5. Retrocommissioning

Revised October 2007

5.1 Overview

Retrocommissioning is the first stage in the building upgrade process. The staged approach accounts for the interactions among all the energy flows in a building (**Figure 5.1**) and produces a systematic method for planning upgrades that increases energy savings. When the staged approach is adopted and performed sequentially, each stage includes changes that will affect the upgrades performed in subsequent stages, thus setting up the overall process for the greatest possible energy and cost savings. In this staged approach, retrocommissioning comes first because it provides an understanding of how closely the building comes to operating as intended. It also helps to identify improper equipment performance, what equipment or systems need to be replaced, opportunities for saving energy and money, and strategies for improving performance of the various building systems.

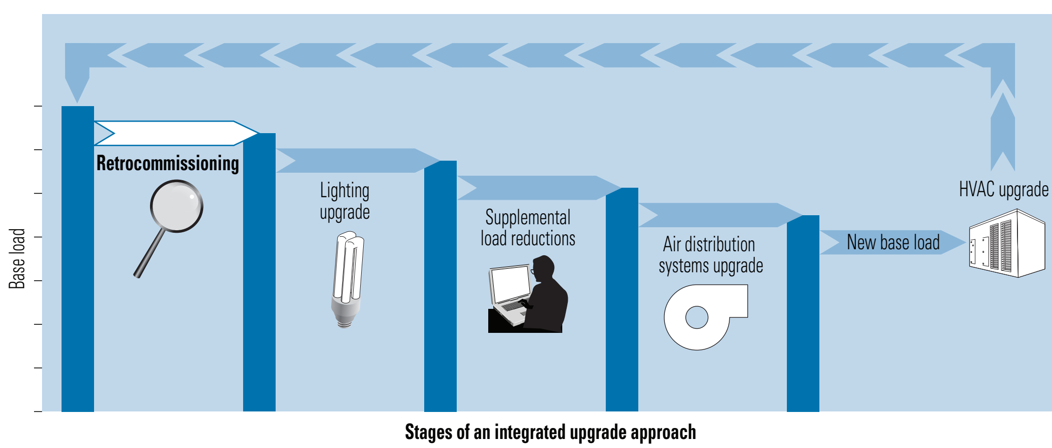
Specifically, retrocommissioning is a form of commissioning. Commissioning is the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained according to the owner's operational needs. *Retrocommissioning* is the same systematic process applied to existing buildings that have never been commissioned to ensure that their systems can be operated and maintained according to the owner's needs. For buildings that have already been commissioned or retrocommissioned, it is recommended that the practices of recommissioning or ongoing commissioning be applied.

Recommissioning (see Section 5.3) is the term for applying the commissioning process to a building that has been commissioned previously (either during construction or as an existing building); it is normally done every three to five years to maintain top levels of building performance and/or after other stages of the upgrade process to identify new opportunities for improvement.

In *ongoing commissioning*, monitoring equipment is left in place to allow for ongoing diagnostics. Ongoing commissioning is effective when building staff have the time and budget

Figure 5.1: The staged approach to building upgrades

The staged approach to building upgrades accounts for the interactions among all the energy flows in a building. Each stage includes changes that will affect the upgrades performed in subsequent stages, thus setting up the overall process for the greatest possible energy and cost savings. Retrocommissioning begins the process because it provides an understanding of how a facility is currently operating and helps to identify specific opportunities for improvement.



Courtesy: E SOURCE

not only to gather and analyze the data but also to implement the solutions that come out of the analysis.

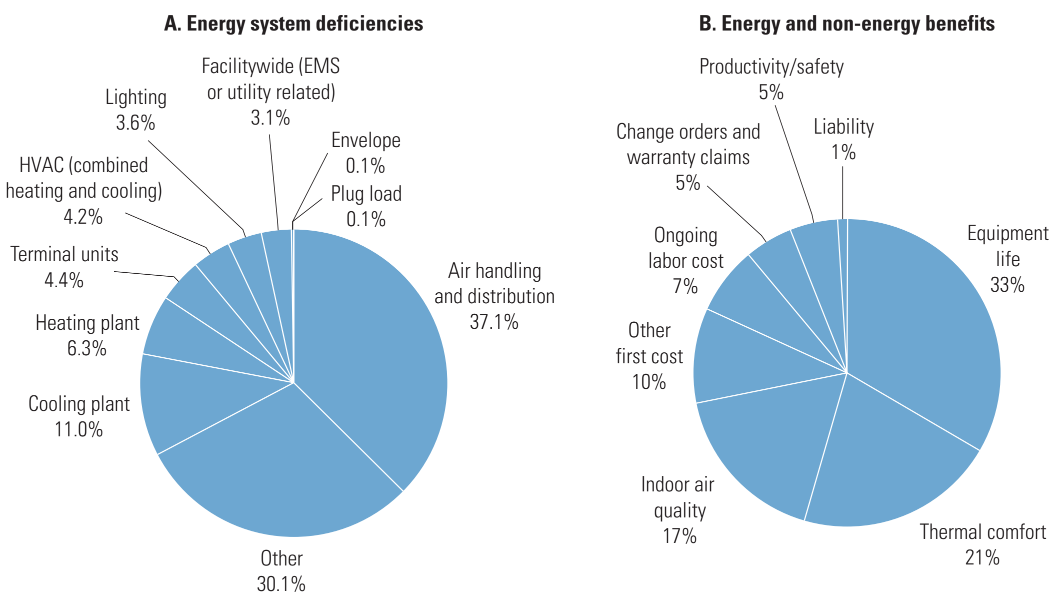
Building owners, managers, staff, and tenants all stand to gain from the retrocommissioning process. It can lower building operating costs by reducing demand, energy consumption, and time spent by management or staff responding to complaints. It can also increase equipment life and improve tenant satisfaction by increasing the comfort and safety of occupants.

Energy and Non-energy Benefits

Researchers at three of the foremost building-commissioning think tanks in the U.S.—Lawrence Berkeley National Laboratory (LBNL), Portland Energy Conservation Inc., and the Energy Systems Laboratory at Texas A&M University—concluded in a study published in December 2004 that retrocommissioning is one of the most cost-effective means of improving energy efficiency in commercial buildings. The researchers statistically analyzed more than 224 new and existing buildings that had been commissioned, totaling over 30 million square feet (ft^2) of commissioned floorspace (73 percent existing buildings and 27 percent new construction). The results revealed the most common problem areas and showed that both energy and non-energy benefits were achieved (**Figure 5.2**). Analysis of commissioning projects for existing buildings showed a median commissioning cost of US$0.27 per ft^2, energy savings of 15 percent, and a simple payback period of 0.7 years. The most cost-effective commissioning projects are typically in energy-intensive buildings such as hospitals and laboratories, whereas the least cost-effective projects are in buildings that are small in comparison with the size of the average commercial building.

Figure 5.2: Retrocommissioning results

Building energy system deficiencies: A recent study of retrocommissioning revealed a wide variety of problems—those related to the overall HVAC system were the most common type (A). Energy and non-energy benefits: Retrocommissioning provided both energy and non-energy benefits—the most common of these, noted in one-third of the buildings surveyed, was the extension of equipment life (B).



Note: EMS = energy management system.

Courtesy: E SOURCE; data from Lawrence Berkeley National Laboratory, Portland Energy Conservation Inc., and Energy Systems Laboratory, Texas A&M University

Target Stores underwent a retrocommissioning project that realized both energy and non-energy benefits. The project was conducted in several SuperTarget® stores where the company identified adjustments to its refrigeration systems, leading to $5,000 to $10,000 in annual energy savings. In addition, according to a study titled "Owner's Strategies for in-House Commissioning," presented at the 2005 National Conference on Building Commissioning, Target funded this effort not only as an energy savings measure but also as a risk-minimization strategy. Optimization of refrigeration equipment reduces risks associated with food quality, which is sensitive to temperature and storage conditions.

Dozens of companies have retrocommissioned their buildings to start their building energy-efficiency upgrade efforts as part of their efforts to earn the ENERGY STAR® Building label (see sidebar). To see descriptions of buildings that have taken this step as part of an ongoing building upgrade process, visit www.energystar.gov/index.cfm?fuseaction=labeled_buildings.showUpgradeSearch&building_type_id=ALL&s_code=ALL&profiles=0&also_search_id=UPGRADE, click on Stage 1, and submit.

The retrocommissioning process described in Sections 5.2 and 5.3 of this chapter follows the recommendations of the "Advanced Retrocommissioning Workbook: A Guide for Building Owners," developed by Portland Energy Conservation Inc. with funding from the U.S. Environmental Protection Agency ENERGY STAR Program. A number of tune-up opportunities may be discovered through this process, as discussed in Section 5.4.

CASE STUDY: The Hatfield Courthouse

Most of the retrocommissioning steps recommended here were carried out when the U.S. General Services Administration (GSA) initiated a full retrocommissioning study of the Hatfield Courthouse, a U.S. federal courthouse located in Portland, Oregon. Built in 1997, the Hatfield Courthouse features 21 floors and a gross square footage of 589,000. The GSA's retrocommissioning goals, as reported by Portland Energy Conservation Inc., were to:

- Improve occupant comfort
- Identify operations and maintenance and energy-efficiency improvements
- Train the building operators on how to help improvements persist
- Review and enhance building documentation

Investigation involved reviewing the building's documentation and utility bills, inspecting building equipment, interviewing building operators, testing selected equipment and systems, and extensive trending of the HVAC control system. The investigation process identified 29 findings that addressed GSA's retrocommissioning goals.

The implementation process involved coordinating efforts among the commissioning provider, facility staff, and building services contractors. The retrocommissioning process resulted in a 10 percent reduction in energy use and significant improvements in building comfort and system operations. Retrocommissioning also increased the building's ENERGY STAR rating from 65 to 75, allowing the building to receive an ENERGY STAR label.

Overall, the project cut annual utility costs by about 10 percent, or $56,000. The project cost (including investigation and implementation, and project oversight costs) was $180,554. Incentives and tax credits brought that number down to $154,772, or about $0.29 per square foot.

5.2 Project Planning

Initial planning activities are critical to the success of any retrocommissioning project because they set the objectives and lay the foundation for the effort. The planning phase begins with the selection of a project, based in part on the generation of an initial benchmark score using the ENERGY STAR national energy performance rating system; selecting and hiring a retrocommissioning service provider and assembling the team that will see the project through to completion; and developing a scope of work.

Selecting a Project

Retrocommissioning is appropriate for most buildings, but there are indicators that can help determine the buildings for which it will be most cost-effective. Owners and property management firms that have building portfolios can look across their holdings to find those properties that should be prioritized for retrocommissioning. Factors to consider are the age and condition of a building and its equipment, existing comfort problems, utility costs, opportunities to share costs with tenants, and the availability of utility and state incentive programs.

The top candidates for retrocommissioning are those buildings with:

- A low ENERGY STAR performance rating or a high energy use index (Btu per ft^2, Btu per patient, and so forth) that cannot be explained, or unexplained increases in energy consumption
- Persistent failure of building equipment, control systems, or both
- Excessive occupant complaints about temperature, airflow, and comfort

Benchmarking

Owners of multiple buildings (private building owners, investment trusts, and property management firms) can evaluate the potential for energy improvement across a portfolio of buildings and select those with the most potential benefit. Owners may choose to have a commissioning provider conduct a study of all their facilities to support development of a multiyear retrocommissioning plan. At a minimum, owners considering retrocommissioning should develop a spreadsheet to understand, compare, and prioritize their building stock to determine which sites present the most opportunity for retrocommissioning. The ENERGY STAR Portfolio Manager benchmarking tool is an effective resource that owners can use for building selection. This tool, including a detailed description of its capabilities, can be accessed by visiting www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager.

Portfolio Manager is the most widely used building benchmarking tool in the United States—roughly 17 percent of the eligible commercial space (on a square-footage basis) in the U.S. has been benchmarked using this tool. The building information needed is minimal and can be easily entered online in a private account that owners can create and manage for their buildings.

The tool uses the national energy performance rating system, which was built using statistical algorithms based on an analysis of national survey data conducted by the Department of Energy's Energy Information Administration. This national survey, known as the Commercial Building Energy Consumption Survey (CBECS), is conducted every four years and gathers data on building characteristics and energy use from thousands of buildings across the United States. A specific building's peer group of comparison is defined by those buildings in the CBECS survey that have similar building and operating characteristics. A building is not compared to the other buildings entered into Portfolio Manager to determine the ENERGY STAR rating. For a given building, energy bill data and building characteristics are used to rank the facility on a scale of 1 to 100. The tool accounts for factors that affect energy use but are not the result of inefficient energy use, including climate, occupancy level, hours of operation, and hours of space use. The ranking received by a building reflects how its performance compares to that of similar buildings. A score of 75, for example, means a particular building outperforms approximately 75 percent of its peers. Buildings with a rating of 75 or higher are eligible to receive the ENERGY STAR label, signifying their outstanding level of performance. In general, the lower the rating, the greater the opportunity to improve energy performance levels.

Selecting a Provider and Team

Retrocommissioning projects are often led by a third-party commissioning provider, with varying degrees of involvement by the building owner and staff. When reviewing a commissioning provider's qualifications, it is important to consider the provider's certification (see sidebar), technical knowledge, relevant experience, availability, and communication skills. The building owner should ask if the agent has been involved with ENERGY STAR buildings and benchmarking through Portfolio Manager. If the building does not currently have a rating, this would be a good opportunity to benchmark and get one.

The selection of the commissioning provider is done either by competitive bid or by selection by qualification. A competitive bid requires the owner to issue a request for proposal (RFP). This can be time consuming and expensive but may be the most appropriate method if the project is complex. One word of caution—when comparing bids, be sure to account for any differences in the proposed scope of work from different bidders. Not every bidder responds to the full scope of the RFP.

Many public agencies are required to go with the lowest qualified bidder and should, if using an RFP process, carefully define the minimum qualifications. Selection by qualification is

RESOURCES: Commissioning Certification

The following five organizations currently certify commissioning providers. Visit the organizations' web sites for more information on their certification programs and to obtain lists of certified commissioning providers:

- "Certified Commissioning Professional (CCP)": Building Commissioning Association (BCA), www.bcxa.org/certification/index.htm
- "Certified Commissioning Provider": Associated Air Balancing Council Commissioning Group (ACG), www.acgcommissioning.com/membershipcertification
- "Accredited Commissioning Process Provider": University of Wisconsin at Madison (UWM), http://epdweb.engr.wisc.edu/courses/index.lasso (use link to Building Systems and Construction to find certification training)
- "Systems Commissioning Administrator": National Environmental Balancing Bureau (NEBB), www.nebb.org/bsccertif.htm
- "Certified Building Commissioning Professional (CBCP®)": Association of Energy Engineers (AEE), www.aeecenter.org/certification

often simpler but requires that the owner carefully evaluate the providers' qualifications and interview past clients and references. The process also allows the owner to select the most qualified provider regardless of cost. A sample template and a checklist of factors is included in the "Advanced Retrocommissioning Workbook: A Guide for Building Owners."

Developing a Scope of Work

To develop a scope of work, the commissioning provider visits the site, talks with operations and maintenance staff, and reviews current operating conditions. The commissioning provider then identifies areas of opportunity in the building for energy savings. The following items are indicators of retrocommissioning opportunities commonly found during a building walkthrough. Their presence indicates potential problems that can be identified and fixed through a retrocommissioning project:

- Systems that simultaneously heat and cool, such as constant and variable air volume reheat
- Economizers, which often need repair or adjustment—potential problems include frozen dampers, broken or disconnected linkages, malfunctioning actuators and sensors, and improper control settings
- Pumps with throttled discharges
- Equipment or lighting that is on when it may not need to be
- Improper building pressurization (either negative or positive), that is, doors that stand open or are difficult to get open
- Equipment or piping that is hot or cold when it should not be; unusual flow noises at valves or mechanical noises
- Short cycling of equipment
- Variable-frequency drives that operate at unnecessarily high speeds
- Variable-frequency drives that operate at a constant speed even though the load being served should vary

The next step is to define the scope of work—a proposal for work negotiated between the commissioning provider and the owner that outlines the processes and procedures to be undertaken, provides a schedule of activities, identifies the roles of team members, and includes sample forms and templates that the commissioning provider will use to document the retrocommissioning activities.

5.3 Project Execution

The execution phase of retrocommissioning begins with an investigation phase that leads to an understanding of how and why building systems are currently operated and maintained, the identification of issues and potential improvements, and the selection of the most cost-effective measures for implementation. The tasks required to fulfill these goals include:

- A review of facility documentation, which covers operating requirements; original design documents; equipment lists; drawings of the building's main energy-using systems; controls documentation; operations and maintenance manuals; and testing, adjusting, and balancing reports.

- Diagnostic monitoring of energy systems, which can help determine where particular problems lie. Data are typically gathered using a building's existing energy management system (EMS) along with portable data loggers to obtain any data not available through the EMS. Variables typically monitored include whole-building energy consumption (including electricity, gas, steam, or chilled water), end-use energy consumption, operating parameters (such as temperatures, flow rates, and pressures), weather data, equipment status and run times, actuator positions, and setpoints.

- Functional testing, which takes a system or piece of equipment through its paces while personnel observe, measure, and record its performance in all key operating modes. Functional testing also may be used to help verify whether a particular improvement is really needed and is cost-effective. For example, the commissioning provider may observe that the throttling valve on a pump is not fully open. This may indicate that energy savings could be achieved by trimming the impeller so the valve can be fully open. A functional pump test will determine the value of this possible improvement.

Implementing the Recommendations

The recommendations from the investigation are typically implemented according to one of three basic approaches:

- Turnkey implementation is usually applied to projects in which the retrocommissioning provider is capable of providing the service and the in-house staff is either not available to implement any of the measures or does not have the necessary skills. The main advantage of this approach is that only one contract is held by the owner, and any subcontracts are held and managed by the commissioning provider.

- Recommendations can be implemented with the assistance of the retrocommissioning provider, in which case the provider oversees the implementation process but does not directly complete the majority of the work. This strategy works best when a highly skilled in-house staff is available and can carry out much of the work or when the specialized skills of contractors (controls contractors, design professionals, and testing specialists) are required. Working with a commissioning provider to implement the retrocommissioning findings can build in-house skills among facility staff so that they are better able to maintain performance of systems over time.

- Owner-led implementation may be attractive to owners who have strong, established relationships with a service contractor or a highly capable in-house engineer who can implement and verify the retrocommissioning measures.

Whichever approach is used, the recommendations of the investigation phase can be adopted in a staged fashion to accommodate budgeting constraints or implemented in one overall project. Implementing all or most of the measures immediately maintains project momentum and staff involvement and maximizes cost savings. Another key factor is the continued involvement of the commissioning provider, which can be more difficult to maintain if too much time passes without the project moving forward.

As measures are implemented, it is important to verify the results. This verification ensures that the work is completed correctly; it also establishes a new baseline for performance and updates cost savings estimates. The new baseline can be used to establish criteria or parameters for tracking whether or not the improvements are performing properly throughout the life of the equipment or systems and can serve as the baseline for the next round of upgrades on the road of continuous improvement.

RESOURCES: Operator Training

An example of training that is available in many locations across the country is Building Operator Certification (BOC) courses. This series is designed specifically for building operators to improve their ability to operate and maintain comfortable, efficient facilities. There are two skill levels for the courses, and both address multiple topics, including electrical, HVAC, and lighting systems; indoor air quality; environmental health and safety; and energy conservation. More information on locations, schedules, and descriptions is available on the BOC web site at www.theboc.info.

Maintaining the Benefits

Implementation is not the end of the project. Without training for facility staff and an operations and maintenance program, the benefits that accrue will not last. The building owner should request that the commissioning provider develop and conduct additional training for facility staff at the end of the project (see sidebar). A training session usually involves a classroom workshop with some hands-on demonstrations on the building equipment. Owners should consider videotaping the training session for later use and as a resource for training new facility staff. Suggested topics for training sessions include:

- Energy usage analysis
- Operating schedules and requirements
- Methods for identifying problems and deficiencies
- A description of project findings and measures that were implemented
- Improvements expected as a result of the project (show before and after trends if available)
- Operations and maintenance procedures needed to ensure that benefits are maintained
- Staff role in helping to maintain the persistence of savings

A typical preventive maintenance plan consists of a checklist of maintenance tasks and a schedule for performing them. The checklists are kept for each piece of equipment and are updated after maintenance tasks are performed. Incorporating operations into the current maintenance plan entails similar rigor for recording setpoints, settings, and parameters for the control strategies. It also means that operators regularly review and update the owner's operating requirements as occupancy or operational changes are made. A good preventive operation and maintenance plan encourages building operators to continuously ask questions such as:

- Have occupancy patterns or space layouts changed?
- Have temporary occupancy schedules been returned to original settings?
- Have altered equipment schedules or lockouts been returned to original settings?
- Is equipment short-cycling?
- Are time-clocks checked monthly to ensure proper operation?
- Have any changes in room furniture or equipment adversely affected thermostat functions?

- Have occupancy patterns or space layouts changed?
- Are new tenants educated in the proper use and function of thermostats and lighting controls?
- Are the building's sequences of operation performing as intended?

Planning for Recommissioning

From the start, the retrocommissioning project includes steps that ensure that the benefits gained will persist and even be improved upon. That is one reason why good documentation, ongoing training, and the performance of preventive operations and maintenance should be included. In addition, planning for recommissioning or ongoing commissioning will help keep a building operating at optimal levels.

The timing of a recommissioning effort will vary depending on the timing of changes in the facility's use, the quality and schedule of preventive maintenance activities, and the frequency of operational problems (see sidebar). Factors that indicate the need for recommissioning include:

- An unjustified increase in energy use or a lower ENERGY STAR score
- An increase in the number of comfort complaints
- An increase in nighttime energy use

CASE STUDY: Recommissioning Provides Rapid Payback

The University of Montana in Missoula, Montana, found that even for a relatively new building, the recommissioning process can be cost-effective. The Gallagher School of Business Administration building was partially commissioned after it was built in 1997. After several years of operation, however, performance problems and complaints began to appear. To address the problems, the university decided to recommission the building.

Working with the Montana Department of Environmental Quality (MDEQ), with funding from the Northwest Energy Efficiency Alliance and support from the U.S. Department of Energy's Rebuild America Program, the university hired a commissioning provider who completed the process by the fall of 2002. The analysis revealed and suggested fixes for 346 problems in the building, including dampers that could not fully open or close, valves that leaked or could not close, and equipment controls that were out of calibration. Implementing many of these measures produced an estimated annual energy cost savings of approximately $19,500. The simple payback for the commissioning provider fee of $24,380 was 1.25 years (the university used its own building staff to implement the corrective measures).

The recommissioning effort delivered several lessons. A big factor in the building's declining performance was that its occupancy load had changed. As enrollment in the business school increased, the number of new people and computers added loads that the heating and cooling systems had not been designed to handle. Periodic recommissioning can help a building to meet such changing needs. In addition, periodic recommissioning is required for complex HVAC control systems to maintain their efficiency and performance. Based on the commissioning findings and a payback analysis, the MDEQ recommended that the university recommission the Gallagher building every three to five years to keep it operating efficiently.

- An awareness of problems but lack of time or expertise to fix them
- Overriding of control logic or setpoints by staff or occupants to quickly "fix" problems
- Frequent equipment or component failures
- Significant tenant build-out projects
- Replacement of major systems or controls since the last commissioning or retrocommissioning effort

The recommissioning process is similar to that followed for retrocommissioning, although it can be less expensive because it can build on the data collection and documentation that will have already been completed. Recommissioning typically involves minor system improvements but in some projects may require more significant design, scheduling, and budgeting issues.

In some cases, ongoing commissioning can be cost-effective. In these cases, monitoring equipment is installed or left in place to allow for ongoing diagnostics and corrective actions. This approach works best in buildings with modern EMSs, Class A buildings (the most prestigious buildings in a particular market), and any site where there is an individual or champion committed to the process. A modern EMS makes more control strategies available and typically has most of the data needed to do diagnostics. Class A buildings often have dedicated energy managers concerned with both saving energy and keeping occupants comfortable.

5.4 Tune-up Opportunities

As part of the retrocommissioning process, all elements of a building and its energy-using equipment and systems will be examined. Specifically, the commissioning agents will look at lighting, supplemental loads, HVAC distribution systems, and heating and cooling plants to identify tune-up opportunities. The order in which the various measures will be implemented is determined after all the potential improvements have been identified and the most cost-effective measures have been selected for implementation. However, making simple repairs as the need is identified is usually the most effective strategy. Small adjustments, such as a sensor calibration, not only improve current operations but also increase the effectiveness of diagnostic monitoring and testing.

Lighting

The lighting systems within a building are an integral part of a comfortable working environment (see Chapter 6). Over time, all lighting systems become gradually less efficient. Certain efficiency losses are unavoidable, such as reductions in light output due to the aging of lighting equipment. However, other efficiency losses, such as improperly functioning controls, dirt accumulation on fixture lenses and housings, and lumen depreciation can be avoided by regularly scheduled lighting maintenance.

A lighting system tune-up should be performed in the following order:

- Follow a strategic lighting maintenance plan of scheduled group relamping and fixture cleaning
- Measure and ensure proper light levels
- Calibrate lighting controls

Periodically cleaning the existing fixtures and replacing burned-out lamps and ballasts can considerably increase fixture light output (see the section on building in an operations and maintenance plan in Chapter 6, "Lighting"). This simple and cost-effective tune-up item can often restore light levels in a building to close to their initial design specifications.

After cleaning and relamping have been accomplished, measure existing light levels to determine whether or not illuminance levels are appropriate for the tasks being performed in the space (see Chapter 6, "Lighting"). Because space use and furnishings may change over time, it is important to match the lighting level to the current occupant requirements. The Illuminating Engineering Society of North America issues recommended illuminance levels depending on the job or activity performed. Overlit or underlit areas should be corrected. Lighting uniformity should also be assessed, as relocation of furniture and even walls may have altered lighting distribution.

Once the proper light levels and uniformity have been achieved in the space, examine the automatic lighting controls. Many buildings use a variety of automatic controls for time-based, occupancy-based, and lighting level–based strategies (see the section on automatically controlling lighting in Chapter 6, "Lighting"). These controls may have never been properly calibrated during installation, or occupants may have tampered with them. Adjusting these controls and associated sensors will reduce occupant complaints, maintain safety, and ensure maximum energy savings.

Many buildings use EMSs, time-clocks, and electronic wall-box timers to control lighting automatically based on a predictable time schedule. These systems need to be programmed correctly to ensure that lights are operating only when the building is occupied and that overrides are operational where required. Exterior lighting schedules must also be changed throughout the year according to the season.

The performance of occupancy or motion sensors depends on customizing the sensitivity and time-delay settings to the requirements of each individual space. The sensor's installed position should also be checked to ensure adequate coverage of the occupied area. Also, keep furnishings from obstructing the sensor's line of sight. Any indoor and outdoor photocell controls should also be checked to ensure the desired daylight dimming or daylight switching response. Setpoints should be adjusted so that the desired light levels are maintained.

The savings associated with performing a lighting tune-up will vary depending on the quality and performance of the current lighting system. For example, cleaning alone may boost fixture light output from 10 percent in enclosed fixtures in clean environments to more than 60 percent in open fixtures located in dirty areas. Simple calibration of occupancy sensors and photocells can restore correct operation, reducing the energy used by the lighting system in those areas by 50 percent or more.

Supplemental Loads

Supplemental load sources are secondary load contributors to energy consumption in buildings. In the retrocommissioning process, loads can be cut by reducing equipment energy use and sealing the building envelope.

In many facilities, energy is wasted running office equipment that is left on when not in use throughout the workday, at night, and on weekends. Electrical loads from office equipment can be reduced by encouraging occupants to shut off equipment when it is not in use, using ENERGY STAR–labeled office equipment, and enabling power management features (see Chapter 7). Energy-efficient equipment not only uses energy efficiently but typically features a low-power sleep mode for inactive equipment. ENERGY STAR–labeled equipment often costs the same as comparable nonlabeled equipment, but these products typically use about half as much electricity as conventional equipment.

For the building envelope, air infiltration is often a major energy drain that can be addressed during retrocommissioning. Outside air can penetrate a building through a variety of places, most commonly the windows, doors, walls, and roof. In general, a building envelope should meet recommended infiltration standards. A frequent result of infiltration problems is an increase in building heating, cooling, and/or electrical loads (when, for example, occupants may bring in space heaters or fans). In addition, the escape of conditioned air forces the air-handling system to work longer and harder to provide the required space temperature.

To reduce air infiltration, take the following steps:

- Tighten the existing building by locating all air leaks in the windows, doors, walls, and roofs.
- Seal with appropriate materials and techniques such as weather stripping on doors; sealing and caulking on windows; and proper insulation distribution in walls, ceilings, and roofing.
- Encourage the use of revolving doors in buildings so equipped. Revolving doors significantly reduce drafts and the loss of conditioned air.
- Calibrate automatic doors to minimize air loss from the building envelope.

Reducing infiltration will result in a reduction in heating and cooling loads. Typical savings for a large office building range up to 5 percent of heating and cooling costs.

Distribution Systems

The systems that distribute air and water for space conditioning throughout a facility may need to be balanced and cleaned as part of the retrocommissioning effort. In a process known as testing, adjusting, and balancing (TAB), HVAC system components are adjusted so that air and water flows match load requirements. The process begins with testing to evaluate the performance of the equipment in its current state and making recommendations for improvements. Adjustments to flow rates of air or water are then made for the purpose of balancing the system and matching the loads throughout a building. Indications that TAB is needed include frequent complaints from occupants about hot or cold spots in a building, the renovation of spaces for different uses and occupancy, and the need for frequent adjustments of HVAC components to maintain comfort.

A TAB analysis usually includes a complete review of a building's design documentation. Typical HVAC system components and parameters to investigate include:

- Air system flow rates, including supply, return, exhaust, and outside airflow (flows go through main ducts, branches, and supply diffusers that lead to specific spaces in a building)
- Water system flow rates for chillers, condensers, boilers, and primary and secondary heating and cooling coils
- Temperatures of heating and cooling delivery systems (air side and water side)
- Positions and functioning of flow-control devices for air and water delivery systems

- Control settings and operation
- Fan and pump speeds and pressures

The savings associated with TAB come from the reductions in the energy used by the heating and cooling system and can range up to 10 percent of heating and cooling costs.

The heat exchange equipment that cools and heats the air that ultimately reaches building spaces should also be inspected and cleaned if necessary. This equipment usually consists of heating and cooling coils installed in air handlers, fan coil terminal units, or baseboard radiators. These units are typically supplied with chilled water and hot water from a central plant. The heating and cooling coils can also be part of a packaged unit such as a rooftop air-conditioning unit or central station air-handling unit.

All surfaces and filters should be clean—dirty surfaces reduce heat transfer and increase pressure loss, which serves to increase energy use. The cleaning technique depends on the type of equipment:

- For air-side heating and cooling coils, whether in an air handler or in a rooftop unit, the methods for cleaning include compressed air, dust rags or brushes, and power washes. Any of these techniques will reduce deposit buildup. In addition, check baseboard heating systems for dust buildup, and clean them if necessary.
- The water side of heating and cooling systems is generally inaccessible for mechanical cleaning. Chemical treatments are often the best solution for cleaning these surfaces. Ongoing water treatment and filtering of the water side are recommended to reduce dirt, biological, and mineral-scale buildup. Filters for both air-side and water-side systems should be cleaned and replaced as necessary.

In addition, make sure that terminal fan coil units and baseboards are not blocked or covered with books, boxes, or file cabinets. Besides creating a fire hazard (in the case of radiators), blocking the units prevents proper air circulation and renders heating and cooling inefficient.

In general, the cleaner the heat transfer surfaces, the greater the savings. In addition, cleaning coils and filters may reduce the pressure drop across the coil and reduce fan or pump energy consumption. Savings can range up to 10 percent.

Heating and Cooling Systems

Both controls and components of the heating and cooling systems present savings opportunities during the retrocommissioning process. The EMS and controls within a building play a crucial role in providing a comfortable building environment. Over time, temperature sensors or thermostats may drift out of tune. Wall thermostats are frequently adjusted by occupants, throwing off controls and causing unintended energy consumption within a building. Poorly calibrated sensors can increase heating and cooling loads and lead to occupant discomfort. Occupants are likely to take matters into their own hands if they consistently experience heating or cooling problems. To tune up the heating and cooling controls, take the following steps:

- *Calibrate the indoor and outdoor building sensors.* Calibration of room thermostats, duct thermostats, humidistats, and pressure and temperature sensors should be in accordance with the original design specifications. Calibrating these controls may require specialized skills or equipment and may call for outside expertise.

- *Inspect damper and valve controls to make sure they are functioning properly.* Check pneumatically controlled dampers for leaks in the compressed-air hoses. Also examine dampers to ensure that they open and close properly. Stiff dampers can cause improper modulation of the amount of outside air being used in the supply airstream. In some cases, dampers may actually be wired in a single position or disconnected, violating minimum outside air requirements.

- *Review building operating schedules.* HVAC controls must be adjusted to heat and cool the building properly during occupied hours. Occupancy schedules can change frequently over the life of a building, and control schedules should be adjusted accordingly. Operating schedules should also be adjusted to reflect daylight saving time. When the building is unoccupied, set the temperature back to save some heating or cooling energy, but keep in mind that some minimum heating and cooling may be required when the building is unoccupied. In cold climates, for example, heating may be needed to keep water pipes from freezing.

- *Review the utility rate schedule.* Utilities typically charge on-peak and off-peak times within a rate, which can dramatically affect the amount of electric bills. If possible, equipment should run during the less expensive off-peak hours. For certain buildings, precooling and/or preheating strategies may be called for (see Chapter 9, Additional Strategies).

Savings from these control tune-up measures can range up to 30 percent of annual heating and cooling costs. The elements of both heating and cooling systems can also benefit from a tune-up as part of the retrocommissioning process. On the cooling side, the following measures can be effective:

- *Chilled-water and condenser-water reset.* In facilities with a central chiller system, the operating efficiency can be increased through a practice known as chilled-water reset—modifying the chilled-water temperature and/or condenser-water temperature in order to reduce chiller energy consumption. (For more information on chilled water reset and specific types of chiller equipment, see Chapter 9.)

- *Chiller tube cleaning and water treatment.* Cleaning chiller tubes and improving water treatment can also improve performance of a chiller system by providing cleaner surfaces for heat transfer on both the refrigerant and water sides of the chiller tubes (see Chapter 9).

- *Reciprocating compressor unloading.* For smaller chiller systems that use reciprocating compressors with multiple pistons, part-load performance can be improved by making sure that the control system properly unloads pistons as the load decreases. If the controls fail to unload, then the system may cycle unnecessarily during low cooling loads. Because starting and stopping are inherently inefficient, cycling decreases the efficiency of the cooling system. Additionally, increased cycling can lead to compressor and/or electrical failures. Unloading is typically controlled by a pressure sensor that is set for a specific evaporator pressure. This sensor, and the controls dependent upon it, can fall out of calibration or fail.

- *Chiller tube cleaning and water treatment.* Cleaning chiller tubes and improving water treatment can also improve performance of a chiller system by providing cleaner surfaces for heat transfer on both the refrigerant and water sides of the chiller tubes (see Chapter 9).

On the heating side, boiler performance can often be improved by a tune-up. For safety reasons, it is a good idea to obtain specialized expertise for boiler tune-up items. The following measures can be effective:

- *Maintaining boiler steam traps.* Boiler system steam traps, which remove condensate and air from the system, commonly need maintenance. They frequently become stuck in the open or closed position. When a trap is stuck open, steam can escape through the condensate return lines to the atmosphere, and the resulting energy loss can be significant. Check steam traps frequently for leaks, and make repairs as needed.
- *Adjusting combustion airflow.* For fossil-fuel-powered boilers, adjusting the combustion airflow usually improves system performance. More air is typically supplied for combustion than is needed. Excess air helps prevent incomplete combustion, and that action helps eliminate hazards such as smoke and carbon monoxide buildup. However, if too much air is introduced, some of the fuel is wasted in heating this excess air. A tune-up of combustion air consists of adjusting combustion air intake until measured oxygen levels in the flue gas reach a safe minimum.
- *Boiler tube cleaning and water treatment.* As with chillers, these measures improve heat transfer in the system. Both the fire side and water side of the boiler tubes can be cleaned by physically scrubbing the surfaces and sometimes by applying a chemical treatment. Treating the heating water may also be a good option to improve efficiency.

When all retrocommissioning steps are taken together, heating and cooling cost savings can reach upwards of 15 percent.

5.5 Summary

The goal of the retrocommissioning stage in a building upgrade effort is to ensure that the building operates as intended and meets current operational needs. Doing so can be very cost-effective, with field experience showing typical costs of about US$0.27/ ft^2, energy savings of about 15 percent, and a simple payback period of 0.7 years.

A well-planned and -executed retrocommissioning project generally consists of planning and execution phases. In addition, the effort includes plans to ensure that benefits persist and can be added to through such measures as training, preventive operations and maintenance, and performance tracking. Plans should also be made for periodic recommissioning or ongoing commissioning of the building. Recommissioning follows the same process as retrocommissioning, but where *retrocommissioning* applies to buildings that have never been commissioned, *recommissioning* is the term used for buildings that have already been commissioned at least once. In *ongoing commissioning,* monitoring equipment is left in place to allow for ongoing diagnostics.

As part of the retrocommissioning effort, adjustments and fine-tuning may be made to all building systems, including lighting, supplemental loads, building envelope, controls, and all aspects of heating and cooling systems.

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