2022 HVAC Technology Priority Map

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Abbreviations, Acronyms, and Glossary of Terms

Acronym	Meaning
BAS	Building Automation Systems
BCCA	Buy Clean California Act
BUILD	Building Initiative for Low-Emissions Development
CARB	California Air Resources Board
CEC	California Energy Commission
Cx	Building Commissioning
DAC	Disadvantaged Communities
DOAS	Dedicated Outdoor Air System
EBCx	Existing Building Commissioning
EE	Energy Efficiency
EPD	Environmental Product Declaration
ERV	Energy Recovery Ventilator
ET	Emerging Technology
eTRM	Electronic Technical Reference Manual (CA)
EV	Electric Vehicle
FDD	Automated Fault Detection Diagnostics
GHG	Greenhouse Gas Emissions
GWP	Global Warming Potential
HP	Heat Pump
HTR	Hard-to-Reach
HVAC	Heating, Ventilation, and Air Conditioning
IEPR	Integrated Energy Policy Report
IOU	Investor-Owned Utility
LEED	Leadership in Energy and Environmental Design

SCE	Southern California Edison
SME	Subject Matter Expert
TABS	Thermally Activated Building Systems
TECH	Technology and Equipment for Clean Heating
TPM	Technology Priority Map
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, 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.
Emerging Technology Program (ETP) Role	Describes general level of engagement by CalNEXT SMEs. *Note: Roles will change as research is completed.*
Lead Collaborate Observe	"Lead" - CalNEXT expects to take on most or all of the work and cost burden. "Collaborate" – CalNEXT is interested in collaborating and co-funding projects. "Observe" – CalNEXT will track progress but encourage external programs to take lead in unlocking these opportunities.
ETP 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, markets, 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.

2022 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 can expect a shift in focus toward breaking down the barriers to adoption needed to meet California's goal to deploy 6 million heat pumps by 2030[1]. For less mature product markets like air-to-water heat pumps 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 to inform utility programs and standards efforts as they adapt to new appliance standards for central air conditioners & heat pumps and unitary air conditioners & heat pumps which will see new standards, test procedures, and metrics in 2023 as well as new low-Global Warming Potential (GWP) requirements driven by California Air Resources Board (CARB).

Highlighted Priority Areas

Technology Family	Technology Subgroups	Definition	ETP Role	ETP Priority
High Efficiency Heat Pumps for Space Heating and Cooling	Air-to-water heat pumps for space heating; air-to-air heat pumps for space heating and cooling; Variable Refrigerant Flow Systems (VRF); Split System packaged Heat Pumps.	Compressor-based packaged equipment that can provide efficient heating (and potentially cooling). Systems may include air-to-air packaged heat pump units (ducted unitary heat pumps and ducted or duct-less split systems), air-to-water heat pumps used to replace traditional boiler hydronic systems, or variable refrigerant flow systems (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	Building Automation Systems (BAS), Automated Fault Detection Diagnostics (FDD), Advanced monitoring and data analytics, Grid-adaptive controls, load management controls, Smart Thermostats (Residential).	Advancement of sensors, controllers, and demonstrations of new control strategies that improve the performance of a building's HVAC energy use and component functionality with an emphasis on scalability and deployment of controls systems.	1-Lead	1-High
Hybrid or Fully Compressor-less HVAC	Evaporative and indirect evaporative cooling or other alternatives to vapor compression cycles such as desiccant-based, absorption, thermoacoustic, thermoelectric, and radiant heat rejection.	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, and others.	1-Lead	1-High
Heat Pump Market Transformation	Program designs, deployment strategies, financing mechanism, and other research to assist in market transformation of the HVAC sector.	Innovative program designs and supporting research to accelerate deployment and overall market transformation of the California heat pump market. May include financing innovations, turn-key incentive design, or other coordination with various market actors. This technology family will help meet CEC's goal of installing at least 6 million heat pumps by 2030.	1-Lead	1-High
HVAC Design for Decarbonization	Decoupled HVAC systems (e.g., DOAS with an ERV and VRF); Heat recovery chillers; other whole system all-electric designs.	A holistic HVAC design that is aimed at achieving a high efficiency, low emissions system in both new and existing buildings.	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

(ETP Role: Lead, ETP 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

Subgroups

Air-to-water heat pumps for space heating, air-to-air heat pumps for space heating and cooling, VRF, and split system packaged heat pumps.

Definition

Compressor-based packaged equipment that can provide efficient heating (and potentially cooling). Systems may include air-to-air packaged heat pump units (ducted unitary heat pumps and ducted or ductless split systems), air-to-water heat pumps used to replace traditional boiler hydronic systems, or 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: (EE Savings, Decarbonization, Demand Flexibility, and Other GHG)

High-efficiency heat pumps present significant energy efficiency 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 fields demonstrating high efficiency heat pump performance, especially when in heating mode to validate product efficiency, heating capacity, product sizing, and the related heating-performance metrics.

Barriers: (Technical, Market, Program)

Packaged heat pumps are a well-researched field with mature ratings systems and testing methods. Despite this maturity, the current test procedures do a poor job of capturing the real-world performance of variable speed equipment (part-load cooling, mild heating scenarios, and cold climate performance). This can lead to significant uncertainty in real-world performance, especially since the majority of time these products are operating in California's relatively mild climate. Continued research on these products 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.

Scalable HVAC Controls Deployment

(ETP: Lead, ETP 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

Subgroups

Building Automation Systems (BAS), Automated Fault Detection Diagnostics (FDD), Advanced monitoring and data analytics, Grid-adaptive controls, load management controls, and Smart Thermostats (residential & small commercial).

Definition

Advancement of sensors, controllers, and demonstrations of new control strategies that improve the performance of a building's HVAC energy use and component functionality with an emphasis on scalability and deployment of control systems.

Opportunities (EE Savings, Decarbonization, Demand Flexibility, and Other Greenhouse Gas Emissions (GHG))

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 energy efficiency 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. Within the residential sector, HVAC controls are much simpler and already productized with smart thermostat deployment and program enrollment as a focus to actualize energy savings and demand flexibility opportunities.

Barriers (Technical, Market, Program)

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. Codes and standards programs have actively studied 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, both deployment and program enrollment of smart thermostats should remain the focus.

Hybrid or Fully Compressor-less HVAC

(ETP Role: Lead, ETP 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

Subgroups

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

Opportunities: (EE Savings, Decarbonization, Demand Flexibility, and Other GHG)

ET research in this technology family has the potential to yield strong energy efficiency savings potential, result in permanent load reductions, and reduce or eliminate refrigerant emissions related to traditional vapor-compression HVAC systems[2]. However, the most established technology subgroups (evaporative cooling) will likely increase water usage which is an important and growing consideration. 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.

Barriers: (Technical, Market, Program)

Technical performance of evaporative systems is a well-researched area. Design complexities, high first costs, and non-trivial maintenance needs have been traditional barriers to deploying evaporative cooling at smaller scale. Future water scarcity may be an additional barrier. Recent ET research has resulted in development of a measure package for evaporative pre-cooler systems for very large commercial package units (effective in 2022). Meanwhile, non-evaporative, non-vapor compression system are still very nascent stage of development.

[2] The nationwide transition to low-GWP refrigerants will limit the future impacts of refrigerant-less cooling.

Heat Pump Market Transformation

(ETP Role: Lead, ETP Priority: High)

Key Factors

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

Knowledge Index

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

Subgroups

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

Definition

Innovative program designs and supporting research to accelerate deployment and overall market transformation of the California heat pump market. May include financing innovations, turn-key incentive design, or other coordination with various market actors. This technology family will help meet the California Energy Commission's (CEC's) goal of installing at least 6 million heat pumps by 2030.

Opportunities: (EE Savings, Decarbonization, Demand Flexibility, and Other GHG)

Improved heat pump market deployment will have the strongest impact on decarbonization through electrified heating but may also improve the overall market penetration of demand flexibility. Targeted research should address specific deployment strategies for DAC and HTR communities as well as developing strategies specifically designed for the segment of ratepayers who are renters.

Barriers: (Technical, Market, Program)

Technical understanding of the heat pump market is growing through new deployment programs such as BUILD (The Building Initiative for Low-Emissions Development) and TECH (Technology and Equipment for Clean Heating). However, more research is needed to understand different building types, communities, and end users in order to create robust participation across all ratepayers. The overall increase in heat pumps will be expected to increase refrigerant-related emissions.

HVAC Design for Decarbonization

(**ETP Role:** Lead, **ETP 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

Subgroups

Decoupled HVAC systems (e.g., Dedicated Outdoor Air System (DOAS) with an Energy Recovery Ventilator (ERV) and Variable Refrigerant Flow (VRF)), heat recovery chillers, 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 (EE Savings, Decarbonization, Demand Flexibility, and Other GHG)

ET research in this technology family will yield strong energy efficiency savings potential and decarbonization by enabling electrified space heating or removing design barriers to future decarbonization. Prospective research should focus on: (1) design guides or design tools to electrify existing buildings and (2) field studies to validate cost-effectiveness in electrifying "difficult" existing building HVAC systems such as systems using large boilers for hydronic space heating in the case of variable air volume with terminal reheat.

Barriers (Technical, Market, Program)

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 on transitioning these systems. Research is needed on the most cost-effective approaches for an electrified transition of the existing building market, particularly for the commercial and multifamily sector as well as understanding the appropriate program designs to address these complexities.

Scalable Thermal Storage

(ETP Role: Lead, ETP Priority: Medium)

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.

Opportunities: (EE Savings, Decarbonization, Demand Flexibility, and Other GHG)

Incorporating thermal storage into HVAC systems has the potential for significant demand flexibility. Large emissions reductions are possible with significant thermal storage by shifting energy usage to times of day with lower emissions and more favorable thermodynamic operations. Prospective ET studies should focus on lab and field demonstrations of technology with a viable path to scalability.

Barriers: (Technical, Market, Program)

Significant technical and market barriers exist, including lack of uniform thermal storage material, lack of uniform control strategies, lack of uniform design strategies, and high costs of customized systems.

Installation, Operations, and Maintenance

(ETP Role: Lead, ETP 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

HVAC System Commissioning (Cx), Existing-building Commissioning (EBCx), asset management, performance metrics (measurement and monitoring), and flexible load management.

Definition

This technology family is focused on advancements in HVAC commissioning techniques and improvements in installation, operations, & maintenance focused on improving the initial performance at time of installation, ensuring persistence of performance (operations), and improving the useful life of HVAC systems through proper maintenance.

Opportunities: (EE Savings, Decarbonization, Demand Flexibility, and Other GHG)

Improvements in installation, operations, and maintenance have moderate potential for energy savings, demand flexibility, and are expected to reduce refrigerant-related emissions. While Cx has been required in the building code for large buildings, high costs have prevented expansion into smaller buildings. Additionally, opportunities remain for wide adoption in the existing building market. Under a 2020 LBNL study, research found median simple payback time for EBCx to be under 2 years. Prospective research should focus on: (1) demonstrating low-cost approaches to existing building commissioning and continuous commissioning; (2) tools to help small and medium building operators incorporate sophisticated asset monitoring; and (3) improvements to existing utility programs to improve maintenance and persistence of efficiency measures.

Barriers: (Technical, Market, Program)

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 CALGreen or LEED (Leadership in Energy and Environmental Design). While the CA IOUs have previously run retro-commissioning programs, research indicates that existing buildings still have significant cost-effective energy savings opportunities but deployment across building types remains a complex and disaggregated market.

110V/120V Heat Pumps (Portable-, Room-, and Packaged Terminal-HPs)

(ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups

Portable heat pumps, window heat pumps, packaged-terminal heat pumps, and through-the-wall heat pumps.

Definition

Efficient, rapidly deployable heat pumps suitable for compact spaces where heat pumps can replace electric space heaters or where traditional split-systems are too costly or onerous to deploy. Typical scenarios include small homes, 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 heat pumps by 2030.

Opportunities: (EE Savings, Decarbonization, Demand Flexibility, and Other GHG)

Mass deployment of 110V/120V heat pumps has the potential to rapidly electrify space heating and replace existing portable space heaters with more efficient heat pumps. This technology family may be especially important for DAC and HTR customers since they are a majority renter group with limited options to improve HVAC infrastructure. Prospective ET studies should investigate deployment costs of 110V/120V heat pumps when compared with more traditional HVAC solutions and investigate in-field heating performance of these products to ensure they operate as efficient heat pumps rather than electric resistance heaters since these products have historically been optimized for their cooling performance rather than their heating performance.

Barriers: (Technical, Market, Program)

Most 110V/120V heat pump 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 customer purchasing behavior, product usage patterns, customer sentiment, and market availability. Installation is often performed by users as well so identifying common installation challenges would be appropriate (e.g., setting of outdoor air damper position, sealing around unit).

Refrigerant Management & Low GWP Transition

(ETP Role: Collaborate, ETP 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

Low GWP equipment (validating performance) and refrigerant leak mitigation.

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 "slightly flammable refrigerants" (A2Ls). or reclaiming refrigerant at end-of-product life.

Opportunities: (EE Savings, Decarbonization, Demand Flexibility, and Other GHG)

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 significant impact on the overall efficiency, system capacity, and legally installable refrigerant 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.

Note: Refrigerant management of ammonia (R-717) and CO2 (R-744) are discussed separately in the Process Loads TPMs as they are not commonly used in HVAC systems.

Barriers: (Technical, Market, Program)

Technical performance of systems with the new refrigerants is not well known as manufacturers are still developing new products. Any changes in the installation, maintenance, or handling of new refrigerant systems will have to be disseminated for workforce development programs