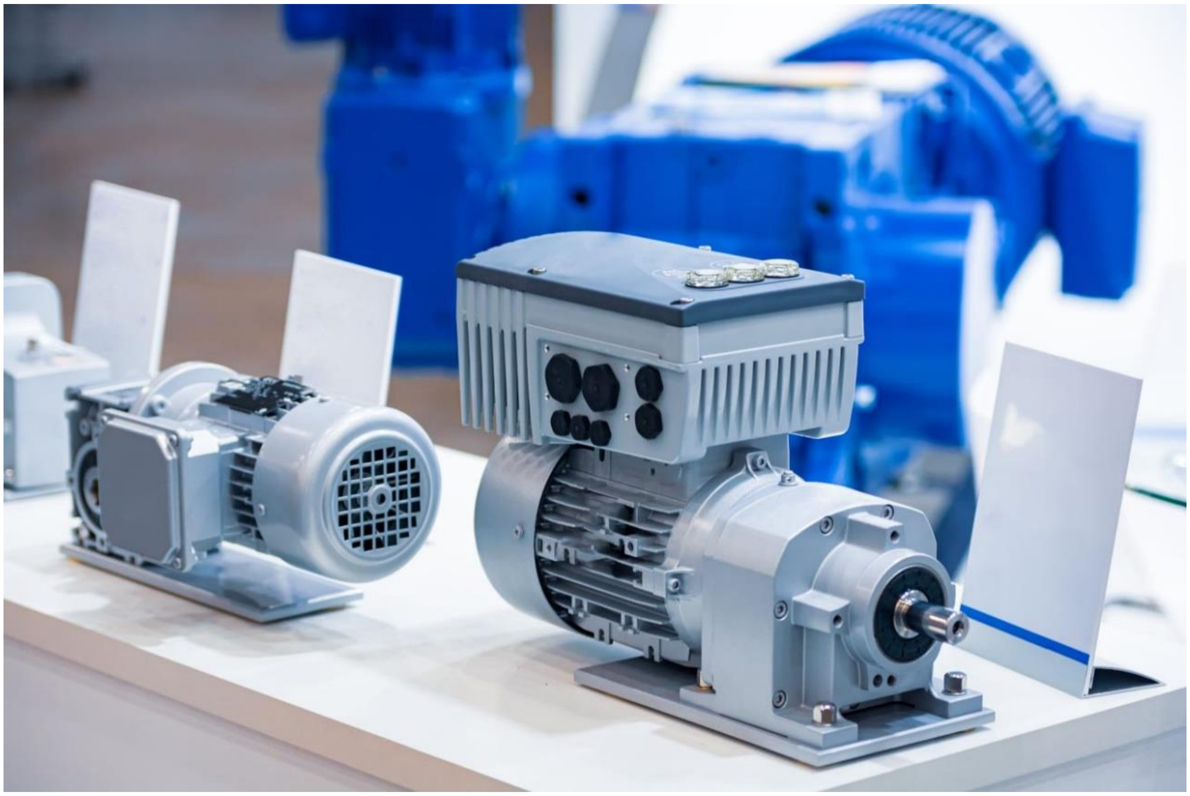
2022 Process Loads Technology Priority Map



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Abbreviations, Acronyms, and Glossary of Terms

Acronym	Meaning
AC	Alternating Current
ACEEE	American Council for an Energy-Efficient Economy
AIM	American Innovation and Manufacturing Act of 2020
BCCA	Buy Clean California Act
CA	California
CARB	California Air Resources Board
CEC	California Energy Commission
CEC-EPIC	California Energy Commission – Electric Program Investment Charge
CESMII	Smart Manufacturing Institute
CORE	Clean Off-Road Equipment Voucher Incentives
CPUC	California Public Utilities Commission
CRAC/CRAH	Computer Room Air Conditioners or Air Handlers
DOE	Department of Energy
DR	Demand Response
EE	Energy Efficiency
EPA	Environmental Protection Agency
ERP	Enterprise Resource Planning
ET	Emerging Technology
FARMER	Funding Agricultural Replacement Measures for Emissions Reductions
FPIP	Food Production Investment Program
GHG	Greenhouse Gas
GWh	Gigawatt Hours
GWP	Global Warming Potential

HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HTR	Hard-to-Reach
HVAC	Heating Ventilation and Air Conditioning
HVAC/D	Heating, Ventilation, Air Conditioning, and Dehumidification
IOU	Investor-Owned Utility
IEPR	Integrated Energy Policy Report
IIJA	Infrastructure Investment and Jobs Act of 2021
IT	Information Technology
LNE	Large Network Equipment
MT	Metric Ton
NMEC	Normalized Meter Energy Consumption
PDU	Professional Development Units
PM	Permanent Magnet
PMAC	Permanent Magnet Alternating Current
PMSM	Permanent Magnet Synchronous Motors
R&D	Research and Development
SM	Smart Manufacturing
SNAP	Significant New Alternatives Policy
SME	Subject Matter Expert
TOU	Time-Of-Use
TPM	Technology Priority Map
TWh	Terawatt Hour
ULTs	Ultra-Low Temperatures
UPS	Uninterruptible Power Supplies
U.S.	United States

USDA	United States Department of Agriculture
VSD	Variable Speed Drive
WE&T	Workforce Education and Training
ZEV	Zero Emissions Vehicle

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 Process Loads TPM

Process Loads Category Overview

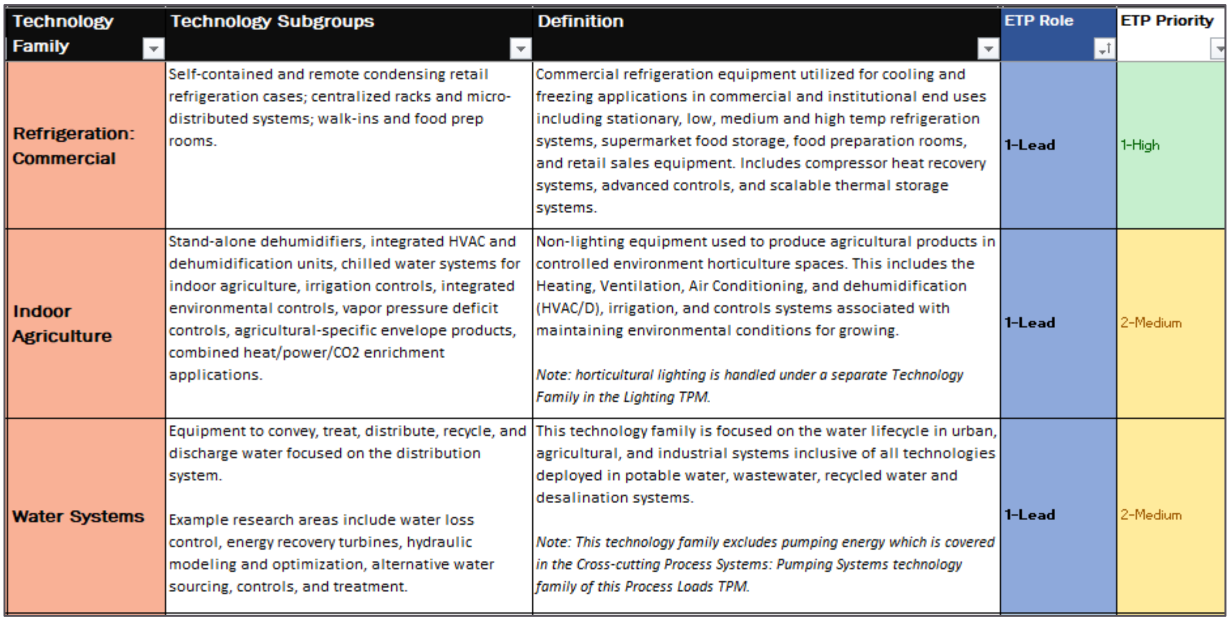
This technology category encompasses a wide range of energy uses from specialized light commercial such as restaurants & healthcare to industrial manufacturing. Recent studies by California Air Resources Board (CARB) indicate agriculture and industrial emissions represent over 30% of statewide emissions indicating a huge potential for energy efficiency (EE) and decarbonization activities. However, energy-related research in this category has significantly lagged other topic areas due to the unique and complex nature in this field.

Note: the 2022 TPMs have been heavily revised to incorporate six cross-sectoral technology approaches to tackle common technologies found in a number of facilities (e.g., motors, pumping systems, steam & hot water).

Unique Opportunities and Barriers

Under process loads, CalNEXT research is broadly focused on projects that will lead to expanded incentive program offerings (EE or fuel substitution) and/or establishment of new standards. Commercial Refrigeration is of particular interest as that sector is a large contributor to HFC emissions and is looking also transitioning to a low-global warming potential (GWP) future.

Highlighted Priority Areas



Technology Family	Technology Subgroups	Definition	ETP Role	ETP Priority
Refrigeration: Commercial	Self-contained and remote condensing retail refrigeration cases; centralized racks and micro-distributed systems; walk-ins and food prep rooms.	Commercial refrigeration equipment utilized for cooling and freezing applications in commercial and institutional end uses including stationary, low, medium and high temp refrigeration systems, supermarket food storage, food preparation rooms, and retail sales equipment. Includes compressor heat recovery systems, advanced controls, and scalable thermal storage systems.	**1-Lead**	1-High
Indoor Agriculture	Stand-alone dehumidifiers, integrated HVAC and dehumidification units, chilled water systems for indoor agriculture, irrigation controls, integrated environmental controls, vapor pressure deficit controls, agricultural-specific envelope products, combined heat/power/CO2 enrichment applications.	Non-lighting equipment used to produce agricultural products in controlled environment horticulture spaces. This includes the Heating, Ventilation, Air Conditioning, and dehumidification (HVAC/D), irrigation, and controls systems associated with maintaining environmental conditions for growing. *Note: horticultural lighting is handled under a separate Technology Family in the Lighting TPM.*	**1-Lead**	2-Medium
Water Systems	Equipment to convey, treat, distribute, recycle, and discharge water focused on the distribution system. Example research areas include water loss control, energy recovery turbines, hydraulic modeling and optimization, alternative water sourcing, controls, and treatment.	This technology family is focused on the water lifecycle in urban, agricultural, and industrial systems inclusive of all technologies deployed in potable water, wastewater, recycled water and desalination systems. *Note: This technology family excludes pumping energy which is covered in the Cross-cutting Process Systems: Pumping Systems technology family of this Process Loads TPM.*	**1-Lead**	2-Medium

Advanced Motors (ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

Energy Savings: High
Decarbonization: Low
Demand Flexibility: Medium
Other Emissions Impacts: None

Knowledge Index

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

Subgroups (Example Technologies)

Switched reluctance motors, synchronous reluctance motors, permanent-magnet (PM) alternating current (AC) (PMAC) motors, PM synchronous motors (PMSM), and motors with an integrated variable-speed drive (VSD).

Definition

Advancement of highly efficient electric motor types and associated control technologies with an emphasis on enhancing new advanced electric motor market awareness, stocking, deployment, and scalability.

Opportunities

A recent US motor market assessment estimates annual energy savings (482,000 GWh/year), annual greenhouse gas (GHG) emission reduction (342 MMT/year CO2), and annual utility bill savings ($53 billion/year) from advanced motors. Advanced technology motors are available and directly substitutable for standard induction motors in many applications. For example, in response to Department of Energy (DOE) motor rulemakings, the California (CA) IOUs docketed 13 advanced motor case studies and a table listing nine advanced motors from five manufacturers that can be substituted for traditional induction motors.

ET research should focus on 1) market research to identify the market share and availability of advanced motors, 2) opportunities to retrofit standard induction motors for advanced motors, and 3) opportunities to educate distributors and train contractors. Emerging Technology (ET) research should include VSD and associated controls and installation support tools that increase drive and motor efficiency, reduce equipment and installation costs, as well as simplify installation and commissioning to avoid errors that prevent full equipment efficiency.

Barriers

While advanced motors have secured a foothold in the US at 1.5-2.0%, there is an opportunity to grow the market for advanced electric motors in CA which will likely encourage even higher performance electric motors. Currently advanced motors are not regulated and therefore it is difficult for consumers to directly compare these advanced options with standard induction motors with many consumers not aware of these options at all. Motor-driven equipment manufacturers are incorporating advanced motors and drives into new equipment designs, but it is unclear how these motors will be replaced in the future nor how existing equipment packages can be retrofitted with these advanced motor retrofits as the supply channels are not well understood. ET research is needed to introduce advanced motors more broadly into all parts of the supply chain, encourage distributors and repair shops to stock them, and train contractors to install them so consumers can begin specifying them.

Pumping Systems (ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

Energy Savings: Medium
Decarbonization: Low
Demand Flexibility: Medium
Other Emissions Impacts: None

Knowledge Index

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

Subgroups (Example Technologies)

High efficiency pumps, advanced pump system monitoring and data analytics, and load management controls.

Definition

This technology family is focused on a holistic approach to design and optimization advancements of all pumped liquid systems across process-based market segments, aimed at achieving peak efficiency and demand flexibility.

Note: Depending on the project scope, prospective projects in the Pumping Systems technology family may fit better under the Water Systems technology family (Process Loads TPM).

Opportunities

Liquid pumping systems are amongst the largest family of electricity consumers in process load systems. Although engineered pumping systems are generally well understood and broadly utilized across market segments, nominal improvements in pump design efficiency and appropriateness of specific pumps can produce substantial grid-wide energy savings due to the sheer number of pumping systems and cross-cutting of market segments. ET research indicates advanced pump monitoring and data analytics can provide optimized system operation and control response, beyond the standard practice of variable speed technology, resulting in significant energy savings and demand flexible functionality. Technologies impacting pump demand, including end-use management, dynamic setpoint feedback controls, and other advanced load management controls, will improve overall pump system performance and increase potential to respond during grid events, as part of integrated load-management systems. This is especially true when paired with system storage, which can serve as a permanent load shifting opportunity. Prospective research may include laboratory based high efficiency pump performance benchmarking and demonstrations of scalable monitoring, load reducing and/or demand flexible technologies.

Barriers

Technical performance of pumps and pumping systems are generally well understood and there have been national EE standards covering most pumps since 2020. Market knowledge regarding implementation, operation, and maintenance of advanced controls and load reducing technologies is less well-developed. While there is significant potential for automated demand response (DR) of pumped systems, facility operators (and by extension customers) have shown some level of apprehension, in part because of lack of familiarity with automated control-based systems and the perception that they introduce additional failure modes when operating out of in-hand operation. Historically programs have provided opportunities to recognize energy and DR savings through custom and deemed incentive pathways. CalNEXT research should focus on program designs or enhancements to ensure the potential improvements of advanced controls and load management strategies are incorporated into existing programs.

Steam and Hot Water Systems (ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

Energy Savings: Medium
Decarbonization: High
Demand Flexibility: Medium
Other Emissions Impacts: None

Knowledge Index

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

Subgroups (Example Technologies)

Electric heating equipment intended specifically for process loads such as: hot water heaters, hot-water heat pumps, electric steam generation equipment, heat recovery chillers, burner fan motor controls, thermal process integration, waste heat recovery, dual-fuel heat pumps, and process end-use load optimization.

Note: Depending on the project scope, prospective projects in the Steam and Hot Water Systems technology family may fit better under the technology families in the Water Heating TPM which focus on light-duty systems (commercial & residential).

Definition

Electrically heated hot water and steam generation will be increasingly utilized to electrify and decarbonize traditionally natural gas fueled steam and hot water heating systems. ETs in heat pumps can increase efficiency, optimize processes, and incorporate waste heat recovery methods to reduce the load on the supply side equipment.

Opportunities

Mass deployment of electric hot-water heat pumps and low-pressure electric steam generating equipment has the potential to rapidly decarbonize otherwise fossil-fueled process heating systems. These technologies could potentially support hot water and low-pressure steam systems across many market sectors including manufacturing, medical, pharmaceutical, and food processing.

While traditional research and development (R&D) is needed to improve efficiency and increase the operating temperature ranges of heat pumps, many low-temperature heating end uses can be converted now, and it is necessary to improve efficiency of the entire process heating system to lay the groundwork for deep sectoral decarbonization. Conversion or partial conversion of steam end-uses to hot water and the general reduction of operating temperatures (for hot water) and reduction of operating pressures (for steam systems) will save energy and enable more opportunities for electrification in the short term. Strategies may include adding more thermal storage (also providing demand flexibility), better pipe insulation, larger heating coils, leak mitigation strategies such as fault detection diagnostics, or incorporating advanced controls. At the plant-level, heat pumps and heat recovery chillers can provide process heating more efficiently than fossil fuel combustion or electric resistance systems and have the potential to recover heat from areas that need cooling if process heating and process cooling loads are near one another.

Prospective ET studies should investigate technical viability of electrified heat sources for hot water and electric steam generation in process applications, including higher temperature limitations and steam operating pressure constraints, design capacity ranges, and deployment costs compared with more traditional gas-fired equipment and in-field performance issues that limit deployment. Additional program opportunities may exist which impact hard-to-reach (HTR) small businesses, for example laundromats and dry cleaners, due to perceived current equipment capacity and current operating temperature ranges.

Barriers

Currently, process hot water and steam heating systems are primarily designed with gas-based equipment and the higher operating temperatures associated with them. Recent industry experiences in pushing facilities toward the thermal operating range of condensing boilers will be similarly useful for electrification. Market understanding of efficient electrified heating is at a nascent stage and it is expected that both designers and facility managers will be reluctant to switch to electric without significant incentive support or specialized electric rates.

Process Heating Technology (ETP Role: Observe, ETP Priority: Low)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Electrically driven industrial process heating for plastics molding, glass manufacturing, cast metals, and other manufacturing processes.

Definition

Processes that dry raw materials, preheat process equipment or materials, and cure or stabilize produced goods, especially in plastic, glass and materials manufacturing.

Note: This technology family excludes process heating used in Steam & Hot Water as well as heating from specialized food processing / food service equipment which are covered in other technology family of this Process Loads TPM.

Opportunities

Applications that use electric resistance or natural gas for drying, preheating, and stabilization after heating could see EE opportunities to improve the coefficient of performance and to decarbonize from natural gas. Demand flexibility is likely limited due to the 24/7 nature of many impacted processes. Applications where electric resistance rods are used directly as heat elements within a mold, such as inside a melting furnace or die casting, would be a good target for demand flexibility controls.

Over the last three decades most industrial processes that could technologically switch from utilizing electricity to natural gas did so because of lower energy costs and the perceived environmental benefit (which was true when the grid was dominated by coal power plants). Now the opportunities are to reverse that trend and capture the greenhouse gas reduction benefit of a grid mix that comprises more renewable energy sources and better electrical controls as compared to the natural gas-fired heating process.

Barriers

While electric resistance heating provides very accurate temperature control, industry perceptions of reduced temperature control remain a challenge for ETs. However, the plastic industry is historically very competitive on operational costs regarding energy utilization and process improvement, thus high-quality energy efficient manufacturing equipment will be expected to quickly advance to the general market. At this point, the greatest barrier to converting from natural gas to electric heating is the energy cost.

Meanwhile, the glass and metal casting markets are slow to change due to high costs of retrofitting the manufacturing process and adoption of innovative technologies. However, both industries have been impacted by high commodity costs, which presents opportunities for testing for novel controls that limit demand charges and Time-Of-Use (TOU) costs. There is the opportunity to address the demand charges and TOU costs that severely impact industrial end-users by developing processes and programs that directly help those industries cope with higher and less predictable energy costs while boosting efficiency, demand flexibility, and decarbonization.

Process Air Systems (ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Blowers, fans, variable speed drives, air filtration, air distribution systems, compressed air systems, vacuum systems, and the design, maintenance, & control of these systems.

Definition

Industrial process systems that move air including fans, blowers, air compressors, and vacuums. This family includes treatment of air streams using filters, particulate separators, and the distribution infrastructure such as ducts, fittings, sensors, controls, and storage (compressed air).

Opportunities

Fans and blowers with aerodynamic blade design, low blade rotational speed, and larger blade lengths use less energy. Flow rate control for fans and blowers using variable speed drives instead of throttling devices dramatically increases efficiency at part loads. However, to fully realize these savings, end-use system pressures need to be known and enabled with feedback controls to safely reduce the system-wide static pressure while ensuring that all minimum airflows are met.

Compressed air end-use technologies such as nozzles, pressure reduction valves, and solenoid valves that shut off air when not needed can dramatically reduce compressed air system energy use. Leaks in compressed air systems typically account for over 20% of the compressed air supply and can lead to artificially high operating pressures, thus leak detection mitigation efforts can be highly cost effective. Compressor EE can also be improved by switching to variable speed controls or a variable-speed trim compressor for multi-stage compressor systems.

Barriers

Technical understanding of compressed air systems is very mature with technical barriers to EE opportunities being minimal. The primary barriers to replacing existing systems are the lack of practitioner expertise within industrial facilities and the relatively high capital replacement costs. Aside from plant replacement, facilities would benefit from expansion of maintenance programs to identify, locate, and fix leaks within their distribution systems or the deployment of technological solutions to automatically alert facilities staff to leaks. However, to fully realize savings potential, programs aimed at educating engineering and air system equipment professionals should be enhanced. For example, many professionals are unaware of the savings from optimizing variable speed drive control or simply designing low pressure drop distribution systems by expanding the duct or pipe diameter. As a result, poorly designed systems continue to be installed despite the cost-effectiveness of more efficient systems. California utilities have been active in developing industrial energy codes (Title 24, Part 6) for compressed air systems, first in developing requirements into the 2013 version and most recently developing updates for the 2022 version. Programs focused on improving code compliance and supporting the transformation of existing underperforming systems should be investigated.

Smart Manufacturing and Controls (ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Advanced sensors, controls, platforms, and modelling for manufacturing.

Definition

Deployment and integration of multiple technologies that together can enable EE improvements in manufacturing and deliver customer and grid benefits, significantly improving capacity for load flexibility, DR participation, and GHG tracking and tracing for enterprise resource planning (ERP) reporting.

Opportunities

Manufacturing consumes 24 quads of primary energy annually in the United States (U.S.), accounting for 79% of total industrial energy use. According to the research by American Council for an Energy-Efficient Economy (ACEEE), Smart Manufacturing (SM) has the potential to generate energy savings of 15-30% per unit with estimated energy savings nationally of $7-25 billion per year by enabling demand flexibility and decarbonization through data-driven control and optimization at the system and unit process levels. SM involves redesigning manufacturing lines with sensors and intelligent controls that can allow them to identify preventative maintenance and limit operational downtime. SM can also bring automated intelligence to equipment by shutting off equipment between cycles to eliminate waste or intelligently navigate plant-level needs, such as minimizing coincident demand through monitoring. Sophisticated use of SM can also involve intelligent staging of energy-intensive processes to optimize TOU energy pricing, limit demand charges, adjust operational peaks to real-time emissions intensity signals, or modify operations during grid events.

DOE’s Smart Manufacturing Institute (CESMII) has developed a smart manufacturing roadmap and is deploying over $140 million in funding across the U.S. to implement and demonstrate new manufacturing solutions and address knowledge gaps and workforce development. CalNEXT research activities should focus on project demonstrations to align with the near-term national goals.

Barriers

Technical performance of SM is poorly understood as this is an emerging field with limited case studies and few experienced practitioners. While more demonstrations would be useful given the wide applicability of SM, interoperability with new and existing systems will be a big challenge and it is unclear to what degree manufacturing lines can be retrofitted at lower cost than fully redesigned. Market knowledge is also poor as a lack of a skilled workforce in the industrial area has been highlighted in DOE’s SM roadmap and SM costs remain high. IOU programs have not been active in smart manufacturing but may consider how to leverage site-level normalized metered energy consumption (NMEC) techniques to validate energy savings.

Indoor Agriculture (ETP Role: Lead, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Stand-alone dehumidifiers, integrated heating ventilation and air conditioning (HVAC) and dehumidification units, chilled water systems for indoor agriculture, irrigation controls, integrated environmental controls, vapor pressure deficit controls, agricultural-specific envelope products, and combined heat/power/CO_2 enrichment applications.

Definition

Non-lighting equipment used to produce agricultural products in controlled environment horticulture spaces. This includes the heating, ventilation, air conditioning, and dehumidification (HVAC/D), irrigation, and controls systems associated with maintaining environmental conditions for growing.

Note: horticultural lighting is covered by the Horticultural Lighting technology family (Lighting TPM).

Opportunities

Indoor agriculture is an emerging industry with energy and water intensive facilities. Recent estimates have total indoor agricultural energy use at 1,000 gigawatt hours (GWh) per year and growing rapidly with estimates of a 30% annual growth rate as well as increasing interest in adoption for production of conventional agricultural crops.

EE is the largest opportunity in this family. As noted above, indoor agriculture has seen rapid expansion which has resulted in a significant amount of inefficient system designs. Currently, most EE opportunities are implemented through custom savings programs, highlighting an opportunity for deemed EE measures to increase the scale of adoption of energy efficient HVAC/D products which are prevalent in most indoor agricultural facilities. Based on the current drought in California as well as the embedded energy in water at agricultural sites, efficient irrigation controls and water reuse may become growing opportunities for energy savings.

Demand flexibility may become a significant opportunity but will be highly dependent on the appetite of growers to fluctuate indoor growing conditions or the ability to cost-effectively incorporate thermal storage strategies into common horticultural system design.

Barriers

While the individual technological components are well-established from development in other sectors, they remain in a nascent stage with respect to indoor agriculture. Standards bodies have yet to develop uniform horticultural HVAC/D testing methodologies or metrics to account for the different horticultural environments which severely limits market understanding. Additionally, the horticultural design industry lacks experienced practitioners of energy efficient systems. Workforce education & training (WE&T), as well as research collecting field data to validate scalable incentive programs is needed to support broader adoption of cost-effective high efficiency systems.

Food Processing (ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Washing, peeling, dewatering, roasting, baking, drying, dehumidifier, and process cooling and process heating systems.

Definition

Equipment used to transform agricultural products into food, or from one form of food into other foods such as value-added products.

Opportunities

The food & beverage industry is one of the largest energy consuming sectors in the U.S., with an estimated 78 million metric tons (MT) of CO_2 emissions in 2020. According to the United States Department of Agriculture (USDA), California alone has over 6,000 food and beverage manufacturing plants. While a wide breadth of processes exists to handle different types of food processing, there are some common characteristics, including heating for pasteurization/sanitation, equipment for conveyance systems, and several "low"-temperature process heating loads for roasting/baking/frying/drying. EE measures are in a nascent stage in this sector, relying primarily on custom savings calculations. The development of industry standards and test protocols for food processing technologies and processes will help standardize energy savings and support the development and adoption of traditional EE measures.

DOE's 2022 Industrial Decarbonization Roadmap indicated substantial impact potential through electrification of the many low-temperature process heating loads with electric boilers, electric fryers, and electric ovens all identified as near-term R&D priorities in that roadmap. The state of California has prioritized the food processing sector through its establishment of the Food Production Investment Program (FPIP) which focuses on project implementation to accelerate the adoption of EE and renewable energy technologies.

Given the strong level of research activities already being conducted by CEC, CalNEXT should focus pre-commercial research on collaborating with existing programs like California Energy Commission – Electric Program Investment Charge (CEC EPIC) & FPIP and market-ready research on developing scalable deployment models, such as deemed incentives.

Barriers

Technical understanding of this sector is well developed but ET solutions are not. Industrial heat pumps are not commonly used and may require a number of highly visible case studies to become trustworthy in a risk-averse industry. Because manufacturing lines are highly customized, complex built-up systems, there are significant technical limitations for retrofit technologies. It will be easiest to provide demonstrations when factories are already upgrading or expanding their production lines.

Restaurant and Food Equipment (ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Commercial food preparation (cooktops, woks, ovens, steamers, fryers, broilers), sanitation operations (dipper wells, pre-rinse operations, dishwashing), kitchen and dish room ventilation (makeup air unit and kitchen hoods), and commercial refrigeration equipment (kitchen refrigerators and freezers, prep tables, salad bars, automatic ice machines, self-contained walk-in coolers & freezers).

Definition

Electric equipment and systems typical of commercial kitchens (cafes, fast food, and sit down) and institutional foodservice facilities (hospitality and cafeterias).

Note 1: Grocery display cases and remote-condensing systems are covered under the "Refrigeration, Commercial" technology family within this Process Loads TPM.

Note 2: Related water heating topics are covered under the Water Heating TPM and the "Steam & Hot Water Systems" technology family within this Process Loads TPM.

Opportunities

Commercial kitchens are incredibly energy intensive, representing five to seven times the energy density of other types of buildings with significant energy savings potential. There is also a tremendous opportunity to decarbonize these facilities as kitchen natural gas consumption makes up approximately 23% of all commercial building gas usage despite being only a fraction of the square footage. While current technology exists to decarbonize many kitchens, to date this has only been implemented in targeted parts of a cookline or to a limited number of new construction facilities.

Within this growing topic of electrification, CalNEXT research should focus on demonstrating emerging electrified products such as electric woks or tandoor ovens as well as demonstrating and assessing the cost effectiveness of deeper electrification retrofits at the full cook line level. For maturing technologies, CalNEXT should continue to develop research that can feed into development of new deemed measures and/or standards development. High electrical savings equipment will be prioritized followed by equipment that will save energy and be complimentary to future electrified kitchens such as heat recovery dish machines, drain water heat recovery, and development of more mature fuel-substitution measures.

Barriers

Despite the strong opportunities and technical maturity of food service equipment, this sector faces significant barriers to electrify and needs both more resources and large structural changes to actualize the decarbonization opportunities. Market understanding has improved as programs are now targeting distribution channels and retailers to ensure ENERGY STAR® products are widely available in like-for-like equipment replacements. However, we are in an early stage for decarbonization activities of this sector with little known about the state of electrical infrastructure and potential costs for upgrades to support fuel substitution. Outside of this, larger structural issues such as energy rates misaligned with decarbonization, tenant-owner split incentives, inability to conduct long-term facility planning, resistance from health departments, language barriers for many restaurant service professionals, thin profit margins within the restaurant sector, and unfamiliarity to outright resistance to electrified cooking. Potential barriers research should focus on developing case studies and design guidelines to familiarize market actors with all aspects of the fossil fuel transition.

Refrigeration, Commercial (ETP Role: Lead, ETP Priority: High)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Self-contained and remote condensing retail refrigeration cases, centralized racks and micro-distributed systems, and walk-ins and food prep rooms.

Definition

Commercial refrigeration equipment utilized for cooling and freezing applications in commercial and institutional end uses including stationary, low, medium, and high temp refrigeration systems, supermarket food storage, food preparation rooms, and retail sales equipment. Includes compressor heat recovery systems, advanced controls, and scalable thermal storage systems.

Opportunities

California is the top producer of agricultural products in the U.S. (14% of total), with commercial refrigeration representing a significant portion of the energy consumption related to food storage, preparation, and sales. Additionally, retail food refrigeration is estimated at almost 45% of California's HFC emissions according to the U.S. Environmental Protection Agency (EPA) significant new alternatives policy (SNAP) & CARB GHG Inventory (2016).

Based on recent action at the national and state level, this sector will begin transitioning to low GWP and natural refrigerants with HFC phase outs in new construction and existing systems as well as a refrigerant reclamation programs. As systems transition, control equipment upgrades, and other high efficiency options should be pursued simultaneously. Future studies should focus on gathering and evaluating data to help quantify the benefits and costs of these systems and document best practices to help guide system design and operational procedures.

Additionally, opportunities to incorporate high efficiency equipment and introduce heat recovery have the potential to both support EE with added decarbonization benefits. As new refrigerants emerge whether for new systems or as drop-in replacements to existing HFC systems, there is need for both laboratory and field testing to evaluate changes in cooling capacity, energy performance, and other operational changes. Additionally, research to limit refrigerant leakage within distribution systems will be broadly beneficial. Finally, there is opportunity to collaborate with other programs to create a clear pathway for technical and financial resources to support this broad transition and actualize the opportunities.

Barriers

Common barriers include initial capital costs, safety concerns, regulatory challenges, and broad business impacts to replacement down time. Potential opportunities should seek to address these barriers and reduce negative impacts to core business operations. While HCFC, HFC remain common, system conversion cost is high which in part informs the slow uptake of low GWP refrigerants. Workforce training needs are high as contractors' knowledge of low GWP and natural refrigerants is limited, making the installation and service of these systems another challenge.

Opportunities to support training and certification of new refrigerants should be considered to expand industry knowledge.

Refrigeration, Industrial (ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Industrial process cooling and freezing including spiral freezers, blast freezers, cryogenic freezers, freeze drying, refrigerated warehouses, large walk-in and drive-in refrigerated spaces, cooling for materials processing, pharmaceuticals, and others, and transportation refrigeration units.

Definition

Industrial cooling, refrigeration and freezing systems for food, materials, pharmaceuticals and other manufactured product applications, and refrigerated transportation distribution from manufacturing facility.

Opportunities

Energy efficient industrial refrigeration opportunities begin at the end-use where many existing products and methods are widely used and where emerging products and methods can further improve energy savings. Process integration, where waste heat from cooling may be utilized for heating uses thereby reducing cooling and heating demand (potentially by incorporating industrial heat pump application). Refrigeration loads can also be reduced by enhanced envelope design, improved insulation, reduced air infiltration, reduced unnecessary heat gain through automated operations and internal heat gains within the refrigerated spaces such as evaporator fans and defrost systems. Materials can be pre-cooled using cooling towers, advanced evaporative cooling, and other less energy intensive methods. On the supply side, energy efficient compressor control, suction and head pressures/temperatures should be optimized when possible. Multi-compressor and multi-suction systems could be employed when demand and/or operating temperatures vary widely. Additional opportunities for energy savings include condenser optimization with fan controls, water flow rates, more effective heat rejection strategies, and temperature reset based on ambient conditions including advanced sub-wet bulb evaporative cooling have the potential to save energy.

Demand flexibility opportunities are significant since the cooling in many cold rooms can effectively be shifted to periods outside of demand emergencies to periods with lower electrical demand costs, periods that coincide with on-site solar electricity production, and/or periods with lower grid electricity carbon intensity. Additional, and likely deeper, load shifting opportunities can be achieved with thermal energy storage. The performance of automated DR controls requires thorough testing.

Emerging low GWP refrigerants and natural refrigerants will start to replace legacy refrigerants pushed along by recent national and state regulations. Opportunities exist to both improve underlying system efficiencies while reducing refrigerant leakage while facilities begin transitions to next generation refrigerants. These multiple co-benefits should be incorporated into future programs.

Barriers

Industrial refrigeration systems require custom engineered solutions which can prevent fast market adoption of ETs. The EE and demand flexibility opportunities described above are limited by uncertainty about temperature fluctuation impacts on product quality, lack of contractor expertise to address these issues, and facility motivation to modify an operable system. End-user requirements for high reliability and process uptime can reduce tolerance to implement less proven technologies and present a timing conflict for retrofit upgrades.

Legacy hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and pumped ammonia refrigerants are still ubiquitous with low adoption of advanced refrigerants indicating a challenge for workforce training. While regulations will motivate retirement of high GWP refrigerants, appetite for additional investments may be limited. Additionally, newly emerging low GWP refrigerants still require laboratory and field testing to verify performance and EE which highlight the research needs on this topic.

Data Centers and Enterprise Computing (ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Liquid-cooled systems, Data Center Storage, Enterprise Servers, Large Network Equipment (LNE), Uninterruptible Power Supplies (UPS), and computer room air conditioners or air handlers (CRAC / CRAH).

Definition

Energy-using equipment related to the functioning of dedicated information technology (IT) facilities, including the IT equipment (servers, storage, networking) itself. Other typical equipment includes power infrastructure such as professional development units (PDUs) & UPS as well as specialized systems for airflow management and air conditioning.

Opportunities

Data centers use significant amounts of energy, making up about 3% of electrical energy use worldwide and many facilities are evaporatively cooled, resulting in significant water use. IT equipment itself makes up the bulk of the energy use, accounting for nearly two-thirds of the energy consumption with the remainder used for cooling [1]. Most large IT equipment (storage, servers, LNE, UPS) now have ENERGY STAR product labelling but there are no national EE standards for this equipment except for CRAC units.

Aside from energy savings, there are opportunities to utilize waste heat by co-location of data centers with district heating networks or other heating needs such as localized space heating (decarbonization potential by displacing natural gas heating). The use of thermal storage technologies has potential to unlock demand flexibility. Evaporatively cooled data centers could also see efficiency improvements leveraging recent advancements in direct/indirect evaporative coolers (note: see the “Hybrid or Fully Compressor-less HVAC” systems under the HVAC TPM). Finally, while still emerging, liquid-immersed systems have the potential for even greater energy and water savings and can support computing scalability, which is important in edge-computing data centers.

Barriers

Data centers are a well-researched area, especially traditional hot-aisle/cold-aisle CRAC/CRAH systems. Despite the prevalence of ENERGY STAR products, there are no deemed rebate measures in this sector and no appliance standards (DOE or Title 20) outside of CRAC units. Statewide water supply concerns are driving aversion to evaporative cooling in lieu of less efficient air-cooled systems. Meanwhile, ETs such as liquid-immersed computing face significant barriers to scale from code compliance, product availability, downtime concerns, and practitioner familiarity. Research to develop code compliance pathways for liquid-immersed systems will be beneficial toward providing a viable pathway toward these scalable impacts.

Labs and Hospitals (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: Medium
Program Intervention: Medium

Subgroups (Example Technologies)

Incubators, autoclaves, biosafety cabinets, ultra-low temperature (ULTs) technologies, medical fridges/freezers, sterilizers, fume hoods, and imaging equipment.

Definition

Advancement of common laboratory and hospital-specific equipment that will improve the energy performance of this broad sector.

Opportunities

Laboratories and hospitals are one of the highest energy consuming facilities due to their energy-intensive equipment, 100% outside air requirements, high airflow rates, and typically continuous operating hours. A 2015 market assessment conducted by the California IOUs, catalogued several large plug loads common in laboratories of which only a few have been studied extensively, notably ULTs which now have ENERGY STAR specifications and fume hoods which were the subject of a California energy code update in 2019. At the time of the 2015 study, it was estimated that just 12 pieces of equipment were likely responsible for between 0.8 and 3.2 terawatt hours (TWh)/year. Several other opportunities such as autoclaves, incubators, and centrifuges remain unexamined and there is still a strong need to conduct product baseline studies on these commonly identified and high energy products. Meanwhile the savings opportunities have continued to grow as biotech and pharmaceutical laboratories have seen significant growth since the COVID-19 pandemic.

Barriers

With the few notable exceptions mentioned above, there is little technical understanding about many of the types of more energy intensive equipment of interest. The primary barrier for much of this equipment is a lack of baseline studies which is limiting progress in this sector. As noted above, there are also no national standards (mandatory or voluntary) for any lab equipment other than ULTs and fume hoods. The 2015 market assessment identified significant interest with end users reporting it was either considered ‘important’ or ‘very important’ to have equipment that was energy efficient or water efficient 70% of the time. This interest has only grown as a number of large publicly traded biotech companies and academic institutions have committed to emissions reductions goals, leaving a huge need for foundational data to launch additional incentive programs.

Water Systems (ETP Role: Lead, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Equipment to convey, treat, distribute, recycle, and discharge water focused on the distribution system. Example technologies include water loss control, energy recovery turbines, hydraulic modeling and optimization, alternative water sourcing, controls, and treatment.

Definition

This technology family is focused on the water lifecycle in urban, agricultural, and industrial systems inclusive of all technologies deployed in potable water, wastewater, recycled water, and desalination systems.

Note: This technology family excludes pumping energy which is covered in the cross-cutting Process Systems: Pumping Systems technology family of this Process Loads TPM.

Opportunities

Approximately 19% of the net energy use in California is associated with the sourcing, conveyance, treatment, distribution, end-use, and disposal of water. Approximately 7% is associated with transmission, distribution, and pressurization of water.

Broad water efficiency efforts (such as high-efficiency toilets) or broad water conservation efforts (such as drought-tolerant landscaping) can reduce the energy expended in the water lifecycle both upstream (e.g., sourcing, conveyance, treatment, and distribution) and downstream (e.g., wastewater treatment and disposal), which have large secondary impacts for energy conservation. Similarly, preventable water loss such as those experienced in aging distribution systems and building piping have strong potential to achieve long-term water and energy savings without impacting operations.

Water systems are highly flexible when water storage is available, which is true for the vast majority of large potable water systems in California, and some wastewater systems. Through further system advancements, such as the inclusion of more storage or alternative energy rates, a water system can often display great flexibility to use energy through pumping operations at nearly any hour of the day. Appropriate modification of energy demand charges, when paired with adequate water storage, may allow pumping time and intensity to be highly directed. This translates to large generation source emission reduction potential. For example, research by UC Davis' Center for Water-EE estimated a reduction of emissions by >300,000 mTCO2 annually in the potable water sector in California if electrical rates better aligned costs with carbon intensity. With the reform of energy demand charges, it is estimated California could load-shift over 1.07 TWh annually in the potable water sector through existing infrastructure.

Barriers

Water systems are mature systems that often lag the energy infrastructure in terms of efficiency, advancement, and modernization. This can be associated in part with the slow progress made in the digital revolution of the water sector, including data availability, data sharing, computer modeling quality, and the complexity of optimizing water system operations. Additionally, water system operations frequently involve a combination of human and machine controls that require risk management when implementing any substantial changes to the water system. To date, operators are highly risk averse in making changes even when there are cost-effective savings opportunities. Finally, water-related industries often have elevated levels of oversight, permitting, and compliance that need to be understood and incorporated to access these savings opportunities. Visible case studies, targeted sector engagement, and best practices guides will help operators become more comfortable with implementing high efficiency energy projects.

Vehicle Charging and Off-Road Fleet Charging (ETP Role: Collaborate, ETP Priority: Medium)

Key Factors

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

Knowledge Index

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

Subgroups (Example Technologies)

Charging of golf carts, forklifts, pallet jacks, airport ground support equipment, automated guided vehicles, and other similar non-automotive vehicles.

Definition

This family focuses on charging and charging management strategies to support the electrified transition of commercial and industrial vehicles used exclusively on-site to perform a variety of functions that would not be suitable for traditional “motor vehicles”. Building energy uses occurs while charging batteries of these vehicles.

Note: This technology family excludes personal mobility devices and traditional electric vehicles which are covered under separate technology families within the Process Loads TPM.

Opportunities

CARB has been leading action in this technology area as it is a key pillar needed to meet California’s ambitious climate goals. In their 2022 Zero Emissions Vehicle (ZEV) Action Plan, CARB highlighted regulatory rulemakings to phase out fossil-fuel powered vehicles such as cargo handling equipment, small off-road engines, forklift vehicles, and others paving the way for zero emissions replacements. In addition, CARB is deploying a variety of incentive programs such as Funding Agricultural Replacement Measures for Emissions Reductions (FARMER), Clean Off-Road Equipment Voucher Incentives (CORE), and a program dedicated to Advanced Technology Demonstration and Pilot Projects aimed at accelerating precommercial and early commercial heavy-duty on- and off-road technologies.

Given the strong level of activity already being conducted by CARB, CalNEXT should continue to observe these developments and look for ways to collaborate to ensure that the charging infrastructure used will be energy efficient with demand flexible capabilities and that building level and utility electrical infrastructure barriers can be minimized.

Barriers

The technical understanding of vehicle battery chargers is mature; however, regulatory action is pushing electrification into previous nascent electrical applications such as construction, ports, and warehouses. While facilities are looking to comply with these emerging ZEV regulations, there is poor understanding of the electrification infrastructure barriers within the buildings themselves and within the transmission and distribution infrastructure. Utility programs have had limited activity in this area and should consider new program elements to help remove electrification barriers for customers through managed charging and demand flexibility opportunities, as well as ensuring that electrical service upgrades that expand capacity investigate future-proofing to electrify future end-uses.