Paths Forward: Approaches to Achieve Plug and Process Load Efficiency and Control in Commercial Buildings

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ABSTRACT

To accomplish net-zero carbon in the built environment by 2050, we must equitably decarbonize commercial buildings, which includes reducing plug and process loads (PPLs). PPLs are plug-in or hardwired electric and gas loads that are not directly associated with major building end uses like lighting and heating, ventilating, and air conditioning. PPLs account for a growing portion of U.S. commercial building energy consumption.

Although commercial building PPL strategies and technologies are available today, they have not been adopted at a level sufficient to achieve significant savings and load flexibility across the building stock. In our "Pathways to Plug and Process Load Efficiency and Control" study, we investigated why these technologies and strategies have not seen widespread adoption and identified five behavior and technology pathways to increase PPL reduction in commercial buildings. In this paper, we expand beyond identifying the pathways and discuss approaches for achieving them.

We discuss the importance of collecting and sharing data and case studies on PPL energy consumption and savings from control technology implementation, including code-required measures, for increasing adoption. Centralizing case studies and data, engaging industry organizations, and promoting awareness of PPL efficiency benefits to relevant groups are also key approaches. Additionally, funding, incentives, and rebate programs play important roles in driving PPL efficiency and control adoption. Finally, we discuss integrating PPL efficiency into broader company goals, such as environmental, social and governance (ESG) strategies and green building certifications, to further drive adoption.

1. Introduction

Commercial buildings contributed 16% of U.S. greenhouse gas (GHG) emissions (EIA 2023) and 18% of total national energy consumption in 2022 (EIA 2024), making the commercial sector a critical one to address to combat the global climate crisis. Plug and process loads (PPLs) are plug-in or hardwired electric and gas loads in a building that are not associated with another building end use, such as heating, ventilating, and air-conditioning (HVAC) or lighting. This end use encompasses a diverse range of equipment and device types, including computers, printers, kitchen equipment, vertical transportation, and medical imaging equipment, all of which are integral to the daily operations of commercial buildings. PPLs represented 28% of commercial building energy consumption in 2018 (EIA 2022). Increasing use of plug load devices, along with ongoing efficiency improvements in other end uses, have made PPLs an increasingly significant contributor of total building energy use.

While commercial building PPL efficiency and control technologies exist today, they have not seen the uptake needed to achieve meaningful savings and load flexibility across the

building stock. The PPL Technology Research Team at the National Renewable Energy Laboratory (NREL) conducted a study to investigate the key factors impacting adoption of PPL efficiency and control in commercial buildings (Van Sant et al. 2024). We interviewed 22 commercial building stakeholders and hosted a workshop with 22 members of the smart buildings industry. Study participants included building owners, facility managers, design engineers, building energy management technology manufacturers, and sustainability managers. Using grounded theory (Glaser and Strauss 1967), we analyzed participant responses using coding and categorizing the response narratives, resulting in five pathways to greater PPL efficiency and control implementation:

- **Funding**: Increase funding opportunities to implement PPL efficiency and control, such as incentives and rebate programs.
- **Case studies**: Increase the number of available PPL efficiency and control case studies and disseminate best practices across the commercial building industry.
- **Data**: Compile PPL baseline consumption data en masse for the whole U.S. commercial building stock.
- **Energy codes**: Continue to include PPL monitoring and reduction measures in commercial building energy codes.
- **Company goals**: Promote adoption of company goals, including but not limited to, environmental, social and governance (ESG) goals, sustainable development goals (SDG), and emissions targets.

This paper details the approaches by which these pathways can be achieved—via a coordinated effort across building owners, facility managers, industry, utilities, researchers, and government/national labs.

2. Background

Commercial building owners and operators have various methods to manage PPLs. One approach is to implement load reduction strategies, where non-essential PPLs are deliberately turned off when they are not in use, such as during unoccupied hours. These strategies include occupant awareness programs that feature training sessions and informational campaigns to educate occupants about the energy impact of PPLs. These programs often involve communication and signage reminding occupants to turn off PPLs when not in use, as well as PPL champions who organize and promote energy-saving initiatives. Additionally, these programs are frequently linked to the adoption of PPL control technology (Jenkins et al. 2019). Another effective approach is gamification and incentive programs that reward occupants for energy-saving behaviors, which have been shown to reduce energy consumption and foster energy stewardship (Hafer et al. 2018; Paone and Bacher 2018).

Additionally, there are various types of plug load control (PLC) technologies, also known as plug load management (PLM) systems. Most of these technologies cut power to PPL devices to reduce standby energy consumption when they are not in use. Existing control technologies include advanced power strips (APSs), smart outlets, and automatic receptacle controls (ARCs). Some of these technologies are beginning to incorporate load flexibility capabilities.

Integrating PPL control systems with other building controls can significantly enhance energy savings, and several such integration projects have emerged in the past 3-5 years. PPL control technologies are often well-suited for integration with lighting control systems, as they can utilize occupancy sensor data already used by the lighting system (Davalos et al. 2020; Myer and Sandahl 2022). Integration with building automation systems (BAS) is less common. This area is actively being researched, with one demonstration showing that integrating smart outlets with a BAS on a university campus resulted in 66% energy savings (Chia et al. 2023).

Studies on PPL efficiency and control adoption are limited. Tekler et al. (2021) found that concerns about automated PLM systems included usability, disruption to plug loads, and workflow interference. Ideal PLM systems were seen as intuitive, easy to use, and easily integrated with other management systems. Kandt and Langner (2019) discovered that occupant frustration with incompatible schedule controls led to unplugging PLM devices, reducing energy savings. Engagement with both operations staff and occupants is crucial for successful implementation. Hafer et al. (2018) demonstrated a 21% reduction in daily energy consumption through a PLM system that enabled active occupant engagement, highlighting the effectiveness of this strategy.

Newer, larger, owner-occupied buildings are more likely to adopt energy-efficient technologies due to affordability, while rental buildings face the split-incentive problem (Andrews and Krogmann, 2009). Solutions to the split-incentive problem include green lease structures (White et al. 2020). Policy plays a critical role in energy efficiency adoption, with mandatory, voluntary, and economic incentive categories each presenting unique challenges (Shen et al. 2016). Complementing voluntary policies with mandatory ones can enhance adoption, especially at regional/local levels where coordination is often limited (Björklund et al. 2023). Focused policy strategies can improve technology adoption, as seen with residential heat pump water heaters (Mills 2022). Building energy codes like ASHRAE 90.1, IECC, and California Title 24 have been found to drive the adoption of energy-efficient technologies and product innovation (Schwartz and Krarti 2022; Vaughan and Turner 2013).

3. Methods

We virtually interviewed commercial building stakeholders and hosted a virtual workshop with members of the smart buildings industry. Study participants included building owners, facility managers, design engineers, building energy management technology manufacturers, and sustainability managers (Table 1). Interview participants were recruited using an online form that was distributed to commercial building stakeholders via existing email distribution lists, colleague contacts, and professional social media (LinkedIn) posts. We received 32 form submissions and selected 22 participants based on achieving an even distribution by category. We hosted the workshop in collaboration with a smart buildings industry group. All group members were invited, and 22 attended. Applying grounded theory (Glaser and Strauss, 1967), we analyzed study participant responses by coding and categorizing the narratives, identifying five pathways to enhance PPL efficiency and control implementation.

Table 1. Study participant category definitions and counts

Category	Definition	Interview Participant Count	Workshop Participant Count	Total Participant Count
Building Occupant	Occupants of office buildings	3	0	3
Building Owner	Owners of one or more commercial buildings	4	4	8
Consultant	Consultant in the commercial building industry	0	1	1
Design Engineer	Mechanical or electrical engineers working for a commercial building design firm	4	2	6
Facility Manager	Facility managers for one or more commercial buildings	4	5	9
Lighting Industry	Lighting manufacturer, lighting manufacturer representative, lighting industry expert	4	0	4
Sustainability Manager	Sustainability managers for municipality	2	0	2
Technology Company	Building energy management technology company	1	10	11
Total		22	22	44

4. Pathways

In this section, we discuss potential approaches for achieving the pathways published in "Pathways to Plug and Process Load Efficiency and Control" (Van Sant et al. 2024), as summarized in Table 2. The approaches were developed using commercial building stakeholder responses collected as part of the study and our combined 20+ years of experience researching PPLs and the buildings industry. We present the most impactful approaches, but this is by no means an exhaustive list. Note that the next sections are numbered for readability and do not indicate a specific order for implementation.

Table 2. Pathways approaches summary

Pathway	Approaches
Funding	• Promote cost savings opportunities in existing legislation. • Engage utilities to include PPL efficiency and control incentives. • Engage utilities to showcase potential energy savings and grid-interactive capabilities. • Promote awareness of PPL efficiency and control benefits to regional energy efficiency organizations (REEOs), state energy offices (SEOs), and the National Association of State Energy Offices (NASEO). • Share energy savings potential with Energy Service Companies (ESCOs).

Case Studies	• Provide technical assistance to building owners interested in controlling and reducing their PPL energy use. • Create a technology campaign or challenge for PPL efficiency and control. • Identify the building owners who are controlling their PPLs and collaborate with them to develop case studies. • Host the case studies and best practices in a central location. • Disseminate case studies and best practices to high potential sectors. • Build relationships with organizations that can provide funding
Data	• Identify the most impactful data. • Create a central database to host the data. • Establish standardized data collection and reporting protocols. • Increase PPL metering in buildings. • Determine data collection sources. • Encourage owner participation to share consumption data.
Energy Codes	• Create case studies for code-required PPL control technologies. • Get designer and building operator buy-in through messaging and case studies. • Get buy-in from codes and standards organizations. • Inform code requirements through research.
Company Goals	• Communicate the need for ESG, SDG, and other emission reduction targets during ESG leader summits. • Provide sample language for PPL efficiency and control that companies can include in an ESG strategy or plan. • Include PPL efficiency and control measures into green building certification. • Monetize ESG goals implemented into companies and buildings.
Additional Pathways	• Train the workforce. • Standardize technology implementation topologies, protocols, and interoperable systems for PLC

4.1. Funding—Increase Funding Opportunities to Implement PPL Efficiency and Control, such as Incentives and Rebate Programs

Our research showed that lack of financial support for PPL efficiency measures has been limiting technology uptake (Van Sant et al. 2024). By increasing available funding opportunities, stakeholders can implement PPL control strategies and realize reductions in PPL energy consumption. This section outlines approaches to expand funding options, including the implementation of incentives and rebate programs, aimed at accelerating the adoption of energy-efficient PPL technologies in commercial buildings.

4.1.1. Promote cost savings opportunities in existing legislation. Under the Inflation Reduction Act Energy Efficient Commercial Buildings Deduction program, tax code 179D "Provides a tax deduction for energy efficiency improvements to commercial buildings, such as improvements to interior lighting; heating, cooling, ventilation, and hot water; and building envelope" (The White House 2023). While PPL efficiency and control measures are not

explicitly mentioned, building owners may still qualify for deductions through these measures. Building owners should always consult a tax professional or energy efficiency expert to identify applicable tax incentives and ensure compliance with eligibility requirements.

4.1.2. Engage utilities to include PPL efficiency and control incentives. PPL efficiency and control measures have savings potential once completed, but the initial investment by building owners can be cost prohibitive. Incentives are financial rewards or benefits offered by a utility company to encourage customers to adopt energy-efficient practices or technologies. They can help reduce these initial costs, enabling greater PPL efficiency and control implementation. Example PPL efficiency and control measures that could be included in an incentive program include ENERGY STAR®-certified appliances, advanced power strips, computer power management, occupancy sensors that control plug loads, smart outlets, and vending machine controllers.

4.1.3. Engage utilities to showcase potential energy savings and grid-interactive capabilities. Engage with utilities to convey the utility benefits derived from PPL efficiency and control incentives. Utilities can benefit from remote control of certain plug loads during emergencies via smart outlets or ARCs with demand response capabilities. For example, consider the CTA 2045 communication module for PPLs where energy use data is easily exchanged, and demand response messages via OpenADR can be sent from utilities to PPLs to control non-critical loads. This application would be similar to rebates offered for residential smart thermostats or hot water heaters that can be controlled remotely by the utility.

4.1.4. Promote awareness of PPL efficiency and control benefits to regional energy efficiency organizations (REEOs), state energy offices (SEOs), and the National Association of State Energy Offices (NASEO). REEOs, SEOs, and NASEO have access to funding for energy efficiency funding opportunities, rebates, and incentives. Share case studies showing energy and non-energy benefits with these target stakeholder groups to encourage them to incorporate PPL efficiency and control measures in their funding opportunities and incentives.

4.1.5. Share energy savings potential with Energy Service Companies (ESCOs): Disseminate energy savings potential and target sectors with ESCOs. Encourage ESCOs to incorporate PPL efficiency and control measures into their business models and efficiency packages for customers. Share opportunities for integration such as integrated lighting and PLC measures or integrating PLC with the BAS as part of a proposed package to customers. ESCOs could increase funding for PPL management by demonstrating its potential for energy savings and cost reductions, thereby attracting more investment and resources.

4.2. Case Studies—Increase the Number of Available PPL Efficiency and Control Case Studies and Disseminate Best Practices Across the Commercial Building Industry

Lack of available savings data was a common barrier mentioned by Pathways to PPL Efficiency and Control study participants (Van Sant et al. 2024). Dissemination of savings potential and best practices is key for driving widespread implementation and achieving net-zero

carbon goals in the commercial buildings sector. This section outlines the approaches to increase availability and dissemination of PPL efficiency and control case studies.

4.2.1. Provide technical assistance to building owners interested in controlling and reducing their PPL energy use. Many building owners have little to no experience implementing PPL efficiency and control measures. Technical assistance could be offered to building owners to help them assess and reduce their PPLs in accordance with the guidance provided in NREL's *Assessing and Reducing Plug and Process Loads in Office Buildings* guide (NREL 2020). This may include assistance in benchmarking PPL energy use, developing a business case for addressing PPLs, and offering guidance on available PPL reduction strategies. Technical assistance could be offered via the U.S. Department of Energy's (DOE) Better Buildings program, utility programs, technology campaigns, prize awards, lab vouchers, etc. When designing the technical assistance program, a component should include building owners' consent to a case study publication as part of the offering. The building owner would provide final approval before publication.

4.2.2. Create a technology campaign or challenge for PPL efficiency and control. Technology campaigns and challenges can be an effective tool to increase awareness, build interest, and drive implementation of energy efficiency measures. Campaigns and challenges can be facilitated by a utility, a community, within an organization (i.e., from company leadership), or by DOE. The campaign mechanism has been successfully deployed several times in DOE's Better Buildings program.[1] Campaign winning projects gain national recognition and can be used for case study development. A campaign for PPL efficiency and control could include a call for commercial building projects that are controlling and reducing their PPLs with demonstrated energy savings. Like technical assistance programs, a component of the challenge or campaign should include the stipulation that participants must consent to a case study publication, the building owner would provide final approval before publication.

4.2.3. Identify the building owners who are controlling their PPLs and collaborate with them to develop case studies. Building owners successfully controlling their PPLs can be identified via inbound, outbound, and engagement communication efforts. Inbound efforts might include technology campaigns or challenges that attract such building owners, offering recognition in return. Outbound efforts could involve strategic messaging to specific building owners or groups, like Better Buildings partners and energy consultants, to connect with those managing their PPLs. Engagement could include networking at relevant conferences (e.g., Greenbuild, Energy Exchange, International Facility Management Association [IFMA], ASHRAE). Strategic messaging is crucial, as many building owners may not realize they are controlling their PPLs (i.e., it may be embedded in their current practices and not called out as PPL control). Case studies could be written by research organizations, utilities, vendors, REEOs, or SEOs.

[1] Read more about Better Buildings technology campaigns on their website: betterbuildingssolutioncenter.energy.gov/alliance/tech-campaigns.

4.2.4. Host the case studies and best practices in a central location. As PPL efficiency and control case studies and best practices are developed, they should be widely available to foster knowledge sharing and enable implementation. Many organizations host relevant case studies like New Buildings Institute, Northeast Energy Efficiency Partnerships, Northwest Energy Efficiency Alliance, DOE's Better Buildings Solution Center and the U.S. General Services Administration. Federally funded case studies can also be found on websites like DOE's Office of Scientific and Technical Information. Hosting them in a central location would increase accessibility and convenience by reducing the need to conduct a wide internet search. A centralized location also allows for standardization of formatting, categorization, and presentation of case studies and best practices. This consistency makes it easier for users to navigate and extract valuable insights.

4.2.5. Disseminate case studies and best practices to high potential sectors. In addition to traditional publications focused on energy efficiency and sustainability, target dissemination at sectors that have greater potential to control and reduce their PPLs such as K-12 schools, higher education, healthcare, and hospitality. These sectors offer significant PPL reduction opportunities due to their often numerous, controllable PPLs and occupancy schedules that favor reducing the building load during unoccupied hours. Also consider that all building occupants interact with PPLs, but many may be unaware of what they are or how they can impact their energy use. Seize opportunities to explain the basics of what PPLs are and opportunities to manage and control them by presenting them to groups who may not be aware (e.g., consider conferences and associations in the sectors mentioned above). Tailor messaging for the audience, making sure to include non-energy benefits as well. For instance, human health improvement driven by reduced on-site emissions as well as asset management insights due to greater visibility from PPL monitoring can be more compelling benefits than energy efficiency or electrification for some audiences. Last, best practices should also include building occupant education. Where available, include sample education materials such as flyers, stickers, and onboarding materials.

4.2.6. Build relationships with organizations that can provide funding. The California Energy Commission and DOE's Better Buildings program are just a few examples of organizations that have demonstrated interest in PPL efficiency and control. Identify, engage, and partner with these organizations or similar ones to identify funding opportunities for case study development and dissemination.

4.3. Data—Compile PPL Baseline Consumption Data En Masse for the Whole U.S. Commercial Building Stock

Existing data on the power, energy consumption and count of PPLs by building type is sparse and outdated, resulting in a lack of information for decision-makers and incorrect assumptions for design engineers and researchers (Van Sant et al. 2024). Access to accurate PPL data can benefit many stakeholders and has broad impacts, from right-sizing HVAC systems to developing incentive programs for reducing PPL energy consumption. Below are approaches for achieving this pathway.

4.3.1. Identify the most impactful data. It is important to identify which type of data is most useful for stakeholders. Pathways to PPL Efficiency and Control study participants mentioned baseline energy consumption data and PPL device counts by device type as being beneficial (Van Sant et al. 2024). For example, stakeholders are interested in average count, and timeseries and annual energy consumption of projectors in K-12 school buildings. Higher-level data, such as timeseries and annual PPL energy consumption data by building type, could also be of use. Including metadata, such as building type, size, location, and occupation type (renter vs. owner), with the baseline consumption and device counts could also be valuable. Additional data needs can be identified through a survey of commercial building stakeholders.

4.3.2. Create a central database to host the data. The PPL baseline consumption data needs to be broadly and easily accessible to be effective. Creating a central database that is public will make the data both easy to find and use. The database should offer easy-to-use tools and interfaces for data collection, making it convenient for contributors to submit their data. Privacy is also often a concern with sharing data publicly, and data should be anonymized prior to being transferred to the database. Additionally, aggregating the data into broader categories or summaries can reduce data privacy risks.

4.3.3. Establish standardized data collection and reporting protocols. Inconsistent data labeling is a hurdle for compiling data from multiple sources (Present et al. 2020). Creating industry standards and protocols for PPL metering data collection, formatting, and sharing will streamline the data collection process and ensure compatibility across different systems and platforms.

4.3.4. Increase PPL metering in buildings. PPL power and energy consumption data at the whole-building and individual device or appliance level would benefit many stakeholders. However, PPL metering is not common among commercial buildings, and most Pathways to PPL Efficiency and Control study participants were not actively metering PPLs in their buildings (Van Sant et al. 2024). Recent versions of building energy codes, like California Title 24 and ASHRAE 90.1, require submetering in new construction. Additionally, building owners are seeing the benefit in understanding their buildings' energy consumption at an end-use level. Some portfolio owner study participants also highlighted they were beginning to implement submetering for this purpose.

4.3.5. Determine data collection sources. Data can be collected from many sources, including building submeters, device-level meter manufacturers, and energy auditors. Additionally, third-party data providers, such as ENERGY STAR Portfolio Manager, collect commercial building energy data including for PPLs and could contribute to the database.

4.3.6. Encourage owner participation to share consumption data. As availability of PPL metered data increases, what motivates owners of the data to share it publicly? Present et al. (2020) noted three categories of motivation for stakeholders to contribute commercial data to energy research at a large scale: (1) Direct value to themselves from what is done with the data; (2) A strong drive or mission to support energy research; (3) Using data as a business asset and

its sale as a business venture. Additional motives could include incentives, such as utility-offered discounts on energy bills, tax credits, financial awards, recognition, or access to advanced analytics based on contributed data.

Partnering with industry organizations like ASHRAE, IFMA or the Building Owners and Managers Association (BOMA) can promote data contributions and collaboration. Regulations, such as energy codes and mandates, also play a key role. Submetering requirements in recent building energy codes could be expanded to include data sharing mandates in future versions. Mandates at the federal, state, or city-level mandates could further enforce data sharing. Emphasizing the benefits of data sharing—such as access to benchmarking information, insights on energy usage patterns, and opportunities for cost-saving measures—can encourage participation.

4.4. Energy Codes—Continue to Include PPL Monitoring and Reduction Measures in Commercial Building Energy Codes

Commercial building energy codes were the most mentioned driver by Pathways to PPL Efficiency and Control study participants (Van Sant et al. 2024). This section offers approaches toward continued inclusion of PPL measures in energy codes.

4.4.1. Create case studies for code-required PPL control technologies. As mentioned previously, case studies can facilitate the adoption of PPL reduction strategies and technologies. This approach emphasizes the importance of developing case studies for code-required PPL control technologies in actual buildings and their interaction with occupants. Factors like cost-effectiveness, ease of implementation, and energy savings achieved should be included in the results that are shared for informing best practices and lessons learnt in these studies.

4.4.2. Get designer and building operator buy-in through messaging and case studies. It is crucial to highlight the benefits and successes of PPL reduction measures to commercial building designers and facility managers. Case studies showcasing real-world examples of successful implementation can illustrate the practicality and effectiveness of PPL monitoring and reduction, making it more appealing and feasible for designers and facility managers to adopt these measures. Messaging should emphasize how these measures align with broader sustainability goals, such as achieving net-zero carbon emissions.

4.4.3. Get buy-in from codes and standards organizations. The codes and standards organizations play a pivotal role in setting national energy efficiency standards and guidelines, making their endorsement important for driving widespread adoption. Securing their support can help validate the effectiveness and necessity of PPL measures, providing a strong foundation for their integration into building energy codes.

4.4.4. Inform code requirements through research. Current ARC energy code requirements specify that “all controlled receptacles shall be permanently marked to visually differentiate them from uncontrolled receptacles…” (ASHRAE 2022). While this requires markings on controlled receptacles, it does not specify how the receptacles should be marked, resulting in inconsistent

markings and confusion among building occupants. Researchers are investigating which markings are most effective at indicating controlled receptacles through online surveys (Abboushi and Myer 2023). The results of these studies should be shared with manufacturers to inform consistently designed future PPL control products.

4.5. Company Goals—Promote Adoption of Company Goals, Including but Not Limited to, ESG, SDG, and Emissions Targets

A key driver for adopting PPL control strategies and technologies is the inclusion of energy efficiency in company goals, such as ESG, SDGs, and emission targets. Research shows that organizations with these goals are more likely to adopt PPL control strategies to optimize building performance. Companies with climate-conscious occupants also face less pushback on PPL controls, leading to greater adoption (Van Sant et al. 2024). This section focuses on empowering companies to define and adopt energy-saving goals.

4.5.1. Communicate the need for ESG, SDG, and other emission reduction targets during ESG leader summits. Peer sharing and competition can significantly encourage the adoption of energy efficiency strategies. Companies often draw from each other's trends to stay competitive, attract employees, and meet financial goals. Recently, ESG has become integral to corporate values due to increasing pressure from regulators, investors, and stakeholders for transparency. Additionally, ESG investing, tracked by Bloomberg,[2] can indicate a company's financial health.

Incorporating ESG goals, SDGs, and emission targets in workshops for company leaders promotes the exchange of best practices and lessons learned. This includes strategies for implementing these goals, managing their communication, and ensuring employee adoption. PPL efficiency can be highlighted as a method to achieve ESG goals, with the implementation strategy communicated concurrently. Examples of relevant events include the DOE-hosted Better Buildings Summit, which focuses on decarbonizing buildings. Additionally, integrating ESG working sessions into industry conferences is a viable option.

4.5.2. Provide sample language for PPL efficiency and control that companies can include in an ESG strategy or plan. Example language for PPL efficiency can be provided by PPL experts or found from other successful PPL control strategies. These are not standalone but rolled into a greater building efficiency strategy such as accomplishing zero energy. Without PPL control, buildings could fall from their zero-energy status because PPLs are diverse and numerous. Language for PPL efficiency should match the structure of the organization. For example, organizations that have top-down directives like the military may want to include efficiency. But organizations that may have harder-to-reach building occupants like retail and offices in commercial real estate may have to find an indirect path, such as signage at outlets and switches, and frequent communication through regular communication channels such as global emails, intranet, and new employee orientations. These strategies will be more easily deployed in energy- or climate-conscious organizations (CCAC et al. 2021; HARC 2021).

[2] Bloomberg publishes international ESG investing news on their “ESG Investing” page: www.bloomberg.com/green/esg-investing.

4.5.3. Include PPL efficiency and control measures into green building certification. Green building certifications are credentials awarded to buildings that meet criteria for environmentally sustainable and resource-efficient design, construction, operation, and maintenance. These certifications recognize the companies that own and occupy certified buildings, as well as the architects, engineers, and construction companies that design and build them. Commercial building certifications include the U.S. Green Building Council's (USGBC) LEED certification, ENERGY STAR, the Living Building Challenge, and the WELL Certification.

These certifications should incorporate PPL efficiency and control measures to drive further energy efficiency. Example measures include metering requirements, procuring ENERGY STAR-certified equipment, appliances, and devices, and implementing control technologies like smart outlets. USGBC included PPL credits in their LEED v5 first public comment draft of Building Design and Construction: New Construction (USGBC 2024).

4.5.4. Monetize ESG goals implemented into companies and buildings. The need for resiliency in infrastructure will continue to increase as the impacts of climate change cause more frequent extreme weather events (e.g., irregular precipitation, extreme temperature, wind, wildfire, and flooding). Infrastructure that can survive extreme weather or provide resiliency to a community is needed to overcome these environmental challenges and can reduce its financial impact on communities and businesses. PPL control technologies could provide load flexibility and curtailment, as well as identify critical loads in buildings during extreme weather events. However, resilience measures cost money to implement, and organizations who can be financially innovative and capture the financial value of resiliency, such as monetizing ESG goals, will have a financial pathway for enabling PPL efficiency.

There are challenges to monetizing ESG. Hillenbrand et al. (2019) found that the average lifespan of an S&P 500 company has decreased significantly since the early 20th century and is now about 20 years. Smaller businesses could be even younger with half below the age of 10 years (J.P. Morgan Chase & Co. n.d.). This timeframe may be too short for companies to achieve their environmental goals. Thus, innovative ESG monetizing strategies are needed to capture ESG value in the short term, enabling companies with shorter lifespans to realize this value.

4.6. Additional Pathways

The above pathways were developed based on study participant responses. As the leading experts on PPLs, we took that information and identified two additional pathways that will be important for improving efficiency and control uptake—training the workforce and standardizing systems. This section discusses these pathways and approaches toward achieving them.

4.6.1. Train the workforce. ESCOs, facility managers, and energy auditors may benefit from PPL efficiency and control training**,** including what PPLs are, how to assess and reduce them, and available control technologies. IFMA, BOMA, ASHRAE, Association of Energy Engineers, Building Performance Institute, National Association of Energy Service Companies, and USGBC could be great associations to connect with for a training audience.

4.6.2. Standardize technology implementation topologies, protocols, and interoperable systems for PLC. Standardization through interoperable systems ensures that devices can communicate and work together seamlessly, regardless of their manufacturer or functionality. Proprietary closed-loop systems may be less favorable to building owners due to the complexity of managing multiple systems. Establishing common industry standards for PLC systems allows building owners and facility managers to integrate new technologies and upgrade existing systems without compatibility issues. Standardized components also ensure reliable long-term operation, easier maintenance, readily available replacements, and lower inventory needs. Semantic interoperability efforts (Bergmann et al. 2020) and standards like MATTER[3] enable seamless integration and communication among diverse smart devices, simplifying the management and control of plug loads in commercial buildings.

5. Conclusions

PPL efficiency strategies and control technologies have not seen widespread uptake despite their benefits and PPLs' growing portion of commercial building energy consumption. Reduction of PPLs can provide energy and cost savings, as well as emissions reductions. Additionally, PPL control technologies can enable response to grid signals and make buildings more grid interactive. This paper builds upon the pathways toward greater PPL efficiency and control adoption published in "Pathways to Plug and Process Load Efficiency and Control" (Van Sant et al. 2024). Using our experience researching PPLs and commercial buildings, we discussed approaches toward achieving these pathways.

As more cities and states set building performance targets and there is a continued push toward grid-interactive buildings, we hope to see a greater emphasis on PPL efficiency strategies and control technologies. The approaches presented in this paper offer a starting point toward greater PPL efficiency and control adoption.

6. References

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