2023 Process Loads Technology Priority Map

Final Report

ET23SWE0011

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Disclaimer

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Abbreviations, Acronyms, and Glossary of Terms

Acronym	Meaning
ACEEE	American Council for an Energy-Efficient Economy
ASHRAE	The American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASABE	The American Society of Agricultural and Biological Engineers
BIL	Bipartisan Infrastructure Law
BLDC	Brushless Direct Current
CalMTA	California Market Transformation Administrator
Cal TF	California Technical Forum
CARB	California Air Resources Board
CEC-EPIC	California Energy Commission - Electric Program Investment Charge
CESMII	The Department of Energy's Smart Manufacturing Institute
CHIPS	Creating Helpful Incentives to Produce Semiconductors Act
CPUP	California Public Utilities Commission
CRAC	Computer Room Air Conditioning
CRAH	Computer Room Air Handling
DER	Distributed Energy Resources
DOE	United States Department of Energy
DR	Demand Response
EC	Electrically Commutated
EE	Energy Efficiency
EMS	Energy Management Systems
EPA	Environmental Protection Agency
ET	Emerging Technology

Acronym	Meaning
ETCC	Emerging Technology Coordinating Council
ETP	Emerging Technology Program
eTRM	Electronic Technical Reference Manual
EV	Electric Vehicle
FARMER	Funding Agricultural Replacement Measures for Emissions Reductions
FDAS	Flexible Demand Appliance Standards
FPIP	Food Production Investment Program
GHG	Greenhouse Gas
GSA	General Services Administration
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
HTR	Hard-to-Reach
HVAC	Heating, Ventilation, and Air Conditioning
HVAC/D	Heating, Ventilation, and Air Conditioning / Dehumidification
IAQ	Indoor Air Quality
IEPR	Integrated Energy Policy Report
IIJA	The Infrastructure Investment and Jobs Act
IOU	Investor-Owned Utility
IT	Information Technology
IRA	Inflation Reduction Act
LBNL	Lawrence Berkely National Lab
LEED	Leadership in Energy and Environmental Design
LED	Light Emitting Diode

Acronym	Meaning
LGF	Lab Grade Freezers
LGR	Lab Grade Refrigerators
LNE	Large Network Equipment
NEEA	Northwest Energy Efficiency Alliance
NEMA	National Electrical Manufacturers Association
NFPA	The National Fire Protection Association
NMEC	Normalized Metered Energy Consumption
OSHA	Occupational Safety and Health Administration
PA	Program Administrator
PD	Positive Displacement
PDU	Power Distribution Units
PG&E	Pacific Gas & Electric Company
PMASynRM	Permanent Magnet Assisted Synchronous Reluctance Motor
PMSM	Permanent Magnet Synchronous Motor
PPE	Photosynthetic Photon Efficacy
PV	Photovoltaic
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SM	Smart Manufacturing
SME	Subject Matter Expert
SNAP	Significant New Alternatives Policy
SRM	Switched Reluctance Motor
SynRM	Synchronous Reluctance Motor

Acronym	Meaning
TAC	Technical Advisory Committee
TOU	Time-of-Use
TPM	Technology Priority Map
TWh	Terawatt Hour
UPS	Uninterruptible Power Supply
U.S.	United States
VS	Variable Speed
ZEV	Zero Emissions Vehicle

Glossary	Meaning
Technology Category	One of six broad technology categories (e.g., Whole Building, HVAC, Water Heating (WH), Plug Loads, Lighting, Process Loads).
Technology Family	Functional grouping that provides description of program role, opportunities, barriers.
Subgroups	Common examples to further describe each technology family.
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 the work and cost burden. "Collaborate" – CalNEXT is interested in collaborating and co-funding projects. "Observe" – CalNEXT will track progress but encourages external programs to take the 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.
Impact Factor	One of four broad impact areas (energy savings potential, demand flexibility potential, decarbonization potential, and other GHG impacts).
Impact Factor Ratings	A qualitative rating (High-Medium-Low) by the CalNEXT SME team on impact potential if technological advancements are made in key subgroups.
Knowledge Index	One of three types of knowledge areas (technical performance, market understanding, and program intervention) used to assess types of barriers studies necessary to obtain the stated impact potential.
Knowledge Index Rating	A qualitative rating (High-Medium-Low) by the CalNEXT SME team on the relative knowledge of most subgroups within a technology family. A higher rating means that the topic is well understood.

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 which will drive product ideation and inform project selection. This Final Report documents the revision activities, outreach activities, feedback, and adjustments related to the 2023 Process Loads TPM.

Background

The current Process Loads TPM was developed by CalNEXT in 2022 and can be found online at this link: https://calnext.com/resources/process-loads/.

Objectives

The 2022 revision of the Process Loads TPM included a significant reorganization of the technology families and subgroups to improve clarity and reflect significant changes in the market landscape compared to when the previous TPM was developed. This 2023 Process Loads TPM revision aims to improve clarity to program priorities for prospective participants by making updates to the current technology families and adding new technology families as appropriate.

Methodology

The CalNEXT Program Team established a robust process for TPM development. This started with the formation of the Process Loads TPM Subject Matter Expert (SME) Team, which was formed with 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 industrial and specialized commercial EE programs covered by the process load TPM as well as members who support the CA IOUs codes and standards program. The team met in three working groups eight times between May and July 2023 to develop this draft TPM. Table 1 identifies the list of participants.

Table 1: Process Loads TPM Subject Matter Experts & Facilitators

Name	Organization
Tim Minezaki (Facilitating) Kyle Booth DJ Joh Zoe Mies	Energy Solutions

Name	Organization
Kevin Johnson (Co-Facilitating) Antonio Corradini Colin Lee Joseph Ling	AESC
David Vernon Frank Loge Vinod Narayanan	UC Davis
Nicole Duquette Jonathan Thibeault	VEIC
Andrew Leishman	TRC

Prior to starting development of the 2023 TPM, the SMEs conducted an in-depth review of the Process Loads TPM from 2022 along with other key technology families from outside this TPM. After this review, the SMEs held a kickoff meeting to discuss high level changes at the national policy changes (new funding opportunities, new programs, new standards & test procedures), state-wide policy changes (State of CA laws, CPUC decisions, CARB programs), as well as a review of related energy efficiency (EE) portfolio measures, and potential codes and standards efforts related to process loads.

The individual SMEs were then assigned lead research roles for technology families aligned to their expertise and then placed in working groups to obtain critical feedback from different team members (working groups included a cross-cutting topics, food systems and refrigeration, and "other" process loads technologies).

Following the kickoff, SMEs conducted secondary research related to their assigned technology family which includes a review of emerging technology studies and other market changes relevant to different technology families. In the first Process Loads TPM working group sessions, key revisions were highlighted to the working group for feedback. Following this, SMEs developed draft revisions to each technology family. At the second working group session, the SMEs presented final recommendations to the working group. At the conclusion of the working group sessions, SMEs were provided a web-based ballot to determine the recommended revisions to the gradings for key factors, knowledge indices, emerging technology (ET) priority, and ET program role. Finally, a core group of Process Loads SMEs met a final time to review the polling results and discuss results. The initial findings from the eight SME sessions make up the 2023 Process Loads TPM Preliminary Findings Report (submitted on July 19, 2023, and resubmitted on August 8, 2023).

On July 27, 2023, the preliminary findings report was presented to the Process Loads TPM Technical Advisory Committee in order to obtain broad feedback on the Process Loads research priorities of CalNEXT. This external committee includes the California Investor-Owned Utility (IOU) Program Administrators (PAs) as well as stakeholders with ET interests from the State of California, other regions, and those with national interests. Table 2 identifies the list of invitees to the TPM Advisory Committee.

Table 2: Invitees to Process Loads TPM Advisory Committee

Name	Organization
Keshmira McVey	Bonneville Power Administration
Kadir Bedir	California Energy Commission (CEC)
Cyrus Ghandi	CEC
Jeff Mitchell	California Market Transformation Administrator (CalMTA)
Ayad Al-Shaikh	California Technical Forum (CalTF)
Savannah McLaughlin	California Public Utilities Commission (CPUC)
Jes Rivas	Illume
Eric Olsen	Northwest Energy Efficiency Alliance (NEEA)
Mark Alatorre	Pacific Gas & Electric Company (PG&E)
Thomas Mertens	PG&E
Monika Jesionek	PG&E
Justin Westmoreland	PG&E
Jenny Chen	Southern California Edison (SCE)
Raymond Liu	SCE
Navniel Pillay	SCE
Rafik Sarhadian	SCE
Sean Gouw	SCE
Jerine Ahmed	SCE
David Rivers	SCE
Hsin-Hao (Kevin) Lin	SCE
Gary Barsley	SCE
Charles Kim	SCE
Randall Higa	SCE

Name	Organization
Andre Saldivar	SCE
Merry Sweeney	San Diego Gas & Electric (SDG&E)
Jeff Barnes	SDG&E
Kate Zeng	SDG&E

The Process Load TPM team refined the 2023 Process Loads TPM based on initial stakeholder feedback from the TAC meeting and incorporated changes into the 2023 Process Loads TPM Draft Report. Due to the breadth of topics under the Process Loads TPM, additional industry-specific and market-specific stakeholders were reached following the TAC to help further inform the Final Report of the 2023 Process Loads TPM.

Draft Report Feedback

TPM Advisory Committee Meeting

The TPM Advisory Committee meeting was held on July 27, 2023, via the Microsoft Teams platform. Invitees of the meeting are listed above in Table 2.

This meeting allowed advisory members to provide real-time, candid feedback with the opportunity to provide written comments and suggestions afterwards via a collaborative Word document hosted on Microsoft SharePoint. Suggestions were reviewed by the TPM coordinator and incorporated into the Revised 2023 Process Loads TPM section below.

A detailed table of the changes made can be found in the Stakeholder Feedback & Resolution Matrix in Table 4 in the Appendix of this Final Report.

Additional Stakeholder Feedback

In addition to the technical advisory committee, in order to obtain additional specialized insights, the Process Loads TPM team sought feedback from IOU program implementation teams related to key technology families. Table 3 summarizes those key stakeholders, their respective organizations, relevant IOU activities, and applicable technology families. Key findings were added to the Stakeholder Feedback and Resolution Matrix below.

Table 3: Additional Specialized Stakeholders

Name	Org	Relevant IOU Activities	Technology Family
Sabarish Vinod	Lincus	Statewide WISE Program	Pumping Systems Water Systems
Josh Chanin	Energy Solutions	Statewide Foodservice Instant Rebates Program	Commercial Kitchen Decarbonization Refrigeration, Commercial
Kyle Larson	VaCom	Title 24 Refrigeration CASE Author (2022 and 2025 cycle)	Refrigeration, Industrial Refrigeration, Commercial
Russell Hedrick	Frontier	Title 24 Commercial Kitchens CASE Team (2025 cycle)	Commercial Kitchen Decarbonization
Graham Lierley	kW Engineering	CoolSave Program Lead	Commercial Refrigeration
Duane Kubischta	kW Engineering	SmartLabs Program Lead	Labs & Hospitals
Taylor Fessenden Sam Skidmore	Cascade Energy	Strategic Energy Management (SEM) Program	Various (Industrial)

CalNEXT Website TPM Mock-up (2022 Process Loads sample below)

The 2023 Process Loads TPM website update will be in the same format as the 2022 Process Loads TPM website update that can be seen below here. The CalNEXT role and priority for each technology family will also be updated based on the revised roles and priorities documented here. The link to the 2023 Process Loads TPM Final Report will appear in the top right corner with the option to download.

CROSS-CUTTING

2022 Technology Research Areas	Role	Priority	
Advanced Motors	COLLABORATE	MEDIUM	+
Pumping Systems	COLLABORATE	MEDIUM	+
Steam & Hot Water Systems	COLLABORATE	MEDIUM	+
Process Heating Technologies	OBSERVE	LOW	+
Process Air Systems	COLLABORATE	MEDIUM	+
Smart Manufacturing & Controls	COLLABORATE	MEDIUM	+

2023 Process Loads TPM

Process Loads Technology Category Overview

The process loads technology category encompasses a wide range of building types and processes, including light commercial buildings such as restaurants and healthcare facilities, to industrial manufacturing and agriculture processes. Recent studies by the California Air Resources Board (CARB) indicate agriculture and industrial emissions represent over 30 percent of statewide emissions, representing a significant potential for EE and decarbonization advancement. However, energy-related research in process loads has historically lagged other topic areas due to the unique and complex nature of this field. Recent federal action under the Bipartisan Infrastructure Law (BIL), the Inflation Reduction Act (IRA), and the Creating Helpful Incentives to Produce Semiconductors Act (CHIPS) provide for an increase in funding to research new decarbonization technologies, demonstrate their effectiveness, and increase access to financing for both the manufacturing and deployment of these emerging technologies.[1]

Unique Opportunities and Barriers

Under the process loads category, CalNEXT research is broadly focused on projects that will lead to expanded incentive program offerings (EE or fuel substitution) and/or establishment of new standards. The CPUC's recent decision to phase out future gas incentives (D. 23-04-035)[2] shifts CalNEXT priorities to identify and evaluate new electric alternatives for gas-dominate equipment to prepare for future gas phase-out.

Highlighted Priority Areas

Technology Family	Definition	CalNEXT Role	CalNEXT Priority
Refrigeration, Commercial	This technology family focuses on commercial cooling, refrigeration, and freezing systems serving stationary applications in agriculture, food sales, food service, commercial kitchens, and healthcare.	Lead	High
Steam and Hot Water Systems	This steam and hot water systems technology family is focused on 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.	Lead	Medium
Controlled Environment Horticulture	Non-lighting equipment used to produce agricultural products in controlled environment horticulture spaces. This includes the heating, ventilation, air conditioning, and dehumidification (HVAC/D), precision nutriment monitoring, irrigation, and controls systems associated with maintaining environmental conditions for growing.	Lead	Medium
Water Systems	This technology family is focused on the water lifecycle in urban, agricultural, and industrial systems, inclusive of all technologies deployed in potable water, wastewater, recycled water, and desalination systems.	Lead	Medium

[1] https://www.energy.gov/industrial-technology/industrial-decarbonization-technologies

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

Advanced Motors

ETP Role: Collaborate | ETP Priority: High (increased)

Key Factors

Energy Savings: High
Decarbonization: Low
Demand Flexibility: Medium
Other Emissions Impacts: None

Knowledge Index

Technical Performance: High
Market Understanding: Medium
Program Intervention: Medium

Example Technologies

Switched reluctance motor (SRM), synchronous reluctance motor (SynRM), permanent magnet assisted synchronous reluctance motor (PMASynRM), permanent magnet synchronous motor (PMSM), brushless direct current (BLDC) motor (also referred to as an electrically commutated or "EC" motor), and motors with an integrated speed and load controller (power drive system).

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.

Opportunities

Advanced motors have tremendous energy savings opportunities. A recent Lawrence Berkely National Lab (LBNL) motor market assessment estimates an annual United States (U.S.) energy savings of 482,000 GWh/year.[3] 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 document the opportunities and barriers specific to the retrofit market for advanced motors; 3) research to better understand key market actors and the customer experience, the contractor experience, and current relevant manufacturer and supplier activities; and 4) opportunities to educate distributors and train contractors. Research should also extend to identifying innovative approaches to address commissioning needs to ensure high-quality installation.

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 directly substitutable for standard induction motors in many applications however, they require additional engineering to size and specify for the correct application. The California IOUs have found 13 advanced motor case studies and identified nine advanced motors from five manufacturers that can be substituted for

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

traditional induction motors and provided detailed comments on a recent standards rulemaking.[4] 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, 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, fans, and heating, ventilation, and air conditioning (HVAC) packaged systems, among others 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.

[4] https://downloads.regulations.gov/EERE-2020-BT-STD-0007-0030/attachment_1.pdf

Pumping Systems

ETP Role: Collaborate | ETP Priority: Medium

Key Factors

Energy Savings: Medium
Decarbonization: Low
Demand Flexibility: Medium
Other Emissions Impacts: None

Knowledge Index

Technical Performance: High
Market Understanding: Medium
Program Intervention: Medium

Example Technologies

High-efficiency pumps, advanced pump system monitoring and data analytics, load sensing pumps, variable volume positive displacement (PD) pumps, variable speed pump motors, remote management, and load management controls.

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, the water systems technology family within the Process Loads TPM, or pool heating and circulation withing the Water Heating TPM.

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. 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.

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.

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).[5] 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

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

assessment or a customer survey to get a better understanding of why this hesitancy exists is required.

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.

Steam and Hot Water Systems

ETP Role: Lead (increased) | ETP Priority: Medium

Key Factors

Energy Savings: Medium
Decarbonization: High
Demand Flexibility: Medium
Other Emissions Impacts: None

Knowledge Index

Technical Performance: Low
Market Understanding: Low
Program Intervention: Low

Example Technologies

Electric heating equipment intended specifically for process loads such as: hot water heaters, hot-water heat pumps, electric steam generation equipment, heat recovery chillers, burner fan motor controls, thermal process integration, solar thermal systems, waste heat recovery, dual-fuel heat pumps, and subsequent process end-use load optimization.

Note: Depending on the project scope, prospective projects in the steam and hot water systems technology family may fit better under the technology families in the Water Heating TPM which focus on light-duty systems (e.g., commercial, residential, and pool heating).

Definition

This steam and hot water systems technology family is focused on 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.

Opportunities

The hot water heating and steam generating market is currently dominated by natural gas systems. Mass deployment of electric hot-water heat pumps and electric steam generating equipment has the potential to rapidly decarbonize these process heating systems. Low-temperature electric hot water heating equipment has begun to enter the U.S. market. 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.[6] 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,[7] further demonstrate broad interest in developing the industrial heat pump market.

Many low-temperature hot water end uses could be electrified using commercially available technologies. However, the cost effectiveness has not yet been justified. Other energy saving strategies include thermal storage integration (also providing demand flexibility), 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

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

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

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.

Barriers

Currently, process hot water and steam 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 at a nascent 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.

Prospective ET studies should investigate market assessment for technical viability of electrified heat sources for hot water and electric steam generation in various process applications. This includes temperature limitations and steam operating pressure constraints, design capacity ranges, and deployment costs as compared with more traditional gas-fired equipment and in-field performance issues that limit deployment. Subsequent efforts should consider technical evaluation, field demonstration(s), and codes and standards adoption. Additional program opportunities may exist to target hard-to-reach (HTR) small businesses (e.g., laundromats and dry cleaners).

Beyond system electrification, 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.

Process Heating Technology

ETP Role: Observe | ETP Priority: Low

Key Factors

Energy Savings: Medium
Decarbonization: Medium
Demand Flexibility: Low
Other Emissions Impacts: Low

Knowledge Index

Technical Performance: Medium
Market Understanding: Low
Program Intervention: Low

Example Technologies

Electrically driven industrial process heating for plastics molding, glass manufacturing, cast metals, and other manufacturing processes.

Definition

The process heating technology family focuses on processes that dry raw materials, preheat process equipment or materials, and cure or stabilize produced goods, especially in manufacturing chemicals, plastics, glass, and materials.

Note: This technology family excludes process heating used in steam and hot water, as well as heating from specialized food processing and food service equipment which are covered in other technology families within this Process Loads TPM.

Opportunities

Over the last three decades, most industrial processes that could technologically switch from using electricity to natural gas did so because of lower energy costs and the perceived environmental benefit (which was an accurate perception when the grid was dominated by coal power plants). The opportunity now lies in reversing that trend and capturing the greenhouse gas (GHG) reduction benefit of a cleaner grid and leverage better electrical controls as compared to the natural gas-fired heating process.

Applications that use electric resistance or natural gas for drying, preheating, and production could see EE opportunities to improve the coefficient of performance and to decarbonize from natural gas (for example, replacing gas drying with industrial microwave dryers). Demand flexibility is likely limited due to the 24/7 nature of many relevant processes. However, if the load is variable, then that process could benefit from controls, including demand flexibility integration. EE projects should target scalable and generalizable electric heating improvements that reduce or eliminate unneeded heating. This includes controls, equipment design, insulation, and combinations of these with operational modifications and production timing.

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.

The plastic industry is historically competitive on operational costs regarding 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 technologies could include consideration of the Time-of-Use (TOU) rates structures and localized renewable generation resources.

Alternatively, other industries are 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: Collaborate | ETP Priority: Medium

Key Factors

Energy Savings: Medium
Decarbonization: Low
Demand Flexibility: Low
Other Emissions Impacts: Low

Knowledge Index

Technical Performance: High
Market Understanding: Medium
Program Intervention: Medium

Example Technologies

Blowers, fans, air compressors, air treatment and distribution systems, vacuum systems, and the design, maintenance, and control of these systems.

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.

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 systems are still 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 are soon to be updated following a finalized test procedure completed in May 2023.[8]

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

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.

Smart Manufacturing and Controls

ETP Role: Collaborate | ETP Priority: Medium

Key Factors

Energy Savings: High
Decarbonization: High
Demand Flexibility: Medium
Other Emissions Impacts: Low

Knowledge Index

Technical Performance: Low
Market Understanding: Low
Program Intervention: Low

Example Technologies

Advanced sensors, controls, platforms, process integration, and predictive modelling for manufacturing.

Definition

Deployment and integration of multiple technologies that together can enable EE improvements in manufacturing and deliver customer and grid benefits, significantly improve capacity for load flexibility, DR participation, and GHG tracking and tracing for enterprise resource planning reporting.

Opportunities

Manufacturing consumes 24 percent of primary energy annually in the U.S., accounting for 79 percent of total industrial energy use. According to the research by the American Council for an Energy-Efficient Economy (ACEEE), smart manufacturing (SM) has the potential to reduce process energy intensity by 20 percent with estimated energy savings nationally of $7 - $25 billion per year by enabling demand flexibility and decarbonization through data-driven control and optimization at the system and unit process levels. The DOE's Smart Manufacturing Institute (CESMII) developed an SM roadmap and continues to provide substantial funding to demonstration projects that include new manufacturing solutions. The project findings will be compiled into a CESMII SM Playbook for manufacturers to reference when further developing their product lines.

SM involves the redesign, or enhancement, of conventional manufacturing processes with intelligent controls that enable competitive systemic-optimization of process energy intensity, process carbon intensity, process operation and maintenance, TOU rate arbitrage, carbon impact of utility consumption, plant waste, and other process-specific emissions considerations. SM has the potential to encourage grid connectivity with separate optimization priorities during DR events. SM is anticipated to accelerate the industrial sector's transition to hybrid or fully electric alternatives by prioritizing use of the most optimum equipment based on the priorities established by the facility staff. SM may also enable consolidation of conventional processes through improved control usage and verification practices.

Barriers

Technical performance of SM is poorly understood as this is an emerging field with limited case studies and few experienced practitioners. Market knowledge is also relatively poor as a lack of a skilled workforce in the industrial area has been highlighted in the DOE's SM roadmap. Therefore, demonstration studies are needed of SM as it applies to new construction versus retrofit scenarios, equipment types, process types to improve technical performance (e.g., continuous versus batch), and market segment (e.g., plastics, metals, food, etc.) applicability.

Program intervention has not been active in SM for a variety of reasons. For one, measures are often tailored to site-specific details, which require significant knowledge and skillsets to identify and quantify the energy savings as it applies to program policy. Second, the custom process often requires a Low Rigor Industry Standard Practice Study, which is a substantial barrier to entry for energy projects and a source of uncertainty for project implementation. Third, site-level Normalized Metered Energy Consumption (NMEC) programs are not historically available to non-commercial buildings. Studies that provide content to support industry standard practice development or measure package development will improve program intervention. Demonstration sites of NMEC enhancements for industrial loaded buildings will also improve program intervention.

Controlled Environment Horticulture

ETP Role: Lead | ETP Priority: Medium

Key Factors

Energy Savings: High
Decarbonization: Medium
Demand Flexibility: Medium
Other Emissions Impacts: Low

Knowledge Index

Technical Performance: Medium
Market Understanding: Low
Program Intervention: Low

Example Technologies

Standalone dehumidifiers, integrated HVAC and dehumidification units, chilled water systems for indoor agriculture, ventilation fans, wrap-around heat exchangers irrigation/fertigation controls, integrated environmental controls, vapor pressure deficit controls, and agricultural-specific envelope products for optimal plant growth.

Definition

Non-lighting equipment used to produce agricultural products in controlled environment horticulture spaces. This includes the heating, ventilation, air conditioning, and dehumidification (HVAC/D), precision nutriment monitoring, irrigation, and controls systems associated with maintaining environmental conditions for growing.

Note: Horticultural lighting is covered by the horticultural lighting technology family (Lighting TPM).

Opportunities

Controlled Environment Horticulture (CEH) is an emerging industry with intensive energy and water use. Recent estimates have 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.

Increased EE is the largest opportunity in this industry. As noted above, the CEH market has seen rapid expansion, which resulted in a significant amount of inefficient system designs. Currently, most EE opportunities are implemented through custom 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 winter in California has 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.

Demand flexibility may become a significant opportunity but will be highly dependent on the appetite of growers to fluctuate indoor growing conditions and their ability to cost-effectively incorporate thermal storage 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. 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.

Barriers

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.

Food Processing

ETP Role: Collaborate | ETP Priority: Medium

Key Factors

Energy Savings: Medium
Decarbonization: High
Demand Flexibility: Low
Other Emissions Impacts: Low

Knowledge Index

Technical Performance: High
Market Understanding: Medium
Program Intervention: Low

Example Technologies

Washing, peeling, dewatering, roasting, baking, drying, dehumidifying, process cooling, and process heating systems.

Definition

The food processing technology family focuses on equipment used to transform agricultural products into food or from one form of food into other foods such as value-added products.

Opportunities

The food and beverage industry is one of the largest consumers of energy in the U.S., with an estimated 78 million metric tons (MT) of CO_2 emissions in 2020. According to the U.S. Department of Agriculture, California alone has over 6,000 food and beverage manufacturing plants. While a wide breadth of processes exists to handle different types of food processing, there are some common characteristics, including heating for pasteurization/sanitation, equipment for conveyance systems, and several "low-temperature" process heating loads for roasting, baking, frying, and drying.

The DOE's 2022 Industrial Decarbonization Roadmap indicated substantial impact potential through electrification of the many low-temperature process heating loads with electric boilers, electric fryers, electric ovens, and other underutilized technologies such as infrared or microwave heating all of which were identified as near-term research and development priorities in that roadmap. The State of California has prioritized the food processing sector through its establishment of the Food Production Investment Program (FPIP) which focuses on project implementation to accelerate the adoption of EE and renewable energy technologies.

Additionally, EE measures are in a nascent stage in this sector, relying primarily on custom savings calculations. Developing industry standards and test protocols is another opportunity for this technology family as it will help standardize energy saving calculations.

Barriers

Market understanding and technical performance of high-efficiency conventional processes is well-developed. However, the performance, role, capability, and reliability of heat recovery and heat pumps within food processing is still largely unknown within the market. To improve market understanding and technical performance of heat recovery and heat pump solutions, it is recommended that additional studies be conducted to demonstrate the capabilities and reliability of heat recovery and heat pump solutions that are integrated into conventional processes via new construction design, existing system retrofit, or supplemental add-ons.

Program intervention is anticipated to occur most often when a facility is installing new equipment or when a substantial upgrade is taking place. Both scenarios require insight into industry standard practices, which requires significant investment for custom incentive application development and any potential measure package that is developed. To improve program intervention, the team must conduct studies on industry standard practice for various food processes and conduct market studies with an emphasis on operational data collection for measure package development.

Commercial Kitchen Decarbonization

ETP Role: Collaborate | ETP Priority: Medium

Key Factors

Energy Savings: Medium
Decarbonization: High
Demand Flexibility: Low
Other Emissions Impacts: Low

Knowledge Index

Technical Performance: Medium
Market Understanding: Medium
Program Intervention: Low

Example Technologies

Commercial food preparation (e.g., cooktops, woks, ovens, steamers, fryers, broilers), sanitation operations (e.g., dipper wells, pre-rinse operations, dishwashing), and kitchen and dish room ventilation (e.g., makeup air unit and kitchen hoods).

Definition

The commercial kitchen decarbonization technology family focuses on 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 equipment.

Note: 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.

Opportunities

Commercial kitchens are incredibly energy intensive, representing five to seven times the energy density of other types of buildings, representing 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 fraction of the square footage. While current technology exists to electrify and decarbonize many kitchens, this has only been implemented in targeted parts of a cookline or to a limited number of new construction facilities. 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 recent CPUC Decision 23-04-035,[9] 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

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

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 and design guidelines to familiarize market actors with all aspects of the fossil fuel transition. Most opportunities will be supported by resolving the major cost barriers associated with commercial kitchen electrification.

Refrigeration, Industrial

ETP Role: Collaborate | ETP Priority: Medium

Key Factors

Energy Savings: Medium
Decarbonization: Low
Demand Flexibility: Medium
Other Emissions Impacts: Medium

Knowledge Index

Technical Performance: Medium
Market Understanding: Medium
Program Intervention: Low

Example Technologies

Industrial process cooling and freezing including spiral freezers, large blast freezers, cryogenic freezers, freeze drying, refrigerated warehouses, large walk-in and drive-in refrigerated spaces, cooling for materials processing, pharmaceuticals, and others, and transportation refrigeration units.

Definition

This technology family focuses on industrial cooling, refrigerated transportation distribution from manufacturing facilities, and refrigeration and freezing systems for food, materials, pharmaceuticals, and other manufactured product applications.

Opportunities

EE industrial refrigeration opportunities begin by looking at the end-use, where many existing products and methods are widely used and where emerging products and methods can further improve energy 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. Refrigeration loads can also be reduced by enhanced envelope design, improved insulation, reduced air infiltration, reduced unnecessary heat gain through automated operations and internal heat gains within refrigerated spaces such as evaporator fans and defrost systems. Materials can be pre-cooled using cooling towers, advanced evaporative cooling, and other methods that are less energy intensive. On the supply side, EE compressor control, suction, and head pressures/temperatures should be optimized 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, more effective 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 will start to replace legacy refrigerants, pushed along by recent national and state regulations. Opportunities exist to both improve underlying system efficiencies and reduce refrigerant leakage as facilities begin to transition to next generation refrigerants. These multiple co-benefits should be incorporated into future programs.

Barriers

Market understanding and technical performance of new technologies are often obscured by the fact that each implementation requires site-specific tailoring to the current system loads and capabilities. For this reason, sales and maintenance are often limited to a list of SME contractors. As a result, the value proposition and product risk concerns are often derived from unvalidated tools, general manufacturer application guidelines, and the SME contractor experience. To improve market understanding and technical performance, studies should emphasize the creation of a common pool of knowledge as it relates to design, decision making, and implementation of the new EE technologies. The intent is to encourage the development of small, specialized groups (inside or outside SME contractors) that can bridge the knowledge gap. Additional emphasis should be given when studies include analysis, demonstration, and market feedback on systems that use low GWP refrigerants.

Program intervention is presently limited to custom incentive process. This will often require insight into industry standard practice, which is a substantial investment for custom incentive application development. To improve program intervention, conduct studies on industry standard practice for major industrial refrigeration processes.

Refrigeration, Commercial

ETP Role: Lead | ETP Priority: High

Key Factors

Energy Savings: High
Decarbonization: Low
Demand Flexibility: Medium
Other Emissions Impacts: High

Knowledge Index

Technical Performance: Medium
Market Understanding: High
Program Intervention: Medium

Example Technologies

Self-contained and remote condensing refrigerated cases; multiplex rack systems; gas coolers, condensers, and adiabatic systems; walk-ins and food prep rooms; small blast chillers and freezers; thermal energy storage; compressor waste heat recovery; open case door retrofits; advanced integrated controls; transition to low GWP and natural refrigerants; direct expansion, distributed, and secondary loop systems.

Definition

This technology family focuses on commercial cooling, refrigeration, and freezing systems serving stationary applications in agriculture, food sales, food service, commercial kitchens, and healthcare.

Opportunities

California is the top producer of agricultural products in the U.S. (14 percent of total), with commercial refrigeration representing a significant portion of the energy consumption related to food storage, preparation, and sales. Additionally, retail food refrigeration is estimated at almost 45 percent of California's hydrofluorocarbon (HFC) emissions according to the Environmental Protection Agency (EPA) significant new alternatives policy (SNAP) and CARB 2016t GHG Inventory.

Based on recent action at the national and state levels to phase out HFC refrigerants, this sector has begun transitioning to low GWP and natural refrigerants in new construction and existing systems. As systems transition, component and control upgrades and other high-efficiency options need to be pursued simultaneously. Future studies should focus on gathering and evaluating data to help quantify the benefits and costs of these systems to support technology transfer, 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, and document best practices to help guide system design and operational procedures. Opportunities to incorporate high-efficiency equipment, optimize system configurations, and introduce heat recovery and energy storage have the potential to support EE with added decarbonization benefits. As new refrigerants emerge, there is a need for pilot installations and energy modeling to evaluate changes in cooling capacity, energy performance, and other operational standards. Additionally, research to reduce charge sizes and limit refrigerant leaks will be broadly beneficial for the carbon lifecycle of refrigerants. 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

Common barriers include initial capital costs, safety concerns, regulatory challenges, perceived retail sales impacts related to case door retrofits, and technical understanding in a dynamic regulatory environment. As original equipment manufacturers (OEMs) and chemical companies respond to the rapidly changing refrigerant landscape, equipment performance, energy impacts, and system applications for these new technologies are not well understood. Product costs also remain high to cover the research and development for these new technologies, effectively slowing market adoption. Workforce training needs are high as the number of refrigeration contractors is diminishing and the collective knowledge of low GWP and natural refrigerants is limited, making the installation and service of these systems another challenge. Opportunities to support training and certification for technicians on new refrigerants should be considered to expand industry knowledge.

While there are significant opportunities within commercial refrigeration, and the market remains dynamic, new programs for the California IOU portfolio will require validation of industry standard practices to appropriately set baseline and measure programmatic impacts for most program delivery types.

Data Centers and Enterprise Computing

ETP Role: Collaborate | ETP Priority: Medium

Key Factors

Energy Savings: Medium
Decarbonization: Low
Demand Flexibility: Low
Other Emissions Impacts: Medium

Knowledge Index

Technical Performance: High
Market Understanding: Medium
Program Intervention: Low

Example Technologies

Liquid-cooled systems, data center storage, enterprise servers, large network equipment (LNE), uninterruptible power supplies (UPS), and computer room air conditioners or air handlers (computer room air conditioning [CRAC]/computer room air handing [CRAH]), cell-tower facility or other communications infrastructure, server utilization monitoring and resource allocation software.

Definition

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

Opportunities

Data centers use significant amounts of energy, making up about 2 percent of electrical energy use worldwide. Many facilities are evaporatively cooled, resulting in significant water use. IT equipment itself makes up the bulk of the energy use, accounting for nearly 70 – 80 percent of energy consumption, with the remainder used for cooling. 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. 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.

Aside from energy savings, 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 (decarbonization potential by displacing natural gas heating). The use of thermal storage technologies has potential to unlock demand flexibility. Evaporatively cooled data centers could also see efficiency improvements using recent advancements in direct/indirect evaporative coolers. Note: See the hybrid or fully compressor-less HVAC systems section under the HVAC TPM.

Finally, while still emerging, liquid-immersed systems have the potential for even greater energy and water savings and can support computing scalability, which is important in edge-computing data centers.

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-immersed computing face significant barriers to scale from code compliance, product availability, downtime concerns, and practitioner familiarity. Research to develop code compliance pathways for liquid-immersed 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)

Labs and Hospitals

ETP Role: Collaborate | ETP Priority: Medium

Key Factors

Energy Savings: Medium
Decarbonization: Low
Demand Flexibility: Low
Other Emissions Impacts: Low

Knowledge Index

Technical Performance: Medium
Market Understanding: Medium
Program Intervention: Low

Example Technologies

Incubators, autoclaves, biosafety cabinets, ultra-low temperature (ULT) technologies, medical fridges/freezers, sterilizers, exposure control devices (e.g., gas cabinets, fume hoods), lab-scale ovens, and imaging equipment.

Definition

This technology family focuses on lab and hospital-related devices, as well as HVAC specified for these applications. Plug load management and behavioral technologies that can manage lab or hospital loads are also included, though certain research activities within this family will overlap with the Plug Loads TPM.

Opportunities

Labs and hospitals are one of the highest energy consuming sectors due to their energy-intensive activities and stringent health and safety requirements. A 2015 market assessment conducted by the California IOUs estimated that just 12 pieces of lab/hospital equipment were likely responsible for between 0.8 and 3.2 terawatt hours (TWh)/year. Despite this large opportunity, only lab grade freezers (LGF), refrigerators (LGR), and ULTs had significant development (all three now have ENERGY STAR® specifications). In 2023, the EPA has begun looking more into this sector as ENERGY STAR® looks to develop product specifications for medical imaging equipment[10] and is interested in revising requirements for LGFs, LGRs, and ULTs[11].

For laboratory HVAC, the CA IOUs Codes and Standards Enhancement Team developed requirements for fume hood controls for the 2019 version of the California Energy Code[12] and recently completed comprehensive research for laboratory airflow to update the 2025 version of the California Energy Code[13].

The wide variety of lab and hospital equipment types are not designed with energy saving features in mind, leading to wasted energy when not in use. Because of this, there may be opportunities in managing user behavior to increase efficiency, or additional engagement with OEMs to make EE a priority in product development through voluntary programs like ENERGY STAR®. Meanwhile, the

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[10] https://www.energystar.gov/products/spec/medical_imaging_equipment_version_1_0_pd

[11] https://www.energystar.gov/products/lab_grade_refrigerators_freezers/partners

[12] https://title24stakeholders.com/measures/cycle-2019/high-efficiencyfume-hoods/

[13] https://title24stakeholders.com/wp-content/uploads/2023/08/2025_T24_CASE-Report-NR-Labs-Final.pdf

overall scope of savings opportunities has continued to grow as biotech and pharmaceutical laboratories have seen significant growth since the COVID-19 pandemic[14].

Barriers

With the few exceptions mentioned above, there is limited technical understanding about many of the types of more energy-intensive equipment of interest. The primary barrier for much of this equipment is the diversity of equipment types and uses. This makes baseline studies difficult, as different labs and hospitals may operate their equipment differently. As noted above, there are also no national standards (mandatory or voluntary) for any lab equipment other than ULTs and fume hoods. The 2015 market assessment identified significant interest, with end users reporting it was either considered "important" or "very important" to have equipment that was energy or water efficient 70 percent of the time. This interest has only grown as a number of large companies and institutions have committed to emissions reductions goals, leaving opportunities for utility EE programs, provided they are not found to be industry standard practice.

[14] In response to the COVID-19 pandemic, ventilation needs have increased significantly. It remains unclear what long-term impacts this will have to HVAC ventilation requirements. CalNEXT will look to address this research need in our next update of the HVAC TPM.

Water Systems

ETP Role: Lead | ETP Priority: Medium

Key Factors

Energy Savings: High
Decarbonization: Medium
Demand Flexibility: High
Other Emissions Impacts: Low

Knowledge Index

Technical Performance: High
Market Understanding: Medium
Program Intervention: Low

Example Technologies

Equipment to convey, treat, distribute, recycle, and discharge water focused on the distribution system. Example technologies include water loss control, energy recovery turbines, hydraulic modeling and optimization, alternative water sourcing, controls, and treatment.

Definition

This technology family is focused on the water lifecycle in urban, agricultural, and industrial systems, inclusive of all technologies deployed in potable water, wastewater, recycled water, and desalination systems.

Note: This technology family has strong overlaps with pumping energy which is covered in the cross-cutting process systems: pumping systems technology family.

Opportunities

Approximately 19 percent of net energy use in California is associated with the sourcing, conveyance, treatment, distribution, end use, and disposal of water. Approximately 7 percent is associated with transmission, distribution, and pressurization of water.

Broad water efficiency efforts (such as high-efficiency toilets) or broad water conservation efforts (such as drought-tolerant landscaping) can reduce the energy expended in the water lifecycle both upstream (e.g., sourcing, conveyance, treatment, and distribution) and downstream (e.g., wastewater treatment and disposal), which have large secondary impacts for energy conservation. Similarly, preventable water loss such as those experienced in aging distribution systems and building piping have strong potential to achieve long-term water and energy savings without impacting operations.

Water systems are highly flexible when water storage is available, which is true for the majority of large potable water systems in California and some wastewater systems. Through further system advancements such as the inclusion of more storage or alternative energy rates, a water system can often display great flexibility to use energy through pumping operations at nearly any hour of the day. Appropriate modification of energy demand charges, when paired with adequate water storage, may allow pumping time and intensity to be highly directed. This translates to large generation source emission reduction potential. For example, research by UC Davis' Center for Water-Energy Efficiency estimated a reduction of emissions by >300,000 mTCO2 annually in the potable water sector in California, if electrical rates better aligned costs with carbon intensity. With the reform of energy demand charges, it is estimated that California could load-shift over 1.07 TWh annually in the potable water sector through existing infrastructure.

Barriers

Water systems are mature systems that often lag the energy infrastructure in terms of efficiency, advancement, and modernization. This can be associated, in part, with the slow progress made in the digital revolution of the water sector, including data availability, data sharing, computer modeling quality, and the complexity of optimizing water system operations. Additionally, water system operations frequently involve a combination of human and machine controls that require risk management when implementing any substantial changes to the water system. To date, operators are highly risk averse in making changes even when there are cost-effective savings opportunities. Finally, water-related industries often have elevated levels of oversight, permitting, and compliance that need to be understood and incorporated to access these savings opportunities. Visible case studies, targeted sector engagement, and best practices guides will help operators become more comfortable with implementing high-efficiency energy projects.

Vehicle Charging and Off-Road Fleet Charging

ETP Role: Collaborate | ETP Priority: Medium

Key Factors

Energy Savings: Medium
Decarbonization: Medium
Demand Flexibility: High
Other Emissions Impacts: Medium

Knowledge Index

Technical Performance: High
Market Understanding: Medium
Program Intervention: Low

Example Technologies

Electric charging options for golf carts, forklifts, pallet jacks, automated guided vehicles, survey and agriculture drones, and other similar non-automotive vehicles.

Definition

This technology family focuses on charging management strategies to support the electrified transition of commercial and industrial vehicles used exclusively off-road to perform a variety of functions that would be better handled by electric alternatives. Building energy uses occurs while charging batteries of these vehicles.

Note: This technology family excludes personal mobility devices and traditional street-legal electric vehicles which are covered under separate technology families within the Plug Load and Appliances TPM.

Opportunities

CARB has been leading action in this technology area as it is a key pillar needed to meet California's ambitious climate goals. In their 2022 Zero Emissions Vehicle (ZEV) Action Plan,[15] CARB highlighted regulatory rulemakings to promote the adoption of electric off-road vehicles such as cargo handling equipment, forklift vehicles, and others paving the way for zero emissions replacements. In addition, CARB is deploying a variety of incentive programs such as Funding Agricultural Replacement Measures for Emissions Reductions (FARMER),[16] Clean Off-Road Equipment Voucher Incentives (CORE),[17] and a program dedicated to advanced technology demonstration and pilot projects aimed at accelerating precommercial and early commercial heavy-duty on- and off-road technologies.

Given the strong level of activity already being conducted by CARB, CalNEXT should continue to observe these developments and look for ways to collaborate to ensure that the charging infrastructure used will maintain EE standards and have DR capabilities.

Barriers

The technical understanding of vehicle batteries and chargers is ever evolving; regulatory action is pushing electrification into electrical applications such as construction, ports, and warehouses. Regulations, codes, and standards are being developed and refined for on-road BEVs while paths are still unclear for off-road charging standards. Facilities are looking to comply with these emerging ZEV

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[15] https://business.ca.gov/wp-content/uploads/2022/04/CARB-2022-Action-Plan.pdf

[16] https://ww2.arb.ca.gov/our-work/programs/farmer-program

[17] https://californiacore.org/

regulations, and there is poor understanding of the changes required for electrical infrastructure to support off-road EVs. Utility programs have had limited activity in this area and should consider new program elements to help remove electrification barriers for customers through managed charging and demand flexibility opportunities, as well as ensuring that electrical service upgrades that expand capacity investigate future-proofing to electrify emerging end-uses.

Next Steps

Following the submittal of the 2023 Process Loads TPM Final Report, the Program Team, will do the following:

1. Update CalNEXT website with new 2023 Process Loads TPM.
2. Launch email announcement through email outreach.
3. Develop and submit 2023 Process Loads TPM Distribution Report.

Appendix A: Advisory Committee Feedback & Resolution Matrix (Incorporated in the Draft Report)

Table 4: Stakeholder Feedback & Resolution Matrix

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
All	Key Factor / Knowledge Index Ratings	Request indication on how ratings changed vs. prior year	Noted as "increased" or "decreased" throughout document
All	Definitions	Align with CalMTA's priorities and agenda	CalNEXT has been working directly with CalMTA to ensure alignment between our two programs not just for focused pilots but also other project research activities.
All	Grammatical errors	Various	Accepted
Advanced Motors	Knowledge Indices	Considers market is well understood. It is just in replacement; the case it does not persuade users to switch.	Change not accepted. Comment is contradictory to the 13 case studies docketed by the CA IOUs referenced in the opportunities narrative. Details shown below.
Advanced Motors	Opportunities	Field engineers report potential savings calculations are significantly oversimplified and underestimate motors achievable savings. Advanced motors mentioned below are more efficient but require special controls, do not have the same power and torque curves as regular induction motors, can create power quality issues, and are different shapes/sizes/mounting than regular induction motors.	Suggestion Accepted. Narrative adjusted to reflect the specific points related to difficulty of the replacement motor market.

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
		It is not just a simple change out of the motor but a complete replacement of the motor and motor control system. One opportunity would be to influence equipment manufacturers to incorporate the new motor types in new equipment and systems. It will be too difficult to convince users to replace an existing induction motor.	
Steam and Hot Water Systems	Role/Priority	I think this is a burgeoning opportunity and may be a good fit for CalNEXT.	Agreed. CalNEXT to reach out for one-on-one coordination meeting with commenter related to this topic.
Controlled Horticulture Environment	Subgroups	What technologies is ES specifically looking to prioritize in this family?	HVAC, environmental controls, dehumidification, there are also lots of gaps in codes work that could use more research as well.
Refrigeration (Industrial & Commercial)	Key Factors	Why is decarbonization still rated as low?	Explained verbally during TAC meeting: Decarbonization in our framework is intended to map directly with electrification opportunities. Opportunities related to refrigerant emissions is intended to be captured under the “Other Emissions” key factor. Modified Opportunities narrative related to decarbonization to better reinforce this framework definition. Note: this framework maps directly to the TSB framework which has separate calculations for avoided gas infrastructure and avoided refrigerant emissions.
Refrigeration (Commercial)	Opportunities Narrative	Suggest research into new technologies (e.g., multi-ejectors and parallel compression) to improve the efficiency of transcritical systems in the	Already addressed broadly. CalNEXT to reach out for one-on-one coordination meeting with commenter related to follow-up on specifics of this topic.

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
		US market – currently cannot incentivize these because there is an efficiency penalty.	
Refrigeration (Commercial)	Opportunities Narrative	Suggest investigation of specific need	Accepted. Adjusted wording to reflect completion of research by CA Codes & Standards program.
Labs & Hospitals	Narrative	Suggest looking at ventilation concepts brought up by Covid. Studies were done on impacts and what ET was needed/protocols that were changed. Look at what these short-term impacts or ongoing technology needs may be, should these be researched?	Accepted. Footnote added to narrative, will investigate as part of next update to HVAC TPM.
Labs & Hospitals	Opportunities Narrative	CASE efforts have not concluded	Accepted. Adjusted wording to reflect completion of research by CA Codes & Standards program.