2022 Lighting Technology Priority Map

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Abbreviations, Acronyms, and Glossary of Terms

Acronym	Meaning
AC	Alternating Current
BESS	Battery-Energy Storage System
CPUC	California Public Utilities Commission
DC	Direct Current
DR	Demand Response
EE	Energy Efficiency
EMS	Energy Management Systems
GHG	Greenhouse Gas
HVAC	Heating Ventilation and Air Conditioning
HVAC/D	Space Conditioning and Dehumidification
IEPR	Integrated Energy Policy Report
IOU	Investor Owned Utility
LCD	Liquid-Crystal Display
LED	Light Emitting Diode
LCF	Lighting Control Films
NEEA	Northwest Energy Efficiency Alliance
PoE	Power-over-Ethernet
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SME	Subject Matter Expert
TLED	Tubular Lighting Emitting Diode
TPM	Technology Priority Map

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 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 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 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, 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 Lighting TPM

Lighting Technology Category Overview

This category covers an end-use that was a dominant player in efficiency programs 10 to 20 years ago, but today receives less focus due to stricter codes, a lack of decarbonization potential, and poor prospects for demand flexibility due to the inability to store illumination.

Code readiness efforts are one aspect of lighting efficiency that has been receiving attention in recent years. Control strategies for commercial buildings and signage code requirements, which have received initial investigation for code readiness in recent years, may be candidates for study under future pilots.

Unique Opportunities and Barriers

Lighting control systems have, thanks to rapidly dropping costs in sensor and network communication components, become the most granular, and data-rich sources of information about building conditions. Integration with other building systems creates an opportunity for energy savings and demand flexibility in other building systems and end-uses.

The interconnectedness and variable settings of lighting control systems make for complexity during setup and installation and bring the potential for occupant dissatisfaction. Education of and communication among involved parties from specifier to contractor to customer can avoid poorly executed controls and integration.

Highlighted Priority Areas

Technology Category	Technology Family	Technology Subgroups	Definition	ETP Role	ETP Priority
Lighting	**Connectivity, Controls, and Integration**	Lighting control systems, lighting energy management systems (EMS); home automation; use of integrated sensor information to enhance building EMS performance and for other energy and non-energy uses; daylighting controls that coordinate with fenestration design and other building systems.	Sensors, communication systems, and control algorithms that reduce energy consumption in lighting and other building systems, provide data for other purposes, or enhance occupant comfort and wellness.	**1-Lead**	1-High

Connectivity, Controls, and Integration

(ETP Role: Lead, ETP Priority: High)

Key Factors

Energy Savings Potential: Medium
Decarbonization Potential: Not Applicable
Demand Flexibility Potential: High
Other Emissions Impacts Potential: Low

Knowledge Index

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

Subgroups (example technologies)

Lighting control systems, lighting energy management systems (EMS); home automation; use of integrated sensor information to enhance building EMS performance and for other energy and non-energy uses; daylighting controls that coordinate with fenestration design and other building systems.

Definition

Sensors, communication systems, and control algorithms that reduce energy consumption in lighting and other building systems, provide data for other purposes, or enhance occupant comfort and wellness.

Note: Depending on the project scope, prospective projects in the Connectivity, Controls, and Integrations technology family may fit better under the Envelopes or Integrated Systems technology families (Whole Building TPM) or the Scalable Heating Ventilation and Air Conditioning (HVAC) Controls technology family (HVAC TPM).

Opportunities

Lighting controls and inter-system integration can reduce energy consumption of both lighting and other end-uses all while incorporating increasingly important demand flexibility. Energy benefits from controls may be increased by simplifying on-site commissioning and enabling controls features with more aggressive settings by default. Interconnection with HVAC controls can enable reduction of both HVAC and lighting energy consumption during unoccupied and partially occupied periods. Greater sensitivity and more sensor nodes can allow more sophisticated controls programming and reduce uncertainty in the commissioning process, saving time and lowering energy consumption.

Introducing daylight in buildings via advanced daylighting controls can provide both health benefits for building occupants and energy savings, being careful to consider both lighting and HVAC energy.

Lighting controls in residential applications currently provide mostly amenity; adding a focus on energy could promote higher energy savings.

Barriers

Lighting control strategies are well-understood at a high level, but the complexity of existing systems poses a problem for field implementation. Contractors may not be fully trained on the hardware, and most will not know the proper programming and start-up process for advanced controls. Systems integrated with other building end-uses have increased complexity, adding cost and coordination barriers to projects.

Contractor and customer education is important to address complexity barriers and avoid poor occupant satisfaction. Specifier and architect education can avoid poorly executed controls integration, often stemming from unclear intent, vague specification, and inefficient communication among the multidisciplinary actors involved. Knowledge sharing from successful projects can address resistance to complex controls from facility managers.

The lack of a clear line between code requirements for controls and incentive eligibility also creates a barrier to adoption of advanced controls through program intervention.

Horticultural Lighting

(ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

Energy Savings Potential: Medium
Decarbonization Potential: Not Applicable
Demand Flexibility Potential: Medium
Other Emissions Impacts Potential: Medium

Knowledge Index

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

Subgroups

High-efficacy horticultural luminaire and lamp; horticultural lighting controls; horticultural lighting system design.

Definition

Systems producing light and non-visible electromagnetic radiation for plant growth and horticultural production in indoor facilities or for supplemental lighting in greenhouses, including specific design strategies, lighting technologies and control systems for optimizing productivity, energy efficiency, and resource conservation.

Note: Non-lighting technologies intended for horticulture such as HVAC/D, envelopes, or irrigation controls are handled under the Indoor Agriculture technology family in the Process Loads TPM.

Opportunities

Opportunities include increasing the efficacy and productivity of horticulture through optimization of system designs, controls, light source innovations and reduction of negative impacts from light pollution. Innovations in sensor and control strategies can maximize energy performance and demand flexibility by leveraging spectral tunability and harvesting daylight. Implementing scheduling, utilizing direct current (DC) lighting, and powering the lighting system from renewable energy or embedded electrical energy storage can further increase savings and demand flexibility. Efficient and productive indoor growing enabled by horticultural lighting could also have both direct and indirect greenhouse gas (GHG) benefits over the open-field growing practices. Another non-energy benefit includes the potential of reducing light pollution when lighting is deployed with thermal blocking curtains in greenhouses.

Barriers

Rapid expansion of indoor agriculture has resulted in inefficient system designs, lack of targeted efficiency programs, and need for systems with higher efficacy and greater power quality.

Technical barriers are largely related to system design. There is a lack of clarity for designers and trusted tools for optimizing productivity and efficacy of horticultural lighting systems as well as limited understanding of the interactive impacts of schedule, space conditioning and dehumidification (HVAC/D), and water level.

Market barriers include the lack of confidence due to uncertain cost-effectiveness, limited in-field evaluation of innovative lighting technologies and controls, and lack of best practice lighting designs from experienced practitioners, considering both performance and cost.

Efficiency programs have yet to identify high-priority program opportunities for targeted horticulture applications and sectors with reliable, low-carbon intensity, cost-effective solutions. There is also a lack of consistency among code requirements related to horticultural lighting and systems in different applications and building types.

DC Lighting

(ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

Energy Savings Potential: Medium
Decarbonization Potential: Not Applicable
Demand Flexibility Potential: Medium
Other Emissions Impacts Potential: Low

Knowledge Index

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

Subgroups

Power-over-ethernet (PoE) lighting systems; low-voltage DC lighting (<60VDC); higher-voltage DC lighting; off-grid lighting.

Definition

Any lighting appliance that operates on a direct current (DC) power distribution network.

Opportunities

DC lighting has the potential for improved electrical efficiency, primarily through the consolidation of AC/DC conversion, with proper design and deployment. DC lighting may also support easier battery-energy storage system (BESS) integration, and as a result, greater load shift flexibility.

PoE lighting offers data communication functionality that may support easier building system integration and cybersecurity management.

Off-grid lighting can result in energy savings when replacing mains-powered alternatives while also avoiding embodied carbon attributed to the traditional infrastructure.

Barriers

Technical barriers to DC lighting adoption include lack of interoperability between manufacturers, lack of standard design practices addressing specific DC requirements (e.g., system architecture, switch power supply sizing), and unproven and unquantified system-level efficiency improvements over traditional AC lighting systems.

Market actors lack understanding of the use cases and the associated value propositions of DC lighting, and many contractors lack the familiarity to confidently and correctly install them, and the labor needs for low voltage may not fit their electrician-focused workforce. Confusion regarding appliance repair responsibility within the facility management, cyber-security concerns, and atypical user interfaces are also major market barriers.

DC lighting currently has no significant incremental energy savings or other energy benefits over alternating current (AC) lighting for efficiency programs to leverage for accelerated and large-scale deployment.

Advanced Electric Light Sources

(ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

Energy Savings Potential: Medium
Decarbonization Potential: Not Applicable
Demand Flexibility Potential: Low
Other Emissions Impacts Potential: Low

Knowledge Index

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

Subgroups

Network-connected lamps, retrofit kits, and luminaires; lamps, tubular lighting emitting diodes (TLEDs), retrofit kits, and luminaires with embedded sensors and controls; spectrally tunable light sources; disinfecting luminaires.

Definition

Advanced Electric Light Sources have a primary function of providing high-efficiency illumination and offer additional functionality. The additional capabilities may include network communication, sensors, or built-in intelligence for enhancing the effectiveness and efficiency of light delivery. Other secondary capabilities might include disinfection, light benefiting human health, and IoT and networking functions.

Opportunities

Advanced Electric Light Sources have the potential to continue to drive energy savings beyond LED conversions through built-in sensors and controls. Energy savings are also possible from using light sources for other services like improving circadian rhythm or disinfection rather than deploying separate systems. Light sources with built-in connectivity and intelligence have potential to enable demand flexibility, though the greatest flexible loads may be other end-uses using lighting sensor data rather than illumination itself.

Barriers

Higher cost and unproven energy and non-energy benefits are generally the key market barriers of this technology family. Cost and simplicity are particularly important factors for increasing the penetration of retrofit light sources with onboard sensing and connectivity capabilities that can reduce energy consumption from illumination.

For Advanced Electric Light Sources that can deliver a secondary service, the technical performance of such secondary services is not well-quantified as the supporting science may not be fully developed. Non-visual lighting simulation tools and metrics are currently under development, but validation research is required. Current programs for this technology family are either nonexistent or not able to achieve effective deployment at scale.

Signage

(ETP Role: Collaborate, ETP Priority: Low)

Key Factors

Energy Savings Potential: Medium
Decarbonization Potential: Not Applicable
Demand Flexibility Potential: Low
Other Emissions Impacts Potential: Low

Knowledge Index

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

Subgroups

Light emitting diode (LED) billboards, channel letter signs, back-lit graphics; Light Control Films (LCF); Liquid Crystal Displays (LCDs), and other display signage; LED replacements for neon signs; signage controls.

Definition

Illumination for the display of visual information in interior or exterior environments.

Opportunities

Progress in illumination technologies offers the opportunity for more energy efficient, durable, and long-lasting signage lighting. Higher energy savings and demand flexibility could be achieved through signage controls. Newer technologies offer better lighting quality and the potential to reduce light pollution compared to incumbent technologies.

Barriers

California code requirements for indoor and outdoor signage are based on older technologies such as metal halide and fluorescents light sources. Recent code update proposals have faltered as industry adoption of LED signage is above code baselines, casting doubt on the benefits of stricter code.

ENERGY STAR currently has a Signage Display category, but it does not encompass all common types of signage, so there is a need to ensure product efficacy and quality. No recent utility program is specifically targeted to signage lighting and controls.