2024 Process Loads TPM -DRAFT VERSION

The 2024 Process Loads TPM finalized update will be live on 1/1/2025. This copy serves to allow the public to prepare submissions ahead of time against the updated revisions. Any Process Loads ideas submitted between now and 12/31/2024 will apply against the 2023 updates.

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September 1, 2024

Acknowledgements

This Process Loads Technology Priority Map (TPM) was developed by the Process Loads Subject Matter Expert (SME) Team of the CalNEXT Program, which is responsible for the production of this document, background research, stakeholder engagement of the Technical Advisory Committee, and management of the TPM development process. We thank the Process Loads SME team members, our facilitation team for their contributions in this process:

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Abbreviations, Acronyms, and Glossary of Terms

Acronym	Meaning
AC	Alternating Current
ADLD	Automatic and Dynamic Load Detection
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
CA	California
CARB	California Air Resources Board
CEC	California Energy Commission
CEH	Controlled Environment Horticulture
CDC	Center for Disease Control
CPAP	Continuous Positive Airway Pressure
CPUC	California Public Utilities Commission
DAC	Disadvantaged Communities
DER	Distributed Energy Resources
DERMS	Distributed Energy Resource Management System
DH&C	District Heating and Cooling
DOE	Department of Energy
EE	Energy Efficiency
ET	Emerging Technology
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FDAS	Flexible Demand Appliance Standards
GHG	Greenhouse Gas Emissions
HP	Heat Pump
HTR	Hard-to-Reach
HVAC	Heating, Ventilation, and Air Conditioning
IEPR	Integrated Energy Policy Report
IOU	Investor-Owned Utility

Acronym	Meaning
LBNL	Lawrence Berkely National Lab
NOx	Nitrogen Oxide
NREL	National Renewable Energy Lab
PPLs	Plug and Process Loads
RASS	Residential Appliance Saturation Study
SCE	Southern California Edison
SME	Subject Matter Expert
SPUR	San Francisco Bay Area Planning and Urban Research Association
TPM	Technology Priority Map
TWh	Terawatt Hour
VRF	Variable Refrigerant Flow
WH	Water Heating

Glossary	Meaning
Technology Category	One of six broad technology categories (e.g. Whole Buildings, HVAC, Water Heating (WH), Lighting-Plug Loads & Appliances, Process Loads).
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 explaining if each research initiative is at a level of high understanding, research in progress, immediate needs, or future research needs.
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. *Note: Roles will change as research is completed.*
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 programs to take lead in unlocking these opportunities.
CALNEXT Priority	Communicates expected level of focus by CalNEXT SMEs. *Note: Priorities will change as research is completed.*
High Medium Low	"High" - CalNEXT SME team has highlighted this technology family as having high impacts within the Technology Category. "Medium" - CalNEXT SME team determined this technology family has moderate overall impacts within the Technology Category. "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 a framework to externally communicate priorities of the program, clearly define the central focus areas of the program, and assist with project screening. They will document the impact potential, programmatic research needs, and market readiness of all technology families across each of the end-use technology areas. The TPMs will drive product ideation and inform project selection. This Draft Report covers the revision process for the 2024 Process Loads TPM.

2024 TPM Changes

Table 1 shows how content from the 2023 TPM technology families appears under new technology family headings in this 2024 revision. Within the original 2024 Process Loads TPM, there are also instances where several technology families have been dispersed into various 2024 technology families, as shown below by the arrow pathways.

Table 1: Technology Priority Mapping

2023 Process Loads TPM Technology Families	2024 Process Loads TPM Technology Families
Advanced Motors	Advanced Motors
Pumping Systems	Pumping Systems
Water Systems	
Process Air Systems	Process Air Systems
Smart Manufacturing and Controls	REMOVED for 2024
Process Heating	Process Heating
Steam & Hot Water Systems	
Food Processing	Integrated with respective cross-cutting technology families
Controlled Environment Horticulture	Controlled Environment Horticulture
Commercial Kitchens Decarbonization	Commercial Kitchens Decarbonization
Refrigeration – Commercial	C&I Refrigeration

2023 Process Loads TPM Technology Families		2024 Process Loads TPM Technology Families
Refrigeration - Industrial		
Data Centers and Enterprise Computing	→	**Data Centers and Enterprise Computing**
Lab & Hospitals		**Moved to HVAC and Plug Loads TPMs**
Off Road Fleet Charging		**Moved to Code Readiness Efforts**

Legend: Minor content revision ⇒ **Major content revision and restructuring** →

The Process Loads category has seen revisions aimed to further clarify and expand the program definitions and priorities for prospective participants. Current technology family definitions, opportunities, and barriers were revised where appropriate for every technology family in this TPM. Notable drivers include passage of the Inflation Reduction Act (IRA) of 2022 which continues 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 metric shows implications for demand flexibility. These changes were reflected in different ways in the 2023 TPM update.

A key lesson learned by the project team from 2023, is to consider overlap between technology families. The team was able to consolidate many technology families this year due to the overlap in previous technology families. By looking at the proposals that came in, the team was able to make sensible consolidations where it made sense, such as refrigeration being consolidated to a single Commercial and Industrial, and culling TPM areas that did not have much traction and rolling them up into adjacent TPMs (such as water systems rolling up into pumping systems, as all water system proposals were related to pumping efficiencies rather than water treatment).This will allow stakeholders a simpler view at selecting and proposing topics. Furthermore, the cross-partner collaboration on tech families such as CEH where TRC runs the Agricultural program for PG&E was helpful from a stakeholder feedback perspective.

As for the 2024 TPM update, the CalNEXT Program Team established a robust process for this continuation of the TPM development and revisions. This year, the project team incorporated a stronger outreach push to ensure feedback, directly targeting these potential Deemed measure stakeholders from CPUC, SDG&E, CalMTA, Cascade, etc. 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 EE programs using technologies covered by the Process Loads TPM, and these emerging products are then contextualized into the priority maps through a markets and solutions lens. The team met four times between June and July of 2024 to revise this draft Process Loads TPM.

The SME team worked through a number of visual changes at the start of this revision process which can be seen below in the narratives of the preliminary findings report. These visual changes will serve for submitters and viewers to see what topics are of most interest in a given technology family and what is most important to progress within the portfolio, with an end goal of a simplified view. For example, the table in the Advanced Motors technology family has an initiative named, "Motor controller (VFD) requirements for the different advanced motor designs," and within this deliverable, there has been an addition of icons under each of the overhead criteria, the first two criteria, Performance Validation & Market Analysis are technology-driven, with the next two, Measure Development & Program Development being market driven. When a submitter views the table, the icons and their aided descriptions will help depict what categories projects are the most in need. The changes provide a visual summary of what topics are of most interest within a given technology family and to record the current state of progress. The end goal of these visual summaries is to have a clear representation of where the technology family stands in the portfolio and what remaining research is needed. The Research Initiatives table has a goal of describing what the three to five most important technology areas should be focused on with subsequent versions providing a simplified icon view of where the Process Loads portfolio stands for easier use and external understanding. To date, the majority of research projects take place within a handful of technology families which was a key driver in how the technology families were chosen in 2024.

Some major revisions to the Process Loads TPM is the consolidation of various Technology Research Areas (TRAs) and moving Labs and Hospitals to the Lighting, Plug Loads, and Appliances TPM, specifically in the Medical Equipment technology family, additionally, pushing Off-Road Fleet Charging to Code Readiness. The consolidation of TRAs was driven by proposals received by CalNEXT and sensible changes in light of the technology areas covered. For example, nearly all water systems proposals were related to pump improvements, so water systems is now a part of the advanced pumping TRA. Similarly, the decision to move Labs and Hospitals to Lighting, Plug Loads, and Appliances TPM was driven by the fact that a majority of energy savings for labs and hospitals fell under HVAC, Lighting, Plug Loads, and Appliances related savings.

The structure of the TPM Research Initiatives table was developed to ensure strong coordination among CalNEXT activities. Overall, the changes made in this 2024 TPM aim to focus on increased technology transfer broadly across our portfolio, allowing the CalNEXT team 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 better advance different technologies to the ultimate goal of portfolio savings.

Stakeholder Feedback

TPM Advisory Committee Outreach

The TPM Advisory Committee outreach began in July 2024, stakeholders that feedback was requested from via email, providing a Word document of the technology family narratives are listed below in Table 2. Any further stakeholder feedback conducted will be incorporated in the Final Report.

Table 2: Process Loads Advisory Committee Outreach

Organization
California Energy Commission (CEC)
Cascade Energy
CEC
California Market Transformation Administrator (CalMTA)
California Public Utilities Commission (CPUC)
Frontier Energy
Inner City Fund (ICF)
KW Engineering
SCE
San Diego Gas & Electric (SDG&E)
VaCom Technologies

This outreach conducted allowed advisory members to provide candid feedback with the opportunity to provide written comments and suggestions via a collaborative Word document hosted on Microsoft SharePoint. Suggestions were reviewed by the TPM coordinator, the Process Loads SME team, and incorporated into the Revised 2024 Process Loads TPM section below.

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 (NEMA) 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	Market Analysis	Measure Development	Program Development
Motor controller (VFD) requirements for the different advanced motor designs	⚠	⚠	⚠	⌛
Differentiate and catalog advanced motor options	⚠	⚠	⚠	⌛
Load profile of common electric motor loads	☝	☝	☝	☝
Supply chain readiness (non-OEM)	⌛	⚠	⌛	⌛

KEY 🎯High Understanding ⌛Research In Progress ⚠Immediate Needs ☝ Future Research Need

Opportunities

Advanced motors have tremendous energy savings opportunities. A recent Lawrence Berkeley National Lab (LBNL) motor market assessment estimates an annual United States (U.S.) energy savings of 482,000 GWh/year.[1] However, the savings opportunity of adopting advanced motors is not well known in the marketplace.

To develop this opportunity, CalNEXT ET activities should focus on: 1) California-specific market research to identify the market share, availability, and applicability of advanced motors; 2) research to better understand key market actors and the customer experience, the contractor experience, and current relevant manufacturer and supplier activities; and 3) opportunities to educate distributors and train contractors; 4) documenting the full-spectrum of benefits associated with advanced motors; and 5) demystifying the variable frequency drive product requirements for the different advanced motor technologies and the commissioning needs to ensure high performance operation.

Barriers

While advanced motors have secured a foothold in the U.S. at 1.5 – 2.0 percent, primarily as components within OEM equipment, there are significant market barriers preventing widespread adoption. Technologically, advanced motors are commercially available and, in some instances, directly substitutable for standard induction motors. Other instances may require additional controls or engineering support for the motor to work properly with an existing or new variable frequency drive. The California IOUs have found 13 advanced motor case studies and identified nine advanced motors from five manufacturers that can be substituted for traditional induction motors and provided detailed comments on a recent standards rulemaking.[2] 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.

In addition, 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 such as 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 motor retrofits as the supply channels are not well understood by utilities.

[1] https://motors.lbl.gov/

[2] 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 the 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	Market Analysis	Measure Development	Program Development
Hot water circulation pumps should be on timers set to building occupancy hours.	Immediate Needs	High Understanding	Immediate Needs	Future Research Need
Application of pump controls for water distribution systems for commercial, agricultural, and industrial end uses.	Immediate Needs	High Understanding	Immediate Needs	Future Research Need
Expand Pump Energy Index (PEI) awareness for pumps for industrial, commercial, and agricultural customers. Help them understand savings potential of PEI pumps.	High Understanding	Future Research Need	High Understanding	Future Research Need

KEY High Understanding Research In Progress Immediate Needs Future Research Need

Opportunities

Pumping systems are amongst the largest family of electricity consuming systems in the C&I sector and are generally well understood and broadly used across market segments. Transmission, distribution, and pressurization of clean water makes up 7% of the total net energy use in California.

Nominal improvements in pump design efficiency and ensuring 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. Understanding the market better to see if they have knowledge of Pump Energy Index performance metric and 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 increase potential to respond during grid events, as part of integrated load-management systems.

Technologies do not have to focus solely on pump efficiencies; relevant tangential technologies that can 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 Pump Energy Index (PEI); a performance metric that has since been adapted for the Electronic Technical Reference Manual (eTRM).[3] Market knowledge on 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. This may be in part due to a lack of familiarity and/or higher capital costs. A market assessment or a customer survey to get a better understanding of why this hesitancy exists is required.

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 the priority. Risk averse operators may be more open to switching to more efficient systems when reliability and lower operating costs can be effectively demonstrated.

Proposed studies or projects should incorporate research around the identified barriers to market adoption. Projects could focus around offering new and novel pump technologies, identifying lifecycle cost savings, or increasing productivity through better pump controls such as pressure or volume controls to vary pump drive frequencies.

[3] https://www.caetrm.com/measure/SWWP004/02/

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, etc. as well as to agricultural process heating. This may include, but not be limited to industrial steam and hot water systems such as electrically heated hot water and steam generation systems and electrification of steam and hot water heating systems traditionally fueled by natural gas as well as the ancillary equipment and optimization of downstream end-uses such as steam trap fault detection devices. Heat recovery technologies are included as part of 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 food service equipment which are covered in other technology family TPMs.

Research Initiatives

Research Initiatives	Performance Validation	Market Analysis	Measure Development	Program Development
Industrial Heat Pump Technologies,	Immediate Needs	High Understanding	Future Research Need	Future Research Need
Heat Recovery Technologies	Immediate Needs	Immediate Needs	Future Research Need	Future Research Need
Advanced Controls for energy savings	Immediate Needs	Immediate Needs	Future Research Need	Future Research Need
Electrification of High Temperature Processes	Research In Progress	Research In Progress	Future Research Need	Future Research Need

KEY High Understanding Research In Progress Immediate Needs Future Research Need

Opportunities

Over the last three decades, many industrial processes were switched from electricity to natural gas as a power source due to lower energy costs and sometimes due to perceived environmental benefit (where the grid was dominated by coal power plants). There is now significant decarbonization opportunity in capturing greenhouse gas (GHG) reduction benefits of a cleaner grid.

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, by replacing gas drying with industrial microwave dryers or heat pumps). Variable load processes could benefit from controls, including demand flexibility integration. Hot water systems could also have pumped storage to assist with demand flexibility. EE 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.

Other opportunities may include adoption of heat pumps for so-called “high temperature” (greater than 70°C) applications that 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 justified in many scenarios within California. Successful demonstrations of cost-competitive industrial heat pumps in California will support the nascent US industrial heat pump market. Other energy saving strategies include 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.

For high temperature water and steam systems, deployment is already happening in international markets with IEA’s Annex 58 highlighting promising demonstrations of this technology.[4] Meanwhile, the U.S. market remains in an early piloting pre-commercial phase. Increased federal funding from both the Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA) will bolster 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,[5] further demonstrate broad interest in developing the industrial heat pump market.

Beyond system electrification and energy efficiency, 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 diagnostics.

Barriers

Modern electric resistance heating equipment and controls provide accurate temperature control. However, industry perceptions based on old technology control challenges persist as a barrier to adoption. Currently, process heating systems are primarily designed for natural gas fueled supply equipment, in part due to the higher operating temperatures associated. As a result, 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/or specialized electric rates. Additionally, technology and fuel switching related deployment costs are high due to relatively low industrial process market saturation.

Many industrial processes are historically competitive on operational costs with respect to energy utilization and process improvement. Thus, high-quality EE manufacturing equipment will be expected to quickly advance to the general market. At this point, the greatest barrier to converting from natural gas to electric heating is energy cost. California has set a goal of deploying dynamic pricing by 2030 and with continued large-scale renewables build-outs, there will be opportunities with low electric energy costs. Projects that investigate EE and fuel switching to electric heating

[4] https://heatpumpingtechnologies.org/annex58/

[5] https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M505/K808/505808197.PDF

technologies could include consideration of the Time-of-Use (TOU) rates structures and localized renewable generation resources.

Industries are also generally slower to change due to the high cost of retrofitting the manufacturing process and adoption of innovative technologies. However, these industries have also been impacted by high commodity costs, which presents opportunities for testing novel controls that limit demand charges and TOU costs and warrant further exploration for high-temperature thermal energy storage leveraging deployment during peak expense TOU periods. There is additional opportunity to address the demand charges and TOU 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.

Process Air Systems

ETP Role: Low | ETP Priority: Collaborate

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 which 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	Market Analysis	Measure Development	Program Development
Compressed air system monitoring and controls	⌛	🎯	⚠	👆
Compressed air end-use management system	⌛	🎯	⚠	👆

KEY 🎯 High Understanding ⌛ Research In Progress ⚠ Immediate Needs 👆 Future Research Need

Opportunities

There are opportunities with blowers and fans to use 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 utilizing sensors combined with a variable frequency drive to control the fan or blower speed instead of throttling devices. Motor loads can be further lowered by reducing frictional losses in the duct work and isolating intermittent system users with blast gates or louvres.

For compressed air, energy savings resulting from the use of low pressure drop air treatment equipment, efficient dryers, engineered nozzles, and leak repairs are well documented. Compressed air distribution systems are often undermaintained and overlooked when it comes to reducing energy use. Improving outreach and education for compressed air system operators and users about the inefficiencies in compressed air systems presents an energy savings opportunity. Installing and automating solenoid valves that shut off air when not needed can also dramatically reduce compressed air system energy use. 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

Technical understanding of industrial fans are mature, having been federally covered since 1992, and standards have been updated following a finalized test procedure completed in May 2023.[6]The new test codifies the Fan Energy Index (FEI) a new performance metric that has been adopted in the California Energy Code and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1, but has not yet been adapted for programs in the eTRM.

Technical understanding of compressed air systems is also mature, and technical barriers to EE opportunities are minimal. The primary barriers to upgrading existing systems are the lack of practitioner expertise within industrial facilities and the relatively high capital replacement costs. California utilities have been active in developing industrial energy codes (Title 24, Part 6) for compressed air systems, first in developing and introducing requirements into the 2013 version, and most recently developing updates for the 2022 version. Programs focused on improving code compliance and supporting the transformation of existing underperforming systems should be investigated to inform industry standard practices. Aside from plant replacement, facilities would benefit from 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.

In addition to the California Energy Code (Title 24, Part 6), other governing bodies and standards exist for process air systems which customers must observe. Another important consideration are codes and standards 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 (NFPA) or Occupational Safety and Health Administration (OSHA) standards, of which customers may not even be aware. 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.

[6] https://www.regulations.gov/document/EERE-2021-BT-TP-0021-0046

Controlled Environment Horticulture

ETP Role: Medium | ETP Priority: Lead

Definition

A combination of lighting and non-lighting equipment used to produce agricultural products in controlled environment horticulture spaces. This includes the 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, and controls systems associated with maintaining environmental conditions for growing.

Note: Horticultural lighting is no longer covered by the horticultural lighting technology family (Lighting TPM).

Research Initiatives

Research Initiatives	Performance Validation	Market Analysis	Measure Development	Program Development
Advanced Environmental Controls and Equipment for CEH	⚠	⚠	Future Research Need	Future Research Need
Thermal Energy Storage	⚠	⚠	Future Research Need	Future Research Need
Performance Optimization and Demand flexibility options for CEH	⌛	⚠	⚠	Future Research Need
Performance Standards and Building Codes	⚠	⚠	⚠	Future Research Need

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

KEY ◎ High Understanding ⌛ Research In Progress ⚠ Immediate Needs ☝ Future Research Need

Opportunities

Controlled Environment Horticulture (CEH) is an emerging industry with intensive energy and water use. While there may be many low tech, low energy intensity greenhouses, recent estimates emphasize the impact high energy intensity greenhouses and indoor production facilities have on industry wide energy use. Recent studies estimate the energy use intensity of CEH at 9.3 to 27.9 kWh/ft^2 (100-300 kWh/m^2 per year) with increasing interest in adoption for production of conventional agricultural crops such as leafy greens and tomatoes. HVAC/D comprises a significant portion of the overall energy consumption, using 60 – 80 percent of the total energy use in greenhouse and 30 – 50 percent of total energy use in indoor vertical farming; with lighting systems consuming nearly the remainder. The most significant, proven opportunities for this technology family are for energy savings and demand flexibility.

Increased EE is the largest opportunity in this industry. The CEH market has seen rapid expansion, which resulted in a significant amount of inefficient system designs. Currently, most EE opportunities are implemented through deemed lighting measures, or custom HVAC/D savings programs, highlighting an opportunity for deemed EE measures to increase the scale of adoption of efficient HVAC/D products which are prevalent in most CEH facilities. While the recent wet winters in California have brought the state out of a drought, there remains long-term drought risk for the region as well as the related embodied energy impacts of water itself. Efficient fertigation controls and water reuse may become growing opportunities for energy savings.

Regarding lighting, key drivers of energy savings include increasing the efficacy and productivity of horticulture through optimization of system designs, controls, spectral light distributions, light source innovations, and reducing negative impacts from light pollution. While code requirements and efficiency standards are catching up on light source efficacy, the focus of horticultural lighting as an emerging technology should be on system design and controls to unlock largely untapped savings. Innovations in sensor and control strategies can maximize energy performance and demand flexibility by leveraging spectral tunability and harvesting daylight. Efficient and productive indoor growing enabled by horticultural lighting could also have both direct and indirect greenhouse gas reduction advantages over the open-field growing practices. Another non-energy benefit includes the potential of reducing light pollution when lighting is deployed with thermal blocking curtains in greenhouses.

Demand flexibility benefits can be added via scheduling-based system designs and powering the lighting system and /or HVAC/D systems from renewable energy, thermal storage, or embedded electrical energy storage. Increased demand reduction and demand flexibility from this technology family would have a significant impact on relieving the grid stress at the distribution level. Demand flexibility may become a significant opportunity but will be highly dependent on the appetite of growers to fluctuate indoor growing conditions (i.e. through manipulating vapor pressure deficit or daily light integral) and their ability to cost-effectively incorporate demand management strategies into common horticultural system design.

Opportunities also exist in codes and standards from the development of industry standards through organizations such as ASHRAE and ASABE, particularly in regard to performance standards of existing facilities. Sizing guides, test procedures, and commissioning guidelines specific to CEH HVAC/D systems would enable programs and codes to use uniform efficiency ratings for CEH HVAC/D systems. Finally, incorporation of solar photovoltaic (PV) production into greenhouses has a strong potential for agrivoltaics to help sites drive to net-zero, particularly when paired with heat pumps.

Barriers

Rapid expansion of indoor agriculture has resulted in inefficient system designs, a lack of targeted efficiency programs, and the need for systems with higher efficacy and greater power quality. Technical barriers are largely related to system design. There is a lack of clarity for designers and trusted tools for optimizing productivity and efficacy of horticultural lighting systems as well as limited understanding of the interactive impacts of schedule, space conditioning, HVAC/D, and watering rates. Lighting control strategies, including automatic spectral tuning and tracking daily light inregral, are still new concepts to most growers, and their performance is not well-quantified or accepted by growers. As such, controls are yet to be as widely built into horticultural lighting systems as their counterparts in architectural lighting. Spectral tuning, while not likely to generate additional energy savings, could serve as a catalyst to breaking down growers' hesitancy in adopting efficient light sources and controls by offering promising potential for higher crop yield. Market barriers for lighting and non-lighting systems include the lack of confidence due to uncertain cost-effectiveness, limited in-field evaluation of innovative technologies and controls, and lack of best-practice designs from experienced practitioners, considering both performance and cost.

While the individual technological components in HVAC/D are well established from development in other sectors, they remain in a nascent stage with respect to CEH. Standards bodies have yet to develop uniform horticultural HVAC/D testing methodologies or efficiency ratings to account for the different horticultural environments which severely limits market understanding. There are no sizing guides or commissioning guidelines specific to CEH HVAC/D systems like those available for conventional commercial HVAC systems. Additionally, the horticultural design industry lacks experienced practitioners of efficient systems. Workforce education and training (WE&T), as well as conducting research and collecting field data to validate scalable incentive programs is needed to support broader adoption of cost-effective, high-efficiency systems.

An additional barrier is a lack of energy use intensity data specific to California CEH. Without this data, building codes cannot develop a performance model for CEH facilities. Furthermore, lighting efficacy codes and standards are more effective at influencing new facilities, but there is a high number of existing facilities that will take more time and need more assistance to make that transition.

Research should focus on activities that help build knowledge for the industries (both growers and utilities), including:

Investigate 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, and design 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.

The 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. What is needed next, is to increase the use of those quantitative metrics by institutions.

Develop guidelines based on studies of difference in yields achieved with high intensity discharge (HID) lighting versus LED lighting and how PPE from the different lighting types may affect the overall cost/gram achieved.

Study how controlling the light intensity, spectral distribution, and/or environmental conditions to match a crop growth cycle, as well as to shift demand, can help growers develop strategies to adjust production, increase energy savings, and manage demand.

Study financial benefits and additional production values regarding the use of thermal energy storage on the HVAC/D needs in sealed greenhouses, particularly in an effort to decarbonize.

Conduct market research and lifecycle study to further inform the determination of industry standard practice and claimable program savings.

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

Commercial Kitchen Decarbonization

ETP Role: Collaborate | ETP Priority: High

Definition

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

Note: Commercial kitchen systems that are non-process loads 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. Also, 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	Market Analysis	Measure Development	Program Development
New electric FS equipment for gas equipment that historically had no electric alternative (woks, tandoor ovens, rack ovens, electric rotisseries)	⚠	⌛	⌛	⚠
Economics of FS electrification	⚠	⌛	⚠	⚠
HTR/DAC engagement on FS electrification	⚠	⚠	⚠	⚠

KEY ◎ High Understanding ⌛ Research In Progress ⚠ Immediate Needs ☝ Future Research Need

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. While current technologies exist to electrify many pieces of commercial cooking equipment, there are several commercial cooking equipment technologies that are still mainly gas technologies. In addition to equipment development opportunities, there are opportunities to quantify cost and demand impacts of electrification and resolve economic barriers associated with commercial kitchen decarbonization. The commercial foodservice industry in California is still dominated by gas-fired cooking equipment, presenting a large opportunity for decarbonization in this technology area.

With the CPUC Decision 23-04-035,[7] commercially viable electric alternatives for commercial kitchen cooking equipment will need to be developed, shifting CalNEXT focus for commercial kitchen equipment towards decarbonization. Within this growing topic of electrification, research should focus on demonstrating emerging electrified products such as electric woks and tandoor ovens as well as demonstrating and assessing the cost-effectiveness of deeper electrification retrofits at the full cook line level. Co-benefits of electrification, such as faster cleaning time, improved indoor air quality (IAQ), and reduced cooling and ventilation needs should continue to be validated, especially within existing facilities. For maturing technologies, CalNEXT should continue to conduct research that can feed into development of new deemed measures and standards development. Additional research should focus on resolving major industry barriers associated with commercial foodservice electrification, such as end-user reluctance to use electric cooking technology, incremental equipment cost, operating cost, and infrastructure cost upgrades. While the focus of this technology family will be on decarbonization/electrification, equipment with high EE potential will still be considered, 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.

Barriers

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

An additional barrier is that 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 rates 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.

Larger structural issues such as energy rates being misaligned with decarbonization efforts, tenant-owner split incentives, inability to conduct long-term facility planning, resistance from health departments, language barriers for many restaurant service professionals, thin profit margins within the restaurant sector, and resistance to electrified cooking. Potential barriers research should focus on developing case studies, educational opportunities, and design guidelines to familiarize market

[7] https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M505/K808/505808197.PDF

actors with all aspects of the fossil fuel transition. Cost analysis to identify costs to electrify and explore potential solutions to economic barriers will also be helpful projects in advanced commercial kitchen decarbonization. Most opportunities will be supported by resolving the major cost barriers associated with commercial kitchen electrification.

Refrigeration, Commercial & Industrial

ETP Role: Collaborate | ETP Priority: Medium

Definition

This technology family focuses on commercial and industrial cooling, refrigeration, and freezing systems serving stationary applications in agriculture, food sales, food service, commercial kitchens, laboratories, cold storage warehouses, and 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 Initiative	Performance Validation	Market Analysis	Measure Development	Program Development
Natural refrigerant condensing units (CO2, propane and other emerging natural refrigerants)	⚠	⚠	☝	☝
Low-GWP drop-in refrigerants for retrofit applications	⚠	⚠	☝	☝
Natural refrigerant (ultra-low-GWP) C&I refrigeration system modeling tools	⏳	⚠	☝	☝
Refrigerant management and leak monitoring, detection and mitigation	⚠	⚠	☝	☝

KEY ◎ High Understanding ⏳ Research In Progress ⚠ Immediate Needs ☝ Future Research Need

Opportunities

Commercial and industrial refrigeration lies at the nexus of energy efficiency, demand flexibility, and GHG reductions. Savings opportunities abound, with many existing products and methods widely used to improve efficiency. Emerging products and methods can further increase savings. Process integration — where waste heat from cooling may be utilized for heating uses thereby reducing cooling and heating demand (potentially by incorporating industrial heat pump application) - is a significant opportunity for savings, especially with natural refrigerant CO2 systems which operate at higher working pressures.

Refrigeration loads can also be reduced through enhanced envelope design, incorporation of phase change materials (PCMs), and adaptive controls for more precise load matching. PCMs can be pre-cooled to save energy using cooling towers, advanced evaporative cooling, and other methods. Advanced adaptive controls can optimize load shifting schedules and strategies dynamically, which would provide additional peak demand savings compared to traditional static setpoints.

On the supply side, modulating compressor controls and optimized suction and head pressures/temperatures should be implemented when possible. Multi-compressor and multi-suction systems could be employed when demand and/or operating temperatures vary widely. Additional opportunities for energy savings include condenser optimization with fan controls, water flow rates, parallel compression, passive and mechanical subcooling, multi-gas ejectors, improved heat rejection strategies, and temperature reset based on ambient conditions, including advanced sub-wet bulb evaporative cooling.

Demand flexibility opportunities are significant since the cooling in many cold rooms can effectively be shifted to periods outside of demand emergencies to periods with lower electrical demand costs, periods that coincide with onsite solar electricity production, and periods with lower grid electricity carbon intensity. Additionally, load shifting opportunities can be achieved with thermal energy storage.

Emerging low global warming potential (GWP) refrigerants and natural refrigerants are beginning to replace legacy refrigerants, in response to the EPA and CARB’s phase out of HFC refrigerants. Future studies should focus on gathering and evaluating data to help understand opportunities and barriers in support of market transformation, new measure characterization, and EE program development. Field demonstrations and lab testing of innovative technologies should seek to provide the industry with actionable and scalable results, as well as document best practices. As new refrigerants emerge, there is a need for pilot installations and energy modeling to evaluate changes in cooling capacity, energy performance, and operational standards. Research should explore charge size reductions, refrigerant recycling programs, and leak mitigation and monitoring strategies to help inform LCA and decarbonization opportunities. Finally, there is an opportunity to collaborate with other programs to create a clear pathway for technical and financial resources to support this broad transition and actualize the opportunities.

Barriers

Barriers include capital costs, safety concerns, regulatory challenges, changing product quality, retail sales, and workforce concerns. As OEMs chemical companies respond to federal regulations, equipment performance, energy impacts, and system applications for some new technologies are not well understood. New product costs are high to cover the research and development, slowing market adoption. Workforce training is needed as the refrigeration technician workforce shrinks alongside the need for new skills with low GWP and natural refrigerants. Opportunities to support training and certification for technicians with new refrigerant technologies should be considered to expand industry knowledge.

Market understanding, and in particular, standard industry practices, and technical performance of emerging technologies can be obscured by the site-specific customization needed for each implementation. For this reason, sales and maintenance are often limited to a short list of SMEs, specialized contractors. As a result, the value proposition and product risk concerns often may be derived from unvalidated tools, general manufacturer application guidelines, and a limited perspective of a SME contractor’s experience. To improve market understanding and technical performance, studies should establish and build on a common pool of knowledge of design, decision making, and implementation of new EE technologies to encourage development of small, specialized groups (inside or outside SME contractors) that can bridge knowledge gaps for the broader market. Additional emphasis should be given when studies include analysis, demonstration, and market feedback on systems that use ultra-low and natural GWP refrigerants.

Currently, IOU program intervention is limited to the custom incentive process, which frequently demands considerable investment in sub-metering and understanding industry standard practices for developing these applications. New programs should develop standardized baselines and measure programmatic impacts across delivery types. To enhance program intervention, studies should be conducted on industry standard practices for major industrial refrigeration processes.

Data Centers and Enterprise Computing

ETP Role: Collaborate | ETP Priority: Medium

Definition

The data centers and enterprise computing technology family focus on energy-using equipment related to the functioning of dedicated information technology (IT) facilities., This includes-the servers, storage, and networking IT equipment-as well as other typical equipment such as power distribution units (PDUs) and UPS, as well as specialized systems for airflow management and cooling.

Research Initiatives

Research Initiative	Performance Validation	Market Analysis	Measure Development	Program Development
Liquid Based Cooling Systems	Research In Progress	Future Research Need	Future Research Need	Future Research Need
Demand Side Management	Research In Progress	Research In Progress	Future Research Need	Future Research Need
Waste Heat Recovery	High Understanding	Immediate Needs	Immediate Needs	Immediate Needs

KEY High Understanding Research In Progress Immediate Needs Future Research Need

Opportunities

Data centers use significant amounts of energy, making up about 2 percent of electrical energy use worldwide and trending upward. IT equipment itself makes up the bulk of the energy use, accounting for nearly 60 percent of energy consumption, with the remainder used for cooling[10]. Most large IT equipment (storage, servers, LNE, UPS) now have ENERGY STAR® product labelling but there are no national EE standards for this equipment except for CRAC units although some are in the works. ARPA-E has an initiative on datacenter efficient cooling (COOLERCHIPS | arpa-e.energy.gov). ASHRAE has developed liquid cooling guidelines as well (Liquid Cooling Guidelines for Datacom Equipment Centers, 2nd Ed. | ASHRAE Store (accuristech.com). Open compute has guidelines for liquid cooling as well (ocp-liquid-cooling-integration-and-logistics-white-paper-revision-1-0-1-pdf (opencompute.org).

There is an opportunity for demand side management (DSM) to optimize resource allocation for under-utilized servers. Average server utilization rates are typically under 20 percent and automated software is available to make more effective use of existing servers as opposed to adding new servers.

There is a tremendous potential in energy savings of up to 95%[11] by utilizing liquid cooling compared to traditional CRAC. Aside from energy savings, liquid cooling also simplifies waste heat recovery. There are opportunities to utilize waste heat by co-location of data centers with district heating networks or other heating needs such as localized space heating or water heating. The use of thermal storage technologies has potential to unlock demand flexibility.

Barriers

Data centers are a well-researched area, especially traditional hot-aisle/cold-aisle CRAC/CRAH systems. Despite the prevalence of ENERGY STAR® products, there are no deemed rebate measures in this sector and no appliance standards (from DOE or Title 20) outside of CRAC units. Statewide water supply concerns are driving aversion to evaporative cooling in lieu of less efficient air-cooled systems. Meanwhile, ETs such as liquid based cooling face significant barriers to scale from code compliance, product availability, downtime concerns, and practitioner familiarity. Research to develop code compliance pathways for liquid-based systems will be beneficial to provide a viable pathway toward these scalable impacts. While server utilization monitoring has tremendous savings potential, it requires a monthly subscription making it difficult for standard program delivery models outside of BRO (Behavior, Retro-commissioning, and Operational).

Discussion

The next steps in finalizing the 2024 Process Loads TPM include:

- Work with SMEs to finalize priority and role for each technology family. The SMEs' assessment of each research initiative will feed into prioritization of technology families in the TPM.
- Incorporate feedback from both internal stakeholders and the TPM Advisory Committee outreach into the final draft of the Process Loads TPM, including highlighting any technology families to reinvestigate for the Focused Pilots TPM. Develop narrative statement and media copy in support of TPM dissemination efforts.
- Finalize and publish the Process Loads TPM.
- Note: Some of these steps will be conducted in parallel with one another.

The next deliverable, the Final Report, will resolve any feedback obtained by SCE or include additional feedback and resolution from other on-going stakeholder outreach.