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Advancing Plug Load Efficiency with Utility Incentive Programs

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Abstract

Energy efficiency (EE) programs largely focus on incentivizing investments in major end uses, particularly in heating, cooling, and lighting. However, to meet aggressive goals for reducing GHG emissions researchers and policymakers must also address energy inefficiencies of plug load devices, most of which individually use relatively little energy but are present in ever-growing numbers. In the U.S. commercial sector, end uses such as cooking, computing, and office equipment made up 18% of the electricity purchased in 2019 while “other” uses, such as medical and laboratory equipment, made up 32%. Energy use from plug load devices is expected to rise due to increases in both the types and numbers of devices. Incentivizing customer investments into more efficient models and efficient use of these devices is complicated by several factors, including the wide range of device types and usage patterns. This paper presents research on how U.S. utilities can highlight plug loads in their commercial EE programs. We report results of an in-depth examination of the EE programs of 20 major U.S. utilities, reviewing the types of downstream and midstream incentives and other approaches they use, and linking them to best practices. We offer recommendations about how to effectively integrate plug loads into utility EE incentive programs and discuss barriers.

Introduction

Energy efficiency (EE) programs are motivated by growing concerns about the increasingly serious effects of climate change, grid instability, and lack of energy security [1]. The goal of these programs is to promote cost-effective solutions that reduce and manage energy consumption. Most EE programs in the U.S. focus on HVAC, lighting, and refrigeration; as these become more efficient, plug load devices are an emerging area for savings. Plug load devices are appliances and equipment that plug into standard electrical sockets. In commercial settings this includes such devices as computers and printers in offices, projectors in conference rooms, cash registers in retail outlets, televisions and food service equipment in restaurants, and refrigerators and water coolers in staff breakrooms. Total energy use attributed to plug load devices has risen as the number of such devices in commercial buildings has increased, and there is consensus that plug load energy consumption will continue to grow [2-4]. There is evidence that organizations that implement both technological and behavioral strategies observe a significant decrease in plug load energy consumption and waste [5-9]. Utilities can support their commercial customers in reducing their plug load by offering EE programs that are tailored towards this goal.

In this paper, we present the first large-scale survey of how U.S. utilities are incentivizing EE plug loads in their commercial programs. The goal is to describe the range of approaches attempted by various utilities across the country and identify which have already been more widely adopted, and for which plug loads, and which are less common. In either case, these approaches represent potential energy-saving opportunities for utilities that have not yet fully integrated plug loads into their portfolios. We begin with a brief review of prior research. We then describe the policy context for U.S. utility programs, and how downstream, midstream, and upstream incentive strategies are divided across government and private entities. We then report results of research on commercial EE programs in twenty major utilities across the United States. Our conclusions highlight the various program strategies identified to reach the goal of reducing energy consumption and thus greenhouse gas (GHG) emissions from plug loads.

Prior Research

There have been relatively few comparison studies of utility energy efficiency programs in the United States. Each utility is required by individual states to collect and analyze cost effectiveness data for their program offerings. However, these requirements vary in terms of the quantity and quality of public-facing reports describing program success in reducing energy usage and customer bills. The most widely cited program comparison analyses are conducted by the American Council for an Energy Efficient Economy (ACEEE), producing annual scorecards ranking the top performing utilities on a variety of metrics, such as range of program offerings, program portfolio comprehensive, and selected spotlights on emerging program areas, such as electric vehicle supply equipment, and programs directed at helping disadvantaged customers and communities [10, 11]. ACEEE also publishes reports ranking top states and cities for energy policies, which supports their research on utility performance. In addition to ACEEE's work in this area, there is also an established body of research analyzing the relative economic rewards and trade-offs of particular device incentives and program design and delivery [12-14]. Our research is unique in focusing exclusively on plug load devices, which do not receive much attention in the literature, especially when compared to other building loads such as HVAC and lighting. Furthermore, our descriptive approach serves as a "best practices" model to demonstrate implementation methods and examples for different types of programs and geographical areas, as a complement to other research that focuses on levelized economic impact analysis across utilities and program types.

US Policy Background

It is useful to briefly describe the policymaking context for plug load-related codes and standards in the US. Federal law requires minimum efficiency standards for most domestic and commercial "white goods" appliances. These minimum codes are supported and advanced by additional voluntary labeling programs such as ENERGY STAR, which requires higher levels of efficiency performance and provides qualified product lists to help customers make informed decisions. State laws may build upon minimum federal standards for their jurisdictions. For example, California Title 20 both increases minimum efficiency requirements for federally regulated devices and extends plug-load standards to a greater variety of end-use products, such as consumer electronics (e.g., televisions and desktop computers) [15, 16].

Individual states also have the authority to set requirements for utilities in their jurisdictions for providing energy efficiency incentives. The major utilities in turn are fully responsible as independent operators to incorporate state mandates into their program portfolios, e.g., through offering rebates on EE equipment. This produces an uneven application of programs at the national level, with some states (e.g., California) vastly outperforming other states in the robustness of EE program portfolios.

The primary goal of state and local governments and utility providers is to encourage residents and businesses to use less energy and adopt energy-saving products and practices. There are multiple delivery mechanisms for implementing EE incentive programs: upstream, midstream, and downstream. Upstream programs are aimed at changing manufacturing practices, e.g., through the inclusion of efficient and eco-friendly parts. These changes can be spurred by regulations enacted by federal and state governments as well as codes developed by professional organizations such as ASHRAE and IEEE in the U.S. Utilities operate solely at the downstream and midstream levels. Downstream programs are aimed directly at end use customers, typically through rebates of qualified energy-efficient HVAC, lighting, and other equipment. By contrast, the goal of midstream programs is to increase the market share of energy-efficient products by incentivizing distributors and retailers to stock these products and make them readily available to customers, rather than incentivizing customers directly [17].

Importance of Plug Load Devices for EE

Miscellaneous electric loads (MELs) are all building electrical loads that are not associated with HVAC or lighting, the traditional end uses targeted by utility EE programs [3, 18-20]. The majority of MELs are not regulated by federal standards [1, 4], which creates an opportunity for EE programs to steer the market towards more energy-efficient solutions [21]. MELS include both plug loads (freestanding devices that plug into outlets) and process loads, which are hard-wired into the building circuitry and include systems such as security cameras and doorbells. Process loads are often sold, installed, and incentivized differently than plug loads, and are outside the scope of the current project.

MELs are getting more attention as the traditional end uses, such as HVAC and lighting, have become more energy efficient in commercial buildings [22]. Thus, the relative contribution of MELs to a buildings' total energy consumption is increasing [1, 23]. Moreover, the amount of building energy use attributed to plug load devices has also been on the rise as the absolute number of such devices in commercial buildings has been increasing, and there is consensus that the energy consumption from plug loads will continue to grow [2-4].

Approach and Methodology

This report is an extension of a study performed by the California Plug Load Research Center (CalPlug) for Commonwealth Edison of Illinois, assessing how they might expand their EE program opportunities for greater inclusion of plug load devices. That study focused on a deep dive into one utility's EE programs, comparing them to those of other utilities, to make specific recommendations. The current study pulls back to assess all the target utilities' programs for a broader view on opportunities across the portfolio landscape.

As described earlier, the goal of this study is to review potential downstream and midstream incentive approaches for utilities to target plug loads in their program portfolios. We took a three-pronged approach to identify potential opportunities for plug load related program recommendations. First, we compiled a list of plug load devices and selected devices that were the most promising for achieving energy savings and positive program return on investment potential. Second, we identified all the energy efficiency programs that involved plug load devices in the portfolios of a list of 20 U.S. utilities, based on top performers in the ACEEE Utility Scorecard rankings [11]. Third, we compared these programs to best practices. The results are descriptive; evaluating the effectiveness of all of these programs across or between utilities is beyond the scope of the current project, as is assessing whether any given approach would be cost-effective for a specific utility. To better illustrate how strategy adoption might take place for utilities that do not currently fully incentivize plug loads, we sorted the potential opportunities into three groups: adding a plug load-related program; adding specific plug load devices to existing programs; or modifying the approach of current programs.

Device Selection

The first step was to identify commercial plug load devices that should be considered. We compiled an initial list using inventory and monitoring studies conducted in a range of office buildings and other institutions [1, 22, 24, 25] and from the product list of the Office of Energy Efficiency & Renewable Energy [26]. The next step required determining whether each device offered an energy efficient alternative that could be incentivized, either through utility rebate programs, or point-of-sale discounts. For the majority of devices, this meant locating data on average energy consumption for ENERGY STAR-certified models versus non-efficient models of the same type of device. Some devices did not have ENERGY STAR (or other certification) options but did offer an alternate type that saved energy due to a technological improvement. For example, heat pump dryers are currently assessed under the broader category of clothes dryers, and do not have separate qualification requirements.

Primary data sources included: Federal Energy Management Program (Energy.gov); Stanford Study [27]; Office Plug Load Field Monitoring Report [28]; and ENERGY STAR. After exhausting the top four sources, additional individual sources were found for the remaining devices, most providing data for only one device each.

The estimates for energy usage and energy savings derive from many disparate sources and thus reflect a range of unspecified assumptions and selection criteria. Given this limitation, we are cautious about quoting energy savings for devices, which implies the ability to compare savings across devices. We cannot justify using this information to make more detailed calculations about cost-effectiveness. Instead, the estimates are accepted as *prima facie* evidence that a potential for energy savings exists, and no minimum bar is set for potential consideration.

The team determined whether each device was in scope for the current assessment by using a decision tree, shown as a flowchart in Figure 1. Specifically, a device was considered in scope if it:

1. Offers the potential to save energy through an available energy-efficient alternative, usually an ENERGY STAR-certified option, but possibly another energy-efficient technology; OR
2. Can be made more energy efficient by using plug load control strategies; AND
3. Shows sufficient device population; OR
4. Is a system that controls plug load devices

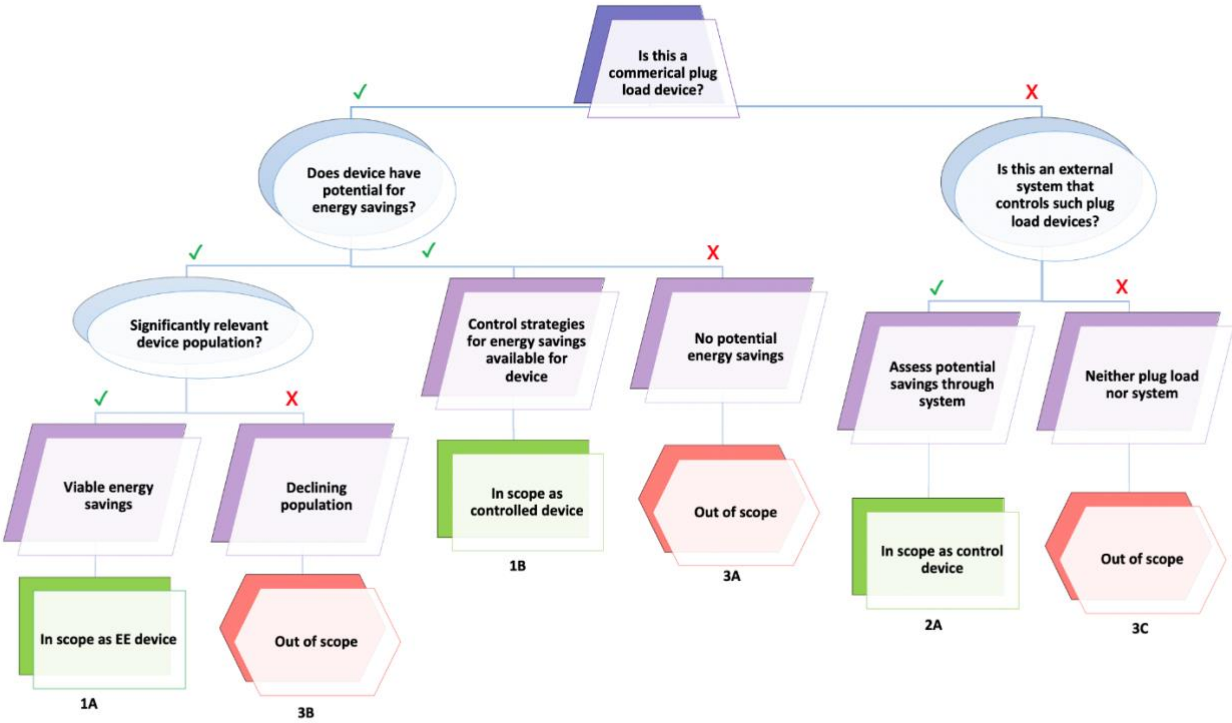

Figure 1. Device Selection Flowchart

Selection was biased toward inclusion rather than exclusion. For instance, any device with an energy saving alternative met that criterion, regardless of the extent of the savings potential. Only two devices were determined to have low enough future population in the commercial sector to justify excluding: DVD players and VCR players.

The device flowchart narrows down selection by removing devices that do not have energy savings alternatives and are declining in the current market. In addition, the flowchart helps to identify which plug load devices can be effectively controlled by external systems, usually through simple power cuts. Such systems can be implemented with existing or new devices, for example a Tier 2 Advanced Power Strip (APS) paired with computers and computer peripherals such as speakers and printers. Table 1 contains a detailed list of the devices determined to be in scope, along with their selection criteria.

Table 1. Selected Plug Load Devices and Standard Incentives in Commercial EE Programs

Devices in Scope	Device Code	Devices in Scope	Device Code
Computer, Desktop	1A, 1B	Cash Register	1A
Computer Monitor	1A, 1B	Residential Freezer	1A
Computer, Laptop	1A, 1B	Residential Refrigerator	1A
Thin/zero client	1A, 1B	Mini-Refrigerator	1A
Computer Power Management Software	(INAP)	Commercial Freezer **	1A
Printer/Copier	1A, 1B	Commercial Refrigerator**	1A
Scanner	1B	Residential Dishwasher	1A
Multi-function Device	1B	Commercial Dishwasher**	1A

Plotter	1B	Commercial Oven **	1A
Server	1A	Fryer **	1A
UPS Units	1A	Hot Food Holding Cabinet	1A
Television	1A, 1B	Griddle	1A
Projector	1B	Wrap Machine	1A
Audio System	1B	Steam Cooker	1A
Speakers	1B	Refrigerated vending machine	1A
Advanced Power Strip, Tier 1	2A	Vending Machine Control/Miser	2A
Advanced Power Strip, Tier 2	2A	Ice Machine	1A
Smart Plug	2A	Microwave	1B
Plug Load Occupancy Sensor	2A	Coffee Maker	1B
Paper Shredder	1B	Espresso Machine	1B
Task/Desk/Floor Lamp	1B	Toaster/Toaster Oven	1B
Room AC	1A, 1B	Hot Water Dispenser	1B
Dehumidifier	1A, 1B	Water Cooler	1A, 1B
Space Heater	1B	Clothes Dryer	1A
Fan	1B	Commercial Clothes Washer	1A
Pool pump (VSD)	1A	Residential Clothes Washer	1A

Utility Selection

Selection of utilities to examine was based in part on whether their plug load programs or overall portfolio had earned accolades in the 2020 American Council for an Energy-Efficient Economy (ACEEE) utility scorecard, which many researchers in the field consider to be a "gold standard" resource for utility program analysis and rankings [11], or had other indications of strong performance on EE programs in general. As the initial research project was funded by Commonwealth Edison (ComEd) in Illinois, utilities in nearby or similar geographical and climate regions were also prioritized.[1] We also consulted the Better Buildings Plug Load Efficiency Utility Incentives List, published by the U.S. Department of Energy, which lists all plug load products included in U.S. utility incentive programs, and compares incentive amount data across utilities.

Utility EE Program Comparisons

The research team compared all EE programs and program components across the 20 selected utilities to assess their inclusion of plug load devices in individual incentive and holistic programs. These programs were either device-targeted (such as specific, or standard, incentive amounts for particular qualified products), or were directed at the level of a holistic program (such as programs targeting small businesses, online marketplaces and midstream delivery systems, and customizable whole-building projects). Thus, two main approaches emerged: device/controls incentives and integrated, holistic programmatic strategies. The key quantitative results of these comparisons identify the types of programs that incorporate plug load devices and how many of the examined utilities use that strategy. The key qualitative results look in more detail at how exactly the programs incorporate plug load devices and applies advice from best practices to these strategies.

After selecting the 20 comparison utilities, we consulted the websites of each company for greater detail of their specific programs. Information obtained included not only incentive amounts for specific devices, but also information on program design, program customer targets/industry segments, and detailed fact sheets on installation steps and how to obtain rebates and/or instant discounts. We entered these details into a comprehensive spreadsheet to facilitate the analysis of quantitative data (i.e., incentive amounts, number of participating utilities), and qualitative data (how programs were implemented and

[1] Specifically, utilities included: Ameren Illinois (Illinois); Baltimore Gas and Electric (Maryland); Commonwealth Edison (Illinois); Consolidated Edison (New York); Consumers Energy (Michigan); Efficiency Vermont (Vermont); Energy Trust of Oregon (Oregon); Eversource Connecticut (Energize CT) (Connecticut); Eversource Massachusetts (Massachusetts); Florida Power and Light (Florida); Georgia Power (Georgia); National Grid (Massachusetts); New York State Electric and Gas (New York); Pacific Gas and Electric (California); Sacramento Municipal Utility District (California); San Diego Gas and Electric (California); Southern California Edison (California); We Energies (Focus on Energy) (Wisconsin); and Xcel Energy (Minnesota)

marketed to customers). We also evaluated the user experience of each utility's website interface, such as ease of access and logical links between pages, clarity of language and presentation of program outlines and requirements, inclusion of useful diagrams/images, and general aesthetic quality.

There are many reasons why utilities would differ in whether they decide to include a particular device in their commercial EE program portfolio. Each utility must judge the measure or program to be cost effective, given their specific regional context and climate and customer base. There are also multiple quantitative analysis methods that utilities may use to calculate program cost effectiveness, ranging from simple return-on-investment calculations to more complex calculations that seek to also account for benefits to society, such as environmental and non-energy benefits. The most common metric is the Total Resource Cost, or TRC, which is defined as the benefits of the measure or program (described as savings or avoided costs) over the cost of program materials and administration (See Appendix A for details of TRC calculation). Net positive programs are those that yield a score greater than or equal to one [29, 30]. Furthermore, many utilities also calculate program attribution (to address the free rider problem) using an additional calculation of the net-to-gross ratio. An independent evaluation of the relative program cost-effectiveness between utilities was beyond the scope of this project, and data published by utilities was inconsistent and incomplete. However, we did consider general program success on a heuristic basis, e.g., that programs that have been continued and built upon for multiple consecutive years would represent a value proposition, and thus a high return on investment for utilities.

Individual Device-based Programs

Standard Incentives

Energy efficient devices

One way utilities incorporate plug load devices into EE programs is through standard incentive programs. Standard incentive programs offer prescriptive incentive amounts or rates for pre-approved qualified products or behaviors, typically administered as rebates. Most standard incentives encourage customers to purchase more energy-efficient equipment, while others encourage purchase of control system devices (e.g., vending machine "misers") or networked computer power management systems. A summary of the standard incentives observed in the utilities in this study is shown in Table 3. This table compares our research on the 20 selected utilities to the plug load incentive database maintained by the Department of Energy [31]. Selected devices are discussed in more depth in this section.

Table 3. Standard Incentives

Device	Selected 20 Utilities: Participating Utilities	Selected 20 Utilities: Incentive Amount	DOE Better Buildings Utility Database*: Participating Utilities	DOE Better Buildings Database*: Incentive Amount
EE devices				
Computer, Desktop	0	-	4	$4-$12/device
Computer Monitor	0	-	1	$5/device
Computer, Laptop	0	-	0	-
Thin/zero client	1	$10/device	5	$5-$50/device
Printer/Copier	0		1	$10/device
Server	1	$100/device	3	$15-$200/device
UPS Units	2	$20/kW; $1,400-$4,000 (by size)	1	$55 per kW
Television	0	-	1	$150/device
Room AC	2	$25-$200/device	2	$25-$50/device
Dehumidifier	3	$25-$50/device	3	$10-$25/device
Cash Register	0	-	0	-

Residential Freezer	1	$50/device	2	$25-$200/device
Residential Refrigerator	3	$35-$150/by size (multi-family)	3	$25-$200 (by size)
Mini-Refrigerator	0	-	0	-
Commercial Freezer **	9	$35-500/device (ranges by size)	0	-
Commercial Refrigerator **	8	$45-400/device (ranges by size)	0	-
Residential Dishwasher	1	$50/device	2	$25-50/device
Commercial Dishwasher **	13	$50-$2000 (ranges by features, size)	2	$25-$50 (ranges by features, size)
Commercial Oven **	13	$170-$2,000/device (ranges by features, size)	0	-
Fryer **	12	$150-$750/device (ranges by features, size)	0	-
Hot Food Holding Cabinet	13	$200-900/device (ranges by size)	0	-
Griddle	13	$130-$650/device or $150-$200/linear ft.	0	-
Wrap Machine	4	$125-275/device	0	-
Steam Cooker	13	$750-$2500/device	0	-
Refrigerated vending machine	1	$50/device	0	-
Ice Machine	12	$50-$800 (varies on type, capacity)	0	-
Water Cooler	1	$50/device	1	amount not available
Clothes Dryer	1 (heat pump)	$200-400/device	2	$50-$300/device
Commercial Clothes Washer	5	$20-$300/device (varies on features)	2	$50-$100/device (varies on features)
Residential Clothes Washer	3	$50-$65/device (multifamily)	1	$50/device
Pool pump (VSD)	4	$100-$600/device	0	-
Control devices				
Computer Power Management Software	3	$10/laptop; $10/monitor; $12-$20/desktop	13	Majority $9-10/device; range $4-$32/device
Advanced Power Strip, Tier 1	4	$4-10/device rebate or discount on marketplace	12 (plus 6 not specifying Tier 1 or 2),	Majority $10-15/device; range $1-$25/device
Advanced Power Strip Tier 2	0	-	5	$20-$50/device
Smart Plug	0	-	0	-
Plug Load Occupancy Sensor	1	$10/device	8	Majority $20/device; range $11-$25/device

Vending Machine Miser	7	$25-$150/device (higher for refrigerated)	96	$25-$150/device (higher for refrigerated)
* DOE Better Buildings Database consists of self-reported data for plug load device incentives (>150 utilities across the U.S.)				
** Programs for commercial food service appliances differentiate by major features, e.g., solid door versus glass door for refrigerators and freezers, or convection versus combination oven				

Results show strong consensus around offering standard incentives for many commercial food service appliances, albeit a wide range of incentive amounts. This reflects the higher up-front cost and larger energy consumption of these devices compared to other plug load devices on this list. Commercial kitchen energy consumption is on average 5 to 7 times higher per unit of floor area than other commercial sectors [32]. Energy-efficient equipment is even more expensive, making it more difficult for businesses to justify. The price differentials between standard kitchen equipment and ENERGY STAR models are generally large enough that even with expected cost savings through energy savings, substantial rebates are needed to incentivize them [33]. ENERGY STAR has recommended incentive amount ranges that they deem appropriate for commercial kitchen appliances. Likewise, clothes washers that are ENERGY STAR certified are about 25% more efficient and use about 45% less water than the standard models.

For major appliances such as clothes washers, clothes dryers, dishwashers, and refrigerators, few utilities offer incentives for residential grade appliances to commercial customers, even if they offer them to residential customers. Adding such incentives can potentially benefit small businesses with lower capacity needs, multifamily building owners furnishing apartments, and businesses using residential equipment in their staff break rooms.

Results also show consensus against using standard incentives to promote energy efficiency for office equipment such as computers, printers, and televisions. Computers (desktops and laptops) and monitors are some of the most prominent plug load devices consuming 10-20% of total energy consumption in commercial buildings [34]. Although ENERGY STAR versions of these devices exist, the generally modest amount of energy saved warrants an equally modest incentive, at best [35]. However, these incentives are quite small compared to the cost of the devices and are thus unlikely to motivate consumers. Also, the majority of products sold in 2018 were ENERGY STAR-certified products, especially in the imaging and notebook category [36]. At the same time, many businesses contain large numbers of these devices, and the small amounts of energy saved per device can add up, suggesting that they should not be ignored. Utilizing centralized power management software can save energy for a large number of computers, making incentivizing these systems through standard incentives cost-effective. NREL estimates suggest that enabling standby mode after 15 minutes of inactivity can save about 500 kWh/yr. per desktop computer [37]. Savings for these devices can also be enhanced by encouraging efficient use of power management settings and external control systems for computers and imaging equipment. Savings may also be incentivized in holistic programs by encouraging replacement of desktop computers with laptops or with thin clients. For instance, one study estimated that switching from desktops to thin clients results in a 66-73% reduction in annual energy consumption [38].

Room air conditioning (AC) units and dehumidifiers condition space in individual rooms, which can be an effective way to save energy when whole-building HVAC systems are not applicable or affordable. Room air conditioning units that are ENERGY STAR certified use 10% less energy on average [39]. In 2016, the DOE finalized new standards for dehumidifiers, which represent energy savings of about 15-25% [40]. Even among utilities that offer incentives for energy efficient options to their residential (and low income) customers, few offer the same incentives to commercial customers.

Heat-pump clothes dryers are a special case. While other major appliances have undergone significant energy efficiency improvements in recent decades, the energy wasted by electric clothes dryers has been consistent since the 1970s [41-43]. Heat pump dryers represent a major breakthrough, being both cheaper to run and gentler on clothes [44, 45]. As of 2020, ENERGY STAR offers a list of 10 dryers designated as “Most Efficient Products," all of which utilize heat pump technology [46]. Tests of heat pump technology in residential-grade dryers indicated they are 50%-60% more energy efficient than conventional dryers and about 47% more energy efficient than efficient electric dryers without heat pump technology (producing 333 kWh/year in energy savings) [41, 45]. Another evaluation concluded that hybrid heat pump dryers save 30% more energy than market average while heat pump dryers save 50% more energy. Moreover, conventional ENERGY STAR rated dryers saved 8% more on average than the market average. This report emphasized the significant energy savings opportunity (200kWh-600 kWh) available through integration of heat pump technology [47]. Only residential-grade heat-pump dryers are currently sold in the U.S. and only one utility in our study (Efficiency Vermont) includes it, but they offer incentives to both residential and commercial customers. Other, smaller utilities are moving forward with incentivizing heat-pump and hybrid heat-pump dryers, and we expect others to follow suit in the near future, as these devices further penetrate the U.S. market.

As major end uses become more efficient and pressures for additional savings increase, plug load devices that have more moderate savings potential may gain more attention, such as cash registers. Commercial retail sectors use point-of-sale equipment that needs a constant energy supply in order to function effortlessly for transactions. This equipment includes cash registers, demagnetizers, barcode scanners and scales, handheld barcode scanners, and conveyer belts. Combined, these devices can use 75–130 W. On average, point-of-sale equipment can cost $100/unit annually to power if left on continuously [48]. Upgrading cash registers to models with standby modes can save up to 222 kWh/year [49, Appendix 1]. Doing a walk-through of the facility to identify equipment that can be updated can save 30-40% on energy consumption [49]. None of the comparison utilities offer a standard incentive for cash registers. ENERGY STAR does not evaluate cash registers, despite the energy savings of models that include standby modes. We are not aware of any efforts in this area. In the meantime, utilities should ensure that facility assessments for relevant businesses include advice about upgrading cash registers and about using external plug load control strategies to ensure the devices are powered down outside of business hours.

Plug Load Control Systems

Another approach to reducing energy consumption in plug load devices focuses on power management: settings and external control strategies that transition devices into low-power modes when they are not being used. Many utilities in this study incentivize control strategies to reduce unnecessary energy consumption from plug loads, either through rebates or through offering the devices at a discounted price through an online marketplace. Monitoring studies in offices have found that most of plug load devices' wasted energy consumption takes place during nights and weekends, when buildings are unoccupied [9, 21, 50-52].This is a clear indication that investing in computers and other devices that have low-power modes, and ensuring that those settings are enabled, could save energy. Control devices with metering capabilities can have the added benefit of providing users with feedback about the device energy use and periods when energy is being wasted [53]. Control devices of any type should allow manual override to accommodate usage during atypical times [53] to avoid user frustration.

One type of control strategy is power management software for desktop computers, which monitors usage patterns and enters the device into low power mode when idle. Three of the utilities in this research incentivize power management software. Another strategy, particularly for devices that do not have this type of internal power management, is to use external control devices. The most common devices include advanced power strips (APS), occupancy sensors, and smart plugs. There are two versions of APS devices: Tier 1 and Tier 2. Tier 1 devices save energy by ensuring that peripheral devices (i.e., monitors, printers etc.) are switched off when the primary device (i.e., desktop computer) is switched off by the user. This prevents the peripheral devices from consuming “vampire”, or standby, power. We found that 7 out of 20 utilities currently incentivize Tier 1 APS devices. This strategy depends on the user to power down the primary device. Tier 2 APS are enhanced versions of Tier 1 devices and include occupancy sensors that track when the primary device has entered idle mode, and automatically powers down the primary and peripheral devices connected to the power strip [54]. Although none of our target 20 utilities offered incentives for Tier 2 devices, the DOE Better Buildings database lists some utilities that do. Smart plugs use internet connectivity to power down devices plugged into the outlet, primarily through mobile apps and voice control. Although we could find no utilities that currently incentivize these devices for the commercial market, they are a growing category in the residential sector, and many potential applications for commercial offices also exist.

Occupancy sensors are triggered when a person enters a room and activates the connected device. When no activity is sensed over a specified period of time, the sensor powers down the device. The most common use of occupancy sensors in commercial buildings are hard-wired lighting systems.

However, a number of plug-in products are also compatible with occupancy sensors. For example, ComEd incentivizes passive infrared and ultrasonic plug load occupancy sensors to control plug load equipment with $10 per sensor. The sensor must be used to control equipment in offices and cubicles, including lighting, shared copiers, and printers [55]. We found that 8 out of 20 utilities in this study incentivized occupancy sensors.

Finally, specialty control devices, such as vending machine ”misers”, utilize occupancy sensors. Vending machine misers use a motion sensor to deactivate the lights and power down other systems when nobody is near, then activates the vending machine when somebody approaches it, saving energy while maintaining key elements of the machine's mechanical system [56]. NREL research indicates that employing load management devices on refrigerated vending machines can save about 950kWh/yr. per vending machine [37].

The savings of external control devices such as APS, motion sensors and misers, and smart plugs depends on how effectively they are installed and maintained by the user and which devices are controlled by the device. Given the variation in model designs and inconsistent terminology across brands, one challenge is effectively communicating to customers which devices qualify under the program. Another challenge is that such devices are deceptively easy to install incorrectly [6], resulting in no energy savings even though the devices appear to be functioning.

Online Marketplaces

Four of the 20 utilities encourage commercial customers to buy energy efficient devices and control strategies through online marketplaces. These marketplaces, maintained by the utility, sell small energy-saving devices directly to customers at discounted rates. As utilities are increasingly looking for new cost-effective measures, online business marketplaces represent a simple, yet profitable way of expanding program portfolios [57, 58]. Online marketplaces provide discounted products, including advanced power strips (both Tier 1 APS and Tier 2 APS), smart thermostats, smart home products, water-saving aerators, and lighting sold directly through the utility website. While such marketplaces are more often targeted to residential customers (true for 12 of the 20 utilities), they can be expanded to commercial customers as well. They may also benefit from including a wider range of control devices, as mentioned earlier. For example, a measure and verification study in 2019 showed Ameren Power’s program (Illinois) to be highly successful. Based on the utility’s net-to-gross ratio calculations, APS devices achieved 100% of the targeted energy savings, while the smart thermostat category achieved 101% of its energy savings goals and lighting savings realized 94% of its target [59].

A second approach is a brokering platform, which helps customers learn what types of products would work for them, which models are incentivized, and where to buy them. Brokering platforms are operated by third parties contracted by the utility, which provide lists of qualified products for their incentive programs along with product comparison tools for price and reviews, and links to retailers in the state that stock rebate-eligible products. Currently, no utilities offer the brokering platform for commercial customers, and are aimed instead at residential customers. However, several examples provide a possible roadmap for future commercial customer inclusion. Efficiency Vermont provides a page with product comparison tools for price and reviews, and links to retailers in the state that stock rebate-eligible products. Consolidated Edison (New York) provides comparison tools along with energy usage and product performance scores on its residential marketplace site.

Midstream Programs

Several utilities in the comparison study use midstream incentive delivery programs, especially for commercial kitchen appliances. The goal of the midstream program design is to encourage market transformation by targeting suppliers, distributors, and retailers. By influencing purchasing decisions of energy-efficient products throughout the supply chain, the product choice set for end customers will tend to become more energy efficient over time. Midstream incentives are generally paid to the supplier or distributors when they select specific approved models for their inventory. Ten of the utilities examined here offer or are pilot testing midstream incentive programs for commercial food service equipment to commercial customers, (ComEd, Focus on Energy, PG&E, SCE, Consumers Energy, SMUD, SDG&E, and Efficiency Vermont).

Although midstream programs do not always require distributors to pass point-of-sale discounts directly to customers, most of the utilities in our comparison study do specify end-use customer incentive amounts. Another type of midstream model offers incentives to individual sales representatives to motivate them to promote energy-efficient equipment; the aim is to disrupt the status quo practice of highlighting the lowest-cost products to customers. For example, PG&E and National Grid offer pre-approved sales commissions (known as "spiffs") to sales representatives at participating distributors for each qualified energy-efficient kitchen product they sell [60, 61].

Best practice research stipulates several characteristics that make technologies and products successful in midstream incentive delivery: the product must constitute a defined market, be cost-effective for long-term energy savings, and produce enough energy savings to merit start-up program costs [62]. Many plug loads, particularly commercial kitchen equipment, meet these criteria. Kitchen equipment is a good category to initially target to midstream programs, because they are more costly and produce greater energy savings than most other plug load categories and yet, like other plug loads, these devices are generally easy to self-install and do not require the deep infrastructure integration that HVAC equipment does. For example, ovens, fryers, refrigerators, and dishwashers are easily exchanged, and require minimal building integration during installation.

Holistic Programs

Custom Incentives

Most utilities (12 out of 20) in the study group also offer their commercial customers custom incentive programs that are based on energy efficiency performance of installed measures, selected on an a la carte basis. Whereas standard incentives offer a set rebate or discount for investing in a particular energy efficient solution, custom incentives are based on results. Custom incentive programs allow the utility customer to develop a tailored energy-efficiency plan for their facility which is evaluated and approved based on the expected energy savings and costs. This gives business customers a wide selection of options that are flexible enough to meet their unique needs. However, this process typically requires the involvement of an energy advisor and a complex application process. By comparison, the clear-cut nature of standard incentives makes the application process easier, faster, and more predictable for customers, and thus appeal to those who may not have the time or resources to commit to a full custom program.

Small Business Programs

Almost all of the comparison utilities (19 out of 20) offer some type of small business incentives package. In practice, this covers most utility customers. For instance, ComEd defines eligibility for "small commercial" as up to 100 kW peak demand, which includes 95% of their commercial customers. Small business program participation typically begins with a free in-person facility assessment conducted by a utility-approved contractor. The service provider installs no-cost "direct install" measures, such as showerheads, bathroom and kitchen faucet aerators, Tier 1 APS, and vending misers [63]. The assessment results in a comprehensive report including specific recommendations for EE measures and projects. Customers then choose which projects they wish to pursue, and the service provider offers full installation services. Assessment paired with direct install offers robust opportunities to effectively integrate plug load control strategies into energy efficiency efforts. Depending on the types, locations, and usage patterns of their equipment, some businesses will benefit more from load-sensing Tier 1 APS devices, while others will benefit more from timer-based APS devices, Tier 2 APS devices, or occupancy sensors.

Addressing plug loads in offices is especially important. Offices use a wide range of plug load products, such as computers, monitors, projectors, TV screens, shredders, printers, and multifunction devices (combining printing, scanning, and copying). Previous California Energy Commission research shows that such devices cumulatively waste considerable energy by being left on when not used, especially overnight and on weekends [28]. Energy Trust OR offers a program specifically targeted at small offices that provides measures for lighting, lighting controls, APS devices, power management software, and data server measures such as UPS and mini-split air conditioning units for server closets. Energy Trust OR also offers this program on a tiered scale, offering greater incentives for more complex and integrated projects

Many utilities also offer small businesses free self-install kits that include devices such as Tier 1 APS devices, smart plugs, lighting measures for small offices, and faucet aerators and pre-rinse spray valves for food service customers. These programs allow an easy first step to engage customers and provides an introduction into further EE programs. However, the gesture could potentially backfire if customers do not actually use the free devices.

Plug Load Education and Training

Many utilities provide educational materials on their website on efficient plug load equipment and control strategies. For example, BGE explains the rationale of offering incentives for smart power strips and other plug load measures. Efficiency Vermont explains various measures, such as APS, energy-efficient computers and monitors, and data center efficiency. Mass Save (Eversource MA, National Grid) addresses, among other things, the rationale of using vending machine misers. The Business Energy Advisor library (offered by FPL, Georgia Power, and We Energies) describes plug load technologies and offers savings tips for a variety of business types.

Facility assessments often focus on large energy end-uses, but they can be an excellent opportunity to encourage customers to reduce plug load energy consumption. For example, ComEd's facility assessment program offers no-cost and low-cost measures to increase the operational efficiency of existing equipment at the site [64].

Emerging Areas of Research

Grid-Interactive Efficient Buildings

“Smart” buildings are an emerging target for EE programs, spurred in part by the growing need for flexible grid management to handle an increasingly dynamic distribution of energy resources. While definitions of this emerging technology are constantly evolving, the key feature is deploying building-wide energy management systems (EMS) that allow holistic internal control of multiple systems and enable dynamic external interactions with the energy grid. The ultimate goal of the GEB is to integrate energy efficiency, demand response, distributed generation sources, EVs, and energy storage measures into a holistic, synergistic system of energy management and savings [65, 66].

GEB technology is still in early stages of development. GEB-related initiatives offered by the utilities studied here currently exist as enhanced automatic demand response (ADR) programs. These programs incorporate EE measures into existing demand response programs and use advanced metering infrastructure (AMI) technology to identify energy waste and suggest upgrades. For example, PG&E offers to install efficient equipment for large commercial customers if done in conjunction with enrollment in their ADR program. The Real Time Energy Management program, offered by the New York State Energy Research and Development Authority, promotes a GEB prototype system that collects real-time smart meter data from commercial, industrial, and multifamily buildings. Data analytics software performs assessments of the participating properties and generates information on energy optimization opportunities for each site [66].

EV Chargers

Over half of the comparison utilities encourage commercial customers who own or operate parking spaces to help expand infrastructure for EVs through EV charging station host programs (ConEd, Consumers Energy, Eversource MA, Georgia Power, National Grid, NYSEG, PG&E, SCE, SMUD, and Xcel Minnesota). This measure affects a wide range of commercial customers, including retail businesses, office buildings, universities, government buildings, and large multifamily residences. The customer initiates program participation by submitting an application. If accepted, the utility visits the property to conduct a consultation, assessing a suitable location for installation. The customer purchases the charger(s) from a vendor qualified by the utility. Note that for many utilities, such as Eversource MA and National Grid, the customer is responsible for the cost of the charging station and initial installation. After sending in proof of purchase, the utility takes on all infrastructure work to connect the charging station to the grid. The utility generally pays for 100% of the consultation and grid infrastructure requirements (e.g., laying new line). Utilities also provide coordination assistance to complete permitting paperwork and equipment inspections (for example, Eversource MA, SCE, National Grid).

Key Findings

We found that successfully implementing plug load EE incentives for commercial customers is often a multifaceted task, that needs to consider not only individual devices, but also information about the customer industry sector, user and building manager behaviors and needs, and technical requirements of individual offices, commercial kitchens, and other commercial buildings. We recommend a multipronged and targeted approach for standard incentives, starting with device upgrades that yield high returns on investment in energy savings and utility bill costs over time. One method that many utilities are piloting is the midstream incentive program for commercial kitchen products, which not only seeks to yield energy savings for the customer and utility, but also aims to transform the availability of products on the market.

Furthermore, individual device incentives should be informed by whole-building energy saving strategies. For example, we do not recommend incentivizing mini refrigerators to commercial customers, as energy efficiency models do not represent large savings, and much higher savings can be achieved by replacing personal office refrigerators with shared full-sized models. Removing underused full-sized refrigerators can save up to 400kWh/yr. per device, and consolidating personal mini-fridges into one full-sized shared refrigerator can save 350kWh/yr. per mini-fridge removed [67]. Additionally, some relatively low-tech devices can be incorporated into incentive programs to better support hard-to-reach customers. For example, we recommend further exploration of incentives for commercial room air-conditioning units, particularly as these devices may benefit small businesses, particularly those who rent space in older buildings and/or in disadvantaged communities.

Similarly, self-install control devices should be paired with informational materials and targeted at more IT-savvy customers, while other customers should be guided toward control device use through interactions with utility advisors and facility assessments. For example, when selecting devices for inclusion in free small business kits, we recommend that utilities design kit combinations that target specific plug load control device(s) to business type (e.g., office, retail, grocery) and offer clear instructions on use.

Our assessment of how utilities managed custom incentive programs suggested to us that holistic custom incentive programs (including training of utility staff) should clearly link to those plug load devices that are covered under standard incentives as alternatives. However, within the custom incentive programs, more efforts could be made to identify plug load alternatives whose smaller savings do not individually merit large standard incentives but that can, in the aggregate, sum to substantial savings. We envision a two-tiered system of evaluation, where standard incentives would be recommended for qualified plug load products for initial or low-investment approaches, while for those customers pursuing larger renovations involving custom incentives, utilities would recommend including a wide range of plug loads, particularly those that are hard-to-reach (e.g., specialized and/or custom equipment for specific industries and applications).

Successful implementation and maintenance of savings from EE programs is further underpinned by education and training of technicians and users. Based on best practices in the field, we recommend training technicians to identify and solve specific plug load devices inefficiencies in facility assessments and EE project recommendations, including determining which type of plug load control strategy is appropriate for the situation. Technicians could demonstrate how exactly to set up an APS or occupancy sensor with a range of devices, and how to check whether multiple types of devices have their standby modes activated. Training and outreach should extend to all stakeholders, including building occupants as well as building managers, IT managers at data centers, and distributers involved in midstream programs. In addition to facility assessments, courses and demonstrations could be held at the utility's sites or remotely.

Finally, investing in up-and-coming technologies, such as EV chargers and GEBs helps to future-proof the utility for the shifting energy policy landscape, which will continue to evolve towards the direction of distributed energy resources (DERs), flexible load and demand side management, and trends in connectivity and the Internet of Things (IoT).

Barriers

Plug Load Diversity

The wide range of plug load devices and the diversity of the commercial sector make it difficult to design programs that are effective for multiple types of businesses. Other types of EE programs apply very broadly, as every building needs lighting, HVAC, and envelope measures such as insulation and windows. But plug load devices--such as printers, ovens, cash registers, and clothes washers--are more specialized and thus have more limited application. As devices do not fit into every program type, utility programs need to take more care to correctly align each device with specific measures that fit the targeted customers.

Plug Load Functionality

Plug loads have unique operational characteristics that make them harder to target in EE programs than HVAC and lighting measures. Individual plug load devices do not use much energy, but the waste accumulates over large numbers of devices. Limited savings per device and relatively short product lives translate to low incentive amounts, which can be discouraging for utilities and customers.

Most plug load devices involve a close level of user involvement, and any perception that energy-efficient appliances translate to a lower quality user experience can be problematic. For instance, energy-efficient dryers and dishwashers have longer run cycles than traditional appliances. Particularly for devices operating in commercial settings, longer operation times can be a strong negative factor. This disadvantage must be outweighed, along with the higher cost, to persuade the customer to purchase energy-efficient options.

There are also special considerations for plug load products when integrated into GEB and ADR programs. Few plug load devices can have their power cut without complete loss of functionality. Users expect devices like computers, projectors, copiers, and cash registers to function whenever needed. Refrigerators and freezers also have physical limitations for load shift and shed without risking food spoilage. Smart connected solutions promise to link up webs of devices, sensors, and energy monitors, but this has not been realized yet. The connectivity features in smart connected devices and appliances do not necessarily save energy; worse, they require a concurrent overhead energy demand for cloud computing needs. Meanwhile, the behavioral strategies that connected devices do enable only save between 3-6% energy over baseline, which is similar to savings that can be achieved by purely behavioral interventions. Finally, interoperability problems--between smart connected devices at the building level and between utility protocols at the grid level--need further resolution before comprehensive GEB programs can achieve goals; GEB programs available in some utility service areas today are largely ADR programs with some integration of energy-efficient building controls and sensors.

Behavioral Barriers

For many plug loads, user behavior greatly impacts the device's ability to save energy. Factors such as selecting temperature and speed settings, load type, and load size greatly influence the ability of some appliances (such as heat pump dryers and dishwashers) to achieve the energy savings promised by the device. Other devices require users to pro-actively enable power management settings, or at least comply by not disabling default settings, to ensure that devices transition to standby mode when not used. Customers generally prioritize energy efficiency rather low in purchasing decisions unless it is connected to saving money. It can be difficult to communicate and convince individual businesses about the importance of reducing plug load energy use at the aggregate building level. In the absence of clear measurement and feedback mechanisms, energy use is invisible in everyday life, and most people are unaware or misunderstand how much energy is used by personal devices in office spaces such as mini-fridges and desktop computers. Similarly, CFS customers and distributors are poorly informed on the energy-saving benefits of ENERGY STAR equipment. Even IT managers, who are experts about computers and data centers, may dismiss or overlook the energy use of these devices.

Changing behavior is generally approached by providing clear information about what to do and motivation about why to do it: in EE programs, this means improving educational resources and incentives. Although education about how to achieve plug load energy savings is universally needed for all business types, the kind of comprehensive training that is required is difficult to provide to each individual business due to the variability of businesses in the commercial sector.

Website interface also has an important impact on customer engagement. This is especially important for promoting information on saving energy with plug load devices, as few customers are even aware of plug loads or plug load controls as device categories and are unlikely to be actively seeking them. Any lack of consistency or problems with navigating across website pages can confuse users and hinder program participation.

Financial Concerns

ENERGY STAR-certified equipment and other energy-efficient options can be much more expensive than alternatives. Furthermore, researching the types of energy-efficient appliances that might be cost-effective for a specific organization, building, or operation takes time. Money and time constraints are common barriers to major investments such as data center hardware and commercial food service equipment, especially for small businesses. Pressures on short term cash flow can prevent customers from investing in energy efficient upgrades, even if it would save money in the medium to long term. For example, low profit margins in the CFS industry leads to replacing equipment only on burnout, which can result in buying the least expensive option that is immediately available. In response, the suppliers and distributors who compete for their business tend to stock older models and refurbished equipment, which are less expensive but also less energy efficient. Similarly, heat pump dryers are considerably more expensive than conventional products, which may inhibit their uptake in commercial laundry facilities, multi-resident apartment buildings, and institutional settings such as hospitals, assisted living, and universities. In terms of power management strategies, Tier 2 APS devices cost more than Tier 1 APS devices, which may discourage businesses from using Tier 2 products, even when their facilities would be more suited to these more sophisticated devices.

Conclusion

In this research, we have assessed the state of the art in commercial utility programs in the U.S. and identified opportunities for improving their inclusion of plug load savings. As lighting and other major end uses such as HVAC become more efficient, plug load energy consumption is garnering attention as an emerging program category. All utilities in the study have measures in place to reduce energy use from certain appliances and electronics. However, some plug load strategies are more effective best practices, such as offering an increased variety of standard incentives for highly efficient “big ticket” products (e.g., commercial kitchen appliances), incentivizing and advising on low-cost solutions for energy management (e.g., APS devices, smart plugs, and power management software), and offering a robust combination of direct install, midstream, and online marketplace programs. Since plug load energy consumption also depends heavily on user behavior, we recommend addressing both technical and educational approaches for improving program engagement.

Finally, we also identified several key barriers to reducing plug load energy consumption through utility EE programs. These barriers broadly include plug load diversity, plug load functionality issues, behavioral barriers, and customers' financial concerns.

Appendix A: TRC Calculation

$$\mathrm{TRC} = \frac{\mathrm{Benefit}}{\mathrm{Cost}} = \frac{\mathrm{UAC_t + TC_t}}{\mathrm{PRC_t + PCN + UIC_t}}$$

	Variables	Definition of Variables	Explanation
Benefits	UACt	Utility avoided supply costs in year t	The avoided supply costs should be calculated using net program savings, savings net of changes in energy use that would have happened in the absence of the program.
	TCt	Tax credits in year t	Any state or federal tax break considered a reduction in the costs test. The inclusion of tax credits or incentives depends on the region considered
Costs	PRCt	Program Administrator program costs in year t	Overhead costs are administration, marketing, research and development, evaluation, and measurement and verification

	PCN	Net Participant Costs	Participant cost = measure cost - participant incentive Can be incremental or total costs, depending on age of pre-existing equipment (i.e., replacing older equipment at the end of its EUL usually uses incremental cost for the new measure)
	UICt	Utility increased supply costs in year t	The costs in this test are the program costs paid by both the utility and the participants plus the increase in supply costs for the periods in which load is increased

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