



2026 Portfolio Enhancements Technology Priority Map

Final Report

ET26SWE0011



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Abbreviations, Acronyms, and Glossary of Terms

Acronym	Meaning
ALD	Automated leak detection
CPUC	California Public Utilities Commission
DAC	Disadvantaged communities
DER	Distributed energy resources
EE	Energy efficiency
ET	Emerging technology
GHG	Greenhouse gas
GWP	Global warming potential
HTR	Hard-to-reach
HVAC	Heating, ventilation, and air conditioning
IOU	Investor-owned utility
LRM	Lifecycle refrigerant management
MRL	Market Readiness Level
NAPA	National Asphalt Pavement Association
NMEC	Normalized metered energy consumption
SCE	Southern California Edison
SMB	Small and medium businesses

Acronym	Meaning
SME	Subject matter expert
TAC	Technical Advisory Committee
TPM	Technology Priority Map
TRC	Total Resource Cost
TRL	Technology Readiness Level
TSB	Total System Benefit

Glossary Term	Meaning
Technology Category	One of six broad technology categories (Whole Buildings; HVAC; Water Heating; Lighting, Plug Loads, and Appliances; Process Loads; and Portfolio Enhancements).
Technology Family	Functional grouping that provides description of program role, opportunities, and barriers.
Research Initiatives	Initiative in place of both subgroups and knowledge indices.
Research Initiatives Key	Visual aid explaining if each research initiative is at a level of high understanding, ranked on a low, medium, or high scale.
Rankings	<p>Future Needs: Covers items that are not yet ready for consideration due to having high needs in performance validation, market analysis, measure development, and performance development. Programs should not be discouraged from submitting proposals for research initiatives with a “Future Needs” classification but instead focus on making a strong argument for how the project outcomes can help fill in the missing gaps for validation or market analysis.</p> <p>Low: Covers items that have lower industry interest and/or uncertain impacts for energy efficiency due to having an expansive data set or information readily available or not being pertinent to the research initiative.</p> <p>Medium: Covers items that are an evolution or offer promise to existing and common technologies for energy efficiency. This can be in the form of needs that are currently being addressed with existing projects or needs that may exist but are not critical to the objectives of meeting efficiency metrics.</p> <p>High: Covers items that have high industry interest and high impacts for energy efficiency.</p>
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 Priority	Communicates expected level of focus by CalNEXT subject matter experts (SMEs). <i>Note: Priorities will change as research is completed.</i>
High	High: CalNEXT has highlighted this technology family as having high energy savings with any known barriers surmountable through targeted interventions within the Technology Category and will prioritize funding projects under this technology family.
Medium	Medium: CalNEXT has highlighted this technology family as having moderate to high overall energy savings with known barriers to entry that may be more challenging to address within the Technology Category and

will consider funding projects under this technology family.

Low

Low: CalNEXT has highlighted this technology family as having moderate to high overall savings but faces difficult or unknown barriers to adoption within the Technology Category and will not prioritize funding projects under this technology family.

Introduction

Technology Priority Maps (TPMs) provide the CalNEXT Program with a framework to externally communicate priorities of the program, clearly define the central focus areas of the program, and assist with project screening. They document the impact potential, programmatic research needs, and market readiness of all technology families across each of the end-use topic areas, as well as drive product ideation and inform project selection. This Final Report covers the revision process for the 2026 Portfolio Enhancements TPM.

2026 Key Technology Priority Map Changes

The 2026 Portfolio Enhancements TPM revises the 2025 Portfolio Enhancements TPM based on recent changes in policy and portfolio priorities for the investor-owned utilities (IOUs) and the California Public Utilities Commission (CPUC). The Portfolio Enhancements TPM is designed to address issues that span individual end-use technologies and represent emerging policies, markets, or product trends. In interviews about CalNEXT's research and pathways for moving promising emerging technologies (ETs) into the portfolio, emerging technology stakeholders reported significant barriers, including cost-effectiveness challenges for energy efficiency (EE) measures; programmatic barriers such as the lack of availability of new measures; the need for additional load shape research; insufficient demand flexibility measures to meet fluctuating grid peak needs; affordability concerns for electricity and barriers to fuel substitution measures; and limited adoption of low-global-warming-potential (GWP) measures. Unlike the barriers typically associated with a particular technology or end use, these barriers arise from the overall parameters of the EE programs that the CPUC funds and oversees. At the same time, programmatic opportunities arising from local, regional, and statewide policy developments such as building performance standards (BPS) may be undervalued as the landscape evolves.

To address these portfolio gaps, this TPM gathers a targeted list of portfolio opportunities and barriers into one document for consideration by the larger community of EE stakeholders and provides actionable suggestions on the types of portfolio-related research CalNEXT has interest in conducting. Additionally, the Portfolio Enhancements TPM aims to further clarify potential areas of study and offers definition, opportunities, and barriers for identified research families.

Notable drivers include:

- Integrating disadvantaged community (DAC) and hard to reach (HTR) designations into technology TPMs rather than treating them as separate topics
- Streamlining topics to align with Technical Advisory Committee (TAC) feedback (i.e., prioritizing kWh and kW while maintaining a secondary focus on co-benefits such as benefits for low-income customers, demand response (DR), demand flexibility, and low-GWP technologies)
- Focusing on short-term (one- to three-year) EE portfolio impacts
- Incorporating technology transfer outcomes

- Incorporating the Market Readiness Level and Technology Readiness Level (MRL and TRL) frameworks
- Heightening the Portfolio Enhancements TPM's focus on identifying EE portfolio gaps and opportunities (e.g., assessing measures based on high to low Total Resource Cost (TRC), Total System Benefit (TSB), and adoption to prioritize those with more immediate portfolio benefits)
- Incorporating ET stakeholder feedback on portfolio benefits, technology transfer, and market and program barriers.

For the 2026 Portfolio Enhancements TPM, which includes new content, the CalNEXT program team established a streamlined process for developing and revising the TPM. This year, the project team is conducting a more targeted outreach push to ensure that feedback directly aligns with IOU and third-party implementer (3PI) needs, with an increased focus on kWh savings, affordability, and technology transfer outcomes. The project team is comprised of representatives from each program team partner: VEIC, Franklin, TRC, UC Davis, and Energy Solutions, with The Ortiz Group adding stakeholder feedback at the Draft Report stage. The Portfolio Enhancements SME Team represents members that collectively support an array of EE programs using technologies covered by the various TPM domains; these emerging products are then contextualized into priority maps through a markets and solutions lens.

As in the 2025 Portfolio Enhancements TPM, the 2026 Portfolio Enhancements TPM incorporates a simplified icon view in the Research Initiatives table to identify the three to five most important research areas the team can prioritize in subsequent versions. The intent is to more clearly demonstrate how the SME team assessed each research initiative's maturity level.

Table 1: Rankings and their meanings.

Icon	Meaning
 Future Needs	Covers items that are not yet ready for consideration due to having high needs in performance validation, market analysis, measure development, and program development. Programs should not be discouraged from submitting proposals for research initiatives with a "Future Needs" classification but instead focus on making a strong argument for how the project outcomes can help fill in the missing gaps for validation or market analysis.
 Low	Covers items that have lower industry interest and/or uncertain impacts for EE due to having an expansive data set or information readily available or not being pertinent to the research initiative.

Icon	Meaning
 Medium	Covers items that are an evolution or offer promise to existing and common technologies for EE. This can be in the form of needs that are currently being addressed with existing projects or needs that may exist but are not critical to the objectives of meeting efficiency metrics.
 High	Covers items that have high industry interest and high impacts for EE.

Stakeholder Feedback

Technology Priority Map Advisory Committee Outreach

Outreach to the TPM Advisory Committee began in August 2026 by emailing stakeholders a survey. Their feedback informed additions to the research family narratives in this document. The TPM Advisory Committee members are listed below in Table 2.

Table 2: Advisory Committee outreach.

Organization
California Public Utilities Commission (CPUC)
California Technical Forum (Cal TF)
California Market Transformation Administrator (CalMTA)
Pacific Gas & Electric (PG&E)
Southern California Edison (SCE)
San Diego Gas & Electric (SDG&E)

The team's outreach allowed Advisory Committee members to provide candid feedback in written comments and suggestions, which the TPM coordinator and the 2026 Portfolio Enhancements SME Team reviewed and incorporated into the revised 2026 Draft and Final Report sections. Feedback can be found in Appendix A.

Energy Efficiency Success Opportunities

CalNEXT Priority: High

Definition

This research family is focused on identifying opportunities to increase cost-effectiveness, adoption, and participation in EE programs and ways that EE can mutually reinforce other initiatives and policies such as BPS and building decarbonization programs.

Additionally, this technology family may focus on increasing awareness and understanding of the market and programmatic constraints of cost-effective EE solutions, including assessments of measure energy savings, TRC and TSB benefits and cost implications, adoption rates, and other factors contributing to EE measure adoption. This research may also consider market constraints on program participation such as limited financing solutions for certain market segments. While California has a rich and diverse set of measure delivery approaches, including deemed, custom, and normalized metered energy consumption (NMEC)—in addition to recent policy changes that encourage innovation under the TSB metric and through NMEC solutions—overall measure utilization remains low. Some measures have inherent barriers to adoption and implementation. Shedding light on these barriers, research needs, and tools can enhance awareness and uptake of EE savings, TSB, NMEC, and other methods, thereby supporting and validating a more robust EE portfolio.

Research Initiatives

Table 3: EE success opportunities research initiatives.

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Identify measure packages that may require updates to load profiles to enhance TSB achievement and/or cost-effectiveness				
Conduct a review of existing measure packages in the electronic Technical Reference Manual (eTRM) to assess their benefit to the EE portfolio from a range of attributes such as TRC, TSB, and measure adoption				

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Assess additional potential value streams for EE measures/measure packages for grid and customer value such as TSB and non-energy benefits (NEBs) ¹				
Identify barriers and opportunities to increase NMEC solutions and market participation				
Identify ways that EE programs can support or enable other programs including BPS, decarbonization, or low-GWP programs				

KEY  High Needs  Medium Needs  Low Needs  Future Needs

Opportunities

Rethinking how we measure success by looking at EE through the lens of TSB, TRC, and NEBs creates natural opportunities to promote awareness, use, adoption, and benefits of these metrics:

- Increases awareness and understanding of TSB and TRC and their interactive effects as primary metrics of the EE portfolio
- [Initial research presented to the Cal TF](#) suggests the common understanding that current cost-effectiveness metrics promote electrification may often be incorrect. In the examples given, low TRC values may limit program promotion of heat pump water heaters as replacements for gas units, while high TRC values may encourage gas heating in new packaged heating, ventilation, and air conditioning (HVAC) units. Further research may highlight opportunities to align EE metrics with California policies.
- Addresses potential gaps in the EE portfolio, such as co-benefits or NEBs
- Identifies potential NEBs, including health, safety, and comfort benefits from fuel-substitution measures; job creation; improvements in non-energy material consumption or product quality; waste heat recovery; and implications for departing loads.

¹ Are market participants (customers, implementers, supply chain actors) adequately compensated to support emerging needs such as load shift, grid resiliency, and climate change impacts?

- Identifies potential gaps, such as opportunities to incentivize market activities for demand management, load flexibility, and other system benefits in TSB.
- Analyzes and classifies existing measures and participation to identify non-technology barriers, such as low TRC or TSB, to aid in the identification and prioritization of opportunities for study to support impactful measure updates.

Barriers

Current discussions with EE stakeholders revealed the following barriers:

- A limited understanding of how to optimize TSB despite increasing awareness of TSB as an operating metric.
 - There is a general need for broader awareness of the drivers of TSB, such as long-lived measures (long effective useful lives) and their potential trade-offs with market uptake because these measures typically require higher capital investment, which may impact market participation. There is also a limited understanding of the interaction between TSB and TRC. TSB replaced kilowatt-hours (kWh) and kilowatts (kW) as primary goals but did not replace TRC for cost-effectiveness. Some stakeholders have mistaken TSB as a replacement cost-effectiveness metric for TRC. There is also increased interest in, but limited understanding of, the flexibility around TRC.
- Some stakeholders have noted that while TRC captures all participant and program costs, it does not capture all participant benefits, such as health and safety benefits associated with fuel-substitution measures.
- Certain infrastructure-heavy electrification measures could be much more successful if incentives exceeded current deemed incremental measure cost values due to inherent system benefits, despite the resulting TRC value.
- EE policies left over from years or decades past may no longer serve California's decarbonization goals well.
 - A recent State of California Auditor's Report on EE programs highlighted that the current TRC calculation does not include certain NEBs—as accounted for by other states—despite including participant costs. This omission could discourage utilities from implementing certain EE programs or prevent them from achieving cost-effective program portfolios.² In these states, an estimate of NEBs is attributed to EE programs, similar to how spillover effects are estimated and included in California's EE evaluation framework.
 - Existing EE policy restricts some NMEC opportunities, such as limiting NMEC to strategic energy management programs in the industrial sector or to cases where site-specific NMEC resembles that used for large commercial buildings. EE policy also currently restricts fuel switching from unregulated fuels, e.g., wood or propane, to regulated fuels, e.g., electricity or natural gas, and is under consideration as part of the 2024–2035 Business Plan filings. Recently, strategic energy management has expanded in California beyond the industrial sector; however, further study of additional untapped markets could yield new program pathways for the EE portfolio.

² For more information, visit: <https://www.auditor.ca.gov/reports/2023-127/>

CalNEXT Related Projects

- ET25SWE0038 - [Optimization of Deemed Data Collection Requirements](#)
- ET25SWE0041 - [Load Shape Planning Tool Development](#)

Affordability and Fuel Substitution

CalNEXT Priority: High

Definition

This research family is focused on supporting affordability, electrification, fuel substitution from regulated fuels, and fuel switching from unregulated fuels, as well as identifying critical barriers and developing consistent and effective solutions. The CPUC defines “affordability” fairly broadly in D. 20-07-032 as “the degree to which a representative household is able to pay for an essential utility service charge, given its socioeconomic status.” In this vein, CalNEXT focuses on the affordability of energy services related to electricity bills for residential customers (i.e., the reference to “a representative household”). Nonresidential customers (e.g., commercial, industrial, agricultural) are not directly implied based on the reference to “households,” although there may be other interpretations of “affordability” among EE market actors, including policymakers; program implementers and IOUs (e.g., program cost-effectiveness); supply chain actors such as manufacturers, distributors, and contractors (e.g., whether or not it is affordable to participate in the EE market); and other parties not mentioned. CalNEXT will focus on affordability from the point of view of end-use customers in terms of their ability to afford electricity services.

California has some of the highest electric rates in the nation. The California legislature passed a suite of new bills intended to provide policy support, with some directly targeting affordability concerns. However, ratepayers need more support from ET programs to identify additional pathways to help address energy affordability. Potential solutions should continue to encourage consumers to conserve energy as well as support investment in EE improvements, especially among populations experiencing the highest energy burden.

Decarbonization involves the use of the most efficient conversion or fuel-substitution strategies, switching from a carbon-intensive fossil fuel source in building and transportation end uses to electricity generated from a clean, renewable energy source. Electrification is commonly achieved for individual end uses but often requires a broader assessment of impacts on the building, community, or utility infrastructure. Associated impacts can include necessary upgrades to building and utility electrical infrastructure to accommodate the higher electric demand associated with increased electrification of building energy, transportation, and process loads in California homes and businesses, as well as the incorporation of onsite renewable energy and energy storage.

Electrification of California’s buildings, end uses, and transportation will be essential to meet California’s goal of achieving carbon neutrality by 2045, reducing carbon emissions by 85 percent from 1990 levels (AB 1279, statutes of 2022), and requiring 100 percent of electricity by 2045 to be from renewable energy and zero-carbon resources (SB 100, statutes of 2018). In addition, the South Coast and the Bay Area air quality management districts have passed new rules regulating emissions from space and water heating appliances, which will be significant drivers of electrification. California is making significant investments in building electrification through statewide and regional efficiency programs, large heat pump market transformation efforts such as TECH Clean California, and other rebates that encourage higher-efficiency products and electrical upgrades.

Research Initiatives

The goal of the research initiatives for California’s decarbonization strategies described below is to identify both common and unique affordability, electrification, fuel-substitution, and fuel-switching pain points and to support the development and demonstration of innovative, scalable solutions. The focus areas of this portfolio enhancement will include program solutions and multiple end-use control solutions to support scalable, targeted electrification for both buildings and communities, ultimately helping to avoid expensive electrical infrastructure upgrades.

Table 4: Affordability and fuel substitution research initiatives.

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Technologies supporting increased energy savings, energy affordability, and bill savings, including through behavioral measures and BPS				
Scalable and targeted cost-effective electrification, load flexibility, and control strategies				
Commercial, industrial, and agricultural market sector electrification research and tools				
Decarbonization with fuel substitution/switching and program strategy alignment				
Technology gaps for all market sectors and application electrification				

KEY High Needs Medium Needs Low Needs Future Needs

Opportunities

A higher-level market assessment is needed to improve policies, program strategies, tools, and technology solutions to maximize the overall impact of funding investments and reduce the financial

burden of building electrification on owners and tenants. The team identified the following opportunities:

- Comprehensively assess the costs, barriers, benefits, and effectiveness of technology solutions and load flexibility controls at the individual end-use, building, and utility levels to support increased energy savings, energy affordability, and bill savings, including through behavioral measures.
- High-priority electrification areas, such as HVAC and water heating, have competing solutions. These solutions prioritize benefits to the customer, either through improved performance or reduced installation or operational costs; alternatively, the benefits may go to the utility for mitigating the impact on the grid. These solutions are often achieved with different degrees of complexity, cost, and required market and contractor engagement.
- Historically lagging market sectors, such as small and medium businesses (SMB), require targeted research and tools to support successful electrification strategies. In addition, identifying specific technology gaps and appropriate solutions is necessary to achieve comprehensive electrification in California. Potential opportunities may include studying successful electrification strategies in other states that may be suitable for California but must account for California's "spark spread"—relatively high electric versus natural gas fuel rates.
- Identify, research, and analyze the most cost-effective ways to scale electrification, e.g., zonal electrification.
- Insights into appliance controls, including distributed energy resources (DER), DR, and home management—will provide programs with different control strategies and inform the level of compatibility among the various load flexibility solutions.
- Partner with and capture insights from utility pilot electrification programs to inform new technology and programmatic research needs and accelerate electrification.

Barriers

The primary barriers to building electrification are the complexity, cost, and time associated with the replacement of existing fossil fuel end uses with electrification solutions.

- Gaps in the availability of simplified electrification solutions and the increased burden of building code, permitting, and program requirements significantly impact scaled electrification.
- Unplanned building electrification can also require expensive electrical panel replacements and utility service upgrades in homes and businesses to accommodate new electrical loads. In addition to cost escalation, increased permitting requirements and the complexity of electrification projects can overly burden small contractors and homeowners.
- Increasing peak electric demand also leads to increased grid infrastructure requirements, such as the replacement of transformers and distribution wires and the need for additional generation, increasing future costs for all ratepayers.
- The cost of electrical upgrades, especially for lower-income households and small businesses, can pose a significant barrier to scaling electrification in California.
- The diversity of water and space heating needs, the complexity of owner and tenant decision-making, and split costs and benefits in SMBs can limit the rate of adoption of electrification.

- Technologies are needed to support increased energy savings, energy affordability, bill savings, and energy conservation, including through behavioral measures, to allow customers to optimize their energy use and save money.

CalNEXT Related Projects

- ET26SWE0046 - [Enabling Meter Socket Adapters for Utility Electrification Programs](#)

Integrated Demand Side Management, Including the Value of Load Flexibility

CalNEXT Priority: High

Definition

This research family is focused on adaptation in the EE portfolio to maximize decarbonization and TSB benefits by properly considering the time dependence of energy consumption throughout the day and year. Currently, EE savings are attributed based on a limited set of load shapes, load shifting, and demand management. Conversely, demand flexibility has not been included in EE measures in terms of EE benefits, largely because it has been framed as part of the DR policy scope.³ This research family will assess opportunities to consider the co-benefits of demand flexibility for EE measures as part of an integrated demand side management (IDSM) strategy. It will investigate ways to incorporate demand management, load-shifting, and demand flexibility attributes as part of EE measures, including by identifying necessary research, the potential costs and benefits of incorporating demand flexibility co-benefits into EE programs, and ways to incorporate DR and decarbonization approaches alongside existing EE measures and programs.

Research Initiatives

Table 5: IDSM, including the value of load flexibility research initiatives.

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Research supporting implementation of standard load shapes for measures				
Evaluate TSB and cost-effectiveness of current measures versus policy alternatives that incorporate more demand flexibility ⁴				

³ The CPUC created a proceeding to address demand flexibility through rates in 2022 in [R.22-07-005](#) (Order Instituting Rulemaking to Advance Demand Flexibility Through Electric Rates). Subsequently, in [R.25-09-004](#) (Order Instituting Rulemaking to Enhance Demand Response in California) and in related staff proposals/Scoping Memo, the CPUC framed demand flexibility as a related concept within the broader demand response framework. While demand flexibility policy is still developing, particularly with ongoing pilots led by CalFUSE (California Flexible Unified Signal for Energy), this research family will monitor policy developments and consider how to support demand flexibility's benefit to both EE and DR portfolios.

⁴ Evaluate policy pathways for CalNEXT research to inform technical potential studies to enhance TSB recognized value in EE goals.

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Measure characterization and market study of measures with added demand flexibility costs and benefits				
Cost-effective and future-proof program implementations for various degrees of connectivity				

KEY  High Needs  Medium Needs  Low Needs  Future Needs

Opportunities

On May 20, 2021, the CPUC, through [D.21-05-031](#), officially announced TSB as the new metric to replace kWh as the primary metric for savings accounting in the EE portfolio. The CPUC's decision created the following opportunities:

- Evaluate and identify new benefits, such as demand management and load flexibility, especially when considering peak demand, time of use, and other temporal factors.
- Match measures to and create more accurate load shapes and load shape variations based on peak-avoidance, load-shifting, and demand management strategies.
- Study potential measures and policies to address system needs, such as time-of-use benefits to customers, demand flexibility measures, incentives, locational benefits, and grid resilience.
- Research new technologies and applications, such as upsizing thermal energy storage, demand flexibility, and connected EE measures.
- [D. 23-06-055](#) also encouraged IOUs to expand the use of NMEC approaches in the EE portfolio. These and other meter-based measurement activities may create a data source for identifying specific measure opportunities and creating new load shapes.
- IOU smart water heater programs and market transformation activities, such as TECH Clean California, may also provide useful project data for analysis.
- Due to aggressive code baselines, a significant number of EE measures have been sunset due to a lack of cost-effectiveness. With hourly and monthly valuations now the default, some sunset measures—as well as creative new decarbonization measures—may once again benefit the EE portfolio.

Barriers

The team identified the following barriers to using time-of-use and load flexibility:

- The existing eTRM load shapes are out of date and inadequate for calculating TSB value.
- There is limited market understanding of TSB and whether demand flexibility should be addressed under EE, DR (current practice), building decarbonization, or other policies and proceedings. Thus, there are opportunities for market education and awareness about TSB and demand flexibility in general.
- Updates to measures and program policies may be needed to address the overlap between demand management and EE. As the hourly cost of energy embedded in the TSB calculation is constantly shifting, it is unclear how the eTRM impacts and schedule may change relative to the Database for Energy Efficiency Resources updates and what is necessary in EE measure development to capture changing peak values.
- A lack of definition related to the valuation of DERs in EE measures poses barriers to assessing the benefits of new technologies, such as 120-volt induction stoves with batteries, as well as comparing thermal and electric energy storage benefits.
- Cost-efficiency⁵ and the valuation of equipment costs and benefits related to load flexibility vary across different market actors (e.g., utilities, vendors, contractors, and customers).
- Developing standardized measurement and verification methods, quantifying potential demand flexibility benefits across hourly load shapes and locations, identifying solutions, assessing their equipment, program delivery, and customer engagement costs, and addressing program complexity and benefits may strengthen the case for broader incorporation of load flexibility approaches into EE measures.

CalNEXT Related Projects

- ET25SWE0043 - [Multifamily Central Heat Pump Water Heater Storage and Control Strategies for Increasing TSB](#)

⁵ “Cost efficiency” refers to how costs are valued by different market actors, whereas “cost-effectiveness” refers to EE policy on cost-effectiveness rules which should not vary in terms of interpretation across market actors.

Low-Global Warming Potential Technologies⁶

CalNEXT Priority: Medium

Definition

The refrigerants used to heat and cool buildings efficiently with heat pumps often contribute significant greenhouse gas (GHG) emissions over the lifetime of the equipment in which they are used. This concept is referred to as “global warming potential” (GWP), and all refrigerants are assigned a GWP index relative to that of carbon dioxide (CO₂), which describes the cumulative radiative forcing of a given refrigerant on the climate over the lifetime of that refrigerant in the atmosphere. Because a significant amount of refrigerant may be released from equipment due to leaks during installation, decommissioning, or operation, when refrigerant GWP is considered in the context of the GHG resulting from operating a piece of equipment, a high-GWP refrigerant used in that equipment may partially or completely offset any GHG emissions reductions resulting from using that equipment in place of less efficient electric equipment or fossil fuel equipment.

Fortunately, many low-GWP refrigerants, including natural refrigerants such as CO₂, ammonia, and propane, also deliver efficiency benefits compared to synthetic refrigerant alternatives, which may have high GWPs. This research family is focused on determining pathways to integrate low-GWP refrigerant technology into the EE portfolio while simultaneously identifying opportunities to reduce costs, energy use, and lifecycle emissions.

This research family focuses on technology strategy and policy frameworks that could impact multiple end uses. The objectives include:

- Creating an actionable framework for reducing refrigerant emissions across end uses
- Examining barriers to replacing refrigerants with low- and ultra-low GWP alternatives
- Aligning refrigerant emission reduction calculations within the TSB metric with current practices in the field

Reducing leaks in existing refrigerant systems will complement the approaches within the HVAC, Water Heating, and Process TPMs, which will also drive active recovery, reclamation, and destruction of high-GWP refrigerants. Refrigerant emissions reductions should be pursued primarily as a co-benefit of broader energy efficiency investments, rather than as a standalone objective. Opportunities such as the early retirement and replacement of HVAC, water heating, and refrigeration equipment can provide an effective pathway for refrigerant recovery, reclamation, and low-GWP adoption.

This framework also emphasizes the need to expand consideration of disruptive innovations, such as non-vapor-compression systems that avoid refrigerants entirely, eliminating the risk of leakage and the need for refrigerant management. It will also be important to more clearly define lifecycle refrigerant management (LRM) within the California EE portfolio and incentive structures, which will create more cost-effective, impactful incentives and program interventions.

⁶ This technology family is not intended to be a primary objective but rather a secondary (co-benefit) of focus alongside of existing EE opportunities such as conducting refrigerant swap-outs as part of overall EE upgrades (e.g., early retirement of HVAC equipment).

LRM broadly refers to the full lifecycle of refrigerants—from system selection and installation to refrigerant leak prevention, detection, and repair—during the operational life of equipment, as well as refrigerant recovery and reclamation or destruction at the end of the equipment’s life. Proper refrigerant charges are required for systems to operate at rated efficiencies, so LRM is essential to maximizing the performance of all systems that use refrigerants. The goal of LRM is to eliminate the GHG impact of refrigerant emissions, given these are primarily gases with GWP values thousands of times higher than CO₂.

Research Initiatives

Table 6: Low-GWP technologies research initiatives.

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Improve refrigerant recovery rates, including targeted incentives for end-of-life refrigerant recovery				
Automated leak detection (ALD), and alternative monitoring options				
Equipment selection and installation practices including natural refrigerant systems and lower system leak rates				
Data collection and analysis on refrigerant charge size, leak and recovery rates to inform TSB assumptions				
Evaluate non-vapor compression technologies for HVAC and refrigeration				
Identify ways to harmonize low-GWP benefits with existing EE measures and/or building decarbonization programs and policies				

KEY  High Needs  Medium Needs  Low Needs  Future Needs

Opportunities

The following are some examples of opportunities related to LRM and emissions reductions:

- The TSB metric recognizes GHG benefits from mitigating refrigerant leak emissions.
- Despite some progress, further work is needed regarding how EE portfolios handle refrigerants to meet utility regulatory requirements and state emissions reduction goals.
- Utility EE programs, traditionally valued for energy savings, can also serve as cost-effective platforms for reducing refrigerant emissions when paired with energy savings.
- One near-term opportunity for utilities is to incorporate refrigerant emissions reductions into existing EE programs, capturing additional GHG reduction benefits without creating separate, standalone program components.
- Refrigerant emissions reductions often result in energy savings, allowing:
 - Seamless integration of LRM efforts into existing programs
 - Delivery of both direct energy savings and indirect cost and emissions savings across sectors
 - Promotion of ultra-low-GWP refrigerant-based systems
- Transitioning to an LRM-based approach for calculating refrigerant emissions impacts will:
 - Enable more accurate measurement of lifetime CO₂ equivalent (CO₂e) savings
 - Enhance program effectiveness
- A comprehensive approach to LRM includes equipment selection, installation best practices, leak monitoring and repair, and proper refrigerant disposal at equipment end-of-life.
- For large commercial and industrial refrigeration, the greatest opportunity is replacing existing high-GWP refrigerant systems, while for residential and small commercial HVAC, the greatest opportunity is recovering refrigerant during decommissioning.
- Accelerating the adoption of emerging non-vapor-compression technologies will help California meet key climate policy deadlines while delivering significant cost savings across multiple sectors.

Barriers

Though substantial progress with natural refrigerants has been made in commercial refrigeration, the HVAC sector faces several challenges:

- Lack of harmonization between US national codes and international safety standards for natural refrigerants
- Misuse of Environmental Protection Agency Significant New Alternatives Policy guidance for hydrofluorocarbon alternatives
- Misaligned efficiency and emissions metrics
- Limited project data, leading to perceived technology viability issues
- A shortage of skilled HVAC and refrigeration technicians experienced with low-GWP refrigerants.
- Low rates of refrigerant recovery due to:
 - Added time and cost to achieve compliance

- Lack of financial incentives and low enforcement rates
- Concern from utilities that recognizing current conditions with LRM may erode existing savings
- Lack of ultra-low-GWP products in many product categories, e.g. mini-splits

CalNEXT Related Projects

There are no CalNEXT projects related to this technology research area at this time.

Discussion

Following approval of the 2026 Portfolio Enhancements TPM, the program team will:

- Update the CalNEXT website with the revised 2026 Portfolio Enhancements TPM and this final report
- Launch an email announcement
- Develop and submit the distribution report
- Highlight any technology families to reinvestigate for the 2026 Focused Pilot TPM, which will support the 2027 Focused Pilot projects

Appendix A: Portfolio Enhancements Advisory Committee Feedback and Resolution Matrix

Table 5: Advisory Committee feedback and resolution matrix.

Portfolio Enhancements TPM Technology Family	Section	Suggestion or Comment	Action Taken and Justification
General Narrative	General	Generally aligned with the TPM. Also just like to reiterate that the program should also focus on projects with a specific portfolio use, a committed recipient (someone to take the ball and run with it), and a clear path to implementation.	The CalNEXT team will continue to identify potential Technology Transfer recipients for each approved project result.
General Narrative	General	When evaluating barriers (and opportunities), it may be helpful to identify the expected time horizon for overcoming that barrier—short, medium, long. The TPM describes a focus on near-term benefit (1–3 years) to the EE portfolio. Understanding if critical barriers are forecasted to remain unresolved for longer periods of time may help inform portfolio priorities, intervention timelines, and expectations about measure impacts.	The CalNEXT team will evaluate the barriers based on a short, medium, and long-term time horizon during their assessment. However, given project prioritization for near-term benefits (1–3 years) for the EE portfolio, there is likely to be a higher focus on short- to medium-term barriers. Identified long-term market barriers will be identified for potential Market Transformation Initiatives (MTIs) where appropriate.
Low-GWP Technologies	Priority	Suggest lowering the priority of Low-GWP technologies to low/medium.	The CalNEXT team reduced the Low-GWP technology family's priority to medium and added details to the relevant section.
IDSMP, Including the Value of Load Flexibility	Priority	Suggest increasing the priority of the IDSMP/Value of Load Flexibility to high.	The CalNEXT team increased the IDSMP/Value of Load Flexibility technology family's priority to high and added details to the relevant section.