2022 Whole Buildings Technology Priority Map

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Abbreviations, Acronyms, and Glossary of Terms

Acronym	Meaning
BCCA	Buy Clean California Act
BMS	building management system
CEC	California Energy Commission
CCx	continuous commissioning
CPUC	California Public Utility Commission
Cx	building commissioning
DAC	disadvantaged communities
DC	direct current
DHW	domestic hot water
EBCx	existing building commissioning
EE	energy efficiency
EPD	environmental product declaration
ET	emerging technology
eTRM	Electronic Technical Reference Manual (CA)
EV	electric vehicle
GEBs	grid-interactive efficient buildings
GHG	greenhouse gas
GWP	global warming potential
HP	heat pump
HTR	hard-to-reach
HVAC	heating, ventilation, and air conditioning
IEPR	Integrated Energy Policy Report
IOUs	investor-owned utilities
MBCx	monitoring-based commissioning

NMEC	normalized metered energy consumption
PG&E	Pacific Gas and Electric
RCx	retro commissioning
SCE	Southern California Edison
SDG&E	San Diego Gas and Electric
SME	subject matter expert
TABS	thermally activated building systems
TPM	technology priority map
V2X	vehicle-to-everything
VPP	virtual power plant
WH	water heating

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

2022 Whole Buildings TPM

Whole Buildings Technology Category Overview

This category covers a wide range of technologies and innovative approaches focused on Whole Buildings or systems that cut across multiple TPM categories. One of the main policy drivers is the growing interest in studying and removing electrification barriers to support building decarbonization through heat pumps (SB1477) while simultaneously supporting electrical growth driven by electric vehicles (EVs). The electric growth reinforces the need of smarter buildings and smarter appliances with flexible-demand capabilities (SB49) to enable a clean, resilient, and flexible grid. Finally, multiple state and local policy changes such as the Buy Clean California Act, Marin County's Low Global Warming Potential (GWP) Concrete Ordinance, and State of California action, aimed at reducing emissions from the cement sector (SB596) highlight research needed to support the transformation of the construction industry to support efforts to lower the embodied carbon in building materials and building designs.

Unique Opportunities and Barriers

Integration and interoperability across multiple systems remain a huge challenge within Whole Buildings. With decarbonization and demand flexibility being large areas of interest under this category, CalNEXT will look to partner with the Demand Response ET, Gas ET, and other programs to coordinate efforts across historically siloed research.

Highlighted Priority Areas

Technology Family	Technology Subgroups	Definition	ETP Role	ETP Priority
Integrated Systems	Multifunction Equipment, Integrated Controls, and Integrated/Interactive Measure Packages. Examples includes combined space heating, cooling, and water heating systems.	Components, systems, or controls with integrated approaches that differentiate them from other TPM Technology Families. Includes single products that serve multiple end-uses (e.g. HP serving DHW and HVAC), BMS controls that integrate control between multiple end uses (e.g. networked lighting sensors used for lighting and HVAC control), and integrated packages of measures (e.g. electrification packages with measures to improve envelope and reduce loads to a heat-pump HVAC retrofit OR integrated design that provides multiple services/benefits from each component such TABS embedded radiant floor panels, or broadly GEBs: Grid Interactive Efficient Buildings).	**1-Lead**	1-High
Electrical Infrastructure	Electric Panel Upgrades, Transformers, DC-Power Systems.	Site-level electrical infrastructure needs and capabilities to enable low- or carbon-neutral buildings, demand-flexible end-uses, distributed energy resources, and grid harmonization. Refers to single and multi-structure sites that use a common utility connection.	**1-Lead**	1-High
Whole Building Design & Construction	Manufactured Housing, Modular Building Components, Panelized Components, Low-Embodied Carbon designs, Site-built design, and High-Performance Building Design.	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, or panelized construction.	**1-Lead**	1-High

Integrated Systems

(ETP Role: Lead, ETP Priority: High)

Key Factors

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

Knowledge Index

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

Subgroups

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

Definition

Components, systems, or controls with integrated approaches that differentiate them from other TPM Technology Families. Includes single products that serve multiple end-uses [e.g. Heat Pump (HP) serving Domestic Hot Water (DHW) and HVAC], Building Management System (BMS) controls that integrate control between multiple end uses (e.g. networked lighting sensors used for lighting and HVAC control), and integrated packages of measures [e.g. electrification packages with measures to improve envelope and reduce loads to a heat-pump HVAC retrofit OR integrated design that provides multiple services/benefits from each component such thermally activated building systems (TABS) embedded radiant floor panels, or broadly Grid-Interactive Efficient Buildings (GEBs)].

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

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 improving demand flexibility (e.g., an integrated heat-pump system that combines water heating, thermal storage, space heating, and cooling).

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

Barriers (Technical, Market, Program)

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 (CA) electronic Technical Reference Manual (eTRM) database includes predominantly single technology or single end-use measures, resulting in most integrated systems solutions having to follow a custom-engineered approach.

Potential barriers studies should address:

1. Lack of interoperability between systems.

2. Lack of field performance data (including system reliability, energy performance, and cost-effectiveness).

1. Lack of maturity of system efficiency testing and ratings (particularly for combination HVAC and Water Heating (WH) products).

2. Lack of software tools for designers to quickly model and assess system performance and costs for integrated systems.

3. Lack of deployment infrastructure for integrated systems: need to better understand resources for designers, installers, and effective maintenance strategies.

Electrical Infrastructure (ETP Role: Lead, ETP 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

Subgroups

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

Definition

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

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

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 other gas end-uses (clothes dryers, cooktops, etc.). EV charging will also drive the need for added electrical capacity. Strategies and technologies to improve cost-effectiveness in deploying electrical infrastructure and/or demonstration of effective load management strategies that enable electrification are of high interest (e.g., smart circuit breakers, smart panels, and the ability to support the flexible demand technologies under SB49).

Note: for prospective electrical infrastructure projects that primarily support Demand Flexibility such as Vehicle-to-Everything (V2X), CalNEXT will look for ways to collaborate with existing ET programs.

Barriers (Technical, Market, Program)

Electrical infrastructure upgrades are new to the utility program landscape having recently been incorporated into several CA 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 which can often have other costs associated with an electrical upgrade such as tree removal, relocation of key systems, replacement of legacy electrical system (e.g., knob-and-tube wiring).

Potential barriers studies should address:

1. Lack of experienced practitioners. The industry has broad lack of understanding of electrical infrastructure costs to support building electrification (especially in hard-to-reach (HTR) and disadvantaged communities (DAC) and multi-family and non-residential building types).
2. Disconnect between implementers / National Electric Code and policymakers on electrification infrastructure needs and address safety risks for load management approaches.

3. Lack of program integration to combine enabling technology (electrical upgrades) with electrification (HVAC HPs and heat pump water heaters) and demand response benefits.

Whole Buildings Design & Construction (ETP Role: Lead, ETP 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

Subgroups

Manufactured Housing, Modular Building Components, Panelized Components, Low-Embodied Carbon designs, Site-built design, and 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, or panelized construction.

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

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 GWP 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 (2021), which will develop a statewide net-zero emissions strategy for the cement sector.

Improvements in off-site or partial off-site construction can reduce construction costs and deployment times while improving the performance and reliability of building systems, as well as de-risk integration of new strategies (such as the 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 expect significant growth to address the state's housing affordability crisis.

Prospective ET studies should focus on the development and deployment of lower embodied carbon buildings or high-performance whole buildings through demonstrations, scaled deployments, improvements to modeling and analysis tools, or other strategies.

Barriers (Technical, Market, Program)

While a mature industry, Whole Building Design and Construction has not been a focus for the California utilities ET Program. This has been a dynamic area in recent years with a variety of recent policy changes (as mentioned in the opportunities above) and represents an area of significant potential for utility programs to research and develop initiatives that align with policy goals to reduce embodied carbon emissions.

Potential barriers studies should address:

1. Lack of market understanding including associated implementation costs, and verifiable benefits.
2. Lack of programs to incentivize behavioral change of building designers.
3. Lack of programs supporting electrification of accessory dwelling units, manufactured housing, and other manufactured structures.
4. Lack of consistent disclosure of Environmental Product Declaration (EPD) from materials suppliers.
5. Lack of experienced practitioners.

Lack of factories equipped to deliver high-performing off-site construction solutions.

Whole Buildings Operational Performance (ETP Role: Lead, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups

Behavioral Interventions, New Building Commissioning (Cx), Existing Building Commissioning (RCx, MBCx, CCx), System Modeling, and Normalized Metered Energy Consumption (NMEC)

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 that can ensure proper operation of new buildings and new systems. Similarly, existing building commissioning (EBCx) can improve building performance by implementing controls, optimizations, or upgrades that improve how systems function together or respond to varying conditions (e.g., Retrocommissioning (RCx)). 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). This technology also includes other operational strategies that can improve performance such as behavioral interventions. *Note: projects that are primarily HVAC-focused should investigate alignment with the technology families in the HVAC TPM category.*

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

Under Whole Building Operational Performance, prospective ET studies should demonstrate low-cost, scalable strategies (products or services), to improve deployment of commissioning for new and existing buildings scenarios. Technologies that focus on real-time feedback would be especially valued for improved operational resilience.

Behavioral strategies that can show viability for future programs would also garner significant interest.

Barriers (Technical, Market, Program)

While mature, many proven strategies to improve Whole Building Operational Performance have not reached wide market adoption. While building code commissioning has helped, it is only required for non-residential buildings under 10,000 square feet with limited mechanisms to ensure performance will persist over time. ET investments should focus on supporting wider market adoption.

Potential barriers studies should address:

1. Lack of experienced practitioners.
2. Lack of market understanding and associated implementation costs.
3. Lack of programs to incentivize behavioral change of builders.

4. Lack of understanding of technical performance and market understanding for whole building occupant-responsive systems.

Envelope (ETP Role: Collaborate, ETP 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

Subgroups

Roofing, Fenestration, Opaque Envelopes, Air Sealing

Definition

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, 'second skins,' 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 (EE Savings, Decarbonization, Demand Flexibility, and Other GHG)

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. 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.

Barriers (Technical, Market, Program)

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 barriers studies 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 trusted tools to facilitate accurate savings estimates in support of programs.

Community Scale Strategies (ETP Role: Observe, ETP 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

Subgroups

Microgrids, Virtual Power Plants, District Heating & 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. The benefits include higher system efficiency, energy resilience, load flexibility and/or grid harmonization.

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

For CalNEXT, prospective ET studies should demonstrate performance benefits in terms of magnitude and cost-effectiveness of emissions reductions. Microgrids sites should target regions most susceptible to grid outages (Public Safety Power Shutoff events) or within DAC or HTR communities. For virtual power plants, studies should demonstrate effective program designs for DAC and HTR communities.

We expect 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 (VPP) and/or electric service resiliency in the case of microgrids.

Barriers (Technical, Market, Program)

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 market understanding for microgrid controller products.
4. Lower market penetration rates of VPP for DAC and HTR communities.