2026 Whole Buildings Technology Priority Map

Final Report

ET26SWE0005

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Abbreviations, Acronyms, and Glossary of Terms

Abbreviation/Acronym	Meaning
BPS	Building Performance Standards
CalMTA	California Market Transformation Administrator
Cx	Building commissioning
CCX	Continuous commissioning
CPUC	California Public Utilities Commission
DAC	Disadvantaged community
DER	Distributed energy resource
EBCx	Existing building commissioning
GHG	Greenhouse gas
HEMS	Home energy management system
HTR	Hard-to-reach
HVAC	Heating, ventilation, and air conditioning
IOU	Investor-owned utility
MBCx	Commissioning based on monitoring
NMEC	Normalized metered energy consumption
REA	Residential energy automation
SCE	Southern California Edison
SME	Subject matter expert
SDG&E	San Diego Gas & Electric
TPM	Technology Priority Map

Abbreviation/Acronym	Meaning
VCx	Virtual commissioning
VPP	Virtual power plant
WH	Water heating

Glossary Term	Meaning
Technology Category	One of six broad technology categories (Whole Buildings, Heating, Ventilation, and Air Conditioning (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	Future Needs: Covers items that are not yet ready for consideration due to having high needs in validation and market analysis. 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 energy efficiency due to having an expansive data set or information readily available or not being pertinent to the research initiative. 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. High: Covers items that have high industry interest and high impacts for energy efficiency.
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). *Note: Priorities will change as research is completed.*
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.

Glossary Term	Meaning
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 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. TPMs are used to drive product ideation and inform project selection. This Final Report covers the revision process for the 2026 Whole Buildings TPM.

2026 TPM Key Changes

The Whole Buildings category has seen significant changes over the years, relative to that of other technology areas. Notable recent drivers for these changes include the passage of the One Big Beautiful Bill (OBBBA) Act1 in 2025, which repealed many of tax credits and funding for state-administered incentive programs targeting the heat pump market originally signed into law under the Inflation Reduction Act (IRA) of 2022. In addition, research conducted by California's investor-owned utility (IOU) Codes and Standards Enhancement (CASE) Team related to multiple technology families has impacted the state of knowledge to varying degrees. Finally, the continued need for programs to transition to the Total System Benefit (TSB) metric has implications for both demand flexibility (with respect to assigning time-dependent energy value) and low global warming potential (GWP) refrigerants.

The CalNEXT Program Team established a robust process for this initial phase of the TPM development and revisions. This year, the process began with the reformation of the Whole Buildings TPM SME Team, with representatives from each of the program team partners: AESC, Energy Solutions, TRC, UC Davis, and VEIC. With the Ortiz Group providing feedback at the stakeholder outreach stage during the Draft Report. The Whole Buildings SME Team includes members who support an array of energy efficiency programs using technologies covered by the Whole Buildings TPM, as well as members who support the California IOUs' Codes and Standards (C&S) program. These emerging technology products are then contextualized into priority maps through a markets and solutions lens.

In 2025, the research initiatives were revised as needed based off any market changes that had occurred since the 2024 Whole Buildings TPM revision. In 2026, the Whole Buildings SME team is focusing on revising and cleaning up the technology families based on energy efficiency and affordability standards, among annual revisions considering market changes and CalNEXT program priorities. Research initiatives should be at a higher level than project or proposal-specific details. The intent of these is to provide guidance for project submitters, rather than providing specific examples.

The end goal of these visual summaries is to have a clear representation of where the technology family stands in the portfolio and what remaining research is needed. The research initiatives tables describe the three to five most important technology areas, with the current version providing a

[1] To read the One Big Beautiful Bill Act, see: https://www.congress.gov/bill/119th-congress/house-bill/1/text.

simplified ranking view of where the Whole Buildings portfolio stands for easier use and external understanding. To date, most research projects take place within a handful of technology families across Whole Buildings, which was a large driver in how the technology families were chosen in 2026.

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 validation, market analysis, measure development, or 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 energy efficiency due to having an expansive data set or information readily available or not being pertinent to the research initiative.
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.
High	Covers items that have high industry interest and high impacts for energy efficiency.

Overall, the changes made in the 2026 TPM aim to increase technology transfers broadly across the portfolio, allowing the CalNEXT team to define new measures of interest and illustrate its efforts to bring them to the portfolio. Even for longer-term investments, the visual format of the research initiatives tables will provide more tactical guidance as to what type of research is needed to better encourage the progress of different technologies toward the goal of portfolio savings.

Stakeholder Feedback

TPM Advisory Committee Outreach

The TPM Advisory Committee outreach began in late May 2026. The team requested stakeholder feedback via email, through survey questions targeted for the Whole Buildings TPM, which resulted in updates to the Word document of the technology family narratives based on that feedback. Stakeholders are listed below in Table 2, as in previous years, CalNEXT reached out to portfolio programs for their input.

Table 2: TPM Advisory Committee outreach

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

This outreach allowed advisory members to provide candid feedback, with the opportunity to provide written comments and suggestions via a collaborative Word document hosted on Microsoft SharePoint and a survey through Microsoft forms. Suggestions were reviewed by the TPM coordinator and the Whole Buildings SME team and were then incorporated into the Revised 2026 Whole Buildings TPM section. A detailed table of the changes made can be found in the feedback matrix in Appendix A of this report.

Integrated Systems

CalNEXT Priority: High

Definition

This category covers components, systems, or controls with integrated approaches to save energy that differentiate them from other TPM technology families. It also includes a single product — or coordination of multiple products — that can serve multiple end-uses, as well as integrated packages of measures, such as electrification packages with envelope improvement measures. Examples include weatherization and air leakage sealing, integrated designs such as thermally activated building systems, or broadly grid-interactive efficient buildings. The measures can be installed as existing building retrofits or in new construction.

Research Initiatives

Table 3: Integrated systems research initiatives

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Multifunction residential and small and medium commercial heat pump technology that reduce barriers to adoption[2]	High	High	High	Medium
Equipment or product solutions that reduce barriers to adoption[3]	High	High	High	Medium
Controls solutions that reduce barriers to adoption	High	High	High	Medium
Equipment and controls that use open frameworks for interoperability	High	High	Medium	Medium
Building design methods and practices to integrate systems	High	High	Medium	Medium

KEY: High Needs; Medium Needs; Low Needs; Future Needs

[2] Relates to the Residential Multifunction Heat Pump technology family cross-listed in the HVAC and Water Heating TPMs.

[3] Relates to the Residential Multifunction Heat Pump technology family cross-listed in the HVAC and Water Heating TPMs.

Opportunities

Opportunities for study for this technology family include, but are not limited, to:

- The development of efficiency measures or strategies that integrate or replace multiple, single-function technologies, resulting in energy savings, improved performance, and reduced deployment costs.
- The study of integrated systems that reduce barriers and costs by providing electrification with large energy savings and improving affordability. Examples of multiple systems include:
    - Integrated lighting and space cooling system that reduce the total number of installed sensors in a building.
    - Residential integration of home area networks with smart appliances and smart load coordination (panels, breakers, circuit sharing).
    - Heat pumps that integrate space conditioning and water heating or other loads that are typically separate.
- Low-cost retrofits that modify or add equipment to leverage existing building infrastructure for energy savings. Examples include:
    - Add-on nighttime ventilative cooling.
    - Add-on passive solar shades.

Barriers

Potential studies of barriers may address:

- Integrated systems can be significantly more complex. They may span multiple building systems, and typically require a greater level of design, assessment, installation skill, and more complex maintenance.
- The path for integrated systems efficiency measures to become deemed measures may be more complex, potentially including multiple load shapes.
- Barriers to adoption include:
    - Lack of interoperability among software programs in controls systems.
    - Lack of open communication protocols for controls equipment, particularly for small and medium residential and commercial buildings.
    - Lack of field performance data, including system reliability, energy performance, and cost-effectiveness.
    - Lack of maturity of system efficiency testing and ratings, particularly for combination heating, ventilation, and air conditioning (HVAC) and water heating (WH) products.
    - Lack of software tools for designers to quickly model and assess system performance and costs for integrated systems.
    - Lack of standard methodologies for estimating savings of integrated systems.
    - Lack of a standard applicable baseline for new systems that integrate new functionality that did not apply to previously existing systems.
    - Lack of deployment infrastructure or workforce for integrated systems; need for better understanding of resources available for designers, installers, and maintenance strategies.

- Default settings are often left unmodified, meaning systems may never achieve optimal performance, especially as the building's use and characteristics change.

CalNEXT Related Projects

- ET22SWE0044 – Lab Evaluation of Integrated Controls for Commercial Buildings
- ET22SWE0021 – Residential Multi-Function Heat Pumps: Product Search
- ET22SWE0051 – Residential Multi-Function Heat Pumps: Heat Exchanger Improvement
- ET23SWE0047 – Residential Multi-Function Heat Pump Laboratory Testing
- ET23SWE0066 – Lab Test of a Variable Speed Air-to-Air Multi-Function Heat Pump
- ET24SWE0058 – Multi-Function Heat Pump Research Home Test – Variable Speed
- ET25SWE0024 – Residential Multi-function Heat Pump Market Study

Electrical Infrastructure

CalNEXT Priority: High

Definition

This technology family refers to single- and multi-structure sites that use a common utility connection; it encompasses electrical infrastructure site needs and capabilities to enable energy efficient and low- or carbon-neutral buildings, demand-flexible end uses, distributed energy resources (DERs), and grid harmonization.

Research Initiatives

Table 4: Electrical infrastructure research initiatives

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Interoperability of building management system with microgrid controllers	High	High	Low	Low
Interoperability of smart panels with distributed energy resource (DER) gateways	High	Low	Low	Low
Interoperability of home area networks with smart panels	High	Low	Low	Low
Impact of integrated energy storage systems on residential electrical infrastructure	High	High	Low	High
Electrification enabled by panel or circuit level load management devices	High	High	High	High

KEY High Needs | Medium Needs | Low Needs | Future Needs

Opportunities

Opportunities for study within this technology family include, but are not limited to:

- Studies on different panel replacement options, such as upsizing, power-efficient alternatives, and National Electric Code calculation alternates.
- Improved resilience and load prioritization through load segregation and panel controls.
- Small-scale and temporary or mobile power storage systems based on 120V power grid.
- Replacement and improvement of ageing transformers to improve efficiency and electrical load capabilities.
- Integration of vehicle-to-everything (V2X) strategies with existing electrification and transportation emerging technology projects on this subject.
- Demonstration of the integration of a battery storage system into the electrical load panel that houses the elevator motors in a high rise building as a means of reducing demand charges caused by elevator motor stops and starts.
- Portable energy storage systems, smart panels, and/or smart circuits to facilitate electrification in disadvantaged community (DAC) and hard-to-reach (HTR) residences as an alternative to traditional electrification retrofits involving panel and service upsizing.[4]

Barriers

Potential studies of barriers may address:

- Research to fully understand how electrical infrastructure acts as a barrier to electrification efforts.
- Lack of experienced electrical practitioners, especially for HTR, DAC, multifamily, and nonresidential buildings.
- Disconnect between the National Electric Code and normal power consumption with electrification and how best to address safety risks for load management approaches. Different stakeholders often have varying perspectives and goals regarding electrification activities.
- Lack of whole-building thinking in electrification programs that promote best practices in design and construction first — such as adequate envelope insulation and rightsizing electric appliances.
- Extensive and complex local city and utility codes that can make panel replacements and upsizing a major and expensive project, often requiring permitting or approval processes that can take months to complete.
- High cost of transformer replacements in addition to the limited number of manufacturers, resulting in longer payback periods and lead times for equipment replacement.
- Site-level infrastructure analysis not coordinated with utility-level system planning and the broader evaluation of costs and benefits.

CalNEXT Related Projects

- ET23SWE0061 – Residential Smart Panel Field Demonstration
- ET22SWE0057 – Market Study of Household Electric Infrastructure Upgrade Alternatives for Electrification

Design and Construction

CalNEXT Priority: Medium

Definition

This technology family focuses on reducing costs, energy use, and lifecycle emissions in the design and construction of whole buildings. It includes construction practices that reduce waste and improve compliance with high performance standards, as well as the use of off-site construction practices, such as manufactured housing, volumetric modular construction — a construction method where entire rooms or building sections are fully built off-site in a factory — or industrial panelization — a construction method where only flat panels, such as walls and floors, are pre-manufactured in a factory and then transported to site for assembly. Building design includes project delivery practices and building standards that maximize energy efficiency and promote low-lifecycle carbon and cost in the design, construction, and operation of a building.

Lifecycle carbon and lifecycle cost analyses support building design that delivers the same or greater energy savings at lower upfront carbon emissions or lower cost in the near- or long-term.

Research Initiatives

Table 5: Design and construction research initiatives

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
High-performance manufactured housing	High	High	Medium	High
Energy efficient Industrialized construction	High	High	Medium	High
Building lifecycle carbon or cost analysis	High	High	Low	Low
Energy efficient integrated design and construction project delivery	High	High	Low	Low

KEY High Needs Medium Needs Low Needs Future Needs

Opportunities

Opportunities for study for this technology family include, but are not limited to:

- Characterization through residential building simulation modeling of buildings built with aerated autoclaved concrete to determine energy saving benefits in California climates.
- Characterization of energy savings and economics of high albedo standing seam metal roofs paired with cellulose blown in attic insulation in residential buildings in California.
- An evaluation of the performance of building integrated ducted wind turbines as a means of generating enough energy under the net billing tariff to justify the cost.
- Studies on how to reduce energy intensity and emissions from the manufacturing of construction materials, e.g., cement, steel, glass, insulation materials, and others.
- Studies to improve on-site construction practices and overall building performance through integrated design and construction project delivery.[5]
- Demonstrations, scaled deployments, improvements to modeling and analysis tools, or other strategies to increase the development and deployment of low-lifecycle carbon buildings or high-performance whole buildings.
- Studies to improve building design practices, which have the potential to reduce lifetime energy and emissions associated with construction by creating systems that exceed California energy and building standards, and favor building materials with lower embodied carbon.
- Market research to harmonize low-embodied-carbon design with energy efficiency and expand it into the private sector, especially in off-site or partial off-site construction.

Barriers

Potential studies of barriers may address:

- Market recognition and understanding of benefits of low carbon building materials, and verifiable energy and life cycle cost benefits compared to existing materials, technology, and implementation costs.
- Barriers to design practices, including practices that facilitate meeting higher energy efficiency standards such as ENERGY STAR®, CA Title 20, and CA Title 24 that result in high efficiency and low carbon buildings by manufacturers, developers, construction managers, and building designers.
- Limited information on efficient building products and end-use systems for designers, engineers, and others to easily assess high-efficiency options across various metrics, including performance, cost, embodied carbon, and others. Data, even when available, is often siloed across many different government and industry-specific product lists — e.g., the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) for HVAC, the Design Lights Consortium (DLC) for lighting, and others.
- Education and training the construction trades in the efficient and effective construction of all electric homes. Measures such as heat pump space conditioning, heat pump water heaters and smart panels require wiring and interconnection by installers on site.
- Programs supporting high-performance electrification of manufactured and modular low-income housing, such as the US Department of Energy (DOE) Zero Energy Ready Home program; the US Department of Housing and Urban Development (HUD) Manufactured Housing program, low-income housing programs applying to single-family and multifamily housing, and accessory dwelling units.

[5] AIA California, "Integrated Project Delivery."

- Education and training in the integration of design, construction, and building commissioning in residential and commercial work. Accounting for co-benefits can also move the needle on justifying the costs for higher performance options, e.g., improved building resilience, health, safety, productivity, and more.

CalNEXT Related Projects

- ET23SWE0017 – Mobile and Manufactured Housing Market Characterization Study
- ET23SWE0031 – Manufactured Housing Electrification Measure Development Support

Resources and Links

- US Department of Housing and Urban Development (HUD). Operation Breakthrough. Office of Policy and Development. https://www.huduser.gov/portal/Operation-Breakthrough.html
- Electric Power Research Institute (EPRI) and Systems Building Research Alliance. Scalable Decarbonization Strategies for Manufactured Homes. The design, advancement, prototyping and field testing of scalable technologies and strategies for manufactured homes to decarbonize.pdf
- American Council for an Energy-Efficient Economy (ACEEE). Ignoring Resilience Benefits Limits Growth of Energy Efficiency Programs. https://www.aceee.org/blog-post/2024/03/ignoring-resilience-benefits-limits-growth-energy-efficiency-programs.

Operational Performance

CalNEXT Priority: Medium

Definition

Whole-building operational performance accounts for the dynamic interactions between a building and its environment, energy systems, and occupants, with a particular focus on optimizing energy efficiency and minimizing unnecessary energy consumption over time. Many of the strategies within this category are enabled by controls, automation, and analytics technologies that support ongoing optimization of building performance. Building commissioning (Cx) is an important strategy for achieving, verifying, and documenting proper operation of new buildings and new systems in ways that ensure systems deliver designed energy performance. Similarly, existing building commissioning (EBCx), also called retro-commissioning, is a process that seeks to improve how building equipment and systems function together to identify and capture persistent energy efficiency opportunities in existing buildings. EBCx can also include more sophisticated approaches that ensure operational changes and energy savings persist, such as commissioning based on monitoring (MBCx), continuous commissioning (CCx), and virtual commissioning (VCx).

System modeling and analytics includes the software — algorithms, machine learning and artificial intelligence, digital twins, predictive models, first-principle or physics-based energy models — and data sources — building controls, internet of things (IoT), market and demographic data, external data sources — used to improve operational performance by enabling more efficient operation, reduced energy waste, and continuous identification of energy efficiency improvements. Building performance standards (BPS) are outcome-based policy and law requiring existing buildings to meet energy or greenhouse gas (GHG) emissions performance targets. Normalized metered energy consumption (NMEC) measures meter data before and after building energy interventions to determine savings. Residential energy automation (REA) systems are a network of devices that automate and control a home's energy systems, such as home energy management systems (HEMS) and distributed energy resource (DER) hardware, with increasing emphasis on improving household energy efficiency alongside load management.

Operational Performance is distinguished from Integrated Systems by its emphasis on measurement, verification, and persistence of savings through operational improvements. Projects that are primarily HVAC- or Water Heating-focused should investigate alignment with the technology families in the HVAC and Water Heating TPMs.

Research Initiatives

Table 6: Operational performance research initiatives

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Site-level normalized meter energy consumption	!	!	!	!

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Scalable residential operational performance and REA				
Automated operational performance				
Automated building commissioning				

KEY High Needs Medium Needs Low Needs Future Needs

Opportunities

Opportunities for study for this technology family include, but are not limited to:

- REA systems that provide centralized and integrated control of building loads to improve energy efficiency, optimize energy use, and reduce costs for homeowners, which may include electric vehicle charging systems, photovoltaic generation, battery energy storage inverters, and traditional building loads like lighting, HVAC, water heating, and plug loads.
- System modeling and analytics solutions that ingest existing building data, e.g., building automation system trends, IoT, advanced metering infrastructure (AMI), and census data, and output solutions to improve operational performance, such as fault detection, preventive maintenance recommendations, energy efficiency improvement measures, energy resiliency planning, or controls optimization.
- Measure development, tools, and program offerings that have a streamlined custom measure verification process for operational energy efficiency measures to increase program participation.
- Measures and technologies that help buildings achieve BPS targets or improve NMEC incentives, including through reductions in energy use and improved operational efficiency.
- Measure development to increase program participation in MBCx, CCx, and VCx. Measure development that aligns with Cal TF custom measure efforts, such as a hybrid or deemed approach for commissioning sub measures with higher effective useful life and clearer linkage to energy efficiency outcomes.
- Technologies that focus on real-time feedback for maintaining operational performance and sustaining energy efficiency gains while minimizing costs for customers, utilities, and grid operators — including those that leverage grid-responsive or grid-interactive technologies.
- Emerging operational performance solutions designed for small commercial buildings, multifamily properties, and sites without dedicated facility staff or building automation systems, including scalable, low-cost approaches such as contractor-deployed controls

packages, simplified commissioning workflows, and cloud-based analytics platforms that reduce reliance on complex on-site infrastructure.
- Reaching underserved or HTR populations with existing operational performance technologies to deliver equitable access to energy efficiency improvements and associated bill savings.

Barriers

Potential studies of barriers may address:

- Barriers to adoption of operational performance approaches include challenges related to customer participation, availability and capability of service providers, data access and management, savings verification and quality assurance, and uncertainty around applicable program pathways (e.g., site-level NMEC, population-based NMEC, custom programs, or potential future deemed approaches).
- Lack of understanding of the technical and market barriers to BPS and NMEC, as well as limited tools and technologies for meeting targets or achieving cost-effective energy efficiency improvements.
- REA systems face several challenges, including the cost of smart panels, complexity for residential occupants, uncertainty and dynamics of loads and generation, optimal capacity configuration, control strategies, infrastructure limitations, and microgrid challenges, which can limit their realized energy efficiency potential.
- Need for validation of automated NMEC software and calculation algorithms, including ways to handle nonroutine events. Lack of understanding of NMEC service providers business models and technology and market barriers to scaling energy efficiency-focused NMEC applications.
- Need for a detailed breakdown of benefits by feature combined with comparative analysis among REA products, including impacts on energy efficiency, peak demand, and total consumption.
- Need for more field validation of physics-based models used for measure identification and program delivery. Lack of understanding of types of service providers, technology applications, and market barriers to implementing energy efficiency-driven operational performance solutions.
- Need to measure the savings and cost-effectiveness of automated commissioning technology. Lack of understanding of technology and vendor landscape of smart building software, interoperability, and open standards.

CalNEXT Related Projects

- ET23SWE0040 – AMI Intelligence Connected Building Energy Modeling
- ET23SWE0049 – Enhanced Normalized Metered Energy Consumption Analysis with Rapid Interventions
- ET22SWE0055 – Performance Evaluation of Advanced HEMS
- ET24SWE0063 – Electrification Enablement via Load Balancing Solutions Focus Pilot

Envelope

CalNEXT Priority: Medium

Definition

The envelope category covers products, design, and controls strategies, or installation techniques that reduce building energy demand, particularly as it enables electrification with heat pumps. This includes individual products — such as insulation, windows, air and weather barriers, and insulated cladding — as well as construction techniques — such as quality insulation installation, thermal bridge-free design, and retrofit air seal. The envelope category also includes strategies and technologies that reduce the cost of building energy retrofits.

Note: See the design and construction technology family for additional defined project categories, such as innovative building assembly design.

Research Initiatives

Table 7: Envelope research initiatives

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Thermal mass additions and improvements				
Window improvements				
Window attachments				
Air sealing retrofits				

KEY  High Needs  Medium Needs  Low Needs  Future Needs

Opportunities

Opportunities for study for this technology family include, but are not limited to:

- In climates with a significant heating load, building envelope upgrades, including high-performance window replacement, that make heat pump electrification successful by minimizing the use of supplemental heat, improving cost-effectiveness, reducing the heat load, and ensuring comfort.
- In climates with heavy cooling loads, envelope upgrades—including low-cost window attachment products—can significantly reduce HVAC energy use, reduce peak demand, shift peak, and improve thermal comfort and resilience during power outages and demand response events.
- Market research on products, such as more cost-effective insulation and air sealing materials, or on advancing construction practices. Studies are limited to deployable technologies for building sectors or types representing a significant portion of California's building stock.

- Studies that address the high cost of building envelope energy retrofits, and techniques that can be deployed with minimal disruption to building occupants or neighboring properties.
- Field studies, modeling simulations, or market research that demonstrates the magnitude of energy and demand savings from envelope improvements to support new programs.
- Characterization through modeling of the energy saving effects of thermal mass integrated into the building envelope with an emphasis on the implications of the added cost over the life of a typical 30-year home loan when the energy savings are taken into consideration.
- Demonstration of the performance of thin film photovoltaics integrated into a high-rise building facade.
- Research into low carbon, natural or fire-retardant insulation materials that can compete with fiber glass on cost.
- Manufactured home envelope design improvements that enable heat pump electrification without electric resistance supplement at minimal additional cost.

Barriers

Potential studies of barriers may address:

- Lack of information and scalable solutions related to retrofit technologies for existing residential and commercial buildings.
- The high cost of retrofit improvement to the building enclosure.
- Lack of information on energy and demand impact of lower-performing envelope components.
- Lack of customer awareness of benefits of higher-performing envelope components.
- Overcoming the gap between nominal and effective energy code compliance or assembly performance.
- Lack of trusted tools to facilitate accurate savings estimates in support of design decisions and programs.

CalNEXT Related Projects

- ET23SWE0018 – Commercial Windows Market Study and Measure Package Development
- ET23SWE0043 – Residential High-Performance Windows Measure Package Development
- ET22SWE0033 – Low-Income Multifamily Housing Characteristics Study
- ET23SWE0017 – Mobile and Manufactured Housing Market Characterization Study

Resources and Links

- US Department of Energy (DOE). Embodied Carbon Reduction in New Construction. https://www.energy.gov/sites/default/files/2024-02/bto-abc-embodied-carbon-022624.pdf
- Pacific Northwest National Laboratory (PNNL) and Guidehouse, Inc. Research Opportunities for Building Decarbonization Through Industrialized Construction. 20240722160808656_c708524e-edb8-4570-9bab-d48af396720a.pdf
- American Council for an Energy-Efficient Economy (ACEEE). Empowering Electrification through Building Envelope Improvements. https://www.aceee.org/sites/default/files/pdfs/empowering_electrification_through_building_envelope_improvements_-_encrypt.pdf
  Getting Heat Pumps Under Control: The Success of the Heat Pump Revolution Requires Getting Heat Pump Controls and Sizing Right. by Christian Douglass and Josh Rushton presented at

ACEEE.
https://www.aceee.org/sites/default/files/proceedings/ssb24/pdfs/Getting%20Heat%20Pumps%20Under%20Control%20-%20The%20Success%20of%20the%20Heat%20Pump%20Revolution%20Requires%20Getting%20Heat%20Pump%20Controls%20and%20Sizing%20Right.pdf

Community Scale Strategies

CalNEXT Priority: Low

Definition

Community-scale strategies can aggregate, balance, and control the flow of energy — thermal or electric — among multiple buildings and end-uses for improved performance. They include hardware and software technology solutions that orchestrate end-use and building operations across building boundaries. The costs, value streams, and benefits are measured across multiple utility meters and are shared by the community's members, the local grid (e.g. a neighborhood or town block, the whole neighborhood or town, a specific feeder or transformer), and the larger grid system. The benefits support California's market transformation goals related to higher system efficiency, energy resilience, load flexibility, and grid harmonization.

Community-scale strategies can contribute toward the CalNEXT program goal of achieving GHG reductions benefits, particularly when community strategies include the use of renewable distributed generation, such as solar energy combined with energy storage. These solutions have achieved market readiness individually. However, the coordinated operation to support grid harmonization using solar, energy storage with thermal storage and other building loads across multiple buildings requires further research along with valuation of end user and utility benefits. Energy efficiency is a necessary and essential element of maximizing economically feasible community-scale strategies. Energy efficiency reduces the load and therefore, the size and the installed cost of the community-scale solutions. In this respect, energy efficiency becomes an enabling technology for the distributed generation and results in an integrated approach for community-scale strategies.

CalNEXT expects significant research activity will primarily continue in other emerging technology programs with focus areas beyond this program, such as demand response aggregation in the case of virtual power plants and microgrid electric service resiliency. As such, priority designation for this technology family is set to "low" to minimize overlap of research efforts with the other emerging technology programs.

Research Initiatives

Table 8: Community scale strategies research initiatives

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Understanding of microgrid controller products	❗	❗	❕	❕
A market for virtual power plants (VPP) and community microgrid interactions	❕	❗	❕	❕

Research Initiatives	Performance Validation Needs	Market Analysis Needs	Measure Development Needs	Program Development Needs
Operation of a VPP and community microgrid under a real-time pricing tariff				
Value stacking by community microgrid operators				
Opt-in or opt-out solutions for customers of community microgrids				

KEY  High Needs  Medium Needs  Low Needs  Future Needs

Opportunities

Opportunities for study for this technology family include, but are not limited to:

- Modeling studies that demonstrate performance benefits in terms of magnitude and cost-effectiveness of emissions reductions, e.g., retirement or decommissioning of gas infrastructure in an existing block or avoided cost of installing new gas infrastructure in a new residential development.
- Market research, lab testing, modeling, and field studies that help define benefits and value propositions.
- Virtual power plant (VPP) research — modeling the effects on energy consumption and energy savings of integrated energy efficiency, solar and batteries, and flexible loads control and management — the VPP aspect of the modeling effort will look at the benefits on a large scale in relieving grid constraints and enabling greater renewable energy consumption.
- Modeling studies for community microgrids, projects may test or assess the potential and feasibility of receiving benefits from multiple value streams, such as participation in ancillary services markets while operating in parallel with the grid and energy resilience during a grid outage to better understand the economic viability.
- Zonal electrification research involving powerflow modeling at distribution feeder level. When paired with both VPPs and community microgrids, zonal electrification can have beneficial utility distribution grid level impacts. If sited in areas known to have distribution grid congestion, strategies and plans can be developed and demonstrated by virtual power plant aggregators and community microgrid operators with the local utility distribution services provider to offer grid support.

Barriers

Potential studies of barriers may address:

- Nascent standards environment for interoperability of grid assets.
- Lack of empirical data and case studies on project costs, operational performance, and benefits.
- Lack of market understanding for microgrid controller products.
- Lower market penetration rates of non-wires alternatives for DAC and HTR communities.
- Lack of demonstrated value stacking by community microgrid operators to show economic viability, such as by including participation in ancillary services markets.
- Lack of demonstrated opt-in and opt-out opportunities[6] for customers of community microgrids.
- Limited types of revenue opportunities in existing markets for technologies used for VPPs and community microgrids to sell into and purchase power from.
- Lack of a real-time pricing tariff to demonstrate economic viability for technologies, such as VPPs and community microgrids, among others.

CalNEXT Related Projects

- There are no CalNEXT projects related to this technology family at this time.

Resources and Links

- Canary Media. Four ways virtual power plants can help the US grid keep up with demand. https://www.canarymedia.com/articles/virtual-power-plants/four-ways-virtual-power-plants-can-help-the-us-grid-keep-up-with-demand

[6] Not all members of a community will want to participate in a community microgrid. Since DERs serving community microgrids are typically in front of the meter assets, community members should be able to opt in or out of participating in the community microgrid. This is especially important when there is an outage so that only those who have subscribed to the service will get the resiliency benefits during that time. This feature is possible through a switch that is part of the utility's smart meter on most people's homes, although it has never been demonstrated to work in this context. Microgrids that are not owned by utilities should avoid depending on the utility smart meter, as doing so adds another layer of complication.

Discussion

Following approval of the 2026 Whole Buildings TPM, the program team will:

- Update the CalNEXT website with revised 2026 Whole Buildings TPM and this final report.
- Launch an email announcement through email outreach.
- 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: Whole Buildings Advisory Committee Feedback & Resolution Matrix

Table 9: Advisory committee feedback and resolution matrix.

Whole Buildings TPM Technology Family	Section	Suggestion or Comment	Action Taken and Justification
General Commentary	General Narrative	Who is asking for this program to look into VPP and microgrid work? That type of work happens with different teams that aren't typically involved in EE programs and should CalNEXT do those types of projects we would need to bring in a new team to keep aware.	VPPs and microgrids are addressed primarily in the Community Scale Strategies tech family, which is a low priority for CalNEXT. CalNEXT is only concerned with addressing how these topics intersect with EE, and would consider projects on that basis, likely in collaboration with other teams if such an opportunity arose.
General Recommendations	General Narrative	A number of the opportunities discussed involve controls, interoperability, operational performance, electrical infrastructure, and integrated systems. Bringing those types of manufacturers into the discussion would be useful. I also think there may be value in hearing from organizations actively working in manufactured housing, affordable housing, multifamily retrofits, and electrification in DAC and HTR communities. Many of the implementation challenges discussed in the TPM are already being encountered in those markets. Conversations with practitioners, integrators, and organizations working in the field may be just as valuable as conversations with equipment manufacturers.	Thank you for your suggestion. CalNEXT strives to get feedback from a wide range of stakeholders, including manufacturers and organizations focused on reaching DAC/HTR communities.

Whole Buildings TPM Technology Family	Section	Suggestion or Comment	Action Taken and Justification
General Recommendations	General Narrative	• Add an implementation-readiness screen to all technology families. • Define minimum evidence packages for measure development and program adoption. • Evaluate workforce and contractor readiness in future TPM updates. • Develop segment-specific pathways for residential, multifamily, commercial, DAC, HTR, and manufactured-housing markets. • Track deployment metrics alongside technical metrics, including installation complexity, customer acceptance, contractor participation, commissioning success, operational persistence, and scalability potential.	Thank you for your suggestions. TPMs take a technology-focused approach to these challenges by centering the technology end-use in question. TPM SMEs try to incorporate implementation, workforce, and other challenges into the technology narratives as much as possible but must also be cognizant of space constraints and readability. Many of the metrics suggested in the comment are a better fit for evaluating specific proposals or measures than entire technology areas.

Whole Buildings TPM Technology Family	Section	Suggestion or Comment	Action Taken and Justification
General Commentary	General Narrative	I found this TPM to be grounded in implementation realities. The emphasis on electrical infrastructure, operational performance, existing buildings, and deployment barriers felt timely. I also appreciated the attention given to manufactured housing, disadvantaged communities (DAC) and hard-to-reach (HTR) communities, and alternatives to traditional panel and service upgrades. The discussion of zonal electrification and community-scale strategies was interesting. Even with a lower priority designation, these concepts will become / may become more important as utilities and local governments explore neighborhood-scale approaches to electrification and infrastructure planning. The TPM left me thinking about the importance of reducing the friction associated with deploying multiple technologies in existing buildings.	Thank you for your comments. The Whole Buildings TPM strives to include technologies and topics that are cross-cutting in nature and are best considered wholistically.
Electrical Infrastructure	Opportunities	Electrical Infrastructure — Opportunities Suggested adjustment: Widen slightly The discussion of panel alternatives, load management, and smart electrical infrastructure is one of the strongest parts of the TPM. It could be worth expanding the discussion of these approaches in existing residential buildings, particularly where service upgrades become a barrier to electrification. This could include additional attention to retrofit applications in older housing stock, manufactured housing, and smaller multifamily buildings.	The project team agrees. As currently written, the opportunity descriptions do not discriminate between new construction versus existing buildings, including older housing stock. While these are not called out explicitly, they are also not explicitly excluded from study.

Whole Buildings TPM Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Electrical Infrastructure	Narrative	Electrical Infrastructure is a key enabler for electrification and should place greater emphasis on panel-upgrade avoidance, load management, smart panels, distributed energy resources (DER) integration, and infrastructure alternatives. The section should distinguish residential, multifamily, and commercial barriers; address installer capacity, permitting bottlenecks, and electrical workforce constraints; and evaluate customer economics such as avoided panel or service upgrade costs. Special interest should be taken into looking into how current normalized metered energy consumption (NMEC) codes may be adjusted to help customers electrify.	Thank you for your suggestions. Panel upgrade (and avoidance), load management, smart panels, and DERs integration are all important topics for study that fit within this technology family. CalNEXT has completed (and has ongoing) a number of projects that cover many of these topics. While these topics are all still broadly important and much research remains to be done, the research initiatives are meant to be forward looking and cover new and future topics for study that have not already been as studied (smart panels, for example, have had multiple studies completed by CalNEXT in the last couple years). CalNEXT does not typically categorize the TPM technology families by customer type, but distinguishing the different challenges residential, commercial, and multifamily customers face is an important distinction for electrical infrastructure.

Whole Buildings TPM Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Electrical Infrastructure	Definition	Electrical infrastructure, on its own, does not deliver direct energy savings; rather, it serves as an enabling component for advanced technologies. How do you envision this being structured as a standalone measure, or alternatively, justified within the TSB?	In an older home, without the upgrade of the electrical panel or the use of a smart panel that can schedule and/or switch loads on and off, electrification cannot take place. This results in loss of the use and benefits associated with highly efficient electrical appliances such as heat pump water heaters, dryers and air conditioners.
Electrical Infrastructure	Opportunity #6	Under which research initiative would this be categorized?	Opportunity #6 involves the installation of a battery storage system in a manner that it interconnects within the electrical panel of an elevator system in a high rise. This would fall under the research initiative “Impact of integrated energy storage systems on residential electrical infrastructure. “The objective would be to reduce the demand charges associated with the electrical surges resulting from the stopping and starting of the elevator motors.
Design & Construction	Narrative	It is unclear if this section is a fit for the program but should it remain, the section should separate priorities for new construction, major renovation, manufactured housing, multifamily, and affordable housing. It should more directly address builder adoption barriers, procurement practices, financing, workforce needs, and how industrialized construction or manufactured-housing innovations can transition from research concepts into mainstream delivery, codes, standards, and market transformation strategies.	Thank you for your comment. While these exact categories are not used, the research initiatives do call out construction and manufactured housing, and financing and workforce challenges are discussed in the opportunities and barriers sections.

Whole Buildings TPM Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Design & Construction	Definition	Given that this is ultimately intended to lead to a program measure, please elaborate on how this is relevant and supports that objective.	Utilities commonly offer new construction and manufactured housing energy efficiency programs, and this technology family supports those programs and design/construction approaches to improving energy efficiency.
Design & Construction	Definition	How is this applicable to current TSB.	Operational lifecycle carbon is currently a part of TSB, but the upstream carbon emissions from manufacturing, raw material extraction, transporting, or disposing of energy equipment are currently considered non-energy benefits and excluded from the formal TSB equation. However, the embodied carbon resulting from EE programs and measures is not insignificant and not very well-studied. Understanding the intersection between EE and upfront carbon emissions is an appropriate intersection for CalNEXT to explore and discuss in a D&C TPM. In fact, preliminary research on this topic was conducted in the recent CalNEXT project ET25SWE0031: Embodied Carbon One-for-One Material Substitution Market Characterization.

Whole Buildings TPM Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Design & Construction	Opportunity #2	Is this similar to a cool roof?	Yes, high albedo standing seam metal roofs are comparable to what are commonly known as “cool roofs.”
Design & Construction	Opportunity #4	Do current policy guidelines recognize or allow energy benefits to be attributed to this measure?	Yes, the direct energy benefits from the manufacturing of construction materials can be captured through existing industrial EE (or similar) programs. For example, if the industrial process to make one of these building materials were made more efficient through the incentivized installation of an emerging technology that consumes less energy, then the resulting energy savings could be claimed by an IOU.
Design & Construction	Opportunity #5	What is project delivery 4?	“4” is intended to be a footnote. This formatting error has been fixed.
Design & Construction	Opportunity #6	Is this new or emerging?	Yes, a number of new modeling and analysis tools to facilitate the construction of low-carbon buildings have emerged in the last few years.

Whole Buildings TPM Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Design & Construction	Opportunity #7, #8, and #9	Do current policy guidelines recognize or allow energy benefits to be attributed to this measure?	Thank you for the thoughtful comments. For #7 and #8, current policy guidelines would not allow reduced GHG emissions resulting from the use lower embodied carbon materials to be attributed to EE programs. However, if lower embodied carbon building materials were to have better energy efficiency performance over current materials, then the resulting energy benefits could be recognized. It is this intersection with EE that makes these opportunities for further study in scope for CalNEXT under D&C. The opportunity outlined in #9 would be very challenging the recognize energy benefits under current policy guidelines, that is an astute observation. #9 has been removed and we will re consider in future years if policy guidelines change.
Design & Construction	Barrier #2	How does it compare with California's T-24 and T-20 standards	Barrier updated to incorporate CA T-24 and T-20 standards.

Whole Buildings TPM Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Operational Performance	Opportunities	Operational Performance — Opportunities Suggested adjustment: Widen slightly Many of the examples in this section appear to assume larger commercial buildings or sophisticated building operators. It could be useful to include examples of operational performance approaches for smaller commercial buildings, multifamily properties, and facilities that don't have dedicated facility staff or building automation systems.	Added bullet in opportunities section to address concern. Adding that research area includes smaller commercial buildings, MF properties, and facilities without dedicated staff or systems.
Operational Performance	Narrative	Operational Performance is one of the strongest sections because it aligns with NMEC, commissioning, automation, analytics, measured savings, and operational persistence. The TPM should further define implementation barriers for NMEC adoption, including customer participation, service provider capability, data management, savings verification, quality assurance, and whether solutions are best suited to site-level NMEC, population NMEC, custom programs, or future deemed approaches. The naming of it might fit better if it was named after controls, since “Operational Performance” seems to be the general idea behind high efficiency equipment. There also seems to be a great deal of overlap with the Integrated Systems section.	Added bullet to barriers section addressing concerns on NMEC barriers. In the definitions section added sentence clarifying that Operational Performance in CalNEXT Whole Buildings is defined as controls, automation, and analytics tech that support optimization of performance, but did not make a change to the name of Operational Performance. Added a sentence clarifying that Operational Performance should be picked over Integrated Systems if project emphasizes measurement, verification, and persistence of savings through operational improvements.

Envelope	Narrative	The Envelope section should more explicitly position envelope improvements as electrification-enabling measures, especially for heat pump deployment. It should differentiate opportunities by segment, including single-family, multifamily, manufactured housing, and commercial buildings, while addressing customer value propositions such as comfort, resilience, indoor environmental quality, bill impacts, contractor training, and technologies closest to measure-package or program deployment.	The envelope definition section explicitly states: “The envelope category covers products, design, and controls strategies, or installation techniques that reduce building energy demand. This includes individual products — such as insulation, windows, air and weather barriers, and insulated cladding — as well as construction techniques — such as quality insulation installation, thermal bridge-free design, and retrofit air seal. The envelope category also includes strategies and technologies that reduce the cost of building energy retrofits.” The envelope improvements described all result in a lowering of the building energy load resulting in a smaller design requirement for electrification measures such as heat pumps. The narrative regarding opportunities will be further refined to differentiate between opportunities by segment as requested. Customer value propositions such as comfort, bill impacts and indoor air quality are best addressed in the HVAC TPM. Resilience is addressed in the building integrated wind turbine research opportunity. Contractor training is difficult to address due to the wide variety of envelope measures possible. Purpose of reducing building energy demand as heat pump electrification added to definition.

Whole Buildings TPM Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Envelope	Opportunities	Additional opportunity is the emergence of vacuum insulated glass (VIG) for replacing single pane or double pane clear (no low-E) glass while retaining existing frames. This technology and application would benefit from field performance validation (currently, there is no rating system for VIG for SPR like there is for window attachments (AERC).	Thank you for the feedback. Vacuum insulated glass are eligible for study under the building envelope technology family. It appears that VIG does reduce heat gain, so this technology was added to the opportunity for reducing heat load.
Envelope	Opportunity #4	Are these field studies or lab studies? Prioritizing field studies, real-world data and corresponding case studies would maximize value.	Thank you for the feedback. The opportunity as written allows both field studies and lab studies to be considered.

Whole Buildings TPM Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Envelope	Opportunity #5	Given that each building is more or less unique, and also given site-specific HVAC/envelope interactions, energy savings would be better informed by field studies rather than market research (which is already plentiful).	Thank you for your comments. Opportunity #5 has been revised to reflect this suggestion. We agree that field studies have greater value. However, extensive envelop improvements for buildings are challenging to implement in the field due to their costs. Building simulations can do a fairly good job estimating the energy saving benefits of building envelope improvements, including HVAC/envelope interactions when field demonstrations are cost prohibitive. Similarly, market research focused on the types of envelope improvements that can cost effectively be done for each market segment remains relevant and thus is included in this opportunity description.
Community Scale Strategies	Narrative	This is another section does not look as if it is a fit for the program. However, should it continue then the section should clarify their relationship to California market transformation activities, utility planning, tariffs, interoperability, value stacking, customer participation models, and equitable deployment in DAC and HTR communities. The section should distinguish concepts requiring continued research from those approaching market readiness and identify the evidence needed to move from research interest to practical deployment.	Thank you for your comment. Clarifying edits have been added.

Whole Buildings TPM Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Community Scale Strategies	Definition	Community Scale Strategies — Definition Suggested adjustment: Clarify The current scope sits somewhat between utility-scale, community-scale, and building-scale applications. It may be helpful to better define where neighborhood-scale electrification fits in relation to utility planning and building-level projects.	Clarification added. We agree that the term community is used loosely in this section. This is in part intentional, to allow for flexibility in study scope, which can be on the scale of several adjacent residential and/or commercial buildings, up to all meters served by a distribution circuit or feeder.
Community Scale Strategies	Research Initiatives	Given that significant research activity will primarily continue in other programs, should these research initiatives still be incorporated into this SWEETP TPM?	The team acknowledges that field demonstrations of community scale strategies are such that needed funding exceeds typical project budgets in CalNEXT. Traditionally, field demonstrations of community strategies have been funded by the federal government through the national labs and funneled through the California Energy Commission. In this TPM, the intent is to focus on market research and modeling studies which are lower cost to execute, to help define benefits and value propositions so that private entities and municipalities in California can pursue these projects in collaboration with their utilities.