Green Retrofitting 101

© 2009 Strategic Sustainability Consulting

Barbara Summers

STRATEGIC SUSTAINABILITY CONSULTING

Summary

The green building label is not reserved for only new buildings; it is just as plausible to turn the millions of existing buildings into environmentally friendly structures. Green buildings are proven to reduce water and energy use and costs, create greater worker productivity and satisfaction, improved brand image, and better community relations. Renovations to a building include improving energy efficiency, improving the heating and cooling system, creating a more sustainable site, improving water efficiency, installing renewable energy, and using eco-friendly materials. There are many projects that can be completed on a smaller budget, while others require a larger commitment. Even though there tends to be a high upfront cost, the average return on investment for a green retrofit is two to five years and there are substantial incentives that can reduce on the initial cost.

Contents

Introduction

According to government estimates, "Commercial buildings account for more than 60% of the nation's electricity consumption, and generate 30% of all greenhouse gas emissions."[1] The average building certified as green using the U.S. Green Buildings Council's (USGBC) Leadership in Energy and Environmental Design (LEED) rating system uses 32% less electricity and saves 350 metric tons of CO2 emissions annually.[2] It is a common misconception that the only buildings that can be considered 'green' are newly constructed buildings, but this is not at all the case. In actuality new green buildings make up only a small fraction of the 4.7 million commercial buildings in the United States. Companies that cannot afford to construct a new green building, or that cannot afford the cost and disruption of moving to a green building or of undertaking a top-to-bottom green renovation of their existing conventional workplaces, may find that green retrofits are a practical way to improve their sustainability, reduce their greenhouse gas emissions, and reap the many benefits of green workplaces.[3] Green retrofitting is a growing trend that is receiving more and more support from the government and other organizations. Also a number of local and state governments are starting to mandate energy-efficient green building construction and renovations, starting in the public sector, and now moving into the private sector. As of April 2008, 28 states, 24 counties, and 96 municipalities had mandated some level of LEED criteria for new and renovated public buildings.[4]

1 Cortese, Amy. "'Green' Buildings Don't Have to Be New" The New York Times. January 27, 2008 http://www.nytimes.com/2008/01/27/realestate/commercial/27sqft.html?_r=1&pagewanted=all

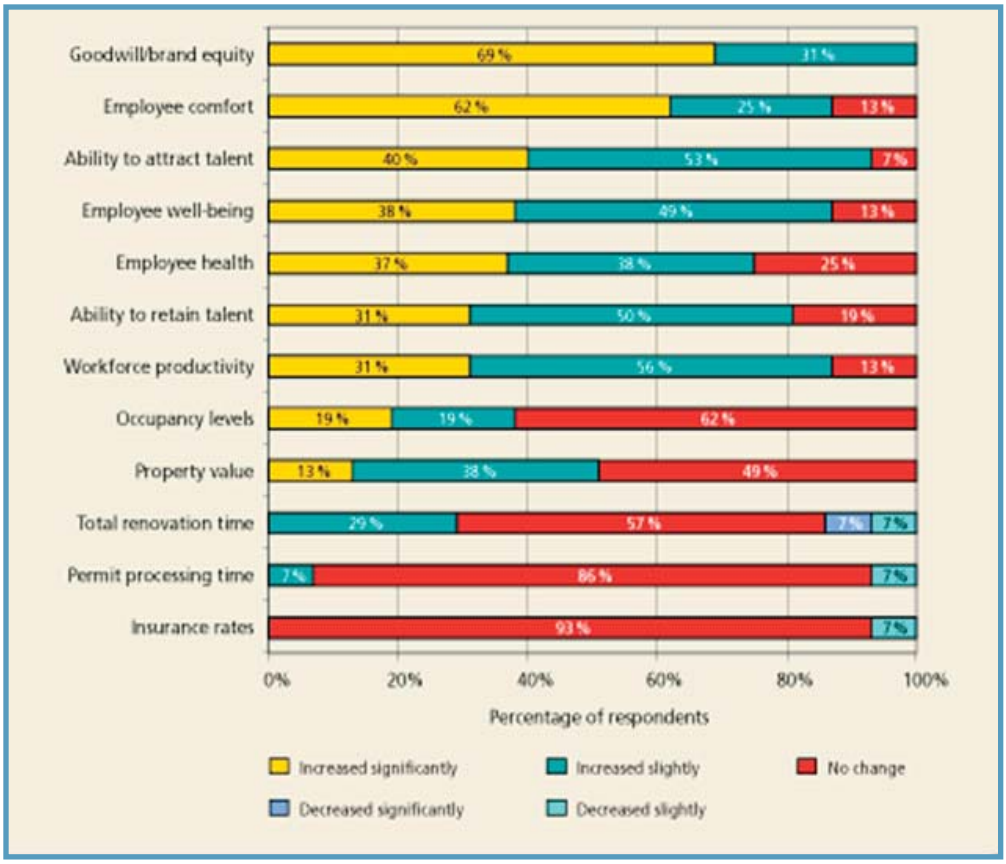
2 Deloitte/Charles Lockwood. "The Dollars and Sense of Green Retrofits." Greener Buildings. July 28, 2008 http://www.greenerbuildings.com/files/document/us_re_Dollars_Sense_Retrofits_190608_.pdf

3 Deloitte/Charles Lockwood

4 Deloitte/Charles Lockwood

Appeal of Green Buildings

It is a very common misconception that green buildings are only appealing because they can save money and produce significantly less carbon emissions than a standard building, but there are in actuality many more benefits. Green buildings offer their owners and tenants a number of bottom-line benefits, including reductions in water and energy use and costs; opportunities with respect to tax credits, permitting, and other regulatory incentives; and greater worker productivity and satisfaction, improved brand image, and better community relations.[5] According to a survey of 16 project owners or members of LEED Existing Building certified projects by Charles Lockwood and Deloitte, 93% of respondents reported greater ability to attract talent, 81% saw greater employee retention, 87% reported an improvement in workforce productivity, 75% saw an improvement in employee health, and 73% reported that they had achieved cost reductions as a result of implementing green measures.[6] This can be seen in the figure below..



Impact of Green Retrofit

5 Deloitte/Charles Lockwood

6 Deloitte/Charles Lockwood

The Challenge of Retrofitting

Many companies are apprehensive about a green retrofit because it is often considered to be much more difficult to retrofit than build new. It is definitely a more extensive and complicated process to retrofit, especially because it is important to work without halting business practices. Doug Gatlin, the vice president for market development at the Green Building Council stated that "With an existing building, you have to make the most of what you've got. We recognized that most buildings are not going to go through a gut rehab.", but he also stated that there were basic actions building managers could take to greatly improve a building's energy efficiency and effect on the environment.[7]

Another issue that presents itself to building owners or managers is that they must be sure that they want to continue to own the building after putting so much work and money into the building, especially since some larger projects such as updating the HVAC system or installing solar panels will have a many year return on investment (ROI). The retrofit process is also much more complex if you are leasing as opposed to owning a building. If you are leasing, you most likely cannot make structural changes to the building or office, and most of the larger projects must be ruled out. But some simpler projects as Doug Gatlin suggested, such as changing the lighting, replacing existing appliances with energy efficient appliances, replacing fixtures with low-flow fixtures, using rain barrels, and use of VOC free furniture and paints can greatly change a buildings affect on the environment. Many commercial office buildings contain multi-tenants, which can make the retrofitting process much more complex. It is necessary to obtain approval of all tenants and also make sure that they are aware of the kind of work that will be done on the building and why. By completing many of the retrofit projects, the energy consumption will significantly decrease, but it can decrease even more if the tenants use sustainable practices. The tenants of a building are also likely to change, which can add complications. But may in fact attract more environmentally conscious, greater numbers of potential tenants and allow for the building owner to raise the cost of rent.

7 Cortese, Amy

Before You Retrofit

There are three very important steps to take before beginning the retrofit process. The best way to start is with an energy audit by a certified contractor or consultant. The needs of every building are very different and an audit will show the problems that may, when corrected, save significant amounts of money over time. The audit will provide a sense of what needs to be done, what can be done, and what the estimated price tag will be. Specifically an audit can pinpoint where a building is losing energy, the efficiency of the heating and cooling systems and also may show ways to conserve hot water and electricity. A professional auditor uses a variety of techniques and equipment to determine the energy efficiency of a structure. Thorough audits often use equipment such as blower doors, which measure the extent of leaks in the building envelope, and infrared cameras or thermal scanners, which reveal hard-to-detect areas of air infiltration and missing insulation.

The second step is to establish goals for the retrofit process. It is important to figure out exactly what the budget is going to be because this can be a major determinant on the type of projects that are considered. Along with establishing a budget one should consider exactly how far that they want to go in the retrofit process, is it just an a basic retrofit of updating appliances, fixtures and lighting or do you want to do a compete building retrofit including insulation and heating and cooling systems. It is also important to determine what the primary motivation is, is it to make the building more comfortable, reduce the energy bill, reduce carbon output, or etc. Something else to consider is if there are any projects that you want to specifically focus on, such as updating the building's lighting or insulation.

After establishing the goals and figuring out what projects that you plan on completing, the third step is to contact the necessary contractors and other professionals. Although before getting in touch with professionals, it is important to figure out which projects can be done on your own or need to be contracted out. This depends on your comfort level or skill level with many of the different projects. But in the retrofit section below, it is discussed as to which projects must be contracted out and others that can be attempted on your own. But if there is any question as to your skill level is enough to make sure that something in particular such as a low-flow sink fixture, it would be worth it to have a professional install the device so that it is able to be the most efficient.

After establishing which projects need to be contracted out, you need to figure out who should be contacted. There are design and remodeling firms that will handle the entire retrofit project. A company like this will handle all of the details such as what kind of professionals should be brought on for each individual project and will greatly simplify the process for the building owner, but can add significant overall costs. If you feel confident about the different areas you can just hire specific trades to handle projects individually. You should make sure that you are knowledgeable of the overall process if this is the case. This will most likely require contacting an insulation contractor, a window company, an HVAC contractor, a plumber, and a solar company or other

renewable energy company. This does not mean that you should call up the first window company in the phone book; significant research should be done to make sure that the professionals are knowledgeable and can help you in your specific circumstance. A contractor should also not be chosen specifically because they have provided the lowest price estimate; the quality of work should be taken into consideration. A good way to do this is to ask for ask for references from previous clients, particularly on energy efficient upgrades.

Eneregy Efficiency

In 2004, Exelon Corporation began consolidating several Chicago-area offices into 220,000 square feet of renovated space occupying ten floors of the landmark Chase Tower. In 2005, Exelon set a goal of reducing the greenhouse gas emissions from its operations 8% from 2001 levels by the end of 2008. Exelon achieved much of the required efficiency improvements through its new headquarters, despite its location in a building originally constructed in the late 1960s.Efficiency strategies include a direct-indirect lighting system with daylight dimming and controllable task lighting for every employee, ENERGY STAR equipment and appliances for 96% of all rated power, demand-based ventilation, and an automated system that controls the project's lighting, heating, and cooling systems. Exelon now enjoys a 50% reduction in annual energy costs since becoming certified and 43% less energy than its previous offices. Through energy savings alone, Exelon will now save enough money to pay for the project's green features in less than five years. (LEED EB- project profile)

Lighting

One of the easiest and cheapest ways to save energy is to make some simple changes to the building lighting. Things that should be considered are the type of light, positioning of lights, fixture design, and the color of the ceilings and walls. There are three major types of lighting, incandescent, compact fluorescent, which is commonly referred to as CFL, and light emitting diode or LED. Incandescent lights are the least expensive, most common, but also the least efficient and have the shortest life of only 750 hours. All incandescent lights should be replaced by either CFL or LED lights. CFL bulbs last ten times longer than incandescent bulbs and reduce energy consumption by 66%.[8] CFLs cost more to purchase than incandescent bulbs, but they more than pay for themselves because of their efficiency and long lifespan, as seen in the chart below. LED lights are the most efficient type of lighting and can last up to 100,000 hours. LED bulbs are a newer and more expensive technology that is not as commonly used as either incandescent or CFL bulbs, but they are steadily decreasing in price. Since LED lights have such a long life span and are extremely efficient, they are a good option for lights that are on constantly, such as exit signs. LED exit signs cost about $70 to retrofit, but they have a savings potential of about $24 per year, per sign.

Pushing a Bright Idea

Wal-Mart is promoting consumer use of compact fluorescent light bulbs over incandescents. Here's how the bulbs compare.

	INCANDESCENT	FLUORESCENT
Energy used (watts)	60	13
Light output (lumens)	850	800
Average cost (dollars)	$0.25 to 0.60	$2 to 4
Annual savings (dollars)	$0	$8
Annual carbon savings (pounds)	0	roughly 100
Life (hours)	1,000	5,000 to 10,000
Mercury in the bulb (miligrams)	none	4
Mercury emissions (miligrams)	10	2.4
Number of bulbs sold annually*	1.5 to 2 billion	130 to 150 million

*Includes all wattages

Sources: Environmental Protection Agency; Environmental Defense; Ikon; Philips The New York Times

In order to make the most efficient use of lighting in a building, it is important to take into account the fixture design and positioning of the fixtures. Fixtures should optimize the amount of light deliv-

8 Cherry, Richard M. "Green Retrofitting: Start with an Energy Audit." Habitat. August 2007. http://www.habitatmag.com/publication_content/save_the_environment_save_the_world/green_retrofitting_start_with_an_energy_audit

ered to a room. The type of fixture that is the most efficient at delivering light can depend on the situation, but wall sconces and chandeliers for example are not very efficient at providing the most light. Lighting used for purely decorative reason should be avoided at all costs, especially accent lighting. Typically in open areas such as hall ways or meeting rooms, the optimal amount of lighting is needed, but in work areas task lighting can be a better option. Task lighting can result in significant energy savings and improved visibility for workers. For example, task lighting for a desk in an office or cubicle can decrease the overall luminance needed in that space. The coloring of the ceiling and walls can also make a significant difference in the amount of lighting needed. Lighter colors are preferred over darker colors because they reflect more light back into the room than dark colors.

There are some more extensive projects that can be done to make the lighting of a commercial building even more efficient beyond changing the type of bulbs and fixtures used. By incorporating natural light as much as possible; less energy will need to be spent on artificial light. This can be done by installing skylights and/or large windows. This will be very expensive project, but it well worth it in savings if using artificial lighting can be significantly limited or avoided during the working day. A simpler step to incorporate natural light can be the installation of sheer curtains that let light into the room, but still protect privacy. Another way to incorporate natural lighting and reduce artificial lighting is installing ambient light or daylight sensors. This type of sensor adjusts the amount of lighting used according to the amount of natural light or ambient light in a room and can save up $90 in annual savings. Another type of sensor that can save energy is motion or occupancy sensors. These sensors will turn on the lights if there is movement in a room. There are three basic types of motion sensors: passive infrared which uses heat, ultrasonic which uses sound waves and dual technology which is a hybrid of the two. An occupancy sensor can cost anywhere between $25 and $80, but can save about $40 per year depending on where the sensor is installed. A newer and less common type of light sensor is the combination of a motion and ambient light sensor.

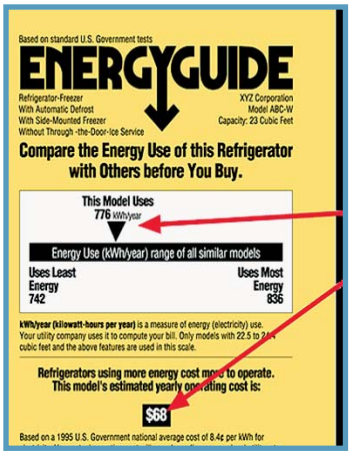
Operating Cost Comparison Open Office Area, 1,000 sq. ft.		
Performance	Occupancy Sensors	Daylighting
Annual Energy Use	5,000 kWh	4,200 kWh
Annual Energy Cost	$300	$250
Annual Energy Cost Savings	$40	$90

The Alliance Center in Denver, Colorado underwent a full building retrofit in 2006 and is LEED EB gold certified. As part of the retrofit they exchanged the building's T-12 fluorescent lights for more energy-efficient T-8 fluorescent lamps and installed daylight sensors to regulate the amount of electricity used for lighting based on the amount of sunlight coming through the windows. The total cost of the lighting retrofit was $17,000 and they broke even in just 2 1/2 years. (http://www.sustainable-colorado.org/center/tour.php)

Energy Star

Energy Star is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy. Energy Star is dedicated to helping

people save money and protect the environment through energy efficient products.[9] A major appliance that has the Energy Star label is not necessarily a better product than a comparable model, but in order for it to be Energy Star; it must meet very strict energy efficiency guidelines that are set out by the program. Appliances that have the Energy Star rating are usually 10 to 20% more energy efficient than non-rated models. Energy Star products range anywhere from refrigerators, copy and fax machines, heating and cooling, lighting fixtures, and many more. To see all of the different types of products that are part of the Energy Star program, check out their website at energystar.gov. It is important that an appliance has the Energy Star logo, instead of just stating on the label that a product is energy efficient. Just because a product says that it is energy efficient does not necessarily mean that it is better than other products, and there is a lot of 'green-washing' of products. Also look for "Energy Guide" tags, which show a model's expected annual energy use and how that ranks against peer models.[10]



Source: EERE

It may not be the most cost efficient to replace all appliances with Energy Star products, it is best to start with the older appliances. A good rule of thumb is that if a product is over ten years old, then it should be replaced. If an appliance is only several years old, then it is not as essential to update the product because it will still work more efficiently than the older appliances. It is suggested that extensive research should be done on each appliance and whether the savings from newer products will be worth it. One way to compare the energy usage of the existing appliance to a new energy star appliance is the use of a Kill-A-Watt. A Kill-A-Watt is plugged into the wall, and then the appliance is plugged into the Kill-A-Watt. The display will count energy consumption by the Kilowatt-hour, same as the local utility. It allows you to calculate the electrical expenses by the day, week, month, even an entire year. A Kill-A-Watt is very cheap and averages around $30 and are readily available to order online. A Kill-A-Watt is a very useful tool that can help people make better informed decisions about their appliances.

Insulation

Not matter how efficient your HVAC system is supposed to be, it will not make any difference if your insulation is not effective at keeping air in or out. An energy audit should provide a good estimate as to how effective the current insulation is. To really get a full understanding on the type of insulation and where exactly air is leaking through, an insulation expert should be contacted. When dealing with replacing or updating insulation, it can be a very extensive and expensive process and should always be contracted out. A contractor should use a thermal scanner, which can tell exactly how much air is passing through the walls and where the problems spots are. When finding a contractor, make sure that they are trained in cellulose or spray foam insulation as opposed to the more traditional fiberglass insulation.

Insulation is measured by its R value, or thermal resistance, the higher the R value, the better the in-

9 "ENERGY STAR Qualified Products." 2009. Energy Star. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.

10 "ENERGY STAR Qualified Products."

sulation. There are three types of insulation as mentioned above, Fiberglass, Cellulose, and Foam, each increasing in R value. Fiberglass is the cheapest option, but harder to install and harder to fit into tight spaces. This is the kind of insulation that one would normally think of when they think of insulation, big puffy sheets, but Fiberglass is in actuality very inferior to other commercially available options. Cellulose costs more to install, but overall it has a much higher return n investment or ROI. It is sprayed into wall cavities, which helps form an excellent air barrier. It is also approximately three times denser then fiberglass which helps deaden sound transmission through walls.[11] Cellulose outperforms fiberglass by 20-40%. Foam insulation is more expensive than cellulose, but it does have a much higher return on investment. It is the most efficient form of insulation that is commercially available. Foam is also typically sprayed into wall cavities and it stops air flow into and out of the home, reduces noise, and blocks the infiltration of dust, pollen and other airborne pollutants, and helps to prevent mold, mildew and moisture.[12] By replacing fiberglass insulation with spray foam, electricity bills are cut about 30-40%. Something to consider is that in most office buildings, particularly in high rise and multi floor buildings, replacing wall insulation is more important than roof insulation.

Most experts agree that caulking and weather stripping any gaps will pay for itself within one year in energy savings. Caulking and weather stripping will also alleviate drafts and help the building feel warmer when it is cold outside. One should look at areas where different materials meet, like between brick and wood siding and between foundation and walls. Also inspect around the following for any cracks and gaps that could cause air leaks: door and window frames, electrical and gas service entrances, phone lines, air conditioners, and vents and fans. Once again, an insulation expert should be able to tell you where air is leaking and where additional caulking and weather stripping is needed or where it should be replaced.

Windows

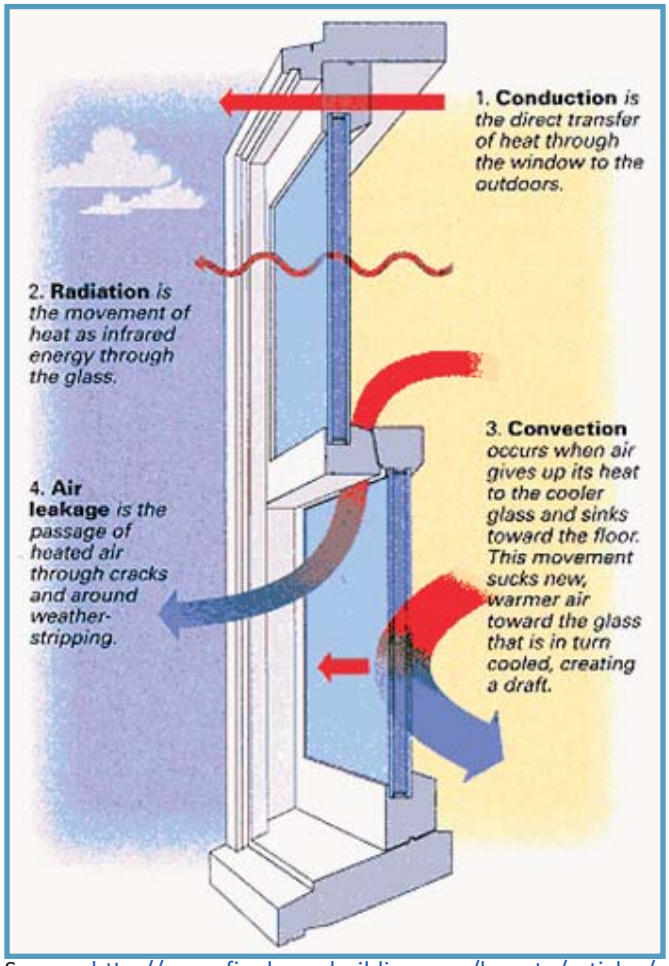
Old drafty windows not only make a building uncomfortable, but they are a major cause of energy loss. Window technology has advanced significantly in the past 10 years, so it is well worth it to update older windows. Thermal scanning equipment can also be used on windows to tell the extent of energy loss. In addition to improved energy efficiency, the reduction of water and air infiltration, reduction of outside noise and the ability to maintain a better pressurized building are other factors that need to be considered in the replacement decision. This type of project should always be contracted out, as make sure that windows are properly sealed to prevent any air leakage. It is important to do your research and find a good company that will help you find the type of window that will be best for your building and not what they want to sell. Although replacing windows can be a big expense the pay back is well worth it. Windows replacement typically has a return on investment around 10-15 years.

Windows lose heat in four ways: conduction, radiation, convection and air leakage, as seen in the chart below. The rate at which a window loses heat through the four ways, the combination of the four

11 "Green Energy Retrofits." Green Building.com. 2009. http://www.greenbuilding.com/green-home-improvement/green-energy-retrofits

12 "Green Energy Retrofits."

is called its U-value. It is the inverse of the R-value, therefore the lower the U-value, the greater the insulative value of the window.[13] These ratings are standardized and offer a non-biased evaluation of a whole window and not just the glass. There are 3 major components that give a window the lowest U-value currently available that a consumer should look for. One of these is low-e or low-emissivity, which is a film that coats the glass. Low-e reflects infrared energy back towards the warm side of the glass. For example, on a cold day, your body heat is reflected back at you, instead of sucked away from you.[14] Another component is glass filled double paned windows. Older windows typically are only singled paned, which means there is only one sheet of glass between the inside of a building and outdoors, this is a very energy inefficient design. Some older buildings may have some sort of externally installed storm window which may be somewhat more efficient than the original single pane window. Today windows are usually doubled paned, with and inside and an outside sheet of glass. A gas filled window has either argon or krypton between the panes, instead of normal air, which creates a convective loop that better insulates. The other component to consider is the type of frame. The best types of frames are vinyl or fiberglass, or wood. Wood is more expensive than the other two, but typically more aesthetically pleasing. The type of frame to avoid at all costs is metal. Metal conducts and creates thermal bridging between the inside and outside of a building allowing heat exchange. After the most efficient type of window has been established for the building and the windows are installs, the frames must be properly sealed to avoid any air leakages. Also if window are relatively new or are too expensive to replace, they can be re-sealed to decrease any energy loss through windows.



Source: http://www.finehomebuilding.com/how-to/articles/understanding-energy-efficient-windows.aspx)

Heating and Cooling

An HVAC or heating, ventilation, and air conditioning system typically accounts for 40 to 60% of a buildings energy use.[15] Most HVAC systems and

13 Fisette, Paul. "Understanding Energy-Efficient Windows." FineHomebuilding.com. February 1, 1998. http://www.finehomebuilding.com/how-to/articles/understanding-energy-efficient-windows.aspx

14 "Green Energy Retrofits."

15 Martin, Greg L. "Coming Up Green: Energy-Saving Retrofitting Options Provide Financial Returns." All Business. November 1, 2008. Journal of Property Management. http://www.allbusiness.com/construction/building-fixtures-mechanical-systems-hvac/11715472-1.html

their components have normal service lives of 15 to 25 years if properly maintained and otherwise should be updated. Updating the heating and cooling system can be another very extensive and expensive process, and it can often disrupt business. Through energy-efficiency improvements in the retrofit process including updating the insulation and windows, a smaller HVAC system may be required, which will save money. It is important to make sure you find a contractor who is up to date on HVAC systems; they should help you figure out what type would be the best for your unique building and not stick with one type of system. For example they should be able to properly size a furnace or boiler for your specific building.

Heating

A furnace or boiler's efficiency is measured by annual fuel utilization efficiency (AFUE). AFUE is a measurement of how efficient the furnace or boiler is in producing energy from its fuel over the course of a typical year. More specifically it measures the ratio of heat output of the furnace or boiler to the total energy consumed by a furnace or boiler. So therefore an AFUE of 90% means that 90% of the energy in the fuel becomes heat for the building and the other 10% escapes up the chimney and elsewhere.[16] AFUE does not include the heat losses in the duct system or piping, it only measures the efficiency of the actual boilers or furnaces. It is required by the Federal Trade Commission that all new furnaces and boilers must display their AFUE rating. This allows the consumer to be able to compare heating efficiencies of various models.

The minimum allowed AFUE rating for a non-condensing fossil-fueled, warm-air furnace is 78%; the minimum rating for a fossil-fueled boiler is 80%; and the minimum rating for a gas-fueled steam boiler is 75%.[17] The AFUE rating for a condensing unit can be more than 10% higher than a non-condensing furnace. A condensing furnace or boiler condenses the water vapor produced in the combustion process and then uses the heat from the condensation. Although condensing units are more expensive than non-condensing units, a condensing unit can save you money in fuel costs over the 15 to 25 year life of the unit, particularly in colder climates. Older furnace and boiler systems had efficiencies in the range of 56–70%; modern conventional heating systems including condensing systems, can achieve efficiencies as high as 97%.[18] This converts almost all of the fuel to useful heat for a building. Upgrading to a new high-efficiency heating system can often cut the fuel bills and a furnace's pollution output in half. If you were to upgrade your furnace or boiler from 56% to 90% AFUE rating in a cold climate will save 1.5 tons of carbon dioxide emissions each year if you heat with gas or 2.5 tons if you heat with oil.[19]

16 Energy Savers. February 24, 2009. U.S. Department of Energy: Energy Efficiency and Renewable Energy. http://www.energysavers.gov/your_home/

17 Energy Savers

18 Energy Savers

19 Energy Savers

Annual Estimated Savings for Every $100 of Fuel Costs by Increasing Your Heating Equipment Efficiency*									
	New/Upgraded System AFUE								
Existing System AFUE	55%	60%	65%	70%	75%	80%	85%	90%	95%
50%	$9.09	$16.76	$23.07	$28.57	$33.33	$37.50	$41.24	$44.24	$47.36
55%	----	$8.33	$15.38	$21.42	$26.66	$31.20	$35.29	$38.88	$42.10
60%	----	----	$7.69	$14.28	$20.00	$25.00	$29.41	$33.33	$37.80
65%	----	----	----	$7.14	$13.33	$18.75	$23.52	$27.77	$31.57
70%	----	----	----	----	$6.66	$12.50	$17.64	$22.22	$26.32
75%	----	----	----	----	----	$6.50	$11.76	$16.66	$21.10
80%	----	----	----	----	----	----	$5.88	$11.11	$15.80
85%	----	----	----	----	----	----	----	$5.55	$10.50
90%	----	----	----	----	----	----	----	----	$5.30

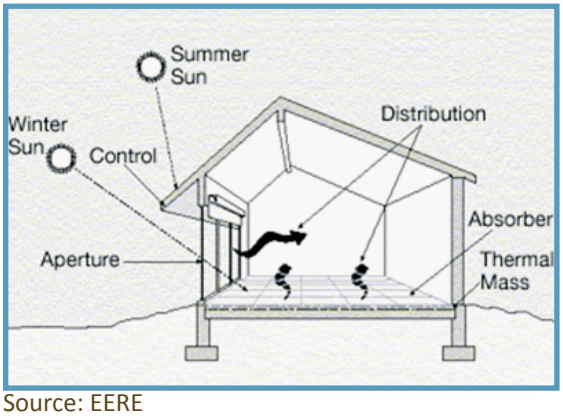
*Assuming the same heat output (source: EERE)

Cooling

Air conditioning technology has come a long way in the past few years and even if your air conditioner is only 10 years old, you can save 20% to 40% of your cooling energy costs by replacing it with a newer, more efficient model.[20] The most efficient models use 30%–50% less energy to produce the same amount of cooling as air conditioners made in the mid 1970s. Central air conditioning models are also much more energy efficient in cooling a building than window or single room models. A central air conditioning system can cool an entire building for about the same price as running an air conditioner in one room. The best way to find the most energy efficient air conditioners is to compare the energy guide tags and look for Energy Star rated models.

Passive Solar

A passive solar design uses a structure's windows, walls, and floors to collect, store, and distribute the sun's heat in the winter and reject solar heat in the summer. In the winter, sunlight enters a building through south-facing windows. It then strikes the building's thermal mass usually dark-colored masonry floors and/or walls in the interior space that absorb and store the solar heat. At night, as the building cools, heat stored in the floors and walls warms the rooms. Also by using large over hangs, in the summer when the sun is higher up in the sky, sunlight will be rejected from entering the building. This kind of design is traditionally used when building new structures, but many of the characteristics of a passive solar building can be incorporated into existing structures. For example large windows with large over hangs can be installed on the south side of a building, and the walls and flooring in the rooms on the south side should be made of very heat absorbent materials. Incorporating passive into a building can reduce the amount of energy needed to heat a building and cool a building.



Source: EERE

20 Energy Savers

Ventilation

Modifications to air distribution systems are difficult to make in existing buildings, except during a major renovation. Although by updating to a high-efficiency air distribution system, it can substantially reduce fan power required by the HVAC system which results in dramatic energy savings. Modifications that could be done include: making sure that the system is delivering only the air needed, increase the duct size, use low-face-velocity handlers, eliminate some ducting, and make sure the fans are correctly sized. Delivering a large mass of air at low velocity is a far more efficient design strategy than pushing air through small ducts at high velocity. Also, supplying only as much air as is needed to condition or ventilate a space through the use of variable-air-volume systems is more efficient than supplying a constant volume of air at all times.[21] An easy step to make sure that your ventilation system is working efficiently is to replace the filter once a month. Air filters do not cost anything to clean and only about $2 to replace, but they can save as much as $60 per filter, depending on the size of the HVAC system.

Energy Conservation Projects

There some other projects that can reduce the amount of energy needed to heat and cool a building and save a lot of money. For example a light colored reflective roof will reflect sunlight and therefore keep a building cooler; this can produce significant savings in warmer climates. An energy management system with automatic temperature controls is proven to lessen energy consumption by reducing the overheating and overcooling. Energy consumption is further reduced by incorporating temperature setbacks for heating and temperature setup for cooling, during unoccupied or other times of the day.[22] An energy management system will also automatically turn off devices when they do not need to be used and can provide real time data on energy usage. A simpler and cheaper method to an energy management system is the installation of a programmable thermostat. A programmable thermostat can be set to not go below or above certain temperatures and keep the building cooler or warmer depending on the season or business hours. A programmable thermostat can save as much as 15 % on heating and cooling costs.

21 Energy Savers

Water Efficiency

There are several cheap and easy ways to reduce a building's water usage and lower the water bill. The first project should always be to fix water pipe leaks, especially if the building is old and has not replaced the pipes. Along with pipes, all appliances and irrigations systems should also be checked. Often these leaks are not very significant, but overtime they add up. It is possible to check for leaks on your own, but for a more thorough examination a plumber should be used. After the pipes are all sealed up the next easy project would be to install water-conserving indoor plumbing fixtures and fittings. These include low flow toilets, sinks and showers, by installing these water-conserving fixtures, indoor water use can be reduced by 30-40%.[23] Federal standards are beginning to lean towards these new water saving devices. In fact all new toilet installations must meet the federal standard of 1.6 gallons of water per flush (GPF), while toilets manufactured before 1994 use at least 3.5 GPF.[24] In the past people were very wary of installing low flow water devices because they

22 Martin, Greg L.

23 Rich, Sarah. "Green building 101: Water Efficiency." Inhabitat. July 12, 2006. http://www.inhabitat.com/2006/07/12/green-building-101-water-efficiency/

24 Rich, Sarah

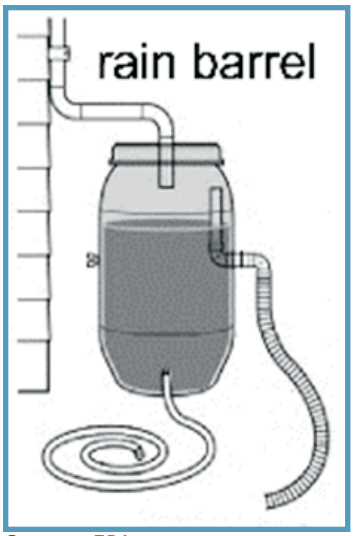
were not nearly as efficient as traditional fixtures, but these devices have become much more advanced in the past few years and do not have a lack of efficiency as some earlier products did.

The Alliance Center in Denver, Colorado underwent a full building retrofit in 2006 and is LEED EB gold certified. They replaced toilets and water fixtures with low-flow fixtures to cut down on water use. The $22,000 water retrofit has reduced water use by 84% a year, produced savings of $4,500 a year and has an expected return on investment of less than 5 years. (http://www.sustainablecolorado.org/center/tour.php)

A more extensive project that reduces and reuses water is the implementation of a gray water system. Gray water is all waste water excluding human waste (black water), i.e. any waste water that comes from a building excluding toilets and urinals. Gray water can be collected in tanks and reused as an on-site supply for watering and in some cases can be reused indoors for flushing toilets and washing. In order to be able to reuse grey water, eco-friendly soaps and products must be used at all times within the facility. It also depends on the type of work being done in the building, since water cannot be contaminated in any way, so this kind of system should not be used where there is extensive manufacturing or chemical use in the building. There are also extensive regulations and restrictions on the gray water systems, and they are much more complex for indoor gray water reuse. The regulations differ from state to state, but all proper regulations must be met in order to use a gray water system. It is always a good idea to consult a plumber because you must know what you are doing when you disconnect pipes or redirect water flow. It is a very extensive process, but if it is carried out properly can reduce water usage significantly.

Sustainable Site

There are several easy and cheap steps to make the land surrounding a commercial building more sustainable. One of these steps is the installation of rain barrels. They are attached to the downspouts or gutters of a building and collect rain water. The collected rainwater can be used to water plants and will reduce the water bill and in some cases reduce the sewer bill. Rain barrels on average cost around 100 dollars, but there are much cheaper products that are commercially available. One of the main reasons that some barrels are much more expensive than others is because of the aesthetic look of a barrel. Another easy step is to plant only water efficient, climate-tolerant native or adapted plantings. By planting native and water efficient plants, they will not have to be watered very often because they will already be adapted to the climate. Not only will this provide savings on the water bill, but these plants will be much easier to take care of and require less maintenance time.



Source: EPA

A more extensive project that would also greatly reduce the amount of water used for landscaping purposes is the installation of highly efficient irrigation system. For example a smart, programmable sprinkler system with moisture sensors allows you to measure the amount of water a yard or garden needs at any given time, and control irrigation from a central shut-off valve. This will be an expensive venture

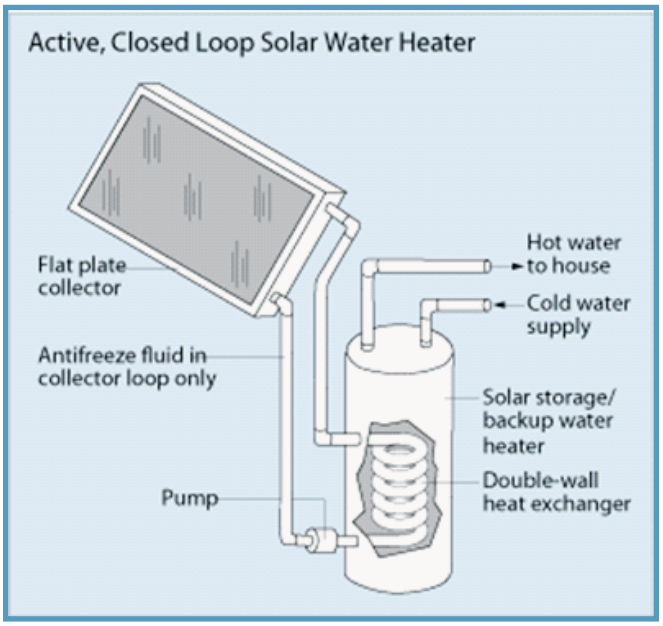
and will require a lot of underground work. While this is an expensive project, it will greatly reduce the amount of unnecessary water used for irrigation purposes and save money. According to researchers at the University of Florida, a moisture sensor can yield a water savings of 69% to 92% and can cut the overall water bill by about 40-45%.[25]

Renewable Energy

Renewable Energy should be the very last project in a green building retrofit. The more efficient the building, the less energy is needed to supply it. For example the more energy efficient a building is, the less solar panels would need to be installed to power a building than would be needed before the retrofit process. This reduces the upfront cost of renewable energy. All renewable energy projects have to be contracted out to professionals who are experienced in each of the different types of renewable energy, considering the fact that the actual technology are complex, but also the specific installation processes such as wiring are very complex.

Solar Hot Water

Solar hot water is often considered the simplest and cheapest form of renewable energy. It uses solar thermal technology, through a direct or in-direct design. In a direct design solar radiation heats water that is being pumped through heat-absorbing solar thermal collectors and then that water is used in the building directly. In an indirect design the liquid pumped through the solar thermal collectors is an anti-freeze, and then is circulated through coils in the water tank to heat the surrounding water. In most cases the water is not hot enough to be used in a building and must be heated additionally, but significant energy is saved because much less energy must be used to raise the water to the desired temperature. A solar hot water heater is fairly easy to install, but a professional should be contacted to do the installation to make sure that everything is hooked up properly. Solar hot water heaters typically cost $5-6,000, and they should have an ROI of more than 10 years, but with an installation of solar hot water heater, water heating bills should drop 50-80%.[26]



Source: EERE

Solar PV

Solar panels are rapidly growing renewable energy technology. They use solar photovoltaic or solar PV technology converts energy from sunlight directly into electricity. Solar panels are not just for sunny California anymore; they are growing in popularity and can provide significant amounts of energy to buildings throughout the United States. The most important consideration for a solar panel is that there is absolutely no shading on the module between 9 AM and 3 PM because any shading can drastically reduce the power output.

25 "Green Energy Retrofits"

26 Energy Savers

There are three major mounting styles for solar panels. The first type is pole or ground mounted. This type of mounting is separate from a building, but can be in very close proximity as long as there is no shading. The second type of mounting is roof attached, which is mounted on top of the roof of a building. When placing a solar module on your roof, it is highly suggested that the roof be replaced just prior to the installation. Also, it is important to make sure that the module is firmly attached to the roof, preferably to a support system such as the rafters. The last type of solar PV cells is the newest and most advanced technology, roof integrated solar panels. This can only be installed if you are redoing your roof, since the solar cells are completing integrated as part of the roof. It is a newer technology and is currently not quite as efficient as the other two types of PV cells, but the technology is advancing very quickly and is likely to be as efficient, if not more efficient than the mono or polycrystalline modules most often used in the more traditional mounting types. A 5 kW system typically costs anywhere from $35-40,000 and has a many year return on investment anywhere from 10 to 30 years, it can vary from situation to situation.[27]

Wind

A wind turbine is another renewable energy technology that can provide electricity directly to a building. They are the most efficient in an area of high wind; a wind map can be used to help determine if your location is appropriate for a wind turbine along with the consultation of a professional. Up to a year of research must be done before installing a turbine in order to determine if there is enough wind, and also whether it will harm any birds or bats. A wind turbine must be very high in the air, up to 100 feet of the ground without any nearby obstructions in order to obtain the best wind. Wind is a very viable option in certain situations, but it also has its issues. One must make sure that the turbine complies with all city or community codes and make sure that there are not any problems with migratory birds or bats. Another issue to deal with is the noise that a wind turbine produces, most communities have a noise ordinance, in many communities there is a noise ordinance of 50 decibels after 9 PM. Small wind energy systems cost from $3,000 to $6,000 for every kilowatt of generating capacity. The payback period can be anywhere between 6 and 30 years, but a small-scale wind turbine that is in an ideal site can have an ROI of less than 15 years.[28]

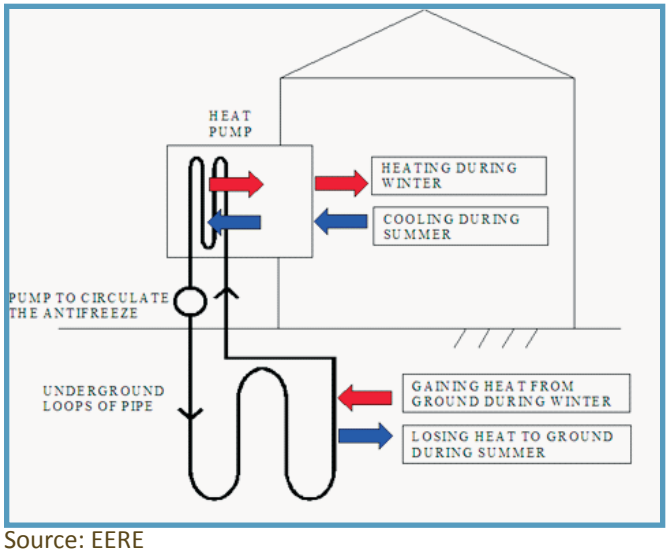
Geothermal

A geothermal heat pump is also a possible renewable energy option; it can greatly reduce energy needed to heat a building. A geothermal heat pump uses the moderate temperatures of the Earth to either warm a building in the winter or cool a building in the summer. Although it does have a very high upfront cost due to extensive drilling and lying of pipes. The installation process can become very complex with the laying underground pipes, but the pipes can last up to 20 years. The initial drilling can cost anywhere from $10,000 to $30,000, while the actual heat pump can cost as little as $2,500. There is typically a 2-10 year return on

27 "How Much Do Solar Panels Cost?" Cost Helper. 2009. http://www.costhelper.com/cost/home-garden/solar-panels.html

28 "Small Wind: Frequently Asked Questions." AWEA. 2009. American Wind Energy Association. http://www.awea.org/smallwind/faq_buying.html#Howmuchdoesawindsystemcost

investment (ROI) even with the high cost of the initial drilling and savings can range from30 to 60 %.[29]



Source: EERE

For more information on renewable energy and what type is best for your business please view the Renewable Energy Technologies for Small to Medium Sized Enterprises white paper on the SSC website.

Materials and Resources

The materials and resources part of a green retrofit is the broadest and most vague part of a green retrofit. It deals more with the concept of leaving the smallest environmental footprint and does not provide a straightforward economic benefit. In order to do so, there are some key things to consider about the materials you plan to use and will require asking lots of questions about the origin of materials used in the building retrofit. It is important to find out find out where the materials come from and who's supplying it. For example when choosing wood, you should always research available FSC certified woods. The FSC (Forest Stewards Council) certifies products and companies on their sustainable forestry practices, therefore buying FSC certified products guarantees that the materials are at least harvested sustainably. It is also important to be cautious of green-washing of products, by asking the right questions, one can discover the true lifecycle of a product.

Another way to create the smallest environmental footprint is the use of local materials. For example, rapidly renewable bamboo or plyboo is a good alternative to traditional oak flooring. But if reclaimed oak is locally available, it may be wise to opt for the product that does not come from China.[30] The transportation of sustainable materials from far distances and the can overpower the fact that slightly less sustainable materials are located nearby. Reused materials from onsite or offsite can also lower the environmental footprint of a building. By reusing materials it helps mitigate waste and debris from going to a landfill. Post consumer or post industrial materials are a common reusable source for roofing, flooring, and various other parts of a building.

The L.L. Bean Company just finished a whole-building retrofit of its store in Mansfield, MA retail location and received a Platinum LEED certification. Construction material selection was a primary issue in the design of the space, and the project team wanted to use materials that wouldn't take from the earth's natural resources. The project used carpet and rubber flooring which contained recycled content, FSC-certified hardwoods and reclaimed barn boards for finish materials. While upfront cost was higher for these special materials, the significant energy and water use reductions the store has experienced since opening its doors have more than compensated for the added first costs. L.L. Bean also aimed for 75% construction waste diversion from landfills, and by meticulously sorting waste, the project was able to divert 94% of its waste. (LEED EB project profile)

29 "Geothermal heat pumps: A down-to-earth investment." Western Area Power Administration. Department of Energy. http://www.wapa.gov/es/pubs/fctsheet/GHP.pdf

30 Kujak, Piper. "Green building 101: Materials and Resources Part 1." Inhabitat. July 19, 2006. http://www.inhabitat.com/2006/07/19/green-building-101-materials-and-resources-part-i/

Volatile organic compounds (VOCs) seep into the air in a building or mix with outdoor pollutants to create ground level ozone (smog). VOCs are in many common household items and materials including paints, varnishes, many plastics, and furniture. For example many conventional interior grade composite materials, like carbon fiber and engineered wood, contain urea-formaldehyde binder, which has been classified as a Toxic Air Contaminant. So throughout the retrofit process it is important to try to use materials that have the lowest level of VOCs. For example, low-VOC and zero-VOC paints contain a reduced number of grams of VOC per liter (under 150 grams for low-VOC and under 5 for zero-VOC).[31] Many eco-friendly products will have on their label whether they are low-VOC or zero-VOC, but in many cases thorough research must be done to find products that contain the least amount of VOCs and can provide the best indoor air quality. For more information on eco-friendly interior decorating please view the Sustainable Interior Commercial Design white paper on the SSC website.

Green Roof

A green roof is a roof that has been covered with dense plant life. It consists of a drainage layer and a waterproof membrane typically covered in a thin layer of 2-4 inches of soil compacted with low growing plants. Local weather conditions, temperature, and structural factors should determine the appropriate types of plants that are used. There are a lot of benefits to installing a green roof including significantly reducing the heat island effect of a building and capturing pollution particles, breaking them down and reabsorbing them as fertilizer and putting oxygen back into the air. Other benefits include allowing for the absorption of storm water (up to 90% of an areas rainfall), reducing pollution runoff, and reducing noise pollution. This is a very extensive process that should not be done without proper research on your specific type of roof and whether the roof can support a green roof. It is highly suggested that the roof of the building be reroofed prior to installing a green roof unless it has been redone very recently, (within the past year).This is definitely a project that requires getting external help from people who are experts in roofs and particularly green roofs. For more information on green roofs please view the Green Roofs and Living Walls: A Guide for Small Businesses white paper on the SSC website.

31 Kujak, Piper

Return on Investment

The return on investment (ROI) or time it makes to break even for the overall retrofit process can significantly vary depending on the types of projects completed. If major projects such as renewable energy, replacing windows, or the HVAC system is updated are included in the process then the ROI time is going to be much longer than it would be otherwise. The average time it takes to break even is between two to five years depending on the situation and according to the USGBC the average ROI is 20% over a buildings lifetime. Although the actual return on investment in energy or water savings may take several years, there are many upfront benefits such as lower operating costs, increased property value, higher rental rates, and customers that are willing to pay cost premium. One of the participants of a survey of project owners or members of LEED Existing Building certified projects by Charles Lockwood and Deloitte said their property value increased, "The appraised value of the property today, with the high-tech, computer-controlled HVAC system and electrical system, is about a half a million dollars greater than the appraised value when we completed the construction project a year ago. Selling the building at a premium would not be a problem." Another participant of the survey said, "If you look at only the capital costs, there is a cost premium for green. But when you extend your definition of the value added, such as productivity increases and better retention, you'll find that it's actually cheaper to go green."

Adobe Systems invested $1.4 million for a green retrofit of its headquarters in San Jose, California. Even with a 35% increase in staff, Adobe has had a 35% drop in electricity use, a 41% decline in natural gas use, a 22% reduction in domestic potable water consumption and a 76% reduction in landscape irrigation water use. This retrofit has generated a 121% return on investment, the average payback time for each project is just 9 ½ months, and the company saves the company about $1.2 million in utility costs per year. Additionally, Adobe received $389,000 in grants and equipment purchase rebates for installing energy-efficient technologies. (Deloitte/Charles Lockwood)

What About LEED?

LEED or Leadership in Energy and Environmental Design is a green building certification program developed by the U.S. Green Building Council (USGBC). LEED is a voluntary certification program that can be applied to any building type (both new and existing) and encourages a whole-building approach to sustainability by recognizing performance in several major areas. LEED points are awarded on a 100-point scale, and credits are weighted to reflect their potential environmental impacts with 10 additional bonus points. A project must satisfy all prerequisites and earn a minimum number of points to be certified. The LEED certification for Existing Buildings or LEED EB, is the specific certification for retrofitting existing buildings. The certification is broken down into the following categories and points; Sustainable Site (26), Water efficiency (14), Energy and Atmosphere (35), Materials and Resources (10), Indoor Environmental Quality (15), Innovation in Operations (bonus 6), and Regional Priority (bonus 4).

There are four level of certification:

- Certified- 40+ points
- Silver Level- 50+ points
- Gold Level- 60+ points
- Platinum Level- 80+ points

There are pros and cons to using the LEED certification. LEED is an established and respected certification program and when you don't have a certification system like LEED, it's easy to say one thing and do something else and there are no consequences for cutting down on green features because of the expense.[32] It also provides very specific direction for people and companies who desire to decrease their buildings' impacts, which essentially makes green building accessible to a much broader audience than would otherwise be the case. If you are looking to gain notoriety for the work you have done, becoming LEED certified will certainly provide it.

As for the negative aspects of the LEED program, it is incredibly detailed, time consuming, and adds extra expenses. The process of becoming certified often requires a LEED consultant, someone who is an expert on the program. In a survey of members of LEED Existing Building certified projects by Charles Lockwood and Deloitte, one member stated that "[The LEED certification process] was pretty intense. The USGBC audits your credits, and then you have to provide backup documentation. We had one guy who worked as the link to our commissioning agent who did absolutely nothing but gather documentation and keep it in the right order for the USGBC to see."[33] The LEED certification is certainly not for every building retrofit, especially since the same energy savings and reduced carbon dioxide emissions can be achieved without going through the certification program. For a less extensive building retrofit, the expensive program is not a very plausible option, but if you are expecting to go through a complete remodel/retrofit LEED is a better option.

32 Deloitte/Charles Lockwood

33 Deloitte/Charles Lockwood

Incentives

There are a substantial amount of financial incentives currently available that can make a green retrofit much more financially reasonable. Most of the incentives are in the renewable energy or energy efficiency areas. The commercial building tax deduction in the Energy Policy Act of 2005 provides a tax deduction of $1.80 per square foot; eligible buildings must save at least 50 % of projected energy costs and buildings with lesser annual energy savings are eligible for a partial deduction of $0.60 per square foot. A major federal renewable energy incentive in the American Recovery and Reinvestment Act of 2009 provides a 30% tax credit or federal grant for the equivalent amount of money. The American Recovery and Reinvestment Act is part of the government stimulus package, which provides significant economic incentives to develop a greener economy including $4.5 billion dollars for building green federal buildings. For more information on the allocation of stimulus money please view the How Small Business Can Take Advantage of Stimulus Money in the Energy Sector white paper on the SSC website. There are also many other government grant, tax credits, and loan programs that currently out there or are being developed.

There are many state incentives as well, but they differ from state to state. It is necessary to do research on your individual state, a great resource is the Database of State Incentives for Renewable Energy and Energy Efficiency or DSIRE located at dsireusa.org. This database also has an up to date list on federal incentives. An example of state incentives in Pennsylvania is the Alternative Energy Investment Fund which provides $650 million for renewable energy and energy efficiency. This program includes $180 million for solar photovoltaic (PV) or solar thermal systems, $165 million for other renewable energy projects, $25 million for green building projects, either new or retrofitting, and $280 million for various other projects. The funding for programs such as the Alternate Energy Investment Fund will not last forever and will eventually run out. Evidence strongly suggests that green retrofitting projects should be completed sooner than later in order to receive economic incentives because retrofits will become more common and the incentives will disappear.

After the Retrofit

Work does not stop after the completion of a green retrofit; many sustainable practices that don't involve the actual infrastructure of a building can also contribute to a greener building or workplace. It is important to continue to work with employees or tenants to uphold sustainable practices. This could mean making a company policy to turn off lights and appliances when they are not needed or unplug unused appliances. Phantom loads are appliances that continue to draw energy when they are turned off but still plugged in; this includes most common office appliances. A recycling and waste management program should be established and if there is already one in place, it should be updated. The business can incentivize using other forms of transportation or carpooling for those employees that commuter. Another step is the creation of a green team, or a group of employees who meet on a regular basis to discuss the company's environmental policy's and work to create a more environmentally friendly working environment. Simple behavioral changes such as only sending out memos via e-mail or buying from other environmentally friendly companies can have a much larger impact.

Glossary

AFUE – A measurement of how efficient a furnace or boiler is in producing energy from its fuel over the course of a typical year.

Gray Water – Wastewater produced from baths and showers, clothes washers, and sinks.

Green Wash – term used to describe the practice of companies dishonestly spinning their products and policies as environmentally friendly

HVAC – (heating, ventilating, and air conditioning) refers to the equipment, distribution network, and terminals that provide either collectively or individually the heating, ventilating, or air-conditioning processes to a building.

LEED – LEED or Leadership in Energy & Environmental Design is a green building certification program developed by the U.S. Green Building Council (USGBC).

Low-e – A type of window glazing where microscopic metal or metallic oxide is layered onto a piece of glass to suppress thermal radiation and radiant heat transfer. They are produced at various rates to allow for different levels of solar gain

Passive Solar – Passive solar is the technology of heating and cooling a building naturally, through the use of energy efficient materials, and proper site placement of the structure.

R Value – A measure of thermal resistance used in the building and construction industry. The bigger the number, the better the building insulation's effectiveness.

U Value – Amount of heat transferred through a material. The lower the U-value, the slower the rate of heat flow and the better the insulating quality.

VOC – Volatile organic compounds seep into the air in a building or mix with outdoor pollutants to create ground level ozone (smog).

Sources

Abbott, Kelsey. "Green Retrofits More Than Pay for Themselves." TheStreet.com. October 10, 2008. http://www.thestreet.com/story/10440217/2/green-retrofits-more-than-pay-for-themselves.html

"About Green Roofs." Green Roofs for Healthier Cities. 2005. http://www.greenroofs.org/index.php?option=com_content&task=view&id=26&Itemid=40

Building Technologies Program: Commercial Buildings: Energy Efficient Building Practices. July 17, 2008. U.S. Department of Energy: Energy Efficiency and Renewable Energy. http://www1.eere.energy.gov/buildings/commercial/index.html

"Building Tour." Alliance for Sustainable Colorado.2009. http://www.sustainablecolorado.org/center/tour.php

Cheeseman, Gina-Marie. "How Green Retrofitting is Beneficial." Triple Pundit. October 9th, 2008. http://www.triplepundit.com/2008/10/how-green-retrofitting-is-beneficial/

Cherry, Richard M. "Green Retrofitting: Start with an Energy Audit." Habitat. August 2007. http://www.habitatmag.com/publication_content/save_the_environment_save_the_world/green_retrofitting_start_with_an_energy_audit

Cortese, Amy. "'Green' Buildings Don't Have to Be New" The New York Times. January 27, 2008 http://www.nytimes.com/2008/01/27/realestate/commercial/27sqft.html?_r=1&pagewanted=all

Deloitte/Charles Lockwood. "The Dollars and Sense of Green Retrofits." Greener Buildings. July 28, 2008 http://www.greenerbuildings.com/files/document/us_re_Dollars_Sense_Retrofits_190608_.pdf

Energy Savers. February 24, 2009. U.S. Department of Energy: Energy Efficiency and Renewable Energy. http://www.energysavers.gov/your_home/

"ENERGY STAR Qualified Products." 2009. Energy Star. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.

Fisette, Paul. "Understanding Energy-Efficient Windows." FineHomebuilding.com. February 1, 1998. http://www.finehomebuilding.com/how-to/articles/understanding-energy-efficient-windows.aspx

Geline, Evan. "Green building 101: Indoor Environmental Air Quality." Inhabitat. August 2, 2006. http://www.inhabitat.com/2006/08/02/green-building-101-indoor-environmental-quality/

"Green Energy Retrofits." Green Building.com. 2009. http://www.greenbuilding.com/green-home-improvement/green-energy-retrofits

"Green Retrofit Checklist." The Green Home Guide. 2008. US Green Building Council. http://www.greenhomeguide.org/guide_for_green_renovation/green_retrofit_checklist.html

"Geothermal heat pumps: A down-to-earth investment." Western Area Power Administration. Department of Energy. http://www.wapa.gov/es/pubs/fctsheet/GHP.pdf

"How Much Do Solar Panels Cost?" Cost Helper. 2009. http://www.costhelper.com/cost/home-garden/solar-panels.html

Koerner, Preston. "Nau Examines the Pros and Cons of LEED." Jetson Green. April 15, 2008. http://www.jetsongreen.com/2008/04/nau-examines-th.html

Kujak, Piper. "Green building 101: Materials and Resources Part 1." Inhabitat. July 19, 2006. http://www.inhabitat.com/2006/07/19/green-building-101-materials-and-resources-part-i/

"LEED EB." Armstrong. 2005. US Green Building Council. http://www.armstrong.com/common/c2002/content/files/37082.pdf

LEED for Existing Buildings. 2008. US Green Building Council. http://www.usgbc.org/DisplayPage.aspx?CMSPageID=221

Liggett, Howard. "Green Building RetroFitting Makes Good Dollar Sense." Gerson Lehrman Group. February 12, 2008. http://www.glgroup.com/News/Green-Building-RetroFitting-Makes-Good-Dollar-Sense-21697.html

Makower, Joel. "Three Ways to Green Up Your Office on the Cheap." Scientific American. March 18, 2009. http://www.scientificamerican.com/article.cfm?id=three-ways-to-green-up-yo

Martin, Greg L. "Coming Up Green: Energy-Saving Retrofitting Options Provide Financial Returns." All Business. November 1, 2008. Journal of Property Management. http://www.allbusiness.com/construction/building-fixtures-mechanical-systems-hvac/11715472-1.html

NK. "Green building 101: sustainable Sites." Inhabitat. July 5, 2006. http://www.inhabitat.com/2006/07/05/green-building-101-sustainable-sites/

"Passive Solar Building Design." U.S. Department of Energy: Electricity Delivery & Energy Reliability. May 17, 2006. http://www.eere.energy.gov/de/passive_solar_design.html

Rich, Sarah. "Green building 101: Water Efficiency." Inhabitat. July 12, 2006. http://www.inhabitat.com/2006/07/12/green-building-101-water-efficiency/

"Small Wind: Frequently Asked Questions." AWEA. 2009. American Wind Energy Association. http://www.awea.org/smallwind/faq_buying.html#Howmuchdoesawindsystemcost