2022 Plug Loads & Appliances Technology Priority Map

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Disclaimer

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Abbreviations, Acronyms, and Glossary of Terms

Acronym	Meaning
AC	Alternating Current
ACEEE	American Council for an Energy-Efficient Economy
ADLD	Automatic and Dynamic Load Detection
CARB	California Air Resources Board
CEC	California Energy Commission
CPUC	California Public Utilities Commission
CCD	Consumer Clothes Dryer
CDC	Center for Disease Control
CPAP	Continuous Positive Airway Pressure
DC	Direct Current
DOE	Department of Energy
EE	Energy Efficiency
EPIC	Electric Program Investment Charge (CEC program)
ESA	Energy Savings Assistance
ET	Emerging Technology
ETCC	Emerging Technology Coordinating Council
eTRM	Electronic Technical Reference Manual
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FDAS	Flexible Demand Appliance Standards
GHG	Greenhouse Gas
IEPR	Integrated Energy Policy Report
IOU	Investor-Owned Utility
LBNL	Lawrence Berkely National Lab

L1	Level 1 (EV Charging)
L2	Level 2 (EV Charging)
NEEA	Northwest Energy Efficiency Alliance
NEB	Non-Energy Benefits
NREL	National Renewable Energy Lab
PG&E	Pacific Gas and Electric
PNNL	Pacific Northwest National Lab
PPLs	Plug and Process Loads
RASS	Residential Appliance Saturation Study
SB-49	California Senate Bill 49 (2019-2020): flexible appliance standards
SCE	Southern California Edison
SME	Subject Matter Expert
TPM	Technology Priority Map
TSB	Total System Benefits
TWh	Terawatt Hour
U.S.	United States

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 Plug Loads and Appliances TPM

Plug Loads Category Overview

Plug Loads and Appliances is a broad category centered on consumer or light-commercial appliances and other miscellaneous plug loads which includes the Electric Vehicle Supply Equipment (EVSE), common household appliances, medical equipment, and light-duty battery-powered equipment.

Unique Opportunities and Barriers

EVSEs continue to be a focus of the emerging technology (ET) program due to the enormity of expected load growth in the coming years. As EVSEs have matured, CalNEXT is now focused on how to best limit idling power use of these devices, how to best remove electrical infrastructure barriers, and how to leverage technology and/or program design to educate, navigate, and funnel end-users into demand response programs. As decarbonization has taken a more prominent role, CalNEXT is interested in how to effectively deploy high-efficiency electric cooktops and high-efficiency electric clothes dryers in a market that is dominated by natural gas cooktops and clothes dryers.

Highlighted Priority Areas

Technology Family	Technology Subgroups	Definition	ETP Role	ETP Priority
Decarbonizing Household Appliances	Heat pump clothes dryers (residential), induction cooktops & ranges (residential), all-electric ovens & ranges (residential), residential kitchen hoods, and commercial clothes dryers.	This technology family focuses on decarbonization of large gas-powered appliances used in cooking and other housekeeping tasks such as cooking ranges, dryers, and ovens, that are capable of functioning with different fuel sources (natural gas, electric, or propane).	**1-Lead**	1-High
Electric Vehicle Supply Equipment (EVSE)	AC Level 1 chargers, AC Level 2 chargers, DC chargers, bi-directional chargers (AC or DC), Local Load Management technologies, chargers with integral communication functions, and charging connector standardization.	Electric Vehicle Supply Equipment (EVSE) is defined as the conductors, connectors, related equipment, and control software that delivers energy to an electric vehicle (EV). *Note: A number of mobile battery charging applications exist outside of traditional passenger vehicles and are covered in separate technology families within the plug loads TPM and process loads TPM. These include applications such as e-bikes, motorized wheelchairs, forklifts, and golf carts.*	**1-Lead**	1-High

Decarbonizing Household Appliances

(ETP Role: Lead, ETP Priority: High)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Heat pump clothes dryers (residential); induction cooktops & ranges (residential); all-electric ovens & ranges (residential); residential kitchen hoods; and commercial clothes dryers (CCDs).

Definition

This technology family focuses on decarbonization of large gas-powered appliances used in cooking and other housekeeping tasks, such as ranges, dryers, and ovens, that are capable of functioning with different fuel sources (natural gas, electric, or propane).

Opportunities

In California, the majority of homes have some gas appliances, creating a huge opportunity for electrification with additional non-energy benefits (NEBs) from improved indoor air quality and increased safety. The 2019 California Statewide RASS indicated that 58% of clothes dryers were gas-powered (commercial dryer gas usage is even higher at approximately 82%). The RASS survey also indicated that 54% of households have a gas cooktop and 55% have a gas oven. Aside from the decarbonization benefits from fuel substitution, both dryers and cooktops have significant energy savings opportunities. ENERGY STAR estimates that conventional gas cooktops are approximately 32% efficient, compared to induction cooking which is around 85% efficient. In the residential clothes dryer market, heat pump dryers continue to emerge as a high efficiency alternative to traditional electric dryers. Meanwhile, CCDs lag their residential counterparts as previous analysis by the CA utilities found 20% to 50% savings opportunities using readily available technologies but there currently is not a standard or test procedure. Additionally, CCDs are disproportionately used by renters and other low-income households which total about 20% of all households without access to in-unit laundry.

Prospective research should continue to validate heat pump dryers as a mass-market alternative and understand if concerns around dryer cycle time or drying quality will persist as the technology develops in the residential market. Other prospective research should focus on technologies to break down fuel-substitution barriers such as load management solutions or deployment of 110V clothes dryer products to defer expensive panel upgrades. CCDs research should continue to work toward establishment of foundational test procedures and ratings.

Barriers

Despite the status as a mature product area, knowledge of technical performance lags other large household appliances. As of September 2022, neither cooktops, ovens, nor CCDs have national efficiency standards, although ENERGY STAR has recently taken action to establish voluntary standards for cooktops and the Department of Energy (DOE) may soon follow suit. Despite the large

savings opportunities, significant deployment barriers exist from basic consumer understanding of induction for residential cooking while heat pump dryers face initial concerns on drying time. Existing electric panel constraints are also a potentially large barrier where these products compete with other electrification opportunities such as EVs. On the programs side, California's electronic Technical Reference Manual (eTRM) has established measures for fuel substitution for cooking and heat pump clothes dryers. Despite this, significant barriers remain for this market especially for low-income programs like Energy Savings Assistance (ESA) program which has not been developed for fuel substitution measures. CalNEXT research should focus on the programmatic changes needed to help all types of consumers effectively navigate these decarbonization efforts.

Electric Vehicle Supply Equipment (EVSE)

(ETP Role: Lead, ETP Priority: High)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Alternating Current (AC) Level 1 (L1) chargers; AC Level 2 (L2) chargers; Direct Current (DC) chargers; bi-directional chargers (AC or DC); Local Load Management technologies; chargers with integral communication functions; and charging connector standardization.

Definition

EVSE is defined as the conductors, connectors, related equipment, and control software that deliver energy to an electric vehicle (EV).

Note: Mobile battery charging applications outside of traditional passenger vehicles such as e-bikes, wheelchairs, and forklifts are covered in separate technology families.

Opportunities

Electrified transportation is expected to be the major driver of load growth within California and EVSE are a key enabling technology to unlock this decarbonization strategy. In CEC's latest IEPR, it is projected that by 2030, electrical consumption from transportation will make up more than 20 Terawatt hours (TWh) or 6.7% of all electrical consumption. With the expected growth, there is need to ensure not only rapid deployment but also that EVSE are functioning with EE and demand flexibility in mind. To that end, products must limit standby energy usage and ensure that demand flexibility is incorporated into EVSE devices themselves or as programmatic elements with specialized devices. While there currently are no EE standards for EVSE, ENERGY STAR® has been taking a lead role in developing voluntary standards 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.

Load management will also be an area of rising importance, whether as a strategy to decarbonize plug loads without the need for electric panel upgrades or to deliver monetary benefits such as savings from time of use rates or by limiting monthly demand charges.

Barriers

While EVSEs are relatively new, their technical performance is well-understood especially for L1 and L2 equipment. Market understanding is growing as well, although as EVs transition to mass market end-users, there is need for both broad and specialized consumer education to help end-users navigate the complexities of: (1) installing efficient EVSEs, (2) limiting the need for expensive panel upgrades, and (3) enrolling and educating users in demand-response programs. Prospective CalNEXT research should look at innovative program designs to address these multi-pronged barriers.

Household Appliances

(ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Refrigerators and freezers; beverage coolers: clothes washers (including commercial clothes washers); dishwashers; air purifiers; and counter-top cooking appliances (microwaves, coffee makers, air fryers, etc.).

Definition

Large and small appliances that aid in routine home keeping and housework that are powered exclusively by electricity and without a battery. They can be located within the home, in multi-family buildings, or light commercial settings.

Note: products that commonly use gas such as clothes dryers, ovens, cooktops, and ranges are covered in a separate plug load technology family to focus on the unique challenges for decarbonization.

Opportunities

These products are very technologically mature with effective energy and water standards implemented at a national level for products including refrigerators, beverage coolers, residential clothes washers, and dishwashers. For products with mature efficiency standards there are limited impact opportunities with the lone exception being dishwashers since access has lagged and traditional handwashing is significantly more energy and water intensive. In the latest California Statewide Residential Appliance Saturation Study (RASS), dishwashers had a high penetration rate among homeowners at 81% while only 51% of renters reported having a dishwasher. Of those that do own a dishwasher, 21% of homeowners and 34% renters respectively report not using their appliance.

Outside of products with a national standard, research to develop representative test procedures or demonstrate new novel technologies in support of deployment of new standards remains an opportunity for significant energy savings impacts, especially for products such as large commercial clothes washers and air purifiers.

Barriers

Technical understanding of products in this family is well-established and while market knowledge around consumer purchasing behavior is known, the actual use of these products is not well understood. The utilities codes & standards teams have been active in regulatory rulemakings to push higher standards, but certain products may need further intervention. For example, dishwashing is likely a significant area of energy and water savings but will likely need innovative program designs focused on improving consumer education of dishwashers as well as a focus on tackling deployment and equitable access.

Light Duty Battery-Chargers

(ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Mobile devices (laptops, tablets, phones); non-medical mobility devices (e-bikes, scooters); battery-powered yard equipment (mowers, chainsaws, leaf blowers); miscellaneous battery-powered equipment (power tools, vacuums, drones); stand-alone rechargeable batteries; and wireless charging devices.

Definition

Electronic devices with onboard batteries that may be operated while plugged in but largely operated untethered via battery. Building energy use occurs while charging battery or during concurrent usage.

Note: this technology family excludes medical mobility devices which are covered under a separate technology family within the Plug Load TPM.

Opportunities

Battery-chargers are mature technology that have become ubiquitous in our society, charging everything from billions of small devices like smartphones and electric toothbrushes to a growing number of larger devices like electric bicycles and lawn equipment. This growth is expected to continue, especially among larger battery equipment, as the California Air Resources Board has recently required the use of zero-emissions landscaping equipment starting in 2024. Across all battery sizes, 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 FDAS under SB-49 (Skinner) which may have significant opportunities for certain applications of large battery chargers.

Wireless charging technologies have seen widespread growth in consumer electronics which represents an opportunity to research efficiency performance in this growing area. Other ET activities should support California Air Resources Board (CARB) efforts in decarbonizing lawn equipment & other similar fossil-fuel powered mobile energy products as well as efforts to embed demand-flexible capabilities into the battery charging infrastructure in support of FDAS.

Barriers

The technical understanding of battery chargers is mature, with the exception of the emerging wireless charging platforms. Market incentives are not well aligned because consumer purchasing decisions are not driven by battery chargers themselves but rather by the products to be charged. The state of California & utility programs have had limited activity in this area with the exception of incentive programs for all-electric landscaping equipment which are funded by a number of regional air quality districts.

Plug Load Optimization & Management Technologies

(ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Smart Receptacles; advanced power strips; plug load management devices; and product-embedded plug load management.

Definition

Components, platforms, and foundational communications protocols with the ability to communicate, coordinate, and optimize energy use of plug-in and hardwired electric loads in a residential or commercial building. This cross-cutting technology family is aimed at broadly enabling devices to operate at lower power modes when they are not providing their main function(s).

Opportunities

Emerging technologies in this family have the potential to result in significant energy savings and decarbonization benefits. According to the National Renewable Energy Laboratory (NREL), "Plug and process loads (PPLs) account for 47% of U.S. commercial building energy consumption" and are expected to continue steady growth. Managing plug load operations to communicate across devices and minimize 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 the understanding of the energy savings potential associated with optimized plug load management; (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; and (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.

Barriers

Significant barriers must be overcome to actualize and scale plug loads optimization to the broader market. Technical demonstrations have been done to prove viability of certain product types, but larger broad-based opportunity will come if standardized communication protocols across different product types can be developed to allow manufacturers to embed intelligence into their products. Until these technical and market challenges are fully developed, it is unlikely traditional utility programs will be able to identify cost-effective savings outside of a couple specialized products (e.g., refrigerated vending machines & water coolers).

Home Entertainment, Networking, Office, and Security Equipment

(ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Televisions; home and facility automation; security equipment; set-top boxes; home entertainment equipment; gaming consoles; computers and peripherals; imaging equipment; and home networking equipment.

Definition

Devices used for home entertainment, computing and home offices, networking, and security.

Opportunities

Energy consumption for many of these products has been addressed by appliance standards (televisions, computers), voluntary certifications (computers, monitors, televisions, imaging equipment) and industry voluntary agreements (set-top boxes, small network equipment). Energy efficiency (EE) savings may be limited to either new technological innovations such as advances for televisions and monitors, or energy savings from inactive modes, which have become more significant as many of these devices are never fully off. ET projects on inactive power can leverage and contribute data to the CEC's ongoing proceeding on Low Power Modes.

Barriers

In aggregate these devices consume significant power, but the savings per individual device are low, as is consumer awareness. EE does not drive purchasing behavior, and efficiency programs largely ignore these devices. Customer engagement is low for features such as automatic brightness control and automatic power down that can determine power consumption. ET projects may address this family most effectively via code-readiness projects rather than supporting voluntary efficiency programs. Energy consumption trends have been driven by customer expectations for network connectivity and availability of video and audio, and network connection often defaults to basic Wi-Fi even when data rate and latency needs allow for more efficient technologies.

Medical Equipment (Residential and Assisted Living)

(ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

Energy Savings: Medium
Decarbonization: Low
Demand Flexibility: N/A
Other Emissions Impacts: N/A

Knowledge Index

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

Subgroups (Example Technologies)

Oxygen concentrators; continuous positive airway pressure ventilators (CPAP); power wheelchairs; personal vertical transport; automated reclining chairs; circulation pumps for beds; precision heaters; and emergency back-up power for medical equipment.

Definition

This category includes the specialty medical equipment intended for the elderly and people with disabilities for personal mobility or medical treatment in residential and assisted living facilities.

Note that this technology family excludes hospital-specific equipment, such as imaging equipment (CT scans, MRI, X-ray), medical-grade cold storage, and biosafety cabinets which are covered under the Process Loads TPM.

Opportunities

Medical devices in the United States (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% 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 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). Demand flexibility, while technically feasible, is unlikely to have significant uptake due to concerns for safety and health impacts.

Barriers

Significant barriers exist for this technology family. Technical performance is poorly understood as there is limited data on actual energy use of this equipment and despite the maturity of this sector, these products have been historically exempted from appliance standards. Market signals are misaligned as equipment purchasers are reimbursed by health insurance for the capital expense and end-users pay a lower 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).