2023 HVAC TPM

Final Report

ET23SWE0005

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This Heating, Ventilation, and Air Conditioning (HVAC) Technology Priority Map (TPM) was developed by the HVAC 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 HVAC SME team members, our facilitation team for their contributions in this process as well as the guidance provided by the TPM Technical Advisory Committee and other key advisors:

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Disclaimer

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Abbreviations, Acronyms, and Glossary of Terms

Acronym	Meaning
A2Ls	Mildly Flammable Refrigerants
ADU	Additional Dwelling Units
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
AI	Artificial Intelligence
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BAS	Building Automation Systems
BUILD	Building Initiative for Low-Emissions Development
CA	California
CALGreen	California Green Building Standards (Title 24, Part 11)
CARB	California Air Resources Board
CASE	Codes and Standards Enhancement
CEC	California Energy Commission
CO2	Carbon Dioxide
CPUC	California Public Utilities Commission
Cx	Building Commissioning
DAC	Disadvantaged Communities
DOAS	Dedicated Outdoor Air System
DOE	U.S. Department of Energy
EBCx	Existing Building Commissioning
EE	Energy Efficiency
EER2	Energy Efficiency Ratio
EPA	U.S. Environmental Protection Agency
ERV	Energy Recovery Ventilator
ET	Emerging Technology

Acronym	Meaning
ETCC	Emerging Technologies Coordinating Council
eTRM	Electronic Technical Reference Manual (CA)
EV	Electric Vehicle
FDD	Automated Fault Detection Diagnostics
GHG	Greenhouse Gas Emissions
GWP	Global Warming Potential
HEEHRA	High-Efficiency Electric Homes Rebate Act
HOMES	Homeowner Managing Energy Savings
HP	Heat Pump
HSPF2	Heating Seasonal Performance Factor
HTR	Hard-to-Reach
HVAC	Heating, Ventilation, and Air Conditioning
IEPR	Integrated Energy Policy Report
IO&M	Installation, Operations, and Maintenance
IOU	Investor-Owned Utility
IRA	Inflation Reduction Act
LBNL	Lawrence Berkely National Lab
LEED	Leadership in Energy and Environmental Design
NMEC	Normalized Metered Energy Consumption
SCE	Southern California Edison
SEER2	Seasonal Energy Efficiency Ratio
SME	Subject Matter Expert
TABS	Thermally Activated Building Systems
TECH	Technology and Equipment for Clean Heating
TPM	Technology Priority Map

Acronym	Meaning
TSB	Total System Benefit
VRF	Variable Refrigerant Flow
VS	Variable Speed
WH	Water Heating

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 California's Statewide Emerging Technologies Program (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.
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.

Glossary	Meaning
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 document the impact potential, programmatic research needs, and market readiness of all technology families across each of the end-use technology areas, driving product ideation, informing project selection, and determining eligibility for future focused pilot efforts. For the TPMs to provide this guidance, they require regular updates to reflect specific changes to technology, market, and policy. This Final Report documents the development of the 2023 HVAC TPM.

Background

The TPMs were originally developed by Southern California Edison's Emerging Technologies program in 2017. They have been incorporated as a key element of the CalNEXT program to provide clarity to the program on our priorities. They require frequent updates to reflect the technical advancement, policy changes, and market developments in order to maintain their relevance. In 2022, the CalNEXT team did a thorough revision to the TPMs and published them to our website at https://calnext.com/resources/.

Objectives

The HVAC category has seen significant changes relative to that of other technology areas. Notable drivers include passage of the Inflation Reduction Act (IRA) of 2022 which will provide additional market support over the next decade in the form of tax credits and state-administered incentive programs targeting various aspects of the heat pump market. In addition, research conducted by California's Investor-owned utility (IOU) Codes and Standards Enhancement (CASE) Team related to multiple technology families (Scalable HVAC Controls Deployment, HVAC Design for Decarbonization, Scalable Thermal Storage) have impacted the state of knowledge to varying degrees. Finally, the continued need for programs to transition to the Total System Benefit metric has implications for both demand flexibility and low global warming potential (GWP) refrigerants. These changes are reflected in different ways in the 2023 TPM update.

Methodology

The 2023 HVAC TPM revision begins with multiple meetings of the CalNEXT HVAC subject matter experts (SMEs) to review the existing 2022 HVAC TPM and identify key changes expected based on technology, market, and policy for different technology families. Common sources of research include publications from the U.S. Department of Energy (DOE), the Emerging Technologies Coordinating Council (ETCC), CA IOU CASE Team, electronic Technical Reference Manual (eTRM), IOU program evaluations, California Energy Commission (CEC) rulemakings, California Public Utilities Commission (CPUC) decisions, California Air Resource Board (CARB) rulemakings, and recently passed state and federal legislation. The team also leverages outside resources from other emerging technologies programs, national building codes and standards bodies, and voluntary programs. Following this research, the SME team then drafts changes to the narratives, definitions, opportunities, and barriers which is then presented in the Preliminary Findings Report (submitted on March 23, 2023).

Following the development of the Preliminary Findings Report, the HVAC SME team were given digital ballots to provide guidance on potential changes to the program role and program priority, key factors, and knowledge indices through an online balloting platform. Concurrent to this activity, the initial narratives were presented to the Technical Advisory Committee (presented April 27, 2023) as well as supplemental feedback from the CalNEXT equity specialist (Ortiz Group). The Technical Advisory Committee attendees were given a presentation of key changes and access to a cloud-based draft to provide suggestions for each technology family's key factors, knowledge indices, and narratives for opportunities and barriers. This initial feedback was documented and incorporated into the Draft Report submitted on May 5, 2023.

The SME Team then refined the HVAC TPM based on stakeholder feedback for this Final Report. Note: any technology families that show potential for a Focused Pilot will be identified for further development under that effort.

Draft Report Feedback

Following submission of the Preliminary Findings Report, the CalNEXT program team obtained additional feedback from SCE on May 19, 2023. A summary of each comment can be found in Table 1 with changes incorporated into this Final Report.

Table 1: Additional Draft Report Feedback & Resolution

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
N/A - Intro	Acronyms Table	Include additional acronyms for DOE, AHRI, HOMES, HEERA.	Suggestion accepted.
N/A - Intro	Methodology	Add DOE to list of research sources.	Suggestion accepted.

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
Scalable HVAC Controls Deployment	Highlighted Priority Areas (Definition)	"Do you see flexibility in this technology family"	No action taken. Yes, the definition of this technology family is quite broad and we expect it will be adaptable to most research needs in this area.
Scalable HVAC Controls Deployment	Opportunities	Here are some latest from a DOE control roundtable: Energy Management and Control Systems Research and Development Opportunities Roundtable. I extract relevant opportunities related to HVAC control scalability.	Incorporated in the Opportunities narrative.
110V/120V Heat Pumps	Highlighted Priority Areas (Definition)	Is repetition of "6 million HP" goal needed?	Suggestion accepted.
High-Efficiency Heat Pumps for Space Heating and Cooling	Key Factors: Demand Flexibility	Suggest this be raised from Medium to High	Declined. While among the more impactful technology areas within HVAC, we considered Thermal Storage and HVAC Controls to be much more impactful for demand flexibility.
High-Efficiency Heat Pumps for Space Heating and Cooling	Definition	Suggested wording change from "and often cooling" to "combined with cooling"	Declined. This was written to be inclusive of air-to-water heat pumps that would replace gas-fired hydronic boilers which may not provide space cooling.
High-Efficiency Heat Pumps for Space Heating and Cooling	Opportunities	Suggested wording change to field testing	Suggestion accepted.

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
High-Efficiency Heat Pumps for Space Heating and Cooling	Barriers	Requested further definition on small heat-pumps	Suggestion accepted.
Scalable HVAC Controls	Definition	"In the past reliability was an issue and that may have improved along with miniaturization"	Not recognized as a suggestion. No action taken.
Scalable HVAC Controls	Opportunities	"Are there opportunities in residential buildings and hard-to-reach (HTR)/disadvantaged communities (DAC). Can the current HVAC controls take advantage of all the features that are available in high efficiency variable capacity residential."	Suggestion accepted. Incorporated into write-up, particularly the gap in the current ENERGYSTAR Specification.
Scalable HVAC Controls	Opportunities	"Elaborate if controls "much simpler" to install, operate. Are they compatible with various variable capacity systems."	See previous response.
Scalable HVAC Controls	Barriers	"What are the features smart thermostats, maybe add to glossary"	Accepted. Added footnote to clarify that ENERGYSTAR is renaming connected thermostats to Smart Thermostats.
Hybrid or Fully Compressor-less HVAC	Key Factors: Decarbonization	Suggest this be raised from Medium to High	Declined. Our team does not consider this technology family to have a high relative impact on displacing current natural gas usage.
Hybrid or Fully Compressor-less HVAC	Barriers	Suggest adding "availability" of non-evaporative & non-vapor compression as a barrier	Suggestion accepted.
Heat Pump Market Development	Definition	Is repetition of "6 million HP" goal needed?	Declined. Our team views the reinforcement of this goal is necessary

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
			within individual tech families given the diverse stakeholder set and how we envisioned the Tech Families are utilized in practice from the web.
Heat Pump Market Development	Opportunities	Should improvements in technology that were considered to be a barrier in the past be also addressed/informed. For example, Low temperature heat pumps (HPs) are now available.	Suggestion accepted. Incorporated cold climate heat pumps into narrative.
Heat Pump Market Development	Barriers	Spell out the acronym and add to glossary	Suggestion accepted.
110V/120V Heat Pumps	Definition	Is repetition of “6 million HP” goal needed?	Declined. Our team views the reinforcement of this goal is necessary within individual tech families given the diverse stakeholder set and how we envisioned the Tech Families are utilized in practice from the web.

A detailed list of feedback provided by the Technical Advisory Committee through April 27, 2023, is included in Appendix A: Advisory Committee Feedback & Resolution Matrix at the end of this document.

CalNEXT Website TPM Mock-up (2022 HVAC sample below)

The 2023 HVAC TPM website update will be in the same format as the 2022 HVAC TPM website update that can be seen below here, the 2023 final report link will appear in the top right corner with the option to download.

2022 Technology Research Areas	Role	Priority	
High-Efficiency HVAC Heat Pumps	LEAD	HIGH	+
Scalable HVAC Controls Deployment	LEAD	HIGH	+
Hybrid or Fully Compressor-less HVAC	LEAD	HIGH	+
Heat Pump Market Transformation	LEAD	HIGH	+
HVAC Design for Decarbonization	LEAD	HIGH	+
Scalable Thermal Storage	LEAD	MEDIUM	+
Installation, Operations & Maintenance	LEAD	MEDIUM	+
110V/120V Heat Pumps	COLLABORATE	MEDIUM	+
Refrigerant Management & Low GWP Transition	COLLABORATE	MEDIUM	+

2023 HVAC TPM

HVAC Technology Category Overview

High-efficiency all-electric HVAC systems continue to be a priority for CalNEXT. Emerging Technology (ET) activities for maturing products such as high-efficiency air-to-air packaged heat pumps (HPs) can expect a shift in focus toward breaking down the barriers to adoption needed to meet California's goal to deploy 6 million HPs by 2030[1]. For less mature product markets like air-to-water HPs intended for gas boiler replacements, CalNEXT expects the continued need for field demonstrations and other early-stage research to aid in program development. For complex HVAC systems, CalNEXT is focused on deploying scalable HVAC solutions and holistic HVAC design strategies focused on decarbonization to actualize high-impact opportunities for the commercial and multi-family sectors.

Unique Opportunities and Barriers

CalNEXT anticipates significant activity within HVAC to inform future investor-owned utility (IOU) programs as the market adjusts to a broad decarbonization emphasis, a refrigerant transition, new test procedures, and new efficiency standard metrics. CalNEXT research will continue to break down these multiple market barriers across different market sectors focused on bringing long-term market transformation.

Highlighted Priority Areas

Technology Family	Definition	ETP Role	ETP Priority
High Efficiency Heat Pumps for Space Heating and Cooling	High-efficiency compressor-based packaged equipment that can provide efficient electric heating (and often cooling). Systems may include high efficiency air-to-air packaged HP units (ducted unitary HPs and ducted or ductless split systems), air-to-water HPs used to replace traditional boiler hydronic systems, or Variable Refrigerant Flow (VRF). "High-efficiency" equipment typically contains variable speed (VS) fans, compressors, and/or pumps. Other pathways to high efficiency include advanced heat exchangers and advanced controls algorithms.	1-Lead	1-High
Scalable HVAC Controls Deployment	Advancement of sensors, controllers, and demonstrations of new control strategies and technologies that improve the persistent performance of a building's HVAC energy use and component functionality with an emphasis on scalability and deployment of control systems. This technology family has strong overlaps with the Installation, Operations, and Maintenance technology family.	1-Lead	1-High
Heat Pump Market Development	Innovative program designs and supporting research to accelerate deployment of the California HP market. May include financing innovations, turn-key incentive design, or other coordination with various market actors focused on HP deployment. This technology family was previously referred to as "Heat Pump Market Transformation".	1-Lead	1-High
Scalable Thermal Storage	Thermal or non-electric energy storage solutions with the capability to scale and integrate with HVAC systems, including both active storage (charged and discharged with controls, e.g., hot water storage tanks) and passive storage (charged and discharge without dedicated controls, e.g., heat capacitance of building structure).	1-Lead	1-High
110V/120V Heat Pumps	Efficient, rapidly deployable HPs that often do not require professional installation and are suitable for compact spaces where HPs can replace electric space heaters or where traditional split-systems are too costly or onerous to deploy. Typical scenarios include small homes, additional dwelling units, apartments, mobile homes, hospitality, assisted living facilities, and schools.	1-Lead	1-High

[1] Recommendation by the California Energy Commission in their 2021 Integrated Energy Policy Report (IEPR) Volume I Building Decarbonization (Docket: 21-IEPR-01).

High-Efficiency Heat Pumps for Space Heating and Cooling

CalNEXT Role: Lead | CalNEXT Priority: High

Key Factors

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

Knowledge Index

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

Example Technologies

Variable Speed heat pumps: Air-to-water HPs, air-to-air HPs, Variable Refrigerant Flow, and split-system packaged HPs.

Definition

High-efficiency compressor-based packaged equipment that can provide efficient electric heating (and often cooling). Systems may include high efficiency air-to-air packaged HP units (ducted unitary HPs and ducted or ductless split systems), air-to-water HPs used to replace traditional boiler hydronic systems, or Variable Refrigerant Flow (VRF). "High-efficiency" equipment typically contains variable speed (VS) fans, compressors, and/or pumps. Other pathways to high efficiency include advanced heat exchangers and advanced controls algorithms.

Opportunities

High-efficiency HPs present significant energy efficiency (EE) and decarbonization potential relative to fixed-speed equipment with traditional gas-fired heating. Variable speed compressors also enable more robust demand flexibility. Generally, any heat pump replacing a furnace or boiler will result in improved local air quality and potentially indoor-air quality through avoided gas combustion which may be a consideration for Disadvantaged Communities (DAC) and Hard-to-Reach (HTR) communities. Prospective research should focus on field validation of high efficiency HP performance, especially when in heating mode to validate product efficiency, heating capacity, product sizing, and the related heating-performance metrics.

Barriers

Packaged HPs are a well-researched field with mature ratings systems and testing methods. Federal standards for residential central air and split system HPs were recently updated on January 1, 2023, which established new efficiency ratings (EER2/SEER2/HSPF2) and test procedures which include additional rating data at colder temperatures. However, new standards may continue to under-represent the benefits of variable speed equipment and other advanced features that are poorly captured under current metrics. This may be particularly important for the predominately mild heating needs of California and the common oversizing practices. This can lead to uncertainty in real-world benefits of these products when compared with single speed products. Continued research will be helpful to ensure right-sizing of products and may help programs fully account for the known benefits of high efficiency, variable speed products. As new products emerge to meet the broad decarbonization space-heating needs such as air-to-water HPs for boiler replacements or small-scale heat pumps designed for single rooms, there is a need for similar industry standardization of test procedures and ratings as well as field performance validation both of which are limiting the ability of utility programs to influence these new markets.

Scalable HVAC Controls Deployment

CalNEXT Role: Lead | CalNEXT Priority: High

Key Factors

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

Knowledge Index

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

Example Technologies

Building Automation Systems (BAS), Automated Fault Detection Diagnostics (FDD), Advanced monitoring, data analytics and benchmarking, grid-adaptive controls, load management controls, and smart thermostats (residential & small commercial).

Definition

Advancement of sensors, controllers, and demonstrations of new control strategies and technologies that improve the persistent performance of a building's HVAC energy use and component functionality with an emphasis on scalability and deployment of control systems. This technology family has strong overlaps with the Installation, Operations, and Maintenance technology family.

Opportunities

Emerging technologies in Scalable HVAC Controls have strong opportunities to improve energy savings and demand flexibility performance in commercial buildings. The February 2020 DOE report "Innovations in Sensors and Controls for Building Energy Management," estimated an aggregated annual energy savings of 29% is possible in the commercial sector alone through the implementation of EE measures using current state-of-the-art sensors and controls innovations. Studies showed 10-20% of commercial building peak load can be temporarily managed or curtailed to provide grid services but require better interoperability. Recent development to standardize advanced control strategies through efforts like American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Guideline 36 provide significant opportunity to scale quality control implementation at lower cost to building owners[2]. Future research should focus on (1) demonstration of strategies to reduce system complexity, installation, and commissioning cost; (2) field validation to support value proposition; and (3) enhancement of technology to support autonomous and operator-centric operation; and (4) development of technology to improve system interoperability.

For residential and small commercial buildings with unitary HVAC systems, there is a rapid adoption of smart thermostats, either provided by third-party or integrated with the HVAC product, that support automated energy and load management and integration with connected devices. The Environmental Protection Agency (EPA) has led the way in bringing demand flexibility capabilities and system monitoring to unitary systems under the ENERGY STAR® Smart Thermostat Specification

[2] https://www.energy.ca.gov/publications/2022/demonstrating-scalable-operational-efficiency-through-optimized-controls
Note: EPA previously named this product category "Connected Thermostats" and is revising the name to "Smart Thermostats."

V1.0[3],suggesting CalNEXT focus on “smart” thermostat deployment and program enrollment. While new thermostats optimized for variable capacity HVAC systems remains an untapped opportunity, there is limited performance validation such that they will not be incorporated under the ongoing ENERGY STAR® Specification v2.0 update[4]. New research should seek to validate the performance of variable-capacity smart thermostats to inform future product standards.

Barriers

Technical understanding of advanced HVAC controls is a well-researched area, often studied in larger buildings. Due to the varied components, complexity, maintenance procedures, and climate needs in commercial buildings, the magnitude and persistence of savings can vary significantly. CA IOUs codes and standards programs have been actively researching commercial HVAC controls in support of building code enhancements and retro-commissioning programs have provided incentives for improving existing building HVAC controls. In the residential sector, deployment of smart thermostats should remain the focus with special attention to research in program designs that can improve consumer education to ensure the energy savings potential is realized across all communities.

[3] https://www.energystar.gov/products/connected_thermostats/partners

[4] https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%202.0%20%20Smart%20Thermostat%20Draft%201%20Program%20Requirements.pdf

Hybrid or Fully Compressor-less HVAC

CalNEXT Lead | CalNEXT Priority: High

Key Factors

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

Knowledge Index

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

Example Technologies

Evaporative and indirect evaporative cooling or other alternatives to vapor compression cycles such as desiccant-based, absorption, thermoacoustic, thermoelectric, electrochemical, and radiant heat rejection.

Definition

HVAC cooling and heating systems that use alternatives to vapor compression cycles or hybrid combinations of alternatives along with vapor compression cycles. While evaporative cooling represents the most mature and developed of these, this family also includes desiccant systems, absorption, adsorption, thermoacoustic, thermoelectric, magnetocaloric, electrochemical, and others.

Opportunities

ET research in this technology family has the potential to yield strong EE savings potential, result in permanent load reductions, and reduce or eliminate refrigerant emissions related to traditional vapor-compression HVAC systems. While evaporative cooling is the most established technology subgroup, the water usage continues to be an important consideration for long-term drought conditions that warrants careful consideration to balance the energy savings benefits compared to increased water usage. Several non-evaporative technologies have seen minimal market uptake and appear to be several years away from broader adoption. Prospective research should focus on (1) lab and field demonstrations of non-evaporative, non-vapor compression alternative HVAC technologies with the ability to scale to mass production in the near term and (2) novel water efficiency strategies to reduce blowdown and drift from cooling towers.

Barriers

Multiple studies have demonstrated significant energy savings for evaporative systems. Design complexities, high first costs, and non-trivial maintenance needs have been traditional barriers to deploying evaporative cooling, particularly at smaller scale. Future water scarcity may be an additional barrier. At the residential level, increasing frequency of heat waves may push consumers to adopt low first-cost evaporative coolers.

Recent ET research has resulted in the development of a measure package for evaporative pre-cooler systems for very large commercial package units[5]. Meanwhile, non-evaporative, non-vapor compression systems are still in a very nascent stage of development, with limited commercially available products. Prospective research should focus on (1) understanding ideal use cases of evaporative systems, (2) lab and field studies testing of new evaporative equipment designs that reduce or overcome these barriers, (3) developing efficiency program strategies for overcoming market barriers, and (4) enhancement of existing design tools to include hybrid or fully compressor-less HVAC systems.

[5] SWHC042-03: https://www.caetrm.com/measure/SWHC042/03/

Heat Pump Market Development

CalNEXT Role: Lead | CalNEXT Priority: High

Key Factors

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

Knowledge Index

Technical Performance: Medium
Market Understanding: Medium (increased)
Program Intervention: Low

Example Technologies

Program designs, deployment strategies, financing mechanisms, and other research to assist in market deployment of the HVAC sector.

Definition

Innovative program designs and supporting research to accelerate deployment of the California HP market. May include financing innovations, turn-key incentive design, or other coordination with various market actors focused on HP deployment. This technology family will help meet the California Energy Commission's (CEC's) goal of installing at least 6 million HPs by 2030. This technology family was previously referred to as "Heat Pump Market Transformation".

Opportunities

HP deployment is a key pathway for decarbonizing California's building stock and to maximize their impact, they will need to be energy efficient with demand flexible capabilities. Within colder regions of California, there is need to investigate opportunities to deploy cold climate heat pumps[6] in place of furnaces or dual-fuel heat pumps. The 2021 Inflation Reduction Act (IRA) will accelerate the existing HP market deployment activities over the next decade. The law establishes tax credits for high efficiency HPs and provides point-of-sale incentives for income-qualified households. Multifamily and Commercial buildings will also be eligible for tax credits.

CalNEXT research should inform changes needed to the existing statewide HVAC and fuel substitution programs to prepare strategic alignment with the new federal programs as well as inform the direction of the new federal programs. Additionally, CalNEXT should continue to investigate HP deployment strategies specifically designed for renter ratepayers which are not well targeted by these federal programs nor current statewide program offerings.

Barriers

Technical understanding of the HP market continues to grow through deployment programs such as BUILD (The Building Initiative for Low-Emissions Development), California Energy-Smart Homes, and the relaunched 2023 Technology and Equipment for Clean Heating (TECH) Clean CA program. The IRA will continue to accelerate these activities and current and future programs should seek alignment with federal tax credits and the HOMES and HEEHRA programs where appropriate. However, more research is needed to understand the appropriate deployment strategies and technologies for different building types, communities, and end users in order to ensure benefits for all ratepayers.

[6] Established in ENERGYSTAR® V6.0 for Central Air Source Heat Pumps and Central Air Conditioners.

HVAC Design for Decarbonization

CalNEXT Role: Lead | CalNEXT Priority: High

Key Factors

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

Knowledge Index

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

Example Technologies

Decoupled HVAC systems (e.g., High efficiency Dedicated Outdoor Air System (DOAS) with an Energy Recovery Ventilator (ERV) and Variable Refrigerant Flow (VRF)), heat recovery chillers, air-to-water HPs, and other whole system all-electric designs.

Definition

A holistic design that is aimed at achieving a high-efficiency, low-emissions HVAC system in both new and existing buildings.

Opportunities

ET research in this technology family will yield strong EE savings potential and decarbonization by electrifying space heating, enabling energy recovery, or removing design barriers to future decarbonization. Prospective research should focus on: (1) developing design tools to electrify existing buildings utilizing existing studies and design guides when available, (2) conducting field studies to validate the performance and cost-effectiveness in electrifying "difficult" existing building HVAC systems such as systems using large boilers for hydronic space heating, and (3) developing program strategies for overcoming technical and market barriers.

Barriers

HVAC designs have been evolving to meet the needs of a decarbonized building future. While technical understanding is growing, particularly in the new construction market, the existing building sector needs research to overcome considerable technical barriers and market complexity in transitioning these systems. Research is needed for cost effectively retrofitting and electrifying HVAC systems in the existing building market, particularly for the commercial and multifamily sector, as well as understanding the appropriate program designs and deployment mechanisms to address these technical and market barriers.

Scalable Thermal Storage

CalNEXT Role: Lead | CalNEXT Priority: High (increased)

Key Factors

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

Knowledge Index

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

Subgroups

Thermal energy storage and thermally activated building systems.

Definition

Thermal or non-electric energy storage solutions with the capability to scale and integrate with HVAC systems, including both active storage (charged and discharged with controls, e.g., hot water storage tanks) and passive storage (charged and discharge without dedicated controls, e.g., heat capacitance of building structure).

Opportunities

Incorporating thermal storage into HVAC systems has the potential for significant demand flexibility and can reduce energy consumption by shifting HVAC cooling and heating loads to periods with more favorable ambient conditions for heat extraction or heat rejection. This shift can also result in permanent load reductions, reducing peak demand by spreading heating and cooling loads over longer periods of time and by shifting to non-peak hours. Large emissions reductions are possible with significant thermal storage by shifting energy usage to times of day with lower emissions in the energy supply. Thermal energy storage can also support and accelerate decarbonization by allowing electric heat extraction and heat rejection systems (e.g., air-to-water HPs, heat recovery chillers, etc.) to serve non-simultaneous heating and cooling loads commonly found in larger HVAC systems. Prospective ET studies should build upon the ongoing research of the CA IOU CASE Team on this topic[7] as well as conducting lab and field demonstrations of emerging technologies with a viable path to scalability. As this is an emerging technological space, there is a need for new market studies to characterize different emerging product types and their uses for particular building types and HVAC system typologies.

Barriers

Significant technical and market barriers exist, including high capital cost, added complexity of design and controls, lack of available space for equipment, risk of equipment failure, lack of cross-trade coordination, particularly for storage systems with significant space requirements or those that integrate directly with a building structure. Thermal storage ideas and projects should identify barriers and provide strategies for mitigating or removing such barriers.

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[7] https://title24stakeholders.com/measures/cycle-2025/nonresidential-hvac-space-heating/

Installation, Operations, and Maintenance

CalNEXT Role: Lead | CalNEXT Priority: Medium

Key Factors

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

Knowledge Index

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

Subgroups

HVAC System Commissioning (Cx), Existing-building Commissioning (EBCx), asset management, benchmarking & monitoring, building performance standards, flexible load management, and artificial intelligence (AI) building management systems.

Definition

This technology family is focused on advancements in HVAC commissioning techniques and improvements in installation, operations, & maintenance focused on improving the initial energy performance at time of installation, ensuring persistence of performance, improving the useful life of HVAC systems through proper maintenance. This technology family has strong overlaps with the Scalable HVAC Controls technology family.

Opportunities

Improvements in installation, operations, and maintenance have moderate potential for energy savings, demand flexibility, and can reduce refrigerant-related emissions. Under a 2020 Lawerence Berkely National Lab (LBNL) study, research found median simple payback time for EBCx to be under 2 years[8] yet despite the benefits, initial cost remains a significant barrier. The continued maturity of Normalized Metered Energy Consumption (NMEC) programs have the potential to improve program delivery within this technology family[9].

Prospective research should focus on: (1) demonstrating low-cost approaches to existing building commissioning, continuous commissioning, and quality installation programs; (2) demonstration of tools to help small and medium building operators incorporate sophisticated asset monitoring; and (3) improvements to existing program models to improve the quality of installations, maintenance practices, and ultimately the persistence of energy efficiency measures.

Barriers

Technical understanding of installation, operations, and maintenance is a mature area. To date, adoption of Cx has been mostly driven by mandatory building code requirements or voluntary code requirements such as California Green Building Standards (Title 24, Part 11) (CALGreen) or Leadership in Energy and Environmental Design (LEED) ratings. While research indicates that existing buildings still have significant cost-effective energy savings opportunities, deployment across building types remains a complex and disaggregated market. Utility incentive-based approaches may continue to be important to develop the market capabilities while California's policy makers further assess systematic existing building policy approaches such as building performance standards[10].

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[8] https://eta-publications.lbl.gov/sites/default/files/crowe_-_building_commissioning_costs_and_savings_.pdf
[9] CA IOUs NMEC studies: ET17SCE1130, ET17SCE7050, ET17SCE1080, ET17SDG1061, ET18PGE1211, ET19SCE7010.
[10] https://www.energycodes.gov/BPS

110V/120V Heat Pumps

CalNEXT Role: Lead (increased) | CalNEXT Priority: High (increased)

Key Factors

Energy Savings: Medium
Decarbonization: High (increased)
Demand Flexibility: Low (decreased)
Other Emissions Impacts: Low

Knowledge Index

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

Subgroups

Portable HPs, window HPs, packaged-terminal HPs, and through-the-wall HPs.

Definition

Efficient, rapidly deployable HPs that often do not require professional installation and are suitable for compact spaces where HPs can replace electric space heaters or where traditional split-systems are too costly or onerous to deploy. Typical scenarios include small homes, additional dwelling units, apartments, mobile homes, hospitality, assisted living facilities, and schools. This technology family will help meet the California Energy Commission's goal of installing at least 6 million HPs by 2030.

Opportunities

Mass deployment of 110V/120V HPs has the potential to rapidly electrify space heating and simultaneously replace existing portable space heaters and older, less efficient room air conditioners with more efficient HPs. Advancements in this technology family may be especially important for DAC and HTR customers since they are a majority renter group with limited options to improve their HVAC infrastructure. These products have the potential to provide a low up-front cost alternative compared to traditional central heat pump systems that is significantly more efficient than current systems (portable electric resistance heaters and gas-fired heaters). Prospective ET studies should investigate deployment costs of 110V/120V HPs when compared with more traditional HVAC solutions and investigate in-field heating performance of these products to ensure they can fully displace existing electric resistance heaters since these products have historically been optimized for their cooling performance rather than their heating performance. Studies investigating customer usage patterns may also help inform the real-world efficiency and electrification potential of these products.

Barriers

Most 110V/120V HP products are adaptations of familiar products such as room air conditioners or portable air conditioners. ET investments in this technology family can help better understand product costs compared with similar heating/cooling devices, product usage patterns, customer sentiment, and market availability. Installation is often performed by users so identifying common installation challenges would be appropriate (e.g., setting of outdoor air damper position, sealing around unit).

Refrigerant Management & Low GWP Transition

CalNEXT Role: Collaborate | CalNEXT Priority: Medium

Key Factors

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

Knowledge Index

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

Subgroups

Performance validation of low and ultra-low global warming potential (GWP) systems, refrigerant recycling strategies, refrigerant leak mitigation, low-charge system design, and low-leak pipe fittings & installations.

Definition

Research for transitioning HVAC systems to low and ultra-low GWP refrigerants, reducing the overall refrigerant charge, reducing refrigerant leakage, ensuring adequate safety of "mildly flammable refrigerants" (A2Ls), or reclaiming refrigerant at end-of-product life.

Opportunities

HVAC manufacturers are rapidly transitioning away from R-410A to "low-GWP" refrigerants with a GWP below 750 such as R-32, R-454B, and R-466A. These are substantive changes that may have a significant impact on the overall efficiency, system capacity, and legally installable refrigerant charge limits.

Highest impact research under this technology family will assist with an orderly transition of the HVAC market (including existing IOU programs) in adherence to the regulatory enforcement deadlines. This will include analyzing the impact of different low-GWP refrigerants against the baseline energy usage to avoid sacrificing overall system performance while transitioning to alternative refrigerants as well as ensuring safe installation practices for A2L refrigerants. In addition, with the shift from kW, kWh, and therms to total system benefit (TSB) as the IOU program performance metric, programs that target refrigerant emissions reductions will be able to claim savings starting in 2024. Research into new program models that focus on refrigerant emissions reductions would be valuable. CPUC has undertaken research to this effect in recent years, ET work should build on their findings.[11,12]

Note: Refrigerant management of ammonia (R-717) and CO2 (R-744) are discussed separately in the Process Loads TPMs as they are not currently used in HVAC systems. However, we are aware of early-stage product development using these refrigerants targeted for the HVAC market.

Barriers

Technical performance of systems with the new refrigerants is not well known as manufacturers are still developing new products. Building codes, in particular the mechanical code (Title 24 Part 4), are in the process of being updated to safely allow the use of mildly flammable refrigerants. Any changes in the installation, maintenance, or handling of new refrigerant systems will have to be disseminated for workforce development programs.

[11] https://www.calmac.org/publications/CPUC_HVAC_Refrigerants_-_PDS_05032021_FinalReport.pdf.
[12] https://pda.energydataweb.com/#!/documents/2772/view.

Next Steps

Following submittal of the 2023 HVAC TPM, the Program Team will do the following:

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

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

Table 2: Advisory Committee 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.
N/A	HVAC TPM Overview	Request image replaced by table	Incorporated change
High-Efficiency HPs for Space Heating and Cooling	Opportunities & Barriers	As a cooling dominated climate, should the focus be on cooling first and heating 2nd?	Incorporated change within narrative.
High-Efficiency HPs for Space Heating and Cooling	Barriers	Requested clarifications regarding test procedure performance statements & lack of standardization for emerging heat pump product types.	Incorporated changes within narrative.
Scalable HVAC Controls Deployment	Example Technologies / Subgroups	Is there overlap with “Installation, Operations, and Maintenance” area?	Incorporated note on overlap with IO&M Tech family.
Scalable HVAC Controls Deployment	Barriers	Suggest additional details about consumer education needed to actualize technical potential for DAC/HTR.	Incorporated changes within narrative.
Hybrid or Fully Compressor-less HVAC	Definition	Is phase change materials part of this too?	No change made. Subgroups / example technologies under this technology family can include novel phase change technologies but were not specifically called out by our SME team.
Hybrid or Fully Compressor-less HVAC	Opportunities	From a consumer perspective, is there data or research results on how much more water these systems use? Is there a	Modified narrative to clarify most common uses of evaporative cooling.

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
		scenario where the efficiencies gained by this technology outweigh the excess water usage?	
Hybrid or Fully Compressor-less HVAC	Barriers	What is a “heat storm”	Incorporated changes within narrative for more common “heat wave” term.
Heat Pump Market Development	Tech Family Title	Development or Transformation? The highlighted Priority area table shows Transformation.	Incorporated change to table and made note in narrative of previous title.
Scalable Thermal Storage	Opportunities	Can “particular markets” be elaborated. And also, applications.	Incorporated changes within narrative to clarify research needs. Also added reference to relevant Title 24 CASE research.
Installation, Operations, and Maintenance	All	Include AI (Artificial Intelligence) technologies to the list of example technologies.	Incorporated change into narrative.
Installation, Operations, and Maintenance	Definition	How will duplication be avoided?	No change made. Overlapping technology families is an unavoidable feature of the TPMs as emerging products and solutions can often address multiple technology research needs. Our Scanning & screening team reviews for overlapping project scope to ensure projects are not duplicating efforts.
Installation, Operations, and Maintenance	Opportunities	However incorrect installation could lead to energy penalties due to impact on performance/operation	Incorporated as a direct research need.
110V/120V Heat Pumps	Examples Technologies / subgroups	Recommend adding ADU to subgroups	Incorporated into subgroups.
110V/120V Heat Pumps	Opportunities	especially important to DAC/HTR because of first cost considerations.	Incorporated into subgroups.

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
Refrigerant Management & Low GWP Transition	All	We have engaged in ET projects that have looked at ammonia/CO2 for HVAC for commercial settings. Suggest this should be flagged due to interest from research/manufacturing on these areas for the future.	Incorporated into narrative.