2024 Whole Buildings Technology Priority Map

Final Report

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Abbreviations, Acronyms, and Glossary of Terms

Acronym	Meaning
BAS	Building Automation Systems
CalMTA	California Market Transformation Administrator
CEC	California Energy Commission
Cx	Building Commissioning
CPUC	California Public Utilities Commission
DAC	Disadvantaged Communities
DH&C	District Heating and Cooling
EBCx	Existing Building Commissioning
EE	Energy Efficiency
EMIS	Energy Management Information System
EPRI	Electric Power Research Institute
ET	Emerging Technology
eTRM	Electronic Technical Reference Manual
EV	Electric Vehicle
FDD	Automated Fault Detection Diagnostics
GHG	Greenhouse Gas Emissions
HP	Heat Pump
HTR	Hard-to-Reach
HVAC	Heating, Ventilation, and Air Conditioning
IOU	Investor-Owned Utility
LBNL	Lawrence Berkeley National Laboratory
SCE	Southern California Edison
SME	Subject Matter Expert

Acronym	Meaning
SDG&E	San Diego Gas & Electric
TPM	Technology Priority Map
VPPs	Virtual Power Plants
WH	Water Heating

Glossary	Meaning
Technology Category	One of six broad technology categories: Whole Buildings, HVAC, Water Heating (WH), Plug Loads, Lighting, Process Loads.
Technology Family	Functional grouping that provides description of program role, opportunities, barriers.
Research Initiatives	New 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, research in progress, immediate needs, or future research needs.
High Understanding	Projects have run in this technology category before, overall, the market is comfortable with this technology category, and it is well known.
Research In Progress	CalNEXT projects are currently running regarding this technology category.
Immediate Needs	There is a need to learn about this technology, and there may not be any CalNEXT projects taking place at this time.
Future Research Needs	The technology is not on the immediate horizon and requires further understanding and research before becoming fully developed.
Definitions	Narrative to provide additional clarification on the technology family scope.
Opportunities	Description of potential impacts and potential research areas.
Barriers	Description of barriers and potential barriers research.
CalNEXT Role	Describes general level of engagement by CalNEXT SMEs. *Note: Roles will change as research is completed.*
Lead	"Lead"— CalNEXT expects to take on most or all the work and cost burden.
Collaborate	"Collaborate" —CalNEXT is interested in collaborating and cofunding projects.
Observe	"Observe"— CalNEXT will track progress but encourage external programs to take lead in unlocking these opportunities.
CalNEXT Priority	Communicates expected level of focus by CalNEXT SMEs. *Note: Priorities will change as research is completed.*
High	"High"— CalNEXT SME team has highlighted this technology family as having high impacts within the Technology Category.
Medium	"Medium" — CalNEXT SME team determined this technology family has moderate overall impacts within the Technology Category.
Low	"Low" — CalNEXT SME team has highlighted this technology family as having

Glossary	Meaning
	low impacts within the Technology Category.

Introduction

Technology Priority Maps 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. Technology Priority Maps are used to drive product ideation and inform project selection. This Final Report covers the revision process for the 2024 Whole Buildings Technology Priority Map.

2024 TPM Key Changes

The Whole Buildings category revisions in 2024 aimed to further clarify priorities for prospective participants, facilitate stronger coordination among CalNEXT projects, and further encourage technology transfer. Current definitions, opportunities, and barriers were revised where appropriate for every technology family in this Technology Priority Map. Notable drivers of this year's revisions include passage of the Inflation Reduction Act (IRA) of 2022, which continues to support the market over the next decade in the form of tax credits and state-administered incentive programs. Additionally, the continued need for programs to transition to the Total System Benefit metric continues to blur divisions between efficiency and demand flexibility. These changes were reflected in different ways in the 2023 Technology Priority Map update.

For the 2024 Technology Priority Map update, the CalNEXT Program Team built on the existing robust process for continuation of the Technology Priority Map development and revisions. The SME team met with representatives from each of the Program Team partners: VEIC, AESC, TRC, UC Davis, and Energy Solutions. The Whole Buildings SME team represents members that collectively support an array of energy efficiency (EE) programs using technologies covered by the Whole Buildings Technology Priority Map. These emerging products were then contextualized in the priority maps through a markets and solutions lens. The team met five times between April and July of 2024 to revise this draft Whole Buildings Technology Priority Map.

For the 2024 TPMs, a main change is the visual summaries at the beginning of each technology family. Two goals of these visual summaries are to have a clear representation of where the technology family stands in the overall CalNEXT portfolio and what remaining research is needed. Second, the visual summaries intend to encourage greater diversity of project applications, since to date the majority of CalNEXT research projects targeted just a handful of technology families to achieve these goals, the CalNEXT Program Team created Research Initiatives tables for each technology family, which describe the three to five most important areas for project focus by prospective CalNEXT applicants. For example, the Research Initiatives table for the Envelope technology family has an initiative named, "window improvements." Icons were added throughout under each of the overhead criteria columns in the table. The first two criteria, Performance Validation and Market Analysis, are technology-driven. The next two criteria, Measure Development and Program Development, are market-driven.

Table 1. Icons and their meanings

Icon	Meaning
	High Understanding
	Research In Progress
	Immediate Needs
	Future Research Need

One additional change to this Whole Buildings Technology Priority Map in 2024 is the absorption of the DC Lighting technology family into the Electrical Infrastructure technology family. This follows the sunsetting of the Lighting Technology Priority Map also in 2024 to reduce the overall number of technology families, to reorganize and better balance, the program's research priorities within each technology family, and to clarify how those priorities connect with others throughout the portfolio.

This year, the project team also incorporated a stronger outreach push for stakeholder feedback. The project team targeted additional deemed measure stakeholders at CPUC, CEC, SDG&E, CalMTA, CLEAResult, LBNL, and California Technical Forum. The push yielded positive results in more feedback received, compared to 2023, which is seen in Table 3 of the Appendix of this Final Report.

Overall, the changes made in this 2024 Technology Priority Map aim to bolster increased technology transfer across our CalNEXT portfolio, allow the CalNEXT team to define new measures of interest, and illustrate our efforts to bring them to the portfolio. These changes should improve shorter-term technology transfer such as measure packages for expansion of the existing Resource Acquisition programs. Even for longer-term investments, the new visual format will hopefully provide more tactical guidance as to what type of research is needed to advance different technologies to utility resource portfolio energy savings.

Stakeholder Feedback

Technology Priority Map Advisory Committee Outreach

The Technology Priority Map Advisory Committee outreach began in May 2024, stakeholders that feedback was requested from via email, providing a Word document of the technology family narratives are listed below in Table 2. Any further stakeholder feedback conducted was incorporated in this Final Report.

Table 2. Technology Priority Map Advisory Committee Outreach

Organization
CalMTA
CalTF
CEC
CPUC
EPRI
LBNL
SCE
SDG&E

This outreach encouraged advisory members to provide candid feedback with the opportunity to provide written comments via a collaborative Word document hosted on Microsoft SharePoint. Suggestions were reviewed by the Technology Priority Map coordinator, the Whole Buildings SME team, and incorporated into the Revised 2024 Whole Buildings Technology Priority Map section above. A detailed summary of the changes incorporated from this feedback can be found in the Advisory Committee Feedback & Resolution Matrix in Table 3.

Integrated Systems

CalNEXT Role: Lead | CalNEXT Priority: High

Definition

This category covers components, systems, or controls with integrated approaches that differentiate them from other Technology Priority Map technology families and includes a single product or coordination of multiple products that serve multiple end uses. Examples include a single heat pump (HP) or coordination of multiple HPs serving domestic hot water (DHW) and HVAC and building management system (BMS) controls that integrate control among multiple end uses such as networked lighting sensors and HVAC control. This technology family also includes integrated packages of measures, such as electrification packages with envelope improvement measures, for example, weatherization and air leakage sealing, that reduce heating and cooling loads for a heat-pump HVAC retrofit or integrated design that provides multiple services and benefits from each component such as thermally activated building systems, embedded radiant floor panels, or broadly grid-interactive efficient buildings. The measures can be installed as existing building retrofits or in new construction.

Research Initiatives

Research Initiative	Performance Validation	Market Analysis	Measure Development	Program Development
Multifunction residential and small commercial heat pump technology that reduces barriers to adoption and deployment				
Equipment or product solutions that reduce barriers to adoption and deployment				
Controls solutions that reduce barriers to adoption and deployment				
Equipment and controls that use open frameworks for structuring building operation data to enable interoperability and extensibility				

Research Initiative	Performance Validation	Market Analysis	Measure Development	Program Development
Building design methods and practices to integrate systems	⏳	⚠	☝	☝

KEY 🎯 High Understanding ⏳ Research In Progress ⚠ Immediate Needs ☝ Future Research Need

Opportunities

Integrated Systems have the potential to bring large performance improvements beyond that of individual components or individual systems. Certain applications have the potential to reduce barriers and costs by providing electrification of multiple systems that can also result in large energy savings and improve demand flexibility. An example might be an integrated lighting and space cooling system that reduces the total number of installed sensors in a building. In residential buildings, opportunities exist for integration of home area networks with smart appliances and smart panels.

Prospective ET projects should focus on the development of efficiency measures or strategies that integrate or replace multiple, single-function technologies, resulting in improved performance and reduced deployment costs.

Barriers

Most performance improvements are component approaches addressing one piece of equipment or end use at a time. Integrated Systems can be significantly more complex, can span multiple building systems, and typically require a greater level of design, assessment, and more complex maintenance. For example, most deemed efficiency measures in the California Electronic Technical Reference Manual (eTRM) database are single technology or single end-use measures, whereas most Integrated Systems solutions involve multiple pieces of equipment and end uses and currently are covered in the custom energy efficiency programs. Progress toward deemed measures to support scaling of Integrated Systems is a priority.

Potential barriers that studies should address:

- 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 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 deployment infrastructure for integrated systems; need for better understanding of resources available for designers, installers, and maintenance strategies.
- Default settings are often left unmodified, meaning systems 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

Electrical Infrastructure

CalNEXT Role: Lead | CalNEXT Priority: High

Definition

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

Research Initiatives

Research Initiative	Performance Validation	Market Analysis	Measure Development	Program Development
Interoperability of BMS with microgrid controllers	⚠	⚠	☝	☝
Interoperability of smart panels with DER gateways	⚠	🎯	☝	☝
Interoperability of home area networks with smart panels	⚠	🎯	☝	☝
Impact of integrated energy storage systems, on residential electrical infrastructure	⚠	⚠	☝	☝
Electrification enabled by panel or circuit level load management devices	⏳	⏳	⚠	☝

KEY 🎯 High Understanding ⏳ Research In Progress ⚠ Immediate Needs ☝ Future Research Need

Opportunities

Improvements to the electrical infrastructure deployment will be necessary to support broad decarbonization efforts. Many existing buildings will need electric panel replacements and upsizing to support the efficient electrification of end-use systems such as water heating, space heating, and appliances like clothes dryers or cooktops. Electric vehicle charging will significantly drive the need

for added electrical capacity. This includes any customer-side transformers, which will need to be upgraded to handle additional loads.

Opportunities exist for panel replacements and upsizing, with or without smart panels, to clearly separate loads so that critical and uncritical usage can be more easily identified, not only for energy efficiency through daily schedules, but also for demand response and demand flexibility opportunities, and to increase resiliency in the event of outages. In addition, there are opportunities to demonstrate portable energy storage systems providing backup to residences by plugging into a 110-volt outlet. As sub transformers age, they give off more heat and have minor electrical losses, operating less efficiently. With more electrical equipment being installed through decarbonization, there will be a greater need for upgraded transformers that can handle the added load.

Strategies and technologies to improve cost-effectiveness in deploying electrical infrastructure or demonstration of effective load management techniques that enable electrification are of high interest. Examples include smart circuit breakers, smart panels, and ability to support the flexible demand technologies under SB49.

For projects that directly support demand flexibility such as vehicle-to-everything (V2X), CalNEXT will look for ways to collaborate with existing ET projects.

Barriers

Electrical infrastructure upgrades are new to the utility program landscape, having recently been incorporated into several eTRM measures as a cost component for fuel substitution measures. Still more work is needed to fully understand the role electrical infrastructure plays as a barrier to electrification efforts.

Potential studies of barriers should address:

- Lack of experienced practitioners. The industry lacks broad understanding of site-level electrical infrastructure costs to support building electrification, especially for hard-to-reach (HTR) and disadvantaged communities (DAC) as well as multifamily and nonresidential buildings.
- Disconnect between implementers, including electricians, contractors, and program administrators and the National Electric Code and policymakers on electrification infrastructure needs and how best to address safety risks for load management approaches. Different stakeholders often have differing perspectives and goals when it comes to electrification infrastructure.
- Lack of integration in electrification programs to promote best practices in design and construction, such as adequate envelope insulation and rightsizing electric appliances, and foster demand response benefits, while also combining enabling technology (electrical upgrades) with electrification (HVAC HPs and heat pump water heaters) when necessary.
- Extensive and complex local city and utility codes that make panel replacements and upsizing a major project, sometimes requiring permitting or other approval processes that can take months to complete.
- Transformers are expensive, resulting in long payback periods; there are also a limited number of manufacturers, which results in longer lead times for equipment replacement.

Identifying alternatives to transformer upgrades, when possible, will enable increased electrification by removing a major bottleneck for utilities.

- Interoperability of home area networks with smart panels.
- Lack of demonstration of portable energy storage or appliance integrated energy storage and its impact on a home's electrical infrastructure.
- Interoperability of building management systems (BMS) with microgrid controllers.
- Interoperability of smart panels with DER gateways enabling control and monitoring.

CalNEXT Related Projects

- ET23SWE0061 Smart Panel Market Characterization Study, AESC, Inc., December 2023
- ET22SWE0057 Market Study of Household Electric Infrastructure Upgrade Alternatives for Electrification

Design and Construction

CalNEXT Role: Collaborate | CalNEXT Priority: High

Definition

This technology family is focused 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 such as manufactured housing, volumetric modular construction, or industrial panelization. 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

Research Initiative	Performance Validation	Market Analysis	Measure Development	Program Development
Manufactured housing electrification	⚠	⚠	⌛	⚠
Industrialized construction	⚠	⚠	☝	☝
Lifecycle carbon or cost analysis	☝	☝	☝	☝
Integrated design and construction project delivery	☝	⚠	☝	☝

KEY High Understanding | Research In Progress | Immediate Needs | Future Research Need

Opportunities

Construction material efficiency. The design and construction industries are notoriously inefficient, despite being one of the largest sectors of the world economy. McKinsey and Company notes that construction-related spending accounts for 13 percent of the world's GDP, but the sector's annual productivity growth has only increased 1 percent over the past several decades.[1] In addition to the efficiencies found in off-site manufacturing, there may be opportunity to greatly improve on-site

[1] McKinsey Global Institute, "Reinventing Construction: A Route to Higher Productivity"

construction practices and overall building performance through integrated design and construction project delivery.[2]

Industrialized construction. Improvements in off-site or partial off-site construction can reduce construction costs and deployment times while improving energy efficiency, overall performance, and reliability of building systems, as well as derisk integration of new strategies such as incorporation of low embodied carbon materials or all-electric building designs. Improvements in this area may be of particular importance for the residential housing market as additional dwelling units and manufactured housing are expected to grow significantly to address the state's housing affordability crisis.

Prospective ET studies should include consideration of development and deployment of low-lifecycle carbon buildings or high-performance whole buildings through demonstrations, scaled deployments, improvements to modeling and analysis tools, or other strategies.

Integrated design practices: Improvements in building design practices 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. The State of California and local jurisdictions have been driving change in this area with policies such as:

- The Buy Clean California Act, which set global warming potential limits for steel, concrete, glass, and mineral wool insulation used in state projects.
- Low-Carbon Concrete Requirements adopted by the County of Marin in 2019.
- SB596 in 2021, which will develop a statewide net-zero emissions strategy for the cement sector.

Opportunities exist to expand low-embodied-carbon designs into the private sector, especially in off-site or partial off-site construction. Additionally, standardization of carbon impact calculators on building assemblies with layered materials would deepen the impact of low embodied carbon design.

Barriers

While a mature industry, whole building design and construction has not been a focus for the California utilities ET programs. This has been a dynamic area in recent years with a variety of recent policy changes as mentioned in the Opportunities section above. It represents an area of significant potential for utility programs to research and develop initiatives that align with policy goals to reduce embodied carbon emissions and greatly improve overall building performance.

The residential manufactured housing sector in particular has shown reluctance to embrace low carbon materials and high-performance building design due to a lack of market pressure and a lack of progressive federal energy codes and standards. Manufactured housing is often seen as an affordable alternative to site-built homes. Consumers, and thus manufacturers, are sensitive to changes in standards and regulations perceived to increase price points.

Potential studies of barriers may address:

[2] AIA California, “Integrated Project Delivery”

- Market recognition of manufactured housing benefits, and verifiable energy benefits compared to associated materials, technology, and implementation costs.
- Design practices that result in high efficiency and low carbon buildings by manufacturers, developers, construction managers, and building designers.
- Education and training the construction trades in electrified manufactured housing. Measures such as heat pump space conditioning and smart panels require wiring and interconnection by installers on site.
- Programs supporting electrification of manufactured and modular housing including US Department of Housing and Urban Development (HUD) Manufactured Housing, volumetric modular housing including single-family and multifamily housing, and Accessory Dwelling Units.
- Stacking incentives and tax credits to make high performance industrialized construction cost competitive. Integration of design, construction, and building commissioning in residential and commercial work.

CalNEXT Related Projects

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

Resources and Links

- U.S. Department of Housing and Urban Development (HUD). Operation Breakthrough. Office of Policy and Development. Retrieved 6/21/2024 from https://www.huduser.gov/portal/Operation-Breakthrough.html
- Electric Power Research Institute. Pilot Construction of Wildfire Resilient, Net-Zero Manufactured Homes. In collaboration with Systems Building Research Alliance and with funding from California Energy Commission. Retrieved 6/24 from https://www.epri.com/about/media-resources/press-release/LBKJEdBJbsCRd7XRZbFXT and Retrieved 7/8/2024 from https://www.youtube.com/watch?v=UcwJ5I5I8P0

Operational Performance

CalNEXT Role: Lead | CalNEXT Priority: Medium

Definition

Whole Building Operational Performance accounts for the dynamic interactions between a building and its environment, energy systems, and occupants. Building Commissioning (Cx) is an important strategy for achieving, verifying, and documenting proper operation of new buildings and new systems. Similarly, existing building commissioning (EBCx), also called retrocommissioning (RCx), is a process that seeks to improve how building equipment and systems function together. 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. Building performance standards (BPS) are outcome-based policy and law requiring existing buildings to meet energy or 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. There are various ways these technologies result in operational savings such as automation of manual commissioning activities, tracking and identifying sources of energy waste at the whole building level, reducing the transaction cost of identifying and measuring performance of efficiency measures, and influencing operator and occupant behavior.

Projects that are primarily HVAC-focused should investigate alignment with the technology families in the HVAC Technology Priority Map. Projects focused on envelope are highly valued, but often overlooked, particularly as part of an 'envelope first' strategy to ensure those benefits are not forfeited before considering HVAC upgrades.

Research Initiatives

Research Initiative	Performance Validation	Market Analysis	Measure Development	Program Development
Normalized Meter Energy Consumption (NMEC)				
Residential Energy Automation Systems				

Research Initiative	Performance Validation	Market Analysis	Measure Development	Program Development
System Modeling and Analytics	⚠	⚠	☝	⚠
Automated Building Commissioning	⌛	⌛	☝	☝

KEY High Understanding ⌛ Research In Progress ⚠ Immediate Needs ☝ Future Research Need

Opportunities

Prospective ET studies should demonstrate cost-effective, scalable operational performance strategies for products or services to improve deployment and benefits in new and existing buildings scenarios. System modeling and analytics solutions should ingest existing building data, e.g., BAS trends, IoT, AMI, and census data, and output solutions to improve operational performance such as fault detection, preventive maintenance recommendations, energy improvement measures, energy resiliency planning, or controls optimization. Technologies that help buildings achieve BPS targets or improve NMEC incentives are valuable. Technologies that focus on real-time feedback would be especially valued for maintaining operational performance. REA systems should provide centralized and integrated control of building loads, which may include electric vehicle charging systems, photovoltaic generation, battery energy storage inverters, and traditional building loads of lighting, HVAC, water heating, and plug loads.

Projects that are broadly available to populations that have been underserved or hard to reach though existing operational performance technologies are highly valued.

Barriers

While mature, many commissioning strategies have not reached wide market adoption. While commissioning required building code has helped, it is only required for nonresidential buildings over 10,000 square feet, with limited mechanisms to ensure performance will persist over time. ET investments should focus on supporting wider market adoption of commissioning and technologies to ensure performance is maintained over time.

System modeling and analytics solutions are advancing rapidly with growth of sensors and IoT devices, data availability, and software capabilities. Additionally, traditional first-principal energy modeling is time consuming and, in many cases, cost prohibitive. ET investments should focus on demonstrating use cases that reduce cost and timelines: measuring energy and GHG savings, approaches for using analytics in utility programs, and first-principal energy modeling.

BPS and NMEC program solutions are being deployed, but there is a lack of understanding of the technical and market barriers, as well as limited tools and technologies for meeting targets or maximizing incentives. ET investments should focus on technologies that help buildings achieve BPS targets or improve NMEC incentives.

REA systems face several challenges including 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. ET investments should focus on lower cost solutions, proof of usability for residential occupants, pilot adoption scenarios, and demonstrating use cases,

Potential barriers studies should address:

- ***Barriers to NMEC***: There is a need for validation of automated NMEC software and calculation algorithms, including handling of nonroutine events. Market studies should address technology and service providers and technology and market barriers. Measure development and program opportunities include streamlined custom measure verification process and tools to increase program participation for NMEC projects. Measure development should align with California Technical Forum (Cal TF) Custom Measure efforts.
- ***Barriers to Residential Energy Automation Systems***: There is a need for a detailed breakdown of benefits by feature combined with comparative analysis among products. Market studies should address a comprehensive analysis including a market survey, literature review, and energy modeling to quantify benefits by climate zone and system type. Measure development and program opportunities include a preliminary energy model analysis and measure development and should prioritize DAC.
- ***Barriers to System Modeling and Analytics***: There is a need for more field validation of physics-based models. Market studies should address types of service providers, technology applications, and market barriers. Measure development and program opportunities include streamlined custom measure verification process and tools to increase program participation. Measure development should align with Cal TF Custom Measure efforts. Measure and program development should prioritize DAC.
- ***Barriers to Automated Building Commissioning***: There is a need to measure the savings and cost-effectiveness of automated commissioning technology. Market studies should address technology and vendor landscape of smart building software, interoperability, and open standards. Measure development and program opportunities include streamlined custom process, tools, or hybrid measures to increase program participation in MBCx, CCx, and VCx. Measure development should align with Cal TF Custom Measure efforts and could include a hybrid or deemed approach for commissioning submeasures with higher effective useful life (EUL).

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

Envelope

CalNEXT Role: Collaborate | CalNEXT Priority: Medium

Definition

The Envelope category covers products, design, and controls strategies, or installation techniques that reduce building energy demand and improve the moisture and airflow across the building envelope. This includes individual products such as insulation, windows, and insulated cladding, as well as construction techniques such as quality insulation installation, thermal bridge-free design and retrofit air seal or vapor control. 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

Research Initiative	Performance Validation	Market Analysis	Measure Development	Program Development
Thermal mass additions and improvements				
Window improvements				
Window attachments				
Air sealing retrofits				
Non-energy benefits of envelope retrofits				

KEY High Understanding | Research In Progress | Immediate Needs | Future Research Need

Opportunities

Improvements to the building envelope will reduce heating and cooling energy demand, improve thermal comfort, air quality, and moisture control, and make buildings more durable and resilient by maintaining a healthy and safe indoor environment during a power outage, smoky conditions, or an extreme weather event. In climates with a significant heating load, appropriate building envelope upgrades can make heat pump electrification successful by minimizing the use of supplemental heat, improving cost-effectiveness, reducing the heat load, and ensuring comfort.

Prospective emerging technology (ET) research focuses on products, such as improved envelope 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. Important opportunities address the high cost of retrofits and techniques that can be deployed with minimal disruption to building occupants or neighboring properties. Projects that demonstrate the magnitude of energy savings from envelope improvements are also an opportunity for research to support new programs.

Barriers

Envelopes are a mature field, but they have been historically under analyzed in favor of more straightforward and lower-cost widget measures. This is especially true for the nonresidential sector. ET investments in this technology family promise both improved savings and lower lifetime cost.

Potential studies of barriers should 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 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 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

Community Scale Strategies

CalNEXT Role: Observe | 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, and the larger grid system. The benefits include higher system efficiency, energy resilience, load flexibility, and grid harmonization.

Research Initiatives

Research Initiative	Performance Validation	Market Analysis	Measure Development	Program Development
Understanding of microgrid controller products	⚠	⚠	☝	☝
A market for VPPs and community microgrid interactions	⚠	⚠	☝	☝
Operation of a VPP and community microgrid under a real time pricing tariff	⚠	⚠	☝	☝
Value stacking by community microgrid operators	⚠	⚠	☝	☝
Opt in or opt out opportunities for customers of community microgrids	⚠	⚠	☝	☝

KEY High Understanding | Research In Progress | Immediate Needs | Future Research Need

Opportunities

For CalNEXT, prospective ET studies should 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. Projects may include market research, lab testing, modeling, and field

studies that help define benefits and value propositions. Microgrid sites should target regions most susceptible to grid outages such as public safety power shutoff events. Non wires alternatives include energy efficiency, solar and batteries, and virtual power plants, i.e., flexible loads, that relieve grid constraints or enable greater renewable energy consumption.

For district heating and cooling (DH&C), projects may involve system decarbonization, use of low global warming potential refrigerants, data collection, and evaluation methods of DH&C projects. 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.

CalNEXT expects significant research activity will continue by other emerging technology programs with focus areas beyond CalNEXT, such as demand response aggregation in the case of virtual power plants, as well as electric service resiliency in the case of microgrids.

Barriers

Potential barriers studies should 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.
- Limited technology solutions for electrifying DH&C heating systems.
- 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[3] 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 use for demonstrating economic viability for technologies including, but not limited to, VPPs and community microgrids.

CalNEXT Related Projects

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

[3] 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, there should be a way of allowing community members to opt in or opt 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 but has never been demonstrated to work in this context. Microgrids not owned by utilities should not depend on the utility smart meter because doing so adds another layer of complication.

Resources and Links

- *Four ways virtual power plants can help the US grid keep up with demand*, by Maria Gallucci of Canary Media, March 2024. https://www.canarymedia.com/articles/virtual-power-plants/four-ways-virtual-power-plants-can-help-the-us-grid-keep-up-with-demand

Discussion

Following submittal of the 2024 Whole Buildings Technology Priority Map, the Program Team will do the following:

- Update CalNEXT website with new 2024 Whole Buildings Technology Priority Map and this Final Report.
- Launch email announcement through email outreach.
- Develop and submit Distribution Report.

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

Table 3. Advisory Committee Feedback and Resolution Matrix

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Narrative	2024 Changes	Does this relate to the Whole Buildings Technology Priority Map or all Technology Priority Maps? Suggest clarifying the sentence.	Clarified that the Lighting Technology Priority Map was absorbed into the Whole Buildings, Process Loads, and Plug Loads and Appliances Technology Priority Map.
Narrative	2024 Changes	Suggest identifying the technology family where DC Lighting is being added. Based on the call it might be in only one family.	Clarified the DC Lighting technology is now incorporated in the Electrical Infrastructure tech family
Envelope	Barriers	Also, lack of awareness and data showing energy and thermal performance of single pane glass in mild CA climates. Even energy experts often underestimate the energy impacts of single pane glazing in mild climates. The market, in general, is largely unaware. Research documenting the magnitude and range of the problem will make efforts focused on solutions more effective.	Added language to the barriers section regarding customer awareness of benefits.

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Envelope	Barriers	One thought I had on the Envelope barriers is the challenge of finding solutions that are the right fit for what can be a highly variable building stock (esp when considering non-residential applications). This can make it difficult to easily scale solutions and necessitates a pretty well-rounded and available contractor base if they're going to have to serve as 'concierge-type' resources for customers. You may feel this is captured in the "lack of information…" bullet, but just wanted to offer my thought for your consideration.	Added language to barriers section regarding challenge of finding scalable envelope solutions for highly variable building stock
Envelope	Narrative	No mention of needed technology to reduce retrofit costs to improve insulation or cool surfaces.	Added a sentence to the definition about strategies and technologies that reduce cost.
Envelope	Key Factors	No mention of controls strategies and approaches (integrating across systems and DERs would be of real value add here) to incorporate this.	Added language in the Definition to clarify that envelope controls strategies are included. DERs integration is covered in Electrical Infrastructure category.
Envelope	Barriers	Other important barrier could be lack of customer awareness on benefit of these technologies, which leads to lesser market penetration. There is also lack of local manufacturer's interest in energy efficient window technologies as they don't see benefit in the investment.	Added an item to the barriers section regarding customer awareness of benefits.

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Integrated Systems	Definition	Would Combi system be included in this mix? Microsoft PowerPoint - Combi Heat Pumps Intro .pptx - Last saved by user (newbuildings.org)	Yes, combi systems such as the one shared would be included under the Integrated Systems category.
Integrated Systems	Opportunities	Could this also help address the issue of physical space on the electric panel to take up more load?	Yes, and panel replacements and upsizing are covered in more depth in the Electrical Infrastructure category.
Integrated Systems	Barriers	Would an example be the FHR rating table?	Yes, this is an example of the lack of maturity of system efficiency testing and ratings outlined as a barrier.
Integrated Systems	Opportunities	Incorporation of thermal storage, DERs, and I would specifically call out approaches that can improve cost effectiveness and for electrification approaches that work towards reduced or at worst, parity of energy costs (increased utility bills is a major barrier for equitable electrification).	Thank you for the comment. DERs integration and improving cost effectiveness of electrification is covered more directly in other categories such as Electrical Infrastructure and the HVAC Technology Priority Map. CalNEXT team will consider if incorporation of these topics is appropriate for this category in the final draft.
Integrated Systems	Opportunities	Inclusion of specific controls tools and strategies to improve or maintain performance, such as EMIS, FDD etc.	Thank you for noting that controls tools and strategies are an opportunity for research. The lack of interoperability between software programs and the controls system is noted as a barrier that should be studied, in addition to this topic being covered more extensively in the Operational Performance category.

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Integrated Systems	Opportunities	Inclusion of enabling electrification technologies, such as smart panels, smart breakers, sub panels etc.	Enabling electrification through panel replacements and upsizing, smart panels, etc. are covered in more depth in the Electrical Infrastructure category.
Integrated Systems	Barriers	Related barrier to effective use: Even when controls are present, interoperable and installed properly, default setting are often left unmodified, so the system never achieves optimal performance. Periodic retro-commissioning is often lacking, so as a building's use and characteristics change, the control system is often not adjusted accordingly.	Incorporated comment by adding to barriers section.
Operational Performance	Opportunities	Just a general comment that, while investigating opportunities and barriers, envelope solutions are highly valued but often overlooked. Investigating envelope upgrade solutions and their energy/GHG impacts would be valuable, particularly as part of an 'envelope first' strategy to ensure those benefits are not forfeited when skipping directly to HVAC upgrades.	Incorporated comment in definitions section.
Design and Construction	Opportunities	I was excited to see industrialized construction under the D&C family. I had read the recent NYT article that highlighted Operation Breakthrough from the early 1970s as an attempt to ramp up industrialized construction in the US It was very interesting!	Thank you for the historical context. Reference was added to Resources and Links section.

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Design and Construction	Barriers	Is cost of these new materials/processes also an issue? If so, please also mention. I understand some pushback to federal efficiency standards from [manufactured housing] (MH) manufacturers has been, purportedly, due to fears of increasing the costs of MH production. (I'm not sure if these efficiency standards raising costs is true, and if the magnitude of the cost increases warrants opposition to the updates in code. Maybe it's just an excuse to avoid having to change current practices). MH are often seen as an affordable alternative to site-built homes, so consumers, and thus manufacturers, are sensitive to price points.	Incorporated comments in Barriers section.
Design & Construction	Barriers	One barrier I'd add is workforce training for electrified manufactured housing. I've sat through a few presentations on the EPRI Net-Zero MH project funded by CEC. Press Releases (epri.com) I believe EPRI said certain measures needed to be installed on-site (heat pump HVAC and smart panels) and they found a lack of experience/training for workers in electrical planning, wiring, and interconnection.	Incorporated comments in Barriers section.
Design & Construction	Barriers	What does manufactured housing benefits mean? What kind of benefits and for whom?	Added language clarifying the potential GHG reduction benefits of improved manufactured housing techniques and market penetration. Also clarified that energy efficiency benefits apply to residents of homes.

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Design and Construction	Barriers	Sounds like it's similar enough to Passive House but I'm not sure. I think it's not related to Passive House. It's mostly related to manufactured housing related electrification. However, first section on Envelope is somewhat related.	Passive House is a performance-based design standard, and it certainly could be a useful metric for achieving improvements in Design and Construction. This technology family is particularly focused on achieving performance and efficiency gains, like the Passive House standard, through offsite construction strategies. We have not included any particular performance standard to welcome innovation at many levels, from energy to material conservation to carbon.
Electrical Infrastructure	Opportunities	I recommend that electric upgrades be more clearly defined. The CPUC is moving away from the term "electric panel upgrade" and "service upgrade," which doesn't differentiate between replacements for safety reasons, and replacements to increase electrical capacity. Instead, CPUC Building Decarb team is adopting the terms panel and service "replacements" (for safety reasons, or if the equipment is old), which is distinguished from "upsizing" which involves installing new equipment for the purposes of increasing electrical capacity (i.e., upsizing a panel from 100 amp to 200 amp).	Thank you for pointing this out. References to "panel upgrades" throughout have been amended to "panel replacements and upsizing" to be consistent with CPUC's definition.
Electrical Infrastructure	Opportunities	And perhaps also for resiliency measures such as PSPS events or outages?	Language added to incorporate resilience benefits

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Electrical Infrastructure	Barriers	Savannah and/or CalNEXT team, can we have links to these measures that incorporate electrical infrastructure upgrades?	Links to eTRM measures will be provided to CPUC via email.
Electrical Infrastructure	Barriers	To-the-meter (Front of the meter) or behind the meter costs?	Language added to clarify intention was to-the-meter, site costs.
Electrical Infrastructure	Barriers	Who does implementers refer to in this scenario? Electricians? Contractors? Program Implementers?	It refers to all stakeholders involved in implementing electrification measures. Clarifying language added.
Electrical Infrastructure	Barriers	Is it possible to be more specific when addressing this barrier? Maybe provide an example of the disconnect of electrification infrastructure needs?	Additional language added to clarify the disconnect.
Electrical Infrastructure	Barriers	This is a bit confusing – is the barrier that programs that encourage electrification do not also encourage electrical upgrades, or is it the other way around (programs that encourage electrical upgrades do not encourage electrification measures)? In either case, the Building Decarb team wants to add in the strong caveat that any electrical upgrades (panel upsizing, service upsizing) should only be pursued if absolutely necessary. There are many strategies that should be employed, with electric panel and service upsizing as a last resort. See Solving the Panel Puzzle | SPUR for more info.	The barrier is that programs promoting electrification do not do enough to enable it through means including, but not limited to, panel modifications. Authors note that CPUC is moving towards panel upsizing being a last resort and will take this into consideration in future revision cycles.
Electrical Infrastructure	Barriers	Replace with “replacements and upsizing.”	Language updated.

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
Electrical Infrastructure	Barriers	What is the barrier that is being addressed here? The cost of transformers? The lead times? The payback periods? Will there be mention of how to avoid transformer replacement entirely (such as "power efficient" electrification measures and load-sharing devices).	The barrier is the need for transformer upgrades to fully electrify. Added language to clarify the barrier being mentioned.
Electrical Infrastructure	Barriers	Again, what is meant by electrical infrastructure here? Within the home? The utility's electrical infrastructure?	Added language to clarify that the home's electrical infrastructure was the target of this barrier.
Community Scale Strategies	Role/Priority	CalNEXT Role and Priority is low for this family. These research initiatives are being actively pursued by the EM&T program. These initiatives should be also in line with the SWEETP. Since this Technology Priority Map is currently being revised and updated, this is an opportunity to reassess this family.	Energy Solutions discussed the feedback and consulted the Whole Buildings Technology Priority Map subject matter experts. This Technology Family was significantly edited, and the priority level remains low. Will further reassess next year based on number of projects submitted under this Technology Family this year.
Community Scale Strategies	Opportunities	Would a new residential development retire or decommission gas infrastructure? Wouldn't the study focus be on the avoided costs of installing any *new* gas infrastructure?	Incorporated feedback, added clarification to Opportunities section.

Community Scale Strategies	Barriers	This is overly broad and open ended. Seemingly presumes a ‘yes’ to the question of if there should be further policy support for community-scale microgrids. Should state an end-goal that will then be evaluated to see if policy should support it. Just about every proponent of community-scale microgrids seems to think it is in the ratepayer and public interest to let the microgrid use a utility’s distribution system at will and for one-way economic benefits. This is terrible public policy and exacerbates cost shifts for distribution system charges to non-participants. R.19-09-009 Track 5 is examining these issues, with a proposed decision expected in summer 2024.Should really be more explicit about the use cases for community microgrids that this work is meant to support. Many proponents want the community MG to become the service provider to people in the MG footprint during all grid conditions. That means the MG is acting as a utility and there are a lot of regulatory expectations and statutory requirements that come with that. Alternatively, there is a use case where the DERs within the MG footprint act as other grid connected DERs when the grid is up and the community MG provides resiliency when the grid is down. There is a policy role, unclear of what magnitude, for the second use case. Acknowledging the challenging economics. However, it is not at all a settled policy question that the first use case is in the public or ratepayer interest. Yet in R.19-09-009 it is this first use case that the vast majority of parties are	Incorporated feedback, this barrier was deleted.

Technology Family	Section	Suggestion or Comment	Action Taken and Justification
		pursuing due to their perception of favorable economics. This perception seems to be predicated on the community MG getting to act like a utility without being regulated like a utility. Do not assume this is a desirable policy outcome.	
Community Scale Strategies	Barriers	Explanation would be helpful. I assume this means if someone within a community microgrid footprint does not want to participate, then how can they effectuate that choice? Agree that is difficult and no easy ways to accomplish it. Encourage steering away from reliance on the utility smart meter for non-utility owned microgrids because it adds another layer of complication.	Incorporated feedback. Explanation of opt in and opt out capabilities added as footnote.
Community Scale Strategies	Barriers	Disagree with the premise that VPPs and the DERs within a community microgrid footprint are being excluded from any revenue opportunities that are otherwise available to other types of DERs. If this is an argument to increase the types of revenue opportunities available to DERs broadly, then suggest re-stating that more clearly. If this is an argument for revenue opportunities specific to VPP or community microgrids (e.g., carve out), then discourage that approach and encourage something that is technology agnostic and instead characterized by desired performance (e.g., output profile, emissions profile, availability/flexibility, etc).	Incorporated feedback, barrier restated to emphasize limited types of revenue opportunities.
Community Scale Strategies	Barriers	This reads as if RTP tariffs are broadly available, just not to VPPs and community MGs	Incorporated feedback with edits added to real time pricing tariff barrier description.