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ABSTRACT

Commercial building retrofits are often limited to simple upgrades of individual building components such as equipment or lamp replacements. These equipment- or component-level retrofits have been shown to have less potential for whole building energy savings (50% less in studied cases) compared to comprehensive system-based approaches. System retrofits with their potential for much greater savings are critical to achieving aggressive energy reduction goals in the existing building stock but to date there has been little deep analysis of the track record and trends for systems retrofits in commercial buildings.

This paper addresses several questions: 1. To what extent are systems retrofits taking place in the building retrofit marketplace today? 2. Do current systems retrofits in fact save more energy than component retrofits? 3. What kinds of efficiency measures are currently most prevalent in system retrofits? 4. Does systems adoption vary across different retrofit programmatic approaches (e.g. utility incentive programs, federal retrofit programs, ESCOs)?

Findings, based on an analysis of retrofit data from 12,000 projects across the U.S. from custom utility incentive programs, federal retrofit programs, and Energy Service Companies (ESCOs), indicate the state of the current market with respect to adoption of systems technologies. A wide range of stakeholders were also interviewed to define the challenges and opportunities for greater deployment. A range of barriers is presented including technical and structural (i.e. programmatic, policy), along with recommendations to accelerate deployment of these strategic approaches.

Background

Commercial building retrofits present a prime opportunity to improve building energy efficiency. This is increasingly happening, but usually through simple upgrades of individual building components such as equipment or lamp replacements. These equipment- or component-level retrofits, however, have been shown to have less potential for whole building energy savings as compared to comprehensive system-based approaches (Regnier et al. 2018a). A system-based approach goes beyond a single component, such as by incorporating additional elements or controls within an end use system, or leverages interactions with other building components or end use systems to achieve deeper levels of energy savings. Systems retrofits hold the potential for much greater savings and are critical to achieving aggressive energy reduction goals in the existing commercial building stock. Building systems-based approaches have long been recognized as a way to achieve deeper levels of energy savings in buildings. By one estimate, systems level savings in the commercial market can "dwarf component-based efficiency improvements by an order of magnitude" (Elliott et al. 2012). Systems efficiency is emerging as a focus of energy policy efforts (ASE 2016). An analysis by Regnier et al. (2018b) compared three systems-based retrofit strategies and found that not only are deeper levels of energy savings possible (49 to 82 percent additional energy savings), but they can also pose a compelling economic case for investment in some cases, with simple payback ranging from 1.9 to 10.9 years.

The study was conducted in two parts. The primary objective of the study was to conduct a quantitative analysis of systems level retrofits using data from energy efficiency programs. This analysis sought to address three overall questions:

1. What is the *extent of systems retrofits* compared to component retrofits?
2. Do systems retrofits *save more energy* than component retrofits?
3. What *types of measures* are used in systems retrofits?

Furthermore, the analysis sought to address these questions for different types of delivery channels (e.g., energy service companies [ESCOs], utility programs). The second objective of the study was to obtain industry stakeholder perspectives on the current state of practice and barriers to wider deployment of systems retrofits. Toward that end, a series of structured interviews were conducted with various types of industry stakeholders to solicit input on technical, economic, market, policy and other barriers and opportunities to support deployment.

This study focused only on retrofits of existing buildings, as integrated design strategies have been well documented as supporting successful low energy systems approaches in the case of new construction (AIA 2007). Overall, this work aims to illustrate the prevalence of system retrofits, the types implemented, and their correlation to project energy savings. The results point toward areas of potential industry effort, research and growth to aid in broader application of systems approaches to achieve greater energy savings in the building stock.

Systems Definition

"A building system is a combination of equipment, operations, controls, accessories and means of interconnection that use energy to perform a specific function" (ASE 2016). Systems inherently involve the interaction and integration of components within and across various end uses. For the purposes of this study, we defined the following *end use* categories of: 1. Heating, 2. Cooling, 3. Ventilation, 4. Lighting, 5. Domestic hot water, 6. Plug loads (e.g., office equipment), and 7. Commercial refrigeration. Other end use categories, such as process equipment, which is sometimes used to describe equipment such as elevators, might exist in a commercial building application. However, these were only found in very rare occurrences in the data, and have been omitted for ease of analysis and presentation.

We define a building *end use system* as the *set of equipment, supporting devices, distribution (such as piping or ducts), termination, sensors and controls* to maintain a desired service level, such as thermal comfort. Systems integration and systems retrofits may occur between different components within a single end use system or across multiple end use systems. Accordingly, for the purposes of this study we defined three types of system retrofits as illustrated in Figure 1:

1. **End use system retrofits**, which affect a single end use system.
2. **Interactive system retrofits**, which have interactive effects across two or more end use systems.
3. **Integrated system retrofits**, which involve active integration across two or more end use systems.

Each of these three retrofit types presents a unique set of conditions relevant to their technical application and may have unique adoption barriers as well. Each can provide an opportunity for deeper energy reduction beyond a “widget” or equipment replacement of an existing technology. These system retrofit types are described further below.

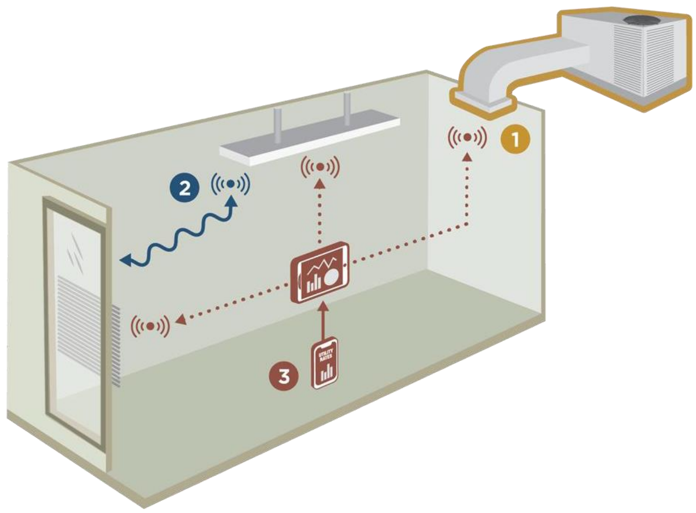

Figure 1 - System Types - End Use System, Interactive System, Integrated System

End Use System Retrofits

An **End Use System Retrofit** is defined as the *retrofit of an existing end use system including measures in at least two of the elements of equipment, supporting devices, distribution, termination, and/or sensors and controls.* By this definition, equipment upgrades alone, such as a chiller and pump replacements, would not qualify as a system retrofit, but an equipment replacement combined with a new controls strategy would. This definition requires that the measures must be in the different categories of the end use system, such as termination and sensors/controls, or supporting devices and sensors/controls. The emphasis here is on *systemic planning and approaches*, i.e., recognizing interactions and coordinated strategies across the end use system, which is more likely to lead to deeper energy savings. Some examples include:

- Cooling tower replacement plus waterside economizer controls (equipment and controls)
- Light fixture replacement plus daylight dimming controls (equipment and controls)

End Use System retrofits may result in a complete change of the end use system, such as a central gas water heater with a recirculating pump being retrofit to point-of-use on-demand electric water heaters. Other end use system retrofits may result in replacements or improvements to select parts of that system, such as the installation of fan VFD controls (sensors/controls) along with low pressure drop filters (distribution). These more incremental system improvements may not have as large of an energy saving benefit, but they are important to the existing building market, as they may be less disruptive or costly to implement.

Interactive System Retrofits

Some building retrofits may have an *indirect* impact on building energy use, such as increasing or reducing internal or external heat gains and thereby affecting HVAC system energy use. All HVAC systems are interactive with the building envelope, and also with other systems that produce internal heat loads such as lighting and plug loads. Lighting systems also may be interactive with envelope components that provide daylight, as shown in Figure 1. A defining characteristic of building system interaction is that there is no active controls engagement across these elements; rather, the interaction happens through generally passive means such as heat produced by one influencing the behavior of the other. (Where there is active controls engagement among building systems, they fall into the Integrated Building System category discussed below.) To identify when an opportunity for these increased energy saving strategies has occurred, we define an **Interactive System Retrofit** as *the modification of a building end use system or envelope component(s), intentionally leading to changes in the state of another building end use system or component, which overall results in a net energy use reduction.* The mere presence of an interactive effect does not in and of itself make for a systems retrofit. Rather, it is considered a systems retrofit when the affected system is *intentionally* configured to enable greater energy savings. An example would be an envelope retrofit that decreased heating or cooling needs to the point where HVAC equipment could be downsized, or changed to another more efficient system type (e.g., rooftop unit cooling and heating switched to a hydronic radiant system). Capturing when these opportunities occur can be important to improving the economics of energy efficient retrofits, as the capital cost savings of downsized equipment can be used to offset the costs of implementing the energy efficient strategies, a strategy known as "Tunneling Through the Cost Barrier" (Hawken et al. 1999).

Integrated System Retrofits

A third systems retrofit opportunity exists in buildings to save energy by integrating design and control between end use systems. End use systems typically operate in a "fractured environment," independently of one another, hence "system integration will be key to enabling more cost-effective operations" (ANSI 2014), including integrated controls. Therefore, we define an **Integrated System Retrofit** as the *retrofit of two or more building end use systems and/or envelope components resulting in a coordinated controls approach for systemic improvements across the end use systems.* A defining characteristic of Integrated System retrofits is that they include active, coordinated controls across end use systems, with a goal to provide more energy savings or greater services (such as peak demand reduction) than the end use system elements in isolation. Some examples of Integrated System retrofits include:

- Dynamic facade (e.g., automated shading and/or electrochromic glazing) combined with lighting controls (daylight dimming) and/or HVAC system controls (e.g., reduction in peak cooling, balancing daylighting with cooling reduction, demand response)

It should be noted that envelope components should be considered building end use systems once they become energy consumers, such as in the above examples of automated facades. Further integration across end uses may be possible beyond these opportunities, including integration with distributed energy resources such as photovoltaics and battery storage.

Data and Methods

Energy measure data was sought for a large number of commercial building retrofit projects from a range of programs. Data sources were targeted for: 1 - Relevance: Project retrofits must have been completed within about five years. 2 - Climatic zone representation: Data should include representation across each of the seven major U.S. climate zones, per the

International Energy Conservation Code (ICC 2018). Differing climatic conditions may affect the types of retrofit measures employed. 3 - Building type: A wide range of commercial building types were included. In addition, data sources were selected to represent a range of differing programmatic methods, to understand if adoption trends differed across these approaches. These included both public sector led programs, such as federal government agency retrofits, and private sector approaches such as custom utility customer incentive programs.

1. Custom Utility Customer Incentive Programs Utility customer incentive programs support a significant number of energy efficiency retrofit investments annually. An LBNL report studied the performance of efficiency programs of 116 investor-owned utilities and other program administrators in 41 U.S. states and found that between 2009 and 2015 these programs expended $13.4 billion (in 2016$) on their commercial and industrial (C&I) programs. Custom utility customer incentive programs represented 37% of the C&I sector savings, with a lifetime gross savings of 836,241 gigawatt-hours (GWh), second in savings only to the residential lighting program (Hoffman et al. 2018). Utility customer incentive programs are typically defined as either prescriptive or custom programs, with prescriptive programs more suited toward equipment upgrades or single measure approaches, and custom programs suited toward more complex applications, including systems retrofits, multiple end use system retrofits, and projects with multiple EEMs, including single measures in different end use systems. LBNL compiled a list of U.S. utilities with active custom incentive programs, identified through ESource (2017) and LBNL's in-house custom utility customer incentive program database (Hoffman et al. 2018). Those with the highest numbers of custom program customers and/or energy savings were approached, while also ensuring geographical and climate diversity. Not all utilities approached were able to participate, despite high interest in some cases, for a range of reasons including regulatory policies that did not permit project data sharing even when anonymized.

The data from the utilities included more than 9,000 projects in more than 8,000 buildings. The kinds of data available by utility varied considerably, both in terms of quantitative metrics (e.g., many projects reported different energy savings metrics, or not at all) and qualitative descriptions of EEMs (e.g., ranging from very light descriptive content to detailed case studies). For the 2,500 projects that had kilowatt-hour (kWh) savings and area details, the average energy savings were 7.52 kWh/sq. ft. per building and 5.62 kWh/sq. ft. per project.

2. FEMP Database of Federal Agency Facility Retrofits The Federal Energy Management Program (FEMP) supports the energy efficient retrofit of U.S. federal government buildings, spanning agencies such as the U.S. Departments of the Interior, Defense, Education, Agriculture and Energy. This dataset included 2,234 projects in 1,025 buildings either leased or owned by the U.S. federal government. The database is maintained to track energy consumption, expenditures and other metrics to evaluate program performance. Retrofit projects included a variety of different management approaches, including some performed by ESCOs. Project records with duplicates in the National Association of Energy Service Companies (NAESCO) database have been removed in such cases. For projects reporting energy savings and for which building square footage was known, the average electricity savings per building was about 29 kWh/sq. ft. per building, about 15 kWh/sq. ft. per project (n = 1,396).

3. NAESCO Database This dataset included 421 projects conducted from 2012 to 2017. The majority of the projects in the database come from the accreditation process of NAESCO, a national trade association for the ESCO industry. As part of this process, ESCOs seeking national accreditation submit applications that include detailed project information. A small percentage of projects (< 10 percent) were provided by state agencies that manage energy efficiency programs and by FEMP. The database includes 6,314 projects implemented from 1982 to 2017, with greater than 98 percent installed after 1990. This database contains projects representing more than $16 billion (2016$) in total project investment levels without financing costs. For projects that included energy data, energy savings averaged about 25 percent.

4. DOE High Performance Buildings Database The U.S. Department of Energy maintains an online repository of example high performance buildings (https://buildingdata.energy.gov/) (DOE 2018). This dataset included 28 projects and buildings that met the study criteria for inclusion in the high performance retrofit category. Reported whole building annual energy savings averaged about 40 percent.

5. GSA Deep Retrofit Program This dataset included 41 retrofit projects in 41 U.S. General Services Administration (GSA) buildings. These projects were not included otherwise in the FEMP / Compliance Tracking System dataset. Reported energy use intensity (EUI) savings ranged from 15 percent to 65 percent, averaging 35 percent.

6. NBI Getting to Zero Database There were 21 retrofit projects and buildings in this New Buildings Institute (NBI 2020) dataset that were not otherwise covered in other data sources, with reported whole building annual energy savings of almost 60 percent on average, and with projects achieving up to 85 percent energy savings.

Data Cleaning and Dataset Characteristics

Table 1 describes the building projects in the dataset for which energy savings as a percent of whole building energy use were provided or calculated.

Table 1. Projects with Whole Building Energy Savings Reported or Calculated

Buildings with Energy Savings (% of Whole Bldg)	No. of Projects	No. of Bldgs	Project Area 5th Percentile (sq. ft.)	Avg. Project Area (sq. ft.)	Project Area 95th Percentile (sq. ft.)
Totals	4,765	3,410	2,000	228,879	1,073,400

Table 2 illustrates the distribution of the retrofit projects with whole building percent energy savings across the U.S. climate zones. It also presents the breakout of building retrofit projects conducted on private sector lead programs (e.g., ESCOs, utility programs) versus public sector lead efforts (e.g., GSA, FEMP).

Table 2. Private and Public Sector Project Representation Across Climate Zones for Projects with Whole Building Percent Energy Savings

IECC Climate Zone	Public Sector Projects	Private Sector Projects
1. Very Hot – Humid (Miami, FL)	11	8
2. Hot – Humid (Houston, TX) and Hot-Dry (Phoenix, AZ)	80	31

3. Warm – Humid (Memphis, TN), Warm – Dry (El Paso, TX) and Warm – Marine (San Francisco, CA)	229	109
4. Mixed – Humid (Baltimore, MD), Mixed – Dry (Albuquerque, NM) and Mixed – Marine (Salem, OR)	398	3,109
5. Cool – Humid (Chicago, IL) and Cool – Dry (Boise, ID)	268	417
6. Cold – Humid (Burlington, VT) and Cold – Dry (Helena, MT)	65	17
7. Very Cold (Duluth, MN)	14	7
8. Subarctic (Fairbanks, AK)	2	-
Grand Total (Projects)	**1,067**	**3,698**

The public sector projects totaled 680,950 sq. ft, and private projects at 85,405 sq ft. Of the projects with energy data, office retrofit projects represented the largest proportion at 29%, followed by hospital (16%), an 'Other/Blank/Unknown' category at 12%, education (10%), retail (8%), lodging (7%), gas station/convenience store (7%) and restaurant (5%).

Results - Prevalence of Systems Retrofits

Figure 2 shows the distribution of various types of retrofits. **The three types of systems retrofits collectively represented less than 20 percent of total projects, indicating that systems retrofits are relatively uncommon.** End Use System retrofits occurred in 17 percent of the projects while only 6 percent had an Interactive System retrofit. Notably there were no recognized instances of any Integrated System retrofits. It may be in some cases there was an Integrated System retrofit, however the retrofit descriptions were not sufficiently detailed to identify these instances. However, upon discussions with stakeholders there is anecdotal support for the interpretation that these types of retrofits are rare. In reviewing Figure 2, also note that some projects with either Non-System retrofits or End Use System retrofits could also have an Interactive System retrofit, and therefore the sum of retrofit types is greater than the total number of projects.

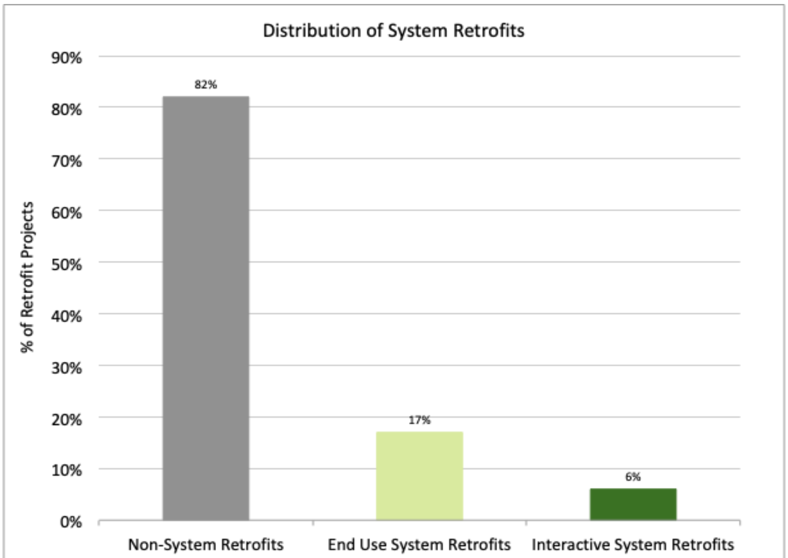

Figure 2 - Distribution of System Retrofits[1]

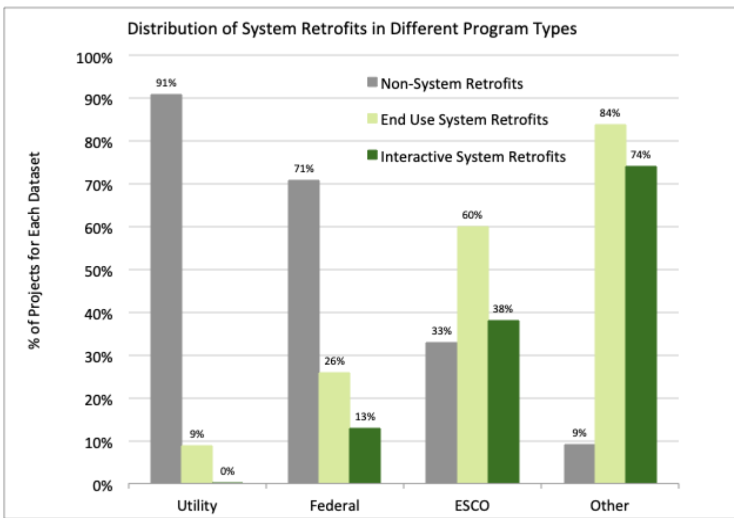

Figure 3 - Distribution of System Retrofits in Different Program Types

Results - Energy Savings of Systems Retrofits

Projects were categorized based on whole building energy savings as either low energy-saving (< 20 percent whole building kWh energy savings) or high energy saving (≥ 20 percent). Almost 80 percent of projects were low-energy savings and only about 19 percent had high energy savings. Figure 4 illustrates the distribution of energy savings for different retrofit types.

[1]A project can have both an End Use System and an Interactive System Retrofit, hence the categories can total > 100%.

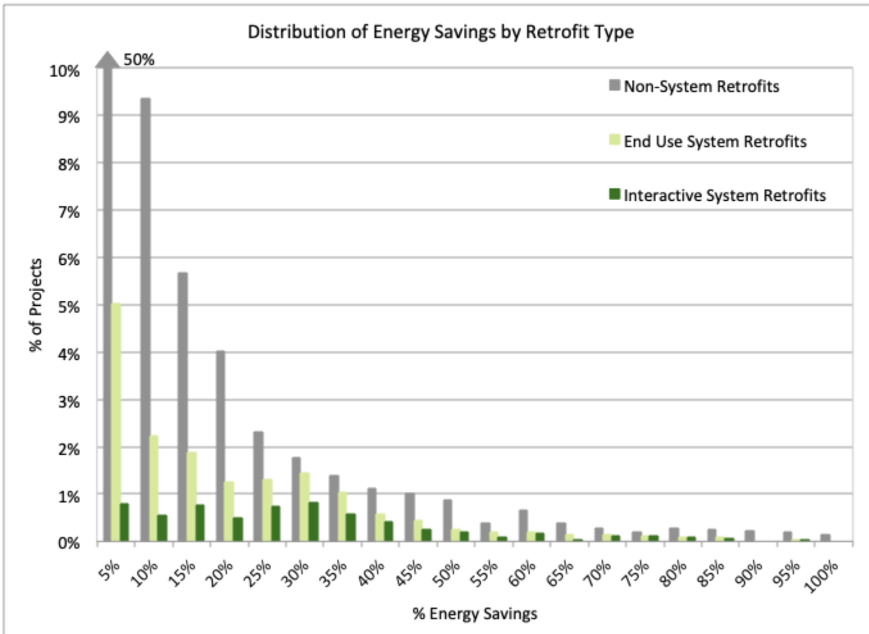

Figure 4 - Distribution of Energy Savings by Retrofit Type

A general observation is that Non-System and Systems retrofits include a wide range of energy savings. However, there are substantially fewer Non-System retrofits for projects with higher whole building energy savings. End Use System retrofits occur at increasing frequencies from lower to higher energy saving projects. It is notable that some Non-System retrofit projects are able to achieve higher levels of energy savings. Further review of data from the utility custom incentive programs, for example, indicates that some buildings may be able to achieve high energy savings through lighting retrofits, likely with an inefficient baseline such as T8 or T12 non-dimming lights. This may represent the current transition from incandescent and fluorescent lighting to high efficiency LEDs. Over time these opportunities to provide substantial energy savings through lighting replacement will become less prevalent. Figure 5 breaks out the distribution of low and high energy savings projects for different retrofit types. End Use System retrofits and Interactive System retrofits show a greater occurrence of higher energy saving projects. The distribution for utility, U.S. federal (FEMP and GSA) programs, and for ESCOs follow in Figures 6, 7 and 8. The breakout of low versus high energy savings projects is provided as well, to contrast against each other and compare with the dataset as a whole.

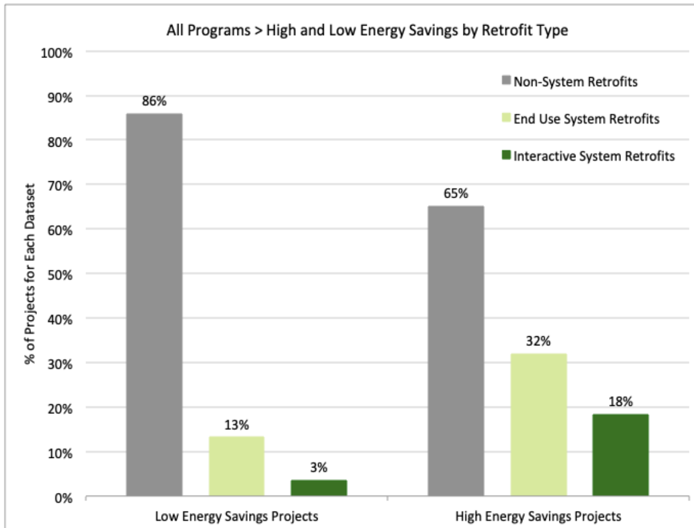

Figure 5 - All Programs > High and Low Energy Savings by Retrofit Type

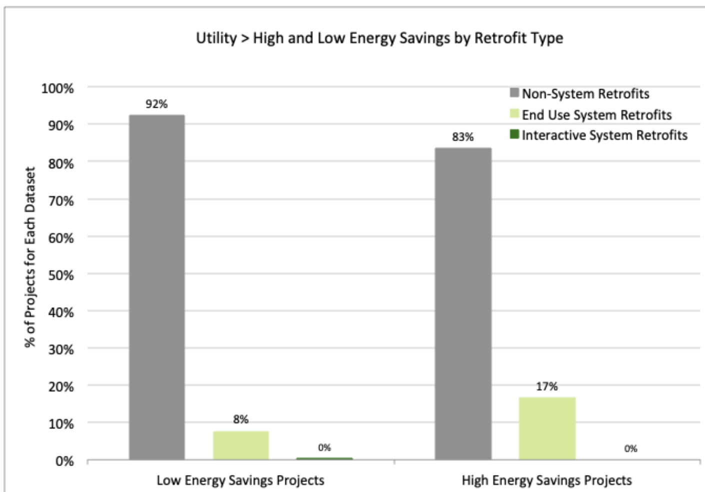

Figure 6 - Utility > High and Low Energy Savings by Retrofit Type

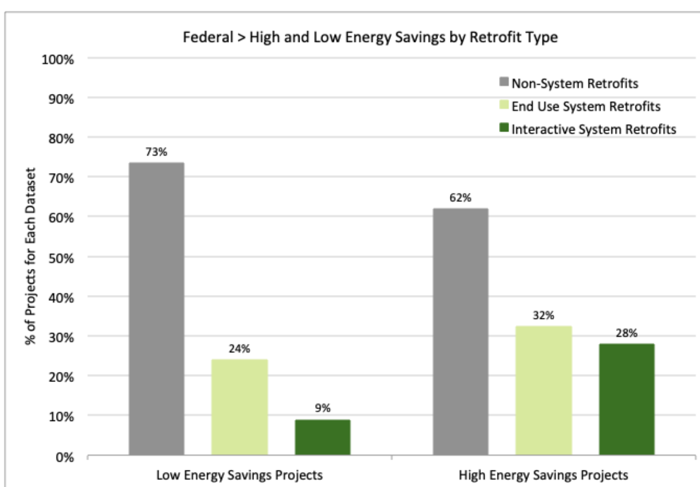

Figure 7 - Federal > High and Low Energy Savings by Retrofit Type

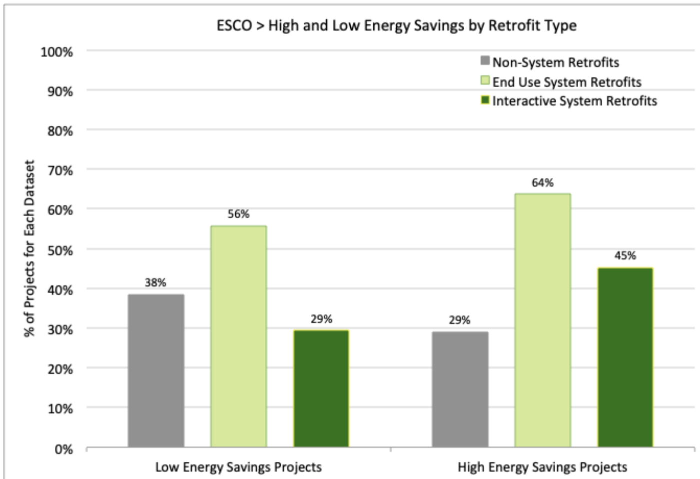

Figure 8 - ESCO > High and Low Energy Savings by Retrofit Type

There is a striking difference in these three programs and their retrofit approaches. Federal programs have a much higher frequency of End Use System and Interactive System retrofits than utility programs, but ESCO projects predominantly focus on End Use System retrofits, even in lower energy saving projects. In all three cases though, End Use System and Interactive System retrofits have a greater percentage of high energy savings projects. However, the figures illustrate that there are cases where high energy savings are possible using Non-System approaches, which will be explored further in the next section. Notably, there may be programmatic differences that support the identification and application of Non-System retrofits.

Utility custom programs appear to strongly favor Non-System approaches throughout, even though custom programs can theoretically support more complex systems-based approaches. The vast majority of their projects are low energy savings; only 15 percent achieve high energy savings, but in a significant number of cases these high energy saving projects are able to achieve these results using Non-System approaches. While utility projects do target more End Use System retrofits for high energy projects (17 percent of them, versus 8 percent of low energy projects), although with a lower prevalence of high energy saving projects in general.

For federal programs, there is a much stronger representation of End Use System retrofits for high energy saving projects (32 percent versus 24 percent for low energy saving projects). There is a substantial showing for Interactive System retrofits, at 28 percent of high energy saving projects, suggesting a more comprehensive approach to these retrofits targeting multiple end use systems and perhaps even envelope measures at once. ESCOs on the other hand strongly appear to favor systems-based approaches across all projects, with an increase of their prevalence in high energy saving projects. However, even the low energy saving projects more frequently applied systems-based retrofits. More than 50 percent of low energy saving projects included End Use System retrofits, and 29 percent included Interactive System retrofits. This suggests a greater level of identification of measures with a given end use, perhaps taking advantage of the labor and trade investments working in that area.

Results - Energy Savings of Systems Retrofits

Figure 9 shows the distribution of EEMs in the projects by end use system category. Overall, lighting was the predominant end use system affected, representing more than 70 percent of the low energy saving project EEMs, followed by heating, cooling and ventilation, which each represented about 10 percent or less of the EEMs. High energy saving projects also emphasized lighting measures, but HVAC retrofits as well, at 20–30 percent of measures. Envelope measures were also notably more frequent at the high energy savings level, although still less than 10 percent of the EEMs. Overall it appears that lighting is still a strong and important contributor, but for higher energy saving projects HVAC is more frequently addressed.

Overall, 17 percent of all projects with whole building percent energy savings data included at least one End Use System retrofit. Figure 10 shows the distribution of End Use System retrofits by end use system category.

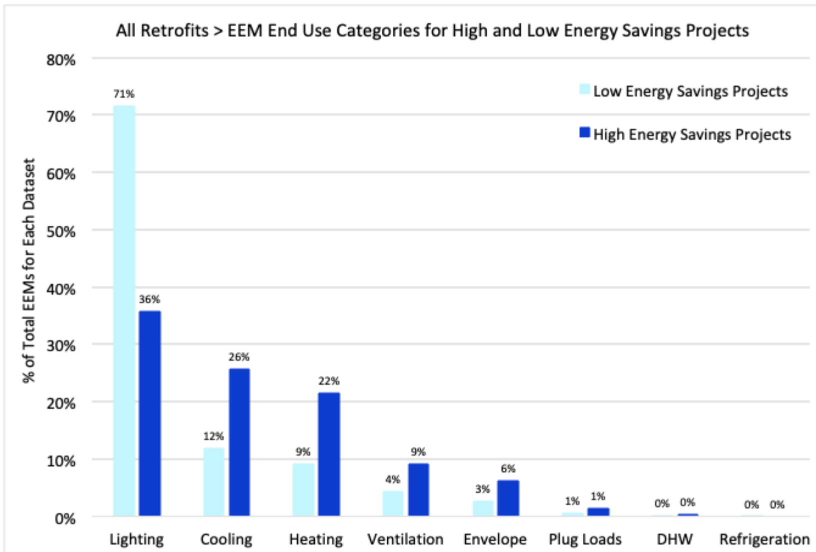

Figure 9 - All Retrofits > EEM End Use Categories for High and Low Energy Savings Projects

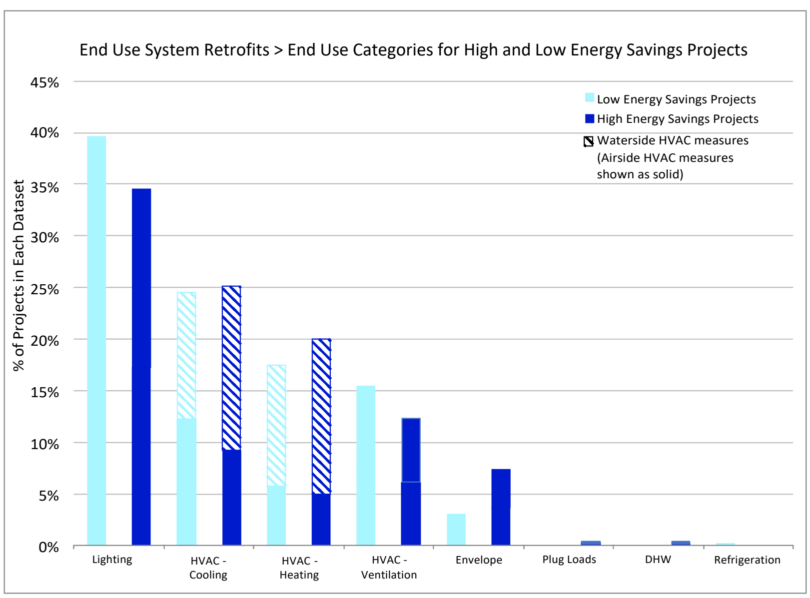

Figure 10 - End Use System Retrofits > End Use Categories for High and Low Energy Savings Projects

Among End Use System EEMs, lighting measures were the most prevalent, but HVAC measures occurred at about twice the rate they did in the Non-System retrofit projects. The main differences in End Use System retrofits between the low and high energy saving projects centered on a greater number of lighting retrofits in the low energy saving projects, and a significantly higher number of envelope retrofits in the high energy saving projects. Notably, the frequency of HVAC retrofits was similar in both datasets. It should be recalled, however, that only 13 percent of the low energy saving projects had End Use System retrofits, compared with 32 percent of the high energy saving projects (Figure 5). At this level there is not a striking difference in the frequency that certain end use system categories are targeted by high and low energy saving projects. Disaggregating by program illuminates some distinct differences:

- Utility programs' top EEM combinations show an even greater proportion of lighting-based measures across all of their retrofit projects. Lighting combinations represent the top 10 strategies for both low and high energy saving projects, with top measures occurring at rates of 21 percent and 18 percent (LED fixtures with occupancy controls), respectively. The lighting measures used are similar across all projects (lamps/fixtures, bi-level switching, occupancy controls).
- Federal programs appear to use a much wider range of End Use System retrofit strategies in all cases. The highest combinations for both low and high energy saving projects, at rates of 9 percent and 6 percent respectively, was a combination of ventilation distribution "other/unknown" and controls "other/unknown." Ventilation, lighting, heating airside and cooling airside systems are most prevalent in the low energy saving projects. High energy saving projects, however, have lighting for 8 of the top 10 combinations. In general, however, most of the top 20 combinations represent only 1 to 4 percent of cases each, so a strong trend is not apparent.
- ESCO projects have an even wider distribution of End Use System retrofits than the federal projects do. The top EEM combinations for ESCO projects occurred in only 3 percent and 2 percent of projects (low and high energy saving projects respectively), so at these rates additional trend analysis is limited. However, it is interesting to note that heating waterside and cooling waterside element combinations are the most prevalent in the Top 20 for both the low and high energy saving projects. Element combinations here included equipment (pumps, chillers, boilers, air handler modifications) and controls (VFDs, energy management system).

EEM combinations favoring equipment and controls retrofits were ubiquitous as the most common strategies used by all end use systems. This may point toward an understanding of relative ease of implementing retrofits in these areas, compared to some other End Use System retrofits that could be more costly and disruptive to implement (i.e., distribution and termination measures). Supporting devices appear to be infrequently used across the programs, pointing perhaps to reduced technical opportunities, or it being an emerging area where value is still being developed in the marketplace, such as the use of storage for reducing peak electricity pricing.

Stakeholder Perspectives

As a supplement to the quantitative data analysis reported above, LBNL also sought input from several stakeholders — utility program administrators, implementers, and advocacy organizations — to understand work to date, future interests, and barriers to wider deployment. We obtained input from 18 organizations. Below is a summary of the responses we received. Each stakeholder was asked to respond based on their actual experience with the programs with which they were engaged, rather than their general impressions of the market as a whole.

The vast majority of respondents indicated that **the most widely implemented types of system retrofits in buildings are lighting upgrades combined with controls, followed by**

HVAC upgrades with controls. Only two respondents indicated that HVAC upgrades with controls were the most common, and in one case that was because of the nature of the program they were offering. **Cost-effectiveness and ease of implementation were cited as the most significant reasons for lighting systems retrofits being the most widely implemented.** Additionally, the savings and controls settings tend to have greater persistence than is the case with other end use systems, and they do not require intensive infrastructure changes.

There was a very wide range of responses to the question of to what extent the **respondents' project have employed system retrofits**. For broad based utility programs, respondents indicated percentages ranging from "virtually none" to 10 percent, with **most saying less than 10 percent**. For respondents that support custom programs, the numbers were much higher, often greater than 50 percent. Almost all respondents stated between 0 and 10 percent of retrofits in their market conduct whole building simulation or other means to understand interactive effects to guide design. Only a few respondents specializing in high performance buildings stated that they routinely use whole building energy simulation.

Several respondents indicated that **larger buildings were more likely to implement systems retrofits.** One respondent noted that public sector institutions are more likely to adopt systems approaches than private sector institutions, because of the longer investment horizon. Not surprisingly, **office, retail and schools were commonly identified as having the most potential for system retrofits because of the size of the sectors.**

Respondents were asked to identify **key barriers** to improving access to and implementing systems retrofits across several categories: (a) Technical, (b) Economic, (c) Market, (d) Policy/regulatory, (e) Other. Most of the responses to this question fell under three broad themes: Complexity of systems retrofits, cost-effectiveness, and utility program structures.

Systems are too complex. Installation, commissioning and operations are more complex than those for component upgrades, and there is a gap in contractor training, understanding and trust. Complexity affects the time it takes to design and implement retrofits and multi-system controls are often too complex for operators, requiring higher levels of attention.

Systems seen as having poor cost-effectiveness, whether or not this may be true. This can be especially true in areas with low utility costs. But even in other areas, putting down capital for energy efficiency remains a major barrier. Most customers require a payback of fewer than two years. In the case of lighting, power densities are already low with LED lighting. The addition of controls is seen as a limited incremental benefit. Cost-effectiveness information is also not available in a timely manner for the decision-making process.

Utility programs for the most part are still highly "widget" oriented. Generally, only custom programs allow for systems retrofits. There are very few systems retrofits that are available with deemed savings[2] alone. Incentive payments are based on measure-based savings without considering the potential additional benefits of interactive effects (e.g., like-for-like replacement with no credit for right sizing). In some regulatory areas there is a requirement for packages of measures to have each measure individually be cost-effective, a strategy that can inhibit system retrofits, which includes multiple measures. The annual energy savings targets and cost-effectiveness requirements set by regulators for utility programs also incent short-term savings. As a result, simpler retrofits with very quick paybacks are emphasized, such as lighting and behavioral programs. The use of a code baseline for existing buildings can also disqualify

[2] Deemed savings are pre-determined, validated estimates of the energy savings attributed to specific energy efficiency measure(s). Deemed savings are commonly applied to 'widget' based technologies such as LED lighting and HVAC equipment.

savings from some controls upgrades. For HVAC, there are cases where an equipment upgrade is a midstream incentive (i.e., applied to the equipment vendor or distributor) while the controls upgrade is for the end user (e.g., owner), making the transaction more burdensome.

Other barriers mentioned included **lack of adequate training and education**. Training of vendors and service providers is needed to deliver services and to sell the value proposition of systems retrofits. The terminology of system retrofits and concepts can be hard for certain customers to understand. It is notable that there was almost no mention of the lack of systems technology options as a barrier, although as stated earlier the complexity of system design, controls and commissioning are seen as deterrents. One respondent spoke to the need for better standards and open protocols for controls.

Industry Needs and Recommendations

There is strong evidence that **systems-based retrofits are more prevalent in, and thus correlated with greater whole building energy saving projects**. This study provided significant evidence that **the most common practice in building retrofits is to focus on non-systems-based single EEM approaches,** even in programs designed to accommodate deeper levels of energy savings such as utility custom incentive programs. Notably some programmatic approaches such as those used by **FEMP, GSA and ESCOs more regularly identify and succeed in systems retrofits**. It is of interest to note that higher energy savings (> 20 percent) can be achieved in some cases through the use of sets of discrete Non-System measures, although it is likely these cases are highly dependent on the existing building conditions (e.g., T12 lamps). It is probable that these opportunities will become less prevalent as this equipment is retrofit. As systems retrofits become increasingly important in delivering deeper levels of energy savings, a number of strategies involving **technology** identification and application, retrofit **program design**, **policy** and **education** may be needed to overcome the barriers identified here.

Technology. Systems-based energy saving technology solutions may already exist but are not well recognized by practitioners, and are perceived as being overly complex to implement. To support growth in this area, it would be prudent to devise additional methods to **streamline systems identification and application**. This could include simplified design and assessment methods, as well streamlined installation practices. System retrofits can have improved cost effectiveness when bundled with key cost effective measures, such as LED lighting, and should be targeted accordingly. **Interactive System retrofits may hold the key to unlocking deeper energy reduction strategies in buildings by unlocking capital savings** from smaller equipment sizes or enabling the change or elimination of a system type. However, methods are needed to identify cost-effective interactive systems retrofits during design. **Methods to reduce the complexity of applying systems solutions** may also help. Efforts can be made by manufacturers and contractors by creating standardized packages of retrofit technologies and controls. **New systems technologies also may be developed to deliver lower energy use, particularly with a focus on lowering their cost of design and installation** (e.g. reducing controls integration complexities with plug and play applications). Systems approaches that can leverage existing infrastructure, such as piping and ductwork distribution, will be less disruptive and have a greater chance of cost-effectiveness. Development of industry standard controls applications — both controls sequences and protocols for deployment — can help improve outcomes and lower risk in general. Development of "self" commissioning controls systems would also lower the costs and complexity of implementation.

Program Design. Utility programs historically have focused on lighting retrofits, and have developed customer acquisition methods and programs structured accordingly. ESCOs, on the other hand, have developed a business practice that requires a strong focus on reducing risks to cost-effective energy reduction, which includes identifying retrofits with good returns and reducing transaction and other soft costs to ensure overall returns on investment are met. In this case, ESCOs may be recognizing that there is a base transactional cost whenever a trade conducts work on a site, and that it is most efficient to leverage that trade to implement additional retrofit measures at the same time thus improving overall cost-effectiveness. Retrofit programs should be designed to recognize this and address other barriers where possible — whether through process approaches, tools or use of incentives. Other means to improve financing, and to identify and make transparent the "lost opportunity" cost of not taking a systems upgrade over a component based retrofit also should be considered. It would also be beneficial to **consider how systems can be administered in a similar, lower touch method as "deemed" programs**. This could include development of "deemed" savings for system packages, and the use of streamlined tools for customer assessment.

Policy. Other policy barriers may also exist, including incentive program cost-effectiveness tests that require individual EEMs to pass, rather than evaluating a package of EEMs collectively, such as in a systems retrofit. Further, programs should be encouraged to incentivize retrofits based on lifetime savings, which will support system retrofits strategies that have longer lifetimes and payback periods. The use of energy code as a baseline for comparison in these programs may also result in owners not selecting some EEMs for application. An existing building baseline is recommended in these cases, which when paired with thoughtful attribution of savings (to both code and incentive programs), can provide a best case scenario of customer adoption and savings realization. Other policy improvements can set metrics for systems performance, rather than emphasizing equipment performance ratings. Outcome-based codes can also support industry engagement in systems based approaches.

Education. Further education and awareness about the potential for system retrofits savings and their non-energy benefits are also needed to help industry value and adopt these approaches. Additional case studies, in particular in comparison with equipment upgrade only approaches, can further illustrate value. Contractors also require training to better understand system implementation and operations.

While the results of this study are of interest to owners and managers of existing buildings, much can be learned about identifying energy saving strategies from systems implemented in new construction efforts. Overall, though, given the size of the existing building market, system retrofit approaches that work with existing building systems will be key to reaching sector-wide energy reduction goals.

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