Energy efficiency retrofits can enable profound energy and cost savings for commercial buildings, but despite a wide array of effective and commercially available technologies, these upgrades are lagging in industry adoption — only about 2.2 percent of the total floor space in the U.S. is retrofitted annually. Construction disruptions and high transaction costs are standing in the way of major savings for commercial buildings.

Reducing transaction costs for owners and integrating energy efficiency retrofits into routine life cycle real estate events, such as tenant fit-outs, major equipment replacement and building renovations, are actions that can be taken to overcome hurdles to energy-saving technologies adoption. The capital threshold for implementing changes is more favorable when demo is ongoing: ceiling opened up, something else torn up or do not have to maintain HVAC operations. It is easy to add energy efficiency when electricians are already there for some reason.

To date, energy efficiency upgrades have often been handled as component-based retrofits, such as individual equipment or lamp replacements, but systems-based approaches are becoming increasingly recognized as the preferred method for building energy upgrades. Integrated systems approaches enable deeper, cost-effective savings — a report from the Lawrence Berkeley National Laboratory (LBNL) reports that comprehensive systems-based retrofits lead to 50 percent more savings. However, in the past, integrated systems approaches have remained difficult to implement for a couple of key reasons.

Building energy retrofits are often approached as standalone engineering projects, causing disruptions to building activities and occupants due to repeated construction requirements. Nobody, building owners and occupants alike, wants to be repeatedly displaced from their desks and normal job activities to make way for building renovations. Time is almost always a constraint and typically everybody is behind the eight ball. As the frequent planner and coordinator of building upgrades, facility managers are often burdened by standalone retrofits, which are time-consuming and cause inefficiencies in the workflow and disruptions to the entire building. Integrated energy-efficient systems approaches require significant engineering expertise to ensure that they are designed, integrated, commissioned and operated effectively, posing additional burdens and transaction costs to FMs and building owners.

So, while systems-level building retrofits are increasingly accepted in the industry as the most effective approach, these barriers are preventing scaled adoption. Worse, the barriers are hindering much-needed progress toward emissions reductions targets and climate goals — and the world cannot afford further delays. Pre-engineered, quasi-standardized packages of integrated retrofits are a promising solution to overcoming these challenges and enabling easier adoption of energy efficiency upgrades for all properties.

Integrated system packages (ISPs)

With support from the U.S. Department of Energy (DOE), researchers at LBNL have developed ISPs, pre-packaged retrofit combinations, to overcome key barriers to energy-saving technology installation. ISPs take a scalable approach to efficiency deployment in commercial buildings by: 1) seamlessly incorporating the upgrades into routine real estate life cycle events to reduce disruption to building activities and occupants (Figure 1); and 2) minimizing the expertise and additional effort required for implementation by pre-engineering the retrofit packages.

Simply put, the ISP approach makes it easier to adopt systems-level efficiency technologies and start saving on energy consumption and costs.

LBNL has developed ISPs for three common real estate events: tenant fit-out, RTU replacement and whole building renovation.

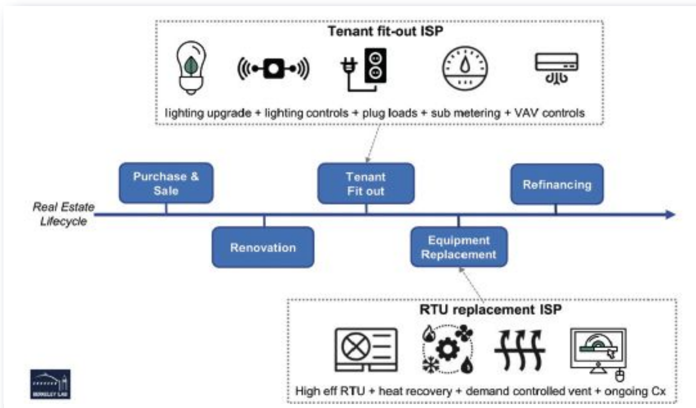

Figure 1. Aligning energy efficiency upgrades with the real estate life cycle.

The Packages

Figure 2 summarizes the measures included in each package, which are described in more detail below. A comprehensive list of measures was considered for each package. The measures finally selected for each package met the following criteria: they are proven and commercially available; they are reasonable to include within the scope of the relevant real estate event; and they are relatively standardizable and do not require highly bespoke engineering. LBNL has developed a toolkit of resources for each package.

● Core ○ Option

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

Figure 2. *The integrated system packages*

Tenant fit-out

This ISP can be implemented in conjunction with a tenant fit-out. These ISPs are cost-effective because: 1) they minimize additional disruption to building occupants and activities beyond what is already occurring due to the tenant fit-out; and 2) they reduce the incremental costs of adding energy efficient measures into a renovation because many of the costs are a result of the baseline tenant fit-out itself.

The core aspects of the package include installing high-efficacy LED fixtures, occupancy-based lighting controls, daylight dimming controls, tenant-level metering, energy performance monitoring and ASHRAE Guideline 36 HVAC controls. Guideline 36 includes trim-and-respond for supply air temperature and duct static pressure, demand-controlled ventilation, intermittent ventilation and VAV box retuning. Optionally and where appropriate, the package also includes installing a network lighting controls system, ceiling fans, automated interior shades and plug-load controls.

These efficiency measures were chosen because they fit well into the scope of medium-to-larger scale tenant fit-outs and they can be easily standardized for routine adoption. Measures that require high levels of customization, such as variable refrigerant flow cooling system retrofits, were excluded.

LBNL utilized laboratory and simulation analysis to reveal significant savings associated with the tenant fit-out ISP. The simulation results from the tenant fit-out showed savings in the range of 23-37 percent depending on location and whether optional measures were included (Figure 3). Laboratory testing was carried out to measure the energy savings, thermal comfort and visual comfort relative to an existing building baseline. Testing was conducted for three orientations, south, west and interior, and with and without optional package components. The laboratory results, retrieved via experiments in LBNL's FLEXLAB, validated the simulation results, showing 69-84 percent savings from lighting, 20-40 percent from HVAC, and 33-40 percent for all end uses relative to an existing building baseline.

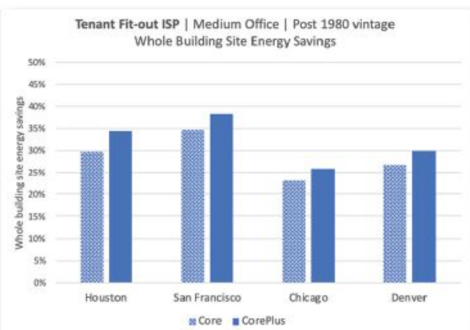

Figure 3. *Simulated whole building site energy savings for the tenant fit-out package*

Additional benefits of the tenant fit-out package are the reduced professional effort and development cost by using pre-engineered energy efficiency packages, the ability to meet corporate environmental, social and governance goals and regulatory requirements, higher property valuation, and a better building occupant experience through improved thermal comfort and indoor air quality.

The tenant fit-out package is applicable for office buildings undergoing a tenant fit-out that includes lighting and HVAC controls. The HVAC controls retrofit assumes a building automation system (BAS) and digital controls down to zone level.

RTU replacement

Another ISP is one that can be aligned with a rooftop unit (RTU) replacement. It includes a high-efficiency RTU, advanced controls based on Guideline 36 and energy monitoring. Optionally and where appropriate, the package also includes window films and a cool roof to reduce the RTU load and size.

The simulation results showed whole building site energy savings ranging from 12-18 percent (Figure 4). The laboratory results, retrieved via experiments in LBNL's FLEXLAB, validated the simulation results.

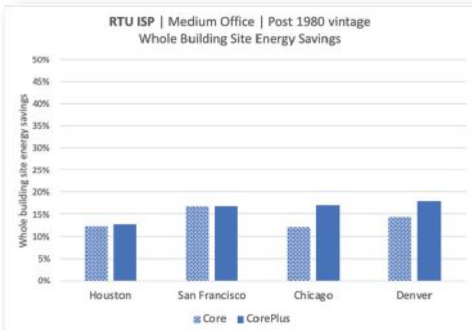

Figure 4. *Simulated whole building site energy savings for the RTU replacement package*

Building renovation

The building renovation ISP can be implemented during any general building upgrade. The package includes LED lighting and daylight dimming controls, high-efficiency RTUs, HVAC controls based on Guideline 36 and energy monitoring. Optionally and where appropriate, the building renovation ISP also includes ceiling fans, automated interior shades, window films, cool roofs and plug-load controls. The simulation results showed savings ranging from about 25 -45 percent depending on location and whether optional measures were included (Figure 5).

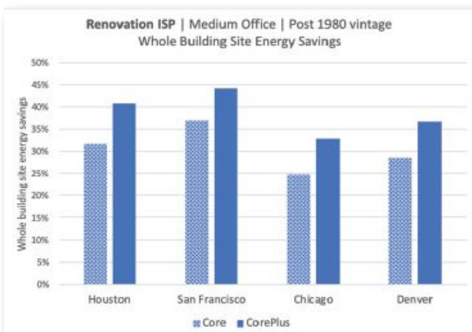

Figure 5. *Simulated whole building site energy savings for the whole building renovation package*

CASE STUDY: ADDING EFFICIENCY TO RENOVATIONS

The world's largest property and FM company and an industry leader in the advancement of energy efficiency for their properties, CBRE was a partner in the development of ISPs. As the property manager for several financial institution properties in the southeastern U.S. that were pending facility renovations, CBRE selected an 8,800 square foot bank in Birmingham, Alabama, USA, as a prime spot to pilot the tenant fit-out ISP.

The bank, built in 2006, already planned upgrading its exterior lighting and adding rooftop solar PV to the building; but with the addition of the tenant ISP, the scope was expanded to include interior lighting upgrades and HVAC controls upgrades. The interior lighting renovation included LED lighting and daylight-based controls, and the HVAC controls upgrade included a static pressure reset, heating lockout, zone-based scheduling, optimized start and widening the deadband to 4 F (-15.56 C). The bank did not have an energy monitoring system, but the site's size did not warrant one to be installed, as recommended in the ISP toolkit; so, CBRE obtained interval meter data from the utility directly.

The International Performance Measurement and Verification Protocol (IPMVP) methodology was used to calculate energy and carbon emission savings from the building retrofits. In total, there were 25 percent annual energy use savings for the entire retrofit, with 6 percent from the exterior lighting upgrade and 19 percent from the ISP measures (Figure 6 left). Including the rooftop PV, the retrofits also resulted in 30 percent GHG savings (Figure 6 right).

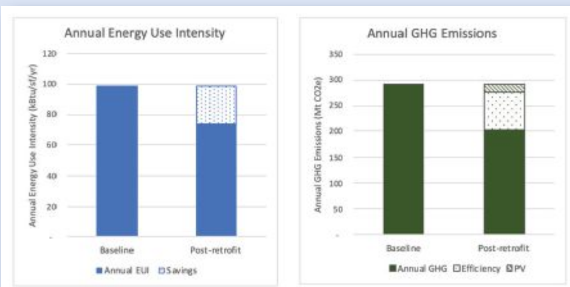

Figure 6. *Annual energy and GHG savings in bank office building located in Birmingham, Alabama, USA.*

Each ISP has a specification template, developed by LBNL and were provided by CBRE to the lighting and HVAC contractors. The lighting retrofits only required a few adjustments regarding lumen output, daylight sensors and color temperature. Because the applicability of Guideline 36 is dependent on the specifics of the HVAC system and control capabilities, the HVAC upgrades required some iteration and adjustment. This process involved one site visit and a follow-up meeting. Researchers at LBNL have now developed an ISP specifications generator tool for users to build customized ISP specifications depending on the characteristics of the site.

The ISP toolkits offer the ability for project developers and planners to easily apply energy-efficient standards into the design specifications of the project. " The toolkits will not only streamline project execution, but will also allow the planner to estimate the energy savings. This will aid in the approval of any potential cost increase due to installing energy-efficient equipment."

The integration of ISPs into a routine renovation allows for 20-25 percent energy and GHG savings with minimal disruption and lower transaction costs because contractors are already in the process of upgrading the building. Going forward, ISP implementation will be even smoother given the development of the ISP specifications generator toolkits, allowing for increased ISP customization, reduced effort level and streamlined decision making.

Conclusion

Through the use of ISPs, efficiency upgrades no longer have to be expensive special projects. Instead, energy efficiency retrofits can be built into routine renovations to lower transaction costs and reduce disruption to building tenants and activities. ISPs are intended to make the lives of building owners, FMs and building occupants easier. The packages enable more buildings to implement energy efficiency, advancing cost and energy savings opportunities, and contributing to global climate goals. Many cities and states in the U.S. are now passing building performance standards that require energy and GHG reductions in existing buildings. The ISP approach can play a critical role in facilitating energy efficiency adoption and mitigating carbon emissions. FMJ

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