RetroFit Depot

Identifying Design Opportunities for Deep Energy Retrofits

RetroFit
AN RMI INITIATIVE

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www.RetroFitDepot.org

Introducing the Retrofit Depot: Deep Energy Retrofit Guides

*Several commercial building energy retrofit guides already exist, but none address **deep** energy retrofits.*

Rocky Mountain Institute wants the owners, occupants, service providers, and retrofit practitioners[1] of our nation's commercial buildings to be aware of the opportunity in deep energy retrofits. We want them to know the value. We want them to have a solid understanding of the process. We also want to arm them with design recommendations that will help make their deep energy retrofits most effective.

Such is the aim of the RetroFit Depot website. It is an unbiased source of information about deep energy retrofits for commercial buildings. On the website people are able to gain a high level understanding of the value of deep retrofits and the required process to achieve them. For those who would like to learn more, we have created a set of three guides.

Since you are now reading the Guide to Managing Deep Energy Retrofits, you are likely motivated to realize the value of deep energy retrofits as described on the RetroFit Depot website and the Building the Case guide. This guide will help you understand the key action items for a deep energy retrofit.

You may be the building owner, or perhaps you are the energy efficiency or sustainability champion at your organization, or maybe you are a service provider preparing a pitch to your client.

Regardless of who you are, you are ready to get started.

1	**BUILDING THE CASE**	Provides comprehensive guidance on framing and quantifying the value of deep energy retrofits.
2	**MANAGING DEEP ENERGY RETROFITS**	Lists the key components of the deep energy retrofit process that limit or eliminate cost premiums, enable risk management, and create maximum value.
3	**IDENTIFYING DESIGN OPPORTUNITIES**	Provides the retrofit practitioner with instructions for identifying opportunities to reduce energy consumption by end-use.

[1]We use "owners" and "occupants" to refer to those individuals making the decision to invest in deep energy savings for their building space. They include owner-investors, owner-occupants, and tenants of buildings. We use "service providers" to refer to those individuals that help business professionals retrofit their building space. These professionals include portfolio, asset, property, and facility managers, as well as other service providers such as brokers, appraisers, lawyers, and sustainability/LEED consultants. We use "retrofit practitioners" to refer to those individuals that help owners renovate and upgrade. These professionals include architects, engineers, and contractors, as well as professionals at energy service companies (ESCOs).

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Design Guidance Overview

Buildings use 42 percent of the nation's energy—much of which is wasted through inefficient design and operation. Standard retrofit approaches that focus on replacement of individual technologies can capture a substantial portion of this efficiency potential. However, much larger savings and greater value can be achieved cost-effectively through integrative design that optimally combines such technologies[2].

This guide gets you started in being able to combine technologies and to truly practice integrative design.

Retrofit practitioners who practice integrative design create a competitive advantage for themselves as a high-value service provider. And they will help transform our buildings from energy hogs into more comfortable, livable, and workable spaces that can help usher in an efficient and renewable energy era.

[2]E.g., a report of 50 recent building retrofits that save 30–80% energy cost states that integrative design and combined measures were more important than particular technologies to achieving the savings (NEEA 2011).

Introducing Integrative Design

Integrative design is a highly collaborative and iterative design process that promotes resource efficiency. It employs whole-systems thinking to derive multiple benefits from single expenditures, often economically justifying much larger resource savings than is typically achieved.

Integrative design applies clear principles and practices that are often ignored and seldom combined during a design process[3]. Below is a list of the most prominent tenets:

INTEGRATIVE DESIGN PRINCIPLES	
1	Focusing on the desired end-use places purposes and applications before equipment, efficiency before supply, passive before active, simplicity before complexity.
2	Broadening design scope embraces whole systems and defines end-use performance goals at the outset (such as increased worker productivity or energy efficiency[4].
3	Designing from scratch, at least initially, creatively harnesses "beginner's mind[5]," spans disciplinary silos, surpasses traditional solutions, and further expands the design space.
4	Analyzing gaps between technical potential energy efficiency and typical inefficiency reveals overlooked opportunities for elegant frugality.
5	Optimizing systems, as opposed to isolated parts, lets single expenditures yield multiple benefits.
6	Evidence-based analysis supplants traditional rules of thumb.
7	Measurement and prudence during design replace unnecessary oversizing and allow operational risks to be managed more explicitly and intelligently.
8	End-use savings multiply upstream energy and capital savings, so efficiency logic is sequenced in the direction opposite to energy flow.
9	Design satisfies rare conditions (making appropriate tradeoffs and engaging end-users), but emphasizes typical conditions to maximize performance integrated over the range.
10	Controls and embedded sensors create intelligence and learning, so design can be optimized in real operation and further improved in future applications.

[3]These principles are taken directly from Lovins (2010). For more integrative design principles and case studies from Amory Lovins and Rocky Mountain Institute, see www.10xe.org.

[4]See the Building the Case Guide for more

[5]"In the beginner's mind there are many possibilities, but in the expert's there are few." – Shunryu Suzuki

How to Use this Guide

The Design Guide for Commercial Building Deep Energy Retrofits provides technical guidance, including both underlying principles and detailed technical advice, for design/retrofit teams seeking to optimize energy use in deep energy retrofits of commercial buildings. Building owners and managers can provide this guide to their retrofit teams. Retrofit practitioners can use this guide to inform their own practices and in-house training. The Guide can also be used in conjunction with the Building the Case and Managing Deep Energy Retrofits guides also provided on the RetroFit Depot.

The guide is a "desk reference" that is divided into several sections to make it easier to find topics of interest. All the practices and approaches described in the document are techniques used by leading retrofit practitioners. As noted in the Managing Deep Energy Retrofits Guide, these techniques should be employed during an ASHRAE Level-3 Energy Audit[6].

The optimal way to use the guide is to read and circulate it among other building stakeholders and retrofit practitioners. A downloadable version of the guide is available on RMI's RetroFit Depot website www.RetroFitDepot.org. After gaining a solid foundation of understanding, set up a meeting of building stakeholders to discuss next steps. If you need more guidance on your commercial building deep energy retrofit project, you may contact Rocky Mountain Institute at bet@rmi.org.

[6]See ASHRAE 2011 for implementing a Level-3 Audit.

The Right Steps in the Right Order

During the course of identifying efficiency opportunities in the building, take these design steps to reap the greatest energy savings and to realize a highly integrated retrofit where individual components provide many functions:

1	DEFINE SPECIFIC END-USER NEEDS	What are the needs and services required by the building occupants? Start from the desired outcome(s): think of purpose and application before equipment. Think of cooling, not chillers; a hole, not a drill; then ask why you wanted the cooling or the hole. How much energy (or other resource), of what quality, at what scale, from what source, can do the task in the cheapest and safest way?
2	ASSESS THE EXISTING BUILDING STRUCTURE AND SYSTEMS	Understand and assess the current state of the building. What needs are not being met? Why not?
3	SPECIFY THE SCOPE AND COSTS OF PLANNED OR NEEDED RENOVATIONS	What systems or components require replacement or renovation for non-energy reasons? What are the costs of interruptions to service or occupancy?
4	REDUCE LOADS	Select measures to reduce loads. First, through passive means (such as increased insulation). Then, by specifying the most efficient non-HVAC equipment and fixtures
5	DETERMINE HOW LOADS CAN BE MET PASSIVELY	Consider methods such as natural ventilation and nighttime air purge.
6	SELECT APPROPRIATE AND EFFICIENT HVAC SYSTEMS	After reducing loads as much as possible, consider what HVAC system types and sizes are most appropriate to handle these drastically reduced loads.
7	FIND SYNERGIES BETWEEN SYSTEMS AND MEASURES	Seek synergies across disciplines. Through this exercise, you can often realize multiple benefits from a single expenditure—such as high performance windows that increase thermal comfort, reduce lighting energy use, and reduce heating and cooling load enough to downsize mechanical equipment. Also, find opportunities to recover and reuse waste streams, such as exhaust air heat recovery.
8	OPTIMIZE CONTROLS	After the most appropriate and efficient technologies have been selected, the focus should shift to optimizing the control strategies.
9	REALIZE THE INTENDED DESIGN	Tune the Owner Project Requirements (OPR) and implement measurement and verification (M&V) and ongoing commissioning to ensure realization of the intended design. M&V will also help facilities staff prevent problems, ensure correct diagnoses, and permit monitoring to improve operation and future retrofit work, as well as educate the owner and occupants.
10	CELEBRATE SUCCESS	Make sure that others recognize your team's success. Seek certifications such as LEED, EnergyStar, and design awards. This helps motivate everyone involved and will make it easier for other teams and other projects to follow.

Lighting (Daylighting & Electric)

In a deep retrofit, opportunities to reduce lighting energy use and improve occupant visual comfort extend well beyond lamp switch-outs, delamping, or installing occupancy sensors. Take advantage of efforts already being invested into the envelope, fenestration, and interior programming to also dramatically improve daylight performance, electric lighting performance, and complementary interior design.

A comprehensive lighting retrofit can result in a dramatically more appealing space, an improved visual environment that better meets the needs of occupants, significant energy savings, along with better control of solar heat gain and reduced cooling loads.

Define Needs

When it comes to visual comfort, more light does not necessarily equate to better vision. Providing a comfortable visual environment is about tuning that environment to specific tasks at hand—you may be surprised to find that, for the most part, light level requirements in most buildings are actually quite low. The following criteria are just as critical as providing adequate light levels:

- Light distribution: Are light levels pleasantly and evenly distributed throughout spaces, or are there uncomfortable dark corners and high contrast areas?
- Color temperature: Is the color temperature in adjacent fixtures uniform? Are the colors appropriate for nighttime and daytime vision?
- Glare: Is it easy for occupants to focus on computer monitors, desktops, and other tasks at hand, or do specific lighting fixtures or direct sunlight cause distracting brightness or reflections?

The Illuminating Engineering Society's *Lighting Handbook* provides detailed lighting guidelines to address different visual tasks in typical space types (DiLaura et al. 2011).

Take a light meter into different spaces to get a feel for current light levels and distribution. When forming a plan for improvement, begin by considering the important qualitative visual needs listed in Table 1. Talk to staff or occupants to find out how well these visual needs are currently being met and identify major deficiencies that should be addressed along with energy efficiency.

Table 1: Visual needs for space types

SPACE TYPE	VISUAL PROGRAMMING NEEDS
OFFICE	• Adequate and evenly distributed light levels for simple visual tasks, typically reading and writing, which tend to be concentrated on horizontal (desktop) surfaces. • More light is needed for more detail-oriented tasks, while much less is required for passageways and around computer monitors. • Light level control depending on occupant age.
INTERIOR AND EXTERIOR CIRCULATION SPACES	• Low-contrast visual environment to promote safety. • Adequate visual cues for wayfinding.
LARGE MIXED-USE SPACES (e.g. gymnasiums, cafeterias)	• Could require the option to choose between different light settings, depending on the activity (e.g. school dance vs. general public assembly).
K–12 CLASSROOMS	• Adequate and evenly distributed ambient light levels for simple visual tasks, typically reading and writing, which tend to be concentrated on horizontal (desktop) and vertical (black/white board) surfaces. • Could require different light level control depending on activity being performed (e.g. audiovisual presentation, exam-taking, etc.) • Ability to minimize glare, especially for viewing blackboards and monitors.

Reduce Loads through Daylighting

Effective daylighting does not only meet the majority of visual needs in typical buildings, but can also add delight and variation to aesthetically challenged spaces. Such effects can transform how occupants perceive their environment and positively impact their ability to work and learn in that space. There is a growing body of case studies and literature supporting the correlation between improved daylighting, productivity, and occupant satisfaction[7].

Maximize the use of daylight as the primary source of ambient light in regularly occupied spaces, thereby minimizing the use of electric lights and decreasing heating and cooling loads. In the majority of retrofits, you will inherit the pros and cons of existing building orientation, massing, and window count and placement. Openings for daylight are already in place and are typically costly to reconfigure. Thus, optimizing daylighting in an existing building is more constrained than for the typical new build. However, added shading devices or replacing glazing can significantly improve daylighting quality as well as energy performance of the space.

The first step of daylighting design for retrofits is to consider the geometric proportions of existing spaces in relation to existing windows and skylights. Next, search for opportunities to improve daylight penetration and distribution throughout regularly occupied areas despite those limitations. The sections below provide suggestions for accomplishing these steps[8].

OPPORTUNITIES IN THE BUILDING ENVELOPE

Adding or retrofitting apertures

In order to use daylight you must first let it into the building through openings in the envelope like windows, skylights, or light tubes. If you are already considering a retrofit to sections of the envelope (for example, to add insulation on the exterior walls or roof, or to reconfigure roof top units and equipment) it could be a good opportunity to piggyback off of required service interruptions or construction to add, re-size, or re-configure envelope apertures.

Strategic sizing and placement of windows are important for balancing visual with thermal performance. More glazing is not always better. Daylight penetration from windows depends not just on size but placement. Higher window placement, and unobstructed ceilings are the most effective. Toplighting (skylights and roof monitors) can be a good solution in situations where immovable interior walls or deep floor plates prevent natural sidelight from reaching core spaces. Consider that, properly designed, only 3–5% of roof area need be dedicated to skylights in order to daylight 100% of the adjacent space below.

Minimize roof penetrations by using light tubes, adding them to existing vertical shafts where possible. Light tubes are also able to reach multiple floors below; position them adjacent to columns or ductwork.

For retrofits involving a major interior reconfiguration, consider an atrium or large light wells to bring light to core spaces while providing connection to the outdoors and welcome views.

[7] For a comprehensive view, see the Building the Case Guide.
[8] For more detailed guidance on daylighting design focused on new build but relevant to retrofits, we recommend Lam (1986), Egan and Olgyay (2002), and DiLaura et al (2011).

Adding or retrofitting exterior shading devices

Exterior shading devices can help control solar heat gain and glare, and intentionally redirect light to ceilings and other interior surfaces for improved distribution. Adding or retrofitting exterior shading devices can help "fix" existing windows that currently let in either too much or too little solar heat, or compromise visual comfort with excessive glare. Consider structural requirements and limitations of the existing envelope when selecting and detailing exterior shading devices.

Replacing or retrofitting glazing in existing windows

Careful glazing selection can also help balance the visual and thermal properties of sunlight entering the building. Glazing measures to consider include: 1) switching out existing glazing for glass with an improved solar heat gain coefficient (SHGC) and visible light transmittance (Tvis), 2) improving glazing performance by adding a second or third pane (or suspended film in between two panes) and/or gas fill, or 3) adding a film directly to the existing window. Because northern light is diffuse, concentrate your retrofit efforts on south-, east-, and west-facing glazing where they will have the most advantageous impact on electric lighting and heating/cooling loads.

OPPORTUNITIES IN INTERIOR CONFIGURATION AND DESIGN

Interior spaces can be shaped and configured to help redirect light, optimize light distribution and illuminance levels, and reduce glare. When changes to windows and exterior shading are possible, relatively inexpensive interior improvements can help make the most of your envelope investments. Even excluding actual window improvements, changes to interior reconfiguration and design can make a big difference in perceived light quality.

Depending on the scope of interior work being considered, your project could take advantage of the following opportunities:

Relocating or reconfiguring program spaces

Are the right rooms getting access to daylight? As part of reprogramming, consider relocating spaces that could most benefit from daylight to the perimeter of the building. In office areas, consider open offices at the perimeter and private closed offices (if required) at the core. Shape new spaces with care so spatial proportions are most compatible with daylight design.

Raising ceiling heights

Higher ceilings can help re-direct and distribute daylight deeper into interior spaces. Even a 12" raise can make a dramatic difference in perceived light levels. If you are already planning to reconfigure or downsize ceiling ducts and HVAC equipment, this could be a good opportunity to eliminate existing dropped ceilings.

If only portions of the ceiling can be raised, consider reconfiguring ducts and equipment if necessary to provide zones of raised ceiling relief that channel daylight deep into the space. Consider providing a sloped ceiling profile (down and away from windows and skylights) to reduce contrast and improve perceived daylight distribution from those apertures.

Adding or retrofitting interior light shelves and louvers

Interior light shelves and louvers can make the most of existing windows by controlling glare and redirecting daylight upward toward the ceiling and further into interior spaces. They can be part of the “fix” for windows in rooms where the blinds seem to be drawn always. Bottom-up shades can also help block glare while allowing light in at the ceiling; choose wide blind slats and encourage occupants to pay attention to angle so they can reap the benefits of redirecting (as opposed to rejecting) light.

Adding glazing to interior partition walls

Do you remember, or still have, transom windows above doors? Openings in partition walls can help perimeter spaces share daylight with adjacent corridors and core spaces. Couple glazing components with doors if you are already considering replacing or reframing doors. Prioritize clerestory glazing to light the ceiling surface of adjacent interior spaces and to preserve visual privacy. Where audio privacy is not an issue, leave cut-outs unglazed.

Reconfiguring furniture

Reconfigure desks and computer monitors so that they sit perpendicular to windows, minimizing glare and distracting contrast. Relocate blackboards, TVs, and projector screens to locations that don’t compete with glare.

Improving surface reflectance

Light-colored ceilings, walls, floors, and furniture can aid significantly in perceived light distribution, enabling lower overall lighting energy use.

BUNDLING MEASURES TO CAPITALIZE ON SYNERGIES

The measures listed above should not be considered in isolation. They work together to optimize lighting conditions; in some cases, it won’t make sense to pursue one measure without pursuing others as well. For example, if you’re going to put a significant investment in skylights or light tubes, don’t diminish the daylighting design by using dark colors for the majority of your interior surfaces. Similarly, bundling light shelves together with raised ceilings can significantly improve resulting light penetration into interior spaces.

Design Efficient Electric Lighting

An electric lighting system should be capable of meeting all of the building's lighting needs during occupied times when daylighting is inadequate. If daylighting can always meet the need during occupied times, then there would be no need to install lighting equipment at all.

A critical piece of efficient electric lighting design is addressing ambient, task, and accent lighting needs separately. This enables placing light only where and when it is needed, enabling overall lower energy use. For example, in an office setting task lighting is able to provide more light on desktops where it is needed and accent lighting can effectively create interest, while ambient levels in common areas and passageways can be made very low. If these lighting needs are not address separately, then the overall ambient levels are usually made very high to place enough light on desktops.

In addition to meeting task, ambient and accent needs separately, controls (discussed in the next section) should be deployed for efficiency. Controls dim or minimize electric lights as appropriate to take advantage of daylight. An important metric to track when assessing electric lighting efficiency is your connected lighting power density, measured in watts per square foot (W/SF). It is best practice to calculate lighting power density for ambient and task lighting separately; see DiLaura (2011) for target recommendations.

To quickly determine where you currently stand with respect to different space types, calculate:

$$\frac{\#\text{ of lamps in room} * \frac{\text{watts}}{\text{lamp}}}{\text{Total square feet in room}} = \text{Watts per square foot in space}$$

INTERIOR LAMP EFFICIENCY

Three effective ways to quickly and cost-effectively increase electric lighting efficiency are:

1. Replace any existing incandescent bulbs with higher efficiency CFLs
2. Replace any existing linear fluorescent lamps with higher efficiency lamps (e.g. switch out 32W T8s to 25W T8s)
3. Delamp fixtures (e.g. remove one or more lamps from a multi-lamp light fixture) in areas that are overlit.

INTERIOR FIXTURE EFFICIENCY

When rethinking fixture selection, consider ambient lighting needs separately from specialized accent and task lighting needs. For ambient lighting, you can get to significantly greater efficiency by simply upgrading each fixture to deliver more lumens per watt (termed "efficacy") where you want them (check the product specifications for efficacy and light distribution).

Be sure to replace all magnetic ballasts with high efficiency electronic ballasts, in appropriate cases dimmable. Consider the use of indirect-direct fixtures in spaces with high ceilings (i.e. 10 ft or higher) to redirect a portion of the light to the ceiling, improving brightness ratios and softening shadows.

Consider efficient upgrades for specialized fixtures as well. For example, remove any remaining inefficient exit signs and replace them with LED signs that consume 5 Watts or less of power.

INTERIOR RECONFIGURATION AND DESIGN

Interior design can go a long way to complement electric lighting design, just as it can with daylighting design. Consider room proportion and geometry, surface reflectance, location and height of interior partitions, and location of specialized tasks or displays to ensure they work well with the electric lighting design and optimize lighting conditions while minimizing contrast. These factors will help determine an optimal fixture mounting type. For example, a suspended indirect/direct will typically provide the most efficient solution for a large open space. These fixtures can be specified with wider distribution so that you only need 18" or so to ceiling—great for computer workstations.

Refer to the table to the right to determine how invasive these measures can be to your building's existing ceiling types.

Table 2: Impacts of recommended lamp and fixture upgrades to existing ceilings

MEASURE	DROPPED GRID CEILING TYPES	DRYWALL, PLASTER AND OTHER CEILING TYPES
REPLACING EXISTING LAMPS WITH HIGHER EFFICIENCY LAMPS	Non-invasive	Non-invasive
DELAMPING EXISTING FIXTURES IN AREAS THAT ARE OVERLIT	Non-invasive	Non-invasive
REPLACING EXISTING FIXTURE BALLASTS WITH HIGH EFFICIENCY ELECTRONIC DIMMING BALLASTS	Non-invasive	Non-invasive
RECONFIGURING EXISTING FIXTURE LAYOUTS	Minimally invasive: Rewiring could be required to support larger loads or new zoning strategy, refer to Controls section below.	Invasive: Requires patching holes in old fixture locations and making incisions at new locations. When this requires significant ceiling demolition, consider bundling with one-for-one fixture replacements (below) and other upgrades to HVAC equipment configuration and ceiling height.
REPLACING EXISTING FIXTURES (ONE-FOR-ONE) WITH HIGH-EFFICIENCY FIXTURES	Non-invasive	Potentially invasive: Level of patchwork required depends on how new fixtures differ in size/shape from existing.

Add Efficient Exterior Lighting

Install high-efficiency, full-cutoff exterior lighting at building facades, outdoor areas, and parking lots. Full-cutoff light fixtures mitigate light pollution in surrounding areas and the sky, and save energy by directing light down toward the ground where it is needed (allowing you to use lower wattage lamps).

The Illuminating Engineering Society and International Dark-Sky Association have jointly introduced a new rating system through the Model Lighting Ordinance (MLO) that goes beyond addressing cutoff alone and assesses luminaires based on the amount of light they emit as backlight, upward, and in glare zones (coined the "BUG" rating system). Consider voluntary adoption of the rating system requirements as part of your retrofit, to limit expenses that may be required should your jurisdiction require mandatory compliance in the near future. Refer to the MLO user guide for more information (Benya, et al, 2012).

Add Lighting Controls

Proper controls are essential for ensuring that electric lighting is 1) minimized during unoccupied periods and 2) integrated with daylighting. To meet these objectives, consider occupancy controls, daylight controls, multi-level switching, and improved zoning. Perimeter and core zoning, in particular, is an excellent strategy for reducing energy use with daylight most cost effectively.

You may need to rewire or re-circuit for improved zoning. In situations where such work could be very invasive to the existing ceiling, consider emergent wireless control technologies. See the table below for a description of the invasiveness of control measures.

Table 3: Impacts of recommended controls upgrades to existing ceilings and walls

MEASURE	IMPACTS FROM CEILING-MOUNTED CONTROLS		IMPACTS FROM WALL-MOUNTED CONTROLS
	Dropped grid ceiling types	Drywall, plaster and other ceiling types	Drywall or plaster wall types
REZONING FIXTURES TO ENABLE BI-LEVEL SWITCHING/DIMMING	Non-invasive, whether or not re-circuiting is required. Install a control device in the ceiling and patch wall/ceiling accordingly.	Non-invasive, if no re-circuiting required: Install a control device in the ceiling and patch wall/ceiling accordingly. Minimally invasive-to-Invasive, if re-circuiting required: Ceiling access is a must. In many cases, majority of work can be done via access panels or light fixtures holes. If not, invasive ceiling work will be required.	Non-invasive, if replacing existing wall-mounted control device. Reuse of existing conduit, wiring, and electrical box. Minimally invasive—to-Invasive, if relocating existing control device or adding new control device in new location: Requires pulling new conduit and wiring and installing new electrical box/control device in desired location. Cut/patch wall accordingly.
OCCUPANCY SENSORS TO ENABLE SHUTOFF WHEN LIGHTS ARE UNNECESSARY	Minimally invasive: Minor cutting/patching required in ceiling panels where occupancy sensors are installed.	Minimally invasive: Minor cutting/patching required in ceiling areas where occupancy sensors are installed.	Same as for rezoning above.
PHOTOSENSORS TO DETERMINE DAYLIGHT LEVELS	Minimally invasive: Minor cutting/patching required in panels where ceiling-mounted photosensors are installed.	Minimally invasive: Minor cutting/patching required in areas where ceiling-mounted photosensors are installed.	Same as for rezoning above.

Consider the Climate

THERMAL RISKS AND OPPORTUNITIES

When making changes to apertures, glazing, and shading, take into account solar heat gain and overall insulation performance of the building envelope. Understand the needs in your local climate and strategize size and location of glazing and shading devices accordingly. Can the building take advantage of solar heat gain? Retrofit shading to allow solar heat gain during winter months when it's desired, and to block solar heat in the summer when it's not. Minimize windows on west- and east-facing facades where solar heat (and glare) are hardest to control.

FAÇADE-SPECIFIC APPROACH TO WINDOW AND DAYLIGHT DESIGN

Daylight color temperature, height of the sun, and controllability all vary over the course of a day and between seasons. Different spaces will have different lighting and thermal concerns, advantages, and disadvantages, depending on their location within the building and relationship to the passing sun. Develop a tailored approach to glazing selection and daylight design that responds to the distinct concerns of each façade and the local climate.

OVERCAST VS. SUNNY SKIES

Consider whether your climate is dominated by sunny skies or cloudy skies. Cloudy sky climates can use daylight to meet most lighting needs as well—but meeting your goals may require different glazing placement, orientation, selection, and shading designs.

EXTERIOR LIGHTING FUNCTIONALITY

Select exterior lighting fixtures and lamps that can function well in your climate type. As a simple rule of thumb: exterior fluorescents perform best in warmer climates like that of California, Arizona, and Florida. LEDs perform better in colder climates. Cloudy sky climates can use daylight to meet most lighting needs as well—but meeting your goals may require different glazing placement, orientation, selection, and shading designs.

Leverage a Planned Facility Improvement

While lighting retrofits are typically some of the most cost effective options for improving efficiencies, combining these measures with planned facility improvements can make them even more cost effective. If you are already replacing the roofing material, now is the time to consider skylights or light tubes. If you were planning on upgrading from single to double pane windows, select the most efficient ones and consider adding other new elements as well, such as light shelves.

Plug/Miscellaneous Loads and Occupant Behavior

Plug and miscellaneous loads represent a significant portion of total building energy use and are typically subject to occupant behavior. There are numerous low- and no-cost solutions, as well as solutions that require significant capital expenditures. A deep retrofit provides an opportunity to consider all measures and perhaps integrate them with other upgrades (efficiency-oriented or otherwise) for greater cost-effectiveness and convenience.

Define Needs

The end-uses of plug and miscellaneous loads generally fall into three categories. The first category is all of the electrical devices needed for basic office functions. These include computers, telephones, printers, and copiers. The second category consists of all the auxiliary appliances in kitchens and similar rooms, such as coffee makers, vending machines, refrigerators and the like. All remaining devices reside in a third category: “other”—including electrical transformers (the devices that take high voltage electricity from the grid and convert it to voltages appropriate for plug loads and some lighting systems) and electronic building controls.

Reduce Loads

The approach to addressing plug and miscellaneous loads can be summarized by three steps:

1. Replacing or decommissioning existing equipment
2. Adding plug load controls
3. Educating building occupants

REPLACING OR DECOMMISSIONING EXISTING EQUIPMENT

Many pieces of equipment in typical buildings are unnecessary, obsolete, and/or inefficient. If the equipment is unnecessary or obsolete, the recommended course of action is straightforward: decommission it, dispose of it, or replace it with something more efficient, preferably ENERGY STAR-certified. If the equipment is simply inefficient, as is likely the case if it is more than several years old, then it should also be replaced.

Many facility managers prefer to wait until equipment has neared the end of its useful life before replacing it with something more efficient. Understandably, they believe that it is wasteful to send a completely good piece of equipment to the landfill. While this is certainly true, there is also waste associated with inefficient operating energy use. Moreover, there may be a recycling company in the region that is willing to pick up the equipment and salvage all materials, which can then become feedstock for new manufacturing, effectively keeping the materials out of the landfill.

Aside from a concern for sending materials to the landfill, managers may not find that the energy cost savings justify replacing the equipment. However, it is important to consider the other benefits associated with the new equipment. For example, an energy-efficient combined copier/scanner/printer may free up just enough space in the office for some new greenery, which contributes to a more friendly and pleasant environment for staff.

Add controls

The purpose of plug load controls is to reduce or completely eliminate energy use when equipment is not being used. Most equipment (even small items like cell phone chargers) still uses energy when it is plugged in but not serving a useful purpose—a phenomenon known as “phantom energy use”. These non-essential items can be wired into an energy management system that turns them off when not in use—a more elegant and reliable solution than power strips with timers. Networks can be used to “push” control strategies to EnergyStar computers.

Some additional plug load control strategies can also be very visible aspects of sustainability in buildings. For example, vending machine lighting can be controlled to switch on only when people approach it, demonstrating that the machine is using energy only when needed. Commercial products are available and customized for this purpose.

Educate the Occupants

Addressing plug and miscellaneous loads offers a great opportunity to engage staff in the process of reducing energy consumption both at work and at home. An effective way to engage building occupants is through a short educational workshop on ways that they can reduce energy use. At a bare minimum, occupants should be consulted while deciding on equipment replacement to ensure new equipment will meet their needs and that they'll use it properly and not override features such as occupancy sensors and sleep-mode timers.

Consider the Climate

Strategies to reduce energy consumption from plug and miscellaneous loads do not vary by climate. However, the effects of reducing plug and miscellaneous energy consumption on other building systems may change by climate, ultimately leading to a different decision as to whether or not to implement the load-reducing measures.

Buildings located in more temperate climates are dominated by internal gains, and heat gain from plug loads has a much larger impact on peak cooling loads. In these climates, a reduction in plug load power (and therefore internal heat gains) could be significant in terms of downsizing the cooling system, especially if these load reductions can be achieved during peak cooling hours in the late afternoon.

Leverage a Planned Facility Improvement

It is clearly advantageous to replace equipment when it is already due for replacement. However there may be other instances that are less obvious. Do you plan to significantly reduce your electricity consumption? Consider decommissioning a transformer or two. Are you rewiring an older building? Consider creating "essential" and "non-essential" circuits that are separately controlled by an energy management system and turned off at programmed times.

Building Envelope

The building envelope serves as a first line of defense against the elements and as a blanket of comfort for those inside, with windows and doors an essential link between environments. Common energy retrofits rarely touch the envelope, but a deep energy retrofit should always address the envelope.

A deep retrofit is an ideal time to address many façade and roof issues and correct original construction defects if applicable. Improving the envelope can dramatically improve the thermal comfort of a space and can reduce thermal loads enough to downsize and reduce the cost of mechanical equipment slated for replacement. In some cases, perimeter heating may be completely eliminated. Envelope technology and products have evolved significantly since the 1990s, so any building constructed before that period is a prime candidate for major envelope retrofits.

Define Needs

A building enclosure should keep welcome air and heat into the building when it's needed, and keep it away when it's not. Basic maintenance assures a functionally sealed building against water infiltration, but too often air infiltration is allowed free reign. Sometimes construction defects from day one make the problem obstinate.

During a deep retrofit, we recommend targeting contemporary performance requirements for air infiltration. Consider ASHRAE 189.1 for high-performance building design or consider Passive House guidelines for even better performance.

Once infiltration is addressed, make it a priority to improve thermal performance by adding insulation to walls and roof. Because the roof is often the largest exposed surface at any time of day, it can be the most valuable location for added insulation.

Reduce Loads

The first step in addressing envelope condition in a deep energy retrofit should always begin with the following questions:

- Where are the weak points in the system?
- Is there significant room for improvement?
- Are envelope conditions affecting more than just energy consumption?
- Is the condition of the envelope affecting occupant performance or behavior?
- How does the climate affect envelope performance?

Answering these most often includes occupant surveys, monitoring, infrared thermal imaging, and blower door testing. Effective analysis can reveal all the ugliness in the system.

WALLS

A building's exterior walls are its public face and are vital in establishing a first impression for occupants and/or passersby. If there have been envelope failures that require reconstruction or the building is in need of aesthetic work through a comprehensive retrofit, it is a great time to address wall performance as well.

Seal the cracks

Addressing infiltration is the highest priority in the envelope system. Infrared thermographic (IRT) images will point to areas where air or water is clearly passing through the walls unintentionally. Most often, unintended infiltration occurs at joints between walls and roof/floor, where materials change, and at penetrations such as vents. If accessible, seal the joint areas from the interior of the building with an expandable sealant appropriate for the adhering material. Seal material transitions and penetrations from the exterior and interior. If the building is constructed of masonry, check mortar and expansion joints for infiltration issues. Extensive repointing may be in order, which can significantly extend the life of a building while reducing energy consumption.

Insulate

Thermal performance is most certainly affected by conduction—the movement of heat through material. Adding insulation adds resistance to the movement of heat. In order to create continuous insulation spanning the enclosure, which is highly desirable, installation on the outside of the wall assembly is the most effective. However, this can change the character of the building significantly, and interior options are entirely viable, albeit sometimes lower energy savings depending on climate, occupancy, and mass. For buildings that need a facelift, consider some of the new high performance insulated façade systems as an alternative to the overused and occasionally problematic synthetic stucco products, although even that may be appropriate in some instances.

Shade and reflect

Radiation is the most obvious source of heat gain when assessing thermal performance and mitigating it potentially adds value to the building. There are two approaches to mitigating radiative effects—shade the building and/or reflect the radiation right back into the atmosphere. In designing a deep retrofit, if you can shade any part of the wall during hot months, do it. If the building needs a facelift on all or a portion of the façade, consider adding a rainscreen, vegetated green-screen, or louvered wall assembly tuned to block the summer sun, and include a radiative barrier if possible within the east and west façade assemblies. Pay attention to exterior finish colors and selective surfaces as this can either create a radiative heat sink (good for cold climates) or reflect heat (good for hot climates), depending on the color and reflectivity. Plant deciduous trees on the grounds in the east, south, and west sides to shade the façade and improve the landscape. If possible, calibrate, construct and/or extend existing roof overhangs to perform a useful function and shade walls during the hotter months.

Reduce heat island

Hot horizontal surfaces are common in urban areas, known as the heat island effect, and they can impact a building envelope in unforeseen ways. An adjacent asphalt parking lot may be affecting cooling loads more than you realize. By creating a pocket of warm air over hard surfaces likely to be located in close proximity to building openings, it is also radiating heat onto walls and creating a source of warm air for infiltration penetrating a building you're trying to keep cool. Is it time to replace the parking surface? Consider concrete or other lighter surfaces – even permeable material. Can you shade the parking surface? Add PV shade structures or landscaped tree islands to reduce the microclimate temperature. Eliminate the hardscape immediately adjacent to the walls and replace with high albedo landscaping. This will lower the temperature of those wall surfaces.

ROOF

The roof is generally the largest area of a building's exposed envelope surface; as a result, the roof experiences the most hours of direct sun exposure. Therefore if the roof is deficient, it can have a considerable impact on overall energy consumption. For one or two story buildings, the roof may actually be the most valuable focus area for enhancing efficiency in an energy retrofit.

Seal the cracks

Roof measures to address infiltration are similar to wall measures, but there are usually more equipment penetrations on a roof than the wall, so assess them thoroughly. Seal skylights and light tubes as well. If infiltration is indeed a problem at the roof-wall intersection, then consider re-roofing during a deep retrofit to completely eliminate the gap, especially if rooftop HVAC equipment is replaced.

Insulate

While adding insulation to walls can be problematic, adding insulation to roofs tends to have few problems. Comprehensive renovations commonly coincide with roof replacement, so take the opportunity to install additional continuous rigid insulation to the exterior of the roof surface and meet roof insulation recommendations stated in ASHRAE 189.1.

Reduce radiative heat gains

Roofs take the brunt of the sun's radiation. Installing a reflective radiant barrier beneath roof decking can reduce heat gain by 40% in very hot climates (Fairey 1984). Radiant barriers, or cool roofs[9], are generally recommended anywhere south of the Mason-Dixon line (40 degrees latitude). If roofing is indeed being replaced, then choose a reflective white or light colored roof to further mitigate the effect of solar radiation on the building in hot, sunny climates. In colder climates, darker roof colors can help warm the building, so treat the roof as an asset.

Additionally, the roof is an ideal location for a vegetated surface, or green roof. New green roof technology has migrated this design element to the forefront of green building features with limited risk for failure if designed by a professional. Vegetated roofs have proven to lower the surface temperature of the roof by as much as 60°F on an average summer day, and reduce interior cooling load by as much as 20% (UT Austin 2008). Cool roofs and green roofs also create an ideal surface for photovoltaic electric systems, which operate more efficiently at cooler temperatures.

[9]The ASHRAE Standard 90.1 (2004 edition) Energy Standard for Buildings Except Low-Rise Residential Buildings, section 5.3.1.1, allows reduced roof insulation (U-factor) if a cool roof is used. ASHRAE 90.1 defines a cool roof as having a minimum solar reflectance of 0.70 and minimum thermal emittance of 0.75.

DOORS/WINDOWS

Doors and windows are the most vulnerable parts of the envelope. They are designed to move, so they require tolerances for movement, feature continuous cracks ripe for infiltration, and must be lightweight enough for human control.

Seal the cracks

Windows and door openings should be weather-sealed during basic maintenance, but the window and door units themselves often develop gaps where dissimilar materials join – such as at the connection of glass to frame. In a common example of construction defects, windows and doors are too often installed badly, with unsealed or uninsulated voids within the framing itself. It may be worthwhile to reinstall good existing windows and doors, if the original installation itself is poor. Deep energy retrofits are a good time to address all of the windows and doors at once to save on costs. Wood units and component assemblies are especially repairable and can be resealed or completely retrofit. If the units are irreparable, replace with high performance products that meet ASHRAE 189.1, and avoid sliding sash units in favor of tilt or casement styles for an optimum seal. Additionally, in moderate to cold climates, construct vestibules at primary entrances if possible to reduce air infiltration due to building users coming and going.

Reduce thermal bridging

Thermal bridging within the frame and/or glazing panel can be particularly detrimental to performance of windows and doors. As stated earlier, some existing units can be retrofit, and some cannot. Insulated glazing panels can even be retrofit to mitigate thermal bridging while also addressing radiation (Empire State Bldg 2011). Older steel windows are particularly challenging. If windows are neither replaceable nor candidates for retrofitting, consider installing either interior or exterior storm windows to achieve a thermal break and potentially meet the requirements of ASHRAE 189.1. Be sure to allow for window operation if the existing unit is operable when adding storms.

Shade and Filter

In the past, many buildings addressed excessive window heat gain by applying dark films and installing full height blinds. This created cave-like interiors, and dissatisfied staff and occupants. Today, spectrally selective window film technology allows us to reject a high percentage of heat (with a low solar heat gain coefficient – SHGC) while admitting more visible light (high visible transmittance or VT), and it's available in a retrofit product with good warranties. Simple tinted or low-e films do not necessarily achieve the same results so choose products wisely. Consider adding or restoring awnings and other shading devices when assessing windows. Exterior window louvers should be designed with the sun's path in mind for real utility—typically, but not always, horizontal slats should be used on the south façade and vertical on the east and west. Often enhancing architectural character while blocking up to 40% of direct sunlight, these simple devices can dramatically improve both the interior learning environment and energy use. Understand that the solution should differ from the south elevation to the east/west elevations for optimal efficacy.

Consider the Climate

As with any architectural decision, each of these recommended measures for consideration should be assessed in its appropriate regional and climatic context. For example, managing solar heat gain is critical in hot and humid climates whereas overall building insulation is most critical in cold and cloudy climates.
However, across all climates, reducing infiltration is critical. Put your money and effort there when prioritizing.

It is important to note that adding insulation to walls can create moisture problems in some climates, so approach with care—mistakes now can cost a lot of money later (Rose 2005). Fortunately hygrothermal modeling tools like THERM, HEAT2, and WUFI can inform the decision and minimize risk.

Leverage a Planned Facility Improvement

Landscaping projects are able to reduce building energy use. Consider how this is true on your next landscaping project. If you have a grant for historic preservation work, then you can repoint brick to reduce air infiltration. Replacing siding or roofing material is the perfect opportunity to add an air barrier and extra insulation.

Service Water Heating

Service water is often overlooked within the commercial building sector, as it is not typically the largest end use in terms of overall energy costs. However, measures to reduce this energy often be some of the most cost-effective and should be considered in any deep retrofit project, especially for lodging and hospital building types where the costs are highest.

Define Needs

Service water heating is necessary in typical buildings to provide warm or hot water for the following end uses:

- Restroom hand washing at lavatory faucets
- Dish washing and general cleaning
- Laundries
- Showers
- Swimming pools

The incoming water from the utility is typically at about 60°F, therefore additional heating is required to satisfy these needs.

Consider the needs that must be met and re-evaluate the water temperatures required. The energy consumption for each additional degree is significant. For example, to raise the temperature of an outdoor swimming pool by 1°F will cost 10–30% more in annual energy costs, depending on your location.

Evaluate the occupant and end-use needs, then specify appropriate temperatures for lavatory faucets, showers, and swimming pools. Don't heat the incoming stream of water to a temperature any higher than necessary.

Reduce Loads

Some efficiency measures only reduce the energy required to heat the service water, but others save energy by simply reducing the amount of hot water that is being used. The cost-effectiveness of these measures is heavily dependent on the water and energy utility rates and their expected escalation in the future.

REDUCE HOT WATER CONSUMPTION

Install aerators in restroom faucets to reduce to flow rates to as low as one-half gallon per minute (gpm). If you are able to replace the faucets, specify sensor or timed electronic faucets with automatic shut-offs. Replace existing showerheads with low-flow (1.5–2 gpm) showerheads, ensuring that the water pressure is adequate.

Additionally, consider instant water heaters under sinks if that is the only load. Also check for continuous re-circulation and replace with circulation on demand or scheduled.

REDUCE ENERGY FOR WATER HEATING

Once you have reduced the amount of water being used, you can tackle the energy required for heating. Make sure you are covering the basics by addressing heat loss and controls. Minimize the standby heat losses from distribution piping storage tanks by increasing insulation, and using anti-convection valves and heat traps.

For swimming pools, use insulated pool covers whenever the pool is not in use. Use recirculation timers to control the circulation of hot water based on demand.

In considering equipment, consider heat pump water heaters, tankless (instantaneous) water heaters, or a solar thermal system. Solar thermal systems are especially appropriate for buildings with high hot water usage. If the distribution piping is already being overhauled, rezone your hot water systems according to temperature requirements and demand patterns. Finally, consider heat recovery options with other air or water streams, especially for indoor swimming pools with dehumidification needs.

Consider the Climate

In general, most service water heating retrofits will be more cost effective in colder climates, particularly those that minimize standby heat loss. The cost effectiveness of solar thermal systems is somewhat dependent on the access to solar heat gain. When considering solar thermal systems, use solar design tools (see RETScreen.net for a free tool) the amount of available solar radiation and the freeze protection requirements.

Leverage a Planned Facility Improvement

Often there are planned facility improvements that can make solar hot water retrofits more cost effective. Is the roof being replaced? This is an excellent time to install roof mounted solar thermal collectors. Is a ground excavation occurring? Consider underground solar thermal storage tanks.

Heating Ventilation, and Air Conditioning (HVAC)

HVAC systems are typically the focus of a standard retrofit designed to save energy. During such retrofits, typically only components of HVAC systems, such as fans and motors, are replaced piecewise, rather than the whole system. During the course of a deep energy retrofit, in contrast, you would likely at least consider an entire system replacement.

Define Needs

HVAC systems affect occupants' thermal comfort by controlling the temperature and humidity of room air. The most cost effective way to reduce energy for HVAC systems is to expand the allowable ranges for indoor temperature and humidity. Carefully study the thermal comfort needs of the occupants in each space type, and determine acceptable ranges for temperature and humidity within their space. These comfort ranges can be found in ASHRAE Standard 55 (ASHRAE 2004b)—be sure to consider radiation effects when performing this exercise, as well as the effect of naturally ventilated or passively heated/cooled spaces on thermal comfort perceptions. For specialty spaces like document-storage and server rooms, ensure that you comply with all applicable codes and standards.

Next, consider the indoor air quality and amount of ventilation air required by the building occupants in each space type. Conditioning outside air can be one of the most energy intensive jobs that an HVAC system performs—the first step is minimizing the amount of outside air that needs to be conditioned. Calculate the required exhaust and ventilation air according to local codes (most reference ASHRAE Standard 62.1), using the actual occupancy rates as opposed to the default occupancies provided in the standard. As the default values are very conservative, this simple step can sometimes reduce the amount of outside air by over 30%, saving energy and also reducing the size the of system required.

Reduce Loads

Evaluate heating and cooling system options only after the loads have been drastically reduced using other retrofit measures. Consider if the space could be cooled with outside air (natural ventilation, night purge, night pre-cool) or evaporative cooling before using compressor-based cooling. Reduced loads can sometimes change the appropriateness of various system options. For instance, passive chilled beams are only viable in spaces with very low cooling density requirements.

Consider the Climate

Climate characteristics should play a role in every decision and strategy within a comprehensive HVAC retrofit. For instance, humid climates would benefit from the use of a dedicated outside air system that decouples the dehumidification load from the sensible cooling load. In hot and dry climates, evaporative cooling should be considered, along with nighttime pre-cooling (should be coupled with thermal mass). Generally speaking, it is valuable to:

- Address the thermal risks and opportunities in the climate: Is there an opportunity to eliminate a perimeter heating system with a super insulated envelope?
- Consider the solar gain characteristics of the climate to guide passive heating and shading strategies and to evaluate renewable alternatives.
- Evaluate contributions to peak heating and cooling loads. Is this building dominated by heating or cooling loads? Is the climate (i.e. envelope loads) a major factor or are the loads driven by internal gains?

Specify Efficient Equipment Type

When choosing a system type, consider the following:

Extent of Renovation
In a major renovation, there is often an opportunity to completely replace the HVAC system. If the renovation is less extensive, it may not be cost effective to completely change the air and water distribution systems.

Climate
What system types can best utilize the climate characteristics of your site?

Occupancy
Is the facility occupied continuously or intermittently? Are there airborne containments that need to be considered?

Standards for Thermal Comfort
What are the comfort requirements (temperature, humidity, air movement) for the space?

Natural Ventilation
Are there options for providing adequate ventilation without mechanical systems for all or part of the year?

Outside Air
What is the best way to condition the outside air? Is it more efficient to decouple the ventilation load from the cooling load? If so, specify a dedicated outdoor air system as part of the design.

Zoning
What system types are appropriate for your building? Where individual room control is desired or diverse loads exist, choose zone level systems, such as chilled beams, fan coils units, or VAV systems.r system as part of the design.

Right Sizing
Accurate sizing of equipment leads to lower equipment costs, lower utility costs, better dehumidification performance, and more comfortable conditions.

Optimize Distribution Design

In a major renovation, there is sometimes an opportunity to overhaul the existing air and water distribution systems. This often translates into very significant fan and pump energy savings. Low-pressure drop (and therefore low energy use) ductwork and piping design involves short, direct runs with minimal fittings and the least amount of turbulence possible. Finally, group exhaust air streams together to facilitate sensible heat or energy recovery with outside air.

Recover and Reuse Waste Streams

Because conditioning outside air for ventilation is such a big contributor to energy use in a building, either heat or energy recovery from the exhaust air is recommended in all but very moderate climates. Examine other opportunities to capture and reuse heat across zones or between the HVAC system and service water heating systems. Does your building have simultaneous heating and cooling loads? A water-source heat pump or variable refrigerant flow system is well suited to transfer heat from an interior zone, where cooling may be desired, to the perimeter, where heating may be needed. Finally, consider ways to recover and reuse condensate for on-site irrigation needs.

Optimize Controls

Optimizing HVAC controls is the most cost effective energy saving strategy and is a key component to any deep retrofit project. Use direct digital control systems for greater accuracy, performance, and energy savings and incorporate this data into a building automation system that the facility manager can use to operate the building. Some of the most common and profitable control strategies to consider include:

Off Hours Controls

During unoccupied periods, employ temperature setbacks and do not bring in any outside air—unless outside air is used for cooling.

Economizers

Consider the use of either an air-side or water-side economizer to capitalize on “free cooling”. Consider expanding the economizer operating range beyond the ASHRAE recommendations for air temperature, as they are often conservative.

Demand Control Ventilation

With demand control ventilation controls, you can control the amount of outside air provided to each zone based on the occupancy. CO2 sensors should be used in zones that are densely occupied with highly variable occupancy patterns, such as conference rooms, gymnasiums, auditoriums, multipurpose spaces, cafeterias, and some classrooms. For the other zones, occupancy sensors should be used to reduce ventilation when a zone is temporarily unoccupied. Economizer controls should always override demand control ventilation in control sequences.

Static Pressure Reset

Many existing supply fans on variable-air-volume systems are controlled to maintain static pressure within ductwork at a single setpoint. A more efficient strategy, and one that is required by the ASHRAE 90.1 Standard, is to use direct digital controls to reset this setpoint at the zone level. With this dynamic control strategy, the fan only generates the pressure required to satisfy the zone requiring the most pressure, improving overall fan efficiency (Taylor, 2007).

Central Plant Controls

Develop an overall controls strategy for the entire central plant (if applicable) that includes variable speed motors, equipment sequencing, water temperature resets, soft-starting of motors, and demand control.

Bundle Measures to Optimize Synergies

Always consider interrelated measures that should be implemented together to maximize savings and return on investment. For example, a chilled beam system can be coupled with a dedicated outside air system and a separate means for heating (if required).

Leverage a Planned Facility Improvement

If major capital equipment, such as a boiler or a chiller, is nearing the end of its useful life, this is an ideal opportunity to redesign and resize your HVAC equipment. Are changes to the utility rates being considered? Evaluate the cost effectiveness of peak shifting thermal storage systems coupled with a time of use rate. Are the parking lots getting re-paved? This would be an ideal time to install a ground source heat pump.

In Conclusion

Deep energy retrofits offer building owners, tenants, engineers, and architects prime opportunities to increase efficiency and save money. At the same time, deep retrofits benefit society as a whole through the generation of new jobs, reduction in carbon emissions, energy security, indoor quality, and generally improve the built environment. Performing deep energy retrofits across the U.S. building stock makes sense now, more than ever, because the industry is ready, buildings are ripe, and such renovations are profitable.

With enough commitment and vision, retrofit practitioners and building owners can use this and other RetroFit Depot guides to take advantage of this unique opportunity and reap the many benefits afforded by deep energy retrofits. Businesses can become more competitive, profitable, and resilient by leading the transformation of our building stock that is largely inefficient. This transition will build a stronger economy, a more secure nation, and a healthier environment.

We welcome your feedback. Your experiences and observations are valuable to the continued development of the RetroFit Depot website. The journey is just beginning, and we look forward to hearing from you.

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