# 2024 Lighting, Plug Loads, and Appliances TPM – DRAFT VERSION

The 2024 Lighting, Plug Loads and Appliances TPM finalized update will be live on 1/1/2025. This copy serves to allow the public to prepare submissions ahead of time against the updated revisions. Any Lighting, Plug Loads and Appliances ideas submitted between now and 12/31/2024 will apply against the 2023 updates.


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# Acknowledgements

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California Public Utilities Commission

California Technical Forum

Commonwealth Edison Company

National Renewable Energy Laboratory

Northwest Energy Efficiency Alliance

Pacific Gas & Electric

Pacific Northwest National Laboratory

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## Abbreviations, Acronyms, and Glossary of Terms

| Acronym | Meaning |
|---|---|
| AC | Alternating Current |
| ADLD | Automatic and Dynamic Load Detection |
| AESC | Alternative Energy Systems Consulting, Inc. |
| CA | California |
| CARB | California Air Resources Board |
| CEC | California Energy Commission |
| CDC | Center for Disease Control |
| CPAP | Continuous Positive Airway Pressure |
| CPUC | California Public Utilities Commission |
| DAC | Disadvantaged Communities |
| DER | Distributed Energy Resources |
| DERMS | Distributed Energy Resource Management System |
| DH&C | District Heating and Cooling |
| DOE | Department of Energy |
| EE | Energy Efficiency |
| ET | Emerging Technology |
| EV | Electric Vehicle |
| EVSE | Electric Vehicle Supply Equipment |
| FDAS | Flexible Demand Appliance Standards |
| GHG | Greenhouse Gas Emissions |
| HP | Heat Pump |
| HTR | Hard-to-Reach |
| HVAC | Heating, Ventilation, and Air Conditioning |
| IEPR | Integrated Energy Policy Report |
| IOU | Investor-Owned Utility |
| LBNL | Lawrence Berkely National Lab |

| Acronym | Meaning |
| --- | --- |
| NOx | Nitrogen Oxide |
| NREL | National Renewable Energy Lab |
| PPLs | Plug and Process Loads |
| RASS | Residential Appliance Saturation Study |
| SCE | Southern California Edison |
| SME | Subject Matter Expert |
| SPUR | San Francisco Bay Area Planning and Urban Research Association |
| TPM | Technology Priority Map |
| TRC | Total Resource Cost |
| TSB | Total System Benefit |
| TWh | Terawatt Hour |
| VEIC | Vermont Energy Investment Corporation |
| VRF | Variable Refrigerant Flow |
| WH | Water Heating |

| Glossary | Meaning |
|---|---|
| Technology Category | One of six broad technology categories (e.g. 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, 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 | If 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 key barriers and potential barriers research. |
| CalNEXT Role | Describes general level of engagement by CalNEXT SMEs.<br>*Note: Roles will change as research is completed.* |
| Lead<br>Collaborate<br>Observe | "Lead" - CalNEXT expects to take on most or all of the work and cost burden.<br>"Collaborate" – CalNEXT is interested in collaborating and co-funding projects.<br>"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.<br>*Note: Priorities will change as research is completed.* |
| High<br>Medium | "High" - CalNEXT SME team has highlighted this technology family as having high impacts within the Technology Category.<br>"Medium" - CalNEXT SME team determined this technology family has moderate overall impacts within the Technology Category. |

| Glossary | Meaning |
| --- | --- |
| Low | “Low” - CalNEXT SME team has highlighted this technology family as having low relative impacts within the Technology Category. |

# 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. The TPMs will drive product ideation and inform project selection. This Final Report covers the revision process for the 2024 Lighting, Plug Loads, and Appliances TPM.

# 2024 TPM Key Changes

Table 1 shows how content from the 2023 TPM technology families appears under new technology family headings in this 2024 revision. Notably, large amounts of 2023 Lighting TPM content have been merged into the 2024 Lighting, Plug Loads & Appliances TPM. The Labs & Hospitals technology family originally under the 2023 Process Loads TPM has been moved into the Medical Equipment technology family as the energy savings typically result from related HVAC, Lighting, Plug Loads, and Appliances savings. Within the original 2023 Plug Loads Appliances TPM, there are also instances where several technology families have been dispersed into various 2024 technology families, as shown below by the arrow pathways.

*Table 1: Technology Priority Mapping*

| 2023 Plug Loads & Appliances TPM Technology Families | 2024 Lighting, Plug Loads & Appliances TPM Technology Families |
|---|---|
| Electric Vehicle Supply Equipment (EVSE) | Electric Vehicle Supply Equipment (EVSE) |
| Decarbonizing Household Appliances | Decarbonizing Household Appliances |
| Household Appliances | |
| Home Entertainment & Office Equipment | Residential and Commercial Electronics and Electrical Appliances |
| Light Duty Battery Chargers | |
| Medical Equipment | Medical Equipment |
| Plug Load Optimization & Management | Advanced Capabilities and Technologies in Lighting and Plug Load Controls & Integration |
| **2023 Process Loads TPM Technology Families** | |
| Labs & Hospitals | |
| **2023 Lighting TPM Technology Families** | |
| Connectivity, Controls, and Integration | |
| Advanced Electric Light Sources | |
| Advanced Approaches to Exterior Lighting | Advanced Approaches to Exterior Lighting |
| Legend: Minor content revision Major | content revision and restructuring |

The Lighting, Plug Loads, and Appliances category has seen revisions aimed to further clarify and expand the program definitions and priorities for prospective participants. Current technology family definitions, opportunities, and barriers were revised where appropriate for every technology family in this TPM. Notable drivers include passage of the Inflation Reduction Act (IRA) of 2022 which continues to provide additional market support 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 shows implications for demand flexibility. These changes were reflected in different ways in the 2023 TPM update.

As for the 2024 TPM update, the CalNEXT Program Team established a robust process for this continuation of the TPM development and revisions. This year, the project team is incorporating a stronger outreach push to ensure feedback, directly targeting these potential Deemed measure stakeholders from CPUC, SDG&E, CalMTA, and CalTF. The project team is made up of representatives from each of the Program Team partners: VEIC, AESC, TRC, UC Davis, and Energy Solutions. The Lighting, Plug Loads, and Appliances Subject Matter Expert (SME) team represents members that collectively support an array of Energy Efficiency (EE) programs using technologies covered by the Lighting, Plug Loads, and Appliances TPM, and these emerging products are then contextualized into the priority maps through a markets and solutions lens. The team met three times between May and June of 2024 to develop the main TPM narratives and will has met one final time in August to finalize this Lighting, Plut Loads, and Appliances TPM.

The SME team worked through a number of visual changes during this revision process which can be seen below in the narratives of the final report. The most notable change is the addition of the Research Initiatives table under each technology family, The table highlights three to five most important research areas within each technology family with a simplified icon view depicting the current state of progress along four key elements leading to technology transfer; the first two elements, Performance Validation and Market Analysis, are technology-driven, and the next two, Measure Development and Program Development, are market-driven. This visual summary represents where the technology family stands in the portfolio and the remaining research needed to help submitters and viewers identify the research projects that have the highest impact in progressing a technology family within the portfolio.

For example, the table in the Electric Vehicle Supply Equipment (EVSE) technology family has an initiative named (see subsequent EVSE section), "evaluation of hardwired power sharing EVSE hardware (smart panel alternative)," identifying the research area that will progress the EVSE technology family within the portfolio. Under this research initiative, research is already in progress to validate the performance of the power sharing technology while its market potential is well characterized. This puts the immediate research needs on measure development and program development leveraging the knowledge on performance validation and market analysis. In other words, this particular row within the EVSE Research Initiative table is signaling to the public that the program is looking for research projects focusing on measure development and program development.

*Table 2: Icons and their meanings*

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

One additional feature specific to this Lighting, Plug Loads, and Appliances TPM is the addition of the Lighting technology family into various areas of this TPM. This addition ensures consistency with the previous Lighting technology family even with the sunsetting of that specific domain. This addition also reduces the overall number of technology families by reorganizing them to bring better balance and clarity to what the program is researching and how it connects throughout the portfolio.

Overall, the changes made to this 2024 TPM focus on increased technology transfer broadly across our portfolio, allowing the CalNEXT team to define new measures of interest and illustrate our efforts to bring them to the portfolio. These changes should put greater focus on shorter-term activities like measure packages to support the expansion of the existing Resource Acquisition programs. Even for longer-term investments, the new visual format will provide more tactical guidance as to what type of research is needed to better advance different technologies to the ultimate goal of portfolio savings.

# Stakeholder Feedback

## TPM Advisory Committee Outreach

The TPM Advisory Committee outreach began in July 2024, when stakeholders' feedback was requested via email, and the inputs were incorporated into the finalized technology family narratives. The TPM Advisory Committee members are listed below in Table 2.

*Table 3: TPM Advisory Committee Outreach*

| Organization |
|---|
| CalMTA |
| CPUC |
| SCE |
| SDG&E |
| NEEA |
| PNNL |

This outreach conducted allowed advisory committee members to provide candid feedback in written comments and suggestions. Received suggestions were reviewed by the TPM coordinator, the 2024 Lighting, Plug Loads, and Appliances SME team, and incorporated into the Revised 2024 Lighting, Plug Loads, and Appliances TPM section below. A detailed table of the changes made can be found in the Advisory Committee Feedback & Resolution Matrix in Table 3 of the Appendix of this report.

## Electric Vehicle Supply Equipment (EVSE)

CalNEXT Role: Lead | CalNEXT Priority: High

### Definition

Electric Vehicle Supply Equipment (EVSE) is defined as the conductors, connectors, related equipment, and control software that deliver energy to an electric vehicle (EV). This technology family has strong overlaps with the Electrical Infrastructure technology family within the Whole Building TPM.

*Note: A number of mobile battery charging applications exist outside of traditional passenger vehicles and are covered in separate technology families within this TPM. These include applications such as e-bikes, motorized wheelchairs, forklifts, and golf carts.*

### Research Initiatives

The Research Initiatives table describes the most important topic areas this technology family should be focused on, and the simplified icons indicate where the topic areas stand along the path of progression to technology transfer. The table is meant to encourage research projects to fill the current gaps and advance the topic areas on the technology transfer path of progression.

| Research Initiative | Performance Validation | Market Analysis | Measure Development | Program Development |
|---|---|---|---|---|
| Evaluation of hardwired power sharing EVSE hardware (smart panel alternative) | Research In Progress | High Understanding | Future Research Need | Future Research Need |
| Evaluation of plug-in circuit splitting devices (smart panel alternative) | Research In Progress | High Understanding | Future Research Need | Future Research Need |
| Power splitting Level 2 EVSE for multifamily | Research In Progress | Research In Progress | Future Research Need | Future Research Need |
| Locally responsive solar AC EVSE (demand induction) | Future Research Need | Immediate Needs | Future Research Need | Future Research Need |

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

### Opportunities

Electrified transportation is expected to be the major driver of load growth within California, and EVSE is a key enabling technology to unlock decarbonization of this sector. California Energy Commission's (CEC's) latest Integrated Energy Policy Report (IEPR) projects that by 2030 electrical consumption from transportation will make up more than 20 Terawatt hours (TWh) or 6.7% of all electrical consumption. Given the rapid deployment in progress, it is crucial for state energy goals to ensure that EVSE is functioning with energy efficiency, load management, and demand flexibility in mind. To that end, products must limit standby energy usage and ensure that demand flexibility is incorporated into EVSE. Additionally, products should be available that support installation flexibility in regard to panel and service capacity. While there currently are no energy efficiency standards for EVSE, ENERGY STAR® has been taking a lead role in developing voluntary specifications for the critical features that are immediately needed such as idle power mode limits, criteria for grid-connected functionality, and communication with the EV itself.

### Barriers

While EVSEs are relatively new, their technical performance is well understood, especially for Level 1 and Level 2 equipment. Market understanding is growing, although as EVs reach mass market end-users, there is a need for both broad and specialized consumer education to help end-users navigate the complexities of: (1) installing efficient EVSE, (2) limiting the need for expensive panel upgrades, and (3) enrolling and educating users in load management and flexible demand programs. The current California state energy efficiency policy does not allow measures to claim benefits related to load shifting, presenting a challenge for EVSE to be incentivized for their full benefits in EE programs. Prospective CalNEXT research should look at innovative program designs to address these multi-pronged barriers. The multi-family housing market has proven to be a hard-to-reach market and warrants further investigation to determine which are the major barriers. Regarding publicly available chargers, charging failures must be reduced to ensure a convenient driving experience for the end user.

### CalNEXT Related Projects

- ET22SWE0026: Advanced Multifamily Electric Vehicle Load Management System
- ET24SWE0025: 2024 Performance Evaluation of DC EVSE

## Decarbonizing Household Appliances

CalNEXT Role: Lead | CalNEXT Priority: High

### Definition

This technology family focuses on the replacement of gas appliances used in housekeeping tasks (white goods), such as cooking and clothes drying, with high-efficiency electric ones. Products include cooking ranges, cooktops, ovens, clothes dryers, and combination washer-dryers.

*Note: This technology family has strong overlaps with the Electrical Infrastructure technology family within the Whole Buildings TPM.*

### Research Initiatives

| Research Initiative | Performance Validation | Market Analysis | Measure Development | Program Development |
|---|---|---|---|---|
| Induction Cooking (battery & 120V) | Research In Progress | Immediate Needs | Future Research Need | Future Research Need |
| Combination Washer / HP Dryer (120V options) | Immediate Needs | Future Research Need | Research In Progress | Future Research Need |
| Commercial HP Dryers in Multifamily | Immediate Needs | Future Research Need | Future Research Need | Future Research Need |
| AI / Smart Laundry | Immediate Needs | High Understanding | Future Research Need | Future Research Need |
| Residential HP Dryers / Hybrid | Immediate Needs | High Understanding | High Understanding | High Understanding |

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

### Opportunities

In California, most households use gas-powered white goods for cooking and clothes drying, creating a huge opportunity for electrification.[1]

[1] Percentage of white goods that are gas-powered for different end uses based on the 2019 California Statewide Residential Appliance Saturation Study (RASS).

A report by San Francisco Bay Area Planning and Urban Research Association (SPUR) determined that, “Gas appliances in California homes and buildings generate four times as much lung-damaging nitrogen oxide (NOx) pollution as the state’s gas power plants, and roughly two thirds as much NOx as all of the state’s passenger cars.”[2] While the California Air Resources Board (CARB) has moved to ban the sale of new gas space and water heaters by 2030, gas-powered white goods are not yet being phased out on a large scale. A recent study on gas stoves found that even when they are off, they are emitting dangerous air pollutants.[3] There is an opportunity to accelerate the decarbonization of household appliances and prime the market for future regulation. Aside from the decarbonization benefits from fuel switching, both dryers and cooktops have significant energy savings opportunities. ENERGY STAR® estimates that conventional gas cooktops are approximately 32% efficient compared to 75-80% for electric resistance and 85% for induction.[4]

Prospective research should focus on behavioral interventions and technologies to break down fuel-switching barriers. These include the marketing challenges for electric cooktops, avoiding the need for electrical upgrades through the deployment of 120V electrical home appliances (e.g. clothes dryer, combination washer/dryers, induction cooktop/ranges, etc.), and other solutions to reduce barriers to electrification. Research should also focus on the unique challenges and opportunities in low income and multifamily buildings, where commercial laundry is used; apartments often have limited electrical capacity, and high-end electrical appliances, such as induction cooktops and heat pump dryers, may not be the most suitable option.

Testing and survey opportunities exist in the heat pump and hybrid heat pump dryer area as well as combination all-in-one washer-dryers to help address questions raised in ENERGY STAR Clothes Dryer Version 2.0 Specification Discussion Guide March 2024.[5]

### Barriers

Despite the status as a mature product area, knowledge of technical performance lags other large household appliances. As of June 2024, neither standalone ovens nor commercial clothes dryers

*Table 4: Percent of White Good Products That Are Gas-Powered*

| White Good Product | Percent Gas-Powered in California |
|---|---|
| Residential Clothes Dryers | 58% |
| Commercial Clothes Dryers | 82% |
| Cooktop | 54% |

[2] https://www.spur.org/publications/policy-brief/2022-09-20/gas-appliances-and-smog-californias-hidden-air-pollution

[3] https://pubs.acs.org/doi/10.1021/acs.est.2c02581

[4] https://www.energystar.gov/about/2021_residential_induction_cooking_tops

[5] https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%202.0%20Clothes%20Dryer%20Discussion%20Guide.pdf

have national standards nor approved test procedures. ENERGY STAR® established their first voluntary standards for electric cooktops and DOE is in the process of setting performance standards for electric and gas cooktops. In the Dryer Version 2.0 Discussion Guide, ENERGY STAR® requested data to assess the opportunity for developing a commercial clothes dryer specification and test procedure.

Despite the large savings opportunities, significant deployment barriers exist from basic consumer understanding of induction cooking as well as performance concerns around low-voltage combination washer / heat pump dryer models. Existing electric panel constraints are also a potentially large barrier where these products compete with other electrification opportunities. This is particularly stark in low-income and multifamily buildings. For example, 120V cooktops and ranges with an integrated battery currently in development are prohibitively expensive, whereas those without an integrated battery appear to lack sufficient power to provide cooking experiences comparable to 240V or gas products. California currently has measure packages for electric ovens and cooktops; however, some of them suffer from negative Total System Benefit (TSB) and low Total Resource Cost (TRC) values. Given the significant barriers, CalNEXT research should focus on additional program interventions that can help consumers effectively navigate decarbonization efforts.

### CalNEXT Related Projects

- ET22SWE0022 - Residential Housing Characteristics Study
- ET22SWE0057 - Market Study of Household Electric Infrastructure Upgrade Alternatives for Electrification
- ET23SWE0064 - 120V Induction Stoves with Battery Back-Up
- ET24SWE0011 - DAC HTR Statewide SF Housing Characteristics Study
- ET24SWE0023 - Field Demonstration of Electric Clothes Dryer Controller

## Residential and Commercial Electronics and Electrical Appliances

CalNEXT Role: Medium | CalNEXT Priority: Collaborate

### Definition

The Residential and Commercial Electronics and Electrical Appliances technology family is defined as electrically powered appliances and electronics found within commercial and residential environments, including devices that can be operated untethered via battery.

*Note: Products that commonly use gas such as clothes dryers, ovens, cooktops, and ranges are covered in the Decarbonizing Household Appliances technology family in this TPM to focus on the unique challenges for decarbonization.*

*Note: This technology family excludes medical mobility devices which are covered under the Medical Equipment technology family within this TPM.*

### Research Initiatives

| Research Initiative | Performance Validation | Market Analysis | Measure Development | Program Development |
|---|---|---|---|---|
| Inactive/Low Power Modes | 🎯 | ⏳ | ⏳ | 👆 |
| User Behavior/Interaction | 👆 | ⏳ | 👆 | 👆 |
| Battery Integration | ⚠ | ⚠ | 👆 | 👆 |

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

### Opportunities

A number of products in this category are generally technologically mature, energy efficiency for many of these products has been addressed by appliance standards, voluntary certification programs, and industry voluntary agreements, many implemented at a national level. Improvements in energy efficiency may be limited to either new technological innovations such as advances in televisions and monitors, or energy savings from inactive/low power modes, which have become more significant as many of these devices are never fully off or unplugged. Emerging technology (ET) projects on inactive power can leverage and contribute data to the CEC's ongoing proceedings on Low Power Modes.

Outside of products with existing standards, research to develop test procedures or demonstrate novel technologies in support of deployment of new standards remains an opportunity for energy savings impacts.

Battery-integrated devices have unique opportunities for demand flexibility by manipulation of charging times/usage into periods of lower grid utilization, price, and/or source energy GHG emissions. As battery technologies evolve, so will charging profiles, and new research will be needed to ensure that the chargers are maintaining optimal battery performance while in low power modes once battery charging is complete. Across all battery sizes, national efficiency standards for battery chargers have already been codified at the national level covering active mode and standby mode for all non-automotive applications and DOE has an active rulemaking to revise these standards. Meanwhile, the State of California is beginning to set flexible demand appliance standards (FDAS) under SB-49 (Skinner), which may have significant opportunities for certain applications of large battery chargers.

### Barriers

Technical understanding of products in this family is generally well known, and while market knowledge around consumer purchasing behavior is known, the actual use of these products is not well understood. For higher power density products, such as major home appliances, utilities codes & standards teams have been active in regulatory rulemakings to push higher efficiency standards; however, for lower power density devices, such as office equipment, energy efficiency does not drive purchasing behavior, and regulatory rulemaking largely ignores these devices.

For a number of products, renters are in a unique split-incentive situation where the building owner is likely the decision maker in determining whether to install, repair, or replace a dishwasher/refrigerator/etc or not, but it's the renter who would realize the benefits of lower energy/water use (with proper usage) and time saved.

### CalNEXT Related Projects

- ET23SWE0044 – 2023 Benchtop Efficiency Measurements for Residential Mesh Networking Equipment

## Medical Equipment

CalNEXT Role: Lead | CalNEXT Priority: Medium

### Definition

This category includes the energy consuming medical equipment in hospitals, labs and home health care environments.

### Research Initiatives

| Research Initiative | Performance Validation | Market Analysis | Measure Development | Program Development |
|---|---|---|---|---|
| Energy Consumption and Load Profiles | ⚠ | ⚠ | Future Research Need | ⌛ |
| Power Management Strategies | ⚠ | ⌛ | Future Research Need | ⚠ |
| Standard Development | ⚠ | ⚠ | Future Research Need | Future Research Need |

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

### Opportunities

Hospital/Lab: Labs and hospitals are one of the highest energy consuming sectors due to their energy-intensive activities and stringent health and safety requirements. A 2015 market assessment conducted by the California IOUs estimated that just 12 pieces of lab/hospital equipment were likely responsible for between 0.8 and 3.2 terawatt hours (TWh)/year. Despite this large opportunity, only lab grade freezers (LGF), refrigerators (LGR), and ultra-low temperatures (ULTs) had significant development (all three now have ENERGY STAR® specifications). In 2023, the EPA has begun looking more into this sector as ENERGY STAR® looks to develop product specifications for Magnetic Resonance Imaging (MRI).

The wide variety of lab and hospital equipment types are not designed with energy saving features in mind, leading to wasted energy when not in use. Because of this, there may be opportunities in managing user behavior to increase efficiency, or additional engagement with OEMs to make EE a priority in product development through voluntary programs like ENERGY STAR®. Meanwhile, the overall scope of savings opportunities has continued to grow as biotech and pharmaceutical laboratories have seen significant growth since the COVID-19 pandemic.

In a 2015 market assessment, end users reporting it was either considered “important” or “very important” to have equipment that was energy or water efficient 70 percent of the time. This interest has only grown as a number of large companies and institutions have committed to emissions reductions goals, leaving opportunities for utility EE programs, provided they are not found to be industry standard practice.

Residential/Assisted Living: Medical devices in the U.S. are a growing fixture in households. The U.S. Center for Disease Control (CDC) estimates that there are 61 million adults with disabilities and 13.7 percent with a disability that impacts walking and climbing stairs. In addition, a 2021 study by Lawrence Berkely National Lab (LBNL) estimates there are 2.74 million oxygen concentrators and 2.2 million CPAP (continuous positive airway pressure) ventilators. Despite the prevalence of these products, data on energy usage of medical equipment is sparse, so overall energy savings opportunities remain unclear. Many of these devices are used continuously (oxygen concentrators) while others have the potential to have high parasitic loads (such as vertical lifts), so efficiency improvements are likely to save significant amounts of energy (and be cost-effective). The incorporation of low power or sleep modes, where available, may also be beneficial to reducing energy usage. Demand flexibility, while technically feasible, is unlikely to have significant uptake due to concerns for safety and health impacts.

As the population ages more medical resources will be needed to support people with disabilities and chronic diseases[6]. Paired with rising costs of care, home based medical equipment is likely to proliferate in the market.

### Barriers

Hospital/Lab: With the few exceptions mentioned above, there is limited technical understanding about many of the types of more energy-intensive equipment of interest. The primary barrier for much of this equipment is the diversity of equipment types and uses. This makes baseline studies difficult, as different labs and hospitals may operate their equipment differently. As noted above, there are also no national standards (mandatory or voluntary) for any lab equipment other than ULTs and fume hoods.

This technology area also faces challenges in the device area of use. Working in hospitals presents unique challenges, due to the personnel needed for decision making and concerns about patient safety.

Residential/Assisted Living: Significant barriers exist for this technology family. Technical performance is not well understood as there is limited data on actual energy use or load shape of this equipment. Despite the maturity of this sector, these products have been historically examined from a health outcomes perspective and exempted from appliance standards. Efficiency programs do not exist for these devices as market signals are misaligned. The equipment purchasers are reimbursed by health insurance for the capital expense and end-users pay a reduced electricity rate under the utility-run medical baseline program.

Prospective ET studies should address (1) fundamental lack of knowledge in the technical performance in this sector followed by (2) research to improve viability of different market interventions (e.g., federal standards, state standards, voluntary standards, adjustments to the medical baseline program or other programs).

## CalNEXT Related Projects

- ET24SWE0008 - Medical Device Market Characterization Study

## Advanced Capabilities and Technologies in Lighting and Plug Load Controls & Integration

CalNEXT Role: Collaborate | CalNEXT Priority: Medium

### Definition

Components, platforms, control algorithms, advanced diagnostics and analytics, and foundational communications protocols with the ability to communicate, coordinate, and reduce energy use of electric loads in a residential or commercial building. Devices and systems in this cross-cutting technology family are expected to enable lighting and plug load appliances to operate at lower power modes based on either automated control or behavior modifying features.

This technology family can include control of additional building systems and appliances, enhance occupant comfort and wellness, or provide environmental data to building systems in other technology families, including Envelopes, Integrated Systems, and Scalable HVAC Controls.

### Research Initiatives

| Research Initiative | Performance Validation | Market Analysis | Measure Development | Program Development |
|---|---|---|---|---|
| Coordinated load management of lighting and plug loads | Research In Progress | Immediate Needs | Immediate Needs | Research In Progress |
| Open-source scalability of networked controls for lighting and plug loads | Research In Progress | Immediate Needs | Immediate Needs | Research In Progress |
| Lighting and plug load appliance operation when controlled by integrated control layers | Research In Progress | Immediate Needs | Immediate Needs | Research In Progress |

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

### Opportunities

Emerging technologies in this technology family have the potential to result in significant energy savings and decarbonization benefits. Managing lighting and plug load operations to communicate across devices and minimizing consumption when not in use may result in significant energy savings and have broad decarbonization benefits, as fossil-fuel power has contributed to just over 40% of California's total power mix in 2021.

Prospective research should focus on: (1) deepening understanding of the energy savings potential associated with integrated lighting and plug load control; (2) demonstrating energy savings potential for learning behavior algorithms which can manage usage based on learned occupant behavior and automatic & dynamic load detection (ADLD) which identifies devices as they are plugged into a building(3) assessing the market to understand scope, availability, and cost for technologies as well as the viability to embed intelligence into the products themselves; (4) understanding consumer appetite to adopt and interact with these types of technologies, with a particular focus on the customer experience, and potential data privacy concerns. (5) Assessing the potential of available open-source communication protocols to enable sustainable and scalable control layers across multiple building systems.

Any findings from the focused areas above should be communicated to organizations developing communications standards such as CSA.

### Barriers

Significant barriers must be overcome to actualize and scale this technology family to the broader market. Technical demonstrations have been done to prove viability of certain product types, but broader opportunity will come if standardized communication protocols across different product types (such as the matter protocol published by CSA-IOT) can be developed to allow manufacturers to embed communications and controls intelligence into their lighting and plug load products. Until these technical and market challenges are addressed, it is unlikely traditional utility programs will be able to identify cost-effective savings outside of a couple specialized products.

### CalNEXT Related Projects

- ET22SWE004 – 2022 Lab Evaluation of Integrated Controls for Commercial Buildings

## Advanced Approaches to Exterior Lighting

CalNEXT Role: Lead | CalNEXT Priority: High

### Definition

This technology family encompasses products, design strategies, and components that improve the efficiency, adaptability, and resiliency of exterior lighting in commercial and public sectors while also considering best practices for the nighttime lighting environment (human health, visual comfort, public safety, and environmental impacts). This category has the opportunity to produce a large change both visually and in terms of energy consumption if changes are made in design approach and technology deployment.

### Research Initiatives

| Research Initiative | Performance Validation | Market Analysis | Measure Development | Program Development |
|---|---|---|---|---|
| DERs-integrated (hybrid solar outdoor lighting and controls) | | | | |
| Adaptive outdoor lighting design standards | | | | |

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

### Opportunities

There are significant energy savings and demand flexibility benefits if the entire exterior lighting stock is transformed by this technology family. Streetlights managed by the public sector stakeholders and area lighting managed by commercial sector stakeholders are the primary focus. With the peak demand on the California grid moving toward the early evening hours, this technology family could shift a significant portion of exterior lighting demand while also delivering meaningful energy savings. As increased daytime solar energy is produced, reducing nighttime loads will reduce the size of energy storage systems to help decarbonize the power generation in the state.

As utility tariffs continue to evolve, advanced network controls and DERs integration for exterior lighting will become more cost-effective, and increased adoption should drive additional innovation. DERs-integrated exterior lighting also has the potential to serve as part of the essential infrastructure in locations with a high likelihood of power outage, such as areas impacted by the Public Safety Power Shutoff events.

Additional opportunity lies in developing motion-sensing technologies that enable deep savings for installations where the dimensions or other site-specific conditions, such as vegetation or weather, prohibit the deployment of existing motion sensing technologies. Projects focused on refining the definition of idealized visual environments through human factors studies can further reduce energy usage. Advanced exterior lighting, particularly roadway or parking lot lighting, also has the potential to incorporate electric vehicle (EV) chargers into the existing infrastructure for non-energy benefits (equity and low-income sector), plus other municipal support systems like transportation communications and other distributed systems.

Research should focus on the following areas:

- Develop a standardized approach to incorporate exterior lighting as grid dispatchable and controllable loads and connecting to the utility's Distributed Energy Resource Management Systems (DERMS).
- Quantify the total benefits of DERs-integrated exterior lighting and controls in microgrid use cases, especially in areas prone to power outage (e.g. due to Public Safety Power Shutoff) and clarify measure design to account for potential interaction with California self-generation policies.
- Increase and demonstrate the performance reliability of motion-sensing technologies at a wider range of mounting heights and terrain and weather conditions.
- Conduct market research and lifecycle study to further inform the determination of industry standard practice and claimable program savings.
- Investigate the development of an adaptive lighting standards design philosophy to develop aggressive lighting reduction profiles for community deployment.
- Conduct market research into outdoor lighting design standards for the municipalities in the state and determine if local standards require revision to avoid large-scale over lighting due to old lighting conventions that have not been revisited with the recent advancements in lighting technology and the industry's understanding of vision and safety.

### Barriers

Exterior lighting consists of a wide array of applications (roadway, hardscape/area, façade, landscaping, and more), each of which may have more than one accepted design practice that depends on site-specific conditions. Because of this, the performance of advanced exterior lighting technology is understood for some of the example technologies for a range of limited applications but never broadly across the entire breadth of possible deployments. The diversity and scale of exterior lighting applications is a significant barrier to justifying programs for technologies covered under this family. Workforce training related to installation and commissioning and adoption/acceptance by operations and maintenance staff remains a significant barrier to the adoption and deployment of advanced approaches to exterior lighting. Also, the conventional design practice of maintaining nighttime visibility for public safety significantly limits the wide adoption of occupant-based control technology.

## CalNEXT Related Projects

- Projects in development at this time

# Discussion

Following the submittal of the 2024 Lighting, Plug Loads and Appliances TPM, the Program Team will do the following:

- Update CalNEXT website with new 2024 Lighting, Plug Loads and Appliances TPM and this Final Report.
- Launch email announcement through email outreach.
- Develop and submit the Distribution Report.