Package deals for deep savings: Scaling deep retrofits in commercial buildings with integrated systems packages

Paul Mathew, Lawrence Berkeley National Laboratory
Philip Coleman, Lawrence Berkeley National Laboratory
Cindy Regnier, Lawrence Berkeley National Laboratory
Jordan Shackelford, Lawrence Berkeley National Laboratory
Duane Kubischta, kW Engineering
Sarah Zaleski, U.S. Department of Energy
Blake Dressel, U.S. Department of Energy

ABSTRACT

Achieving deep energy efficiency at scale in existing buildings is essential to realizing zero energy goals in the building sector. Integrating energy-efficient technologies has proven to provide deeper savings than component-based retrofits, but these systems-based approaches typically require significant engineering expertise to design, install and operate. Furthermore, such retrofits are often too disruptive to building occupants and activities when they are not aligned with the real estate life cycle. This has limited their wider adoption beyond industry leaders.

In this paper we present a scalable approach to deploying integrated systems in existing commercial buildings by opportunistically incorporating them within real estate business life-cycle events. The approach has two key elements: a) integrated systems packages (ISPs) that are pre-engineered to minimize expertise and effort required for implementation; and b) a design approach that seamlessly incorporates them into routine real-estate life cycle events -- tenant fit-out, equipment replacement, and renovation. Each ISP is also pre-validated with respect to functionality and energy performance to reduce real and perceived risk.

First, we discuss considerations for incorporating deep energy savings measures in routine real estate life-cycle events, based on a literature review and extensive stakeholder interviews. Next, we describe ISPs developed for three real estate life-cycle events: tenant fit-out, rooftop unit replacement and whole-building renovation. We then present preliminary results from the laboratory testing and validation of the tenant fit-out ISP, showing significant lighting and HVAC cooling load savings. Finally, we discuss potential deployment channels for the ISPs.

Introduction

Achieving deep energy efficiency at scale in existing buildings is essential to realizing zero energy goals in the building sector (new construction accounts for 1% of floor space per year in the US [EIA 2020]). An array of commercially available, proven, advanced integrated systems technologies can in fact deliver deeper energy savings cost-effectively. There is also growing consensus in the building industry that using systems approaches may well be a "game changer," as this approach will become increasingly necessary to achieve future meaningful and cost-effective energy savings in buildings. However, integrated systems approaches remain underutilized for a variety of reasons. They often require significant engineering expertise to ensure that they are designed, integrated, commissioned, and operated effectively. Utility incentives, if available, are usually only possible through "custom" programs, which sometimes entail narrow eligibility and cumbersome measurement and verification (M&V) requirements. Savings uncertainty and persistence issues remain a real or perceived risk, which in turn hinders financing based on savings. Furthermore, the customary practice in building energy retrofits is to treat each building as a unique engineering project, making strategies difficult to scale. Such retrofits are often too disruptive to building occupants and activities because they are not aligned with the real estate life cycle. Put simply, it's not currently easy to broadly implement integrated system approaches that yield deep energy savings.

In this paper we present a scalable approach to deploying integrated systems in existing commercial buildings by opportunistically incorporating them within real estate business life-cycle events. The approach has two key elements: a) integrated systems packages (ISPs) that are pre-engineered to minimize expertise and effort required for implementation; and b) a design approach that seamlessly incorporates them into routine real estate business life-cycle events -- tenant fit-out, equipment replacement, and major renovation. Each ISP is also pre-validated with respect to functionality and energy performance to reduce real and perceived risk.

First, we discuss considerations for incorporating deep energy savings measures in routine real estate life-cycle events, based on a literature review and extensive stakeholder interviews. Next, we describe ISPs developed for three real estate life-cycle events: tenant fit-out, rooftop unit replacement and whole building renovation. We then present in-depth results from the testing and validation of the tenant fit-out ISP as a case in point, including energy savings, indoor environmental quality, and soft costs for installation and operation. Finally, we discuss potential scale deployment channels for the ISPs.

Energy efficiency in the real estate life cycle

We focus on the following key events ("use cases") in the real estate life cycle because they are likely to involve changes to building assets or operations that affect energy use, and therefore present an opportunity for energy efficiency to dovetail with other planned upgrades:

- Purchase or sale of a property. Both "core" (low-return, usually "buy-and-hold" investments) and "value-add" (upgrade candidates with high return potential that are usually sold off within a decade) properties provide opportunities for incorporating efficiency improvements in capital planning, although the latter usually offer a broader scope for improvements.
- Renovation. Owners may make substantial renovations to buildings in response to market needs or to meet the requirements of major new tenants.
- Major equipment replacement. These generally happen in two modes -- planned replacement at the end of useful life (EUL), or unplanned, due to unexpected failure prior to EUL.
- Lease turnover and renewal. Most new leases have a tenant improvement allowance (TIA) for renovating the space to meet tenant needs.
- Refinancing. When buildings are refinanced, it may be an opportunity to get additional loan proceeds to upgrade the space. For example, Fannie Mae's Green Rewards program

offers incremental loan funds for implementing energy efficiency upgrades in multifamily properties [Fannie Mae 2019].

Figure 1 conceptually illustrates the key stakeholders involved in each of the above events.

	Purchase/ Sale	Renovation	Equipment Replacement	Lease Turnover	Re-finance
Owner	●	●	●	●	●
Operator	○	●	●	●	
Tenant		○	○	●	
Investor/Lender	●	●	○		●
Developer	●	○			
Architect/Engineer		●	●	●	
Construction		●	●	●	

● Major role   ○ Major role in selected cases

Figure 1. Real estate life-cycle events and stakeholders involved.

In the energy efficiency literature, we found few resources that address energy efficiency in the context of real estate life-cycle events in commercial buildings. There are, of course, numerous resources on how to address energy efficiency in existing buildings - including technologies, strategies and processes — but they generally do not address the interplay with real estate life-cycle events.

The 'Zero Over Time' report by the Rocky Mountain Institute (RMI) [Jungclaus et al. 2018] describes steps and strategies for building portfolios to achieve net zero energy goals by aligning deep energy efficiency, energy storage and renewable energy projects with real estate life-cycle events.

Regarding leasing, NYSERDA's Commercial Tenant Program developed four case studies [NYSERDA 2019] on incorporating energy efficiency into leased spaces. The Urban Land Institute (ULI) Tenant Energy Optimization Program describes a ten-step process to include energy efficiency in a lease fit-out [ULI 2019]. The Green Lease Leaders program by the Institute for Market Transformation (IMT) and DOE's Better Buildings Alliance provides guidance on how to incorporate energy efficiency into lease agreements [IMT 2019]. RMI has a guide for leasing net zero buildings [Carmichael and Peterson 2018]. Earlier, the Northwest Energy Efficiency Alliance (NEEA) identified and developed resources to fold energy efficiency into leasing, property management agreements, tenant improvements, and underwriting standards [Davis et al. 2010].

Building on the above, we conducted 33 interviews with a range of stakeholder types to obtain information on the real estate business process and their roles, as well as their perspectives on incorporating energy efficiency enhancements into the key real estate events identified above [Mathew et al. 2019]. Given the nature of the information we were seeking, we used semi-structured interviews rather than a formal survey because this allowed us to explore nuances and lines of inquiry that could not be anticipated in advance. Figure 2 indicates some of the key interview questions.

About you:

- What is your organizational role and experience?

Real estate lifecycle events: people and process

- Describe your role in the following real estate events: purchase/sale, renovation, equipment upgrade, lease turnover, refinancing
- For the real estate events you have a role in, who are the key stakeholders and what are the primary drivers and sensitivities?

Energy efficiency in real estate events

- Is energy efficiency a consideration in these real estate events? How so?
- What would it take to incorporate or increase the role of energy efficiency in these events? What are the opportunities and constraints?

Figure 2. Key discussion questions

Figure 3 shows the count for each stakeholder type (the total exceeds 33 because a few stakeholders represented multiple roles).

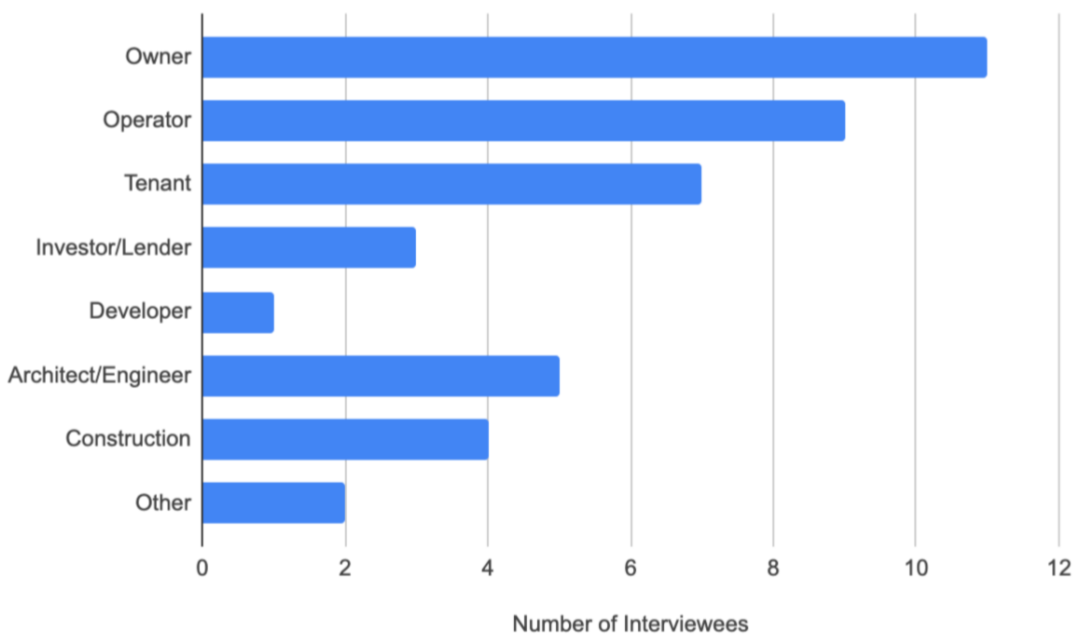

Figure 3. Number of interviewee perspectives for each stakeholder type.

Seven key themes emerged from the discussions, as summarized below. More detailed results are available in Mathew et al. [2019]:

1. Payback is (almost always) still important

The most common responses fell in the three- to five-year range. Interestingly, however, several organizations and individuals that we talked to clearly steer go/no-go project decisions away from energy and toward proposed projects' ancillary or non-energy, often occupant-facing benefits.

2. Packaging and standardization of solutions are valuable

The prospect of standardized, drop-in energy efficiency solutions with well vetted energy savings was welcomed by almost all interviewees. Time urgency was cited as a big obstacle/factor in fit-outs and renovations, and commoditization of solutions (with proven savings) was seen as highly beneficial and much more likely to result in energy efficiency advances than customized approaches.

3. Get in the specs

The importance of having a hard-wired directive or preference — whether housed in a set of specifications, design standards, guidelines, 5-year plans, or even, in one instance, an electronic purchasing portal — cannot be overstated. The predilection to avoid headaches and go with a known, replicated solution is a very strong one. As one respondent put it, "what's easy gets done."

4. Timing is critical

The time pinch in construction is fairly obvious and easy to apprehend, but the phenomenon goes deeper, extending to the planning and design stages for these real estate events. As one developer said, "there's a three- to four-week window" in which key decisions regarding capital outlays take place for a deal. He and others emphasized the importance of getting one's desired outcome into the capital planning process such that these windows are not missed.

5. Lease and ownership structure (and term) matter

The well documented "split incentive" in energy efficiency projects (i.e., the conflicting motivations between those who use the energy versus those who pay the bills) was quite evident in the responses. Additionally, from the standpoint of investors, the "hold period" (i.e., the length of time the investor expects to retain the investment) also has a big impact on investors' acceptable payback period. Similarly, tenant lease period — and expectations/plans for renewal — also impact the amount of investment that building owners are willing to make.

6. Organizational priorities and practices vary widely

Cost reduction and payback are paramount for most organizations when considering energy efficiency. However, several organizations clearly evidence a "green lean" and a few see their savvy in energy as a competitive, "bottom line" advantage. Some interviewees indicated that they were greener in some parts of their footprint than others, which could be driven by individual champions as much as organizational direction.

7. The key influencer is … not obvious

The influencers are diverse, varying by event, organization, region, lease structure, etc. People across the entire spectrum of roles — owner, operator, tenant, asset manager, architect/engineer, project manager, vendor — can play the enabler (and sometimes disabler) of energy-efficiency decisions. This makes getting through to the right person/people challenging.

Figure 4 shows the number of interviewees who provided feedback supporting each theme, illustrating the relative emphasis of each theme across the full set of interviews.

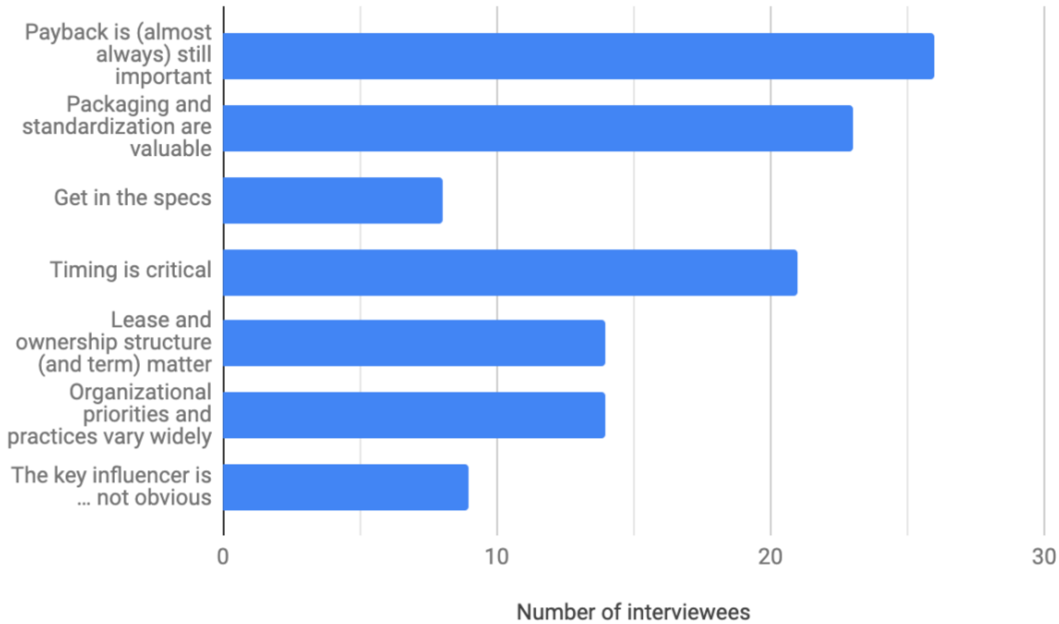

Figure 4. Number of interviewees providing feedback supporting each theme

Based on this feedback, we identified the following takeaways to inform the development of energy efficiency packages optimized for the real estate life cycle:

- Provide context-specific guidance to help users select energy-efficiency packages, with easy-to-use tools (e.g., flow charts) to assist them in selecting the right package and associated options for each of the real estate events.
- Modularize packages to allow for options that account for building-specific characteristics and broaden their applicability. The options should be configured as standardized “plug-in” modules for the package.
- Be technology-agnostic. Most stakeholders seem not to maintain favoritism for specific technologies — their criteria for market adoption, cost-effectiveness and ease of implementation appear to be more important.
- Calculate cost-effectiveness with user-specific baselines, based on incremental savings and costs from the customer’s actual situation (e.g., if motorized roller shades were going to be installed anyway, that planned shading system, not manual venetian blinds, should represent the baseline for cost and savings generated by a more advanced shading upgrade).
- Articulate the value of non-energy benefits, ideally quantitatively. There are a multitude of these, such as higher quality space, smoother operations, easier installation, reduced risk (due to standardization and packaging), carbon footprint reduction, and a variety of occupant benefits like higher indoor air quality and enhanced productivity. These benefits

can be critical to building buy-in within the owner organization, and “selling” projects to the tenant organization.
- Make it easy across the whole delivery chain, by providing a comprehensive set of resources to reduce the burden in every step — selection, specification, procurement, installation, commissioning, and operations.

In sum, the stakeholder interviews fairly clearly pointed to the need for and value of the concept of standardized packages of energy efficiency measures tailored to commercial real estate events. But at the same time, they also underscored the difficulty of creating these packages in a way that appropriately addresses the challenges faced. They need to reliably pay back their incremental expense quickly and must be easy to replicate and “drop in” to existing processes for design, installation, and operations.

Integrated Systems Packages

Design approach

Based on the findings from the stakeholder interviews, we then proceeded to design ISPs for three specific real estate event use cases— tenant fit-out without HVAC, tenant fit-out with HVAC, RTU replacement, and whole building renovation — using the process described below:

1. Develop a list of potential efficiency measures. We generated a broad list of measures drawing on industry experience and expertise, as well as literature such as case studies and efficiency program offerings. The scope included lighting, HVAC, envelope, plug loads, as well as energy monitoring. The focus was energy efficiency and did not include renewables or purely demand response measures. Additionally, given the goal of de-risking energy efficiency, we limited the list to proven commercially available technologies and strategies.
2. Determine applicability for real estate events. For each measure, we determined whether it would apply for each of the four real estate events. This was mostly self-evident based on the scope of the event (e.g., tenant fit out would not include central plant measures, etc.). However, in some cases we included measures that could potentially be included even if they are not ordinarily within the scope of that event. For example, an RTU upgrade could potentially include a cool roof given that there would already be construction activity on the roof and that it could help right-size the RTU.
3. Assess potential for standardization. A key premise of this effort is that packages can be to a large extent standardized in order to minimize bespoke engineering in design, specification, installation and operation. While each building and project may have some unique aspects, many of these can in fact be standardized. We used engineering experience to make a qualitative assessment of whether each measure could be standardized. The design, specifications, and installation process for LED lighting upgrades lends itself to standardization. At the other end of the spectrum, major chiller plant upgrades are complex, with many options, and much more difficult to standardize. Furthermore, they tend to be large projects that can afford bespoke engineering and would not significantly benefit from standardization.
4. Define core and optional measures for each ISP. Once we identified a set of measures for each event, we then separated them into two categories: “core,” which would be

"required" for the package, and "optional," additional elements that might selectively apply or be desirable for various site-specific reasons (e.g., envelope enhancements during RTU upgrades).

5. Assess savings range. The intent is to have each ISP provide approximately 20% or greater whole building energy savings. We conducted a rough assessment of the savings range for the core measures in each package. We reviewed the literature to determine typical savings ranges for each individual measure and then calculated total savings with some adjustments for interactive effects. In general, it appears that all the packages have the potential to deliver on the order of 20-30% savings with the core measures alone.
6. Revise design with stakeholder input. We then presented the package design to several stakeholders via the project's technical advisory group, which includes designers, owners, operators, mechanical contractors, utilities, and industry organizations. We revised the packages based on their input. For example, several stakeholders mentioned that plug load controls, while proven technologically, are often not popular with facilities staff because of the level of occupant engagement and education required. Accordingly, we decided to make this an optional measure.

Package descriptions

Figure 5 summarizes the measures in each of the packages. There are two tenant fit-out packages. The level 1 package assumes that the tenant fit-out is limited to "inside walls and below ceiling" and therefore does not include any HVAC. It consists of lighting including controls, plug loads, and optionally some interior shading. The tenant fit-out level 2 package is designed for fit-outs that also include HVAC controls measures.

The RTU replacement package includes advanced RTUs as well as ASHRAE Guideline 36-compliant controls. Optional are two envelope measures that can reduce the size of the RTU.

The whole-building renovation package is essentially a combination of the level 2 tenant fit-out and RTU replacement packages.

All packages include some level of continuous metering and monitoring, tailored to the scope of the package.

As noted earlier, the individual measures themselves are generally proven, commercially available technologies and strategies. Accordingly, we do not provide detailed descriptions of each of them here. However, some measures merit additional explanation.

High efficiency RTU: High-efficiency RTUs and heat pumps are specified based on Consortium for Energy Efficiency Tier 2 performance requirements. The units have dry-bulb economizers, variable speed fans, and direct digital control. An option for enthalpy recovery wheels is also provided.

ASHRAE Guideline 36: This includes a detailed set of best-in-class control sequences. It covers zone sequences, intermittent ventilation, demand-controlled ventilation, and trim-and-respond sequences for resetting supply air temperature and duct static pressure.

Ceiling fans: Ceiling fans can save energy by allowing for higher cooling set-points while keeping occupants comfortable. The ISP specifies an efficiency requirement for fans, along with sequences to integrate them with HVAC thermal comfort controls.

● Core ○ Option		Tenant Fit-out (Level 1)	Tenant Fit-out (Level 2)	RTU Replacement	Building Renovation
Lighting	LED Fixtures	●	●		●
	Occupancy-based controls	●	●		●
	Daylight dimming controls	●	●		●
	Network lighting controls system	○	○		○
HVAC	High-efficiency RTU			●	●
	ASHRAE Guideline 36 Controls (Including trim and respond for supply air temp and duct static pressure, demand controlled ventilation, intermittent ventilation, VAV box retuning)		●	●	●
	Ceiling fans with 4F setpoint increase		○		○
	High-efficiency low-pressure drop filters			●	●
Envelope	Automated interior shades	○	○		○
	Window films			○	○
	Secondary window inserts				○
	Cool roofs			○	○
Other	Plug load controls	○	○		○
	Metering and performance monitoring	●	●	●	●

Figure 5. Efficiency measures in ISPs

Automated interior shades: These roller, solar or screen shades are specified as an option that can be used to provide optimal daylight conditions for daylight dimming of lights, and also to reduce envelope thermal loads. Parameters for purchasing, mounting, and controlling the shades are provided.

Window films: The ISP specifies performance requirements for window films which can improve comfort and save energy by reducing radiant heat loads, which in turn can reduce the sizing of the RTU replacements.

Metering and performance monitoring: system-level (or tenant-level) metering is specified, along with data collection configurations. The data allows for measurement and verification of energy savings from enacted measures.

Each ISP will have a toolkit of resources to streamline implementation. These resources will provide project requirements and systems specifications, as well as installation, commissioning and operation guidelines. Draft versions of these toolkits have been developed and are available for public review and use [LBNL 2020a]. The toolkit will also include validated performance data from laboratory and field testing (currently in development).

Validation approach

We are validating the ISPs in two major ways. We are conducting laboratory testing to evaluate the performance of the technologies under a set of "controlled" conditions, and identify any installation and commissioning issues. Following that, we are conducting field testing with full-bore implementation in actual buildings during actual real estate events. In addition to energy savings and installation costs, the field testing will provide "real world" experience on the level of effort and related transaction costs for applying ISPs during a real estate event. In the next section, we present preliminary results from laboratory testing of the tenant fit out package, as an illustration of the potential energy savings from ISPs.

Laboratory Testing of a Tenant Fit-out Package

We are conducting laboratory testing of the packages in order evaluate the following aspects:

- technology integration, installation and commissioning procedures;
- energy and demand savings;
- thermal and visual comfort;
- M&V approaches and associated savings uncertainty.

The laboratory tests enable evaluation of energy and indoor environmental quality (IEQ) performance of the ISPs under a wide range of controlled conditions. This helps to “de-risk” the packages, making them more acceptable to site owners, managers and occupants before field installation.

At the time of this writing, we had completed testing for the Tenant fit-out level 2 ISP. This section describes our approach and preliminary results for this ISP. A similar approach will be used for other ISPs

Approach

We used the FLEXLAB facility [LBNL 2020b] at LBNL for the laboratory testing. FLEXLAB allows for side-by-side testing of integrated systems under real-world conditions. Each FLEXLAB test bed consists of two identical test cells (Figure 6). This allows side-by-side testing of baseline and retrofit cases and thereby provides true empirical counterfactuals for energy savings and indoor environmental quality.

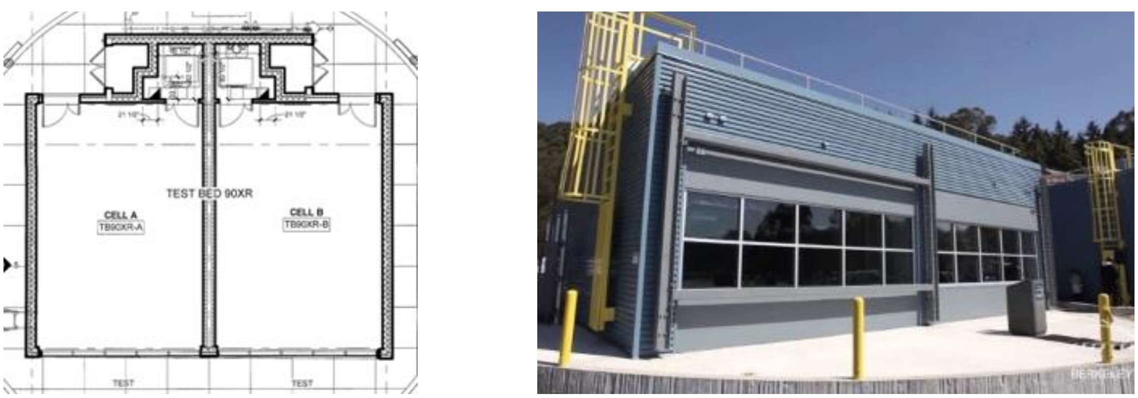

Figure 6 . Floor plan (L) and external view (R) of FLEXLAB testbed showing side by side test cell*s*

Figure 7 shows an interior view of the test cell. It had an open office layout with six workstations. The test included occupant heat generators, motion triggers[1], and plug loads (computers and monitors). We developed separate occupant schedules for each occupant, to simulate diversity in occupant presence in the space during the workday. These schedules were

1 Since the occupancy-based lighting is controlled via both heat and motion, we needed both heat generators and motion triggers to represent the occupants.

applied to the occupant heat generators, motion triggers, and the monitors. Figure 8 also shows the ceiling fans and automated window shades, which were optional measures in the ISP.

Figure 7. Internal view of FLEXLAB test cell for tenant fit-out ISP

Test configurations: We tested a total of six configurations, summarized in Table 1. This included two measure sets to distinguish the savings between core and core-plus-optional packages. We tested three orientations: south facing perimeter zone, west-facing perimeter zone, and an interior zone. We used FLEXLAB's rotating testbed, which allowed us to simply rotate the testbed for south and west orientations. To test the interior zone, we covered the window wall with opaque insulated panels.

The baseline for all configurations represented a typical existing building configuration: T-8 fluorescent fixtures without occupancy controls and daylight dimming; manually operated venetian blinds; standard VAV controls; and no occupancy-based plug load controls.

Test period: We tested each configuration for multiple periods over six months in order to capture seasonal variations in temperature, humidity and solar radiation. Each test period for each configuration typically lasted 5-6 days.

Table 1. Test configurations for level 2 Tenant Fit-out ISP.

Case	**Measures**	**Orientation**
Core-S	Core measures as shown in Figure 6	South
Core-W	Core measures as shown in Figure 6	West
Core-I	Core measures as shown in Figure 6	Interior
Core+Op-S	Core and all optional measures as shown in Figure 6	South
Core+Op-W	Core and all optional measures as shown in Figure 6	West
Core+Op-I	Core and all optional measures as shown in Figure 6	Interior

Measurements: FLEXLAB's built-in measurement infrastructure allows for highly granular measurements of electrical and thermal loads, interior environmental conditions, outdoor weather parameters, and thermal fluxes through envelope components. For this test, we logged and analyzed the following quantities in order to evaluate energy savings, thermal comfort and visual comfort:

- lighting power at the fixture level;
- thermal load for each test cell;
- plug loads for each workstation;
- occupant thermal load for each occupant;
- indoor thermal comfort: each cell had two thermal comfort stations -- at perimeter and interior workstations -- measuring air temperature, humidity, air speed and mean radiant temperature;
- illuminance: a grid of 12 horizontal sensors measured illuminance at 30" height
- daylight glare probability: each test cell had two high dynamic range (HDR) cameras, one at the perimeter workstation at seated height with a view parallel to the window (representing a seated occupant), and another at the back of the cell looking toward the window (representing an occupant walking about the space, looking at the facade).

We also logged a number of HVAC controls parameters to diagnose the operation of ASHRAE Guideline 36 control sequences. These included heating and cooling set points, interior space temperature, heating and cooling control valve positions, outside air damper position, supply air temperature, and supply air fan speed.

We conducted a daily check of the data to ensure that the systems were operating as expected. If the data for a given day were invalid for any reason (e.g., a system did not operate as intended), we then extended the current test period by a day.

Results

At the time of this writing, we had only completed preliminary analysis of FLEXLAB test data. Nevertheless, the data provide some insight into the performance of the system.

Figure 8 shows the results for lighting savings for the CoreOp-S configuration (south perimeter zone with core and optional measures). The figure shows hourly savings, daily savings and average test period savings for test days in August, September and October. Figure 9 shows the same for the Core-W configuration. These preliminary data offer the following key observations:

- Both the south and west orientations show about 80% lighting energy savings in August-September test periods. The south orientation shows a drop to about 70% savings in October. This is due to lower sun angles triggering the deployment of automated shades during most of the day. The effect is less pronounced for the west orientation because the low sun angles are only relevant in the afternoon hours. This effect is consistent with prior studies on daylighting and automated shading [Mathew et al. 2018].
- The interior zone shows a savings of about 70% relative to the baseline. These savings are due to LED lighting and individual fixture occupancy controls. Comparing perimeter and interior zones shows that the contribution of daylight-based dimming provides just over 10% additional energy savings during periods when the shades are not deployed.

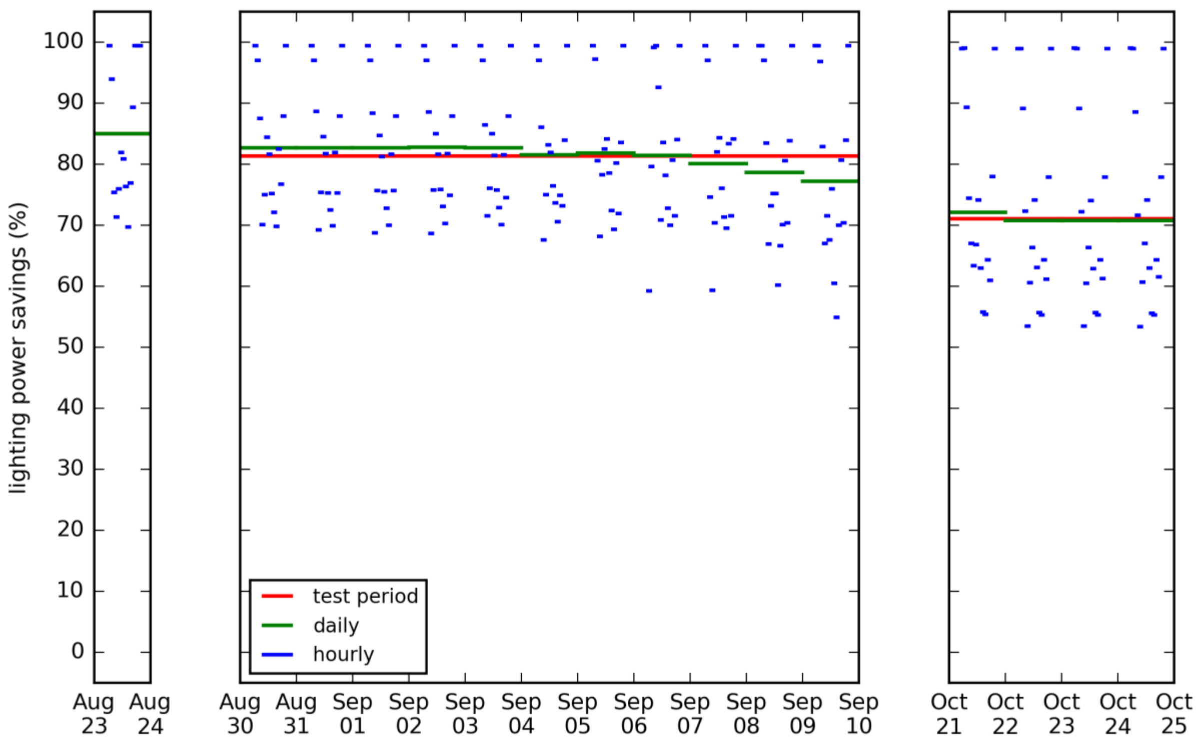

Figure 8. Lighting power savings for the CoreOp-S configuration
(south perimeter zone with core and optional measures)

Figure 10 shows the HVAC daily cumulative load for selected days for the core and options configurations as well as the base case. It shows that the test case has a daily cooling load savings of in the 35-65% range. It should be noted that this was only for these days and does not necessarily represent annual savings. But the data indicate that the measures likely have significant savings.

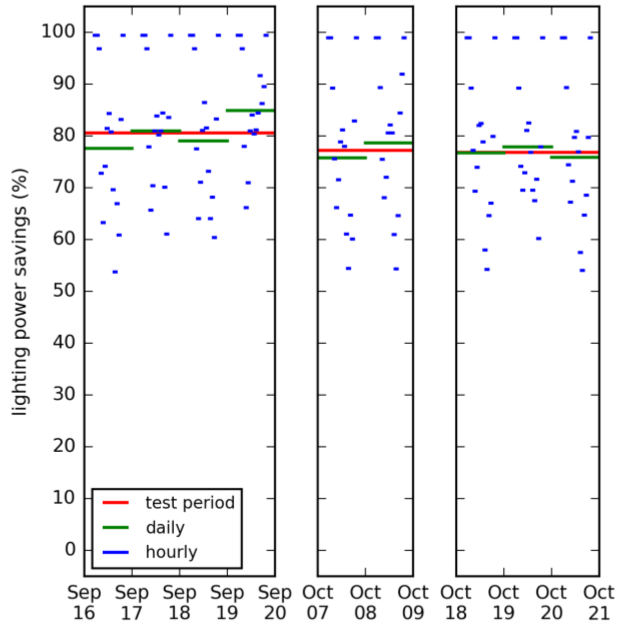

Figure 9. Lighting power savings for the CoreOp-W configuration
(west perimeter zone with core and optional measures)

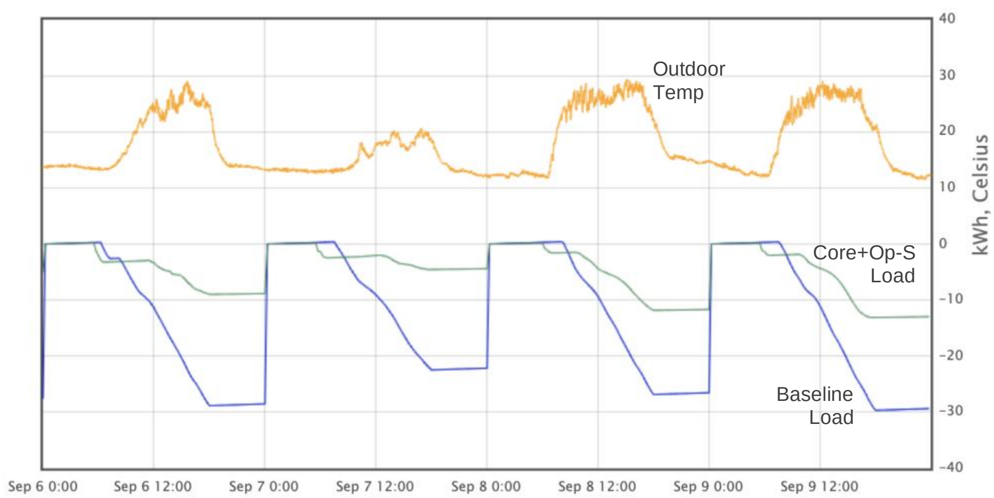

Figure 10. Data logging system screenshot showing HVAC daily cumulative load for the test cell (Core+Op-S configuration) (green line) and baseline cell (blue line) for selected days in September in cooling mode. The orange line shows outdoor temperature.

We are developing annualized savings by extrapolating these measured savings using a hybrid empirical and simulation approach, as described in Mathew et al. [2018]. We use regression models to compute lighting and HVAC load savings for each configuration as a function of weather parameters, and simulation to extrapolate the HVAC load reductions to whole-building energy savings for various building configurations.

Looking ahead: Field validation and Deployment Channels

In addition to the laboratory tests, the ISPs will be pilot-tested in the field using actual buildings undergoing actual tenant fit-outs, RTU replacements, and whole-building renovations. We are partnering with building owners and operators, including CBRE, to conduct the field tests. The scope of the field testing will include evaluation of energy savings, implementation costs, indoor environmental quality, and transaction cost considerations such as the level of effort and skill required to implement the ISPs.

Future market uptake of the ISPs could potentially happen through several channels:

1. Utility programs could offer incentives for ISPs much as they do for individual technologies, on the premise that the savings for ISPs have been validated through laboratory and field testing and therefore do not require the same level of field M&V as custom incentives.
2. Real estate portfolio owners/managers could incorporate ISPs into their standard specs for tenant fit-out and RTU replacements across their portfolios.
3. Architectural/engineering design professionals could use the ISPs as a template to reduce the level of effort required to design and specify energy-efficient alternatives.
4. Product and service providers could offer ISPs as an "up-sell" from simple component replacements, and could leverage the ISP specs and resources to reduce the level of effort to develop package offerings.
5. Financing entities could provide quasi-standardized financing tailored to ISPs. Here again, the validated, standardized ISPs reduce the level of risk and effort for financing.

In all cases, the intent is to embed ISPs in real estate life-cycle events that are happening every day in the building industry. One real estate portfolio owner indicated that this is especially pertinent in jurisdictions with building energy performance standards for existing buildings. The strategies may vary depending on the market sub-sector. For example, a strategy for leased spaces might involve monitoring and leveraging of specific trigger points in the leasing process: periodic review of lease renewals in real estate databases such as CoStar; collaboration with financial institutions to engage customers seeking loans for lease fit-outs; cooperation with brokers to relay program benefits to clients; and more.

Conclusions

This paper presents the concept of integrated systems packages (ISPs) as a scalable approach to deploying multiple integrated efficiency measures in existing commercial buildings by opportunistically incorporating them within real estate business life-cycle events. Interviews with 33 stakeholders informed the technical and implementation approach and requirements for the ISPs. Four ISPs were developed for application in tenant fit-outs, RTU replacements, and whole-building renovations. The ISPs incorporate proven but underutilized energy efficiency technologies and strategies, appropriate for the scope of the targeted real estate events. Laboratory testing of the tenant fit-out ISP provides a preliminary indication of the scale of savings, showing up to 80% lighting energy savings in perimeter zones, and 35-65 % HVAC cooling load savings. The ISPs are currently being field-tested in actual buildings, which will help validate whole building energy savings as well as cost effectiveness and ease of implementation within the context of these real estate events.

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