2023 Whole Buildings TPM

Final Report

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Abbreviations, Acronyms, and Glossary of Terms

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

Acronym	Meaning
LEED	Leadership in Energy and Environmental Design
PAWS	Partnership for Advanced Windows
PNNL	Pacific Northwest National Laboratory
SCE	Southern California Edison
SME	Subject Matter Expert
TABS	Thermally Activated Building Systems
TECH	Technology and Equipment for Clean Heating
TPM	Technology Priority Map
VRF	Variable Refrigerant Flow
VS	Variable Speed
WH	Water Heating

Glossary	Meaning
Technology Category	One of six broad technology categories (e.g. Whole Building, HVAC, Water Heating (WH), Plug Loads, Lighting, Process Loads).
Technology Family	Functional grouping that provides description of program role, opportunities, and barriers.
Subgroups	Common examples to further describe each technology family.
Definitions	Narrative to provide additional clarification on the technology family scope.
Opportunities	Description of potential impacts and potential research areas.
Barriers	Description of key barriers and potential barriers research.
CalNEXT Role	Describes general level of engagement by CalNEXT SMEs. *Note: Roles will change as research is completed.*
Lead Collaborate Observe	"Lead" – CalNEXT expects to take on most or all of the work and cost burden. "Collaborate" – CalNEXT is interested in collaborating and co-funding projects. "Observe" – CalNEXT will track progress but also encourage external programs to take the lead in unlocking these opportunities.
CALNEXT Priority	Communicates expected level of focus by CalNEXT SMEs. *Note: Priorities will change as research is completed.*
High Medium Low	"High" - CalNEXT SME team has highlighted this technology family as having high impacts within the Technology Category. "Medium" - CalNEXT SME team determined this technology family has moderate overall impacts within the Technology Category. "Low" - CalNEXT SME team has highlighted this technology family as having low relative impacts within the Technology Category.
Impact Factor	One of four broad impact areas (energy savings potential, demand flexibility potential, decarbonization potential, and other GHG impacts).
Impact Factor Ratings	A qualitative rating (High-Medium-Low) by the CalNEXT SME team on impact potential if technological advancements are made in key subgroups.
Knowledge Index	One of three types of knowledge areas (technical performance, market understanding, and program intervention) used to assess types of barriers studies necessary to obtain the stated impact potential.
Knowledge Index Rating	A qualitative rating (High-Medium-Low) by the CalNEXT SME team on the relative knowledge of most subgroups within a technology family. A higher rating means that the topic is well understood.

Introduction

The Technology Priority Maps (TPMs) provide the CalNEXT Program a framework to externally communicate priorities of the program, clearly define the central focus areas of the program, and assist with project screening. They will document the impact potential, programmatic research needs, and market readiness of all technology families across each of the end-use technology areas, which will drive product ideation and inform project selection. This Final Report covers the development of the Whole Buildings TPM.

Background

The TPMs were originally developed by Southern California Edison's Emerging Technologies program in 2017. They have been incorporated as a key element of the CalNEXT program to provide clarity to the program on our priorities. They require frequent updates to reflect the technical advancement, policy changes, and market developments in order to maintain their relevance. The current Whole Buildings TPM was developed by CalNEXT in 2022. The Whole Buildings TPM can be found at this link: https://calnext.com/resources/whole-buildings/. There has been a total of 45 Whole Buildings ideas submitted between 2022 and 2023 thus far. The CalNEXT team did not receive any external feedback on the 2022 Whole Buildings TPM prior to the revision process.

Objectives

The prior revision of the Whole Buildings TPM included a significant reorganization of the technology families and subgroups to improve clarity and reflect significant changes in the market landscape compared to the time at which the previous TPM was developed. The 2023 Whole Buildings TPM revision aimed to further clarify and expand the program definitions and priorities for prospective participants. Current technology family definitions and opportunities were revised where appropriate for every technology family in this TPM. Technology examples were added to support and clarify definitions, and barriers were refined, or new ones added to reflect the latest understanding by SMEs of key challenges in each technology family.

Methodology

The Program Team has established a robust development process for TPM development. This started with the formation of the Whole Buildings TPM Subject Matter Expert (SME) team which includes members of Program Team partners (VEIC, AESC, TRC, UC Davis, and Energy Solutions). The team met four times between May and June to develop this Draft TPM. A list of participants is provided in Table 1.

Table 1: Whole Buildings TPM Subject Matter Experts & Facilitators

Name	Organization
Gabe Duarte (facilitating)	Energy Solutions
Zoe Mies (coordinating)	Energy Solutions
Kitty Wang	Energy Solutions
Maureen Guttman	Energy Solutions
Antonio Corradini	AESC/ASK Energy
Keith Downes	VEIC
David Vernon	U.C. Davis
Curtis Harrington	U.C. Davis
Gwelen Paligia	TRC

Prior to starting development, the SMEs reviewed the previous TPM from 2022. The SMEs then held a kickoff to discuss the state of the current TPM and the energy efficiency (EE) portfolio measures and potential code measures in this area. Assignments for SMEs between the first and second meetings included study of relevant efforts and preparation of presentations to the full SME group regarding the following:

- Project reports from the Emerging Technology Coordinating Council (ETCC)
- Project reports from the California Energy Commission - Electric Program Investment Charge (CEC-EPIC) program
- Publications and other research efforts from the national research laboratories
- Publications from other Emerging Technology (ET) programs including: ComEd, Northwest Energy Efficiency Alliance (NEEA), and Northeast Energy Efficiency Partnerships (NEEP)
- Relevant project reports from California Statewide DR Emerging Technology Program
- Recent and upcoming regulatory changes in California standards such as CEC's Title 24, Part 6, California Public Utilities Commission (CPUC) rulemakings such as decision D.23-04-035
- Industry standards such as ASHRAE 90.1, and
- Federal standards such as the ENERGY STAR Residential Windows, Doors, and Skylights Specification Version 7.0, which will go into effect on October 23, 2023

Additionally, SMEs reviewed existing TPM Technology Families to assess the ability of the Whole Buildings TPM to communicate the current research needs of CalNEXT.

In the second meeting SMEs presented findings from the first session's assignments and discussed implications for revising the Whole Buildings TPM. The SMEs used the time between the second and third session to independently contemplate the discussions and recommend key changes to the technology families. At the third meeting, the SMEs presented and debated each other's recommendations to reach a consensus on the revision direction for each technology family. Each SME was assigned a technology family to develop the revised technology subgroups, definitions, opportunities, and barriers as well as recommend adjustments to gradings of ETP role, ETP priority, key factors, and knowledge indices.

Following the Preliminary Findings Report, the TPM facilitators set up a final ballot and distributed it to the SME Team to determine the recommended revisions to the gradings for key factors, knowledge indices, ETP priority, and ETP role. Concurrent to this activity, the initial narratives were presented to the Technical Advisory Committee (presented July 20, 2023) as well as supplemental feedback from the CalNEXT equity specialist (Ortiz Group). The Technical Advisory Committee attendees were given a presentation of key changes and access to a cloud-based draft to provide suggestions for each technology family's key factors, knowledge indices, and narratives for opportunities and barriers. The TPM facilitators then worked with both internal and external stakeholders to obtain feedback. The external committee of stakeholders included the California Investor-Owned Utility (IOU) Program Administrators (PAs) as well as stakeholders with emerging technology interests from the State of California, other regions, and those with national interests.

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

Draft Report Feedback

TPM Advisory Committee Meeting

The TPM Advisory Committee meeting was held on July 20, 2023, via the Microsoft Teams platform. This meeting allowed advisory members to provide real-time, candid feedback with the opportunity to provide written comments and suggestions afterwards via a collaborative Word document hosted on Microsoft SharePoint. Suggestions were reviewed by the TPM coordinator and incorporated into the Revised 2023 Whole Buildings TPM section below.

A detailed table of the changes made can be found in the Stakeholder Feedback & Resolution Matrix in Table 2 in the Appendix of this Final Report.

CalNEXT Website TPM Mock-up (2022 Whole Buildings sample below)

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

2022 Technology Research Areas	Role	Priority	
Integrated Systems	LEAD	HIGH	+
Electrical Infrastructure	LEAD	HIGH	+
Design & Construction	LEAD	HIGH	+
Operational Performance	LEAD	MEDIUM	+
Envelope	COLLABORATE	MEDIUM	+
Community Scale Strategies	OBSERVE	LOW	+

2023 Whole Buildings TPM

Whole Buildings Technology Category Overview

The Whole Buildings TPM covers a wide range of technologies and innovative approaches focused on Whole Buildings or systems that cut across multiple TPM categories. Among the TPMs, it is unique in that respect. There is an increased focus on electrification because of policies such as the Inflation Reduction Act (IRA) at the federal level, SB 596 and the CEC Load Management Rulemaking at the state level, and Title 24 2022 Building Energy Efficiency Standards going into effect. Senate Bill (SB) 596 advances attempts to measure embodied carbon in construction materials and the CEC Load Management Rulemaking expands on efforts to increase efficiency and demand flexibility in California's electricity grid. Title 24, Part 6, includes new electric-ready requirements to enable electrification. All these policy drivers highlight the need to conduct further research into low embodied-carbon design and construction practices, leverage demand flexibility to prepare the grid for electrification, and ensure buildings are ready for electrification.

Unique Opportunities and Barriers

Integration and interoperability across multiple systems remains a huge challenge within Whole Buildings. Technologies that advance decarbonization and demand flexibility will be a focus along with ensuring buildings use the most sustainable practices in design and construction. CalNEXT will look to partner with the Demand Response ET Program, Gas ET Program, and other programs to coordinate efforts across historically siloed research.

Highlighted Priority Areas

Technology Family	Definition	ETP Role	ETP Priority
Integrated Systems	This category covers components, systems, or controls with integrated approaches that differentiate them from other TPM technology families and includes single products that serve multiple end-uses. Examples include heat pumps (HP) serving domestic hot water (DHW) and HVAC; and building management system (BMS) controls that integrate control between multiple end-uses (such as networked lighting sensors used for lighting and HVAC control). This technology family also includes integrated packages of measures, such as: electrification packages with measures to improve envelope (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 (TABS), embedded radiant floor panels, or broadly grid-interactive efficient buildings (GEBs).	1-Lead	1-High
Design & Construction	This technology family is focused on opportunities to reduce emissions, costs, and energy use in the design and construction of whole buildings. This includes techniques to reduce embodied carbon emissions in building materials, as well as the use of partial or whole off-site construction such as manufactured housing, volumetric modular construction, or panelized construction. High-performance building design includes project delivery practices and building standards that promote lifecycle sustainability in the design, construction, and operation of a building.	1-Lead	1-High
Electrical Infrastructure	This technology family refers to single and multi-structure sites that use a common utility connection and encompasses site-level electrical infrastructure needs and capabilities to enable low- or carbon-neutral buildings, demand-flexible end-uses, distributed energy resources, and grid harmonization.	1-Lead	1-High

Envelope

CalNEXT Role: Collaborate | CalNEXT Priority: Medium

Key Factors

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

Knowledge Index

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

Example Technologies

Roofing, Fenestration, Opaque Envelopes, Air Sealing

Definition

The Envelope category covers products, design strategies, or installation techniques that improve the overall performance of the building envelope impacting heat, moisture, and infiltration. This includes individual products such as insulation, windows, secondary windows, and 'retrofit facades' that improve the building envelope. It also includes quality construction techniques to further improve the envelope, such as quality insulation installation, addressing thermal bridging, air sealing, and vapor barriers.

Note: Some prospective envelope projects may better fit under the Scalable Thermal Storage Technology Family under the Heating, Ventilation, and Air Conditioning (HVAC) TPM or the Connectivity, Controls, and Integration Technology Family under the Lighting TPM.

Opportunities

Improvements to building envelopes will provide better thermal comfort, reduced heating and cooling energy usage, improved air quality, moisture control, and better resilience for buildings. Prospective emerging technology (ET) research can be product-based such as improved envelope materials or can be advancements in construction practices. Automated interior or exterior fenestration and shading systems that utilize sensors to reduce energy use based on the season, time of day, and occupancy should also be explored. Studies should focus on deployable technologies for much larger existing building sectors that can address the high costs of retrofits and/or techniques that can be deployed with minimal disruption.

In California, the energy code does not currently require thermal bridging mitigation and air barrier testing/verification. Pilot projects that demonstrate the projected energy savings impacts from these measures may also present significant opportunities for improved building envelope performance.

Barriers

Envelopes are a mature field but have been historically under-analyzed in favor of more straightforward widget-based appliance options (this is especially true for the non-residential sector). ET investments in this technology family can promise both improved savings, lower lifetime cost, as well as several co-benefits that need evaluation.

Potential studies of barriers should address:

1. Lack of information related to retrofit technologies for existing residential envelopes
2. Lack of information related to retrofit technologies for existing commercial envelopes
3. Poor understanding of installation performance gaps (i.e., variance of real-product lifetimes) and embodied carbon impacts of different envelope materials
4. Lack of valid data on energy code compliance and actual building performance
5. Lack of trusted tools to facilitate accurate savings estimates in support of programs

Integrated Systems

CalNEXT Role: Lead | CalNEXT Priority: High

Key Factors

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

Knowledge Index

Technical Performance: Low (decreased)
Market Understanding: Low
Program Intervention: Low (decreased)

Example Technologies

Multifunction Equipment, Integrated Controls, and Integrated/Interactive Measure Packages. Examples include combined space heating, cooling, and water heating systems.

Definition

This category covers components, systems, or controls with integrated approaches that differentiate them from other TPM technology families and includes single products that serve multiple end-uses. Examples include heat pumps (HP) serving domestic hot water (DHW) and HVAC; and building management system (BMS) controls that integrate control between multiple end-uses (such as networked lighting sensors used for lighting and HVAC control). This technology family also includes integrated packages of measures, such as: electrification packages with measures to improve envelope (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 (TABS), embedded radiant floor panels, or broadly grid-interactive efficient buildings (GEBs).

Opportunities

Integrated Systems have 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.

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

Barriers

Most performance improvements are component-based 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, the California electronic Technical Reference Manual (eTRM) database includes predominantly single technology or single end-use measures, resulting in most Integrated Systems solutions needing to follow a custom-engineered approach.

Potential barriers studies should address:

1. Lack of interoperability between software programs in controls systems

2. Lack of open communication protocols for controls equipment, particularly for small and medium buildings (residential and commercial)
3. Lack of field performance data (including system reliability, energy performance, and cost-effectiveness)
4. Lack of maturity of system efficiency testing and ratings, particularly for combination HVAC and water heating (WH) products
5. Lack of software tools for designers to quickly model and assess system performance and costs for integrated systems
6. Lack of standard methodologies for estimating savings of integrated systems
7. Lack of deployment infrastructure for integrated systems; need for better understanding of resources available for designers, installers, and maintenance strategies

Design & Construction

CalNEXT Role: Lead | CalNEXT Priority: High

Key Factors

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

Knowledge Index

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

Example Technologies

Manufactured Housing, Volumetric Modular Building Components, Panelized Components, Low-Embodied Carbon designs, High-Performance Building Design

Definition

This technology family is focused on opportunities to reduce emissions, costs, and energy use in the design and construction of whole buildings. This includes techniques to reduce embodied carbon emissions in building materials, as well as the use of partial or whole off-site construction such as manufactured housing, volumetric modular construction, or panelized construction. High-performance building design includes project delivery practices and building standards that promote lifecycle sustainability in the design, construction, and operation of a building.

Opportunities

Improvements in building design practices have the potential to reduce lifetime emissions associated with construction by implementing 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; and 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.

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

Improvements in off-site or partial off-site construction can reduce construction costs and deployment times while improving performance and reliability of building systems, as well as de-risk

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

2 AIA California, "Integrated Project Delivery"

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 focus on development and deployment of low-embodied-carbon buildings or high-performance whole buildings through demonstrations, scaled deployments, improvements to modeling and analysis tools, or other strategies.

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.

Potential studies of barriers should address:

1. Lack of market understanding within utilities of manufactured housing benefits, associated implementation costs, and verifiable energy benefits.
2. Lack of programs to incentivize behavioral change of manufacturers, developers, construction managers, and building designers.
3. Lack of programs supporting electrification of manufactured housing including, but not limited to, U.S. Department of Housing and Urban Development (HUD) Manufactured Housing, volumetric modular housing including single-family and multi-family housing, and Accessory Dwelling Units (ADU).
4. Lack of consistent disclosure of Environmental Product Declaration (EPD) from material suppliers.
5. Lack of manufacturer understanding on the benefits of low embodied carbon materials and willingness to promote and integrate products into their business model.
6. Lack of manufacturer ability to see a market, incentives and plant tax credits for high-performing off-site construction solutions.
7. Need for opportunities to employ integration of design, construction, and building commissioning in residential and commercial work.

Electrical Infrastructure

CalNEXT Role: Lead | CalNEXT Priority: High

Key Factors

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

Knowledge Index

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

Example Technologies

Electric Panel Upgrades, Transformers, Direct Current (DC) Power Systems

Definition

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

Opportunities

Improvements to the electrical infrastructure deployment will be necessary to support broad decarbonization efforts. Many existing buildings will need electric upgrades to support the 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 would include the customer side's sub-transformers, which will need to be upgraded to handle the additional loads. Strategies and technologies to improve cost-effectiveness in deploying electrical infrastructure and/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.

Opportunities exist for panel upgrades, with or without smart panels, to clearly separate loads so that critical and uncritical usage can be more easily identified, not only for demand response and demand flexibility opportunities, but also for energy efficiency through daily schedules. 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 different voltage requirements.

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:

1. Lack of experienced practitioners. The industry lacks broad understanding of electrical infrastructure costs to support building electrification (especially hard-to-reach (HTR) and disadvantaged communities (DAC) as well as multi-family and non-residential buildings).
2. Disconnect between implementers and the National Electric Code and policymakers on electrification infrastructure needs and how best to address safety risks for load management approaches.
3. Lack of integration in programs to encourage combining enabling technology (electrical upgrades) with electrification (HVAC HPs and heat pump water heaters), promote best practices in design and construction (such as adequate envelope insulation and right sizing electric appliances), and foster demand response benefits.
4. Extensive and complex local city and utility codes that make panel upgrades a major project, sometimes requiring permitting or other approval processes that can take months to complete.
5. Transformers are expensive, resulting in longer payback periods; there are also a limited number of manufacturers which results in longer lead times for equipment replacement.

Community Scale Strategies

CalNEXT Role: Observe | CalNEXT Priority: Low

Key Factors

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

Knowledge Index

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

Example Technologies

Microgrids, Non-Wires Alternatives, District Heating and Cooling

Definition

Community-Scale Strategies can aggregate, balance, and control the flow of energy (thermal and/or electric) between multiple buildings and/or 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/or the larger grid system. The benefits include higher system efficiency, energy resilience, load flexibility and grid harmonization.

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 natural gas infrastructure in an existing block or a new residential development). Projects may include market research, lab testing, modeling, and field studies that help define benefits and value propositions. Microgrids sites should target regions most susceptible to grid outages (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 and/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.

CalNEXT expects significant research activity will continue by other programs with focus areas outside of 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:

1. Nascent standards environment for interoperability of grid assets.
2. Significant policy changes necessary to facilitate community-scale microgrids.
3. Lack of empirical data and case studies on project costs, operational performance, and benefits.

4. Lack of market understanding for microgrid controller products.
5. Lower market penetration rates of non-wires alternatives for DAC and HTR communities.
6. Limited technology solutions for electrifying DH&C heating systems

Operational Performance

CalNEXT Role: Lead | CalNEXT Priority: Medium

Key Factors

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

Knowledge Index

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

Example Technologies

New Building Commissioning, Existing Building Commissioning, System Modeling and Analytics, and Normalized Metered Energy Consumption, Building Performance Standards, Behavioral Interventions.

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 retro-commissioning (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 monitoring-based commissioning (MBCx) and continuous commissioning (CCx).

System modeling and analytics is the software (algorithms, machine learning, digital twins, predictive models, first-principle/physics-based energy models) used to improve operational performance. Building performance standards (BPS) are outcome-based policy and law requiring existing buildings to meet energy-based or GHG emissions-based performance targets. Normalized Metered Energy Consumption (NMEC) is when energy savings from building energy interventions are measured based on normalized utility meter data. This technology family also includes other operational strategies that can improve performance including feedback mechanisms that produce energy savings from changes in individual or organizational behavior.

Projects that are primarily HVAC-focused should investigate alignment with the technology families in the HVAC TPM category.

Opportunities

Prospective ET studies should demonstrate cost-effective, scalable operational performance strategies (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, census data) and output solutions to improve operational performance such as fault detection, preventative 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.

Projects that are broadly available to populations that have been underserved or hard to reach though existing operational performance technologies are highly valued. Feedback mechanisms that produce behavioral energy savings that can show viability for future programs would also garner significant interest.

Barriers

While mature, many commissioning strategies have not reached wide market adoption. While building-code-required commissioning has helped, it is only required for non-residential 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, measuring energy and GHG savings, approaches for using analytics in utility programs, and first-principal energy modeling, that reduce cost and timelines.

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.

Potential barriers studies should address:

1. Lack of market penetration of commissioning, use cases, and quantified benefits of modeling and analytics.
2. Lack of market understanding and proven technology that support BPS and NMEC
3. Lack of understanding of technical performance and market understanding for whole building occupant-responsive systems

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

Table 2: Advisory Committee Feedback & Resolution Matrix

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
Methodology	Narrative	Was ongoing efforts by US DOE and US EPA part of this effort?	We did not discuss any specific ongoing DOE or EPA efforts, but the SME group brings a wide array of expertise and knowledge of Federal research in this domain to the Whole Building TPM revision efforts. If there are any specific ongoing EPA/DOE efforts you think the team should be aware of, please let us know.
Methodology	Narrative	Was recent CPUC Energy Division decisions part of this effort?	We did not previously identify CPUC Decisions for review and will work to do so moving forward. We added in D.23-04-035 based on recent conversations. We welcome your recommendations on other specific Energy Division decisions to study in the near term.
All	Key Factor / Knowledge Index Ratings	Indicate how ratings changed vs. prior year.	Suggestion accepted. Noted as “increased” or “decreased” throughout document.
All	ETP Role/Prioritization	Explain the lack of changes to ETP Role/Prioritization for technology families.	After extensive review and discussion, the SME team determined the ETP Role/Prioritization should remain unchanged at this time and will revisit next year.
Integrated Systems	Subgroup	Remove dual-fuel equipment subgroup.	Suggestion accepted following review of CPUC decision D.23-04-035.
Integrated Systems	Knowledge Indices	Explain why knowledge indices downgraded to low.	Knowledge Indices revised downward due to determination by SME group that this category is not very well understood at this time.

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
Envelope	Definition	Be aware of the recent decision from CPUC on gas incentives and the whole new idea of additional exempt measures. There will be lots of measure package developments in the next year.	Suggestion accepted. Did not incorporate change within narrative, will keep suggestion in mind for next revision cycle.
Envelope	Opportunities	Consider work from recent NEEA and DOE PAWS (Partnership for advanced windows) windows campaign, including BPA's (Bonneville Power Administration) new window measure.	Suggestion accepted. CalNEXT team will further examine work from PAWS as a part of next year's revisions. There is also currently an ongoing CalNEXT Windows Market Study that will incorporate research from NEEA and DOE.
Design & Construction	Technology Family	Clarification on the connection between Design & Construction category and energy efficiency.	Reached out to stakeholder to explain why this technology family is included, and how the outcome of work in this space could be integrated into IOU energy efficiency portfolio.
Design & Construction	Opportunities	Did your team look into the benefits of 3D-printed houses	The team did not examine 3D-printed houses and due to their low market penetration at this time relative to manufacture housing and volumetric modular construction, we suggest maintaining priority focus on the latter. We will continue to monitor this emerging sector and will reevaluate this category next year.
Community Scale Strategies	Opportunities	Can ET Program fund solar and batteries?	The idea is to fund projects that study how solar and batteries support or facilitate electrification of homes and buildings - so in the context of microgrids or non-wires alternatives. We wouldn't fund demonstrations of new battery and solar products per se to evaluate their operating efficiency, for example.

Technology Family	Section	Suggestion or Comment	Action Taken & Justification
			Currently CalNEXT is funding two projects that involve solar and storage: 1) Residential Energy and Automation Systems – Market Study and 2) Performance Evaluation of Advanced home energy management systems (HEMS).