metrics.
 High	Covers items that have high industry interest and high impacts for TSB.

The team developed the structure of the TPM Research Initiatives table to ensure strong coordination among CalNEXT activities. Overall, the team made the changes in this 2025 TPM to increase technology transfer across our portfolio, allowing us to define new measures of interest and illustrate our efforts to bring them to the portfolio. These changes should put greater focus on shorter-term activities like measure packages to support the expansion of the existing resource acquisition programs. Even for longer-term investments, the new visual format will provide more tactical guidance as to what type of research is needed to advance different technologies to the ultimate goal of portfolio savings.

Stakeholder Feedback

Technology Priority Map Advisory Committee Outreach

The TPM Advisory Committee outreach began in August 2025 when the team requested stakeholder feedback via email, which resulted in updates to the technology family narratives Word document. These stakeholders are listed below in Table 2.

Table 2: Technology Priority Map Advisory Committee outreach.

Organization
California Air Resources Board (CARB)
California Technical Forum (CalTF)
California Market Transformation Administrator (CalMTA)
California Public Utilities Commission (CPUC)
Northwest Energy Efficiency Alliance (NEEA)
Pacific Gas & Electric (PG&E)
Pacific Northwest National Laboratory (PNNL)
Southern California Edison (SCE)
San Diego Gas & Electric (SDG&E)

This outreach allowed advisory members to provide candid feedback via written comments and suggestions in a collaborative Word document hosted on Microsoft SharePoint. The TPM coordinator and the Process Loads SME Team reviewed suggestions and incorporated them into the Revised 2025 Process Loads TPM section. More details are available in **Error! Reference source not found.** in Appendix A.

Controlled Environment Horticulture

ETP Role: Lead | ETP Priority: High

Definition

The Controlled Environment Horticulture (CEH) technology family encompasses a combination of lighting and non-lighting equipment used to produce agricultural products in CEH spaces. This includes lighting systems, such as lighting design strategies, lighting control systems, and lighting technologies, as well as non-lighting equipment such as heating, ventilation, air conditioning, and dehumidification (HVAC/D), precision nutrient monitoring, irrigation systems, pumps, controls systems associated with maintaining environmental conditions for growing, and district strategies for shared utilities.

Research Initiatives

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Advanced environmental controls and equipment for CEH				
Thermal energy storage				
CEH colocation: Farm Park Model				
Performance optimization and demand flexibility options for CEH				
Performance standards and building codes				

*Table above is not exhaustive. More technologies and controls are mentioned below.

KEY  High Needs  Medium Needs  Low Needs  Future Needs

Opportunities

Examples of key opportunities for energy efficiency, decarbonization, and demand flexibility in CEH include:

- Energy use intensity in CEH ranges from 9.3 to 27.9 kWh per square foot, particularly in high-tech greenhouses and indoor facilities growing crops like leafy greens and tomatoes, making it a prime sector for efficiency improvements.

- HVAC/D systems represent 60 to 80 percent of energy use in greenhouses and 30 to 50 percent in indoor vertical farms, indicating strong savings potential from more efficient equipment and controls.
- Most efficiency programs focus on deemed lighting or custom HVAC/D measures; there is a clear opportunity to expand deemed measure offerings to include HVAC/D technologies for greater program uptake.
- Water-energy nexus opportunities. Even as drought conditions vary year to year, efficient fertigation controls and water reuse strategies offer dual benefits for water conservation and reduced embodied energy.
- Savings from horticultural lighting can go beyond fixture efficiency through improved system design, optimized spectral distributions, and controls like daylight harvesting and spectral tuning.
- Efficient lighting with thermal curtains can reduce light pollution. Additionally, indoor growing may offer GHG reduction benefits compared to open-field agriculture under certain conditions.
- Demand management strategies—such as scheduling, thermal storage, or pairing with onsite renewables—can help reduce peak loads, depending on growers’ operational flexibility.
- Development of industry-specific standards—e.g., through the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) or the American Society of Agricultural and Biological Engineers (ASABE)—including sizing guides, test procedures, and commissioning protocols for CEH HVAC/D, would support consistent program implementation.
- Co-locating solar PV with greenhouses, especially when paired with heat pumps, offers pathways toward net-zero operations while reducing grid dependency.
- Co-locating CEH operations with data centers and other industrial users in a Farm Park model can unlock resource-sharing opportunities, such as waste heat reuse, shared infrastructure, and microgrid integration, improving cost competitiveness and supporting rural economic development.

Barriers

Examples of common barriers to energy efficiency and demand flexibility in CEH include:

- Rapid industry growth has led to many poorly designed systems lacking efficiency considerations, often due to limited technical guidance or program incentives.
- There is a lack of trusted tools and experienced designers to optimize lighting, HVAC/D, and integrated systems, particularly when balancing energy use and plant productivity.
- Controls like spectral tuning and daily light integral tracking are still novel in this sector and not widely adopted, partly due to limited performance data and grower skepticism.
- Many growers are hesitant to adopt new technologies due to uncertain return on investment, limited in-field evaluations, and a lack of accessible best-practice case studies.
- Existing HVAC/D equipment lacks horticulture-specific efficiency metrics and test procedures, which complicates program inclusion and market comparison.
- The sector lacks a skilled workforce familiar with high-efficiency CEH systems, emphasizing the need for workforce education and technical training.
- There is limited energy use intensity data specific to California CEH operations, which hinders the development of performance-based building codes and benchmarking tools.

- While new facilities can be designed to meet updated standards, existing CEH operations will need time, resources, and incentives to transition to higher efficiency systems.
- Operational and behavioral measures face verification and persistence challenges, especially under current Behavioral, Retro-commissioning, and Operational (BRO) measure rules. Cost-effective measurement and verification strategies are needed to support longer estimated useful life ranges and broader program eligibility.
- Farm-Park-style colocation faces challenges in aligning heat and resource loads across multiple industries. Implementation requires coordinated planning, infrastructure investment, and regulatory alignment to fully capture shared efficiency and decarbonization benefits.
- High real estate and operating costs make it difficult for CEH businesses to compete with other potential land and building uses, raising the bar for profitability and investment in efficiency.
- Escalating electricity rates strengthen the case for efficiency measures but present a barrier to electrification and decarbonization projects, which may increase operating costs in the near term.

In addition to the barriers listed above, research should focus on activities that help build knowledge among both growers and utilities, including:

- Investigating how changes in lighting, temperature, and humidity affect the overall economics for growers, including growth, energy savings, and production value in various types of facilities—as well as designing effective knowledge transfer approaches to present comprehensive side-by-side results in terms of yield versus the cost of energy in different crops, different light sources, HVAC/D systems, controls strategies, fertigation approaches, and different building types. Work has begun to establish quantitative metrics for CEH that can simultaneously characterize the energy performance and crop yield of a solution to allow growers the ability to make true side-by-side comparisons across different solutions. The next step is for institutions to increase the use of those quantitative metrics.
- Developing guidelines based on studies of difference in yields achieved with high intensity discharge lighting versus light-emitting diode lighting, and how photosynthetic photon efficacy from the different lighting types may affect the overall cost or gram achieved.
- Studying how controlling the light intensity, spectral distribution, and environmental conditions to match a crop growth cycle and shift demand can help growers develop strategies to adjust production, increase energy savings, and manage that demand.
- Studying financial benefits and additional production values regarding the use of thermal energy storage on the HVAC/D needs in sealed greenhouses, particularly to decarbonize.
- Conducting market research and a lifecycle study to further inform the determination of industry standard practice and claimable program savings.
- Exploring the technical and economic potential of colocation models—such as Farm Parks—that pair greenhouses with data centers or other industrial users to enable waste heat recovery, shared infrastructure, and microgrid integration, while supporting regional economic development and grid resilience.

Outputs from these research topics would help alleviate growers' hesitancy in trying different technologies or growing practices for fear of lower yields and income.

Related CalNEXT Projects

- ET24SWE0037 – Cooling and Dehumidification for Indoor Farming
- ET23SWE0067 – Smart Controls for Data-Driven Indoor Agriculture Field Evaluation
- ET22SWE0027 – Greenhouse Lighting Controls: https://calnext.com/wp-content/uploads/2023/04/ET22SWE0027_Greenhouse-Lighting-Controls_Final-Report.pdf
- ET25SWE0032 – Electrification of Greenhouse Heating Systems
- ET25SWE0034 – SmartAg Controls: Incentivizing Efficiency & Yields

Commercial Kitchen Decarbonization

ETP Role: Lead | ETP Priority: High

Definition

The Commercial Kitchen Decarbonization technology family focuses on process load electric equipment and systems typical in commercial kitchens (i.e., at cafes, fast food, and sit-down restaurants) and institutional foodservice facilities (i.e., hospitality and cafeterias), with emphasis on conversion and replacement of gas cooking equipment.

Note: Non-process loads commercial kitchen systems are included in other TPMs. Grocery display cases and remote-condensing systems are covered under the Refrigeration, Commercial technology family within this Process Loads TPM. Additionally, related water heating topics are covered under the Water Heating TPM and the Steam and Hot Water Systems technology family within this Process Loads TPM.

Research Initiatives

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
New electric foodservice equipment for gas equipment that historically had no electric alternative (woks, tandoor ovens, rack ovens, electric rotisseries)	High Needs	High Needs	High Needs	Future Needs
Economics of foodservice electrification	High Needs	High Needs	High Needs	High Needs
Hard-to-reach/disadvantaged community engagement on foodservice electrification	Low Needs	High Needs	Low Needs	Low Needs

KEY High Needs Medium Needs Low Needs Future Needs

Opportunities

Commercial kitchens are incredibly energy intensive, consuming five to seven times the energy density of other types of buildings, which presents significant energy savings potential. There is also a tremendous opportunity to decarbonize these facilities, as kitchen natural gas consumption makes up approximately 23 percent of all commercial building gas usage despite being only a small fraction of the square footage. The commercial foodservice industry in California is still dominated by gas-fired cooking equipment, presenting a large opportunity for decarbonization in this technology area.

- New electric commercial food service equipment. While technologies exist to electrify many pieces of commercial cooking equipment, there are several commercial cooking equipment technologies that are still mainly gas fueled, such as woks and tandoor ovens.
- Economics of commercial foodservice decarbonization. There are opportunities to quantify cost and demand impacts of electrification and resolve economic barriers associated with commercial kitchen decarbonization, including incremental equipment costs, operating costs, and infrastructure upgrade costs.
- Commercial foodservice fuel substitution measure package development. CPUC Decision 23-04-035¹ requires the development of commercially viable electric alternatives for commercial kitchen cooking equipment, shifting CalNEXT focus for commercial kitchen equipment toward decarbonization.
- Identifying and quantifying the non-energy benefits of electrification. Electric foodservice equipment can have other benefits, such as faster cleaning time and improved indoor air quality. Reduced cooling and ventilation needs should continue to be validated, especially within existing facilities.
- Measure development and codes readiness. For maturing technologies, CalNEXT should continue to conduct research that can feed into the development of new deemed measures and standards. While the focus of this technology family will be on decarbonization and electrification, the program will still consider equipment with high EE potential, as well as equipment that has secondary electrification in a fully electrified kitchen, such as heat recovery dish machines, drain water heat recovery, and kitchen hoods with advanced controls.
- Addressing user acceptance barriers to electric commercial foodservice equipment. Additional research should focus on resolving major industry barriers associated with commercial foodservice electrification, such as end user reluctance to use electric cooking technology.

Barriers

Despite the strong opportunities and technical maturity of foodservice equipment, this sector faces significant barriers to electrification and needs both more resources and larger structural changes to advance decarbonization opportunities.

- Lack of Market awareness of decarbonization opportunities. Market understanding has improved as programs are now targeting distribution channels and retailers to ensure ENERGY STAR® products are widely available in like-for-like equipment replacements. However, this sector is still in an early stage for decarbonization activities.
- Lack of electric alternatives for foodservice equipment. Some cooking equipment—such as broilers, woks, and rack ovens—do not have proven electric appliance alternatives yet, requiring industry development of electric cooking equipment to suit the entire foodservice industry’s cooking equipment needs.
- Economics of commercial foodservice electrification. Electrical infrastructure upgrades for all-electric kitchens can present significant costs to business owners and add substantial load to the grid at peak load times. Operating costs using current rate structures can double or triple when comparing gas to electric cooking equipment, as electric foodservice equipment typically operates using resistance or induction technology with smaller comparative efficiency benefits to other electrification technologies, such as heat pumps.

¹ For more information, see: <https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M505/K808/505808197.PDF>

- Electric rate impacts on commercial foodservice decarbonization efforts. There are larger structural issues, such as energy rates being misaligned with decarbonization efforts, tenant-owner split incentives, and peak demand charges impacting electric foodservice economics.

Related CalNEXT Projects

- ET22SWE0010 – All-Electric Commercial Kitchen Electrical Requirements Study Evaluation: https://calnext.com/wp-content/uploads/2023/02/ET22SWE0010_All-Electric-Commercial-Kitchen-Electrical-Requirements-Study_Final-Report.pdf
- ET22SWE0019 – Market Potential for Heat Pump Assisted Hot Water Systems in Foodservice Facilities: https://calnext.com/wp-content/uploads/2023/07/ET22SWE0019_Final_Report.pdf
- ET22SWE0048 – Commercial Kitchen Hot Water System Design Guide: https://calnext.com/wp-content/uploads/2023/12/ET22SWE0048_Commercial-Kitchen-Hot-Water-System-Design-Guide_Final-Report.pdf
- ET22SWE0054 – Foodservice Refrigeration: High Efficiency Condenser and Evaporator Units Focused Pilot: https://calnext.com/wp-content/uploads/2024/11/ET22SWE0054_Foodservice-HECU-HEEU-Focused-Pilot_Final-Report.pdf
- ET23SWE0056 – High Efficiency Refrigerated Display Case: https://calnext.com/wp-content/uploads/2025/04/ET23SWE0056_High-Efficiency-Refrigerated-Display-Case_Final-Report.pdf
- ET23SWE0057 – Overcoming Key Barriers to Electrification of Foodservice Hot Water in California
- ET24SWE0024 – Commercial Cooktop Fuel Substitution: https://calnext.com/wp-content/uploads/2024/12/ET24SWE0024_Commercial-Cooktop-Fuel-Substitution_Final-Report.pdf
- ET24SWE0032 – New CFS Measure Prioritization: https://calnext.com/wp-content/uploads/2024/12/ET24SWE0032_New-Commercial-Foodservice-Measure-Prioritization_Final-Report.pdf
- ET24SWE0057 – High Speed Oven Energy Use Field Monitoring for the Commercial Foodservice Industry
- ET22SWE0046 – Restaurant Field Monitoring

Data Centers and Enterprise Computing

ETP Role: Lead | ETP Priority: High

Definition

The Data Centers and Enterprise Computing technology family focuses on energy-using equipment related to the functioning of dedicated information technology (IT) facilities. This includes servers, storage, and networking IT equipment; other typical equipment, such as power distribution units and uninterruptable power supply systems; and specialized systems for airflow management and cooling.

Data centers use significant amounts of energy, with demand projected to grow in the United States from 17 GW in 2022 to 35 GW by 2040 at an annual rate of 10 percent.² PG&E forecasts that AI and cloud workloads will consume about 8.7 GW in new demand in California in the coming decade.³ Additionally, edge computing data centers are projected to grow at a Compound Annual Growth Rate of 26 percent from 2025 to 2033.⁴

Research Initiatives

Research Initiative	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Energy efficient cooling systems	High Needs	Low Needs	High Needs	High Needs
Load flexibility	High Needs	High Needs	Low Needs	Low Needs
Waste heat recovery	High Needs	Low Needs	High Needs	High Needs
Efficient modular/edge computing	High Needs	Low Needs	Low Needs	High Needs

KEY  High Needs  Medium Needs  Low Needs  Future Needs

Opportunities

Energy efficiency in data centers can make a significant impact on new generations, carbon emissions, and grid resiliency. There are opportunities for efficiency improvements in the following areas:

² [Why invest in the data center economy | McKinsey](#)

³ [Surging Data Center Growth to Help Lower Energy Costs for PG&E Customers](#)

⁴ Grandview Research, Edge Computing Market Size, Share & Trends Analysis Report By Component (Hardware, Software, Services), By Application, By Organization Size, By Industry Vertical, By Region, And Segment Forecasts, 2025 – 2033, GVR-2-68038-106-1, [Edge Computing Market Size, Share | Industry Report, 2033](#)

- IT equipment itself makes up the bulk of the energy use, accounting for nearly 60 percent or more in energy consumption, with the remainder due to cooling and electrical losses.
- Several initiatives are underway to promote efficient cooling and standardization of cooling equipment in data centers.
- There is an opportunity for demand side management to optimize resource allocation for underutilized servers. Automated software is available to make more effective use of existing servers as opposed to adding new servers.
- With increasing capacity of data centers, there is a potential to use them in demand response events. On the cooling system side, the use of thermal storage technologies has potential to unlock demand flexibility for data centers with highly variable loads.
- There are opportunities to use waste heat by colocation of data centers with district heating networks or other heating applications, such as localized space heating, water heating, and controlled environment agriculture.
- Edge computing data centers will be on the rise due to low latency and increasing AI inferencing tasks. There is a tremendous opportunity to develop energy efficient, modular, and rapidly deployable data centers to meet this demand.

Barriers

Data centers are well researched, especially traditional hot-aisle and cold-aisle computer room air conditioning and heating systems. However, there are still significant barriers to consider when designing a program to address this end use:

- Smaller enterprises or edge computing centers need guidelines and strategies for energy-efficient retrofits.
 - Hyperscale data centers have optimized energy efficiency by using optimized air, liquid, or immersion cooling methods. However, smaller edge data centers need guidelines or strategies.
- Emerging technologies, such as liquid-based cooling, face significant barriers to scale from product availability, downtime concerns, and practitioner familiarity.
 - It will be beneficial to research and develop code compliance pathways for liquid-based systems, providing a viable pathway toward these scalable impacts.
 - More advanced two-phase liquid cooling technologies must address the impact of per- and polyfluoroalkyl substance fluids.
- Statewide water supply concerns are driving aversion to evaporative cooling in lieu of less efficient air-cooled systems.
- While waste heat recovery is promising, especially with liquid cooling, colocation to use water heating is not always possible. Edge computing applications have a strong potential to address this barrier.
- Methods of achieving energy efficiency vary greatly depending on the size of the data center, IT and server configuration; purpose of the data center, whether it is for AI, high-performance computing, or something else; and the center's cooling method. This makes drafting a statewide code or standard around data centers challenging.

- While server utilization monitoring has tremendous savings potential via demand side management, it requires a monthly subscription. This makes it difficult for standard program delivery models outside of BRO.
- Data center operators and developers prioritize productivity, resiliency, and security over efficiency.

Related CalNEXT Projects

- ET25SWE0046 - Datacenter Liquid Cooling Case Study
- ET22SWE0041 – Residential Multi-Function Heat Pumps: Heat Exchanger Improvement
- ET25SWE0051 - Datacenter Liquid Cooling Lab Evaluation
- ET24SWE0065 – Datacenter Liquid Cooling Market Characterization

Refrigeration, Commercial and Industrial

ETP Role: Collaborate | ETP Priority: High

Definition

This technology family focuses on commercial and industrial cooling, refrigeration, and freezing systems serving stationary applications in agriculture, food sales, foodservice, commercial kitchens, laboratories, cold storage warehouses, refrigeration and freezing systems for food, materials, pharmaceuticals, and other manufactured product applications. It also includes refrigerated transportation distribution from manufacturing facilities and packaged refrigeration systems.

Research Initiatives

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Natural refrigerant and low-GWP refrigeration systems, including non-vapor compression technologies (new and retrofit applications)				
Thermal energy storage systems and demand shift/management				
Natural refrigerant and low-GWP refrigeration system modeling tools				
Refrigerant management, leak detection, and monitoring				

KEY  High Needs  Medium Needs  Low Needs  Future Needs

Opportunities

Commercial and industrial refrigeration has many opportunities for enhancements and improvements via CalNEXT, as identified:

- Adaptive controls to enable dynamic load shifting and peak demand reduction.
- Controls optimization and using reclaimed heat to aid in decarbonization.

- Phase change materials (PCMs), thermal energy storage systems, improved envelope design, and pre-cooling strategies to reduce refrigeration loads.
- Integrating waste heat recovery and dehumidification with CO₂ systems.
- Controls and thermal energy storage that enable load shifting to align with solar generation, grid carbon intensity, and lower-cost periods.
- Low-GWP and natural refrigerants to support regulatory compliance, such as for the Environmental Protection Agency or CARB, and emissions goals through pilot projects, field demonstrations, and energy modeling to validate performance and accelerate market transformation.
- Support new standardized measures to streamline adoption and scale impacts.

Barriers

Commercial and industrial refrigeration also faces a number of barriers, as identified below:

- New technologies, research and development costs, and system integration complexity all slow market uptake.
- Site-specific customizations make scalability and replicable installations difficult.
- Technical and performance data for emerging systems is limited or unvalidated.
- Lack of standardized baselines and insufficient industry data impede program design.
- Technician shortages and lack of training on new refrigerants and systems hinder deployment.
- Compliance with refrigerant safety codes adds complexity and cost.
- Investor-owned utility (IOU) reliance on custom incentive pathways limits scalability.

Related CalNEXT Projects

- ET24SWE0040 – CO₂ Chiller for Agricultural Sector
- ET24SWE0054 – Refrigeration Capacity Load Matching
- ET24SWE0046 – Modeling CO₂ System Refrigeration Loads
- ET24SWE0034 – Lab Grade Refrigerators and Freezers Measure Package Development
- ET24SWE0016 – Large Ultra-Low Temperature Freezer Measure Offering
- ET23SWE0046 – Field Assessment of Refrigerated Display Cases Air Curtain Guiding Vanes
- ET23SWE0056 – High Efficiency Refrigerated Display Case
- ET22SWE0054 – Foodservice Refrigeration: High Efficiency Condenser and Evaporator Units Focused Pilot
- EPRI proj ID 1-112820 ET22SCE0008 – Efficient Load Flexibility in Small Food Stores using AI Technology
- ET21SCE0011 – Low-GWP Refrigerant New Construction Energy Impact Case Studies
- ET21SCE0012 – Low-GWP Refrigerant Remodel Energy Impact Case Studies
- ET21SCE1010 – CARB, NASRC and SCE M&V Evaluation of Low GWP Supermarket Refrigeration Systems

Advanced Motors

ETP Role: Collaborate | ETP Priority: Medium

Definition

The Advanced Motors technology family is focused on advancing electric motors and drive systems that exceed the National Electrical Manufacturers Association premium efficiency standards, with a strong emphasis on enhancing advanced electric motor technology market awareness, increasing equipment stocking and adoption, and supporting scalability.

Research Initiatives

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Motor controller (variable frequency drive) requirements for the different advanced motor designs				
Differentiate and catalog advanced motor options				
Load profile of common electric motor loads to optimize motor selection				
Supply chain readiness, non-original equipment manufacturer				

KEY  High Needs  Medium Needs  Low Needs  Future Needs

Opportunities

A recent Lawrence Berkeley National Laboratory (LBNL) motor market assessment estimates an annual United States energy savings of 482,000 GWh per year.⁵ The savings opportunity of adopting advanced motors is not well known in the marketplace, and as such, this technology family has tremendous energy savings opportunities:

- California-specific market research to identify the market share, availability, and applicability of advanced motors.

⁵ For more information, see: <https://motors.lbl.gov/>

- Research to better understand key market actors and the customer experience, the contractor experience, and current relevant manufacturer and supplier activities.
- Seek out opportunities to educate distributors and train contractors.
- Document the full spectrum of benefits associated with advanced motors.
- Demystify the variable frequency drive (VFD) product requirements for different advanced motor technologies and the commissioning needs to ensure high performance.
- Quantify the technology economics and cost-effectiveness of advanced motors.
- Some motors, such as IE4, can operate without a VFD; the efficiency gains observed in the field often exceeded expectations.

Barriers

While advanced motors have secured a foothold in the United States primarily as components within OEM equipment at a 1.5 to 2 percent market share, there are significant market barriers preventing widespread adoption:

- Substitution for standard induction motors may require additional controls or engineering support to work properly with a new VFD.
 - The California IOUs found 13 advanced motor case studies and identified 9 advanced motors from 5 manufacturers that can be substituted for traditional induction motors; they also provided detailed comments on a recent standards rulemaking.⁶
- However, common practitioner knowledge still lags the technical opportunity, as does program activity within California. Many consumers are not aware of the higher-efficiency options or are reluctant to use a new product over a familiar technology with a much simpler replacement process.
- Advanced motors are not currently regulated by NEMA, which makes it difficult for consumers to directly compare these advanced options with standard induction motors.
- While manufacturers of motor-driven equipment like pumps and fans are incorporating advanced motors and drives into new equipment designs, it is unclear how these motors will be replaced in the future or how existing equipment packages can be retrofitted with these advanced motors, as the supply channels are not well understood by utilities.

Related CalNEXT Projects

- ET23SWE0065 – Central HVAC Advanced Electric Motor Lab Evaluation
- ET23SWE0068 – Advanced Motors Channel Partner Support and Measure Package Development

⁶ For more information, see: https://downloads.regulations.gov/EERE-2020-BT-STD-0007-0030/attachment_1.pdf

Pumping Systems

ETP Role: Collaborate | ETP Priority: Medium

Definition

This technology family is focused on a holistic approach to design and optimization advancements of all pumped liquid systems across process-based market segments, aimed at achieving peak efficiency and demand flexibility.

Note: Depending on the project scope, prospective projects related to pumping systems may fit better under the Advanced Motors technology family within the Process Loads TPM, or pool heating and circulation within the Water Heating TPM.

Research Initiatives

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Application of pump controls for water distribution systems for commercial, agricultural, and industrial end uses.				
Expand Pump Energy Index (PEI) awareness for pumps for industrial, commercial, and agricultural customers. Help them understand savings potential of PEI pumps.				

KEY  High Needs  Medium Needs  Low Needs  Future Needs

Opportunities

Pumping systems are among the largest family of electricity consuming systems in the commercial and industrial sector and are generally well understood and broadly used across market segments. Transmission, distribution, and pressurization of clean water makes up 7 percent of the total net energy use in California, and the following opportunities can help meet CalNEXT's goals of improving the TSB:

- Nominal improvements in pump design efficiency and appropriate use of specific pumps based on the needs of the system can produce grid-wide energy savings.
- Advanced pump designs can be paired with advanced motors to achieve greater energy efficiencies in conjunction with advanced pump monitoring and data analytics.

- These systems can provide optimized operation and control response beyond the standard practice of variable speed, volume, or pressure sensing technology.
- Improving market understanding of the PEI metric through education and outreach could also help end users select more efficient options.
- Technologies impacting pump demand—including end-use management, dynamic setpoint feedback controls, and other advanced load management controls—will improve overall pump system performance and responsiveness during grid events.
- Tangential technologies that fit into this TPM include energy recovery turbines, revised system designs to reduce pump discharge head pressure requirements, and greenfield systems designed to use static head pressure from gravity in place of pumps.

Barriers

The technical performance of pumps and pumping systems is generally well understood and there have been national EE standards covering most pumps since 2020. These standards introduced the PEI, a performance metric that has since been adapted for the California Electronic Technical Reference Manual (eTRM).⁷ However, there are still certain barriers to efficient pumps:

- Market knowledge contextualizing lifecycle costs to PEI may be less developed. While there is significant potential for energy savings via advanced pumping solutions, facility operators—and by extension, customers—have shown reluctance in adopting these newer pumps.
- For critical process or infrastructure systems, such as process pumps in a refinery or a potable water distribution pump, energy efficiency may be a secondary or tertiary consideration, with reliability and performance taking priority.
 - Risk-averse operators may be more open to switching to more efficient systems when reliability and lower operating costs can be effectively demonstrated.

Related CalNEXT Projects

- ET22SWE0031 – Wastewater Treatment SB1383 Compliance Characterization
- ET23SWE0019 – Onsite Wastewater Treatment and Process Water Recycling Systems for Ag Dairy Farms
- ET23SWE0039 – Wastewater Pump Measure Development
- ET24SWE0038 – Water and Wastewater Pump Replacement Industry Standard Practice & Measure Package Update
- ET25SWE0019 – Agricultural Sector Adoption of PEI Pumps Market Study

⁷ For more information, see: <https://www.caetrm.com/measure/SWWP004/02/>

Process Air Systems

ETP Role: Collaborate | ETP Priority: Low

Definition

The Process Air Systems technology family focuses on equipment that alters air flow or pressure for the purpose of using air as a working fluid. This includes blowers and fans that may be used to transport heat, fumes, or particulate, and air compressors and vacuum generators used to modify air pressure to perform useful work. This technology family also includes: 1) treatment of air streams using separators, filters, and dryers; 2) air distribution infrastructure such as ducts, pipes, fittings, and storage; and 3) control devices used to manage air pressure or flow.

Research Initiatives

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Compressed air system monitoring and controls				
Compressed air system modeling and sizing tool				
Vacuum systems				

KEY  High Needs  Medium Needs  Low Needs  Future Needs

Opportunities

The CalNEXT team identified the following opportunities for compressed air systems:

- System configurations should be updated to use more aerodynamic blade designs, low blade rotational speeds, and larger blade lengths that have a higher fan efficiency and use less energy.
- Part-load efficiencies can be improved by using sensors combined with a VFD to control the fan or blower speed instead of throttling devices.
- Motor loads can be further lowered by reducing frictional losses in the ductwork and isolating intermittent system users with blast gates or louvres.
- Tools for right-sizing compressed air plants that may have been excessively oversized for redundancy and projected future expansion.
- The use of low pressure drop air treatment equipment, efficient dryers, adequate receiver volume, proper sequencing, engineered nozzles, and leak repairs are well documented.
- Compressed air distribution systems are often undermaintained and overlooked when it comes to reducing energy use.

- There is an energy savings opportunity in improving outreach and education for compressed air system operators and users about the inefficiencies in compressed air systems.
- Installing and automating solenoid valves that shut off air when not needed can also dramatically reduce compressed air system energy use, in addition to optimizing end-use demands.
- Improving access to affordable leak audits would increase the likelihood of improved system maintenance, but only if repairs are promptly performed. Research should therefore be focused on training programs and technologies that lead to lower air demands and higher system efficiencies.

Barriers

Industrial air systems are well understood from a technical perspective, as the product category has been federally covered since 1992; additionally, the standards were updated following a finalized test procedure in May 2023.⁸ However, the team identified several barriers to adoption of efficient process air systems:

- The new test procedure codifies the Fan Energy Index as a new performance metric that has been adopted in the California Energy Code and the ASHRAE Standard 90.1, but has not yet been adapted for programs in the eTRM.
- The primary barriers to upgrading existing systems are the lack of practitioner expertise within industrial facilities and the relatively high capital replacement costs.
- To inform industry standard practices, the team recommends investigating programs focused on improving code compliance and supporting the transformation of existing underperforming systems.
 - California utilities have been active in developing industrial energy codes—Title 24, Part 6—for compressed air systems, first developing and introducing requirements into the 2013 version, and most recently developing updates for the 2022 version.
- Facilities would benefit from an expansion of maintenance programs to identify, locate, and fix leaks within their distribution systems or the deployment of technological solutions to automatically alert facilities staff to leaks or other system performance issues.
- Developing succinct guidance on the limits imposed by non-energy related codes and standards as it relates to process air systems would therefore help system operators navigate energy saving system improvements while ensuring they stay within regulatory compliance.
 - In addition to the California Energy Code Title 24, Part 6, there are other governing bodies and standards for process air systems, including those related to occupant and operator health and safety. For example, fan or blower speeds for a process air system may be restricted by the National Fire Protection Association or Occupational Safety and Health Administration standards, of which customers may not even be aware.

Related CalNEXT Projects

- ET22SWE0045 – Compressed Air End-Use Air Management System

⁸ For more information, see: <https://www.regulations.gov/document/EERE-2021-BT-TP-0021-0046>.

Process Heating Technology

ETP Role: Observe | ETP Priority: Medium

Definition

The Process Heating technology family focuses on processes that dry raw materials, preheat process equipment or materials, and cure or stabilize produced goods. This applies to manufacturing processes for chemicals, plastics, glass, and more, as well as to agricultural process heating. This may include but is not limited to steam and hot water systems, such as electrically heated hot water and steam generation systems; electrification of steam and hot water heating systems traditionally fueled by natural gas; and the ancillary equipment and optimization of downstream end uses, such as steam trap fault detection devices. Heat recovery technologies are also included in the Process Heating technology family.

Note: This technology family excludes process heating used in commercial and residential steam and hot water, as well as heating for foodservice equipment, which are covered in other technology family TPMs.

Research Initiatives

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Industrial heat pump technologies				
Heat recovery technologies				
Advanced controls for energy savings				
Electrification of high temperature processes				

KEY  High Needs  Medium Needs  Low Needs  Future Needs

Opportunities

Over the last three decades, many industrial processes switched power sources from electricity to natural gas due to lower energy costs. There are now significant decarbonization opportunities in capturing the GHG reduction benefits of a cleaner grid:

- Currently, much of the focus of electrification initiatives does not include the industrial sector, which is a significant consumer of natural gas and energy.
- Applications that use electric resistance or natural gas for drying, preheating, and production could realize EE opportunities to improve performance and decarbonize from natural gas—for example, gas drying could be replaced with industrial microwave dryers or heat pumps.

- Variable load processes could benefit from controls, including demand flexibility integration.
- Hot water systems could have pumped storage to assist with demand flexibility.
- Energy efficiency projects should target scalable and generalizable electric heating improvements that reduce or eliminate unneeded heating. This includes controls, equipment design, insulation, heat recovery, and combinations of these with operational modifications and production timing.
 - Heat recovery technologies include mechanical vapor recompression, which captures savings in steam generation and gas savings.
- Adoption of heat pumps for applications of greater than 70 °C will require higher temperature delivery than can be provided by typical commercial HVAC equipment.
- Many low-temperature hot water end uses could be electrified using commercially available technologies.
 - However, cost effectiveness has not yet been proven in many scenarios within California. Successful demonstrations of cost-competitive industrial heat pumps in California will support the nascent US industrial heat pump market.
- There are many optimization strategies process heating could benefit from, including improved pipe insulation, appropriately sized heating coils, leak mitigation strategies such as automated fault detection diagnostics, and incorporating advanced controls.
- Heat pumps and heat recovery chillers can provide process heating more efficiently than fossil fuel combustion or electric resistance systems and have the potential to recover waste heat from nearby cooling loads.
- High-temperature water and steam systems are already being deployed in international markets, with the International Energy Agency's Annex 58 highlighting promising demonstrations of this technology.⁹
 - The US market remains in an early piloting pre-commercial phase. Increased federal funding from both the Infrastructure Investment and Jobs Act and the Inflation Reduction Act will bolster the commercialization of industrial heat pump technology to help address this market gap. State policies, such as the recent CPUC Decision 23-04-035 to phase out utility gas incentives,¹⁰ further demonstrate broad interest in developing the industrial heat pump market.
- Considering California's goal of deploying dynamic pricing by 2030, along with continued large-scale renewables build-outs, there will be opportunities for low electric energy costs.
 - Projects that investigate energy efficiency and fuel switching to electric heating technologies could include consideration of time-of-use rate structures and localized renewable generation resources.
 - Additionally, special utility rate considerations for electrification technologies providing GHG benefits could prove helpful in increasing market adoption.

⁹ <https://heatpumpingtechnologies.org/annex58/>

¹⁰ <https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M505/K808/505808197.PDF>

- There is an opportunity to address the demand charges and time-of-use costs that severely impact industrial end users by developing processes and programs that directly help those industries cope with higher and less predictable energy costs while boosting efficiency, demand flexibility, and decarbonization.
- Field studies for low cost, deployable technologies should be evaluated for scalable program integration, including technologies such as waste heat recovery, controls, and automated fault detection and diagnostics.

Barriers

Modern electric resistance heating equipment and controls provide accurate temperature control. However, these barriers to adoption must still be overcome:

- Energy cost is a key barrier to converting from natural gas to electric heating.
- Industry perceptions based on old technology control challenges persist.
- Process heating systems are primarily designed for natural gas-fueled supply equipment, in part due to the higher associated operating temperatures. As a result, the market understanding of efficient electrified heating is in an early stage, and it is expected that both designers and facility managers will be reluctant to switch to electric equipment without significant incentive support and specialized electric rates.
- Technology and fuel-switching-related deployment costs are high due to the relatively low industrial process market saturation.
- Process heating industries are also generally slower to change due to the high costs of retrofitting the manufacturing process and adopting innovative technologies.

Related CalNEXt Projects

- ET23SWE0036 – Industrial Heat Pump Market Study
- ET23SWE0062 – Craft Brewery Industrial Heat Pump Screening Tool
- ET23SWE0070 – Industrial Microwave Technologies Market Study

Next Steps

Following submittal of the 2025 Process Loads TPM, the program team will:

- Update the CalNEXT website with new 2025 Process Loads TPM and this final report.
- Launch an email announcement through email outreach.
- Develop and submit the distribution report.

Appendix A: Advisory Committee Feedback and Resolution Matrix

Table 3: Advisory Committee feedback and resolution matrix.

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Controlled Environment Horticulture	Definition	Any rationale for why this was done would be helpful for the reader even if it's in a footnote, especially this seems to be the opposite approach compared to the commercial kitchen category.	The note was outdated and has been deleted; there used to be a separate lighting TPM which has been rolled up under a new "Lighting, Plug Loads, and Appliances" TPM, but per the summary paragraph, horticultural lighting is now considered a process load.
Controlled Environment Horticulture	Opportunities	For opportunity 10, interesting concepts. Any case studies that can be cited?	DOE, LBNL, and Resource Innovation Institute are working on a project related to this topic that should be published in September 2025.
Controlled Environment Horticulture	Barriers	For barriers in general, what about high real estate costs and escalating electricity rates? With higher and higher rates, justifying EE and demand flexibility operating cost savings will remain a major barrier for CEH measures. And high operating costs in turn make it harder to justify CEH relative to other potential land/building uses, given the high cost of real estate.	Added the following two bullets to the end of the barriers section: • High real estate and operating costs make it difficult for CEH businesses to compete with other potential land and building uses, raising the bar for profitability and investment in efficiency. • Escalating electricity rates strengthen the case for efficiency measures but present a barrier to electrification and decarbonization projects, which may increase operating costs in the near term.

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Controlled Environment Horticulture	Related CalNEXT Projects	It would be super helpful to somehow number or tag these and associate them with the various bullets above, so the reader knows which projects to look into for more details on specific ideas/topics.	This idea is good, but the opportunities and bullets don't necessarily correlate to specific projects, and one bullet may reach multiple studies and one study may cover multiple bullets. For the sake of readability, we'll keep this unchanged this cycle but will look into better correlating past reports to updated TPMs.
Refrigeration, Commercial & Industrial	Opportunities	For opportunity three, "shift or flex"? and "demand"?	Shift or flex are both related to demand so not sure what the question is asking. PCMs: mainly demand (load) shift; TESS: could be load shift or load flex; improved envelope design: demand reduction; pre-cooling strategies: load shift.
Refrigeration, Commercial & Industrial	Opportunities	For opportunity seven, complexity acknowledged as a barrier below?	It's true that the lack of established measures are available (the opportunity) is not called out as a barrier related to the system complexity, there are a number of other barriers that would need to overcome first for a measure package to be developed and help with widespread adoption.
Data Centers and Enterprise Computing	Research Initiatives	For research initiative two, this seems vague and should already encompass all the other rows listed. Consider rephrasing to make it more specific.	Agreed, RI has been deleted.

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Data Centers and Enterprise Computing	Opportunities	For opportunity five, can you elaborate on this - what types/characteristics of data centers are good candidates? Traditionally data center IT loads have been pretty flat over the course of a day/week, which does not make them well-suited for TES. However, AI workloads and others may have more variable loads. Does server utilization monitoring/control lead to more variable IT loads and therefore more TES opportunity?	We have expanded the opportunities bullets to include a reference to variable load data centers.
Data Centers and Enterprise Computing	Opportunities	For opportunity five, I suggest combining this bullet with demand response and making it called Demand Flexibility	Opportunities have been combined.
Data Centers and Enterprise Computing	Opportunities	For opportunity four, there are other ways for data centers to participate in DR in addition to this that may be more widely accessible.	Addressed by updating the bullet language.
Data Centers and Enterprise Computing	Opportunities	For opportunity three, do you have a source for this? Does it vary by data center type?	We have eliminated specific references to server utilization.
Data Centers and Enterprise Computing	Opportunities	For opportunity two, is this cooling equipment specifically?	Yes, language has been updated.
Data Centers and Enterprise Computing	Opportunities	For opportunity one, there are also electrical infrastructure losses.	Agreed, updated the bullet.
Data Centers and Enterprise Computing	Opportunities	To Hillary's point, I recommend adding electrical distribution as an area for an opportunity.	First bullet point has been reworded to include this point.
Data Centers and Enterprise Computing	General Narrative	Is there going to be a recommendations/next steps section added?	This is now updated to be part of the opportunities and barriers bullet list.

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Data Centers and Enterprise Computing	Barriers	Potential barrier would be the attitudes of data center developers (output #1, security and resiliency #2 and #3, efficiency and cost are low priorities compared to other industries)	Added as a barrier.
Data Centers and Enterprise Computing	Barriers	For barrier one, not sure how this content fits beneath the first bullet about retrofit guidance for smaller data centers	Barrier has been updated to reflect this.
Data Centers and Enterprise Computing	Barriers	For barrier two, curious how you believe code compliance is a barrier to liquid cooling!	Removed code compliance as an issue.
Data Centers and Enterprise Computing	Barriers	For barrier three, have you found examples of this being implemented commercially? This also creates situations of very lightly loaded (inefficient) data centers when not in use; if this idea is explored in more detail, the full impact of this load shifting approach should be considered (operational energy/carbon impacts, additional infrastructure costs, water use, etc.).	Removed the bullet which added confusion; simplified the barrier bullet.
Process Air Systems	Research Initiatives	What about vacuum systems? For example, in R&D settings, high tech manufacturing, food processing, or biotech applications.	RI has been added.
Process Heating Technology	Research Initiatives	For research initiative two, does this include mechanical vapor recompression (e.g., for food processing applications)? I've reviewed projects where this was successfully implemented for tomato processing, with significant steam/gas savings in PG&E's service territory.	Yes, and this has been expanded upon in Opportunities under Bullet 5.

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Process Heating Technology	Opportunities	Do you mean the CA grid? While coal's contribution may have been significant in the mid-90s (maybe up to 20%), a significant portion even then was from imports from out of state rather than coal plants in CA—and I wouldn't consider 20% a "dominant" contribution regardless. Consider rephrasing or removing the parenthetical text so this isn't misleading.	Thank you for clarifying. The statement has been corrected for accuracy.
Overall report	General	This report presents preliminary findings from the 2025 Process Loads Technology Priority Map (TPM), focusing on energy efficiency, decarbonization, and demand flexibility across various commercial and industrial process load technology families. It highlights research initiatives, barriers, and opportunities for advancing energy solutions in California's evolving energy landscape. Controlled Environment Horticulture (CEH), Commercial Kitchens, Process Heating Technology, and Data Centers have the highest energy intensity than other building types. They offer strong potential for energy savings and decarbonization, but high costs including implementation costs may hinder wide adoption. In contrast, Advanced Motors, Pumping Systems, and Process Air Systems can yield significant savings at lower costs with improved controls. These technologies support PG&E's goals of boosting energy efficiency, grid stability, demand management, and sustainability. We recommend that further life-cycle cost analysis	Thank you for the feedback.

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
		considering incentives and implementation costs for the technologies be performed to help guide California IOUs' prioritization of potential measure packages for incentive programs. For instance, advanced motors and refrigeration (commercial & industrial) may benefit from code updates, pumping systems and process air systems (including blowers, fans, compressors, vacuum generators, air treatment, distribution, and control devices) from custom or deemed measure packages, and kitchen equipment from both new measure packages and future standards.	