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AIA

50»50

version 1 2007

Introduction

Welcome to the 50to50, a how-to resource intended to assist architects and the construction industry in moving toward the AIA's public goal of a minimum 50 percent reduction of fossil fuel consumption in buildings by 2010 and carbon neutrality by 2030.

The AIA has been committed to sustainability as an important component of quality design for more than 30 years. The Institute understands that sustainability means much more than energy conservation alone and has maintained a strong commitment to sustainability in the broadest sense of the term. Growing evidence of global climate change as the result of increased production of greenhouse gases has necessitated some new priorities. The AIA recognizes that buildings are responsible for approximately 48 percent of energy consumption in the United States. Ongoing operation and maintenance of buildings account for approximately 76 percent of U.S. electrical use. With these facts alone, it isn't hard to establish buildings as one of the primary sources of the greenhouse gases contributing to global warming and climate change. This realization has established carbon reduction as the top priority of the Institute's SustAIAnability2030 initiative.

The 50to50 is a product of the Institute's Sustainability Discussion Group (SDiG), a task group of the AIA Board of Directors that was formed early in 2007 to seek action on the critical, focused, measurable, and achievable priority of carbon reduction. The SDiG is made up of volunteer AIA members with various areas of expertise, members of the Institute's Board of Directors, and national staff charged to facilitate development of tools that support the AIA's carbon-reduction objectives.

The 50 strategies, detailed in the pages that follow, have been selected to provide readily available and effective tools and techniques that will have an effective and immediate impact on architects' ability to achieve significant carbon reduction. The strategies span a spectrum from broad-based site and planning objectives to specific, building-based concepts. Each strategy includes an overview of the subject, typical applications, emerging trends, links to information sources, and important relationships to other carbon reduction strategies. In alignment with the charge of the SDiG, the strategies focus on carbon reduction as the primary goal and are not intended to provide all of the tools needed for a comprehensive approach to sustainability. These 50 strategies are, however, extensively interrelated, mutually supportive, and integral to any definition of sustainability. It should also be evident that these 50 strategies will be as effective in achieving the AIA's ultimate goal of carbon neutrality as they are in reaching toward the first 50 percent reduction objective.

The strategies are listed in alphabetical order with no prioritization of any particular strategy over another. This sequencing does not mean that all of the strategies are the same in terms of

effectiveness, applicability, or availability. Rather, it is expected that each user of the list will approach it with his or her own sense of priorities and applicability and will work through the contents accordingly.

The carbon-reduction focused sustainability concepts outlined in the 50to50 must be seen as important contributors to successful high performance buildings. This is a "living" resource that will continue to grow and evolve as more is known about the strategies developed here and as new strategies are identified. With time, the list is likely to be further categorized into subgroups, refined to accommodate regional differences, and prioritized and organized by effectiveness, availability, cost parameters, and other subthemes. The AIA will work to integrate the 50to50 as a key component of integrated project delivery models—more holistic approaches to high performance building design, construction, operation, and maintenance.

The 50to50 is waiting for your investigation, exploration, and input. This tool will expand your understanding of many sustainability concepts and will introduce you to some new ideas. While you are working with the 50to50, you also might want to take advantage of other SDiG products such as the SustAIAnability2030 Toolkit, the SustAIAnability2030 Green Meetings Guidelines, the SustAIAnability2030 Road Show, and an evaluation of three leading rating systems—all available from the AIA Sustainability Resource Center. We are confident that you will find all of these tools to be challenging, interesting, and informative, and will help you decide:

How will you walk the walk?

Walk the Walk
Architects Leading the Sustainable Evolution™

The AIA Sustainability Discussion Group 2007

contents

1 Active Solar Thermal Systems

What are Active Solar Thermal Systems?

Solar collectors

Active solar thermal systems use solar collectors to collect the sun's energy to heat water, another fluid, or air. The heart of a solar collector is an absorber that converts the sun's energy into heat. The heat is then transferred by circulating water, antifreeze, or sometimes air to another location for immediate use or storage for later use. Applications for active solar thermal energy include providing hot water, heating swimming pools, space heating, and preheating air in both residential and commercial buildings.

A standard solar hot water system is typically composed of solar collectors, a heat storage vessel, piping, circulators, and controls. Solar radiation is absorbed by the collector, and the heat collected is commonly used to heat or preheat water or air. Systems are typically integrated to work alongside a conventional heating system that provides heat when solar resources are not sufficient. The solar collectors are usually placed on the roof of the building, oriented south, and tilted around the site's latitude, so as to maximize the amount of radiation collected on a yearly basis.

Although there are several options for using active solar thermal systems for space heating, the most common method involves using glazed collectors to heat a liquid held in a storage tank (similar to an active solar hot water system). Heat from the tank is transferred to radiators, a radiant floor heating system, or through a heating coil in a forced-air system.

Solar-heated water can also be used to preheat outdoor air drawn into a building. Other techniques directly preheat fresh air with solar air collectors. This is used more in commercial buildings and industrial applications. Whereas some solar air collectors are quite sophisticated, one simple system of this type uses a darkly colored, perforated aluminum sheet mounted on a south-facing wall. As the sun heats the sheet, a fan draws

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- By reducing the overall energy use, various building systems (i.e., HVAC) can be reduced in size and cost to make way for further energy-saving materials, designs, and technologies.

Specify energy-efficient equipment and technologies.
- Use an integrated system approach to spec out the most cost-effective, energy-efficient equipment and technologies that can include active solar thermal systems.

Use renewable strategies and purchase green power.
- Use present solar income as a part of a whole-house design strategy.
- Use active solar thermal systems to decrease energy loads and offset emissions of conventional, built energy systems.

Educate building owners, operators, and occupants.
- Provide information on function and operations of installed technology.

outdoor air through the perforations and warms the air. This preheating can significantly reduce energy use by conventional heaters to bring fresh air up to room temperature.

How do I apply Active Solar Thermal Systems?

To determine the financial feasibility of an active solar system, conduct a life-cycle cost analysis of at least a 10-year projected life of the system. The life-cycle analysis can determine what the upfront and operational costs and expected energy savings of an active solar system would be compared with conventional systems. Determine whether the climate and building usage is appropriate for an active solar system. The energy savings for active solar thermal systems depend on the amount of available solar radiation, projected uses of the system, and proper system design.

The results of this analysis can determine the financial feasibility of investment in an active solar system.

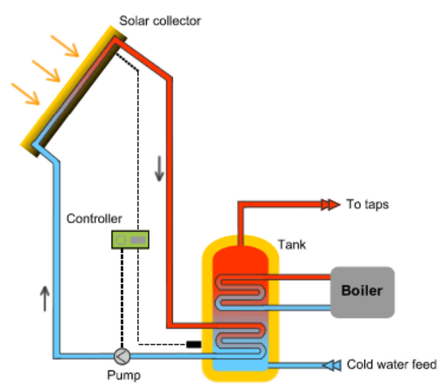
An active solar collection system can provide the following benefits:

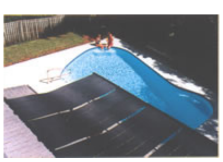
- Offsetting the heating energy from conventional systems over the life of the building and/or the life of the system
- Hot water energy savings given that the demand for hot water is fairly constant throughout the year
- A cost-effective way to extend the yearly use of your pool
- Overall reduction of fossil fuel use and emission of ozone-depleting gases

ESTABLISHED TECHNIQUES

Solar Service Water

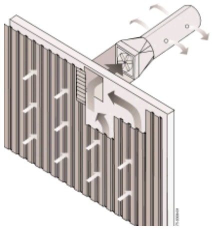
Solar service water systems are often used in residential applications to heat water for basic household needs, such as laundry, bathing, dishwashing, and cooking. In larger buildings, such systems can be especially cost effective where there are large, year-round hot water loads (e.g., laundromats, restaurants, hospitals, car washes, etc.). Hot water systems typically use solar energy to preheat incoming water from wells or water mains. If solar energy is not sufficient to heat the water to the desired temperatures, a conventional water heater is used to make up the difference. The warmer the water from the solar heater, the less conventional fuel will be needed.





Pool Heating

Simple solar pool heaters work by circulating pool water directly through collectors and then rerouting the heated water to the pool. System controllers sense when collectors are warmer than the pool water and open valves to divert water from the pool circulator through the collectors and then back into the pool. Collectors for these simple pool heating systems are generally unglazed and quite inexpensive. The systems are not freeze-proof, so they are used in mild climates or during summer months when there is little chance for freezing. Heating indoor pools in colder climates is also an excellent use of solar energy, but these systems require more expensive collectors and rigorous freeze protection.



Transpired collector components (NREL)

Ventilation Preheat

In a typical ventilation solar preheat system, fresh air is drawn across a heat absorbing south-facing wall or other form of solar collector. The preheated air is drawn into a building's primary heating system where it is further heated, then distributed throughout the building. A solar air heating system augments a conventional heating system rather than replaces it because the system is primarily used to preheat ventilation air for commercial and industrial facilities, such as factories, warehouses, and hangars. Because the air going into the building's primary heating system is already warmer than the outside air, less energy is needed to heat it further.

Space Heating

The chosen solar heating system needs to be compatible and interactive with conventional HVAC systems in the building. Heat-delivery methods that require lower fluid temperatures, such as radiant floor heating or some forced-air heating systems, can often take more advantage of solar heat than high-temperature devices (such as many radiators or convectors). Designers should also be very sensitive to the control of solar heating systems. Solar energy should be used whenever available, but backup heating should be integrated seamlessly to optimize efficiency and comfort.

EMERGING TRENDS

The ever-increasing worldwide demand for energy and the increasing understanding of the link between fossil fuels and the global environment will continue to drive active solar thermal system technology as a viable and important tool in whole-building system design. Increased use of active solar thermal systems is occurring in the United States, the European Union, Japan, and China. In the United States, many states now offer sales tax exemptions, income tax credits or deductions, and property tax exemptions or deductions for active solar thermal systems.

Nevada Solar-One

The use of active solar thermal systems to convert heat to electricity is also growing. One such project taking place in the United States is using solar receivers to convert energy from the sun into electricity by using concentrated solar radiation from parabolic mirrors. The temperature of an oil fluid flowing through receivers is thereby heated to over 750° F. This heated fluid is then used to turn water into steam, which drives a turbine and generates electricity. Once this project is completed, it is estimated that it will result in a reduction of greenhouse gases equivalent to removing approximately 1 million cars from the nation's highways.

What are relevant resources for **Active Solar Thermal Systems?**

- American Solar Energy Society, Inc.: www.ases.org
- Energy Efficiency and Renewable Energy Clearinghouse (EREC): www.eren.doe.gov/consumerinfo
- Florida Solar Energy Center: www.fsec.ucf.edu
- The Radiant Panel Association: www.rpa-info.com
- Solar Energy Industries Association: www.seia.org
- Solar Rating and Certification Corporation (SRCC): srcc@fsec.ucf.edu
- Energy Efficiency and Renewable Energy Clearinghouse (EREC): doe.erec@nciinc.com
- FindSolar.com: www.findsolar.com

Which strategies interact with **Active Solar Thermal Systems?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Photovoltaics
» Building Orientation
» Life Cycle Assessment
» Daylighting
» Renewable Energy Resources
» Sun Shading

What is Alternative Energy?

Alternative energy is defined as energy derived from natural sources that does not use up those sources and that has minimal environmental impact. Alternative energy includes geothermal, wind power, hydropower, and wave action generation.

Alternative Energies

Geothermal: Geothermal comes from the Greek words *geo*, meaning earth, and *therme*, meaning heat. The center of the earth is believed to be approximately 5,500° C (almost as hot as the surface of the sun); only a couple of miles below earth's surface, temperatures can be over 200° C. Geothermal power is energy generated by tapping the heat stored beneath the earth's surface.

Wind power: Wind power is the fastest growing global alternative energy source. Currently, in the United States and the European Union (EU), it is the second source of new power generation after natural gas. Although wind power provides less than 1 percent of the electricity in the United States today, it is growing rapidly, with production around 13 megawatts (MW)—enough to power over 3.4 million homes—and currently reducing carbon dioxide emissions by 19 million tons annually.

Hydropower: Hydropower presently supplies approximately 19 percent of the world's electricity needs (more than 700,000 MW). This energy source can be far less expensive than electricity generated from nuclear or fossil fuel sources while producing no harmful emissions. However, hydropower is not slated for much future expansion because most suitable sites in the United States either have been developed or are unavailable for development.

Wave Action Generation: Wave action generation, also referred to as wave or tidal generation, uses the energy of the ocean tides/waves to generate electricity. Currently, this type of power

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Reducing the overall energy use of a building will put less demand on conventional and/or alternative power plants providing the energy.

Specify energy-efficient equipment and technologies
- Using energy-efficient equipment and technologies as part of the overall building design process will further decrease the load the local power plant must provide while reducing overall emissions.

Use renewable strategies and purchase green power
- Use of electricity sourced from alternative sources or the purchase of green power can reduce a building's overall carbon and emission footprint.

Educate building owners, operators, and occupants
- On where their sourced power comes from and its implications.

generation technology is not widely used. Although Portugal has announced plans to have the world's first commercial wave farm, the technology is being researched and tested globally.

How do I apply **Alternative Energy?**

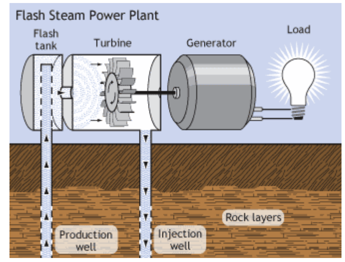
Geothermal: Today, three geothermal power plant technologies are being used to convert hydrothermal fluids (steam or water) to electricity: *flash*, *dry steam*, and *binary cycle*. The type of conversion used depends on the state of the fluid and its temperature. Temperatures are classified as low (less than 90° C or 194° F), moderate (194–302° F), or high (greater than 302° F).

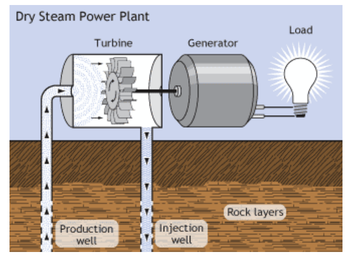
Flash steam plants are the most common type of geothermal power generation plants in operation today because most reservoirs are hot water reservoirs and use water at temperatures greater than 360° F that is pumped under high pressure to the generation equipment at the surface. Dry steam power plants systems were the first type of geothermal power generation plants built. They use steam from the geothermal reservoir as it comes from wells and route it directly through turbine/generator units to produce electricity. Binary-cycle geothermal power generation plants differ from dry steam and flash steam systems in that they use a heat exchanger. Heat is transferred from the geothermal water to a secondary liquid that never comes in contact with the turbine/generator units. The geothermal water is then injected back into the underground reservoir.

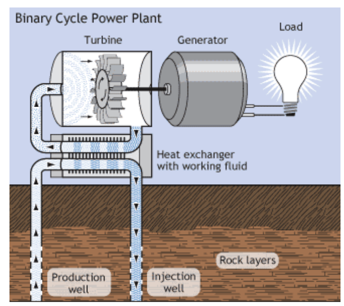
Wind power: In the past 15 years, the cost of wind energy has more than halved, and its production per unit of capacity has more than doubled. A single modern wind turbine produces, on an annual basis, approximately 180 times more electricity at less than half the cost per kilowatt-hour than its equivalent did 20 years ago. Wind turbines are rated by their maximum power output in kilowatts (kW) or megawatts (1,000 kW, or MW). For commercial utility-sized projects, the most common turbines sold are in the range of 600 kW to 1 MW (large enough to supply electricity to 600–1,000 modern homes), while the newest commercial turbines are rated at 1.5–2.5 MW. The power that can be generated from a modern wind turbine is related to the cube of the wind speed. This means that a site with twice the wind speed of another site will generate eight times as much energy. Currently, in the United States, 46 states offer wind resources suitable for commercial development.

Hydropower: Hydropower plants use the energy of falling water to generate electricity. The water falls on turbines, which in turn spin a generator that produces electricity. The farther the water falls and the more water falling through the turbines, the more power is generated. In addition, the greater the flow of water down a river at a hydropower site, the greater the energy the plant can produce. Today, in the United States, hydropower capacity is roughly 95,000 MW and supplies approximately 28 million households with electricity—the equivalent of nearly 500 million barrels of oil.

Wave Action Generation: The amount of energy that can be tapped from waves depends on the wind speed, the time the wind is moving over the waves, and the distance it covers. As this process continues, the energy is concentrated more and more, and the wave can produce over 100 kW of power per meter of wave front. The two main types of technology that tap the energy of the waves are sitters and floaters. Given proper care in siting, installation, and operation, wave action generation may be one of the more environmentally friendly electricity generation technologies.







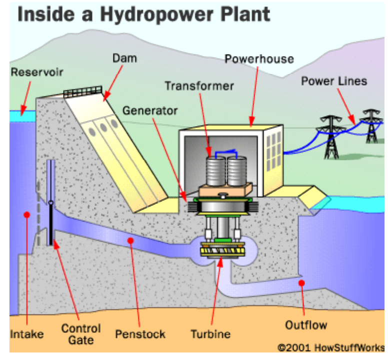
ESTABLISHED TECHNIQUES

Geothermal

- Flash Steam Power Plants—Hydrothermal fluids above 360° F are sprayed into a tank held at a much lower pressure than the fluid, causing some of the fluid to rapidly vaporize, or “flash.” The vapor then drives a turbine, which drives a generator to create electricity. If any liquid remains in the tank, it can be flashed again in a second tank to extract even more energy. In flash plants, both the unused geothermal water and condensed steam are injected back into the reservoir to sustain the life of the reservoir.
- Dry Steam Power Plants—This is the oldest type of geothermal power plant. It uses hydrothermal fluids that are primarily steam. The steam goes directly to a turbine, which drives a generator that produces electricity. The steam eliminates not only the need to burn fossil fuels to run the turbine but also the need to transport and store fuels. Steam technology is used today at The Geysers in northern California, the world’s largest single source of geothermal power. These plants emit only excess steam and very minor amounts of gases.
- Binary-Cycle Power Plants—Most geothermal zones contain water temperatures below 400° F (moderate temperature). Hot geothermal fluid and a secondary (“binary”) fluid with a much lower boiling point than water pass through a heat exchanger. Heat from the geothermal fluid causes the secondary fluid to flash to vapor, which then drives the turbines. Binary technology allows the use of lower temperature reservoirs, thus increasing the number of reservoirs that can be used. Because this is a closed-loop system, virtually nothing is emitted to the atmosphere. Because the most common geothermal zones contain moderate-temperature water, most geothermal power plants in the future will likely be binary-cycle plants.

Wind

Commercial-scale wind power is generated at a wind farm. A wind farm consists of a number of wind turbines in and around a set location. Individual wind turbines are interconnected with a voltage of around 34,500 volts and then stepped up to a higher voltage to integrate into the grid system. The overall production of electricity at a wind farm depends on prevailing wind patterns, the siting of the turbines, and overall power capacity of the wind turbines. Knowing that wind does not blow all the time in all locations, the EU has proposed to interconnect wind farms across Europe, the idea being that EU countries would benefit from a system that captures wind energy anywhere wind is blowing at various EU wind farms. This way, European countries tied to the system could still reap the rewards of wind power electricity generation even if their particular country is not currently producing wind energy. In the United States, many new wind farms are appearing on existing farmland. Power can be produced from these wind farms without hindering the ability of the land to produce crops for food.



Hydropower

A hydropower plant uses the force of falling water to make electricity and consists of three main systems: a *dam* that can be opened or closed to control water flow; a *reservoir* (lake) where water can be stored; and an *electric plant* where the electricity is produced. The amount of electricity that can be generated at a hydropower plant is determined by two factors: head and flow. Head is the distance from the highest level of the dammed water to the point where it goes through the power-producing turbine (how far the water drops). Flow is how much water moves through the system. The more water moving through a system, the higher the flow. One of the biggest advantages of a hydropower plant is its ability to store energy. Water can be stored in a reservoir and released when needed for electricity production. During the day, when people use more electricity, water can flow through a plant to generate electricity, while at night, when less electricity is demanded, water can be held back in the reservoir. Storage also makes it possible to save water from winter rains for summer generating power or to save water from wet years for generating electricity during dry years.

Wave Action Generation

A numbers of companies have devised systems capable of generating power with the waves and tides of oceans and rivers. Because water is more than 800 times denser than air at sea level, slow-moving waves or tides have the potential to generate far more electricity than wind turbines, even if the wind blew at 100 miles per hour. Ocean power also remains far more predictable than other alternative energy sources because waves can be tracked from far offshore, allowing computer models to predict electrical output several days in advance. Tidal power is also predictable because tides are dependent on the gravitational pull of the moon. Currently, potential sites around the world are being investigated for commercial application of this technology.

A few applications of wave action generation going on today are listed below:

- Finavera Renewables and AWS Ocean Energy have created wave power systems that rely on buoys that act as hydraulic pumps. Waves push the buoys down, which drives a turbine. When the wave passes, the buoy returns to its normal spot, only to be pushed again by the next wave.
- Ocean Power Delivery is testing the Pelamis, a device (395 feet long) that looks like a segmented snake. When the segments bob up and down, buoys attached at their joints generate hydraulic pressure. The company has built a 2.25-MW system off Portugal consisting of three 750-kW Pelamis wave-energy converters and is aiming to build 5-MW and 3-MW systems off

the coasts of England and Scotland in the next few years.

- Wavegen, a division of Voith Siemens Hydro Power Generation, is experimenting with the Limpet (a large cement tube submerged in the ocean, but not attached to the bottom). Water rushes into the tube from waves and cranks a turbine. The company is installing a Limpet in Mutriku, Spain, that will produce 250 to 300 kW when opened in late 2008/09. Wavegen has had a prototype running off Scotland since 2000.

EMERGING TRENDS

Geothermal

Currently, in more than 20 countries worldwide, electric power plants driven by geothermal energy provide more than 44 billion kilowatt-hours of electricity per year, with world capacity growing at approximately 9 percent per year. In the United States, a recent, comprehensive study of the potential for geothermal energy within the country found that mining the huge amounts of heat that reside as stored thermal energy in the earth's hard rock crust could supply a substantial portion of the electricity the United States will need in the future, probably at competitive prices and with minimal environmental impact. An 18-member panel led by the Massachusetts Institute of Technology prepared the 400+ page study, *The Future of Geothermal Energy*. Sponsored by the U.S. Department of Energy, it is the first study in 30 years to take a new look at geothermal, an energy resource that has been largely ignored.

The goal of the study was to assess the feasibility, potential environmental impacts, and economic viability of using enhanced geothermal system (EGS) technology to greatly increase the fraction of the U.S. geothermal resource that could be recovered commercially. Although geothermal energy is produced commercially today and the United States is the world's biggest producer, existing U.S. plants have focused on the high-grade geothermal systems primarily located in isolated regions of the West. This new study takes a more ambitious look at this resource and evaluates its potential for much larger scale deployment. The study suggests that 100,000 MW of electrical generation capacity can be met through EGS within 50 years with a modest investment in research and development (R&D) and recommends the following: More detailed and site-specific assessments of the U.S. geothermal energy resource should be conducted; field trials running three to five years at several sites should be done to demonstrate commercial-scale engineered geothermal systems; the shallow, extra-hot, high-grade deposits in the West should be explored and tested first; other geothermal resources such as coproduced hot water associated with oil and gas production and geopressured resources should also be pursued as short-term options; on a longer time scale, deeper, lower grade geothermal deposits should be explored and tested; local and national policies should be enacted that encourage geothermal development; and a multiyear research program exploring subsurface science and geothermal drilling and energy conversion should be started, backed by constant analysis of results.

Wind

According to the U.S. Department of Energy (DOE), good wind areas, which cover 6 percent of the contiguous U.S. land area, have the potential to supply more than one and a half times the *current electricity consumption* of the United States. Estimates of the wind resource are expressed in wind power classes ranging from class 1 to class 7, with each class representing a range of mean wind power density or equivalent mean speed at specified heights above the ground. Areas designated class 4 or greater are suitable with advanced wind turbine technology under development today. Class 3 areas may be suitable for future technology. Class 2 areas are marginal, and class 1 areas are unsuitable for wind energy development.

Although transmission availability, siting and permitting conflicts, and other barriers remain, the American Wind Energy Association (AWEA) expects continued strong growth in wind power capacity. With backing from industry and government, new efforts to explore ambitious long-term targets for wind power are underway. A joint DOE–AWEA report (due for completion this year) will explore the possible costs, benefits, challenges, and policy needs of meeting 20 percent of the nation's electricity supply with wind power. In the European Union today, wind power is saving over 50 million tons of carbon dioxide a year, and wind power installations are on track to deliver one-third of the EU's Kyoto Treaty commitment by 2010.

Hydropower

Although most potential large-scale projects have been in the developed nations, large potential is estimated in such regions as Africa, Asia, and South America, where several countries have hydropower facilities either planned or under construction. Asia and India have about 12,020 MW of hydroelectric capacity under construction. China also has a number of large-scale hydroelectric projects under construction, including the 18,200-MW Three Gorges Dam project (expected to be fully operational by 2009) and the 12,600-MW Xiluodu project on the Jisha River (scheduled for completion in 2020, as part of a 14-facility hydropower development plan). Brazil has plans for a number of new hydropower projects that the country hopes to complete to keep up with electricity demand after 2010, including the 3,150-MW Santo Antonio and 3,300-MW Jirau projects on the Madeira River.

Wave Action Generation

This is still a new technology, as wave power was delivered to the electrical grid for the first time in August 2004. The electricity was generated by a full-scale preproduction Pelamis prototype in Orkney, Scotland, by Ocean Power Delivery Corporation. Presently, in Europe, an array of tidal turbines are being built and tested at various locations. Both wave and tidal energy devices will soon begin tests at the new European Marine Energy Centre (the largest facility of its kind in the world), located in the Orkneys Islands north of Scotland. The Scottish government has pledged that the country will generate 18 percent of its power from renewable resources by 2010. Currently, research and testing are also taking place in the United States, with several wave action generation sites currently under investigation. In New York City, Verdant Power is installing six 36-kW tidal turbines in the East River, with the installation of the first two turbines to be completed by the end of this year. The six tidal turbines will power a shopping center and parking garage on Roosevelt Island, which is located between the boroughs of Queens and Manhattan. In addition, the city of Tacoma, Washington, is investigating the tidal energy potential of the Tacoma Narrows of Puget Sound. These low-impact tidal current turbines, which resemble underwater versions of wind turbines, are still going through R&D and are mostly in the experimental stage, borrowing largely from concepts learned from wind energy technology.

Fuel Cells

Fuel cells are electrochemical devices that combine hydrogen and oxygen to produce electricity, with water and heat as the by-product. As long as fuel is supplied, the fuel cell will continue to generate power. Because the conversion of the fuel to energy takes place via an electrochemical process, not combustion, the process is clean, quiet, and highly efficient—two to three times more efficient than burning fuel. In addition to low or zero emissions, benefits include high efficiency and reliability, multifuel capability, siting flexibility, durability, scalability, and ease of maintenance. Fuel cells operate silently, so they reduce noise pollution as well as air pollution, and the waste heat from a fuel cell can be used to provide hot water or space heating for a home or office. Fuel cell systems have been installed all over the world in buildings and utility power plants, either connected to the electric grid to provide supplemental power and backup assurance for critical areas, or installed as a grid-independent generator for onsite service in areas that are inaccessible by power lines. Fuel cell power generation systems in operation today achieve 40 percent fuel-to-electricity efficiency using hydrocarbon fuels. When the fuel cell is sited near the point of use, its waste heat can be captured for beneficial purposes (cogeneration). In large-scale building systems, fuel cell cogeneration systems can reduce facility energy service costs by 20 to 40 percent over conventional energy service and increase efficiency to 85 percent.

What are relevant resources for **Alternative Energy?**

Geothermal

- U.S. Department of Energy (DOE): www1.eere.energy.gov/geothermal/overview.html
- Geothermal Resource Council: www.geothermal.org/
- Geothermal Energy Association: www.geo-energy.org/
- 2006 MIT Research Report—"The Future of Geothermal Energy": geothermal.inel.gov/publications/future_of_geothermal_energy.pdf

Wind

- American Wind Association: www.awea.org/
- Wind Energy Works: www.windenergyworks.org/
- North American Wind Farms: www.windpowr.info/

Hydropower

- International Hydropower Association: www.hydropower.org/
- National Hydropower Association: www.hydro.org/
- The International Journal on Hydropower and Dams: www.hydropower-dams.com/

Wave Action Generation

- The Renewable Energy Centre: www.therenewableenergycentre.co.uk/wave-and-tidal-power/
- British Wind Energy Association (BWEA): www.bwea.com/marine/resource.html

- Inform Web site (Ocean and Tidal Power Generation news): www.inform.com/Ocean+and+Tidal+Power+Generation

Which strategies interact with **Alternative Energy?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Orientation
» Daylighting
» Life Cycle Assessment
» Passive Solar Collection Opportunities
» Renewable Energy Resources
» Sun Shading

What is **Alternative Transportation?**

Curbing use of the automobile fights suburban sprawl, obesity, and increasingly high medical costs. Alternative transportation choices mean less congestion, reduced pollution, and fewer auto crash deaths and life-changing injuries. There is a wide range of alternative transportation modes to consider to reduce fuel consumption and support reduced carbon emissions. Among them are:

- **Bicycles: a great, sustainable alternative to the automobile for individuals and businesses.**
- **Car Sharing: a system in which a fleet of vehicles is owned and operated by an organization or individual and is made available for use by members of the car-share group.**
- **Electric Vehicle: a vehicle with one or more electric motors for propulsion, although care must be taken to ensure that the source of the electricity is renewable.**
- **Flexible Fuel Vehicle: an automobile that can typically alternate between two sources of fuel, such as gasoline mixed with varying levels of bioethanol (gasohol).**
- **Hybrid Vehicle: a vehicle using an on-board rechargeable energy storage system (RESS) and a fueled power source for vehicle propulsion. Hybrids pollute less and use less fuel.**
- **Hypercar: an automobile applying whole-system design concepts. The hypercar's defining features are ultralight construction, low-drag design, hybrid-electric drive, and minimized accessory loads.**
- **Light Electric Vehicles: vehicles ranging in size from electric scooters small enough to fit under a bus seat to one-person cars capable of driving on freeway high-occupancy vehicle (HOV) lanes.**

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- Not applicable

Specify energy-efficient equipment and technologies.
- Not applicable

Use renewable strategies and purchase green power.
- Not applicable

Educate building owners, operators, and occupants
- Educate building owners, operators, and occupants about the value of alternative transportation and its relation to reduced energy use.
- Support the use of alternative forms of transportation within your office.
- Educate your employees about the various alternative transportation options.

- **Motorized Bicycle**: a bicycle with an attached motor used to assist with pedaling.
- **Paratransit**: an alternative mode of flexible passenger transportation that does not follow fixed routes or schedules.
- **Plug-in Hybrid Electric Vehicle (PHEV)**: a hybrid that has additional battery capacity and the ability to be recharged from an external electrical outlet.
- **Public Transportation**: all transport systems in which passengers do not travel in their own vehicles.
- **Ridesharing/Dynamic Ridesharing**: a system of sharing an automobile ride with someone within and between towns and cities. Numerous Internet sites now make the process convenient. Dynamic ridesharing combines a high-tech instant rideshare request system with incentives for drivers to invite passengers into otherwise single-occupant vehicles. It is also known as online/instant/real-time ridesharing/ridematching or casual carpooling.
- **Zero-Emissions Vehicle (ZEV)**: a vehicle that produces no emissions or pollution when stationary or operating.

How do I apply Alternative Transportation?

In the planning stages of any new project, site selection should include criteria for making accommodations for alternative forms of transportation. Select a site that is located near public transportation or encourages walking and other forms of alternative transportation. Design features into the project to support the use of alternative forms of transportation, such as bike racks, showers, or electric charging or refueling stations for vehicles. Conduct a transportation needs survey among potential clients or building occupants to create an integrated set of strategies that will accommodate a wide range of needs. Consider the sharing of resources such as parking facilities to reduce the need for additional structures.

Identify strategies that reduce pollution and land-use development impacts from automobile use, such as

- Transit-oriented development
- Walkable streets
- Compact and/or mixed-use development
- Bicycle networks, among others

Strategies to implement that support the list above include

- Alternative transportation, including public transportation access
- Bicycle storage and changing facilities
- Alternative fuel vehicles
- Reduced parking capacity
- Priority parking spaces for identified vehicles
- Car-charging stations
- Car-sharing programs

In addition, consider incorporating forms of alternative transportation into your own practice and way of life, including

- Site your office near public transportation or where most employees live.
- Ride a bicycle or walk to work and, whenever possible, build these activities into your daily routine.
- Take public transportation whenever possible.
- Promote the use of alternative transportation modes through educational seminars, incentives, and financial contributions.
- Join a car pool. If your company does not coordinate car pooling, consider establishing it or coordinating it yourself. If possible, coordinate car pooling with nearby businesses.
- Determine whether car sharing will work for you and your employees.
- Consider the viability of telecommuting for employees.
- Promote the use of videoconferencing to reduce the costs and impacts of travel.

EMERGING TRENDS

Numerous policies are being enacted that support the reduction of fuel and improved fuel economy in vehicles. Stringent standards for air quality such as those adopted in California oblige automakers to reduce their global-warming emissions by 30 percent, starting in 2009 and culminating in 2016. Major automakers have agreed to voluntarily reduce the global-warming emissions of cars and light trucks sold in Canada by 5.3 million metric tons, or about 25 percent, by the end of 2010. It could force automakers to adopt similar stringent emissions rules for vehicles sold throughout the United States.

The technology also exists to cost-effectively reduce emissions of smog-forming pollutants and global-warming gases. Future regulations will require all passenger vehicles to meet the same smog-forming emissions standards by 2009, but there are no significant engineering barriers to accomplishing this sooner. Several recent studies have demonstrated that off-the-shelf technologies can reduce global-warming pollution from both cars and trucks while saving consumers money at the pump. Incorporating these technologies into automakers' product plans will yield much needed improvements in public health and environmental quality.

The Sustainable Transportation Movement has been growing since the 1980s. Sustainable transportation is used to describe all forms of transport that minimize emissions of carbon dioxide and pollutants. It can refer to public transport, car sharing, walking, and cycling, as well as technology such as electric and hybrid cars and biodiesel. The movement shifts the emphasis in public spending and actions away from building and supply to management and demand. The movement also focuses on the values of heightened respect for the environment and prudent use of natural resources.

Transit-Oriented Development, which supports a residential or commercial area that is designed to maximize access to public transport and often incorporates features to encourage transit ridership, is also growing as a movement.

What are relevant resources for **Alternative Transportation?**

- American Council for an Energy Efficient Economy: www.greenercars.com—ratings comparison of vehicle environmental performance
- Clean Fleet Guide: tools to help company fleets make "green" vehicle and fuel decisions
- Federal Transit Administration: www.fta.gov—locate information on transportation planning and transit-related development
- LEED for New Construction: www.usgbc.org/DisplayPage.aspx?CMSPageID=220
- MIT Intelligent Transportation Research Center: www.mtl.mit.edu/mtlhome/6Res/ITRC/itrc.html
- NESEA's greener vehicles on the market: www.nesea.org/transportation/evs.html
- Rail Volution: www.railvolution.com/—creating communities with transit
- U.S. Department of Energy Clean Cities—Alternative Fuel Vehicles: www.ccities.doe.gov/afvinfo.shtml
- U.S. Environmental Protection Agency Fuel Economy Web site: www.fueleconomy.gov

Which strategies interact with **Alternative Transportation?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Alternative Energy
» Carbon Offsets
» Walkable Communities

4 Appropriate Size and Growth

What is Appropriate Size and Growth?

The recent period of building boom and rapid urbanization has prompted heated use of code words such as "high density," "overdevelopment," and new development with buildings that "overwhelm surrounding older communities." Discussion of appropriate size and growth must include the planning issues regarding urban sprawl and the smart growth movement, as well as the programming of appropriately sized individual buildings. Buildings might change over time as their ownership and neighborhood context change. Design spaces and services to support new functions and reuse for easy and rapid spatial change.

In *Growing Cooler: The Evidence on Urban Development and Climate Change*, a forthcoming book published by the Urban Land Institute, a team of leading urban planning researchers reports that the key to mitigating climate change is less automobile-dependent development and that key changes in land-development patterns could help reduce vehicle greenhouse gas emissions.

How do I design for Appropriate Size and Growth?

Design buildings for flexibility and future growth and change. Buildings should

- **Be designed with right-sized spaces based on current and projected future needs**
- **Be flexible to accommodate changes to functional spaces within the building**

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

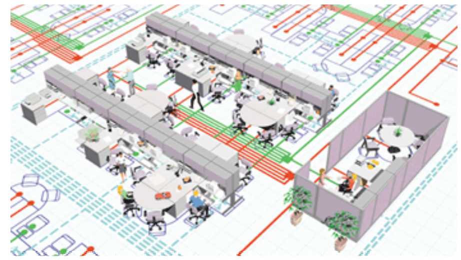
Reduce the overall energy use in your building.
- Appropriate building siting and sizing can help reduce the overall energy use.
- Building size and systems can be reduced to make money available for further energy-saving materials, designs, and technologies.
- Design for flexibility for adaptation to future changes and technologies

Specify energy-efficient equipment and technologies.
- Use low-impact development strategies to reduce green land destruction.
- Specify energy-efficient equipment to promote flexibility.

Use renewable strategies and purchase green power.
- Not applicable

Educate building owners, operators, and occupants.
- Education them on functional and energy-saving advantages of appropriate siting and sizing strategies.

– Be able to adapt to new functions and business methodologies not presently envisioned (Remember when there were no computers?)
– Accommodate future site changes that result from functional space changes
– Address new business technologies and changes to business practice
– Include built-in extra structural, mechanical, and electrical capacity in building element design to handle the addition of future equipment and infrastructure needs
– Be designed with fire protection capacity to accommodate future growth
– Optimize utilization of space while providing adequate circulation paths for future personnel, materials, and equipment
– Relate interior and exterior functions to facilitate the flow of people and goods through the building
– Be able to be recycled into new functions; for example, 19th century industrial buildings can become modern mixed-use and residential buildings with loft-type dwelling units, which can revitalize entire neighborhoods in the process



Architects are challenged to balance conflicting objectives in designing a commercial office building, such as
– Allowance for future growth of personnel and electronic concentration, resulting in greater electrical and cooling loads and space for empty conduits and duct runs
– Spatial and infrastructure requirements for undetermined future technologies
– Owner/developer financial goal to maximize rental floor area and fill the allowable zoning envelope
– Resistance to use of more compact open office layouts for executive and upper/middle management staff
– Need for acoustical comfort and conversational privacy in the open office environment
– Need for visual and speech communication in the open office environment

Integrate new public and commercial buildings into the existing urban fabric by use of pedestrian-friendly scale and street façades. Reclaim former industrial waterfront and brownfield sites to create appropriately scaled redevelopment that unites with and revitalizes surrounding communities. Urban infill and brownfield development can reuse available embedded energy in existing transportation and utility infrastructure, thus reducing the energy needed to build new roads, utility plants, and utility lines, while also preserving green space.

Residential planning and programming encompass smaller buildings than commercial projects, but the process is complicated by the many functions occurring in a relatively small space. In addition, the designer must plan for growth and change inherently embedded into family life as adults and children grow older and their needs change.

ESTABLISHED TECHNIQUES

The Smart Growth Network advances the following principles on compact building design:

- Smart growth provides a means for communities to incorporate more compact building design as an alternative to conventional land-consumptive development.
  Compact building design suggests that communities be designed in a way that permits more open space to be preserved, and that buildings can be constructed to make more efficient use of land and resources. By encouraging buildings to grow vertically rather than horizontally, and by incorporating structured rather than surface parking, for example, communities can reduce the footprint of new construction and preserve more green space. Not only is this approach more efficient by requiring less land for construction, it also provides and protects more open, undeveloped land than would exist otherwise to absorb and filter rainwater, reduce flooding and stormwater drainage needs, and lower the amount of pollution washing into streams, rivers, and lakes.
- Compact building design is necessary to support wider transportation choices and provides cost savings for localities. Communities seeking to encourage transit use to reduce air pollution and congestion recognize that minimum levels of density are required to make public transit networks viable. Local governments find that on a per-unit basis, it is cheaper to provide and maintain services like water, sewer, electricity, phone service, and other utilities in more compact neighborhoods than in dispersed communities.
- Note the relative amount of disturbed land area and street infrastructure needed for these two 85-unit housing developments in Ann Arbor, Mich., pictured here. On the right, conventional single-family tract houses and lots; on the left, more dense townhouses and common open space.
- Research based on these developments has shown, for example, that well-designed, compact New Urbanist communities that include a variety of house sizes and types command a higher market value on a per square foot basis than do those in adjacent conventional suburban developments. Increasing numbers of developers have been able to successfully integrate compact design into community building efforts, despite current zoning practices (such as those that require minimum lot sizes or prohibit multifamily or attached housing) and other barriers, such as community perceptions of "higher density" development, which often preclude compact design.

The cost of building and leasing new space is driving business facility planners to seek strategies that help make commercial buildings more spatially and energy efficient, such as

- Locating open office areas in perimeter zones to maximize worker access to daylight and views and reduce dependence on artificial lighting
- Placing closed private offices in interior zones with windows looking across the open office areas toward daylight

- Using shared workstation strategies such as hoteling (providing office space to employees on an as-needed rather than on the traditional, constantly reserved basis, which reduces the amount of physical space that an enterprise needs, lowering overhead cost while [ideally] ensuring that every worker can access office resources when necessary) and encouraging worker telecommuting to the extent possible
- Trying to group smaller functional business/teams in distinct spatial clusters of workstations to reduce aisle and circulation space
- Using unconditioned exterior circulation and stairs where climate conditions allow

EMERGING TRENDS

On the residential side, the concept that houses can be brought down in overall size and be made more livable and aesthetically pleasing has been beautifully demonstrated. In the *Not So Big House* books, Sarah Susanka, FAIA, presents new thinking about what makes a place feel like a home and identifies the characteristics that many people desire in their homes and their lives but haven't known how to achieve. See www.notsobighouse.com/.

The ability of new software to visually simulate the impact of new development on existing communities enables planners, developers, architects, and community members to model new development in a collaborative manner, to achieve appropriately designed new development, and to avoid unintended consequences.

What are relevant resources for Appropriate Size and Growth?

For buildings:

- The *Not So Big House* books by Sarah Susanka, FAIA
- Whole Building Design Guide/Design Guidance/Design Objectives
- Functional/Operational/Account for Functional Needs: www.wbdg.org/design/account_spatial.php
- Productive/Design for the Changing Workplace: www.wbdg.org/design/design_change.php
- Whole Building Design Guide/Design Guidance/Design Disciplines, Edith Cherry, FAIA: www.wbdg.org/design/dd_archprogramming.php
- *Programming for Design*, Edith Cherry, FAIA, 1999, John Wiley & Sons, Inc.

For planning:

- Whole Building Design Guide/Design Guidance/Design Disciplines/Planning, Ethan Solomon, APA: www.wbdg.org/design/dd_planning.php
- The Congress for New Urbanism—the 27 principles that guide policy to make a city more livable on a regional, neighborhood, and building scale
- Land Use Law Center—Pace University Land Use Law Center
- Policy Guide on Planning for Sustainability—American Planning Association
- Policy Guide on Smart Growth—American Planning Association
- Smart Growth America—What Is Smart Growth?

Which strategies interact with Appropriate Size and Growth?

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Form
» Integrated Project Delivery
» Walkable Communities

5 Building Form

What is Building Form?

Form and its opposite, space, constitute the primary elements of architecture. Form can be thought as the external three-dimensional outline, appearance or configuration of some thing. Building form defines the space that shelters our interior human activity and the negative space, the void between building forms, shapes our exterior human activities in the built environment.

In designing a building form the architect must simultaneously consider site, aesthetic, programmatic, contextual, and functional issues, and then enclose the building in the most satisfactory way possible. In the world of planning regulations and commercial building, maximizing yield from the zoning envelope too often drives the design of the building form. Such building form is often determined by planners, not architects, in setting property lot lines, yard setbacks, density limitations, floor area ratios, and open space allowances.

The architect designs the resultant building form by manipulating standard aesthetic design devices such as shape, massing, scale, proportion, materials, rhythm, surface articulation, texture and color, and light. Variables, such as building orientation to solar access, wind exposure, amount of surface area, and complexity of building form can profoundly influence the energy consumption characteristics of a building throughout its life time, thereby impacting carbon reduction.

The simple following exercise demonstrates the relationship between surface area, configuration, and heating energy. It uses three building designs of equal 2,000 square foot floor areas with similar window to wall distribution in 2-story, 1-story, and a more complex 1-story configuration. The difference in surface area between the three designs is shown to have the greatest

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Design the building form compactly to reduce the overall energy use of a building over its life cycle.

Specify energy efficient equipment and technologies
- Not applicable.

Use renewable strategies and purchase green power
- Use the building form to take advantage of renewable energy sources.

Educate building owners, operators, and occupants
- Educate the owner on how building form decisions will influence energy consumption for the building life cycle.

influence on heating energy required. Contrary to this, a building massing that optimizes daylighting and ventilation would be elongated along the east/west axis with more surface area so that more of the building floor area is closer to the perimeter. Although this may appear to compromise the thermal performance of the building, the electrical load and cooling load savings achieved by a well-designed daylighting system can more than compensate for the increased surface area skin losses.

This example is not given to suggest that designs should be restricted to the simplest buildings or those with minimal surface areas, but to demonstrate that building form does influence building energy use, and that building form can be employed, along with other means to reduce overall building energy use.

Components	Insulation R-value	Unit	2-Story Design	1-Story Design	Complex Design
Gross Floor Area	R-19	SF	2,000	2,000	2,000
Wall	R-30	SF	2,210	1,680	1,941
Floor	R-38	SF	1,000	2,000	2,000
Ceiling		SF	1,000	2,000	2,053
Volume		CF	17,000	16,000	17,250
Surface Area	4,500 Degree Days	SF	4,210	5,680	5,994
Heating Energy		kWh	8,580	9,300	10,640
Energy Increase			0.0%	+8.4%	+24.0%

How do I design a **Building Form?**

Typical New England Salt Box house with distinctive shed roof line.

From an integrated building perspective the architect must balance and reconcile the functional, programmatic, contextual, and economic drivers of the building form; and at the same time investigate passive solar, daylighting, sun shading, landscaping, and natural ventilation strategies to optimize use of the natural features of the site to maximize energy efficiency of the building form.

- Carefully site the building to take advantage of natural site features such as topography, sunlight, shade, and breezes to develop the most energy-efficient and cost-effective building design.
- Design buildings that are responsive to regional climate and site microclimates.
- Understand design elements that have endured and served well from regional historic vernacular architecture such as salt boxes in cold New England, and verandahs and deep overhangs in the warm humid South.
- Orient the building on an east/west axis to allow for the highest winter solar gains and the lowest summer solar gains and to maximize beneficial daylighting to occupied spaces.
- Design buildings that wrap around courtyards, atria, or light wells to provide daylighting in interior zones and control exposure to winds.
- Minimize exterior surface complexity to reduce chance of leaks and energy loss.

Broward County County-Wide Community Design Guidebook, Broward County Board of County Commissioners, Anthony Abbate, Architect PA. Note recommendations for climate-responsive architectural design strategies: building form with deep overhangs to promote sun shading and natural ventilation and use of trees for solar and breeze control.

- Use roof overhangs to shelter facades and exterior walkways from harsh sun and weather.
- Consider use of porches and pergolas to shelter exterior spaces and activities.
- Use the building form to deflect harsh winter winds.
- Use landscaping features to channel and direct natural breezes and deflect harsh winds.

2007 AIA/COTE Award recipient, the Government Canyon Visitor Center, Helotes, Tex., designed by Lake/Flato Architects. This sustainable design minimizes the impact of the building on the land and fragile water resources in this region

ESTABLISHED TECHNIQUES

- Design a compact building form and set its orientation to enhance daylighting and breezes, enhance winter solar gain, and to reduce summer solar gain.
- Use an integrated design process to balance site/natural, economic, and programmatic building form determinants to enhance building performance.

EMERGING TRENDS

- Use electronic building information modeling (BIM) and energy simulation software to understand and predict the effect of building form on energy use for various design concepts in the early stages of design.

The Aldo Leopold Legacy Center, in Baraboo, Wis., a LEED Platinum certified building. Published in Architecture Week, November 28, 2007. Designed by Kubala Washatko Architects Inc.; Photo: Kevin Matthews / Artifice Images

What are relevant resources for **Building Form?**

- Whole Building Design Guide, Resource Pages, Form, Phoebe Crisman, University of Virginia, School of Architecture.
- Compact Building Form Cuts Heat Loss, *Energy Source Builder #36*, December 1994, © Iris Communications Inc.
- U.S. Department of Energy, *DOE Building Tools: Building Configuration and Placement*.

Which strategies interact with **Building Form?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Appropriate Size and Growth
» Building Orientation
» Daylighting
» Energy Modeling
» Natural Ventilation
» Passive Solar Collection Opportunities
» Sun Shading

6 Building Monitoring

What is Building Monitoring?

Monitoring of building systems is critical for ensuring that the systems operate as designed. Improperly operating systems waste energy and water, lead to unacceptable indoor environmental quality, and can cause premature equipment failures.

The primary goal of building monitoring is to ensure that all building systems operate at peak efficiency. Over time, building systems controls can drift out of setting or may have been disabled because of poor system performance or lack of understanding of system operation by the maintenance staff. A secondary benefit is the use of building monitoring as a teaching tool. In a school, for example, a touchscreen display monitor can be set up to display how much power is being used and/or generated at any time. Glass panels, installed in lieu of ceiling tiles, can display the action of HVAC dampers. Such exhibits help make building occupants more aware of building energy use and potential savings.

Among the building systems and equipment that should be monitored are boilers, chillers, electrical equipment, lighting, elevators, fans, pumps, ventilation, filtration, and fire alarm and security systems. Monitoring can be done by building personnel checking individual control devices and systems; it can be computer-based, with all systems monitored at a central location in the building; or it can be remotely monitored as part of a multibuilding, multiple location computer-based system.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Employing building monitoring will reduce the overall energy use by alerting operators when a system or piece of equipment is operating improperly or failing, including HVAC, lighting, pumps, and compressors.

Specify energy-efficient equipment and technologies
- Use an integrated system approach to spec out the most cost-effective, energy-efficient equipment and technologies, which can include controls and monitoring devices.

Use renewable strategies and purchase green power
- Using energy-efficient equipment with effective controls can reduce a building's overall energy load, require smaller and more cost-effective renewable strategies, and reduce emissions.

Educate building owners, operators, and occupants
- On function and operations of installed technology so they can properly use controls and monitoring devices.

How do I apply Building Monitoring?

Building monitoring is most effectively applied by using computer-aided monitoring for predicting building system performance. Of course, in older buildings, individual systems and equipment can be monitored by building operations personnel to determine whether the equipment is operating efficiently and within specified limits. The value of computer-based monitoring is that alarms will sound and reports will be produced when system parameters go beyond upper and lower limit set points, without requiring operations personnel to check each meter and control device.

Monitoring electrical demand can result in saving significant energy costs by alerting operations personnel to switch off equipment before utility "ratchet clauses" kick in, by identifying the correct fuel to use based on real-time fuel costs, and by efficiently combining utility power with onsite-generated renewable energy sources.

Building monitoring can help answer these questions: Are systems and equipment running much longer than originally scheduled? Is equipment running at a time of day that it should be off? Have doors and windows been left open, thereby wasting energy? Is the electric lighting system on at full brightness at times when daylighting sensors should have turned off or dimmed lights to a lower level? Have changes or upgrades to equipment and controls adversely affected system operations? Essentially, are building systems operating at peak efficiency based on their design and specifications?

LV switchboard with multifunction meter on incoming lines and kilowatt-hour meters on selected outgoing circuits.

Building monitoring can include electrical submetering for multiple building campuses or for large buildings with very different zones (i.e., office spaces and warehouse area). Submetering can also be applied to gas, steam, and water systems. Also consider applying submetering when a building or campus houses different tenants or departments that must be billed separately.

ESTABLISHED TECHNIQUES

Controls

Effective building monitoring must include all controls: time switches, occupancy sensors, light-level monitoring, thermostats, demand, and zoning. Building monitoring must monitor all systems: lighting, HVAC, fire alarm, and security. To be most effective, building monitoring must be part of an integrated, intelligent building management system that achieves interoperability among systems. Employing BACnet or LonWorks can provide the interface necessary for controls from different manufacturers to communicate with each other.

Design Tools

Continuous performance monitoring systems in large commercial buildings can provide operators with access to improved information to operate buildings more efficiently and reduce other operating costs. The Specifications Guide for Performance Monitoring Systems (cbs.lbl.gov/performance-monitoring/specifications/) consists of guidance and a set of specifications for continuous performance monitoring systems that can be easily adapted and routinely used by a variety of organizations for both new construction and control system retrofits.

The guide discusses the benefits of performance monitoring, identifying key performance metrics and how measurement accuracy requirements relate to the performance metrics that are used in both troubleshooting and routine reporting. Examples and resources are provided that address the four key aspects of performance monitoring:

- Performance metrics
- Measurement system requirements
- Data acquisition and archiving
- Data visualization and reporting

Adequately Trained Personnel

For building monitoring systems to be most effective, operating personnel must be trained to operate computer terminals, know how to respond to the alarms and reports generated by the monitoring devices, use this information to analyze the source and urgency of building operating system problems, and understand how to set various alarm limits for temperature, humidity, pressure, voltage, and RPMs, among others.

Green Building Rating Tools

The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system has specific requirements related to metering and verification, tenant submetering, fundamental commissioning, and staff education on building operations and maintenance savings to achieve points in the "Energy and Atmosphere" category. The GreenGlobes rating system by the Green Building Initiative also assigns points for building controls and submetering. An effective building monitoring system can help reduce the overall energy use in a building, which helps meet the LEED and GreenGlobes energy performance goals.

Energy Policy Act

The Energy Policy Act of 2005 contains requirements for metering all federal buildings by 2012 (Section 103) and for net metering (Section 1251), which gives the electric consumer credit for energy generated on-site to compensate for the energy purchased from the electric utility.

Electronic single-phase submeter by E-mon

- Scrolling display of kWh usage
- kWh usage in dollars
- Current demand load (kW)
- Cost per hour, based on current load
- Estimated CO_2 emissions in lbs.
- Estimated hourly CO_2 emissions based on current load
- Optional net metering, including delivered, received and net usage

EMERGING TRENDS

Periodic Recommissioning

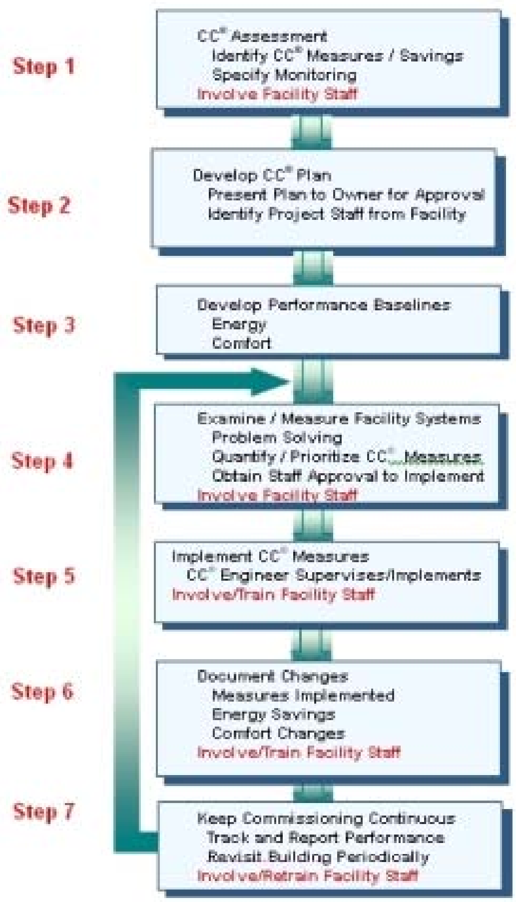
Commissioning is a quality assurance process to ensure that building systems perform as intended. Periodic recommissioning is a process intended to ensure persistent energy savings over the life of a building by reapplying previously conducted commissioning tests. Depending on the complexity of a particular system and changes in the building occupancy or functions, recommissioning may be performed annually or even continuously. Often, a major capital improvement to a building can trigger recommissioning activities. The California Commissioning Guide outlines the following other indicators that can be used to assess when recommissioning is appropriate for a particular building:

- **Is there an unjustified increase in energy use?**
- **Have comfort complaints increased?**
- **Is the building staff aware of problems, but lacks the time or in-house expertise to fix them?**
- **Has control programming been modified or overridden to provide a quick fix to a problem?**
- **Are there frequent equipment or component failures?**
- **Have there been significant tenant improvement projects (buildouts)?**

Continuous Commissioning® has been pioneered by the Energy Systems Laboratory at Texas A&M University. In this case, a commissioning authority or other independent party works with the building operations and maintenance staff to permanently install monitoring equipment to provide feedback on the performance of building systems over time.

According to the Energy Systems Laboratory, applying the continuous commissioning process adds 15 to 45 percent savings over a normally commissioned building as measured by the methods outlined in the U.S. Department of Energy's (DOE) International Performance Measurement and Verification Protocol (IPMVP). IPMVP began as a DOE initiative to develop an international measurement and valuation protocol that would help determine energy savings from energy-efficiency projects in a consistent and reliable manner. In January 2001, *IPMVP Volume I* (version 3): *Concepts and Options for Determining Energy Savings*, which clarified the definition of Option A by removing any ambiguity relating to the use of stipulated values in the engineering calculations/models, was published. *IPMVP Volume II: Concepts and Practices for Improving Indoor Environmental Quality* was published concurrently with Volume I. A nonprofit organization, IPMVP Inc., was formed to maintain and update existing content and develop new content (the name was subsequently changed to the Efficiency Valuation Organization [EVO]).

The flow chart below developed by Texas A&M Energy Systems Lab outlines the steps required as part of Continuous Commissioning®. According to the U.S. Climate Change Technology Program, improved operation and maintenance procedures could save more than 30 percent of the annual energy costs of existing commercial buildings.



What are relevant resources for **Building Monitoring?**

- Energy Policy Act of 2005 (PDF 1.9 MB, 550 pgs)
- Whole Building Design Guide, Tools, Specifications Guide for Performance Monitoring, Philip Haves, Lawrence Berkeley National Laboratory: www.wbdg.org/tools/sgpms.php?a=1
- Whole Building Design Guide, Resource Page, Sustainable O&M Practices, Catherine Coombs Bobenhausen, Sustainable Design Collaborative, LLC: www.wbdg.org/design/sustainableom.php?r=optimize_om-i
- Efficiency Valuation Organization: www.evo-world.org (for IPMVP documents)
- esl.eslwin.tamu.edu/continuous-commissioning-.html

Which strategies interact with **Building Monitoring?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» High-Efficiency Equipment
» Life Cycle Assessment
» Rightsizing Equipment
» Smart Controls
» Staff Training
» Systems Commissioning
» Systems Tune-Up

7 Building Orientation

What is Building Orientation?

Orientation strongly relates a building to the natural environment—the sun, wind, weather patterns, topography, landscape, and views. Decisions made in site planning and building orientation will have impacts on the energy performance of the building over its entire life cycle.

Note: Statements indicated with an asterisk (*) referring to southern solar orientation are true for buildings located in the northern hemisphere. The opposite is true for the southern hemisphere, where a northern solar orientation is best.

Energy conservation strategies relating to building orientation are:

- **Maximizing north and south façade exposure for daylight harvesting to reduce lighting electrical loads**
- **Using southern exposure for solar heat gain to reduce heating loads in the heating season***
- **Using shading strategies to reduce cooling loads caused by solar gain on south façades***
- **Turning long façades toward the direction of prevailing breezes to enhance the cooling effect of natural ventilation**
- **Turning long façades in the direction parallel to slopes to take advantage of cool updrafts to enhance natural ventilation**
- **Shielding windows and openings from the direction of harsh winter winds and storms to reduce heating loads**
- **Orienting the most populated building spaces toward north and south exposures to maximize daylighting and natural ventilation benefit**

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- Proper building orientation can help reduce the overall energy use, so various building systems (i.e., HVAC) can be reduced in size and cost to make way for further energy-saving materials, designs, and technologies.

Specify energy-efficient equipment and technologies.
- Use efficient daylighting controls.

Use renewable strategies and purchase green power.
- Use solar advantages as a part of a whole-building design strategy.
- Use passive solar strategies to decrease energy loads and offset emissions of conventional, built energy systems.

Educate building owners, operators, and occupants.
- Educate them on function and energy advantages of orientation strategies.
- Educate them on use of daylighting control systems.

- Determining building occupant usage patterns for public, commercial, institutional, or residential buildings, and how occupants will be affected by the building orientation, by time of day, on different exposures

The orientation of a building is influenced by numerous environmental and built factors, among them

- Sensory
  Thermal—solar exposure, wind direction, temperature
  Visual—varying daylight qualities in different locations and at different times of day
  Acoustical—direction of objectionable noises
  Environmental—smoke, dust, odors
- Psychological
  Views
  Privacy
  Street activity
- Local development patterns
  Street direction
  Spatial organization, land use, urban design
  Zoning
  Accessibility requirements—main/secondary entrances, parking
- Other considerations
  Aesthetic
  Direction of storms
  Site conditions—topography, geotechnical, wetlands
  Site vegetation—mature trees
  View corridors, scenic easements

How do I design for **Building Orientation?**

The designer must consider and prioritize all factors and site conditions affecting building orientation. For example, a building might have to take heed of multiple orientation factors depending on functional requirements: designing for cooling load or heating load. To take advantage of north–south daylighting, the building may be oriented along an east–west axis. But this may be counter to street lines and other site considerations. Orientation of the building entrance may have to respect street access, activity zones, and local urban design guidelines.

For most regions, optimum façade orientation is typically south.* South-facing* glass is relatively easy to shade with an overhang during the summer to minimize solar heat gain. Light shelves also can work well with the higher sun in the southern exposure. North-facing* glass receives good daylight but relatively little direct insolation, so heat gain is less of a concern.

East and west window orientations and horizontal orientation (skylights) all result in more undesired heat gain in the summer than winter. East and west sun glare is also more difficult to control for occupant comfort because of low sun angles in early morning and late afternoon.

Wind will affect tall buildings more than low structures. Design for wind direction—admitting favorable breezes and shielding from storms and cold weather winds. Wind information is often available from airports, libraries, and/or county agricultural extension offices.

In cold climates, locate pedestrian paths and parking lots on south and east sides of buildings to enable snow melting, but in southern climates locate these on the less sunny east or north sides of the building.*

In temperate and northern climates, locate deciduous trees for south-side shading in the cooling season; in the heating season, the dropped leaves will permit desired solar gain.

In urban settings, orientation may be strongly determined by local regulation, view easements, and urban design regulations. Be aware of unique local and site-specific conditions, such as lake or coastal exposures, effect of mountainous conditions, and special scenic easements.

To minimize heat losses and gains through the surface of a building, a compact shape is desirable. This characteristic is mathematically described as the "surface-to-volume" ratio of the building. The most compact orthogonal building would be a cube. This configuration, however, may place a large portion of the floor area far from perimeter daylighting. Contrary to the cube, a building massing that optimizes daylighting and ventilation would be elongated along its east–west axis so that more of the building area is closer to the perimeter. Although this may appear to compromise the thermal performance of the building, the electrical load and cooling load savings achieved by a well-designed daylighting system will more than compensate for the increased surface losses.

ESTABLISHED TECHNIQUES

Overlay site analysis diagrams to investigate multiple environmental and built factors affecting site layout and building orientation. Use physical three-dimensional models.

EMERGING TRENDS

Among the emerging trends are

- The ability to investigate alternative design strategies using energy-modeling techniques
- Use of electronic three-dimensional documentation and visualization
- Use of software databases with the capability to investigate three-dimensional spatial and visual impacts of proposed large-scale development on existing urban fabric; presumably this database can be enhanced to include solar and weather data for further energy analysis

What are relevant resources for **Building Orientation?**

- U.S. Department of Energy, DOE Building Tools: Building Configuration and Placement
- Olgyay, Victor, ***Design with Climate***, Princeton University Press, Princeton, NJ, 1963
- Whole Building Design Guide, Resource Pages
  - Daylighting, Gregg D. Ander, FAIA, Southern California Edison
  - Sun Control and Shading Devices, Don Prowler, FAIA, Donald Prowler and Associates; revised and expanded by Joseph Bourg, Millennium Energy LLC

Solar Concepts, a concise technical explanation of solar orientation concepts as they affect buildings: www.usc.edu/dept/architecture/mbs/tools/vrsolar/Help/solar_concepts.html

Which strategies interact with **Building Orientation?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Active Solar Thermal Systems
» Building Form
» Daylighting
» Energy Modeling
» Life Cycle Assessment
» Mass Absorption
» Natural Ventilation
» Passive Solar Collection Opportunities
» Sun Shading
» Vegetation for Sun Control

8 Carbon Offsets

What are Carbon Offsets?

Carbon offsets are funds that are used to mitigate the impacts of greenhouse gas (GHG) emissions by channeling corporations' and individuals' voluntary investments into projects that create carbon dioxide (CO2) savings equivalent to their CO2 emissions. Companies and individuals can opt to purchase carbon offsets from companies or organizations that direct these funds toward carbon-offsetting activities to eliminate or reduce environmental impacts associated with carbon-emitting activities.

Consumption of electricity is the largest generator of GHGs, and more than a fourth of U.S. GHG emissions are generated by travel. In addition, business travel accounts for the largest percentage of travel-related emissions; 47 percent of passengers on U.S. domestic flights are traveling for business. Buildings account for the majority of U.S. electrical consumption. Although these activities can be reduced through efficient building renovations and conservation practices, companies often seek to offset remaining emissions that cannot be controlled or further reduced.

There are three types of carbon-offsetting projects: projects that prevent the release of CO2, projects that reduce non-CO2 GHGs, and projects that sequester carbon in vegetation, soil, and/or geologically.

CO2 Prevention

Preventing the release of CO2 before creating emissions is the most important precursor to carbon offsetting. This can be accomplished by analyzing emissions-producing activities and developing a reduction plan. Contributors can include energy, transportation (i.e., shipping, fleet, commuting, sourcing), materials (i.e., paper, office supplies, furniture, vehicles), and events.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- Adopt an energy-conserving approach to minimizing carbon emissions.
- Offset remaining emissions through established programs.
- Plan future building improvements to reduce dependency on offsets in measuring the overall environmental footprint.

Specify energy-efficient equipment and technologies.
- Upgrade systems that rely on highly emitting energy sources or processes.
- Offset remaining emissions through established programs.

Use renewable strategies and purchase green power.
- Install renewable technologies to limit overall carbon emissions.
- Purchase green power as an alternative to carbon offsets.

Educate building owners, operators, and occupants.
- Provide training on carbon-emissions reduction strategies.
- Encourage occupants to invest in carbon-offset programs.

Non-CO2 GHG Reduction

Non-CO2 GHGs significantly contribute to climate change; approximately 30 percent of human-induced GHGs are non-CO2 GHGs. Non-GHGs include methane (CH4), hydrofluorcarbon (HFC), perfluorcarbon (PFC), and sulfurhexafluoride (SF6). Non-GHGs are generated from petroleum systems, natural gas systems, landfills, manure management, electric power systems, semiconductor manufacturing, and refrigeration/air-conditioning use. Reductions in non-CO2 GHG emissions from energy and agriculture would result in the greatest global mitigation. Methane has the largest potential for reduction. Non-CO2 GHGs are less expensive to reduce than CO2. They can be reduced by improving the efficiency of the above-mentioned systems, which will in turn minimize the CO2 emissions from source energy and building energy consumption.

Carbon Sequestration

Carbon sequestration is the process through which agricultural and forestry practices remove CO2 from the atmosphere. The term “sinks” is also used to describe agricultural and forestry lands that absorb CO2. Sequestration activities can help prevent global climate change by enhancing carbon storage in trees and soils.

Investing in Carbon Offsets

By purchasing carbon offsets, companies can voluntarily invest in sequestration or energy-efficiency projects that absorb or prevent the release of a tonnage of CO2 equivalent to their carbon footprint. Other carbon-offset programs invest in renewable energy or clean energy technologies (e.g., wind power). Companies such as TerraPass invest in capturing methane gas in farming practices, and other programs promote industrial efficiency.

Carbon offsetting can also allow companies to counterbalance their carbon emissions through projects that are less costly than internal or direct emissions reductions. Other ancillary benefits to carbon offsets include economic development, spurred in communities in which offsetting projects take place, as well as positive publicity for companies marketing their socially and environmentally responsible practices.

How do I purchase Carbon Offsets?

Buying carbon offsets is like buying environmental credit; there are many options available, but ensure legitimacy before investing.

The first step to purchasing offsets is determining the type and quantity of emissions to be offset (i.e., air travel only, car travel only, building only, a combination, or all emissions). Emissions can be calculated using an emissions calculator. Several Web sites have emissions calculators, including the Environmental Protection Agency, which can be accessed through www.epa.gov/climatechange/emissions/ind_calculator.html.

Again, carbon emissions are most effectively reduced through the implementation of company-wide changes that address policies and practices that contribute to carbon emissions; carbon offsets should be used to counterbalance any remaining emissions.

EMERGING TRENDS

Carbon offsetting has been a controversial topic in the environmental community. Carbon offsets have been critiqued as a "quick fix" or "band-aid" approach to emission reductions that does not promote sustainable changes in corporate practices. Environmentalists advocate for companies to employ conservation and efficiency practices to reduce carbon emissions as the first measure, and to use offsets as a last resort for those emissions that cannot be avoided without significant effort and expense.

Tree planting is one of the most popular and most heavily debated methods of offsetting because the benefits are not always long lasting. Trees take many years to reach the capability to sequester notable amounts of carbon. When a tree dies or is cleared, the stored carbon is returned to the atmosphere; thus, tree planting acts as temporary storage for carbon and does not remove the carbon permanently from the environment.

Some planting practices designed for offsetting carbon can negatively affect the environment. For example, large tracts planted with a single species of tree (i.e., monocultures), typically planted to offset carbon, are more susceptible to disease.

Quantifying the impact of a project can also be very difficult. Working with reputable and transparent organizations to purchase offsets is critical to ensuring legitimacy and quality. It is important to review an organization's current projects and the impact of past projects to assess the effectiveness of their programs.

What are relevant resources for **Carbon Offsets?**

There are many carbon-offset companies and organizations, several of which have unique approaches. Searching the Web is the easiest way to find the option that best suits your needs; verification that the offsets are used as stated is essential. The following list offers a diverse range of carbon-offsetting options:

- ClimateTrust.org was created to administer funds from utilities mandated by Oregon State law to offset the impact of new projects. They offer a wide range of carbon-offsetting services, including energy efficiency, renewable energy, sequestration, fuel replacement, cogeneration, material substitution, and transportation efficiency.
- EasyBeingGreen.com is an Australian company that offers offsets for home and commercial building energy-efficiency improvements (i.e., installation of compact fluorescent lights and low-flow showerheads).
- LiveNeutral.org collaborates with companies and organizations to offset emissions through measuring GHG emissions, providing education on carbon footprint reduction, offsetting emissions that cannot be reduced within the company or organization, and engaging employees, customers, and stakeholders on the issues of climate change.
- TerraPass.com offers offsets for “road,” “flight,” “home,” and “wedding,” as well as gifts. The offsets promote development of clean energy, biomass, and industrial efficiency.

Which strategies interact with **Carbon Offsets?**

All 50to50 strategies relate to each other in some way.
It is recommended that you consider investigating these selected strategies to gain a comprehensive understanding of the topic.

» Alternative Energy
» Co-Generation
» Energy Source Ramifications
» Material Selection and Embodied Energy

9 Cavity Walls for Insulating Airspace

What are Cavity Walls for Insulating Air Space?

The cavity wall has been a popular wall construction technique for commercial and larger multi-family residential buildings that can provide an exterior cladding and veneer, an insulating air space, an internal drainage plane, pressure equalization, and a means to drain water out of the wall assembly.

Although commonly associated with masonry construction, the term cavity wall may be applied to any layered wall system that uses an insulating air space and internal drainage plane to resist rainwater penetration.

The cavity wall typically consists of these elements:

- **An exterior cladding or veneer material that is designed to shed the bulk of the rainwater before penetration into the cavity, and is a primary aesthetic finish element for the wall elevation.**
- **A drainage cavity or air space that collects and controls rainwater penetration and then redirects it back to the exterior through the cladding layer. The air space may be ventilated for rainscreen pressure equalization to protect against water air penetration and air leakage across the cavity.**
- **An internal drainage plane that is the barrier between wet and dry space of the wall assembly. The internal layer may be of masonry or of wood or metal framed construction. The water barrier is applied at the internal drainage plane.**
- **The air barrier controls the flow of air across the wall assembly due to voids in the enclosure system - by infiltration, the introduction of unconditioned air into the conditioned building spaces; and exfiltration, the loss of conditioned air from the building. Also be aware of stack effects in high-rise buildings due to pressure differences between low and high floors.**

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted in order to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building

- By reducing the overall energy use, various building systems (i.e., HVAC) can be reduced in size and cost to make way for further energy saving materials, designs, and technologies.
- By ensuring waterproofing integrity of wall assemblies, insulation will remain dry and effective over the life of the building

Specify energy efficient equipment and technologies

- Use an integrated system approach to design and construction.
- Specify the most cost effective energy efficient construction technologies

Use renewable strategies and purchase green power

- NA

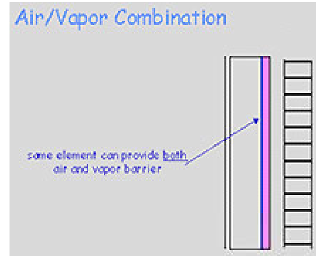
Educate building owners, operators, and occupants

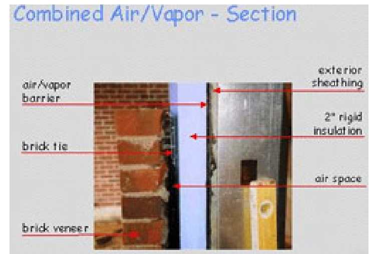
- On proper maintenance of installed construction.

– A vapor retarder that controls the flow of water vapor in the wall to prevent condensation from occurring within the wall assembly.
– An insulation layer that is the barrier between conditioned and unconditioned zones. The insulation layer can be placed inside or outside of the internal drainage plane depending on the climate zone in which the building is located.
– A system of flashing, joints and/or weep holes to redirect any water in the cavity safely back to the outside.
– Cavity walls may be load-bearing or non-load bearing, but in any event must be designed to withstand local wind conditions. Reinforcing and fasteners must be designed to not act as unintended paths for water and air penetration across the wall assembly.

Note that the continuous insulation layer runs across the structural wall and floor elements to insulate the wall and floor slab, and prevent thermal bridging. In metal stud walls avoidance of thermal bridging is critical since metal is such a good conductor for heat loss.

Masonry wall construction has evolved from mass solid bearing wall construction (going back to ancient times) to contemporary multi-layered curtain wall construction techniques. The complexity of multiple materials, layers, fastening devices, and construction trades involved in the modern wall assembly makes construction quality control difficult, but imperative for effective energy control over the building life-cycle.





Installation of Combined Air and Water Retarder (Courtesy of Commonwealth of Massachusetts)

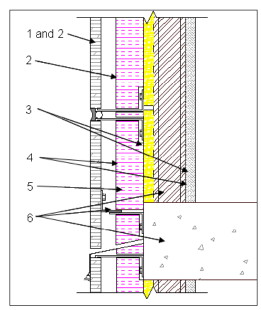
Top: The same material can be both an air and vapor retarder.

Bottom: The photo shows a system that uses a peel-and -stick material as both the vapor retarder and air retarder. The material is installed over the gypsum sheathing but on the warm-in-winter side of two inches of extruded polyethylene insulation.

How do I apply **Cavity Walls for Insulating Air Space?**

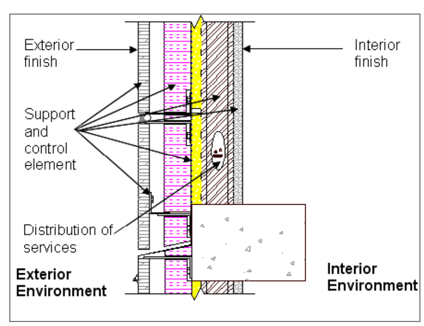
Design everything about the building envelope and particularly insulated cavity walls for the life-cycle of the building. If a wall is improperly designed and executed, and mistakes and leaks are discovered after completion, forensic investigation and complete correction of damaged and corroded elements to an occupied building can be extremely expensive and disruptive. Wet walls and insulation will not permit effective control of heat and cooling loss.

Several design principles should be observed:
– Design the exterior cladding as the first line of defense against water penetration and air exfiltration/infiltration into the wall assembly.
– If water does get into the insulated air cavity, design a drainage plane that permits the water to escape, so as not to cause damage to the building, and allows the cavity to dry out.
– A ventilated wall cavity is more effective for relief of positive and negative air pressures driving water and air leakage.
– Be aware of the local climatic conditions for the heating and cooling seasons as they will determine best design strategies and local energy code requirements.
– Provide a continuous layer of insulation across the exterior face of structural wall and floor slab elements to prevent thermal bridging.



Basic Elements of the Exterior Wall

1. Exterior Cladding (Natural or Synthetic)
2. Drainage Plane(s)
3. Air Barrier System(s)
4. Vapor Retarder(s)
5. Insulating Element(s)
6. Structural Elements



Reduce the overall energy use in your building

- Provide a continuous layer of insulation across the exterior faces of metal or wood wall framing (studs) to prevent thermal bridging.
- Note that wall cavities should be fire-stopped at floor slabs. This is particularly important in high-rise buildings where heat and smoke might migrate from one floor to another through an unbroken wall cavity air space due to air pressure differences caused by stack effect.
- Redirect water to the exterior by flashing through weep holes or joints in the cladding.
- Integrate material fastening devices and anchors into your insulation and water/air barrier schemes. Liquid applied barriers are effective to ensure continuity.
- Integrate required structural reinforcing and anchors into your insulation and water/air barrier schemes.

Cavity walls may be designed for passive heating and/or cooling, using top and bottom of wall vented controls. For heating the vents would be closed to trap heated air in the cavity, thus acting as a warm air buffer between the interior heated space and the exterior. For cooling the vents are opened to promote to circulate cooler air through the wall cavity. Passive systems work best when temperature difference between conditioned inside air and outside air are significant enough to promote natural air movement. In humid climates the designer must take care not to draw unwanted moist air into the building.

ESTABLISHED TECHNIQUES:

- Specify model mockup and field performance testing for quality control assurance
- Provide for integrated design meetings for involved design and construction stakeholders
- Provide for integrated pre-construction meetings for all involved trades
- Follow the continuity of air/water/vapor barriers in wall assemblies across transitions, openings, and movement joints.

EMERGING TRENDS:

- Double-skinned facades, which may be regarded as a type of ventilated cavity wall, are widely used in Europe, but not in the US. See *All That Glass? Is there an appropriate future for double skin facades?* by Donald B. Corner (Journal of Building Enclosure Design, summer 2006), Building Enclosure Technology and Environment Council (BETEC), and the National Institute of Building Sciences (NIBS).
- Building Integrated Photovoltaics (BIPV) - the integration of photovoltaics (PV) into the building envelope often serving as the exterior weather skin. The PV modules serve the dual function of power generator and building skin, replacing conventional building envelope materials.
- Ventilated wall systems
- Coordination of details using three-dimensional representation technology

PV roofing system displaced traditional roofing materials

What are relevant resources for **Cavity Walls for Insulating Air Space?**

- **Brick Institute of America, Technical Notes on Brick Construction:**
  - No. 21A - Brick Masonry Cavity Walls Insulated
  - No. 21B - Brick Masonry Cavity Walls Detailing
  - No. 21C - Brick Masonry Cavity Walls Construction
  - No. 43 - Passive Solar Heating
  - No. 43C - Passive Solar Cooling
  - No. 43D - Passive Solar Heating – Materials
  - No. 43G - Passive Solar Heating - Details
- Whole Building Design Guide, Resource Page, Mold and Moisture Dynamics, Don Prowler, FAIA, Donald Prowler and Associates, Revised and expanded by Heinz Trechsel, R.A. FASTM, NAVFAC Washington, Washington DC
- Whole Building Design Guide, Building Envelope Design Guide, Wall Systems, Daniel J. Lemieux, AIA and Paul E. Totten, PE, Wiss, Janney, Elstner Associates, Inc. http://www.wbdg.org/design/env_wall.php

Which strategies interact with **Cavity Walls for Insulating Air Space?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Orientation
» Energy Modeling
» Integrated Project Delivery
» Mass Absorption
» Windows and Openings

What is Co-Generation?

Cogeneration, also referred to as combined heat and power (CHP), is the use of a heat engine or a power station to simultaneously generate both electricity and useful heat. Cogeneration is more energy efficient than the separate generation of electricity and thermal energy. Heat that is normally wasted in conventional power generation is recovered as useful energy for satisfying an existing thermal demand, the heating and cooling of the building and water supply, thus avoiding the losses that would otherwise be incurred from separate generation of power. Conventional electricity generation is inherently inefficient, converting only about a third of a fuel's potential energy into usable energy. The significant increase in efficiency with CHP results in lower fuel consumption and reduced emissions compared with separate generation of heat and power. This reduced primary fuel consumption is key to the environmental benefits of cogeneration because burning the same fuel more efficiently means fewer emissions for the same level of output.

CHP systems consist of a number of individual components: the heat engine, generator, heat recovery, and electrical interconnection, which are all configured into an integrated whole. Heat engines for cogenerator systems include reciprocating engines, combustion or gas turbines, steam turbines, microturbines, and fuel cells. These heat engines are capable of burning a variety of fuels, including natural gas, coal, oil, and alternative fuels such as biomass, solar, and hydrogen to produce shaft power or mechanical energy. Although the mechanical energy created is most often used to drive a generator to produce electricity, it can also be used to drive rotating equipment such as compressors, pumps, and fans. Thermal energy from the system can be used in direct process applications or indirectly to

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- An onsite cogeneration system will reduce the overall energy use of a commercial or residential building by decreased distribution losses and through the recapturing and reuse of formally lost heat.

Specify energy-efficient equipment and technologies.
- Combining cogeneration technology with energy-efficient equipment as part of the overall building design will further reduce energy usage and overall emissions.

Use renewable strategies and purchase green power.
- The use of CHP systems combined with renewables such as solar energy capture is one of many combined overall building strategies that will further reduce the energy load and carbon emissions of a building.

Educate building owners, operators, and occupants.
- Provide information on function and operations of installed technology.

produce steam, hot water, hot air for drying, or chilled water for process cooling.

Cogeneration is not a new concept. It has successfully been used for more than a century, including industrial, district energy, institutional, government, commercial, and residential applications. CHP can be used in virtually any stationary application that uses waste heat from onsite power for cooling or heating. In fact, in the 1920s, more than half of the electricity used in the United States was produced by some form of cogeneration.

How do I apply Co-Generation?

Fueled by environmental concerns, unease over energy security, and a host of other factors, interest in cogeneration technologies has been growing among energy customers, regulators, legislators, and developers. Installing a cogeneration system designed to meet the thermal and electrical base loads of a commercial or residential building can greatly increase the building's operational efficiency and reduce energy costs and emission of greenhouse gases.

Cogeneration is most effective when the generating units are placed at or near the building for which they supply energy. Although central or onsite CHP systems have been used in commercial buildings, there are now a number of units available for the residential market. Cogeneration systems have the potential for a wide range of applications and lower emissions than separate heat and power generation systems because of their higher efficiencies. The advantages of cogeneration include the following:

- Cogeneration is versatile and can be coupled with existing and planned technologies for many different applications in the industrial, commercial, and residential sectors.
- The simultaneous production of useful thermal and electrical energy leads to increased fuel efficiency and lower emissions compared with conventional systems.
- Cogeneration units can be strategically located at the point of energy use. Such onsite generation avoids grid transmission and distribution losses associated with decentralized power stations.

ESTABLISHED TECHNIQUES

Commercial Buildings

Cogeneration has been used for many years in commercial buildings for large-scale applications such as generating energy for industrial complexes, college campuses, hospitals, and commercial buildings in campus-like settings where there is considerable power and thermal demand. Currently, reciprocating engines are the most common and most efficient prime movers (engines) used in commercial cogeneration systems because of their cost, reliability, and availability. However, microturbines, fuel cells, and Stirling engines may be economically viable for cogeneration in the next few years as technology advances.

As the technology has improved over the years to be more compact and modular and, therefore, cheaper to install, cogeneration is gaining popularity for use in high-rise commercial office buildings. Depending on the size of the system, cogeneration can be a fully self-reliant energy source, generating enough electric power onsite for the entire building, while capturing the waste heat from the generating equipment, which is usually a gas reciprocating engine, combustion turbine, microturbine, or fuel cell. The recovered waste heat is "free energy" that can be used for space heating, domestic hot water production, and space cooling.

Commercial cogeneration unit

Commercial cogeneration unit

Residential Buildings

Because of the large number of successful residential installations in Europe and Japan, several manufacturers are now offering models in the United States. Once available only to large commercial buildings, cogeneration systems are now being produced on a scale that is safe, practical, and affordable to homeowners. A residential CHP system uses fuel such as natural gas to produce heat and electricity simultaneously. The electricity can be used for any household device such as lights and appliances, and the heat produced can be used for water heating and space heating. Microcogeneration units range in capacity from about 1 kW to 6 kW and are about the size of a major appliance. Installation may be performed initially by specialists and, after the technology matures, by an experienced plumber, electrician, or HVAC technician. Units come as grid-tied systems that connect to utility power as backup or as stand-alone systems for remote residences. One 6-kW unit can provide up to 10 GPM of hot water at 140° F to 150° F. This waste heat can be used to heat an entire home; water for domestic use, swimming pools, and spas; or even as an energy source for heat-driven (absorption) cooling systems.

Current units on the market with small-capacity engines can simultaneously produce 1.2 kW of electric power and 11,000 Btus of heat in the form of hot water. These systems can be combined with a high-efficiency, natural gas–fueled warm air furnace or boiler for supplemental space heating. The small engines tend to burn very cleanly—exceeding all emissions requirements for carbon dioxide and nitrogen oxides. The primary challenge for getting the highest efficiency and best economic return on a cogeneration system is to fully use all of the thermal energy produced when generating electricity. As the technology develops, various operating regimes will be tested to optimize the energy available based on variables such as the loads in the home, the climate, and the season. CHP systems are extremely efficient, offering combined heat- and power-generating efficiency of about 90 percent, compared with about 30 to 40 percent for electricity from a central power station.

EMERGING TRENDS

Decentralized Generation

Our current centralized electricity-generation system wastes over two-thirds of the energy contained in the fuel and continues to produce ever-increasing carbon and other harmful emissions because of a continued demand for energy worldwide. At least half of this wasted energy could be recaptured if we

shift from centralized generation to distributed systems that cogenerate power and thermal energy onsite or nearby. Cogeneration offers significant, economy-wide energy-efficiency improvement and emissions reductions. Besides saving energy and reducing emissions, distributed generation also addresses emerging congestion problems within the electricity transmission and distribution grid.

Trigeneration

Also known as combined heating, cooling, and power generation (CHCP), trigeneration takes cogeneration one step further, using one energy source to simultaneously produce mechanical power, heating, and cooling. The additional cooling step produces chilled water for air conditioning to cool a building or for process use with the addition of absorption chillers. By combining a cogeneration system with an absorption refrigeration system, it is possible to achieve overall efficiencies (power and air-conditioning refrigeration) of up to 75 percent, increasing both annual capacity and efficiency of the CHCP system and greatly reducing overall emissions.

Combined Technologies

Cogeneration when combined with other technologies shows promise in effectiveness and efficiency. One such "combining of technologies" is with fuel cells. Fuel cells show electrical efficiencies of 40 to 49 percent in comparison with other competing technologies that are about 10 to 14 percent lower. Fuel cell systems used in cogeneration can achieve an electrical efficiency of close to 80 to 85 percent. Although fuel cell technology is still not the most cost-effective technology, combining the cogeneration aspect has drawn renewed interest in the marketplace.

- **Nuvera, a fuel cell manufacturer, has developed a CHP fuel cell power system slated for Beta testing and precommercialization to begin by 2008. This new cogeneration system will generate approximately 5 kW of electricity and 7 kW of heat and will provide a consistent or "base load" output of thermal and electrical energy. The electric grid and conventional heating equipment are then used to support peak load demand. The CHP system is appropriately sized for small commercial customers who have a steady, consistent demand for thermal and electrical energy, such as hospitals, hotels, dormitories, restaurants, and swimming pools.**
- **FuelCell Energy Inc., will install a 1.2-MW CHP power plant that will be located at the site of Turlock's Regional Water Quality Control Facility, in California's Central Valley by the summer of 2008. Fuel cells will generate power to run the wastewater plant from methane gas generated from treatment of wastewater on site. This combined technology will reduce the site's carbon footprint by 5,200 tons annually, compared with a typical power plant, and will make significant savings on the cost of fuel. The power plant is said to be 47 percent efficient and can achieve up to 80 percent efficiency by using the waste heat as a cogeneration system.**

National Policy

During the past couple of years, cogeneration has become an important part of the national energy debate. The United States has taken the first steps toward setting in place policies to promote cogeneration by establishing a national target. The Department of Energy and the Environmental Protection Agency have begun to review the means for achieving this target. According to the American Council for an Energy Efficient Economy (ACEEE), the primary barriers to greater cogeneration usage are not economic or technical but are regulatory and institutional. The ACEEE states that the private sector must work with government regulators and policymakers to ensure that competition and incentives for innovation are preserved, while creating a favorable regulatory environment for CHP for both environmental and "bottom-line" benefits.

What are relevant resources for Co-Generation?

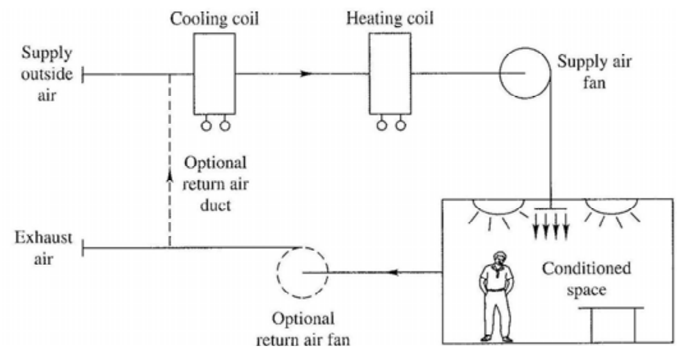
- United States Clean Heat and Power Association: http://uschpa.admgt.com/
- World Alliance for Decentralized Energy: www.localpower.org/
- International Direct Energy Association: www.districtenergy.org/
- Combined Heat and Power Association: www.chpa.co.uk/

Which strategies interact with Co-Generation?

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Orientation
» Daylighting
» Life Cycle Assessment
» Passive Solar Collection Opportunities
» Renewable Energy Resources
» Sun Shading

What are Conserving Systems and Equipment?



Simplified secondary HVAC system for a single zone

The anatomy of a heating, ventilation, and air-conditioning (HVAC) system consists of (1) the central plant, (2) the distribution system, (3) terminal devices, and (4) controls. The latter three are considered the secondary systems that support the HVAC equipment in a building. The secondary systems generally consist of air and liquid handling equipment, such as ducts and pipes, and heating and cooling terminal devices, including mixing boxes and baseboard heating units, fans and pumps, valves, dampers, and controllers.

Air is the medium used in the majority of commercial HVAC systems in the United States, but combination air–water systems and water-only systems are also used. Air–water systems transfer energy from water to the air at a terminal box in each zone. These terminal boxes are also referred to as "fan–coil units." Water systems use components such as radiators or radiant panels to deliver conditioning to the space. These systems can be controlled by air volume or by water temperature or both.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Whenever possible, choose conserving systems and equipment with high-efficiency standards that support a whole-building design strategy and a reduction in overall emissions.

Specify energy-efficient equipment and technologies
- Look for and use rating labels that identify the energy-efficiency level of the product or equipment you are purchasing.

Use renewable strategies and purchase green power
- Specify smaller and more cost-effective renewable strategies and reduce emissions wherever possible.

Educate building owners, operators, and occupants
- On function and operations of installed technologies.

A highly efficient HVAC system addresses the efficiency not only of the heating and cooling equipment but of each component in the secondary system. The HVAC system can incorporate advanced duct or piping design to eliminate stress on the pumps and fans and to minimize delivery losses. Efficiencies of the fans and pumps are carefully evaluated and control strategies are implemented that reduce the need for cooling or heating at unnecessary times. For a truly conserving system, whole-system design is necessary.

How do I apply Conserving Systems and Equipment?

ESTABLISHED TECHNIQUES

Design Strategies for Efficient System Operation

One way to improve the overall efficiency of mechanical systems is to incorporate strategies that use surrounding conditions. For example, the system might use outdoor air that is less costly to heat or cool than the interior conditioned air. A few examples of these types of strategies are listed below.

Economizer Cycle: A system with an economizer cycle uses outdoor air to cool the space without operating a cooling coil. This is typically used in the spring or fall when there is still a cooling load because of occupants, lights, and equipment. When the outdoor air is below the temperature of the air leaving the cooling coil, outdoor air can be used. As temperatures continue to drop below the cold air supply temperature, the amount of outdoor air used for cooling is reduced. Indoor air quality is of most concern during mid-heating and cooling seasons, when minimal outside air should be used. In warm, dry climates where the temperature swings are dramatic between day and night, outdoor air can be used to cool the space when the temperature drops in the evening. This is an excellent strategy to help minimize spikes in temperature during the day in buildings that use thermal mass.

Energy Recovery Systems: These systems use conditioned exhaust air to precondition entering outside air that will need to be heated or cooled. The exhaust air is usually passed through a heat exchanger where the incoming air is preheated or cooled, thereby reducing the amount of conditioning needed.

Return Air Recovery: This method reuses return air in the system to minimize coil loads and energy consumption. Because the air has already been conditioned, little energy is needed to bring it to supply conditions. Filtering and dehumidification are usually the biggest concerns when using return air. These systems are subject to ventilation requirements.

Blow-Through Systems: These systems use a technique in which the fan is situated upstream from the cooling coil and air is blown through the coil, as opposed to the typical method of drawing air through the coil from downstream. The blow-through technique increases efficiency because heat from the fan motor is removed by the coil. In a draw-through system, the motor heat is introduced to the already cooled air and then has to be removed by a subcooling system.

Variable Air Volume (VAV) Systems: The effectiveness of the HVAC system depends on the efficiency and operation at part-load conditions. This is because so much time is spent at less than peak load conditions. Peak loads are used to size equipment, but larger, long-term operating costs of the HVAC depend on the operation at off-design conditions. VAV systems are the most common systems in commercial applications. They supply varying amounts of air to meet varying loads. The most efficient and most commonly used method of reducing air flow is to use a fan with a variable speed motor. It is the only common design that reduces energy consumption significantly as the load is reduced. Zone loads must be determined accurately to minimize part-load penalties, and flow balancing is essential if adequate air is to be supplied to all zones.

Equipment Options for Efficient Systems

Fans: Movement of air through the HVAC systems in a building is caused by fans. The energy used by fans can be very significant because they are required to run constantly and can represent 30 percent of the electricity used in commercial buildings. It is very important that all feasible means be used to control fan power. One method of reducing fan power would be to design efficient duct systems. Proper design of the ductwork, especially immediately adjacent to the fan, is essential for proper fan operation. Consideration should also be given to specifying the most efficient motors economically feasible.

Ducts: The objective of the ductwork is to deliver the amount of air needed to meet loads in each zone. Common constraints to building efficient duct systems include availability of space, need to meet loads in a variety of zones, economic criteria, and noise control. Efficient duct systems generally employ the following features: curved elbows to improve flow through turns, flow vanes located in elbows and transitions to improve air flow and reduce pressure on the fan, and properly sized ducts to maintain the same pressure gradient throughout the system (otherwise known as the equal friction method). These features produce a well-balanced design that delivers the required air flows without the need for excessive dampering. Heat losses or gains through the ducts should be controlled with duct insulation, especially ducts in unconditioned spaces. Insulation can also help with sound control. Refer to the American Society of Heating, Refrigerating and Air-Conditioning standards for recommended levels for specific climates.

Grills and Diffusers: The exit point for the air is called a grill or diffuser. The distribution of air into the space and the speed at which the air exits depend on the design of the grill. They are usually mounted in the ceiling plane and are either round or square. Performance depends on the design details, which are provided in the manufacturer's data. Selecting the correct diffusers depends on variables such as the flow rate desired, the ceiling height of the space, and occupant activity. If occupants are uncomfortable because of poor distribution or excessive air speed, temperature settings in the space will not be optimized. This can happen when supply grills are located too near the return grills, which can cause “short cycling” of the conditioned air. Essentially, the conditioned air is returned to the mechanical equipment without first mixing with the room air. Discomfort can also be caused by air velocities that are too high or low depending on the occupants’ activity. For example, sedentary workers will most likely be uncomfortable at air velocities of 50 ft/min or higher.

Pipes: The objective of pipe design is to deliver water at proper temperatures needed to meet loads in each zone. Constraints are similar to duct systems and include availability of space, need to meet a variety of loads in different zones, and economic criteria. It is essential that these systems are designed at the beginning of the design process to balance flows, minimize lengths of distribution systems, and minimize noise. Here, too, proper insulation of pipes can improve energy efficiency.

Pumps: Similar to variable speed fans, pumps with variable speed drives are also available.

Control Strategies for Efficient System Operation

The purpose of the control system is to sustain a comfortable building interior, maintain acceptable indoor air quality, provide simple and inexpensive (yet reliable) control, and ensure efficient HVAC operation under all conditions. A few basic control strategies include:

- Operate the HVAC only when the building is occupied or heat is needed to prevent freezing
- Consider night setback
- Do not supply heating and cooling simultaneously or dehumidification and humidification
- Use the most economical source of energy first, the most costly last
- Minimize use of the outdoor air during deep heating and cooling seasons
- Establish control settings for stable operation and to avoid system wear and achieve proper comfort

A combination of the above components may produce the most effective, efficient system depending on building use and design.

EMERGING TRENDS

With the ever-increasing global demand for energy and the need to reduce carbon emissions, various trends have emerged and continue to emerge with conserving systems and equipment. A few of these approaches are:

New Technologies

As new technology emerges, simple changes can improve conserving equipment and systems. For example, better motor and fan design can reduce the speed of an HVAC fan while still providing specified air flow. A small change in speed can have a significant effect in energy consumption, as fan and pump energy use varies according to the speed, raised to the third power!

Variable Speed Drives

Some loads driven by motors do not need to operate at the same speed all the time. For example, pumps and fans do not always need to produce the same flow in all conditions. These types of loads offer big opportunities for savings by moderating their speed according to their load. For example, reducing a fan's average speed by approximately 20 percent with a variable speed drive can reduce energy consumption by more than 40 percent.

Whole-Design Approach

Using a "systems" approach to overall design is starting to emerge as a necessity as more energy-conserving measures in buildings are called for. For example, it is often possible to reduce the load on a motor and save energy by reducing pressure losses in duct runs and pipes using low-pressure loss elbows and fittings. These systems with lower pressure losses can often use a slower speed fan or pump to deliver the same amount of flow but without the loss of comfort. It is highly critical for the architect to work with the HVAC designer at the outset of the project to enable such strategies by providing adequate floor-to-floor dimensions and properly sized plenums and shafts to facilitate the proper design of ductwork.

What are relevant resources for **Conserving Systems and Equipment?**

- U.S. Department of Energy—*Best Practices: Motors, Pumps, and Fans (various publications):* www1.eere.energy.gov/industry/bestpractices/techpubs_motors.html
- Air Movement and Controls Association International Inc. (AMCA): www.amca.org
- Canada, Office of Energy Efficiency—*Use of Variable Frequency Drives for Fan and Pump Controls:* www.oee.nrcan.gc.ca/publications/infosource/pub/ici/eii/m92-242-2002-11e.cfm?attr=20
- Kreider, Jan F., and Ari Rabl, *Heating and Cooling of Buildings: Design for Efficiency*, McGraw-Hill, 1994

Which strategies interact with **Conserving Systems and Equipment?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Orientation
» Daylighting
» Life Cycle Assessment
» Passive Solar Collection Opportunities
» Renewable Energy Resources
» Sun Shading

12 Construction Waste Management

What is Construction Waste Management?

Today most of our building waste ends up in landfills, increasing the burden on landfill loading and operation. The practice of minimizing and diverting construction waste, demolition debris, and land-clearing debris from disposal and redirecting recyclable resources back into the construction process is commonly referred to as construction waste management (CWM). Waste management affects carbon reduction efforts by impacting one or more of the following:

- **Energy consumption (specifically, combustion of fossil fuels) associated with manufacturing, transporting, using, and disposing the product or material that becomes a waste.**
- **Non-energy-related manufacturing emissions, such as the carbon dioxide released when limestone is converted to lime (which is needed for aluminum and steel manufacturing.)**
- **Methane emissions from landfills where the waste is disposed.**

It is estimated that anywhere from 25–40 percent of the national solid waste stream is building-related waste and only 20 percent of construction waste or demolition debris (C&D) is actually recycled. In 2004 estimates, landfill tipping fees ranged from $24 in south central United States to more than $70 in the Northeast. In 1998, the U.S. Environmental Protection Agency estimated that 136 million tons of building-related waste is generated in the United States annually. A 2003 update shows an increase to 164,000 million tons annually, of which 9 percent is construction waste, 38 percent is renovation waste, and 53 percent is demolition debris. Employing CWM into the construction process not only is beneficial for the environment, it is beneficial to the bottom line. The architect can influence successful waste management by developing a construction

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted in order to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Not applicable
- Specify energy efficiency equipment and technologies
- Not applicable
- Use renewable strategies and purchase green power
- Develop and employ a construction waste management plan.
- Require wastes to be tracked and monitored to ensure that recyclable materials are being recycled or reused and other wastes are being disposed of properly.
- Involve principal parties to achieve waste reduction goals.
- Educate building owners, architects and engineers, and contractors
- Educating the design team early on in the process reduces the need for excess materials for the project.
- Help others learn about the benefits of construction waste management and energy use in the building.

waste management plan, which is incorporated in the specifications.

Incorporating practices that reduce the production of waste at a project site through reusing, salvaging, and recycling ensures that the project's environmental goals can be met. A comprehensive CWM plan should include:

- A list of materials that are targeted for reuse, salvage, or recycling
- Landfill information (including tipping fees)
- Description of the proposed means of sorting and transporting the recyclable materials
- An estimate of the packaging materials generated, noting whether the supplier can eliminate or recycle packaging)
- A provision for addressing noncompliance of the CWM, including a stop-work order or provisions to rectify noncompliant conditions
- Recycling facility information (including how materials will be recycled and tipping fees)
- Other project specific information relevant to the scope and intent of the project

Comingled construction debris

Making up to 95 percent of the building, some of the more common C&D wastes are lumber, drywall, metals, masonry (brick, concrete), carpet, plastic, pipe, rocks, dirt, paper, cardboard, or green waste related to land development. Of these, metals are the most commonly recycled material while lumber makes up the majority of debris that still goes to a landfill. Diverting 90 percent of construction job site waste and more than 80 percent of demolition debris from landfill disposal is not uncommon.

Wastes can be prevented from ever entering the waste stream by:

- Reducing packaging wastes; purchase available items in bulk
- Reusing/recycling nonreturnable packaging and containers on site
- Purchasing materials in returnable packaging/containers
- Donating nonreturnable/recyclable packaging/containers to local organizations
- Building material-efficient buildings
- Examining demolition and creative salvage techniques

How do I apply Construction Waste Management?

A successful CWM plan involves all the principal parties of a project-owner, architect, engineer, contractor, and subcontractors. Involving each of the vested parties early on in the design process makes accomplishing the established goals more easily obtainable. The CWM plan should include requiring the contractor to minimize waste, developing ways to reuse existing materials, which may be included in the new design or elsewhere. The architect will also need to be familiar with the regional waste management infrastructure and establish a waste management goal for the contractor. Due to the recent interest in CWM, companies are emerging that provide the necessary services of sorting, removal, and recycling. The Construction Waste Management Database contains information on companies that haul, collect, and process recyclable debris from construction projects. Created in 2002 by the U.S. General Services Administration's Environmental Strategies and Safety Division to promote responsible waste disposal, the database is a free online service for those seeking companies that recycle construction debris in their area.

ESTABLISHED TECHNIQUES

Within the conventional delivery methods (design/bid/build) the architect must be very careful to include the CWM plan in the construction documents.

Steel

Steel has been sorted, reused, recycled, and reclaimed for many years. Steel continues to be recycled at a volume higher than all other recyclables combined. In the past 50 years approximately 50 percent of all steel produced in this country has been recycled through the steelmaking process. In 2006 the construction structural recycling rate was 97.5 percent and has been since 2005.

Modular Buildings

Buildings that are prefabricated and assembled on site decrease the amount of waste generated from off-cuts (by-product) and on-site damage. The mass production allows for buying in bulk and using or recycling the majority of the materials at the manufacturing site.

EMERGING TRENDS

Deconstruction

If 25 percent of the buildings demolished every year were deconstructed instead of demolished, approximately 20 million tons of debris could be diverted from landfills. To deconstruct a building is to generate the least amount of waste possible while maximizing the amount of material that can be salvaged. Deconstruction increases building duration and decreases the carbon footprint by minimizing the amount of virgin resources needed to construct the "new" building.

Deconstruction generates materials that can be reused at the project site or can be resold to be used on other project sites. It also creates opportunity for jobs that require a little more skill than just taking a tractor and demolishing a structure. Jobs that require skills command higher salaries and contribute more to local economies.

Deconstruction of a building

What are relevant resources for for Construction Waste Management?

- Whole Building Design Guide:
  This is a comprehensive site that gives an introduction to and highlights important points about construction waste management
- Deconstruction: Building Disassembly and Material Salvage
- EPA - Construction & Demolition (C&D) Materials
- Environmental Design and Construction: Demolition or Deconstruction? Marisa Hegyesi and Brian Yeoman May 8, 2002.

Which strategies interact with Construction Waste Management?

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Carbon Offsets
» Deconstruction and Salvage Materials
» Environmental Education
» Life Cycle Assessment
» Material Selection and Embodied Energy
» Preservation/Reuse of Existing Facilities

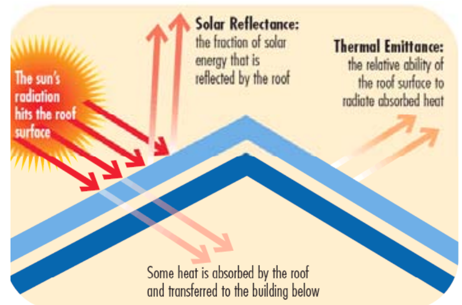
13 Cool Roofs

What is a Cool Roof?

Simply put, a cool roof is one that is highly reflective and emits heat it has absorbed back to the atmosphere. A roof is defined as cool based on two radiative properties: solar reflectance and thermal emittance. Solar reflectance is the fraction of solar energy that is reflected by the roof. Thermal emittance refers to the roof's ability to radiate absorbed heat back to the environment.

Both solar reflectance and thermal emittance are measured on a scale from 0 to 1: The higher the number, the cooler the roof. Some of the benefits of cool roofs include:

- Lower energy bills
- Extended performance lives for roof systems and cooling equipment
- Reduced air pollution caused by electricity generation, including reduced carbon emissions, which contribute to global warming
- Mitigation of the urban heat island effect, which occurs when the ambient temperature in a city is higher than its surrounding areas due to dark surfaces absorbing heat from the sun, and which is a major contributor to smog formation



How do I apply Cool Roof Technology?

ESTABLISHED TECHNIQUES

The use of cool roofs must take into consideration regional climate conditions. Also, it is necessary to understand the maintenance requirements. Solar reflectance of cool roofs tends to decrease over time because surface particles such as dew, dust, and air pollutants accumulate. Another factor that affects long-term

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Reducing the overall energy use of a building will put less demand on and reduce emissions of the power plant that is providing the energy.

Specify energy-efficient equipment and technologies
- Using energy-efficient technologies, such as cool roofs, as part of the overall building design process will further decrease the load the local power plant must provide while reducing overall emissions.

Use renewable strategies and purchase green power
- Not applicable

Educate building owners, operators, and occupants
- On the cool roof products and technologies currently available to them and the benefits of each.

solar reflectance is slope—the greater the angle of roof slope, the more dirt and particles dislodge and fall off the roof surface. Deterioration of the solar reflectance can be mitigated by regular maintenance. For example, if a roof collects large amounts of particulate matter or leaf debris, washing the roof every few years can help maintain high solar reflectance. Another way to address the issue of declining albedo (i.e., reflective power) values is to reapply roof coatings periodically. Some roof coating distributors recommend applying a new coat after 10 years. The major categories of cool roofs include the following:

- Reflectant Roof Coatings: These coatings are applied on-site in thicknesses considerably greater than typical white paints, ranging up to about 1 mm.
- White: White is typically the most reflective of the cool roofs, reflecting up to 70 to 80 percent of the sun's energy.
- Tinted: Tinted coatings are usually produced by adding tints to white coatings. This can greatly reduce the solar reflectance, depending on the color. Reflectance values range from 12 to 79 percent.
- Aluminum: This type of coating generally employs an asphalt-type resin containing "leafing" aluminum flakes. The aluminum flakes greatly enhance the solar reflectance over the 4 percent value for bare asphalt, to above 50 percent for the most reflective coatings.
- Roofing Membranes: These are fabricated from strong, flexible, waterproof materials. The upper surface of the membrane may be coated with a pigmented material that determines the color and solar reflectance, or it may simply be topped with roofing gravel. If roofing gravel is used, the membrane has the appearance and solar reflectance of asphalt shingles.
- Metal Roofing: Metal roofs are usually steel or aluminum. They can have a solar reflectance of roughly 60 percent, but they tend to have a low emittance. This results in very high surface temperatures. Metal roofs are available with a pigmented polymeric coating, similar to paint, which is factory applied. This coating increases the emittance of the roof and produces a solar reflectance nearly as high as the thicker white coatings applied on-site.
- Roofing Tiles: The typical tiles are either ceramic or cement concrete and are available in a wide range of colors. In general, tile roofs tend to be cooler because of the enhanced air circulation inherent in their installation. Reflectance values for roofing tile range from 18 to 74 percent, depending on the color.
- Green Roofs: Green roofs, also called living roofs or eco-roofs, are complete roof systems of vegetation, soil, drainage, and a waterproof membrane. They can range from very lightweight systems with as little as one to one half inches of soil and low succulent plantings, to deeper heavier systems that support a wide variety of plantings. Because of their water-holding capacity and the presence of vegetation, these roofs have lower solar absorptance properties than most conventional roofs, which essentially keep the roof cooler, resulting in lower energy bills.

EMERGING TRENDS

Developing cool roofing materials for residential buildings poses particular challenges. Most homeowners do not want white roofs on their homes. Most commercially available roof shingles are optically dark. Their reflectances range from 5 to 25 percent. One statistic in an article by Lawrence Berkeley National Lab's Environmental Energy Technologies Division (EETD) states that asphalt shingles account for half of the residential roofing market in the Western states. EETD is working with industry partners to develop cool-colored roofing products for residential applications. According to EETD, "the solar reflectance of commercially available clay and metal products has increased from the 5 to 25% range to the 30 to 45% range" since the start of its research in this field.

What are relevant resources for **Cool Roofs?**

- Energy Star Cool Roofs Program: www.energystar.gov/
- Cool Roof Rating Council (CRRC): www.coolroofs.org/
- Cool Colors Project: Improved Materials for Cooler Roofs: eetdnews.lbl.gov/
- The Internal Revenue Service currently provides a tax credit for Energy Star metal roofing products. Visit the Energy Star Web site for more information.

Which strategies interact with **Cool Roofs?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Orientation
» Life Cycle Assessment
» Sun Shading

What are Deconstruction and Salvage Materials?

The term "deconstruction" refers to the process of taking a building apart piece by piece with the intent of recycling or salvaging as many of the building materials as possible. Because of a heightened awareness of environmental issues and green building techniques and the increasing costs of disposing construction waste, deconstruction is becoming more and more popular.

There are numerous benefits of deconstructing a building and salvaging the materials. Below are just a few:

- The amount of solid waste deposited in landfills is reduced. Construction and demolition waste accounts for up to 20 percent of the solid waste stream.
- Salvaged materials are given new life.
- The need for virgin resources is decreased.
- The energy and emissions resulting from refining, manufacturing, and transporting materials are reduced, thereby reducing embodied energy costs.
- New jobs are created. Three to six workers are needed compared with one worker for comparable demolition jobs.

Although deconstructing a building takes more time and money than traditional demolition, costs can be offset by

- Reusing materials that are salvaged
- Selling salvaged materials
- Donating materials, resulting in tax write-offs
- Avoiding tipping fees

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

- Reduce the overall energy use in your building
- Not applicable
- Specify energy-efficient equipment and technologies
- Reusing building materials results in a reduction of energy used to manufacture and transport new materials.
- Use renewable strategies and purchase green power
- Not applicable
- Educate building owners, operators, and occupants
- Specify deconstruction in construction documents and provide participants with contacts and resources for deconstruction and salvaged materials.

Bear in mind that the deconstruction process may need to address hazardous building material (e.g., asbestos, lead-based paint) disposal issues, which should be taken into consideration at the outset. Typically, deconstruction contractors will abate such conditions first, and then proceed with deconstruction work. Associated costs will affect the overall project budget and schedule.

How do I apply Deconstruction and Salvage Materials?

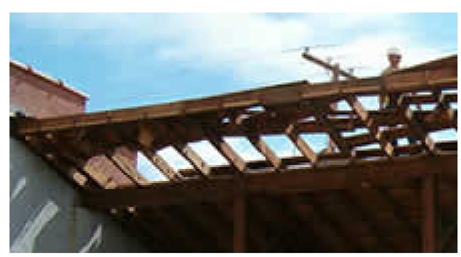
ESTABLISHED TECHNIQUES

There are two basic methods of deconstruction: structural and nonstructural. Nonstructural deconstruction is also referred to as "soft-stripping." It includes reclaiming components such as appliances, doors, windows, and finish materials. Structural deconstruction refers to the removal of building elements such as structural brick, stone, and lumber. Brick and stone actually have a long tradition of reuse, which has seen resurgence because of increased environmental awareness. Even low-end products such as dimensional lumber have become part of this trend.

A number of steps can be taken to aid in the successful completion of a deconstruction project. First, make a list of the local contacts that take used materials, such as architectural salvage businesses, reclamation yards, not-for-profit salvage yards, and dismantling contractors. Next, identify hazardous materials, such as lead and asbestos, in the building. Contact the appropriate remediation companies for advice on when and how to schedule removal of these items. Soft-stripping the building is the next step. Remove all the appliances, windows, doors, hardware, etc. After the nonstructural deconstruction is complete, the building can be dismantled. This usually happens from the roof down. Finally, build an inventory list to manage the products. Note the quantity of each material removed; whether it will be recycled, salvaged, or disposed of; and who will remove each.

EMERGING TRENDS

A major trend in deconstruction is to use more of the building materials than were historically used. In the past, only stone and brick were consistently salvageable. Now, everything from appliances to wood flooring and trim to dimensional lumber is being reused.



Another trend is to design for deconstruction. When architects and builders are still in the design phase, they may choose materials and construction methods that will make deconstructing the building easier and more efficient in the future. Techniques include

- Employing simpler construction methods combined with more durable materials that are less likely to be damaged while in use and in the deconstruction process
- Making components separable by using mechanical fasteners, such as bolts, instead of nails or screws
- Using standardized materials and assembling them in a consistent manner throughout the building
- Avoiding hazardous materials
- Using similar grade materials throughout the project

Green building programs and local jurisdictions are beginning to incorporate deconstruction and the use of salvaged materials into their compliance programs. For example, the U.S. Green Building Council's LEED (Leadership in Energy and Environmental Design) program gives participants credit for diverting waste from the waste stream, reusing building shells, using salvaged materials, and recycling deconstructed building components.

Along with the growth in the use of salvaged materials is a parallel growth in the construction salvage industry. New companies that specialize in deconstruction recovery and reuse can be found by searching the Internet and in most green building and materials guides.

What are relevant resources for Deconstruction and Salvage Materials?

- Building Materials Reuse Association's (BMRA): www.buildingreuse.org/
- The ReBuilding Center: www.rebuildingcenter.org/
- Reuse Development Organization (ReDO): www.redo.org/
- Deconstruction Institute: www.deconstructioninstitute.com/

Which strategies interact with Deconstruction and Salvage Materials?

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Life Cycle Assessment
» Material Selection and Embodied Energy
» Renewable Energy Resources

15 Daylighting

What is Daylighting?

Daylighting is a design strategy that employs the available daytime exterior light to illuminate the interior of buildings. Appropriately designed daylighting brings daylight into the interior space without introducing unwanted glare and heat gain. Studies have shown the value of incorporating daylight into spaces for improved productivity and improved satisfaction with the work environment.

The additional advantage of daylighting spaces is the corresponding reduction in the need for electric lighting during daytime hours. Daylight sensors reduce the light output from the electric lighting system proportionally to the amount of daylight available to maintain a uniform light level throughout the day, saving a significant amount of energy consumed by the building. The amount of daylight is optimum at the time of day when the demand for electrical energy is greatest, resulting in peak demand reduction and substantial energy cost savings.

Further, green building rating systems provide incentives to incorporate daylighting into buildings.

How do I apply Daylighting?

Properly applied, daylighting does not allow the sun to directly enter a space. Top lighting and side lighting are the two primary daylighting design strategies. Top lighting involves letting light in through glazed openings in the roof, such as clerestories, skylights, atria, and monitors, and is usually limited to the top floor of a building. Top lighting openings are often provided with shades, blinds, and other forms of light-blocking devices for times

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- Employing daylighting strategies, along with occupancy and daylight sensors, will reduce the overall energy use, allowing various building systems (i.e., HVAC) to be reduced in size and cost to make way for further energy-saving materials, designs, and technologies.

Specify energy-efficient equipment and technologies.
- Use an integrated system approach to spec out the most cost-effective combination of daylighting and efficient artificial lighting systems.

Use renewable strategies and purchase green power.
- Daylighting in conjunction with energy-efficient lighting equipment with effective lighting controls can reduce a building's overall energy load, require smaller and more cost-effective renewable strategies, and reduce emissions.

Educate building owners, operators, and occupants.
- Educate them on function and operations of installed technology so they can properly use daylighting controls

when daylight is too bright for the functions to be performed in the space. Side lighting involves admitting light through windows and courtyards. Light shelves are devices that direct reflected daylight farther into a space than would occur just from the light entering the window. The light shelf sits above the view windows and throws daylight off a highly reflective ceiling so that occupants in the space away from windows can benefit from daylight. Side lighting can be applied to multiple floors of a building with the correct exposure and orientation. Light shelves can be either exterior or interior mounted or may be a combination of both. Note that in spaces where the suspended acoustical ceiling is eliminated in favor of a higher, brighter hard ceiling, acoustical problems can result from the lack of sound-absorbing material in the space. Typically, exterior light shelves are not considered for buildings in parts of the country that have heavy snowfall.

Dimmable T5 or T8 fluorescent lamps powered by electronic ballasts controlled by photoelectric sensors are currently the best choice for incorporating daylighting into the electric lighting system. On–off switching of the electric lighting is disruptive to occupants, so proportional dimming provides an even illumination level whether it is a bright sunny day or overcast.

Colors and finishes in a space should be bright to optimize daylight and minimize shadows.

ESTABLISHED TECHNIQUES

Using Daylighting Design Tools

Lightscape and Radiance are two of the leading design tools for modeling daylighting. With Lightscape, you can model your proposed daylighting and electric lighting design to render its relative brightness. Radiance was developed by Lawrence Berkeley Laboratories and is a rendering tool that also models electric lighting. Both tools are CAD-compatible. SkyCalc™ is a simple computer tool that helps building designers determine the optimum skylighting strategy that will achieve maximum lighting and HVAC energy savings for a building. Physical modeling in miniature is another away to quickly evaluate different geometries of daylight apertures on the spaces.

Roof monitors by Velux

Controls

Daylighting must be integrated into the electric lighting system with controls to prevent the electric lighting from being on at full power and brightness when the available daylight can provide all the ambient lighting a space needs. HVAC controls for areas of the building that have skylights, atria, and perimeter glass must be separate from HVAC controls for other parts of the building to compensate for overheating. Occupancy sensors can further reduce the power consumption of electric lighting systems by turning off lighting altogether when no one is in the space. Commissioning of daylight controls is highly recommended to ensure their proper operation over time.

Green Building Rating Tools

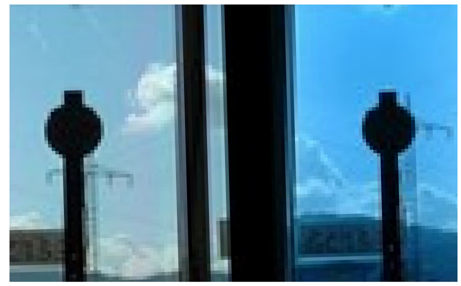
The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED®) rating system has specific requirements for daylighting to achieve a point in the "Indoor

Environmental Quality" category for incorporating daylighting into 75 percent of the spaces in a project. The GreenGlobes rating system by the Green Building Initiative also assigns points for daylighting based on using ASHRAE/IESNA 90.1-2004 to reduce loads on energy-using systems by using daylighting strategies, reducing electric lighting demand, and using daylight controls. An efficient artificial lighting system reduces the overall energy use in a building, which helps meet energy performance goals.

EMERGING TRENDS

Smart daylighting controls that interact with building automation systems for automated energy use optimization and comfort adjustments

New glass technologies that change optical and thermal characteristics of glazing, such as gas fill between glass layers and switchable optics that have dynamic optical properties subject to changes in light, temperature, or photoelectric conditions



Switchable glazing by Fraunhofer ISE

What are relevant resources for Daylighting?

- Federal Green Construction Guide for Specifiers
  Windows: www.wbdg.org/design/greenspec.php
  Lighting: www.wbdg.org/design/greenspec.php
- Whole Building Design Guide, Resource Pages, Daylighting, Gregg D. Ander, FAIA,
- Southern California Edison: www.wbdg.org/design/daylighting.php
- Whole Building Design Guide, Resource Pages, Electric Lighting Controls, David Nelson, AIA, David Nelson & Associates: www.wbdg.org/design/electriclighting.php
- Executive Order 13423 Technical Guidance, Daylighting: www.wbdg.org/sustainableEO/mou_daylight.php
- ASHRAE/IESNA 90.1-2004, Energy Standard for Buildings, Except Low-Rise Residential Buildings
- Moore, Fuller. Concepts and Practices of Architectural Daylighting, John Wiley & Sons Inc., June 1997

What strategies interact with Daylighting

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Orientation
» Efficient Artificial Lighting
» Open, Active, Daylit Spaces
» Smart Controls
» Windows and Openings

What is Earth Sheltering?

Earth-sheltered building enjoyed a wave of popularity as a result of the 1950–1960 perception of protection from nuclear attack, and then again during the 1970–1980 energy crises. However, this is not a new concept. Archeological evidence tells us that prehistoric mankind enjoyed the comforts and security of ready-made cave dwellings for thousands of years. Later civilizations all over the world carved dwellings out of already existing natural formations, often as defensive measures, sometimes originating as burial crypts, but later evolving into living and working spaces. Bernard Rudofsky, in Architecture Without Architects, calls this "architecture by subtraction."

In more modern times earth-sheltered structures have/are being used for:

- Vast storage warehouses and manufacturing facilities
- Missile silos and staffed underground control
- Military installations
- Houses
- Offices

Modern technology, materials, and construction methods have made earth-sheltered structures potentially more economically feasible to build and maintain, and to be more comfortable.

Pros for earth-sheltered buildings are:

- Ease of thermal comfort control due to constancy of the earth's temperature and lack of wind
- Relative physical security against violent weather, fire, and explosion
- Economic benefit because of extraordinary durability and lower maintenance costs over the life of the structure

The NOAA Satellite Operations Center will house current and future environmental satellite operations of national and global significance. The low-impact earth-sheltered building is in keeping with the scale of surrounding structures and has a green roof design that merges with the landscape

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted in order to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building

- Design the earth-sheltered building to reduce overall energy use over its life cycle.
- Specify energy efficient equipment and technologies

As for any other structure:

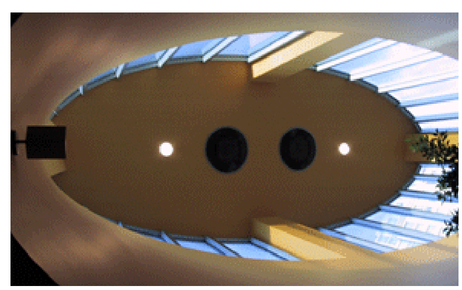
- Use renewable strategies and purchase green power
- Use the earth-sheltered building to introduce thermal solar energy strategies.
- Educate building owners, operators, and occupants on how to operate and maintain building systems.

- Energy efficiency because of massive super-insulated earth surround:
  - heating needs might be satisfied by internal heat generation—people, lights, plug loads, cooking
  - electric cooling may be unnecessary because of the limited exterior thermal and solar exposure
- Acoustic isolation from neighbors and surrounding environmental noise sources

Cons against earth-sheltered buildings are:
- Lack of readily available daylight if totally underground
- Occupant psychological fear of being "buried" and discomfort with being below grade
- Initially higher first cost of the well-built comfortable earth-sheltered structure
- Potential for dampness and water problems in less than ideal site and soil conditions
- Building officials and neighbor resistance
- Building code compliance—fire and smoke mitigation in case of fire and emergency egress issues
- Ventilation issues

How do I design for **Earth Sheltering?**

Investigate passive solar, daylighting, sun shading, landscaping, and natural ventilation strategies to optimize use of the natural features of the site to maximize energy efficiency. These three building techniques or combinations are most often considered for earth sheltered structures:
- Benching: cutting or stepping into a slope to create building terraces or trenches
- Berming: piling of earth against the enclosing walls
- Excavating: total or partially digging into the earth



top: The Coal Harbour Community Center, by Henriquez Partners, is located beneath a landscaped park in a dense urban redevelopment area in Vancouver, British Columbia. right: Light wells bring daylighting into the interior

Site Design Considerations

- Site the building to take advantage of natural site features such as topography, sunlight, and breezes to develop the most energy-efficient and cost-effective design
- Consider siting the building to enhance views for occupants directed down slope toward a nearby natural feature if the building is cut into a natural (or manmade) slope
- Use the earth form to deflect harsh winter winds
- Use landscaping features and earth berms to channel and direct natural breezes
- Consider building orientation if the structure is partially below earth for solar heat gain
- Conduct geotechnical surveys to determine soil and subsurface rock and water conditions
- Elevate a rock layer to determine floor level and extent of earth embedment
- Elevate groundwater level to determine how suitable the site is for an earth-sheltered structure


A sensitive restoration and earth-sheltered addition to the Virginia State Capitol Building, designed by RMJM Hillier. The original architect of the Virginia State Capitol was Thomas Jefferson

Earth-Sheltered Building Design

- Maximize daylighting to occupied spaces using light wells, atria, clerestories, and/or light pipes that follow the sun
- Consider using an open courtyard or enclosed atrium for daylight, solar heat gain, access to outdoor space from subgrade level(s), and natural ventilation.
- Consider thermal solar design strategies to take advantage of the inherent mass of the surrounding earth construction
- Design earth-sheltered building systems to protect occupants from water penetration and dampness:
- Enable subsurface water to migrate away from the structure.
- Divert surface water flow away from the earthen roof cover of the building if on a slope.
- If the building is buried in a flat site create a mild slope over the roof to divert stormwater.
- Earth removal costs can be increased substantially if excavated material is wet.
- Design supports for roof structure for functional column spans and distances from side walls. Also consider that the dead load of wet earth is considerably greater than for dry earth
- Consider using earth berms to shelter partially buried walls with conventionally designed roofs.
- Consider use of stack ventilation strategies to provide natural ventilation to conserve energy.
- Consider using ground source heating and cooling (if needed
- Use light shelves on windows to increase daylight penetration into the interior.

ESTABLISHED TECHNIQUES

- Design the earth-sheltered building and set its orientation to enhance daylighting and views
- Use daylighting strategies to reduce the need for electric lighting in the earth-sheltered building
- Emphasize design to enhance the physiological well-being of the building occupants

EMERGING TRENDS

- Use of electronic modeling and simulation software to predict effects of totally buried or partially buried earth sheltered design alternatives
- New fluid and adhesive-applied waterproofing membrane technologies

What are relevant resources for **Earth Sheltering?**

- *Gentle Architecture,* Malcolm Wells, 1981, McGraw-Hill.
- *Building Underground, The Design and Construction handbook for Earth-Sheltered Houses,* Herb Wade, 1983, Rodale Press
- *Underground,* David Macaulay, 1976, Houghton Mifflin Company.
- *Architecture Without Architects,* Bernard Rudofsky, 1964, Doubleday & Company Inc.; originally published by the Museum of Modern Art in conjunction with the exhibition *Architecture Without Architects,* November 9, 1964 – February 7, 1965.
- Research Web site at the University of Minnesota, the Underground Space Center; www.buildingfoundation.umn.edu/
- *Underground Architecture,* Sterling, Raymond. Underground space design / designed and illustrated by John Carmody; Underground Space Center, Department of Civil and Mineral Engineering, University of Minnesota. 1993.
- For an extensive bibliography of earth-sheltered building resources access, visit www.loc.gov/rr/scitech/tracer-bullets/undergroundtb.html#addinfo

What strategies interact with **Earth Sheltering?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Active Solar Thermal System
» Building Form
» Building Orientation
» Daylighting
» Energy Modeling
» Geoexchange
» Green Roofs
» Integrated Project Delivery
» Mass Absorption
» Natural Ventilation
» Passive Solar Collection Opportunities

17 Efficient Artificial Lighting

What is Efficient Artificial Lighting?

Artificial lighting is lighting produced by electrical generation. Efficient artificial lighting produces the optimum lighting level for the task while using a minimum amount of electrical energy. For both residential and commercial buildings, electric lighting can account for a significant part of the building's total energy bill. For office buildings, 30 percent of the energy used is for lighting—more than any other end use. According to the Environmental Protection Agency, if just one room in every U.S. home were switched to Energy Star qualified efficient lighting, carbon dioxide emissions would be reduced by over 1 trillion pounds over the life of the fixtures and bulbs.

The primary goal for efficient artificial lighting is to provide the recommended lighting level for the task while using the least amount of energy. In the past, general illumination levels were high, but with a better understanding of lighting design, general or ambient lighting levels are now lower, with more emphasis on lighting the task, whether it be assembling electronic components, reading a book, or working at a desk in front of a computer.

In addition, the use of lighting controls has grown significantly, further reducing the energy consumed by artificial lighting by turning it off when not needed or reducing the lighting level to compensate for the availability of daylight.

The Energy Policy Act of 2005, green building rating systems, and standards such as ASHRAE/IESNA 90.[1] have provided guidance and incentives to incorporate efficient artificial lighting systems into buildings.

[1] American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE); Illuminating Engineering Society of North America (IESNA)

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.

- Employing daylighting strategies, along with occupancy and daylight sensors, will reduce the overall energy use, allowing various building systems (i.e., HVAC) to be reduced in size and cost to make way for further energy-saving materials, designs, and technologies.
- Specify energy-efficient equipment and technologies.

Use renewable strategies and purchase green power.

- Using energy-efficient lighting equipment with effective lighting controls can reduce a building's overall energy load, require smaller and more cost-effective renewable strategies, and reduce emissions.

Educate building owners, operators, and occupants.

- Provide information on function and operations of installed technology so they can properly use lighting controls.

How do I apply Efficient Artificial Lighting?

The most efficient artificial lighting is the one that is not turned on. Optimize daylighting to minimize the amount of time the electric lighting is on. Light-colored walls, ceilings, and floors do a better job of reflecting light, including natural daylight, reducing the need for electric lighting. For residential applications, choose compact fluorescent lamps (CFLs) instead of incandescents for which 90 percent of energy is wasted as heat. Also, choose Energy Star fixtures for validated energy savings. Although CFLs cost more than incandescents, they last as much as 13 times longer and use 75 percent less energy.

For commercial buildings, use high-efficiency fluorescent lamps and fixtures powered by electronic ballasts. Apply daylighting strategies and incorporate both daylighting and occupancy sensor controls into the design to minimize the time the electric lighting is on. Lower electric lighting loads can reduce the size of air-conditioning equipment needed to offset the heat generated by the lamps and ballasts. Lighting controls help save energy, meet green building ratings, and comply with energy codes. Today, the most efficient fluorescent lamps are T5 and T8. Both of these have a reasonably good color rendering index (CRI) of 75 to 98.

Some artificial lighting strategies that can be easily applied to most projects include:Avoiding incandescent lights

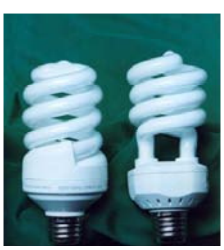
- Using light-emitting diode (LED) exit signs
  Efficient Artificial Lighting
- Reducing the general illumination level by employing task lighting
- Incorporating daylighting and daylight controls into the lighting design
- Using dimming or step ballasts for energy savings when full light level is not required
- Matching the amount and quality of light to the function to be performed
- Switching lighting for perimeter zones to be separate from interior zones
- Specifying higher efficacy light sources to produce more light with lower energy consumption
- Specifying a CRI of 80 or higher for home and office environments

Wall-mounted lighting controls by WattStopper

ESTABLISHED TECHNIQUES

Using Lighting Design Tools

Lumen Designer (formerly Lumen-Micro) and LightScape Model are two of the leading lighting design tools available. Lumen Designer has a user-friendly interface that creates all levels of architectural spaces quickly and accurately. With LightScape, you can model your proposed lighting design to render its relative brightness. Both tools are CAD-compatible.



Compact fluorescent lamps (CFLs)

Lighting Power Density

IESNA has developed an interactive methodology for determining lighting power densities for both individual spaces and whole buildings. This methodology is the basis for the lighting power density numbers found in the ASHRAE/IESNA 90.1-2004

Standard. For example, using direct–indirect pendant-mounted fluorescent fixtures, uniformly generated artificial light with minimal glare can be achieved with as little as 0.8 watts per square foot.

Green Building Rating Tools:

The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED®) rating system has specific requirements for energy cost savings to achieve points in the "Optimize Energy Performance" category. Projects are required to achieve at least two points in this category. Additional points can be gained in the "Indoor Environmental Quality" category for incorporating daylighting into 75 percent of the spaces in a project. The GreenGlobes rating system by the Green Building Initiative also assigns points for energy efficiency based on meeting or exceeding the Environmental Protection Agency's Target Finder performance target of 75 percent. An efficient artificial lighting system reduces the overall energy use in a building, which helps meet the LEED and GreenGlobes energy performance goals.

EMERGING TRENDS

The recent advancements in LED technology will lead to a revolution in lighting systems over the next decade or so. Although currently used in exit signs, traffic lights, and automobile taillights, LED-based lighting fixtures may eventually replace fluorescent and high-intensity discharge (HID) lighting systems for general illumination and task lighting. Even in these somewhat limited applications, LEDs already save the country 9.6 terawatt-hours of electricity a year according to the U.S. Department of Energy. LEDs produce less heat and take longer to burn out and their color rendition is improving.

Philips Lumileds Luxeon® LED

What are relevant resources for **Efficient Artificial Lighting?**

- Energy Policy Act of 2005 (PDF 1.9 MB, 550 pgs)
- Federal Green Construction Guide for Specifiers
  26 50 00 (16500) Lighting.
- Whole Building Design Guide, Resource Pages, Electric Lighting Controls, David Nelson, AIA, David Nelson & Associates: www.wbdg.org/design/electriclighting.php
  Whole Building Design Guide, Resource Pages, Energy Efficient Lighting, David Nelson, AIA, David Nelson & Associates: www.wbdg.org/design/efficientlighting.php
- ASHRAE/IESNA 90.1-2004, Energy Standard for Buildings, Except Low-Rise Residential Buildings
- IESNA, Lighting Handbook, 9th ed., 2000

Which strategies interact with **Efficient Artificial Lighting?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Orientation
» Daylighting
» Energy Modeling
» High-Efficiency Equipment
» Life Cycle Assessment
» Open, Active, Daylit Spaces
» Windows and Openings

18 Efficient Site Lighting Systems

What are Efficient Site Lighting Systems?

Efficient site lighting systems provide the necessary level of light for visibility and safety while minimizing the amount of energy used to generate the lighting. Site lighting should direct the appropriate amount of light on the surface without contributing to glare and light pollution. Site lighting serves to provide a visually pleasing effect on walkways and building façades, as well as providing a safe nighttime environment for pedestrians to walk in and people to travel from their offices to their vehicles in the parking lot. Site lighting should be sensitive to the natural environment and should not disturb the nocturnal habits of wildlife. For instance, lighting levels in rural areas and parks should be lower than those in suburban and urban areas. In downtown areas and shopping centers, site lighting is an aesthetic element meant to attract nighttime shoppers and diners.

The most efficient form of lighting, low-pressure sodium, in great use for decades, has begun to wane. Its color rendition is so poor that it is difficult to find your car in a parking lot. Today's high-intensity discharge (HID) and fluorescent luminaires for exterior lighting are efficient and have significantly better color rendition. These luminaires are powered by high-efficiency electronic ballasts.

How do I apply Efficient Site Lighting Systems?

Efficient site lighting systems shine light on the area that needs to be lit without wasting energy or producing unusable light and glare. This is accomplished by using full cutoff luminaires that do not shine any light above the horizon line. Shorter poles and landscape lights produce light nearer to the ground, thus

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- Whenever possible, choose conserving systems and equipment with high-efficiency standards that support a whole-building design strategy and a reduction in overall emissions.

Specify energy-efficient equipment and technologies.
- Use an integrated system approach to spec out the most cost-effective, energy-efficient equipment and technologies that can include efficient artificial lighting systems.

Use renewable strategies and purchase green power.
- Using energy-efficient site lighting equipment with effective lighting controls can reduce a building's overall energy load, require smaller and more cost-effective renewable strategies, and reduce emissions.

Educate building owners, operators, and occupants.
- Provide information on function and operations of installed technology.

minimizing glare and light pollution. Tall lighting poles are to be used primarily for parking lots where multiple luminaires are mounted on a single pole to reduce the number of poles needed. Typically, full cutoff luminaires use flat glass lens rather than dropped refractors.

Efficient site lighting systems must provide uniform illumination levels so that steps, curbs, and obstacles are not hidden in shadows. Design lighting controls into the project to turn off exterior lighting when the area is unoccupied overnight or after closing time.

ASHRAE/IESNA 90.1-2004[1] provides requirements for exterior lighting, including façades, architectural features, entrances, exits, loading docks, and illuminated canopies, as well as exterior building grounds provided through the building's electrical service. The standard also has provisions for exterior lighting controls to turn off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours.

[1] American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE); Illuminating Engineering Society of North America (IESNA)

ESTABLISHED TECHNIQUES

Sidewalk bollard light by Hadco

Minimize Light Pollution

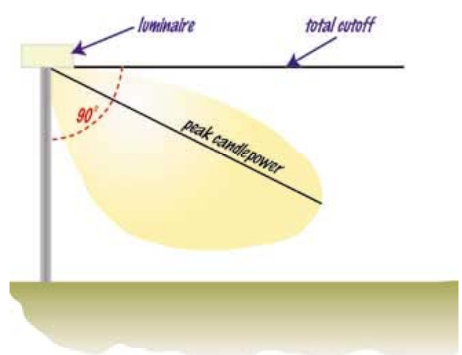
The International Dark Sky Association defines light pollution as any adverse effect of artificial light, including sky glow, glare, light trespass, light clutter, decreased visibility at night, and energy waste. Minimize light pollution by employing full cutoff luminaires that shine light downward, not overlighting. Light building façades from above, not below. Calculate the lumens needed to achieve the required average illuminance. Use low-level landscape lighting on bollards to light walkways. Is exterior lighting needed? The most efficient lighting system is the one that does not exist or is turned off when not needed.

Consider Solar-Powered Lighting

Solar-powered, battery-charging luminaires are available for street and area lighting. They are off the grid and ideal for remote areas where trenching for interconnecting power wiring can be harmful to the environment.

Green Building Rating Tools

The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED®) rating system includes credit for eliminating light trespass from the building and site. The credit includes the requirement that exterior luminaires with more than 1,000 initial lamp lumens are shielded, and all luminaires with more than 3,500 initial lamp lumens meet the full cutoff IESNA Classification. LEED Sustainable Site Credit 8 has specific requirements to be met based on the specific zone, from wilderness and state parks to city centers. The requirement is not just for parking lots; it is also for landscape lighting and building façades. The GreenGlobes rating system from the Green Building Initiative also has points under site design related to site development for minimizing the obtrusive aspects of exterior lighting, including glare, light trespass, and sky glow.



Full cutoff luminaire illustration

A car dealership parking lot in Calgary. Half ofthe fixtures are turned off after closing.

EMERGING TRENDS

The use of lighting controls for exterior lighting is gaining acceptance. For buildings that are normally only occupied in the daytime, a significant amount of energy is wasted by lighting the parking lot all night. For safety reasons, parking lots should not be totally dark, but should maintain a low level of illumination. Also, HID lighting must have a warm-up time of up to several minutes; therefore, they cannot be turned off completely. Lighting controls are now available that sense when someone enters the parking lot and raise the lighting level to full brightness for a period of time. If no motion is detected after a preset time, the parking lot lights will return to the lower light level. Lowering site lighting levels reduces light pollution and minimizes energy consumption.

Light-emitting diode (LED) lighting for building façades and streetlights are used by major retailers such as Wal-Mart to light building façades and signage. The added benefit of LEDs is their exceptionally long life that minimizes the labor needed to replace burned out lamps. Ann Arbor, Mich., will be the first U.S. city to convert all downtown streetlights to LED technology. Ann Arbor's lighting conversion will reduce the city's production of carbon dioxide and gases that contribute to global warming in an amount equal to taking 400 cars off the road for a year.

What are relevant resources for Efficient Site Lighting Systems?

- Energy Policy Act of 2005 (PDF 1.9 MB, 550 pgs)
- Federal Green Construction Guide for Specifiers 26 50 00 (16500) Lighting: www.wbdg.org/design/greenspec.php
- International Dark Sky Association: www.darksky.org/
- IESNA, Recommended Practice Manual: Lighting for Exterior Environments, RP-33, 1999
- Lighting Research Center, Outdoor Lighting: www.lrc.rpi.edu/researchAreas/outdoor.asp

Which strategies interact with Efficient Site Lighting Systems?

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Orientation
» High-Efficiency Equipment
» Life Cycle Assessment
» Smart Controls
» Walkable Communities

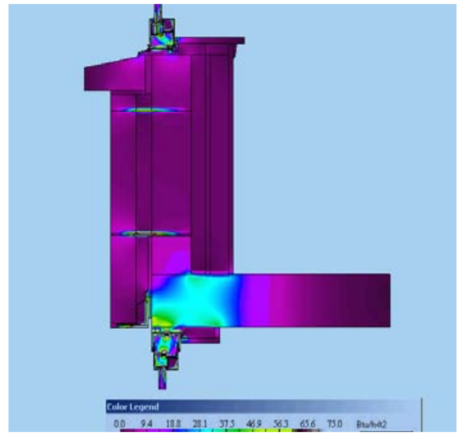
19 Energy Modeling

What is Energy Modeling?

Energy modeling, or simulation, is the practice of using computer-based programs to model the energy performance of an entire building or the systems within a building. This whole-building modeling provides valuable information about the building and system energy use as well as operating costs.

Whole-building simulation is typically performed for an entire year using typical meteorological year weather data. An important aspect of whole-building modeling is that it accounts for the interaction between different elements of the building, such as the impact of lighting on space conditioning loads or the impact of daylighting on electrical lighting loads. The impact of different building uses and occupancy patterns is also accounted for. The most common whole-building simulation tool for larger commercial buildings is DOE-2, which was originally developed by the U.S. Department of Energy and is now the basis for many other tools. For small commercial buildings, the National Renewable Energy Laboratory (NREL) developed Energy-10. Commonly used residential building simulation tools are REMRate, EnergyGauge, TREAT, and Micropas.

In addition to whole-building modeling, the energy performance of individual systems may be modeled for a short-term or design condition. Software programs such as THERM can perform heat transfer analyses using the finite element method to evaluate thermal bridging in a wall detail and a whole-wall R-value. Daylighting modeling tools such as Radiance can simulate the performance and impact of daylighting strategies for a specific space. The specific findings from these programs can then be integrated into the whole-building simulation.


THERM analysis of a curtain wall detail

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible lines of attack. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.

- The proper use of energy modeling throughout the building design process will inform the decision-making process on the energy use implications of various alternative design choices. This will result in a building that has been optimized to reduce energy loads and thus energy requirements.

Specify energy-efficient equipment and technologies.

- Energy modeling provides the opportunity to evaluate the annual impact on energy use and operating costs of different types of equipment and systems with different efficiencies.

Use renewable strategies and purchase green power.

- Many energy-modeling tools can simulate the performance of renewable energy strategies, such as waste heat recovery, solar thermal systems, and solar electric systems.
- Using modeling to optimize the energy performance of the building will reduce the expense of purchasing green power, which is typically more per kilowatt-hour than the standard electricity price.
- Using modeling can help reduce peak time energy demand and thus reduce peak power demand pressure on utilities and resulting carbon emissions.

Educate building owners, operators, and occupants.

- Not applicable

How do I apply Energy Modeling?

Energy modeling can and should be used throughout the design process to optimize the building design for energy performance and reduced carbon emissions. Energy modeling has been applied to building design for decades, but with the advancement and proliferation of computers and the increased emphasis on building operating costs, the use of modeling is more common and often required. It is a valuable tool to assist architects in assessing the impact of various design decisions.

The size, complexity, and potential types of mechanical systems will affect which of the many modeling tools is most appropriate for the project, and the tool may change from one design phase to the next. Thus, it is beneficial to have someone in-house or as a consultant who is familiar with the alternative simulation tools and knows their capabilities in terms of such variables as the number of floors, the number of zones, the ability to define schedules, and the mechanical equipment options. Using a tool that can handle large complex buildings for a simple building can result in a waste of time and expense. Tools have been developed, such as Energy-10, specifically to model smaller buildings. Alternatively, the time and expense to develop a model for a building only to learn late in the process that it cannot model the type of mechanical system that is being proposed by the mechanical / electrical / plumbing firm is also a wasted effort.

There is a cost associated with energy modeling, and it varies with the complexity of the building. A speculative developer may find it difficult to bear costs that will accrue savings to the future building owner in the form of reduced utility bills. However, this should be presented as a feature of the building and worthy of a price premium. The building will also be more comfortable and perform more reliably. In many instances, the cost of modeling can be recovered through the elimination of unnecessary factors of safety, allowing credit for specification trade-offs, and/or qualifying for available incentives.

ESTABLISHED TECHNIQUES

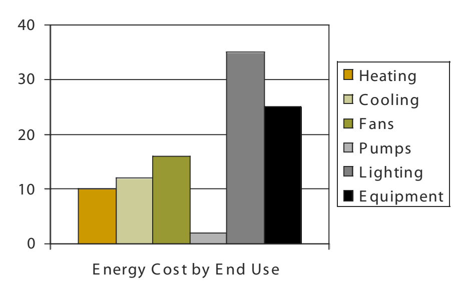
Energy modeling can be applied to various degrees in each phase of the design process.

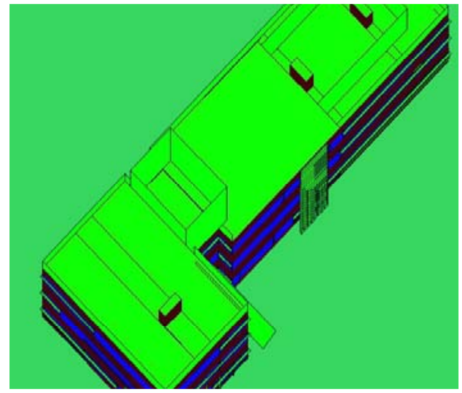
Conceptual Design

During conceptual design, a very simplified model that uses basic assumptions for many of the inputs can be used to examine large-scale impacts such as building configuration and orientation.

Schematic Design

At schematic design, a more detailed energy model is useful for identifying the primary energy uses. Understanding which loads (space heating, cooling, lighting, water heating, etc.) are dominant provides guidance on what aspects of the building design should be targeted for energy savings. The greater the energy use, the greater the opportunity for cost-effective energy savings. For instance, the designers could test alternative percentages of façade glass area on the principal orientations for energy and aesthetic implications.




modeled building geometry

Design Development

During design development, a detailed energy model should be used to conduct parametric analyses to evaluate alternative specifications and more fully understand the trade-offs between initial cost and life-cycle cost. The accuracy of the model is important at this stage; therefore, providing as much information as possible on the expected use and occupancy schedules of the building is important. The phrase "garbage in, garbage out" is particularly relevant to modeling at this stage. It is important to keep the modeler informed of all design and specification changes, and all model inputs and assumptions should be carefully reviewed. For example, using a default 8-to-5 Monday–Friday operating schedule for an office facility that operates 24/7 would significantly underestimate the building's electricity use for lighting and equipment. Using the wrong glazing specifications could significantly affect the heating and cooling load predictions.

Construction Documents

At this phase, the energy modeling will be necessary to document compliance with codes such as the Energy Cost Budget method in the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1 or the Total Building Performance section of the IECC. In many instances, energy modeling is also necessary to demonstrate qualification for specific certification programs, such as Energy Star and the U.S. Green Building Council's Leadership in Energy and Environmental Design or incentives such as the federal tax credits.

EMERGING TRENDS

With the widespread use of computers, the use of energy modeling is common and expected. New tools and applications are being introduced all of the time.

EnergyPlus is one of the newest whole-building simulation tools. The Department of Energy has supported its development for several years as a replacement for DOE-2.1E. It was officially released in April 2001, but its lack of user-friendliness has limited its use to date.

Developing the input file for geometrically complex buildings can be time-consuming. Green Building Studio (GBS) is a relatively new tool that seamlessly links architectural 3-D CAD building designs with energy analysis. The GBS Web service automatically generates geometrically accurate, detailed input files for major energy simulation programs.

With the emergence of building information modeling (BIM), there is interest in integrating BIM and energy modeling. Most energy modeling is currently done independent of BIM because there are still significant limitations in BIM energy modeling capabilities. However, software developers are working to make it easier to derive the energy model from BIM.

What are relevant resources for **Energy Modeling?**

- Building Energy Software Tools Directory: www.eere.energy.gov/buildings/tools_directory/
- Radiance, developed by Lawrence Berkeley National Laboratory, available at no charge: http://radsite.lbl.gov/radiance/home.html
- Rosenbaum, Marc, Understanding the Energy Modeling Process: Simulation Literacy 101, The Pittsburgh Papers (2003).
- www.buildinggreen.com/features/mr/sim_lit_101.cfm
- http://windows.lbl.gov/software/therm/therm.html
- www.doe2.com
- www.nrel.gov/buildings/energy10.html

Which strategies interact with **Energy Modeling?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Form
» Building Orientation
» Daylighting
» Life Cycle Assessment
» Passive Solar Collection Opportunities
» Renewable Energy Resources
» Sun Shading
» Windows and Openings

20 Energy Source Ramifications

What are Energy Source Ramifications?

Buildings use energy. In fact, buildings account for about one-third of U.S. energy generated by fossil fuel resources. However, there are further fuel resources that are consumed by buildings. The inherent acts of construction, operations, and maintaining the infrastructure of buildings use energy. But at what cost? How does this affect us and the landscape around us? What can be done to mitigate our energy use?

Heating, Cooling, Lighting, and Power

The majority of building energy consumption is from the need to provide heating, cooling, lighting, and power distribution. Nearly all energy production for buildings, an estimated 96 percent, is generated off-site and transferred, shipped, or pumped to the building's locale. Of this off-site energy, an estimated 82 percent is derived from fossil fuel resources in the form of oil, natural gas, and coal. This energy production in the United States accounts for nearly 80 percent of air pollution, more than 88 percent of greenhouse gas emissions, and more environmental damage than any other human activity.

Climate Change

A recent study estimates that greenhouse gas emissions increased by an estimated 23 percent between 1987 and 1996 to 939 million tons. In 1996, 43 percent of the greenhouse gas emissions came from electricity generation, 20 percent from transportation, and 29 percent from mining, refining, manufacturing, and construction industries combined. The use of coal for electricity generation and heat production is the largest single source of carbon dioxide emissions in the United States, contributing a total of about 344 million tons of carbon dioxide in 1990, or about 28 percent of the carbon dioxide emitted.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
– The cleanest energy is the energy not used; design buildings to be as energy efficient as possible.

Specify energy-efficient equipment and technologies
– Work with your MEP to correctly size all equipment.

Use renewable strategies and purchase green power
– Specify equipment and technologies that use or are compatible with alternative and renewable energy.

Educate building owners, operators, and occupants
– Not applicable.

More than half the electricity generated in the United States is through the use of coal. Each megawatt-hour of electricity sourced from black coal–fired generators produces about 1,665 pounds of carbon dioxide, a major greenhouse gas.

Air Pollution

In 1992, power stations accounted for an estimated 35 percent of nitrogen oxide and 60 percent of sulfur dioxide emissions in the United States. Emissions from petroleum refineries account for about 37 percent of the volatile organic compounds emitted by major industrial and commercial sources. Trends in recent years show small increases in total emissions; however, there have been large reductions in particulate emissions because of the improvement in filter technology and reporting methods.

The impact of coal mining on the environment includes coal seam methane drainage into the atmosphere and dust created by mining operations. Energy industries incur significant operating and capital expenditures to reduce air and water emissions, translating into cost increases for the consumer.

Water Pollution and Waste

The production, transportation, and storage of fuels can have significant effects on surface and underground water bodies. There are concerns about the leaking of underground storage tanks, disposal of used transformer oil, and coal washery waste discharge (an estimated 89.2 million tons in 1995).

Habitat Disturbance and Aesthetics

The impact of coal mining on the environment includes disturbance from mining operations. Energy distribution systems for both electricity transmission lines and oil and gas pipelines can cause serious habitat disturbance and be aesthetically unpleasant. Electricity is transmitted and distributed via a large network of lines. An unfortunate result from off-site energy generation is the inefficiency of our transmission lines. Nearly one-third of energy produced is lost in transmission alone. The length of high-voltage lines increased by 39 percent from 1979 to 1995. Most lower voltage lines are also overhead, with an increase of 33 percent in the same time period. There is considerable community concern about the health and amenity impacts of high-voltage transmission lines. Discussion on electromagnetic fields and telecommunications cabling affecting the health of children living in close proximity continues in the court system.

Nuclear Electric

An estimated 22 percent of the U.S. electricity generated is from nuclear power plants. Emissions of these plants are much lower than those of fossil fuels; some studies report they are as much as 80 percent cleaner. Greenhouse gas and carbon dioxide are also greatly reduced. Debate continues over the disposal of the radioactive waste resulting from nuclear generation and perceived threat to neighbors. Mining and extraction of core radioactive fuel as well as transportation and storage continue to raise concerns.

Hydroelectric

Hydroelectric power accounts for approximately 10 percent of the U.S. electric generation. With few to no emissions resulting from power generation, hydroelectric facilities affect primarily their immediate surroundings. Damming requires a significant amount of land. This land acquisition displaces wildlife habitats, ecological diversity, and often watersheds, which inevitability affects local human development and resources. Flooding caused by hydroelectric generation creates concentrations of algae and decay from vegetation, resulting in limited greenhouse gas generation, but the most immediate hazard is the possibility of failure of the dam itself. Most of the negative environmental impacts of large-scale hydroelectric installations can be avoided by the installation of small-scale hydroelectric systems. Small-scale systems provide much less power (typically a single site up to a regional or provincial power grid) and require a sizable flow of water on-site to prove economically viable.

Wind

Although only an estimated 2 percent of the total electricity generated in the United States is from wind power, wind generation is gaining popularity, with nearly a 78 percent increase from 1998 to 2005. Inefficiency and noise pollution problems of older technologies have prevented installation of systems in the past, whereas current systems offer much improved solutions.

Solar

In the United States, less than 1 percent of electricity is generated using solar technology. With a huge surge in the mid-1970s, solar power had nearly vanished from the energy market in the United States until the late 1990s. With limited efficiencies, expensive up-front costs, large system requirements, and caustic battery storage systems, solar power appeared to be the last choice for energy needs. However, in light of current and future fuel circumstances, solar is much more attractive. Solar panels are lasting longer, performing better, and are often subsidized with tax incentives. The 1970 cost of a photovoltaic watt was $100; it is now close to $4.

Ethanol and Biodiesel

Ethanol and biodiesel are recent additions to the fuel market, with reports of a 40–60 percent reduction in emissions of nitrogen, hydrocarbons, and particulates. Studies have shown that biodiesel is as much as 72 percent “cleaner” than tradition petroleum diesel. Despite critics’ claims that corn-based ethanol is fundamentally a bust (i.e., that it takes more fossil fuel to produce than it displaces in the fuel tank), the majority opinion within academia and industry is that ethanol and biodiesel do result in net energy gains. Most skeptics concede that if the balance isn’t positive now, it will be soon. Alternatives to corn-based ethanol include sugarcane, wheat, cotton, and switchgrass. Other nations currently use these alternatives, and it will be informative to watch the potential for environmental and social disruption.

How do I design with **Energy Source Ramifications** in mind?

Energy consumption is directly related to the efficiency of a building's envelope and efficiency of mechanical systems. Design buildings with the following in mind:

- Where appropriate, use on-site energy-generation opportunities.
- Consider renewable energy sources as opposed to fossil fuel–derived energy.
- Appropriately insulate the building envelope to accommodate the local environment.
- Appropriately size, install, and commission building mechanical systems.
- Site the building correctly to reduce heating or cooling loads up to 20 percent.
- Explore building heat recovery systems, both mechanically and building-form based.
- Investigate purchasing green power of carbon offsets (power generated from cleaner, alternative fuel sources is available through the current electrical grid system).
- Purchase materials locally fabricated to reduce the energy requirements of transportation; look into recycled or reclaimed materials to reduce embodied energy.
- Purchase materials that are durable and require little maintenance.

What are resources relevant **to Energy Source Ramifications?**

- U.S. Department of Energy—Energy Files
- Energy Policy Act of 2005 (PDF 1.9 MB, 550 pages)
- Alliance to Save Energy
- U.S. National Renewable Energy Laboratory
- U.S. Green Building Council—Leadership in Energy and Environmental Design
- Sustainable Energy Coalition
- World Bank—Energy Projects
- The Energy Foundation

Which strategies interact with **Energy Source Ramifications?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Active Solar Thermal System
» Alternative Energy
» Efficient Artificial Lighting
» Environmental Education
» Life Cycle Assessment
» Passive Solar Collection Opportunities
» Renewable Energy Resources

What are Energy-Saving Appliances and Equipment?

Appliances and equipment used in buildings have a significant role in the overall energy usage, economics, and environmental impact of the structure. However, appliances and equipment usually need to be replaced during the useful life of commercial or residential buildings. For this reason it is vital to understand the importance of using energy-saving appliances and equipment for new construction, remodeling, or simply when it comes time to upgrade appliances and equipment in the building sector. The first step in the process is to look for efficiency standards of various products. Efficiency standards in the United States require some new appliances and equipment such as refrigerators, air conditioners, and electric motors to meet specific energy requirements. Over time older, less efficient products are removed from the market and replaced with more efficient models based on minimum-efficiency standards or better.

Minimum-efficiency standards for appliances and other equipment were adopted by the federal government in order to address market failures, replace various state standards, save consumers money, and reduce energy use and peak electrical demand. In the mid 80s, the National Appliance Energy Conservation Act (NAECA) established uniform national standards on an array of products. The Energy Policy Act (EPACT) of 1992 expanded the coverage to include certain commercial building equipment. The implementation of the energy efficiency standards in the United States through EPACT saved more than 88 billion kWh in the year 2000 alone. This equates to a savings of approximately 28 million tons of carbon dioxide and the further removal of additional sulfur dioxide, nitrous oxide, and carbon monoxide from the environment. Updates to these energy efficiency standards have been projected to a save more than 250 billion by the end the decade.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted in order to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- NA.

Specify energy efficient equipment and technologies
- Make certain to include energy saving appliances and equipment throughout the building specifications

Use renewable strategies and purchase green power
- NA

Educate building owners, operators, and occupants
- Provide regular training on the correct use and maintenance of appliances and equipment.

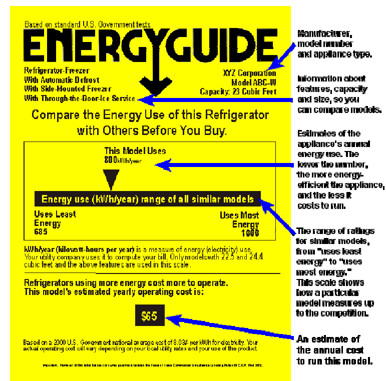
How do I apply **Energy-Saving Appliances and Equipment?**

Residential buildings account for around 20 percent and commercial buildings account for approximately 17 percent of the total energy consumed in the United States. Although energy-saving appliances and equipment may be more expensive to buy than comparable models with lower or average efficiencies, the payback period begins immediately with reduced energy bills that continue to pay you back long before the product wears out. Additionally, what is often overlooked when an individual is ready to buy an appliance or equipment is the operating cost of the product over its lifetime. Many consumers do not consider energy or water efficiency when making their purchases. The cost could be several times greater than the initial purchase price. The cost of using appliances and heating and cooling equipment in residential buildings, on average, cost more than $1,200 per year.

ESTABLISHED TECHNIQUES

Product Labels

A way to apply the use of energy-saving appliances and equipment is to look for the Energy Guide label or the Energy Star label on various products and equipment. The well-recognized Energy Guide label, developed by the U.S. Department of Energy, is required for most home- appliances. The label shows consumers a product's energy usage and operating cost as a way to compare different models in the marketplace. The Energy Guide label can also include the Energy Star label if a particular model qualifies. Created by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy, the Energy Star label helps individuals identify superior energy-efficient products such as appliances, computers, lighting, and home entertainment equipment that exceed the required federal energy standards.



Energy Guide label

According to the U.S. Department of Energy, space heating and cooling uses 46 percent of all energy consumed in U.S. residential buildings. Water heating accounts for an additional 14 percent. Total energy consumption for space conditioning in commercial buildings is 4.5 quadrillion Btu (quads) and commercial refrigeration accounts for 0.6 quads. In some commercial buildings, such as supermarkets, the percentage of energy consumed for refrigeration commonly approaches 50 percent. Thus looking out for the Energy Guide and Energy Star labeled products when you are ready to purchase or upgrade will go a long way in the reduction of energy usage and carbon emissions.

Energy Star label

Advancing Technologies

More than half of the total energy used for heating, cooling, ventilation, refrigeration, and water heating is electrical; and air conditioning is the single leading cause of peak demand for electricity. Advancing technology is the most obvious solution to reducing these loads. Reducing these loads can lower demand for annual power generation and peak capacity. Advanced technologies already have demonstrated success in increasing the energy efficiency of these vital building functions, without compromising occupant comfort or equipment performance. Here are just a couple of areas where advancing technology has taken hold:

- Energy consumption for all lighting in the United States is estimated to be 8.2 quads, or about 22 percent of the total electricity generated in the United States and represents one-fifth of the national electrical consumption. Compact fluorescent light bulbs use one quarter to one third as much electricity as incandescent lamps and last 10 times longer.
- Refrigerators account for 12 percent of U.S. residential energy use and water heaters for another 17 percent. But many of today's appliances are vastly more energy and resource efficient, such as Energy Star qualified refrigerator models that use at least 15 percent less energy than required by current federal standards and 40 percent less energy than the conventional models sold in 2001.

- The average home has roughly two TVs, a VCR, a DVD player and three telephones. Replacing these items with more energy-efficient models that are currently in the marketplace today not only save money of the life of the equipment but could save more than 25 billion pounds of greenhouse gas emissions, the equivalent to taking more than 3 million cars off the road.
- The U.S. Department of Energy reports that an estimated 3.3 quads of energy can be saved through continued improvements in component technologies. This savings is equivalent to 1.6 million barrels of oil per day. Additional improvements can be realized through improved systems approaches leading to more optimal integration of heating, cooling, and ventilation functions within the whole building design.

EMERGING TRENDS

With the ever-increasing global demand for energy, energy-saving appliances and equipment will continue to be an important factor for whole-building system design, construction and/or upgrade. Groups like the American Council for an Energy Efficient Economy (ACEEE) continue to strongly urge the advancement of policy and technology for energy-saving appliances and equipment. Some of ACEEE's current recommendations are as follows:

- Adopt standards for products that do not currently have efficiency standards, including residential torchiere lighting fixtures, building transformers, commercial unit heaters, traffic lights, illuminated exit signs, commercial refrigeration equipment, residential furnace fans, residential ceiling fans, vending machines, and consumer electronic products that "leak" electricity when not in use (phantom loads).
- Save approximately 73 terawatts per hour (TWh) of electricity in 2010 and 164 TWh in 2020 (1 TWh = 1 trillion watts) from the standards above. The savings in 2020 amount to about 5 percent of the projected residential and commercial electricity use for that year and would reduce peak electrical demand by the equivalent of approximately 200 power plants (300 MW

each). These standards would also result in substantial economic savings to consumers and businesses with discounted net benefits (benefits minus costs) of more than $80 billion and a benefit-cost ratio of more than 5:1.
- Continue current rulemakings to set appropriate new standards for commercial cooling and heating.

The increased interest and demand for high performance buildings has led to national green rating systems, such as the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) programs that recognize and reward participants that choose high performance features like energy-saving appliances and equipment for their project.

What are relevant resources for **Energy-Saving Appliances and Equipment?**

- American Council for an Energy Efficient Economy: www.aceee.org/index.htm
- Alliance to Save Energy: www.ase.org/
- Energy Star Products: www.energystar.gov/index.cfm?fuseaction=find_a_product
- U.S. Department of Energy: www.eere.energy.gov/

Which strategies interact with **Energy-Saving Appliances and Equipment?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Conserving Systems and Equipment
» High-Efficiency Equipment
» Smart Controls

22 Environmental Education

What is Environmental Education?

The American public recognizes that the environment is one of the dominant issues of the 21st century. Climate changes, depletion of natural resources, air and water problems, and other environmental challenges are pressing and complex issues that threaten human health, economic development, and national security. Business leaders also increasingly believe that an environmentally literate workforce is critical to their long-term success. They recognize that better, more efficient environmental practices improve the bottom line and help position their companies for the future. Environmental education will help ensure that the nation's population has the knowledge and skills necessary to address these complex issues.

Environmental education increases public awareness and knowledge of environmental issues and challenges. Through environmental education, people gain an understanding of how their individual actions affect the environment, acquire skills that they can use to weigh various sides of issues, and become better equipped to make informed decisions. Environmental education also gives people a deeper understanding of the environment, inspiring them to take personal responsibility for its preservation and restoration.

The components of environmental education are

- Awareness and sensitivity to the environment and environmental challenges
- Knowledge and understanding of the environment and environmental challenges
- Attitudes of concern for the environment and motivation to improve or maintain environmental quality
- Skills to identify and help resolve environmental challenges
- Participation in activities that lead to the resolution of environmental challenges

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible lines of attack. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- Make staff aware of energy-saving opportunities in their activities in their building through education.

Specify energy-efficient equipment and technologies.
- Not applicable

Use renewable strategies and purchase green power.
- Not applicable

Educate building owners, operators, and occupants.
- Provide regular staff training on environmental education.
- Create programs that provide staff with guidance on how to participate in the environmental goals of the firm.
- Engage in the creation of educational programs that integrate sustainable and ecological design.

Environmental education is also the study of the relationships and interactions between dynamic natural and human systems. Environmental education

- Includes learning in the field as well as the classroom setting
- Incorporates the teaching methods of outdoor education, experiential education, and place-based education
- Is inherently interdisciplinary
- Promotes school–community partnerships
- Is hands-on, student-centered, and inquiry driven; engages higher level thinking skills; and is relevant to everyday lives
- Develops awareness, increases knowledge, builds skills, and creates the capacity for stewardship and good citizenship regarding the environment on which we depend for life support
- Increases environmental literacy
- Boosts achievement in math, science, reading, writing, and social studies

A primary outcome of environmental education programs is increased environmental and ecological literacy. People of all ages and backgrounds should be provided multiple experiences that foster development of the combination of knowledge, skills, and attitudes required to be literate. Because environmental education is a process, it cannot in itself improve the environment. However, environmental education provides the capability and skills over time to analyze environmental issues, engage in problem solving, and take action to sustain and improve the environment. As a result, individuals are more capable of weighing various sides of an environmental issue to make informed and responsible decisions.

Architects and design professionals must have the knowledge and skills to create buildings and environments that contribute to the long-term health and welfare of building occupants, community, and Earth. This context requires an expanded view of environmental education and design that is also founded on the principles of ecological design and ecological literacy. Ecological design is the careful meshing of human purposes with the larger patterns and flows of the natural world; it is the careful study of those patterns and flows to inform human purposes. To achieve these goals, designers need an intimate knowledge and understanding of the patterns and flows, which requires a broader, interdisciplinary education and design process. Ecological literacy includes a basic understanding of Earth and the interrelationships and interactions between living organisms and their natural or developed environment.

David Orr, professor and chair of the Environmental Studies Program at Oberlin College and one of the most influential writers on ecology of place and environmental literacy in higher education, offers a foundation and principles for an "Earth-centered education," including

- All education is environmental education
- Environmental issues are too complex to be understood through a single discipline
- Education occurs as a dialogue with a place
- Method is as important as content
- Experience with nature promotes better intellects
- Experience with nature promotes practical competence

How do I apply Environmental Education?

Use an integrated design approach that considers the broader view of buildings and their interconnection to all things. Engage all stakeholders early in the planning process to ensure that a more expansive view of the issues is considered. Engage the integrated project team and stakeholders throughout every phase of the project to ensure that the design solution will contribute positively and creatively to issues of aesthetics, land use, site ecology, community design and connections, water use, energy performance, energy security, materials and construction, light and air, bioclimatic design, durability, and other project goals.

Partner with other professionals to support an interdisciplinary approach to environmental education and design. Work with landscape architects, planners, structural and mechanical engineers, environmentalists, naturalists, and other design professionals to develop and support indoor and outdoor spaces or exhibits that inspire and educate children as well as adults about the natural world. Programs and exhibits of this type can demonstrate how the natural world and the environment are key and integral parts of a person's daily learning experience.

Environmental education should span a broad spectrum of the public, and architects can play an important role in contributing to the process. By engaging in programs, whether through involvement with a local school or university, environmental organizations, or the political process, architects, and design professionals, can teach others how the built environment can contribute to the planet in positive ways.

Environmental education, literacy, and awareness should also be goals that are supported and integrated through every aspect of your business. Support regular programs about the environmental aspects of the building and teach staff to participate in the saving of energy and resources and to contribute to other environmental goals that you establish.

ESTABLISHED TECHNIQUES

Learn About the Environment

- Discover the environment by using geographic maps
- Become familiar with environmental issues and potential risks caused by pollution
- Learn how to protect people from environmental health threats

Protect Yourself and Your Environment

- Protect your home
- Protect people from environmental risks
- Protect people from exposure to mercury
- Help clean the air
- Help reduce and better manage waste
- Help reduce the dangers of lead in drinking water
- Help reduce the impact of development on air and water
- Assist cleanup efforts in your community
- Encourage stewardship of water resources
- Prevent non-point source pollution
- Protect watersheds

EMERGING TRENDS

Ecological Literacy

Expanding the view of sustainability to include a more qualitative and comprehensive approach to building design is growing. Ecological literacy, which includes a basic understanding of Earth and nature, is critical to creating buildings and environments that support the life, health, and diversity of our planet.

No Child Left Inside

The 2001 No Child Left Behind Act (NCLB) does not include environmental education. A movement is growing around the country to push the 2007 draft reauthorization of NCLB. It dedicates 14 pages to environmental education, including two new grant programs to support teaching and learning about the environment. The reauthorization of NCLB in 2007 provides Congress with the opportunity to make changes that will strengthen the act and better prepare students for real-world challenges and careers. NCLB must provide schools and school systems with the incentives, flexibility, and authority to develop and deliver environmental education programs.

What are relevant resources for **Environmental Education?**

- **Campaign for Environmental Literacy— www.fundee.org/—provides a voice and tools to advocate for increased federal funding for environmental, ocean, conservation, and sustainability education at all age levels.**
- ***Ecological Literacy: Education and the Transition to a Postmodern World*, by David Orr. SUNY Press, 1991. This publication asks how the discovery of finiteness of resources affects the content and substance of education. Given the limits of Earth, what should people know and how should they learn it? Ecological Literacy in Architecture Education: www.aia.org/cote_tides**
- **EPA—Environmental Education**
  Office of Children's Health Protection and Environmental Education Web site.
- **North American Association for Environmental Education**
  For professionals and students, global membership, curriculum standards, guidelines on professional qualifications of educators, conferences, etc.
- **The National Environmental Education Act of 1990 provides national leadership to increase environmental literacy.**
- **World Resources Institute (WRI)—www.wri.org/about/—is an environmental think tank that goes beyond research to find practical ways to protect Earth and improve people's lives.**

Which strategies interact with **Environmental Education?**

All 50to50 strategies relate to each other in some way. It is recommended that you consider investigating these selected strategies to gain a comprehensive understanding of the topic.

» Staff Training

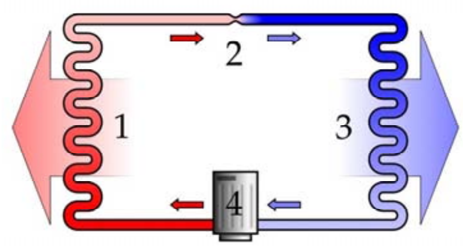
What is Geoexchange?

Because seasonal temperature variations do not reach very deeply into the earth, engineers can sometimes use the relatively consistent temperatures of deep earth for the heating and cooling of buildings. The most common way to use the relatively constant temperatures is through the use of ground-source heat pumps (GSHPs), also known as geothermal heat pumps or geoexchange heat pumps.

A heat pump is a device that moves thermal energy from one location to another. A refrigerator is a form of heat pump; it removes energy from inside the refrigerator and discharges it into the surrounding area. Air conditioners function in a similar manner. Heat pumps used in buildings, however, generally provide both heating and cooling. During winter, a GSHP will move heat from the ground into the building; during summer, it will move heat from the building into the ground.

Almost all heat pumps operate using a vapor compression cycle. This is very similar in concept to what is used in air conditioners or refrigerators. A simple schematic of a vapor compression cycle is shown in the figure. A compressor (4) compresses refrigerant vapor so it becomes hot, high-pressure gas. The hot gas moves to the condenser (1), where the heat is removed and the refrigerant condenses (becomes liquid). This high-pressure liquid refrigerant is then directed through an expansion device (2), where the refrigerant pressure and temperature are lowered dramatically. This cold liquid then enters the evaporator (3), where it absorbs heat and vaporizes. This vapor then returns to the compressor (4) and begins the cycle again.

In a building cooled by a GSHP, heat is removed from the building by the evaporator and directed to the ground by the condenser. During the heating season, the cycle is reversed;



Simple schematic of a vapor compression cycle used by heat pumps for heating and cooling of (1) Condenser, buildings. (2) Expansion device, (3) Evaporator, (4) Compressor.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Incremental cost for ground-source heat pumps can be substantial. However, smaller, less costly systems can be specified to meet smaller building loads.
- Like most heating and cooling equipment, heat pumps can operate more efficiently when well-matched to a small load.

Specify energy-efficient equipment and technologies
- GSHPs are one option for efficient equipment and technology.

Use renewable strategies and purchase green power
- Renewable electricity generated on-site or purchased can be used to power heat pumps.

Educate building owners, operators, and occupants
- Proper control and maintenance of GSHPs will ensure operation at higher efficiencies.

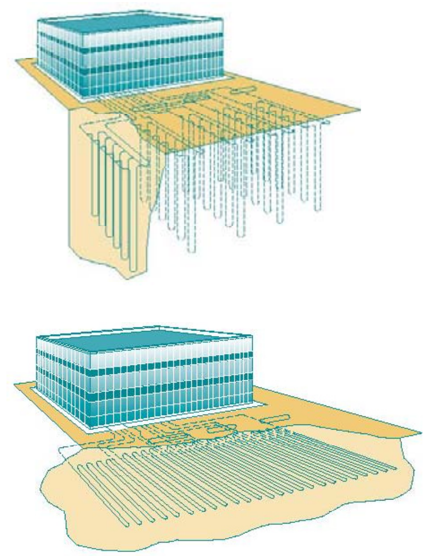
heat is removed from the ground by the evaporator and delivered to the building by the condenser.

Ground-source heat pumps present opportunities for reducing carbon emissions in two main ways. First, if well designed, GSHPs can offer energy cost savings relative to more conventional heating and cooling strategies (air-cooled chillers, air conditioners, boilers, etc.). Second, GSHPs offer an effective way to meet both space heating and cooling loads without use of fossil fuels on-site. If electricity that powers the heat pumps is obtained sustainably, heat pumps can have very low net carbon emissions.

How do I apply Geoexchange?

In most instances, refrigerant is not plumbed directly to the ground. Usually water or an antifreeze solution is pumped from wells or through buried heat exchangers to transfer heat to and from the ground. Because conductivity of ground can vary greatly, knowing ground conditions is important for the sizing of ground heat exchangers.

Because removing or injecting large amounts of heat into the ground over a season can significantly change temperatures of the ground fields, GSHPs may work best when the heating and cooling loads of a building are fairly balanced.



Simple diagrams of a closed-loop vertical geothermal field (top) and a closed-loop horizontal geothermal field (bottom)

ESTABLISHED TECHNIQUES

Ground-source heat pumps are generally divided into two categories with respect to interactions with the ground: open loop and closed loop. In an open-loop system, groundwater is pumped from a well, heat is removed or added by the heat pump, and the water is run back into the ground. Sometimes water is run back into the same well; other times a drywell nearby is used. Open-loop applications require a steady flow of groundwater, and they often work best if the wells can tap an aquifer with relatively constant water temperatures.

Closed-loop systems do not make use of groundwater directly; rather, a water or antifreeze solution moves between the heat pump and heat exchangers within the ground. Sometimes these heat exchangers are run vertically through deep wells; other times coils of pipe are run in coils horizontally. Closed-loop systems work more efficiently with high ground conductivity, and they are sometimes preferred over open-loop systems for other environmental reasons (such as depletion of aquifers or dumping process water).

Inside the buildings, there are typically two types of heat pumps: water to air and water to water. In the winter, water–air heat pumps remove heat from groundwater and send it to the building air directly—typically in an air handler or fan coil. Water–water heat pumps remove heat from groundwater and use it to heat separate process water. This warm water can then be used in several ways: heating a building through a hydronic system (e.g., radiant floors), heating air through a hydro coil, heating service water, etc. During the cooling season, the systems run in reverse: water–air systems cool air directly; water-water–systems chill water for cooling applications.

EMERGING TRENDS

Some designers have been very creative in combining ground-source technology with other building systems. On the most basic level, GSHPs are sometimes combined with auxiliary heating systems (e.g., gas or electricity). If ground conditions are very cold, it may be more costly to heat a building with the heat pump than with an efficient gas boiler, for example. Using other heat sources to meet peak winter loads can sometimes save considerable money in the upfront cost of the heat pump equipment and ground field.

Other engineers have incorporated ways to augment temperatures of groundwater. A heat pump will work much more efficiently moving heat from 60° F water than from 50° F water, so boosting temperatures of the ground loop can dramatically affect heat pump performance. Some designs use solar energy to heat groundwater, whereas others use waste heat from other building processes.

Some GSHPs do not use a groundwater at all. “Direct exchange” systems actually run refrigerant from the heat pump to the ground heat exchanger. Although eliminating the extra heat exchange step (ground to water, water to refrigerant) can improve efficiencies, the added cost for copper piping and refrigerant can be considerable.

If you are considering the use of GSHPs, you should consult with an engineer to evaluate the soil and hydrology early in the design phase.

What are relevant resources for Geoexchange?

- International Ground Source Heat Pump Association: www.igshpa.okstate.edu/index.htm
- Ground Source Heat Pump Consortium: www.geoexchange.org
- Geothermal Heat Pumps on EERE: www.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12640, www1.eere.energy.gov/femp/procurement/eep_groundsource_heatpumps.html
- American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) *Applications* and *Systems* handbooks.

Which strategies interact with Geoexchange?

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

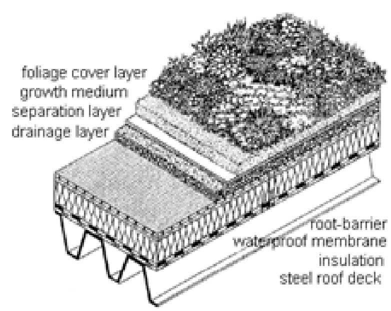
» Conserving Systems and Equipment
» Energy Source Ramifications
» High-Efficiency Equipment
» Radiant Heating and Cooling
» Rightsizing Equipment
» Smart Controls
» Systems Commissioning

24 Green Roofs

What are Green Roofs?

Traditional roofing materials absorb the sun's radiation and reemit it as heat. In cities, this can contribute to temperatures that are substantially warmer than surrounding areas, which is known as the urban heat island effect. This can also be caused by other factors, including modification of the land surface by urban development and waste heat generated by energy usage. According to the U.S. Environmental Protection Agency, heat islands form as vegetation is replaced by asphalt and concrete for roads, buildings, and other structures necessary to accommodate growing populations. These surfaces absorb, rather than reflect, the sun's heat, causing surface temperatures and overall ambient temperatures to rise. Additionally traditional roofs can contribute to excessive water runoff and negatively impact combined sewer-storm water systems.

Green roofs, which were first developed in Germany in the 1960s and continue to grow in number of applications worldwide, can contribute to the reduction of these problems, as well as provide ecological, aesthetic, and economic benefits. A green roof is a roof of a building that is partially or completely covered with vegetation and soil, or a growing medium, planted over a waterproofing membrane. A green roof may also include additional layers such as a root barrier and drainage and irrigation systems. Green roofs can be below, at, or above grade, but in all cases the plants are not planted in the "ground." The term "green roof" may also be used to refer to roofs that incorporate some form of green technology, such as solar panels or photovoltaic modules. Green roofs are also referred to as eco-roofs, vegetated roofs, living roofs, and greenroofs.



Generic Extensive Green Roof Courtesy of *Optigrün Intl. AG*

Green roofs are categorized as "intensive" or "extensive," depending on the depth of planting medium and the amount of

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted in order to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Employ strategies, such as green roofs, that reduce building heating and cooling loads and reduce overall emissions.

Specify energy efficient equipment and technologies
- Not applicable

Use renewable strategies and purchase green power
- Not applicable

Educate building owners, operators, and occupants
- On maintenance requirements of green roofs.

maintenance needed. Traditional roof gardens require a reasonable depth of soil to grow large plants or conventional lawns and are labor-intensive, requiring irrigation, feeding, and other maintenance. Extensive green roofs are designed to be self-sustaining and require minimum maintenance, perhaps an annual weeding or application of slow-release fertilizer to boost growth. Extensive green roofs are 6 inches in depth or less, and are usually designed to satisfy specific engineering and performance goals. Intensive green roofs may become quite deep and merge into more familiar on-structure plaza landscapes with promenades, lawn, large perennial plants, and trees.

The benefits associated with green roofs include

- Control stormwater runoff
- Improve water quality
- Mitigate urban heat island effects
- Filter pollutants and CO_2 out of the air
- Prolong the life span of roofing materials
- Conserve energy (reduce building heating and cooling loads)
- Reduce sound reflection and transmission
- Provide a habitat for plants, insects, and wildlife
- Provide additional outdoor useable space for building occupants
- Improve the aesthetic environment in work and home settings

Green roofs are therefore appropriate additions to commercial, industrial, institutional, and residential buildings.

How do I apply Green Roofs?

The green roof on Chicago's City Hall, completed in 2001, was designed to test different types of green roof systems, heating and cooling benefits, success rates of native and nonnative vegetation, and reductions in rainwater runoff.

Green roofs will succeed in most climates, if designed properly. With appropriate plant selection, sufficient drainage, and adequate structural support for the additional dead weight, green roofs can even survive winter ice build-up. Buildings in arid (desert) zones, however, may not be good candidates for extensive green roofs due to the difficulties and expense of water distribution and retention.

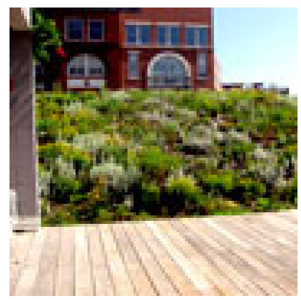
Green roofs can be designed in conjunction with many other building features such as solar panels and also work very well in combination with other low-impact development practices, including infiltration beds, rain gardens, bio-retention systems, cisterns, and rain barrels. The selection of a particular green roof will depend on performance-related considerations, such as runoff control, drought-tolerance, biodiversity, appearance, or accessibility to the public. Many preengineered systems are currently available, but it is frequently necessary to customize these systems to satisfy specific performance objectives.

There are many factors that must be taken into account and balanced when designing a green roof for optimal performance, including

- Climate, especially temperature and rainfall patterns
- Strength of the supporting structure
- Size, slope, height, and directional orientation of the roof
- Type of underlying waterproofing

- Drainage elements, such as drains, scuppers, buried conduits, and drain sheets
- Accessibility and intended use
- Visibility, compatibility with architecture, and owner's aesthetic preferences
- Fit with other green systems, such as solar panels
- Cost of materials and labor

A well-designed green roof must also include subsystems for
- *Drainage*: to maintain optimum growing conditions and manage heavy rainfall without sustaining damage due to erosion or ponding of water
- *Plant nourishment and support*: to meet requirements for grain-size distribution, void ratio, moisture retention
- *Protection of underlying waterproofing systems*: from human activities (including the impact of maintenance) and biological attack



The green roof of the American Society of Landscape Architects, Washington, D.C.

The green roof should also be designed with long-term maintenance in mind and f or possible re-roofing when the roofing system beneath the green roof eventually breaks down. Strategies and methods for accomplishing this include leak detection and green grid systems, among others. Also bear in mind that extensive green roofs in particular may be maintenance intensive, especially during the first year. Maintenance of green roofs often includes fertilization to increase flowering and succulent plant cover. If aesthetics is not an issue, fertilization and maintenance is generally not needed. Extensive green roofs should only be fertilized with controlled release fertilizers in order to avoid pollution of the stormwater. It is recommended that conventional fertilizers never be used on extensive vegetated roofs. Consider partnering with landscape architects and roofing specialists to create the optimal environment and to select appropriate plantings.

Green roof designs are regulated in the United States using existing standards for ballasted roofs. The International Code Council (ICC) recognizes roof gardens. The code requires that the wet weight of the green roof be treated as an additional dead load. It also supplies live load requirements for maintenance-related foot traffic and for regulated pedestrian access.

EMERGING ISSUES

The National Roofing Contractors Association (NRCA) is developing guidelines for waterproofing with green roof installations in mind. American Standard Testing Methods (ASTM), through the Green Roof Task Group E06.71, is also in the process of developing guidelines and testing procedures specifically for green roof products.

Some regional groups and agencies have distinguished themselves in the promotion of green roofs, including the Earthpledge Foundation in New York City, Northwest Eco-Builders Guild, and Cleveland Green Building Coalition. Chicago is home to more than 200 green roofs, covering 2.5 million square feet, more than any other U.S. city. They sit atop City Hall, a Target store, the Apple store, and a McDonalds, among others. The City of

Chicago's Green Roof Grant Program has provided a much needed incentive and the resources to support new installations.

Vegetated roof covers may now be purchased in conjunction with most conventional waterproofing systems. At least 10 North American roofing companies offer green roof assemblies as standard auxiliary products, and more companies are entering the field all the time.

There is still a lack of thorough understanding about green roofs and their benefits in the United States. However, it is the expectation that many more applications will be installed in the future as current installations are documented and can demonstrate their environmental, aesthetic, and economic benefits.

What are relevant resources for Green Roofs?

- *Dach + Grün*: the most respected green roof publication worldwide, a German language quarterly published by FBB (Fachvereinigung Bauwerksbegrünung e.V.). To subscribe, contact Verlag Dieter A. Kuberski GmbH, Postfach 102744, 70023 Stuttgart, Germany (Fax 011-711-2388619)
- Green Roofs for Healthy Cities: Online Green Roofs information
- *Green Roof Infrastructure Monitor*: the most comprehensive English language periodical dedicated to green roofs is published quarterly by Green Roofs for Healthy Cities (GRHC). A quarterly Web-based publication, *Green Roof Infrastructure Journal*, is available to GRHC members.
- GRHC GreenSave Calculator: an online tool to help define cost-benefits of various components of a green roof project
- Greenroofs.com
- RoofNav: is a free Web-based tool developed by FM Approvals™ that provides fast access to the most up-to-date FM-approved roofing products and assemblies

Which strategies interact with Green Roofs?

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Active Solar Thermal Systems
» Conserving Systems and Equipment
» Earth Sheltering
» Photovoltaics
» Vegetation for Sun Control

25 High-Efficiency Equipment

What is High-Efficiency Equipment?

High-efficiency equipment is based on design and functionality, and consumes far less energy over time than conventional equipment that performs the same function. How then, does one know whether a piece of equipment is "high efficiency"? The question is not so easy to answer, as there are currently no national standards for high-efficiency equipment. However, in the United States, certain types of equipment used in residential and commercial buildings have to meet national efficiency standards. The National Appliance Energy Conservation Act (NAECA) placed uniform national standards on an array of products, and the Energy Policy Act of 1992 (EPACT) expanded the coverage to include certain commercial building equipment. EPACT was updated in 2005. Many organizations use these efficiency standards as a benchmark to specify high-efficiency equipment. This is most commonly accomplished through the use of a rating. In addition to ratings developed for equipment and appliances, other industries have developed or are promoting ratings for a wide array of products, including windows, lighting, and solar panels. The U.S. Environmental Protection Agency (EPA) promotes its Energy Star program and is a good source of information.

Most commonly used residential and commercial equipment (i.e., HVAC systems, boilers, furnaces, water heaters, washing machines, and toilets) carry a rating, typically developed through industry consensus. Some examples of common ratings are as follows:

- Annual Fuel Utilization Efficiency (AFUE): This rating measures the seasonal or annual efficiency rating of equipment that uses such fuels as natural gas or oil (i.e., furnaces and boilers). Size is one of the most important factors affecting the AFUE, as too large a system not only costs more but operates less efficiently.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building

- Whenever possible, choose products and equipment with high-efficiency standards, demonstrated by industry rating that support a whole building design strategy and a reduction in overall emissions.
- Using energy-efficient equipment can reduce a building's overall energy load, require smaller and more cost-effective, renewable strategies, and reduce emissions.

Specify energy-efficient equipment and technologies

- Look for and use rating labels that identify the energy-efficiency level of the product or equipment you are purchasing.

Use renewable strategies and purchase green power

- Not applicable

Educate building owners, operators, and occupants

- On function and operations of installed technologies.

- Seasonal Energy Efficiency Rating (SEER): This rates the efficiency of equipment during the cooling season ("cooling efficiency"). This rating can be found on residential and commercial central air-conditioner systems.
- Heating Seasonal Performance Factor (HSPF): This rates the efficiency of equipment during the heating season ("heating efficiency"). This rating can be found on heat pumps.
- Energy Efficiency Rating (EER): This rating can be found on residential room air conditioners. In each of the above, the higher the rating number specified, the higher efficiency the equipment will be.
- Gallons per Minute (GPM): This rating indicates the gallons of water used per minute.

How do I apply **High-Efficiency Equipment?**

High-efficiency equipment usually has a higher initial cost than more conventional, less efficient models. However, the economics of owning equipment goes beyond the initial price to include the cost to operate over its lifetime, as well as maintenance and repair costs. All these costs need to be taken into consideration when choosing a piece of equipment. It should be pointed out that the rating goes hand in hand with cost, as the higher efficiency equipment will decrease the overall lifetime energy use cost.

Comparing rating numbers on different equipment rating labels will show the efficiency of the equipment and thus the amount of energy a specific model uses. The higher the rating, the more efficient the product, and the less energy the piece of equipment will use. However, to get the most efficiency out of the equipment, it must be specified for its application and integrated properly with other equipment. This means that all equipment must be properly sized and located, taking into consideration the type of climate and environment. In addition, the persons using the equipment need to be educated in the operation and general maintenance of the equipment for continued efficiency.

Figure 1. Efficiency Comparison Test Summary

Model: BWC MI40T6FBN2	Model: BWC M440T6FBN4	Model: Tankless #1	Model: Tankless #2
Energy Factor for 1st 2 week test: 0.6756	Energy Factor for 1st 2 week test : 0.6769	Energy Factor for 1st 2 week test: 0.6875	Energy Factor for 1st 2 week test: 0.8081
Energy Factor for 2nd 2 week test: 0.6733	Energy Factor for 2nd 2 week test: 0.7054	Energy Factor for 2nd 2 week test: 0.7076	Energy Factor for 2nd 2 week test: 0.7987
Energy Factor for 3rd 2 week test: 0.6654	Energy Factor for 3rd 2 week test: 0.6929	Energy Factor for 3rd 2 week test: 0.7321	Energy Factor for 3rd 2 week test: 0.7929
Average Energy Factor: 0.6714	Average Energy Factor: 0.6917	Average Energy Factor: 0.7091	Average Energy Factor: 0.7999
Annual Operating Cost:	Annual Operating Cost:	Annual Operating Cost:	Annual Operating Cost:
$338.55	$328.61	$320.55	Gas: $284.16 Electric: $4.31 Total: $288.47

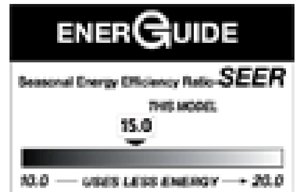
Comparing ratings of different model equipment

Water rating label

ESTABLISHED TECHNIQUES

A number of independent organizations have developed rating systems that have been largely adopted by other groups and institutions. One such organization, the Gas Appliance Manufacturers Association, or GAMA, rates the efficiencies of heating and water heating equipment for both commercial and residential applications. This rating system makes it possible to compare the efficiencies of similar equipment, such as commercial boilers or water heaters. The GAMA directory is widely used by government and independent energy programs when specifying equipment that must have a minimum rated efficiency to meet that program's requirements.

EFFICIENCY RATING CERTIFIED Gama



SEER rating label

Additional Measures

The following additional measures can be used along with a rating in the selection of high-efficiency equipment:

- Determine the equipment's overall application and cost-effectiveness.
- Choose a higher rated efficiency than standard-rated equipment.
- Size equipment appropriately.
- Choose the best options for the application (i.e., gas or oil furnace).
- Choose the best technological options (i.e., smart controls).
- Confirm proper installation and understand operations and maintenance.

EMERGING TRENDS

With the ever-increasing global demand for energy, high-efficiency equipment is becoming an important factor in whole-building system design.

National Standards

The U.S. Department of Energy (DOE) has a schedule for setting new efficiency standards over the next five years to meet all of the statutory requirements established in the Energy Policy and Conservation Act (EPCA 2000 and EPACT 2005. Statutes require DOE to set appliance efficiency standards at levels that achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. Standards already in place for residential products are expected to save consumers nearly $93 billion by 2020 and to save enough energy to operate all U.S. homes for approximately two years.

Tax Incentives

Local, state, and federal tax incentives continue to emerge for manufacturers, businesses, and consumers who choose high-efficiency equipment. Local utilities offer a wide array of incentives, typically in the form of rebates, which can help defray higher first costs. These incentives typically apply to upgrades, purchases, and/or installation of such equipment.

Local Jurisdictions

More and more local city governments and building departments are beginning to require compliance with national energy and green building programs that require minimum equipment efficiencies. For instance, many cities require compliance with the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) program, which certifies buildings as "green" if they attain a minimum number of points from the program's checklist of approved measures. New, stricter guidelines have been developed that require all LEED projects to achieve at least two "optimize energy performance" points in the LEED credit system. This change will reduce energy used in new LEED buildings by 4 percent and in renovated buildings by 7 percent compared with the old LEED credit system.

What are relevant resources for **High-Efficiency Equipment**

- U.S. DOE: www1.eere.energy.gov/femp/procurement/eep_unitary_ac.html#efficiency
- National Energy Policy Act of 2005: www.epa.gov/oust/fedlaws/publ_109-058.pdf
- National Efficiency Standards: www.epa.gov/watersense/docs/matrix508.pdf
- www.toolbase.org/

Which strategies interact with **High-Efficiency Equipment?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Life Cycle Assessment
» Material Selection and Embodied Energy
» Passive Solar Collection Opportunities
» Renewable Energy Resources
» Sun Shading

26 Integrated Project Delivery

What is Integrated Project Delivery?

The whole-building movement has highlighted the importance of designing buildings that use resources efficiently and provide productive and healthy environments for occupants. These criteria, as well as many other design objectives such as accessibility, safety and security, cost-effectiveness, functionality, and aesthetics, are often considered separately: by separate design disciplines, by separate development and operations staff, and from separate project construction and operations budgets.

Recently, a more holistic approach to building design, construction, and operations and maintenance has emerged. With a whole-building approach, it is not enough to simply design a sustainable building, or a secure building, or an accessible building. Rather, by understanding how these separate goals are related to each other and can be integrated, it is possible to create a truly high-performance building. All the design objectives are prioritized, optimized, and balanced through an integrated project delivery process.

Integrated project delivery uses an integrated design approach in an integrated team process to achieve high-performance buildings.

How do I implement Integrated Project Delivery?

The key to creating a high-performance building is an integrated approach that brings together, early in the process, all the professionals who have a hand in designing, constructing, operating, and maintaining the building. The integrated process requires the design team and all affected stakeholders to work

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- Reduce the overall energy use with buy-in from building stakeholders.
- Better coordinate various building systems and design decisions.
- Incorporate a life-cycle perspective early in the design process.
- Use an integrated decision process to decrease energy loads and offset emissions of conventional building energy systems.

Specify energy-efficient equipment and technologies.
- Use an integrated project delivery approach to use the most functional and cost-effective, energy-efficient equipment and technologies.

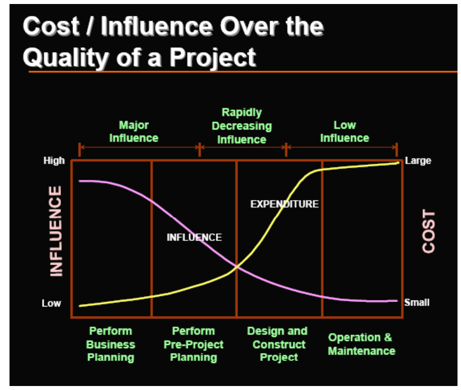
Use renewable strategies and purchase green power.
- Use existing site, climate, and natural assets as part of an integrated project design strategy.

Educate building owners, operators, and occupants.
- Engage in an integrated charrette process to inform all stakeholders and hear all ideas.
- Educate about function and initial and long-term cost-effectiveness of available energy-efficiency design methods and technology.

together throughout the project phases and to evaluate the design for cost, quality of life, future flexibility, energy efficiency, overall environmental impact, productivity, and the well-being of the occupants. This approach is different from the typical planning and design process of relying on the expertise of specialists who work somewhat isolated from each other.

No one aspect takes precedence over any other. The goals for each building are identified by the project team and will determine how each design consideration is balanced against the others. Every project is unique; therefore, the relative importance of each of those design objectives will vary for each situation.

Budget restrictions, energy-efficiency goals, building schedules, and material selection are all issues that can be discussed and agreed on during the charrette process at appropriate points along the progress of the project. Key people to include are mechanical, structural, electrical and construction engineers; facilities executives; operations and maintenance staff; architects; cost-management experts; owners; occupants; and building consultants. Ideally, contractors or construction managers should be included early in the process as cost-effectiveness and constructability will be critical issues—the more people at the table, the more well-informed and integrated the process can be. This can save the pain of having energy conservation measures being "value engineered" out later in the project.



This diagram illustrates the inverse relationship between influences on the project and relative cost over the life of a project.

Examples of the Integrated Process for Energy Conservation

- Investigating the use of natural ventilation or a combination of mechanical cooling and ventilation involves the discussion and design trials of many stakeholders from the building design team, owner and users, and operations and maintenance personnel. The design team must set building orientation to optimize envelope exposure to prevailing breezes; optimize the passage of air through the spaces by design of façades and window openings, interior partitions and door openings, and vertical flues, atria, and roof openings; size mechanical equipment in accordance with calculated loads; allow user control of ventilation; and design ventilation/cooling strategies to adjust for variations of swing days and seasons. It has been demonstrated that occupants have tolerance for a greater thermal comfort range under natural ventilation conditions with adequate air movement when compared with total air conditioning. If all parties can come together, significant savings in operating costs and energy use can result—on initial cost of HVAC equipment, operating costs for cooling, reduction of potable water for cooling towers, and overall energy use.
- Optimize daylighting with proper building orientation, shading, and glare control. Along with daylighting, the team will allow for a reduction in lighting fixtures, wattage, and heating and/or cooling loads. Such synergies can reduce, or at least not increase, estimated construction costs, and can contribute to occupant comfort and a reduction in operations and maintenance costs.
- It is only through an integrated project delivery process that such synergies are made possible because they require the collaboration and buy-in of so many stakeholders.

The end result of the integrated project delivery process is a high-performance building. Such buildings can be all shapes, sizes, budgets, types, and functions, and they result from careful consideration of design objectives, energy-efficiency concerns, constructability issues, stakeholder and occupant education, and operations and maintenance issues.

ESTABLISHED TECHNIQUES

The charrette process is a good vehicle for accelerating the education of the stakeholders, facilitating the design process, allowing for buy-in of major decision makers, and ensuring that all important and complex issues are addressed and explored.

The integrated project delivery process draws from the knowledge pool of all stakeholders across the life cycle of the project, from defining the need for a building through planning, design, construction, building occupancy, and operations and maintenance. An integrated team approach is required throughout the construction phase to ensure that all parties continue to communicate and realize the design objectives.

Total building commissioning is performed throughout the entire process and tracks all design goals, as well as consideration of the envelope, mechanical and electrical systems, controls, and so forth. Total building commissioning helps ensure that the agreed-on design intent is fulfilled and that the design objectives and energy-efficiency goals are being realized in the constructed building systems.

EMERGING TRENDS

– Engaging in an integrated process requires a change in the budgeting of A/E fees and time estimates. The process requires more A/E time assigned to more experienced, higher salaried project leaders at the front end, as they will be involved in project goal setting, design charrettes, and coordination of information with all stakeholders. It is anticipated that this added front-end effort “to get it right” will result in less time in the construction documents phase to correct coordination errors and make unforeseen design changes in later phases of the design process, resulting in no net increase of design fees or time. But like all new processes, A/E project managers should allow time and budget money for a learning curve on the first few integrated projects.
– Reinforcing adoption of integrated project delivery is the use of building information modeling (BIM) technology in the building design professions. Right now, the majority of architects using BIM are primarily using it for three-dimensional modeling. As facility owners and developers try to accelerate the building development process, the A/E design team will be under pressure to populate the building information model database with more complete and detailed information earlier in the design process than before, which will require early well-informed decision making. The impacts on BIM in A/E practice are summarized in AIArchitect, April 27, 2007, and are based on the 2006 AIA Firm Survey.

What are relevant resources for **Integrated Project Delivery?**

- *Engage the Integrated Design Process,* Whole Building Design Guide/Design Guidance/Design Objectives/Aesthetics: www.wbdg.org/design/engage_process.php
- Betterbricks.com—Integrated design process
- Buildinggreen.com—Articles related to integrated design process
- U.S. Department of Energy, Building Technologies Program, Building Toolbox, *Integrated Building Design for Energy Efficiency* (and links to other specialized categories): www.eere.energy.gov/buildings/info/design/integratedbuilding/
- Green Federal Facilities, Section 4.1 Integrated Building Design, by U.S. Department of Energy, 2001
- "Integrated Building Design," by Ira Krepchin. E Source, ER-00-15, Sept. 2000
- Integrated Building Design for Energy Efficiency, by U.S. Department of Energy Building Technologies Program
- "Strategic Issues Paper: Energy-Efficient Buildings: Institutional Barriers and Opportunities," by Amory Lovins. E Source, Dec. 1992
- A Handbook for Planning and Conducting Charrettes for High-Performance Projects, by Gail Lindsey, Joel Ann Todd, and Sheila J. Hayter, National Renewable Energy Laboratory
- Integrated Project Delivery: A Guide. The American Institute of Architects, 2007: www.aia.org/ipdg

Which strategies interact with **Integrated Project Delivery?**

Integrated project delivery can interact with all 50to50 strategies because any of them might be in play on any given project, but these are the most potentially interactive.

» Active Solar Thermal Systems
» Appropriate Size and Growth
» Building Form
» Building Orientation
» Daylighting
» Energy Modeling
» Geoexchange
» High-Efficiency Equipment
» Life Cycle Assessment
» Mass Absorption
» Natural Ventilation
» Passive Solar Collection Opportunities
» Photovoltaics
» Preservation/Reuse of Existing Facilities
» Radiant Heating and Cooling
» Rightsizing Equipment
» Smart Controls
» Space Zoning
» Sun Shading
» Systems Commissioning
» Vegetation for Sun Control
» Windows and Openings

What is **Life Cycle Assessment?**

Life cycle assessment (LCA) is the evaluation of the environmental impact of a product or service throughout its lifespan. This evaluation is distinct from Life Cycle Cost Analysis (LCCA), which is a method for assessing the total cost of facility ownership, taking into account all costs of acquiring, owning, and disposing of a building or building system. LCA is a cradle-to-grave analysis which looks at the materials used to create a product or service from their extraction to their return to the earth. LCA includes the assessment of the production of raw material, manufacture, distribution, use and disposal, and all transportation required, as well as an analysis of pollution caused by usage, damages such as global warming, smog, ozone depletion and more. Because an LCA can be extremely complex, an internationally agreed upon standard (ISO 14040) was created by the International Organization for Standards (ISO) and the Society for Environmental Toxicology and Chemistry (SETAC).

The primary goals of LCA are to

- Provide a mechanism for systematically evaluating the environmental impacts of a product or process
- Aid in the selection of the product or service with the least environmental impact
- Guide improvement efforts for processes or products
- Contribute to sustainable development by promoting cleaner production and cleaner consumption

LCAs can be used in several ways. Some of the most common include making decisions about how to develop, improve, and produce products; how to develop government policies; and how groups such as environmental organizations and trade unions

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted in order to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building

- Use efficient lighting, in commercial applications this can account for nearly 25 percent of a building's energy use.
- Detail an efficient, well-insulated building envelope to include windows, curtain walls, and doors.

Specify energy efficient equipment and technologies

- Simply siting your project correctly can reduce up to 20 percent of energy costs.
- Specify Energy Star appliances where appropriate.
- Size mechanical systems appropriately to suit your particular project.

Use renewable strategies and purchase green power

- Investigate the alternatives; solar, wind, and carbon offset purchasing.
- Specify materials with low embodied energy.

Educate building owners, operators, and occupants

- Inform developers and investors about the financial as well as environmental benefits of energy savings.
- A building is a complicated machine, provide instructions for its use to its inhabitants.

can produce environmentally sensitive guidelines. An LCA can be applied to a whole product, such as a building, or just to an individual element or process in that product. For example, an entire building can be evaluated or individual building materials (e.g., linoleum v. VCT flooring), a composite system (e.g., concrete and steel v. steel), or HVAC systems (e.g., electric v. natural gas v. solar).

One of the key steps in developing an LCA is determining the embodied energy of a product or service. The embodied energy refers to the energy consumed by all of the processes associated with production. This can apply to anything from a light bulb to an entire building and includes everything from the acquisition of natural resources to product delivery. Until recently, it was thought that the embodied energy of a building was small compared to the energy used in operating it over its life. But the embodied energy can be the equivalent of many years of operational energy. One of the most important factors in reducing the embodied energy is to design long life, durable, and adaptable products. For buildings, that pertains to everything from the landscaping to the wall construction to the finishes.

Embodied energy content varies greatly with different construction types. Generally, the more highly processed a material the higher the embodied energy. In many cases, a higher embodied energy level can be justified if it contributes to creating buildings that are more energy efficient. For example, large amounts of thermal mass (which is high in embodied energy) can reduce heating and cooling needs in well-designed passive solar buildings. The true consequences of using materials high in embodied energy can only be fully quantified through a complete LCA. It should be noted that estimates can vary widely, so figures from LCAs should be used as guidelines and to compare materials or products to one another.

When trying to minimize the environmental impact of a product or service, it is not uncommon for one set of solutions to create new problems. The net effect of the decisions is what is important. Ways to avoid making things worse are to optimize recycling whenever possible, choose materials that are durable and reusable, and limit the quantity of materials used by minimizing the design.

How do I design with **Life Cycle Assessment** in mind?

ESTABLISHED TECHNIQUES

A full Life Cycle Analysis consists of four distinct phases, the first of which is called Goal and Scope. This phase includes a description of the methods applied for assessing potential environmental impacts and states which impact categories are included. The architect should bear in mind that LCA is a relatively new concept and obtaining good thorough information is often difficult, as manufacturers like to guard such information. Additional research may be needed to develop a robust LCA database.

The second phase is the Life Cycle Inventory and includes modeling of product systems, data collection, and description and verification of data. During this portion of the assessment careful accounting of all the measurable raw material inputs (including energy) is conducted, including product and co-product outputs and emissions to air, water, and land. A sample flow chart of the Life Cycle Inventory for a building constructed with wood is shown here.

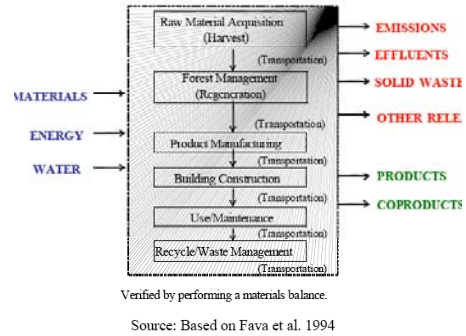
This particular inventory begins with harvesting trees and includes analysis of use of gasoline, oil lubricants, saw blades, tires, transport of products, and regeneration of forest as well as processes involved and materials recovered at the time of demolition at the end of the structure's life.

Life Cycle Impact Assessment (phase three) entails evaluating the product's or service's contribution to each impact category such as global warming. It also examines aspects of product production not considered in the LCI phase such as impacts on ecosystems, human health, and long-term resource availability.

Interpretation is the final (fourth) phase of an LCA where conclusions are drawn from all the data collected.

If a complete LCA is too lengthy or costly for a particular project, designers can still build with life cycle considerations in mind. The guidelines listed below come from the document, Embodied Energy: Life Cycle Assessment, created by the Australian government and can be used for reducing embodied energy and environmental impacts of buildings.

- Design for long life and adaptability, using durable low maintenance materials.
- Ensure materials can be easily separated.
- Avoid building a bigger building than you need. This will save materials.
- Modify or refurbish instead of demolishing or adding.
- Ensure materials from demolition of existing buildings and construction wastes are reused or recycled.
- Use locally sourced materials (including materials salvaged on site) to reduce transport.
- Select low embodied energy materials (which may include materials with a high recycled content) preferably based on supplier-specific data.
- Avoid wasteful material use.
- Specify standard sizes; don't use energy-intensive materials as fillers.
- Ensure off-cuts are recycled and avoid redundant structure. Some energy intensive finishes, such as paints, often have high wastage levels.
- Select materials that can be reused or recycled easily at the end of their lives using existing recycling systems.
- Give preference to materials manufactured using renewable energy sources.
- Use efficient building envelope design and fittings to minimize materials (e.g., an energy-efficient building envelope can downsize or eliminate the need for heaters and coolers, water-efficient taps allow downsizing of water pipes).
- Ask suppliers for information on their products and share this information.



Schematic of a Life Cycle Inventory of Wooden Building Construction

Each designer should select the best combination of materials and products for their project based on factors such as climate, regional availability of materials, and cost.

EMERGING TRENDS

The use of Life Cycle analysis is increasing as environmental performance becomes more important. Many international bodies, national governments, universities, and private companies now acknowledge the usefulness of LCA and the need for further development of the technique.

In response to this demand, the National Renewable Energy Lab and Canada's Athena Sustainable Materials Institute are working together on a project called the U.S. Database Project. The purpose of the project is to

- Create a publicly available national LCI database for commonly used materials, products and processes
- Support public and private organizations in developing LCA support systems and tools
- Evaluate the environmental attributes of new products and technologies
- Provide a firm foundation for life cycle assessment tasks

What are relevant resources for **Life Cycle Assessment?**

- Lifecycle.org - links to LCA sites and resources www.life-cycle.org/
- Department Life Cycle Engineering - LBP – University of Stuttgart. www.lbpgabi.uni-stuttgart.de/english/index_e.html
- UNEP/SETAC Life Cycle Initiative http://lcinitiative.unep.fr/
- Life Cycle Analysis: A Key to Better Environmental Decisions www.dovetailinc.org/reports/pdf/DovetailLCA0105rm.pdf
- Life cycle assessment http://en.wikipedia.org/wiki/Life_cycle_assessment
- Embodied Energy: Life Cycle Assessment. Your Home Technical Manual. A joint initiative of the Australian government and the design and construction industries. www.greenhouse.gov.au/yourhome/technical/fs31.htm

Which strategies interact with **Life Cycle Assessment?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Form
» Building Orientation
» Efficient Artificial Lighting
» Energy Source Ramifications
» High-Efficiency Equipment
» Passive Solar Collection Opportunities
» Renewable Energy Resources

28 Mass Absorption

What is Mass Absorption?

Mass absorption refers to the process of storing energy in building materials for use at a later time. Materials used in this application are commonly referred to as “thermal mass.” These materials absorb heat from the sun during the day and slowly release it as temperatures drop. The slow release of stored heat in the mass prevents rapid temperature fluctuations in the building space. In addition to absorbing solar energy, mass walls provide the benefit of dampening heat swings in buildings by absorbing internal heat. The materials commonly used for mass absorption applications are masonry, concrete, wallboard, and even water, and are an integral part of many passive solar designs in residential and commercial buildings. In using mass absorption, some elements of the building, or the entire building itself, make use of the natural energy characteristics in materials and air created by exposure to the sun. Implementing mass absorption techniques into a whole-building design strategy can reduce or even eliminate the need for mechanical cooling and heating. Thermal mass is inexpensive compared with mechanical systems, is usually simple in design, has few if any moving parts, and requires minimal to no maintenance.

Thermal mass is incorporated into buildings is throughout the world in climates that require both heating and cooling. It has been shown to result in buildings that have low energy costs, reduced maintenance, and superior comfort. Currently, much of the literature pertaining to the use of mass absorption addresses heating concerns. However, installing a mass storage medium in a building in a hot climate with cool nighttime temperatures can also be appropriate. Because of the lag time associated with thermal mass, heat that is absorbed by the mass does not start to heat the space until later in the day, when outside temperatures

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- The implementation of mass absorption techniques can reduce the overall energy use of a building by decreasing the size of heating and cooling systems and thus cost.

Specify energy-efficient equipment and technologies
- Use an integrated system approach to spec out the most cost-effective, energy-efficient equipment in a building that also includes thermal mass will reduce overall energy use and emissions.

Use renewable strategies and purchase green power
- Implement mass absorption by using present solar income to decrease energy loads and offset emissions of conventional, built energy systems.

Educate building owners, operators, and occupants
- On function and operations of installed technology.

are beginning to drop. Cooler nighttime air is then used to cool the mass, which will be ready to absorb heat again the next day. This is a proven method of reducing cooling loads in hot, dry climates.

Proper use of mass absorption includes appropriate solar orientation of the building to take advantage of how the sun moves across the sky, proper ventilation and window placement, optimum mass-to-glass ratios, and knowledge of the local climate.

A specific strategy is the use of a Trombe wall. The wall typically consists of an 8- to16-inch-thick masonry wall on the south side of a building, with glazing mounted about 1 inch or less in front of the wall's surface. Solar heat is absorbed by the wall's dark-colored outside surface and stored in the wall's mass, where it radiates into the interior space. The Trombe wall distributes or releases heat over a period of several hours. Solar heat migrates through the wall, reaching its rear surface in the late afternoon or early evening. When the indoor temperature falls below that of the wall's surface, heat begins to radiate and transfer into the interior space.

How do I apply Mass Absorption?

Residential

In applying mass absorption to either a residential or commercial building, the designer will need to pay particular attention to the sun to minimize heating and cooling needs. Given the proper building site, just about any type of architecture style can integrate mass absorption into the design. Although proper design for thermal mass in a building need not be complex, it does involve knowledge of solar geometry, window technology, the local climate, and familiarity with the site's solar and wind patterns, terrain, and vegetation.

Commercial

The use of mass absorption can also aid energy conservation efforts because the overall building design directly relates to its overall energy use. Buildings that use thermal storage can use the sun to offset heating, cooling, and lighting loads. This will reduce the need for the building to consume energy from other sources while still providing a comfortable environment inside. When the sun's rays enter a building, they are partly reflected and partly absorbed by the surfaces. The absorbed radiation heats these surfaces, which in turn raises the temperature of the surrounding air to various degrees depending on the density of the material.

For instance, a floor material such as ceramic tile on a bed of grout would tend to heat up fairly slowly. Because of this energy absorption process, the surface temperature of the ceramic tile would remain relatively low and would not significantly raise the temperature of the surrounding air. This type of high-density surface has excellent thermal mass properties. Therefore, when the sun stops shining on this floor surface, it would give off its heat to the room fairly slowly as the absorbed heat deep in the grout works its way back to the surface of the ceramic tile. However, a lighter density surface would have poor thermal mass properties (such as a vinyl floor on plywood) and would tend to heat up relatively quickly when exposed to the sun. Because the surface temperature of the vinyl would be high, it would raise the temperature of the surrounding air. Once the sun stops shining on this floor, the mass would tend to give off its heat to the room quite quickly and cool back to room temperature.

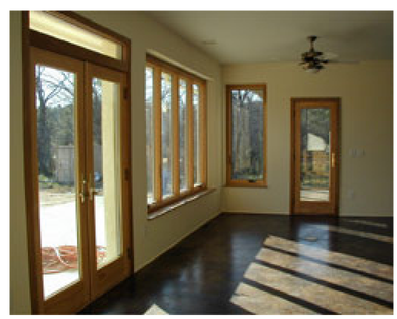
The slow release of energy from massive building components contributes to load dampening, which is a result of the reduction in the extreme temperatures that cause spikes in cooling and heating loads. In other words, in the above examples, the massive building will not see internal temperatures as cold or as hot as the same building built with lighter materials. This means that peak cooling loads in cooling climates and peak heating loads in heating climates are significantly reduced. Drastic spikes in temperature are reduced, increasing occupant comfort and energy savings.

ESTABLISHED TECHNIQUES

Material Selection

Mass absorption works best with heavyweight materials, such as concrete, that provide a high level of thermal mass. The level of thermal mass of a material is often measured in terms of admittance, which has units of watts per square meter Kelvin (W/m2 K). An example of high thermal mass construction is a traditional brick and block wall with a plaster finish, which has an admittance of around 6 W/m2 K. An example of a low thermal mass construction is a timber frame wall, which has an admittance value of approximately 0.85 W/m2 K. As can be seen from these examples, material selection is important for proper mass absorption as a heavyweight wall can have as much as seven times more thermal mass than a lightweight wall. Typical thermal mass building elements are poured concrete floors, ceramic tile floors on a bed of grout, hardwood flooring, brick or stone feature walls, multiple layers or thicker drywall, and water.

Residential Applications



Opportunities abound in the residential sector for use of mass absorption techniques. There are two basic types of passive solar systems that employ the use of thermal mass: direct gain and indirect gain systems.

In a direct gain system, thermal mass is incorporated into the living space in the floors or walls. When the ratio of south-facing glazing to floor area begins to exceed approximately 8 percent, thermal mass should be installed to store excess energy and prevent overheating of the particular room. Adding mass will allow for the use of more glazing for increased solar contribution without overheating. For optimum and effective use of the thermal mass, it is important to charge the mass during sunlight hours and discharge it during the night. When adding mass, its use and location must be considered. For example, the decision to add carpet over a floor surface, which acts as insulation, can reduce potential heat storage by as much as 70 percent. The benefits of proper application of mass absorption in a residential building will be comfort (warm in the winter and cool in the summer), economical (by decreasing heating and cooling loads), and durable (by using long-lasting, low maintenance materials).

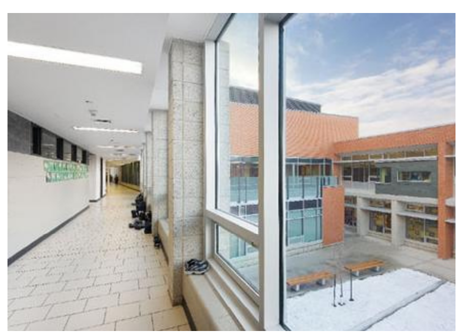
In an indirect gain system, components such as sunspaces, thermal mass walls, or Trombe walls are used. These structures are designed to collect a large amount of heat during the day and release it at night. Sunspaces are similar to greenhouses, but they are generally not heated or cooled by the home's mechanical equipment, and their primary function is to supply the house with heat. Thermal storage walls can be used in heating climates or cooling climates that have large variations in daily temperature. In heating climates, they generally consist of a floor-to-ceiling mass wall located in direct sunlight and are separated from the exterior by a glazing unit and an air space. The sun strikes the mass through the glass, heats up, and radiates into the room. A Trombe wall is essentially a thermal storage wall with vents evenly distributed along the bottom and top of the wall. Heated air flows through the top vents into the living space by natural convection, and cool air is drawn in from the living space through the bottom vents. In heating climates, it is recommended that dampers be installed to prevent the backflow of conditioned air from the living space into the Trombe wall space when the Trombe wall is too cold.

Commercial Applications

In commercial buildings, such as offices, mass absorption techniques can delay peak internal temperature up to five or six hours, which typically occurs in the late afternoon or evening after the occupants have left. At this time, heat gains from the sun, occupants, lighting, and office equipment are greatly diminished and the building mass stops absorbing heat. As the evening progresses and the external air temperature drops, the use of an automatic ventilation system is an effective way of removing accumulated heat from the building and lowering its temperature for the following day. To make this heating and cooling cycle most effective, it is essential that heavyweight mass elements, such as floor slabs, are thermally exposed so heat can move freely between the internal environment and the concrete.

The ability of thermal mass to absorb heat results in a lower cooling load in buildings, which helps reduce associated energy use and carbon dioxide emissions. In many cases, air conditioning can be avoided altogether through the use of thermal mass and effective ventilation, a combination that has been used very successfully in many commercial and public sector buildings.

EMERGING TRENDS



The increasing understanding of the link between fossil fuel use and the global environment, along with the ever-increasing worldwide demand for energy, continues to push approaches that maximize energy and reduce overall emissions in the commercial and residential building sectors.

Currently, the biggest trend in mass absorption techniques is their use in whole-building design strategies. Mass absorption techniques are most effective when used with complementary systems and approaches. The U.S. Department of Energy outlines the variables that need to be considered when deciding to effectively implement mass absorption in a building. These are building orientation, including glazing and room layout; climate variables such as sun, wind, air temperature, and humidity; building use types to include occupancy schedules and use profiles; lighting and daylighting to include electric and natural light sources; the building envelope such as its geometry, insulation, fenestration, air leakage, ventilation, shading, thermal mass, and color; internal heat gains from people, lighting, office equipment, and machinery; HVAC systems and controls; and energy costs to include fuel sources, demand charges, and conversion efficiencies.

What are relevant resources for Mass Absorption?

- U.S. Department of Energy: www.eere.energy.gov/buildings/info/design/integratedbuilding/passive.html
- Sustainable Industry Building Council: Passive Solar Design Strategies: www.sbicouncil.org/store/builderguide.php?PHPSESSID=7b1ed41fbbd9ef02d27456e2e1c8ac3d
- National Renewable Energy Lab (NREL) Fact Sheet: www.nrel.gov/docs/fy01osti/29236.pdf
- Sustainable Building Sourcebook: www.greenbuilder.com/sourcebook/PassSolGuide1-2.html

Which strategies interact with Mass Absorption?

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Orientation
» Daylighting
» Life Cycle Assessment
» Passive Solar Collection Opportunities
» Renewable Energy Resources
» Sun Shading

29 Material Selection and Embodied Energy

What is Material Selection and Embodied Energy?

When building or renovating residential and commercial buildings, the choice of materials can have important immediate and long-term economic, environmental, and health effects. As these effects of the built environment are becoming better and better understood, important questions are being asked regarding proper material selection. When selecting materials from a whole-building standpoint, the following questions that might arise regarding material selection:

- **Are these materials or products recycled? How much is preconsumer or postconsumer content?**
- **Have any of these materials or products been reclaimed?**
- **Have these materials or products been extracted, processed, or manufactured locally?**
- **What does this material or product cost? What is its life-cycle cost, which includes all the costs over the lifetime of the product?**
- **Can the product be recycled?**
- **Does the product contain toxic materials?**

One additional question that needs to be asked is, What is the embodied energy of the material or product that is under consideration for use in a building? Embodied energy can be defined as a measure of the total energy consumed by a product during its life or complete life cycle. It includes all the energy used during mining or milling the raw materials, manufacturing the raw materials into a product, transporting the product, and installing the product, as well as finally removing or recycling the product.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Implementing well-thought-out material selection that includes understanding as much as possible about the embodied energy of materials as part of a whole-building design approach will reduce the overall energy use of the building over its life cycle.

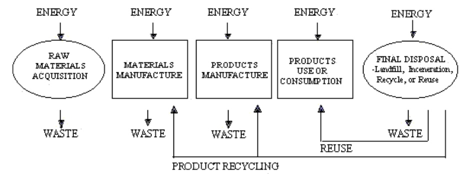
Specify energy-efficient equipment and technologies
- Specifying low embodied energy materials along with energy-efficient equipment for a building will further reduce its energy use and overall emissions.

Use renewable strategies and purchase green power
- The use of proper material choices combined with renewables and the purchase of green power can be part of overall building strategies that will further reduce the life-cycle energy load and carbon emissions of a building.

Educate building owners, operators, and occupants
- On material selection and embodied energy of materials and products in building.

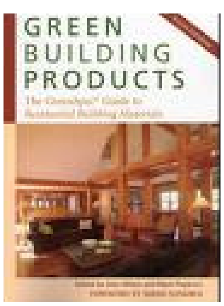
How do I apply **Material Selection and Embodied Energy?**

The selection of building materials greatly impacts the overall sustainability of any building project. For example, by carefully selecting materials, the depletion of resources, such as wood or other raw materials that make up such things as metals, can be minimized. In addition, the energy and water used in the initial manufacturing process can be reduced, along with the fuel and energy that were used to initially extract the raw materials. Careful selection can also allow for efficient reuse or recycling of materials and building components if a building is to be demolished or deconstructed. For a building that is being commissioned, selection of materials can have an effect on the overall indoor air quality in the structure, as well as how often material systems need to be maintained, repaired, and/or replaced.



When used in buildings, the embodied energy in materials can be broken down into two parts: initial embodied energy and recurring embodied energy. Initial embodied energy is the energy consumed in acquiring the raw materials and includes processing, manufacturing, transportation (to the building site), and then the physical construction of the building. Recurring embodied energy can be viewed as the energy required to maintain, repair, replace, or refurbish the systems, components, or any materials over the life of the building. The amount of embodied energy in buildings can vary widely. The embodied energy depends on the type of building (residential or commercial, number of floors, etc.); the materials used; the source of these materials; the durability of the building materials, components, and systems installed in the building; how well these are maintained; and the life of the building. The longer a building exists, the longer the building's recurring energy consumption will be, even for buildings that are considered to be zero-energy structures. Currently, it is estimated that the embodied energy of many building materials can contribute from 15 to 20 percent of the energy used by a building over a period of approximately 50 years.

ESTABLISHED TECHNIQUES



Calculating the various economic, environmental, and health impacts and effects of building materials can be difficult. A life-cycle analysis, which accounts for the impacts of resource extraction through manufacturing, use, and disposal, can involve extensive data collection and analysis. Some analysis has already been done, and the results are available through various manufacturers, databases, and books that list environmentally preferable building materials, products, and the embodied energy of various building materials.

Material Selection Criteria

The following considerations are ways to promote sustainable design through building material selection. Although no single material or product will exhibit all of these characteristics, whenever possible, as many materials as possible ultimately should

- Be biodegradable
- Be made using natural and/or renewable resources
- Be recycled easily

Green Features

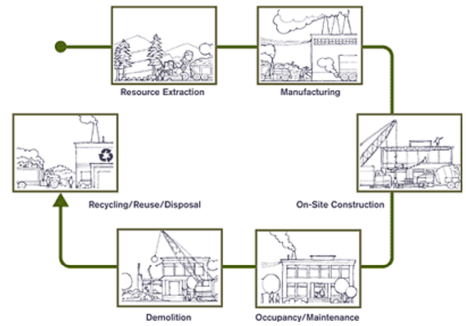
Manufacturing Process (MP)	Building Operations (BO)	Waste Mgmt. (WM)
Waste Reduction (**WR**)	Energy Efficiency (**EE**)	Biodegradable (**B**)
Pollution Prevention (**P2**)	Water Treatment & Conservation (**WTC**)	Recyclable (**R**)
Recycled (**RC**)	Nontoxic (**NT**)	Reusable (**RU**)
Embodied Energy Reduction (**EER**)	Renewable Energy Source (**RES**)	Others (**O**)
Natural Materials (**NM**)	Longer Life (**LL**)	

- Be reusable and easy to disassemble
- Incorporate recycled content (postconsumer and postindustrial) and/or "biobased" materials from rapidly renewable plant products
- Be resource efficient
- Employ "sustainable harvesting" practices for wood products
- Have low embodied energy
- Be locally manufactured with local resources
- Have a long life cycle
- Be nontoxic or have low toxicity (from manufacturers to installers to occupants) and nonpolluting
- Not contain chlorofluorocarbons, hydrochlorofluorocarbons, or other ozone-depleting substances
- Create minimal waste generation
- Be easy to install
- Have minimal maintenance requirements (be durable)
- Not affect indoor air quality adversely

Embodied Energy Analysis

Generally, for building materials, embodied energy is measured as a quantity of energy per unit of building material, component, or system. For example, it may be expressed as megaJoules (MJ) or gigaJoules (GJ) per unit of weight (kg or ton) or area (square meter). The process of calculating embodied energy is complex and involves numerous sources of data, including associated environmental implications of resource depletion, greenhouse gases, environmental degradation, and reduction of biodiversity. Embodied energy can be used as a reasonable measure of the overall environmental impact of building materials, assemblies, or systems. However, it must be carefully weighed against durability and performance since these can affect the initial and long-term environmental impacts associated with embodied energy.
But embodied energy also includes the energy required to extract, manufacture, and transport a building's materials, as well as that required to assemble and "finish" it. As buildings become increasingly energy efficient, the energy required to create them becomes proportionately more significant in relation to that required to run them. This is particularly true because some modern materials, such as aluminum, consume vast amounts of energy in their manufacture. The common building material with least embodied energy is wood (about 640 kilowatt-hours per ton, which includes the industrial drying process and manufacture of and impregnation with preservatives). Brick has the next lowest amount of embodied energy (4 times that of wood), then concrete (5 times more), plastic (6 times more), glass (14 times more), steel (24 times more), and aluminum (126 times more). Therefore, a building with a high proportion of aluminum, no matter how energy efficient, may not be so green when considered from the perspective of total life-cycle costing. From the perspective of embodied energy, every building, no matter what its condition, has a large amount of energy locked into it. (See Preservation and Reuse of Existing Buildings and Deconstruction and Salvaged Materials.) Also, the fact that the energy used in transporting materials becomes part a building's embodied energy creates an incentive to use local materials.

LIFE CYCLE OF BUILDING PRODUCTS



Life-Cycle Analysis

Life-cycle analysis (LCA) is an objective process that helps identify the environmental burdens of specific building materials from cradle to grave and attempts to quantify all elements in the process. However, the manufacturing of materials or products can be very complex, as raw materials can come from many different sources. To examine how much a product impacts the environment, it is necessary to account for all the inputs and outputs throughout the life cycle of that product, from its birth, including design, raw material extraction, material production, part production, and assembly, through its use and final disposal.

The first step of a life-cycle analysis consists of an inventory analysis, which examines all the inputs and outputs in a product's life cycle, beginning with what the product is composed of, where those materials came from, where they go, and the inputs and outputs related to those components during their lifetime. It is also necessary to include the inputs and outputs during the product's use, such as whether or not the product uses electricity. The purpose of the inventory analysis is to show what comes in and what goes out, including the energy and material associated with materials extraction, product manufacture and assembly, distribution, use and disposal, and the environmental emissions that result. From here the next step is the impact analysis, which may include the impacts of generating energy to make the material and the emissions produced during the manufacturing process. Once the impacts of all the inputs and outputs of a material's life cycle are analyzed, the life-cycle analysis generates a number that represents how much the material impacts the environment, including the overall building environment. Once its general environmental impact is calculated, the final step is to conduct an improvement analysis to see how the material impacts the built environment. For example, substituting a nontoxic chemical for a toxic one inside the building would help improve indoor air quality. This change is then incorporated in the inventory analysis to recalculate the overall impact.

Obtaining good, complete information to conduct and LCA is often difficult, as manufacturers guard such information. Additional research may be needed to develop a robust LCA database.

EMERGING TRENDS

Advanced Building Materials

Many types of new and environmentally friendly building materials and products are now available. They include products for insulation, load-bearing systems, products with low levels of volatile organic compounds, efficient lighting, and indigenous materials. Some of these materials are even recycled from other materials. A sustainable building means that the system or building could exist forever and be self-supporting and living—advanced building materials are helping support that end. Similarly, some environmental building materials are starting to share the concept that they could be recycled and reused over and over again. As buildings are now understood to affect energy use, the environment, indoor air quality and health, and overall emissions for the life of the structure, building materials continue to emerge as one more tool to advance the whole-building system approach and thus reduce a building's overall footprint.

Embodied Energy Measures

Embodied energy can be a very useful measure in material selection provided it is not viewed in absolute terms. The initial embodied energy of various materials, components, and systems can vary between projects, depending on suppliers, construction methods, site location, seasonality of the work (e.g., winter heating), and other variables. Although strong correlations exist between embodied energy and environmental impacts of materials, the recurring embodied energy is difficult to estimate over the long term because the nonrenewable energy content of replacement materials, components, or systems is difficult to predict. For example, how energy intensive will glass be 50 years from now? However, as buildings become more energy efficient and the amount of operating energy decreases, embodied energy becomes a more important consideration. Although it is still difficult to calculate or predict the embodied energy of all materials over their entire lifetimes, the trend toward embodied will likely continue to grow and become more definitive as the overall impact of a building and its materials and components becomes better understood.

Building Programs

The increased interest in and demand for high-performance buildings has led to national green rating systems that recognize and reward participants that choose intelligent green materials, such as materials with low embodied energy that are manufactured locally.

What are relevant resources for Material Selection and Embodied Energy?

- *The American Institute of Architects Environmental Resource Guide,* Joseph A. Demkin (Ed.), Wiley, 1996.
- Athena Institute Environmental Impact Estimator: www.athenasmi.ca/tools/impactEstimator/
- Building for Environmental and Economic Sustainability (BEES) software: www.bfrl.nist.gov/oae/software/bees/
- U.S. Environmental Protection Agency—Environmentally Preferable Packaging (EPP) Tools: www.epa.gov/opptintr/epp/
- U.S. Environmental Protection Agency —"Lists of Manufacturers and Suppliers" of Recycled Content Products: www.epa.gov/cpg/
- GreenSpec Product Directory and Guideline Specifications Binder: www.buildinggreen.com/ecommerce/gs.cfm
- Product Ecology Consultants (Life-Cycle Assessments): www.pre.nl/life_cycle_assessment/default.htm

Which strategies interact with Material Selection and Embodied Energy?

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Deconstruction and Salvage Materials
» Life Cycle Assessment
» Preservation/Reuse of Existing Facilities
» Renewable Energy Resources

What is Natural Ventilation?

Human comfort is a function of four primary variables: air temperature, air movement, humidity, and mean radiant temperature of interior surfaces. Natural ventilation is an energy-efficient way to increase human comfort because air movement increases heat transfer from the skin when cooler outside air replaces warm and humid indoor air. Perceived temperature differences of 4° to 8° F may occur with air movement of 100 to 350 feet per minute, the upper limit being when papers might flutter off the table.

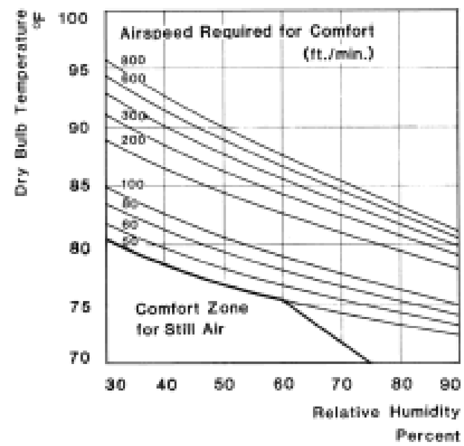
Effectiveness of natural ventilation depends on

- The temperature and humidity of outside air in the evening and early morning, as compared with daytime inside conditions
- The amount of shading around the building
- Active participation of building occupants to control window opening and closing at the proper times
- Active participation of occupants to control ventilation fans at proper times
- Ambient noise and pollution at the site

Natural air movement is the product of air flow caused by temperature and/or pressure differences. Wind is produced when a large mass of air moves from a high-pressure area in one location to a lower pressure area in another or from an area of one temperature to a higher or lower temperature—as in on-shore or off-shore breezes one experiences in coastal regions.

Natural air movement is influenced by pressure differences as air moves around and through a building: positive on the windward side, negative on the leeward side, and influenced by pressure and air density differences induced by height. For example, it is helpful to have cooling breezes enter a building on

Effect of air motion on comfort



Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.

- Appropriate orientation to wind direction, and shielding from harsh winds, can help reduce the overall energy use, so various site and building systems can be reduced in size and cost to make way for further energy-saving materials, designs, and technologies.

Specify energy-efficient equipment and technologies.

- Use natural ventilation to reduce size and/or need for cooling equipment and energy use.
- Specify energy-efficient fans and equipment to induce natural ventilation.
- Investigate use of mixed-mode cooling systems to reduce cooling load and energy use.

Use renewable strategies and purchase green power.

- Use of natural ventilation is a renewable strategy.

Educate building owners, operators, and occupants.

- Provide information on functional and energy savings advantages of natural ventilation strategies.

a low level and exit on a high one because that releases heat from the interior. This is the principle behind the wind chimney, used in ancient cultures in the Middle East where the air was cooled by being directed by passages in the building design to pass over a cooling water source before circulating through the interior spaces. The air carrying the interior heat was then released up and out naturally through the wind chimney.

How do I design for **Natural Ventilation?**

Design for natural ventilation requires data on wind speed and direction, terrain and landscaping, room layout and building geometry, and air flow patterns that might be affected by nearby natural features or structures. Use of natural ventilation is usually thought to be limited to only temperate climates, such as mid- to northern Pacific and Atlantic coastal regions, with moderate humidity.

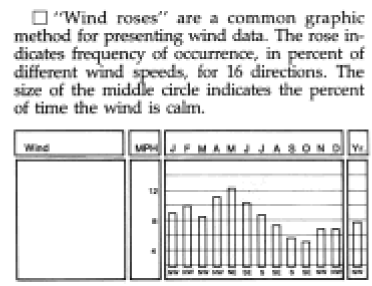
Soft and hard landscape features or building design elements may be used to channel desirable breezes and shield from objectionable winds and storms. Building elevations can be designed with wing walls, overhangs, and strategically placed openings to enhance otherwise poor wind speed. Abrupt changes in direction, imbalance between windward and leeward openings, and blocking interior walls and doors will impede air flow.

Wind speed does not depend on precise orientation of the building, but principal façades should be oriented to within 30 degrees of the direction of prevailing breezes for maximum benefit. To enhance cross-ventilation, buildings should be set with the long axis to the wind, ideally be long and narrow with rooms not more than two spaces deep, and have strategically placed overhangs and openings to increase air pressure and speed.

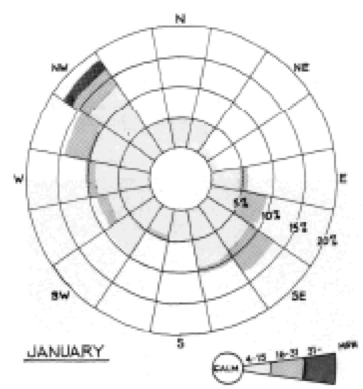
Recall older buildings with narrow floor plates, overhangs, high ceilings, operable transom panels over doors, and interior louvered doors—all means of inducing cross-ventilation before air conditioning became commonly used. Note also the similarities to long and narrow forms being preferred for daylighting and solar strategies. From a whole-building design perspective, strive to balance passive solar, daylighting, sun shading, landscaping, and natural ventilation strategies to optimize use of the natural features of the site to maximize energy savings.

Roof shape and cross-section of the building will also affect air flow. Sloped roofs will tend to shed harsh storm winds better than flat roofs. Selection of window type is also important. Casement, awning, and hopper windows reduce effective aperture area by 25 to 33 percent, as compared with a 50 percent reduction for double- or single-hung and horizontal sliding windows. The air flow diagrams on the following page demonstrate several natural ventilation design devices.

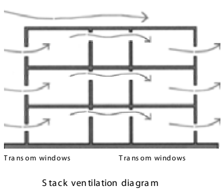
Use of such ventilation strategies must be carefully modeled to ensure achievement of the desired comfort objectives. Noise, smoke, and fire can also come with air movement through spaces of a building, so the designer must balance the achievement of natural ventilation with acoustical and fire



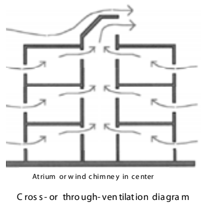
Wind speed and direction



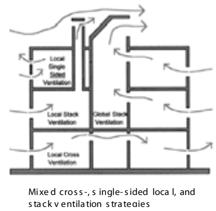
Wind rose



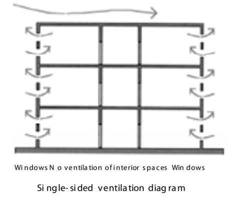
Stack ventilation diagram



Cross- or through-ventilation diagram



Mixed cross-, single-sided local, and stack ventilation strategies



Single-sided ventilation diagram

protection considerations and building code requirements. Natural ventilation may also be supplemented by use of electric fans and mixed-mode cooling, which use electricity but far less than what is used for total mechanical cooling.

Mixed-mode cooling is a strategy that uses air conditioning and natural ventilation in various combinations. Ideally, a building would use natural ventilation whenever suitable for occupant comfort and would supplement with mechanical cooling only when needed. Mixed-mode strategies require highly integrated design collaboration between the design professionals to optimize building form, orientation, window size and placement, and appropriate mechanical design. Mixed-mode cooling can be used on swing days or in shoulder seasons in humid climates previously thought not suitable for natural ventilation.

There are several mixed-mode types that are differentiated by their operating strategies:

- Concurrent—uses mechanical cooling and natural ventilation in the same spaces at the same time
- Changeover—switches between mechanical cooling and natural ventilation on a daily or seasonal basis
- Zoned—uses mechanical cooling and natural ventilation in different zones of the building
- Any combination of the above

ESTABLISHED TECHNIQUES

- Building orientation to receive prevailing breezes
- Vegetative shading and water cooling to cool air flow to building spaces
- Balanced use of passive solar, daylighting, sun shading, and landscaping strategies to optimize natural ventilation
- Integrated design process to enhance performance

EMERGING TRENDS

- Greater emphasis on providing natural ventilation in public and commercial building within temperate climate zones
- Modern adaptation of traditional architectural devices, such as wind chimneys, atria, courtyards, windows, and operable blinds to induce natural air flow
- Electronic modeling of natural ventilation and building form

What are relevant resources for **Natural Ventilation?**

- Whole Building Design Guide, Resource Pages, Natural Ventilation, Andy Walker, National Renewable Energy Laboratory
- For local climatic data and wind roses, see the Web site of the National Climatic Data Center: www.ncdc.noaa.gov/oa/ncdc.html
- *Architect's Handbook of Energy Practice*, now an out-of-print series of publications, 1982, American Institute of Architects:
  - Explanation of natural ventilation and air flow is in Design—Passive Heating and Cooling, in the section titled "Direct Cooling," pages 42–47
  - Explanation of a "wind rose" diagram, a graphic representation of wind data, is found in *Predesign—Climate and Site*, in the section titled "Wind," pages 24–27
- For more detailed wind flow diagrams and information, see the "Natural Ventilation" pages in *Architectural Graphic Standards*, 11th ed., by Charles Ramsey & Harold Sleeper, John Wiley & Sons, 2007
- Case studies of postoccupancy surveys of buildings having natural ventilation, National Renewable Energy Laboratory, accessible at www.eere.energy.gov/buildings/high_performance
- "Mixed-mode Cooling," Gail S. Brager, PhD, *ASHRAE Journal*, August 2006
- Cross-sectional ventilation diagrams were taken from the paper NISTIR 6781, "Natural Ventilation Review and Plan Design and Analysis Tools," by Steven J. Emmerich, W. Stuart Dols, and James W. Axley, National Institute of Standards and Technology, U.S. Department of Commerce, August 2001; captioning was modified to include reference to architectural features for the purpose of this paper

Which strategies interact with **Natural Ventilation?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Form
» Building Orientation
» Integrated Project Delivery
» Sun Shading
» Vegetation for Sun Control
» Windows and Openings

What is Open, Active, Daylit Space?

Glebe Elementary School—Arlington, Va., by BeeryRio Architecture + Interiors. Passive solar design strategy incorporated into the exterior of the building (photo courtesy of Loan Pham).

Indoor environments, especially attributes such as the amount and quality of light and color, sense of enclosure, sense of privacy, access to window views, connection to nature, sensory variety, and personal control over environmental conditions, have strong effects on occupant well-being and functioning. Designing to enhance psychological well-being will therefore have positive impacts on building users. Although difficult to quantify, some studies have linked increased occupant productivity to daylit space.

Well-controlled daylight harvesting can reduce the amount of artificial lighting needed and the associated cooling load imposed by excess electric lighting. By incorporating controlled daylighting and passive solar strategies, solar gain can be used to advantage in the heating season and reduced in the cooling season.

More than other building types, school facilities have a profound impact on their occupants and the functions of the building, namely teaching and learning. Children in various stages of development are stimulated by light, color, the scale of their surroundings, even the navigational aspects of their school. Children can also react negatively to adverse conditions.

Increasing numbers of studies are beginning to suggest that support for communication and collaboration as well as for individual cognitive activity is a fundamental aspect of organizational productivity. The U.S. General Services Administration (GSA) agrees and concludes in The Integrated Workplace that “since people are the most important resource and greatest expense of any organization, the long-term cost benefits of a properly designed, user-friendly work environment should be factored into any initial cost considerations.”

The library/media room receives ample daylight (photo courtesy of Duane Lempke/Sisson Studios).

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Properly controlled daylit spaces can reduce overall energy use; various building systems (i.e., artificial lighting and HVAC) can be reduced in size and cost to make way for further energy-saving materials, designs, and technologies.

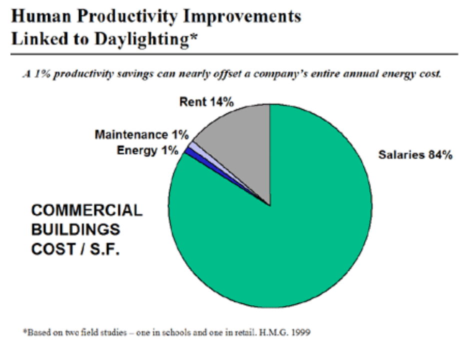
Specify energy-efficient equipment and technologies
- Use efficient lighting fixtures, daylighting controls, and passive solar strategies.

Use renewable strategies and purchase green power
- Use present solar strategies as a part of a whole-house design strategy.
- Use daylighting and passive solar strategies to decrease energy loads and offset emissions of conventional building energy systems.

Educate building owners, operators, and occupants
- On functional, productivity, and operational advantages of daylighting strategies.
- On use of daylighting controls.

A business case can be made that when salaries, benefits, and absenteeism are taken into account, people—the building occupants—are the most valuable assets in a building. Present life-cycle analysis uses 30 years as the normal useful life for a commercial building. The initial construction cost of energy and productivity design strategies can be easily recouped in improved occupant performance well within that life cycle, and economic benefits can then continue to add value to the building or business operation.

Three studies of different occupant groups—telephone call center workers, school students, and retail shoppers—were conducted by the Herschong Mahone Group in California. All showed significant correlation between productivity and daylighting availability. Productivity of the call workers was increased, performance of students improved, and retail sales increased with the introduction of daylighting (see citation in the Resources section).



How do I design for Open, Active, Daylit Space?

Plan buildings such as schools, laboratories, and business centers to have spaces that are centers of activity and social interaction. People are the common assets, and they are most productive and satisfied in an environment with good daylight and acoustical properties that encourages social interaction. Places for planned or chance meetings can be in atria, cafeterias, and lounges and can be visually accessible to common circulation paths. Design such spaces to be comfortable and inviting, with controlled daylight. A common device is a major circulation path being designed as a "street" or "spine" with well-lit skylights or windows.

School Solution

Boscawen Elementary School in Boscawen, N.H., was designed with "room-like" noninstitutional corridors, plenty of views out and in, and windows between the classrooms and the hallway, which all combine to improve the safety and sense of security.

Workplace Solution

- Open spaces at central nodes for spontaneous interaction
- More meeting spaces of a greater variety
- A centrally located café for meetings and lunch
- A new daylit entry space

The new daylit entry space in the GSA building at the Denver Federal Center (pictured at right) creates not only a positive impression, but also a central social space where associates frequently encounter one another on their way to different areas in the building.

The skylit café (pictured at left), located right off the entryway, is used for informal meetings as well as lunchtime gatherings.

Daylighting design strategies are discussed further in the Daylighting page and in greater detail in the Relevant Resources section. To recap, they are as follows:

- Building orientation and shape to optimize daylight gain
- Sun shading
- Top and side lighting
- Clerestories
- Skylights
- Light pipes
- Atria with interior windows and top lighting from skylights or clerestories
- Interior controls (e.g., shades, blinds, curtains)
- Light shelves used to bounce light deeper into the interior space (Light shelves must be set above the view line so reflected light does not disturb those near the window)
- Sloped suspended ceiling (higher near the window)
- Reflective (but not shiny) interior finishes
- Electric lighting controls with dimmable ballasts that react to changing daylighting conditions in perimeter and interior space zones
- Separately zoned HVAC controls for areas that might overheat from solar gain

ESTABLISHED TECHNIQUES

- Orient exposures to receive south and north light and shield against east–west sun glare.
- Control against direct sunlight and glare entry into the space.
- Use horizontal daylight opportunities, such as skylights or clerestory windows, to provide daylighting into the interior of building with large floor plates.
- Provide daylit social spaces where people can gather and interact.
- Provide user-activated devices to control daylight at workstations and in school classrooms.
- Provide occupants with view access to the outside.

EMERGING TRENDS

- Schools that feature high-performance design and technologies to enhance learning, support community use, and function well during natural and other disasters
- Smart daylighting controls that interact with building automation systems for automated energy use optimization and comfort adjustment
- New glass technologies that change optical and thermal characteristics of glazing, such as gas fill between glass layers, double-skin façades, fritting, films, and switchable optics that have dynamic optical properties subject to changes in light, temperature, or photoelectrical condition

What are relevant resources for **Open, Active, Daylit Space?**

- Whole Building Design Guide/Design Guidance/Design Objectives/Productive: www.wbdg.org/design/productive.php
- Whole Building Design Guide/Design Guidance/Building Types/ Educational Facilities/Elementary Schools, by Ellen Larson Vaughan, Steven Winter Associates, Inc.: www.wbdg.org/design/elementary.php
- Daylighting productivity studies by the Herschong Mahone Group: www.h-m-g.com/projects/daylighting/projects-PIER.htm

Which strategies interact with **Open, Active, Daylit Space?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

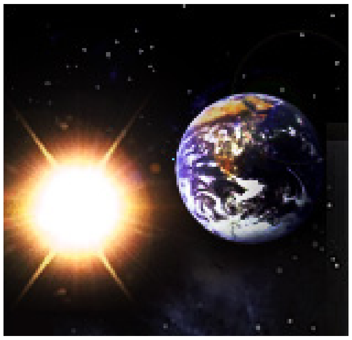
» Daylighting
» Smart Controls
» Sun Shading
» Windows and Openings

32 Passive Solar Collection Opportunities

What are Passive Solar Collection Opportunities?

Solar collection is simply harvesting the sun's energy and using that energy for heating, cooling, daylighting, and water heating in buildings. Solar collection can be extremely high-tech, such as an array of precisely aligned solar photovoltaic panels to generate enough energy to power a neighborhood, or very simple, such as a sunny warm spot on the front porch in which to curl up and read a book. Whether it's active collection or passive collection, the use of the sun to power, light, and warm our structures offers a low environmental impact alternative to fossil fuels. Solar collection may be large or small in scale, local or remote in installation, and costly to free in price. This brief discusses passive solar collection strategies. The key to successful passive solar design is analysis and understanding of the project's specific site, solar angles, local vegetation, regional climate, and the building's thermal loads.

Passive solar collection systems often use no machinery or equipment. Designs are typically physically static in nature, relying primarily on initial building design and site orientation to service the structure. Because passive solar collection systems use the building design, many passive design strategies are available at no or limited additional initial costs—the building becomes the energy system. These strategies include proper siting, use of existing landscaping for shade, and in some instances use of building mass as a heat storage system. The four essential ingredients are collection (south-facing glazing), storage (usually masonry, water, or other mass), distribution (typically natural heat transfer such as radiation and convection), and control (shading and insulation of the collection area). There are three primary system types: direct gain, indirect gain, and isolated gain. Combination systems can also be designed.



Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- The implementation of solar collection techniques can directly reduce the overall energy use of a building.

Specify energy-efficient equipment and technologies
- Use an integrated system approach to specify the most cost-effective, energy-efficient equipment in coordination with the solar collection system(s).

Use renewable strategies and purchase green power
- Use of solar collection opportunities will decrease purchased energy requirements.

Educate building owners, operators, and occupants
- On the design intent and operation of the solar collection system(s).

- Direct Gain: Collection is at the building skin, allowing light and heat directly into the use space, with storage integral within it (walls, floors, etc.).
- Indirect Gain: Collection and storage are at the building skin, and the storage is thermally coupled to the use space (as opposed to isolated gain). Examples include Trombe walls, mass walls, water walls, roof ponds (Skytherm as a product type), and attached sunspaces (where the thermal mass is connected or coupled to the use space).
- Isolated Gain: Convective loops usually are attached to sunspaces (when they are thermally disconnected to the use space by insulated walls, control devices, etc.).
- Combination: Collection incorporates a variety of these system types in the same building based on thermal and use needs.

Direct Gain

Direct gain is the simplest form of solar collection. Energy from the sun travels through the glazing of a building into an interior space and warms the space. This warming can greatly reduce heating loads with proper overall building design, especially if used in conjunction with thermal mass. Often in larger scale commercial buildings, this added heat is unwanted, causing an increased cooling load, resulting in higher energy costs. In these cases, mitigation of direct solar gain is very important. Light shelves, external screens, awnings, and landscaping all serve to control direct solar gain.

Attached Sunspace

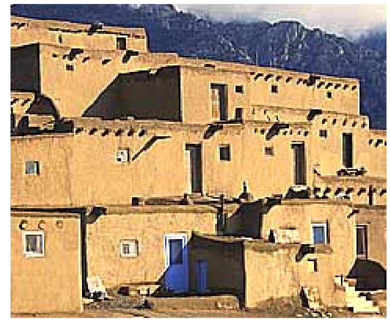
Attached sunspaces (indirect or isolated gain systems) can take virtually any shape and size; however, proper sizing relative to the size and required service needs of the project is key to proper performance. Sunspaces may be residential in scale, such as solariums and small greenhouses. Larger commercial projects may also take advantage of sunspaces in the form of atria or enclosed courtyards. The attached sunspace captures direct gain solar heat and transfers its heat throughout the project through either natural convection or mechanical systems. These sunspaces often can serve an entire project, reducing the heating and cooling loads dramatically. An added feature of the attached sunspace is often its aesthetics. Sunspaces create a sustainable interior environment for plants, allowing for interior gardens year round.

Convective Loop

The use of a convective loop (indirect or isolated gain systems) in conjunction with other passive design strategies allows for a collection system that uses no external energy. The convective loop technology operates on the basic principle that hot air rises. When air moves through a space in which the heat gain is solely by solar energy, convection occurs naturally. This air can be guided to heat other areas of the project or to siphon cooled air in, thus cooling the space. The control of convective systems can be very exact with proper sizing, controllability of direct solar gain, and thermal mass storage systems.

Thermal Mass Storage

Thermal mass storage (all above-mentioned passive systems) uses the mass of the building to collect solar energy during the day and release it at night. Building construction of thermal storage systems is typically masonry and may be located in the floors, walls, or roofs. These surfaces are typically heated by direct sunlight through adjacent glazing. The stored heat is radiated back to the space at night. One of the most classic examples of thermal mass storage is the adobe homes of the Navajo in the southwestern United States.



How do I design with Passive Solar Collection Opportunities?

Passive solar collection design systems provide a near limitless source of energy for our buildings. Choosing the correct technology for your project will reduce fossil fuel consumption, in turn eliminating carbon and greenhouse gas emissions. The benefits of reduced operating costs, local environmental impact, potential government offsets, and potential public relations exposure add to the incentives of these green technologies.

Technologies that may be used in your designs include:

- Building Mass: Solar heat storage within building mass to be used later as space heating.
- Site Orientation: Proper siting of the structure to take full advantage of local solar gains. Rotating a project as little as 8º on the site can significantly affect operating costs of a building (see Daylighting).
- Passive Solar Cooling: Often referred to as "thermosiphoning," using rising heat generated from the sun to pull cool air into and condition a building's space.
- Daylighting: Reducing energy loads by providing natural light in lieu of artificial light.
- Attached Sunspace: A virtual habitable furnace for a building, allowing heating and cooling combined with daylighting and functionality.
- Landscaping: Trees and plants providing shade, reducing heat gain, and blocking wind, thus reducing heating and cooling loads.
- Building Design and Shape: Regionally designed buildings that take advantage of potential solar gains.

What are relevant resources for **Passive Solar Collection Opportunities?**

- National Renewable Energy Laboratory (NREL): www.nrel.gov/learning/re_passive_solar.html
- DOE Building Technologies Program—Passive Solar Design: www.eere.energy.gov/buildings/info/design/integratedbuilding/passive.html
- DOE Consumer Guide to Energy Efficiency and Renewable Energy: www.eere.energy.gov/consumerinfo/
- www.ases.org

Which strategies interact with **Passive Solar Collection Opportunities?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Form
» Building Orientation
» Daylighting
» Earth Sheltering
» Energy Source Ramifications
» Life Cycle Assessment
» Mass Absorption
» Open, Active, Daylit Spaces»
Photovoltaics
» Renewable Energy Resources
» Sun Shading

What is Photovoltaics?

PV array

Photovoltaics or PV is a technology in which sunlight is converted into electrical power. It is best known as a method for generating power using solar cells packaged in photovoltaic modules, often electrically connected in multiples as solar photovoltaic arrays, to convert energy from the sun into electricity. PV requires little to no maintenance, makes no pollution, and does not deplete materials. In some cases, it is possible to generate enough electricity from PV to power an entire building.

PV is made of semiconducting materials similar to those used in computer chips. There are two basic commercial PV module technologies available on the market today: thick crystal products and thin-film products.

Solar cells are typically combined into modules that hold about 40 cells; about 10 of these modules are mounted into a PV array. The arrays can be mounted at a fixed angle facing south or mounted on a tracking device that follows the sun, allowing them to capture the most sunlight over the course of a day. PV is appropriate for small- and large-scale applications. PV arrays can be designed into a new structure or be retrofitted into existing buildings; in this case, they are usually fitted on top of the existing roof structure. Alternatively, an array can be located separately from the building but connected by cable to supply power for the building.

Thin-film solar cells use layers of semiconductor materials only a few micrometers thick. Thin-film technology has made it possible for solar cells to double as rooftop shingles, roof tiles, building façades, or skylight and atria glazing. The solar cell roof shingle offers the same protection and durability as ordinary asphalt shingles.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- Photovoltaics should be considered after reducing energy needs and use in a building.

Specify energy-efficient equipment and technologies.
- Specify equipment and technologies carefully to optimize the PV design.

Use renewable strategies and purchase green power.
- Photovoltaics is a renewable technology that supports the reduction or elimination of energy produced by fossil fuels.

Educate building owners, operators, and occupants.
- Help others learn about the benefits of photovoltaics and the relation to energy use in the building.

How do I apply **Photovoltaics?**

PV systems should be considered where energy-conscious design techniques have been employed first and equipment and systems have been carefully selected and specified. PV should be viewed in terms of life-cycle cost, and not just initial, first-cost, because the overall cost may be reduced by the avoided costs of the building materials (in the case of building-integrated photovoltaics) and labor they replace and the fact that solar energy is free (i.e., there are no fuel costs).

By serving as both building envelope material and power generator, building-integrated photovoltaics (BIPV) systems provide the following benefits:

- **Reduced materials and electricity costs**
- **Reduced use of fossil fuels and emission of ozone-depleting gases**
- **Added architectural interest to the building**

PV systems either can be interfaced with the available utility grid or they may be designed as stand-alone, off-grid systems. When a building is at a considerable distance from the public electricity supply (or grid)—in remote or mountainous areas—PV may be the preferred possibility for generating electricity, or PV may be used with wind, diesel generators, and/or hydroelectric power. In such off-grid circumstances, batteries are usually used to store the electric power. The benefits of power production at the point of use include

- **Savings to the utility in the losses associated with transmission and distribution**
- **Savings to the consumer through lower electric bills because of peak shaving**
- **Availability of power on-site when utility power is disrupted**

A benefit of grid-tied BIPV systems is that the storage system is essentially free with a cooperative utility policy. It is also 100 percent efficient and unlimited in capacity. Building owners and the utility both benefit from grid-tied BIPV. The on-site production of solar electricity is typically greatest at or near the time of a building's and the utility's peak loads. The solar contribution reduces energy costs for the building owner, and the exported solar electricity helps support the utility grid during peak demand time. The benefit of stand-alone or off-grid systems is that the storage batteries provide power continuously, even at night.

ESTABLISHED TECHNIQUES

Building-Integrated Photovoltaics System

BIPV is the integration of PV into the building envelope, often serving as the exterior weather skin. The PV modules serve the dual function of power generator and building skin, replacing conventional building envelope materials. By avoiding the cost of conventional materials, the incremental cost of PV is reduced and its life-cycle cost is improved.

A complete BIPV system includes:
- The PV modules (which may be thin-film or crystalline, transparent, semitransparent, or opaque)
- A charge controller to regulate the power into and out of the battery storage bank (in stand-alone systems)
- A power storage system
- Power conversion equipment, including an inverter to convert the PV modules' DC output to AC, compatible with the utility grid
- Backup power supplies such as diesel generators, and
- Support and mounting hardware, wiring, and safety disconnects

PV roofing system displaced traditional roofing materials

Panels are usually mounted at an angle based on latitude, and often they are adjusted seasonally to meet the changing solar declination. Solar tracking can also be used to access even more perpendicular sunlight, raising the total energy output. PV modules usually have a 25-year warranty, but they should be fully functional even after 30–40 years.

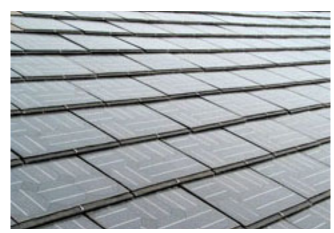
CIS Tower, Manchester, UK, includes a vertical PV façade

Designing a Building-Integrated Photovoltaics System

Design considerations for BIPV systems must include the following:
- Building's use and electrical loads
- Site planning, building location, and orientation
- Local climate and environment
- Appropriate building and safety codes
- Relevant utility issues and costs

BIPV systems can also be designed to blend with traditional building materials and designs, or they may be used to create a high-tech, future-oriented appearance. Semitransparent arrays of spaced crystalline cells can provide diffuse, interior natural lighting. High-profile systems can also demonstrate the building owner's preference or requirement to provide an environmentally conscious work environment.

PV may be integrated into many different assemblies within a building envelope, including:
- *The façade of a building*, complementing or replacing traditional view or spandrel glass
- *Awnings and saw-tooth designs* on a building façade, increasing access to direct sunlight while providing additional benefits such as passive shading
- *Roofing systems*, providing a direct replacement for batten and seam metal roofing and traditional asphalt shingles
- *Skylight systems*, providing both an economical use of PV and an exciting design feature



PV shingle

EMERGING TRENDS

The use of BIPV is growing worldwide. The manufacture of PV cells has also expanded dramatically in recent years. Total nominal "peak power" of installed solar PV arrays was around 3,700 MW as of the end of 2005, a 42 percent increase for the year, and most of this consisted of grid-connected applications.

Financial incentives, such as preferential feed-in tariffs for solar-generated electricity and net metering, have supported solar PV installations in many countries, including Germany, Japan, and the United States.

Solar panels will continue to come down in price as people use and buy more—as manufacturers increase production to meet demand, the cost and price are expected to drop in the years to come. In 2007, investors began offering free solar panel installation in return for a 25-year contract to purchase electricity at a fixed price, normally set at or below current electric rates. Prices are also dropping because of technological advances in manufacturing PV components.

The efficiency of solar cells continues to increase. A concentrator solar cell produced by Boeing-Spectrolab has recently achieved a world-record conversion efficiency of 40.7 percent. Increased power density of thin-film and crystalline solar cells is leading to efficiencies of near 20 percent. Although commercial production of high-efficiency solar cells exceeding 20 percent may not be imminent, the continued improvement of PV materials and technology means that it is only a few years away.

Net metering is an electricity policy for consumers who own generally small, renewable energy facilities, such as wind or solar power, that are tied to the utility grid. "Net," in this context, is "what remains after deductions"—the deduction of any energy outflows from metered energy inflows. A system owner receives retail credit for at least a portion of the electricity generated. Forty U.S. states have some form of net metering in place.

Energy pay-back time—the time required to produce an amount of energy as great as what was consumed during production—is being researched and documented more carefully. For silicon technology, an energy pay-back of one year may be possible within a few years. Thin-film technologies now have energy pay-back times in the range of 1 to 1.5 years in some parts of the world.

PV array, Wellfleet Wildlife Sanctuary, Massachusetts

What are relevant resources for **Photovoltaics?**

- Building-Integrated Photovoltaic Designs for Commercial and Institutional Structures: A Sourcebook for Architects
- Energy Policy Act of 2005 (PDF 1.9 MB, 550 pages)
- Federal Green Construction Guide for Specifiers 48 14 00 (13600) Solar Energy Electrical Power Generation Equipment
- Incorporating PV in Buildings: A Gathering of Eagles
- PV F-Chart—Provides analysis and rough sizing of both grid-connected and stand-alone PV systems
- PVFORM—Offers simulation of grid-connected and stand-alone systems, including economic analysis; available from Sandia National Labs, Albuquerque
- TRNSYS—Simulation system for renewable energy applications; originally for solar thermal, now has extensions for PV and wind
- HOMER——Hybrid Optimization Model for Electric Renewables (HOMER) is a design-optimization model that determines the configuration, dispatch, and load-management strategy that minimizes life-cycle costs

Which strategies interact with **Photovoltaics?**

All 50to50 strategies relate to each other in some way. It is recommended that you consider investigating these selected strategies to gain a comprehensive understanding of the topic.

» Active Solar Thermal Systems
» Building Orientation
» Daylighting
» Life Cycle Assessment
» Passive Solar Collection Opportunities
» Renewable Energy Resources
» Sun Shading

What is Preservation/Reuse of Existing Facilities?

Preservation is the act of saving from destruction or deterioration old and historic buildings, sites, structures, and objects, and providing for their continued use by means of restoration, rehabilitation, reconstruction, or adaptive reuse. In the post-WWII era, we lost our appreciation for our older buildings and communities and did not hesitate to demolish them in the name of slum clearance and urban renewal or new highway intrusion into our urban fabric.

The seminal book by Jane Jacobs about how cities really function, The Death and Life of Great American Cities (1961), and newspaper columns by Ada Louise Huxtable, former architecture critic of the New York Times, slowly raised national consciousness of the need for preservation of our older urban centers and buildings. But it took the shocking destruction of McKim Mead and White's classic Pennsylvania Station in New York City to finally galvanize the beginning of the modern historic preservation movement. The movement was severely tested a few years later in the public opinion and legal battle that saved Grand Central Station and resulted in the establishment of the legal groundwork to support the historic preservation movement.

Now we see that two great movements can be combined—preservation and sustainability.

Preservation and reuse of existing older and historic buildings are inherently sustainable. Although potential for conflict can arise between these two objectives, they are sympathetic on many levels. Both objectives:

- Reuse existing materials and infrastructure and conserve the energy and resources needed for demolition and total replacement

Indoor ice arena: Audrey Tepper (courtesy of National Park Service)

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- Combine the adaptations for natural daylight and ventilation within the older historic buildings with new sustainable strategies to help reduce the overall energy use.
- Take advantage of the embedded energy and infrastructure in the existing building.
- Replace windows with historically appropriate new energy-efficient windows.
- Consider appropriately designed interior storm windows if total window replacement is not economically feasible.

Specify energy-efficient equipment and technologies.
- Specify energy-efficient replacement equipment and appliances in preserved buildings.

Use renewable strategies and purchase green power.
- Adapt renewable energy applications to the existing building in sympathetic ways to preserve historical character and fabric.

Educate building owners, operators, and occupants.
- Provide information on functional and energy-saving advantages of historically appropriate and sympathetic technologies.

- Reduce the amount of demolition and construction waste going to landfills
- Preserve the historic character of older communities, towns, and cities and provide a historical context for new buildings and sustainability technologies
- Preserve the embedded energy in an existing building, which can be 30 percent of the embedded energy of maintenance and operations for the entire life of the building
- Respond to climate and site and provide daylight and natural ventilation, qualities that can now supplement new sustainable design strategies at far lower cost than needed to create them from scratch, and do so without compromising unique historic character
- Bring about substantial energy savings when existing buildings are effectively restored, reused, and combined with modern technologies and materials

Preservation is also sustainable beyond the level of physical development in these aspects:

- Environmental—conserves building materials and embedded energy and avoids negative environmental impacts of demolition, landfills, and new construction
- Economic—respects the limits of ecosytems on which the building depends and helps stimulate local community revitalization and viability of existing buildings and neighborhoods
- Cultural—helps conserve local cultural resources and makes them available for the education of future generations

Federal, state, and local tax incentive programs are typically needed to motivate historic preservation efforts in blighted urban areas. However, the return on investment in terms of economic recovery and revitalization is often five dollars to one dollar invested. Under the Economic Recovery Act of 1981 [36 CFR Part 67], the U.S. Department of the Interior published the Standards for Rehabilitation, which forms the basis for federal tax benefits for historic preservation work in the United States. Similar to historic preservation tax incentives, the Energy Policy Act of 2005 also established federal tax incentives to stimulate the use of energy conservation measures in private sector development.

The federal preservation standards are adapted by state and local preservation organizations to guide their preservation efforts. Look to your State Historic Preservation Officers (SHPO) for applicable historic preservation regulations, listings of historic properties, and regulatory processes. The standards set forth 10 basic principles created to help preserve the distinctive character of a historic building and its site, while allowing for reasonable change to meet new needs. The standards apply to historic buildings of all periods, styles, types, materials, and sizes. They apply to both the exterior and the interior of historic buildings. The standards also encompass related landscape features and the building's site and environment, as well as attached, adjacent, or related new construction.

LEED® Silver Rated Balfour-Guthrie Building, Portland, Ore.

The standards are applied to projects in a reasonable manner, taking into consideration economic and technical feasibility.

1. **A property shall be used for its historic purpose or be placed in a new use that requires minimal change to the defining characteristics of the building and its site and environment.**
   Encourages reuse and adaptive reuse and discourages removal and demolition, saving energy involved in demolition and totally new construction. Reuse of an older building can avoid development of a pristine greenfield site for a totally new facility.
2. **The historic character of a property shall be retained and preserved. The removal of historic materials or alteration of features and spaces that characterize a property shall be avoided.**
   Encourages preservation and reuse of existing fabric, thus saving the energy and avoiding possible pollution to manufacture replacement material.
3. **Each property shall be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or architectural elements from other buildings, shall not be undertaken.**
4. **Most properties change over time; those changes that have acquired historic significance in their own right shall be retained and preserved.**
   Imagine that a current building with sustainable design features will have historic preservation significance 50 years in the future.
5. **Distinctive features, finishes, and construction techniques or examples of craftsmanship that characterize a historic property shall be preserved.**
6. **Deteriorated historic features shall be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature shall match the old in design, color, texture, and other visual qualities and, where possible, materials. Replacement of missing features shall be substantiated by documentary, physical, or pictorial evidence.**
7. **Chemical or physical treatments, such as sandblasting, that cause damage to historic materials shall not be used. The surface cleaning of structures, if appropriate, shall be undertaken using the gentlest means possible.**
   Discourages use of destructive preservation methods and materials. Use of sustainable preservation methods and materials is encouraged.
8. **Significant archeological resources affected by a project shall be protected and preserved. If such resources must be disturbed, mitigation measures shall be undertaken.**
   Discourages wholesale demolition that adds to landfills and disruptive construction activities that decrease air quality.
9. **New additions, exterior alterations, or related new construction shall not destroy historic materials that characterize the property. The new work shall be differentiated from the old and shall be compatible with the massing, size, scale, and architectural features to protect the historic integrity of the property and its environment.**

10. New additions and adjacent or related new construction shall be undertaken in such a manner that if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

More information about the treatment standards, including illustrated guidelines, can be found on the National Park Service Website. www.nps.gov/history/hps/tps/standards_guidelines.htm

How do I design for Preservation/Reuse of Existing Facilities?

Monticello, Charlottesville, Va., Thomas Jefferson, 1768 to 1782. (Credit: Library of Congress, Prints & Photographs Division, FSA-OWI Collection, John Collier Photographer. Reproduction number, e.g., LC-USF35-1326)

Four Treatment Approaches

Within the Secretary of the Interior's Standards for the Treatment of Historic Properties there are standards for four distinct approaches to the treatment of historic properties: preservation, rehabilitation, restoration, and reconstruction.

- Preservation focuses on the maintenance, stabilization, and repair of existing historic materials and retention of a property's form as it has evolved over time.
- Rehabilitation acknowledges the need to alter or add to a historic property to meet continuing or changing uses while retaining the property's historic character.
- Restoration depicts a property at a particular period of time in its history while removing evidence of other periods.
- Reconstruction re-creates vanished or nonsurviving portions of a property for interpretive purposes.
- Additional Standards and Guidelines for the Treatment of Cultural Resources—Landscapes and archaeological and maritime resources, etc., are maintained by the National Park Service.

Although each treatment has its own definition, they are interrelated. For example, one could "restore" missing features in a building that is being "rehabilitated." This means that there is sufficient historical documentation on what was there originally. For example, a decorative lighting fixture may be replicated or an absent front porch rebuilt, but the overall approach to work on the building falls under one specific treatment.

Changes—both big and small—can have a significant cumulative impact over time. Care must be taken during initial project design and periodic upgrades to avoid the incremental loss of integrity. Following are four basic principles to keep in mind when upgrading systems in historic properties:

- Sympathetic Upgrades: Building systems upgrades should be sympathetic to the architect's specific design intent (e.g., utilitarian spaces vs. highly finished spaces).
- Reversibility: Building systems upgrades should be installed to avoid damage to—or be removable without further damaging—character-defining features and/or finishes.
- Retention of Historic Fabric: Work around the historic fabric as much as possible. The basic mindset prescribes forethought and respect for historic materials. For example, design systems efficiently enough to fit into existing openings or be accessible off-site.

This former rail station depot was converted to a hotel with reception areas

– Life-Cycle Benefit: Long-term preservation emphasizes life-cycle benefits of reusing historic properties and planning for changing needs.
http://www.wbdg.org/design/design_change.php

As such, consider the following:
- Minimize intrusions and long-term impact on historic materials as future repairs and replacements are made.
- Complex systems will require more maintenance to perform properly.
- Explore alternatives that will allow the reuse of existing system elements (e.g., reuse ducts to avoid replacement costs).
- Design zone systems that will allow repairs to be done without disrupting the entire building.
- Take advantage of financial benefits of historic properties, such as special use rental or increased rental rates, gained from restoring lobbies and other significant spaces previously altered.

Instead of demolishing the former train shed, it was converted into an indoor ice arena.

Photo of indoor ice arena:
Audrey Tepper (courtesy of National Park Service)

What are relevant resources for **Preservation/Reuse of Existing Facilities?**

- National Park Service
- National Register of Historic Places
- U.S. General Services Administration—Historic Preservation
- Advisory Council on Historic Preservation (ACHP)
- National Conference of State Historic Preservation Officers (NCSHPO)
- National Trust for Historic Preservation
  - See the National Trust Sustainability Initiative program, which promotes the understanding that historic preservation is a green building practice and the integration of green technologies into existing buildings
  - See the National Main Street Program for preservation and economic issues at the local community scale: www.mainstreet.org/
- Sustainable Preservation Coalition: Member organizations include the National Trust, AIA, and Association for Preservation Technology
- National Preservation Institute
- Smithsonian Institution
  - Architectural History and Historic Preservation Division
  - Office of Facilities Engineering and Operations
- Whole Building Design Guide/Design Guidance/Design Objectives/Historic Preservation/Sustainable Historic Preservation: www.wbdg.org/design/sustainable_hp.php?r=historic_pres-i
- www.aiatopten.org/hpb/

Which strategies interact with **Preservation/Reuse of Existing Facilities?**

All 50to50 strategies relate to each other in some way. It is recommended that you consider investigating these selected strategies to gain a comprehensive understanding of the topic.

» Conserving Systems and Equipment
» Walkable Communities

What is Radiant Heating and Cooling?

Radiant heat is infrared radiation moving from a warmer object to a cooler object. A hot stove, for example, emits invisible, infrared radiation that is easily felt by much cooler human bodies. When applied effectively, radiant heating and cooling can provide outstanding comfort and efficiency in buildings.

Convection—as opposed to radiation—is the more common method for maintaining comfort in buildings. Convection, as used here, is the heating or cooling of the air within a building (by ducted, forced-air systems; hydronic baseboard convectors; etc.). In these conditioning systems, the comfort of building occupants is established by controlling the temperature of the air in the building.

With radiant heating and cooling systems, radiant energy is transferred directly to occupants and objects within a space (although there is certainly some heat transfer to air as well). When energy is used to heat or cool occupants directly—rather than heating the air surrounding them—there is potential for higher levels of comfort and efficiency.

Radiant heating was used long before convective heating in buildings. Making use of the sun, of course, is the oldest radiant heating strategy, but open fires and wood stoves also rely on radiation to heat people and spaces. Before fans and pumps were available to move hot air and water, steam radiators provided distributed heat to many buildings. Although all of these systems are still used today, larger radiant panels, such as radiant floors, walls, and ceilings, are used in high-performance buildings. Of these, radiant floors are the most common.

In most radiant heating systems, warm water is circulated through polymer tubing embedded within floor systems. The flow of the water, and often the temperature of the water, is controlled

Wood stoves and steam radiators are early radiant heat devices still in use today.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- When designed and controlled properly, radiant heating or cooling systems can reduce energy use.
- Radiant systems are effective heating or cooling individual building zones, which can reduce whole-building energy use.

Specify energy-efficient equipment and technologies.
- The energy efficiency of a radiant heating or cooling system is directly tied to the efficiency of the equipment providing the heated or chilled water that is circulating.

Use renewable strategies and purchase green power.
- Radiant heating systems can be effectively integrated with active solar thermal systems.

Educate building owners, operators, and occupants.
- The control and response rate of radiant systems can be different than for forced-air systems, making education key.
- With radiant cooling, control of humidity within the space is critical.

to maintain comfort. Radiant heating systems can sometimes be more efficient because of the low water temperatures needed. Often water within radiant piping is between 90° and 120° F; baseboard convectors, by contrast, often operate between 160° and 180° F. At lower temperatures, heating plants—especially plants with condensing boilers—can operate much more efficiently. The lower temperature requirements also open possibilities for alternatives such as ground-source heat pumps and active solar heating. Some radiant floor systems make use of electric resistance elements beneath the finished floor. Although not expensive to install, the cost of electricity used by these heaters usually prohibits their application except in smaller spaces.

Although not yet as common as radiant heating, radiant cooling—often in ceiling panel radiators—has growing applications, especially in commercial buildings. “Chilled beams” are another radiant cooling device with growing applications, although many chilled beams rely primarily on convection rather than radiation. In all of these systems, chilled water is distributed through radiant panels, and, as with radiant heating systems, milder water temperatures often can be used, allowing for higher chiller efficiencies.

Radiant tubing for a greenhouse before slab is poured.

Concrete is poured over radiant tubing and insulation in a home.

How do I apply Radiant Heating and Cooling?

ESTABLISHED TECHNIQUES

Although the principles behind radiant heating and radiant cooling are similar, their applications in systems are often quite different. Hydronic radiant heating—in particular, radiant floors—has been used for decades.

Designers, engineers, and contractors familiar with radiant heating systems have several methods for including radiant tubing in any type of floor system. In concrete slabs, radiant tubing is often installed before concrete is poured and embedded within the slab. Above deck floors, tubing is often installed in metallic heat transfer plates that conduct and spread heat across the floor’s surface. There are even specialized products available that incorporate heat transfer plates into a structural subfloor. Many floor systems require insulation beneath the radiant elements so that heat is directed upward rather than down to the ceiling below.

One of the appealing aesthetic aspects of radiant floor heating is the lack of any visible heating system elements. There is no need for grilles, registers, or convectors when the floor itself provides the heat. Finish floor material, however, is important in the design of radiant heating systems. Insulating materials (such as thick carpet and pads) will require higher water temperatures and are usually not recommended. Highly conducting finish materials (such as tile or finished concrete) allow for the best transfer of heat to the space and occupants. Although more insulating than tile, wood flooring can work well above radiant floors. With any finished floor product, care should be taken to follow the manufacturer’s instructions for installation above a radiant floor. With hardwood flooring, for example, it is

These chilled beams incorporate lighting as well as cooling

Highly conductive tile is a very effective radiant floor finish usually necessary to limit the temperature of the floor to avoid warping and gaps.

Although radiant heating does offer potential for improved efficiency and comfort, it is not guaranteed. Good design of the mechanical systems and controls is essential. In some of the best radiant heating systems, for example, the temperature of water circulated through the floor varies with the load and with outdoor temperature. In addition, not all boiler plants can be controlled to efficiently provide low-temperature water.

EMERGING TRENDS

Some modern condensing boilers are an excellent match to low-temperature radiant heating systems. At lower temperatures, these boilers can reach the highest efficiency levels. Similarly, radiant heating can be an excellent match to the modest temperatures provided by some solar thermal systems and ground-source heat pumps.

Although in use for a decade or more in Europe, radiant cooling systems are relatively new in the United States. In radiant cooling systems, cool water is circulated from a chiller plant to radiant panels installed in the building. Just as radiant floors are most effective for heating, natural convection makes radiant ceiling applications most effective for cooling. Prefabricated radiant ceiling panels and chilled beams are becoming more common, but radiant panels are also created by installing pipes or tubes above finished ceilings.

Regardless of the type of panel, control of the chilled water temperature and humidity of indoor air is critical to prevent condensation on radiant cooling panels. In many buildings, outdoor air—either by ventilation or infiltration—is the primary source of humidity. Some designers have found that radiant cooling and radiant heating work well when paired with dedicated outdoor air systems (DOASs). If radiant heating and cooling systems maintain thermal comfort, a forced-air system's only functions may be conditioning and distribution of fresh, outdoor air. When not responsible for space heating and cooling, a DOAS can more efficiently and effectively provide fresh air. It can also maintain humidity levels to minimize the risk of condensation on radiant cooling panels.

Examples of a ceiling panel radiator (above) and more intricate chilled beam (below)

What are relevant resources for **Radiant Heating and Cooling?**

- Radiant Panel Association: www.radiantpanelassociation.org
- Toolbase: Radiant Cooling: www.toolbase.org/Technology-Inventory/HVAC/hydronic-radiant-cooling
- Hydronic Heating Association: www.comfortableheat.net
- Dedicated Outdoor Air Systems: http://doas-radiant.psu.edu/

Which strategies interact with **Radiant Heating and Cooling?**

All 50to50 strategies relate to each other in some way. It is recommended that you consider investigating these selected strategies to gain a comprehensive understanding of the topic.

» Active Solar Thermal Systems
» Co-Generation
» Mass Absorption
» Space Zoning

What are Renewable Energy Resources?

Although it is increasingly common for designers to incorporate renewable energy generation (especially solar energy) into buildings, it is also becoming more common for building owners and operators to purchase "green" or renewable electricity that is generated off-site.

Purchasing green power does not imply that the specific electricity generated off-site is transmitted directly to the green power purchaser. Rather, it involves taking advantage of one of several methods to track renewable energy generation and stimulate more renewable energy-generating capacity.

Where available, green power programs sponsored by local utilities can be a simple way to purchase renewable energy. Some electric utilities offer customers the option of purchasing renewable energy for part or all of their electricity consumption. The utility usually offers green power at a premium, and this premium goes toward developing new renewable energy generation or purchasing credit for renewable energy generated at existing facilities.

When utilities purchase "credit" for renewable energy generated, these are referred to as "renewable energy certificates" or "renewable energy credits" (RECs). Utilities are not the only entities that buy and sell RECs. Building owners can purchase RECs directly from brokers to cover part or all of their building's energy use.

RECs, also called "green tags" or "tradable renewable certificates" (TRCs), are intangible assets created whenever electricity is generated from a renewable source. TRCs are essentially the "credit" for generating power from a sustainable source. REC brokers purchase RECs from energy generators and market them to consumers, utilities, and others.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- Lower energy loads will reduce the need for purchasing energy—renewable or otherwise.

Specify energy-efficient equipment and technologies.
- Efficient equipment will also reduce need for purchasing power.

Use renewable strategies and purchase green power.
- Enroll in renewable programs offered by the local utility.
- In deregulated markets, purchase electricity from a supplier of clean energy.
- Purchase renewable energy certificates (RECs) to offset on-site energy consumption.
- Investigate power purchase agreements (PPAs).

Educate building owners, operators, and occupants.
- Building owners and operators will ultimately make decisions about power purchasing moving forward; it is key that they be informed of renewable energy purchasing options.

All RECs are not necessarily created equal. RECs are classified in several ways, including type of renewable energy generation (solar, wind, hydro, biomass, geothermal, etc.). Some customers, for example, value solar RECs over large-scale hydro RECs because solar technologies generally have fewer negative environmental impacts. RECs are also classified by the location where the energy was generated. To track and verify the generation of renewable energy and the associated RECs, an independent certification program such as Green-e is necessary. Green-e, operated by the nonprofit Center for Resource Solutions, provides certification and verification of renewable energy across the country (see the Resources section for more on Green-e).

For some designers or owners who have space for renewable energy installations at their sites but do not want to be burdened with the cost, power purchase agreements (PPAs) are an option growing in popularity. Through a PPA, a renewable energy contractor will generally install, operate, own, and maintain a renewable energy installation at a host site. The system owner will then sell energy generated by the system to the host at prices determined in the PPA. This can be an effective way to host a renewable energy system without being burdened by the up-front cost. Be aware, however, that the "credit" associated with generating electricity renewably (the RECs) is generally retained by the system owners and sold elsewhere through brokers.

How do I apply **Renewable Energy Resources?**

The local electric utility is often the best place to begin looking for renewable energy purchasing opportunities. In response to consumer demand—and often state legislation—many utilities offer "clean" or "green" energy purchasing programs. In some programs, customers are able to purchase distinct "blocks" of renewable energy (e.g., a fixed number of kilowatt-hours each month). Other programs allow purchase of 100 percent energy from renewable sources. Details of these programs vary tremendously, so check with local utilities.

Under deregulation, utilities are generally responsible only for transmission and distribution of electricity. The energy itself is generated and sold to consumers by separate entities (although the utility still operates as a middleman). In these areas, it is often possible to select from several energy providers offering an array of clean energy products.

If these options are not viable, it is still possible to purchase RECs directly from brokers to offset energy consumption at a site. RECs can be selected for different types of renewable energy (solar, wind, etc.) and can often be purchased from local generators if desired. Green-e offers an online tool to help consumers find opportunities to purchase renewable energy in their area (see Resources).

PPAs are usually quite customized. If interested, confer with local renewable energy distributors or contractors. The Findsolar site (see Resources) is a useful tool for finding renewable energy contractors, including contractors who can provide PPAs.

What are relevant resources for Renewable Energy Resources?

- Green-e (www.green-e.org) is an independent organization that certifies and verifies renewable energy assets. The site has a search feature to find specific types of green power purchasing opportunities available in your state.
- The U.S. Green Building Council (www.usgbc.org) acknowledges the value of green power purchasing in its Leadership in Energy and Environmental Design program for new construction (LEED-NC) in Energy and Atmosphere, Cr 6.0.
- The U.S. Environmental Protection Agency has developed a "Guide to Purchasing Green Power" available online: www.epa.gov/greenpower/buygreenpower/guide.htm
- The findsolar.com (http://www.findsolar.com/) web site is a tool to find local solar energy contractors or distributors. It can also find contractors willing to provide PPAs.

Which strategies interact with Renewable Energy Purchasing?

All 50to50 strategies relate to each other in some way. It is recommended that you consider investigating these selected strategies to gain a comprehensive understanding of the topic.

» Alternative Energy
» Carbon Offsets
» Geoexchange
» Photovoltaics

37 Rightsizing Equipment

What is Rightsizing Equipment?

The concept of rightsizing equipment is commonly applied to a building's heating and cooling (HVAC) systems and is a fundamental element in the integrated approach to building design. When equipment is "rightsized," all of the building's design specifications are considered, as well as their interactions in determining the appropriate capacity or size of the building's heating and cooling systems. No "rules-of-thumb" are allowed. Keep in mind that the size of all of the ancillary components such as pumps, cooling tower, and ducts are affected by the size of the primary system as well.

HVAC equipment is responsible for approximately 45 percent of commercial buildings' electrical energy use, according to the U.S. Department of Energy's Commercial Buildings Energy Consumption Survey. Therefore, even modest improvements to the HVAC system will have significant impacts on the building's total energy performance.

Rightsizing equipment has many benefits, not the least of which is a savings in initial equipment cost, which can then be used to upgrade the efficiency of the HVAC system or applied elsewhere to enhance the energy efficiency of the building. In many instances, a higher efficiency rightsized system will have a comparable or lower initial cost than a system that is sized using "old school" methods. These old methods assume poor building envelope performance—high lighting, equipment, and occupancy densities—and then add an unnecessary "fudge" factor.

Beyond an initial cost savings, rightsizing equipment can reduce the inefficiencies attributable to operating equipment at low part-load conditions. Advancements have been made in technology and controls to improve part-load performance, but there are still limits to how low in capacity systems can operate.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- Rightsizing reduces the inefficiencies of operating at low part-load conditions.

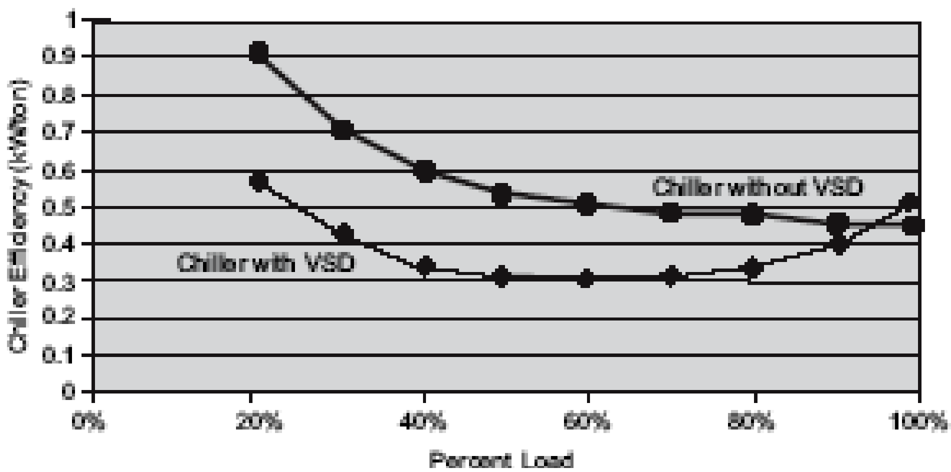
Specify energy-efficient equipment and technologies.
- Rightsizing produces initial cost savings that can be applied to higher efficiency equipment.

Use renewable strategies and purchase green power.
- Using rightsized equipment can reduce a building's overall energy load, require smaller and more cost-effective renewable strategies, and reduce emissions.

Educate building owners, operators, and occupants.
- Educate them on optimum control of rightsized systems.

A fan system sizing study funded by the U.S. Environmental Protection Agency found that 60 percent of the buildings surveyed had systems that were oversized by 60 percent. For single-stage or constant capacity systems, oversized systems must cycle on and off more frequently, which causes wear and tear on equipment and poor comfort with larger temperature swings.

Another potential benefit of rightsized equipment is better control of indoor humidity levels. In most instances, when air-conditioning systems are oversized, they are ineffective at removing moisture from the air. This results in high indoor humidity levels and uncomfortable, clammy conditions.



Variation in chiller efficiency with load and the impact of a variable speed drive (VSD)

How do I apply **Rightsizing Equipment?**

ESTABLISHED TECHNIQUES

Rightsizing HVAC equipment is an integral part of the integrated design process. Although HVAC system sizing is the responsibility of the mechanical engineering firm or, for small residential projects, the HVAC contractor, the architect plays the important role of providing accurate building specifications. As decisions are made on glazing, lighting, and envelope specifications, the impact on HVAC equipment sizing should also be considered.

The methodology used for HVAC system sizing should be based on procedures developed by established organizations such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) for commercial buildings or the Air Conditioning Contractors Association (ACCA) for residential buildings. These procedures are often cited in building codes.

These procedures provide guidance, but true rightsizing requires detailed knowledge of the building's intended use and specifications. As a designer, it is important to provide that information to the engineers and make sure that the information is used. Challenge "rules of thumb."

It is also critically important that all other assumptions are reviewed and confirmed to be appropriate. As an example, building codes allow for fairly high internal lighting densities that add significant loads to the cooling system. Unless the engineer is told that an alternative approach such as daylighting with automated controls will be used, the higher code levels will be assumed for the sizing calculation and the cooling system will be oversized. Worst-case assumptions are also commonly made for building orientation and distribution system losses.

A good practice is to use computer-based energy models that account for the diversification of peak loads for each zone and air-handling system and add a modest factor of safety. These models also account for efficiency measures, such as innovative shading systems. In addition to programs such as DOE-2, Equest, and EnergyPlus, leading equipment manufacturers have developed programs for sizing. For example, Carrier offers E20-II and Trane offers TRACE.

Modular boiler installation

The additional fee for an engineering firm to perform a careful and thorough design calculation using a whole-building approach will be recovered immediately.

For buildings with widely varying loads, a modular approach can provide rightsizing benefits. This approach uses several smaller chillers and/or boilers, and the number of units operating fluctuates with the building load. This approach also provides equipment redundancy, which can make servicing equipment less disruptive to building operation, and the likelihood of a complete cooling or heating system failure is minimized.

A common excuse for equipment oversizing, or barrier to rightsizing, is the need to quickly recover from a thermostat setback or setup (e.g., Monday morning recovery after a weekend). With today's programmable controls, comfortable conditions can be achieved by simply starting the system a few hours earlier.

Another excuse for equipment oversizing is to accommodate for future expansion and flexibility. Planning for the future needs to be balanced with the better performance of a system that is designed and sized for the present building. The modular approach mentioned earlier may be appropriate.

EMERGING TRENDS

The increased use of energy modeling that accounts for part-load inefficiencies and retro-commissioning that monitors the loads on equipment has raised awareness of the extent of equipment oversizing and its negative impact on overall building performance. Code enforcement is on the rise and programs such as the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) emphasize optimization of energy performance.

What are relevant resources for **Rightsizing Equipment?**

- Air Conditioning Contractors Association (ACCA) Manual J Residential Load Calculation Procedure
- American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Handbooks, Atlanta
- Building Energy Software Tools Directory: www.eere.energy.gov/buildings/tools_directory/
- *HVAC System Size: Getting It Right—Right-sizing HVAC Systems in Commercial Buildings.* Cooperative Research Centre for Construction Innovation, ISBN 978-0-9803503-8-8, July 2007
- Proctor, J., Katsnelson, Z., and Wilson, B. (1996). "Bigger is not better: Sizing air conditioners properly," *Refrigeration Service and Contracting,* Vol. 64, No. 4. (Also published in *Home Energy* magazine, May/June 1995)
- Vieira, R. K., Parker, D. S., Klongerbo, J. F., Sonne, J. K., and Cummings, J. E. (1996). How Contractors Really Size Air Conditioning Systems, *Proceedings ACEEE Summer Study on Energy Efficiency in Buildings*
- Laboratories for the 21st Century: Best Practice Guide—Right-Sizing Laboratory Equipment Loads. EPA, August 2005: www.labs21century.gov/pdf/bp_rightsizing_508.pdf

Which strategies interact with **Rightsizing Equipment?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Orientation
» Daylighting
» Energy Modeling
» Life Cycle Assessment
» Space Zoning
» Sun Shading

38 Smart Controls

What are Smart Controls?

Smart controls or intelligent controls are sophisticated devices that perform multiple functions well beyond turning systems and equipment off and on. Smart controls are used for energy management, HVAC and lighting systems control, and to alert operations and maintenance (O&M) personnel of impending equipment failure. Smart controls may be PC-based or may have the necessary intelligence built into the control device. Because buildings in the United States, on an annual basis, consume a large portion of America's energy and a significant portion of its electricity and contribute to atmospheric emissions, it is important to minimize overall energy consumption and to optimize the use of renewable energy sources to meet the demands of energy-consuming systems in the building and at the same time have an impact on carbon-reduction strategies. Smart controls are a key part of achieving these goals.

For energy management, smart controls can make the choice of which utility source has the best rates at any given time. They can help determine the best fuel source to use based on pricing and availability. They can also identify the best combination of on-site renewable energy and purchased power to serve the building at the highest efficiency and lowest possible cost.

For HVAC systems, smart controls can adjust temperature in different zones within the building based on solar gain and internal building loads. They can make adjustments to humidity, airflow, fresh air mix, and indoor air quality necessary to provide occupant comfort.

For lighting systems, smart controls can adjust the artificial (electric) lighting level based on available daylight, room occupancy, and the functions performed in each building space. They can interface lighting system occupancy sensors with

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Reduce the overall energy use in your building
- Employing smart controls will reduce the overall energy use, allowing various building systems (i.e., HVAC and lighting) to operate efficiently and cost effectively.

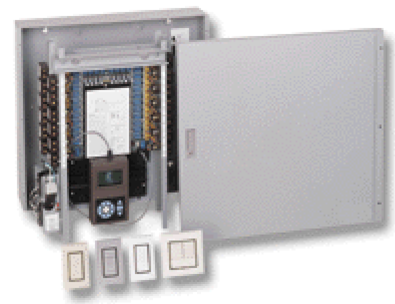
Specify energy-efficient equipment and technologies
- Use an integrated system approach to spec out the most cost-effective, energy-efficient equipment and technologies that can include smart controls.

Use renewable strategies and purchase green power
- Using smart controls can reduce a building's overall energy load, optimize renewable strategies, and reduce emissions.

Educate building owners, operators, and occupants
- On function and operations of installed technology so they can properly use smart controls.

the building's security system to detect intruders after hours and in unoccupied spaces.

How do I apply **Smart Controls?**



Design smart controls into the building as part of an integrated (whole-building) approach to optimize the energy savings and indoor air quality of the project. They should be considered at the earliest stage of project development to ensure interoperability among systems and compatibility of control devices. Consider

- Involving the smart controls designer early in the building design process to identify potential benefits
- Identifying the required interactions between building subsystems to ensure successful integration
- Determining the appropriate media for remote monitoring and diagnostics
- Working with experienced contractors

The cost of incorporating these controls is offset by the energy saved in their use. Paybacks ranging from a few months to two or three years are typical for integrated lighting level controls and occupancy sensors.

Incorporate smart controls into the building automation system (BAS) using direct digital controls (DDCs) with graphical user interface (GUI) for ease of operation. Smart control systems can send alarm reports and system status information to personal digital assistants (PDAs) and cellular phones so that O&M personnel can get immediate notice of equipment trouble or failure.

Smart controls can be interconnected by twisted pair wiring, fiber optics, power line carrier (PLC), wireless technology, or Internet protocol–based (IP) devices.

ESTABLISHED TECHNIQUES

Systems Interface

Smart controls can be applied to boilers, chillers, electrical equipment, lighting, elevators, fans, pumps, ventilation, filtration, and fire alarm and security systems. Their value over individual system controls is their ability to interface between multiple systems and provide the ability to make adjustments without human interaction.

Commissioning

Smart controls will be most effective by commissioning them along with all the building's systems and equipment. Once commissioned, smart controls can ensure that the building's benchmarked parameters are maintained to optimize energy efficiency and occupant comfort.

i.LON 100 e3 Internet Server: a remote access gateway to remotely monitor and manage an entire control system by Echelon Corp.

Design Tools

Energy analysis and design tools must be part of the integrated design process to determine the appropriate systems needed to achieve optimum energy efficiency. Smart controls cannot compensate for inadequate design.

Adequately Trained Personnel

Smart controls can be more complicated than standard individual equipment and system controls. Unless O&M personnel are adequately trained to understand how smart controls work, the controls may be incorrectly set, bypassed, or ignored.

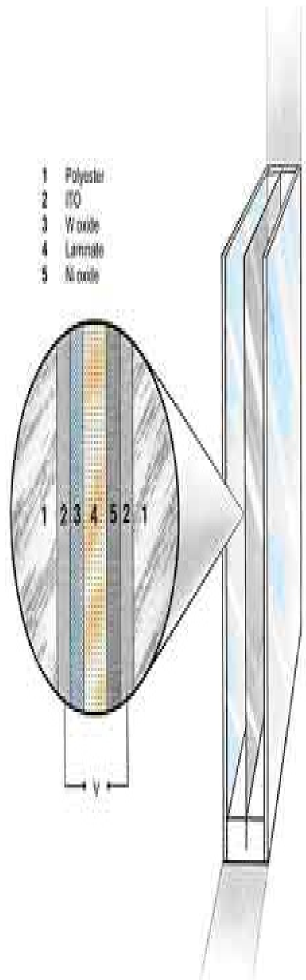
EMERGING TRENDS

Dynamic Window System

Lawrence Berkeley National Laboratory (LBNL) in conjunction with the U.S. Department of Energy (DOE) is developing dynamic, integrated façade systems for energy efficiency and comfort. The challenge for LBNL was to provide a fully functional and integrated façade and lighting system that operates appropriately under a wide range of environmental conditions and addresses the full breadth of occupant subjective desires as well as objective performance requirements. The further challenge was to simultaneously control sunlight admittance while admitting adequate daylight to offset electric lighting needs. LBNL produced a system of automated shades and dimmable lighting controls for use on the New York Times building. The combination yielded significant lighting energy savings over the nine-month testing period. Studies are under way to determine how to use smart controls to bring the building to a "low-power" mode of operation that would allow essential building functions to continue while substantially reducing overall electric power use on a hot summer day if the stability of the grid was threatened.

Smart Windows

Photochromics (changing transparency in response to light intensity), thermochromics (changing transparency in response to temperature), and electrochromic windows are advanced technology that, when used in conjunction with smart controls, will provide optimum daylighting while minimizing glare and heat gain to reduce a building's reliance on utility-generated electric power.



Smart Window with variable transparency.
Uppsala University

What are relevant resources for **Smart Controls?**

- Energy Policy Act of 2005 [http://www.wbdg.org/pdfs/epact2005.pdf] (PDF 1.9 MB, 550 pages)
- Whole Building Design Guide, Resource Page, Energy Analysis Tools, Richard Paradis, Steven Winter Associates: www.wbdg.org/design/energyanalysis.php?r=minimize_consumption
- Whole Building Design Guide, Assure Appropriate Product/Systems Integration, WBDG Functional/Operational Committee: www.wbdg.org/design/ensure_integration.php
- DDC-Online provides unbiased information on direct digital controls and tutorials: www.ddc-online.org/
- The buildingSMART alliance™: The focus is to guarantee lowest overall cost, optimum sustainability, energy conservation and environmental stewardship to protect the earth's ecosystem: www.buildingsmartalliance.org/
- Dynamic, Integrated Façade Systems for Energy Efficiency and Comfort, Stephen Selkowitz and Eleanor Lee, Lawrence Berkeley National Laboratory, *Journal of Building Enclosure Design,* Summer 2006: www.nibs.org/jbed.html

Which strategies interact with **Smart Controls?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Monitoring
» High-Efficiency Equipment
» Life Cycle Assessment
» Rightsizing Equipment
» Staff Training
» Systems Tune-Up
» Total Building Commissioning

39 Space Zoning

What is Space Zoning?

There are many different types of spaces in a building, each with its own spatial characteristics and functional requirements, which require that systems serving them be differentiated accordingly. All design objectives—accessibility, aesthetics, cost-effectiveness, functionality, historic, productive, security/safety, and sustainability—and their interrelationships must be understood, evaluated, and appropriately applied within the spaces.

Building spaces may be grouped or zoned by several categories or combinations of categories:

- Site relationship: orientation, solar exposure, daylighting orientation, wind orientation, view, natural features
- Program: functional activity, space population, time of day/night use, interior/exterior relationships
- Location within the building: interior or exterior zone, a high-rise core or perimeter, or a low-, mid-, or high-level floor
- Building codes: by fire hazard and building type groups

How do I apply Space Zoning?

Building spaces can maximize energy savings if their zoning and configuration are integrated with other sustainable design strategies for daylighting, cooling, and heating. Use space zoning opportunities for energy savings and reduction of carbon emissions to:

- Maximize daylighting to reduce use of electric lighting
  - Orient the long axis of the building on an east–west axis so the long façades face north–south.
  - Establish daylighting space zones: perimeter for maximum

Use An Integrated Approach To Reduce Carbon Emissions

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Reduce the overall energy use in your building
- Optimize daylighting to reduce building overall energy load and reduce emissions.
- Use occupancy and daylight sensors to reduce energy use.
- Program functional activities in appropriate building space zones to optimize energy conservation.
- Rightsize building systems (i.e., HVAC) to make way for further energy-saving materials, designs, and technologies.

Specify energy-efficient equipment and technologies
- Use an integrated system approach to design the most cost-effective combination of space zoning and planning strategies with appropriately designed and sized building systems.

Use renewable strategies and purchase green power
- Optimize daylighting with functional activities to reduce building overall energy load and emissions.

Educate building owners, operators, and occupants
- On function and operations of installed systems so they can properly use controls.

use of daylighting, transitional where both daylighting and electric lighting are used, and interior zones where only electric lighting is used. Depth of daylighting space zones will vary with true building orientation, time of day, time of year, latitude of the building location, ceiling height, and openness of interior space layout.
  - Integrate HVAC systems with space zoning and provide adjustable individual controls.
  - Group people-intensive spaces along the north and south perimeter zones for maximum daylighting benefit to occupants.
  - Group spaces that require security, privacy, and service spaces in interior zones.
  - Provide open space layouts to maximize daylight penetration to the interior.
  - Reduce depth of spandrel beams and mechanical systems at the perimeter of the building to permit maximum penetration of high daylight.
  - Provide flexible and adjustable electric lighting controls in perimeter and transitional zones to adjust to changing daylighting conditions.
  - Provide interior windows and borrowed lights to enable daylight exposure for spaces in the transitional and interior zones.
  - Use skylights and clerestories to provide daylighting to interior zones.
- Reduce heat gain in cooling-dominated climates
  - Use interior thermal mass to shift daytime heat gain to off-peak or nighttime.
  - Size and shade windows to reduce heat load in perimeter zones.
  - Maximize use of natural ventilation and mixed-mode cooling in perimeter zones for summer and swing seasons.
  - Use cross-ventilation strategies to cool interior zones, such as operable transoms and electric fans, to move the air rather than mechanically cool the air.
  - Use cool roof and/or green roof designs to reflect roof heat and reduce cooling load throughout all space zones.
- Provide heat gain in heating-dominated climates
  - Size and orient windows to maximize solar gain to perimeter zones in heating season.
  - Use thermal mass to absorb and store heat.
  - Increase heating efficiency by using floor radiant heating.
- Manage HVAC systems
  - Specify separate hours of operation for different zones based on occupancy, use, etc.
  - Provide mechanical ventilation schedules by zone, based on occupancy, use, etc.

What resources are relevant to **Space Zoning**?

- *Tips for Daylighting*, Jennifer O'Connor, Eleanor Lee, Frances Rubinstein, Stephen Selkowitz; Building Technologies Program, Energy & Environment Division, Earnest Orlando Lawrence Berkeley National Laboratory, Publication LBNL-39945: windows.lbl.gov/daylighting/designguide/dlg.pdf
- *High-Performance Building Guidelines,* City of New York, Department of Design and Construction, April 1999
- *Guidelines for Creating High-Performance Green Buildings*, Commonwealth of Pennsylvania, 1999
- Ensure Appropriate Product/Systems Integration, Whole-Building Design Guide/Design Guidance/Functional-Operational, on the WBDG Web site: www.wbdg.org/design/ensure_integration.php.
- *Configuring Structure to Improve Daylight Access in Multistory Buildings*, Christine Theodoropoulos, G. Z. Brown, Arthur Johnson, Michael Hatten, Christopher Flint Chatto, Jeff Kline, Dale Northcutt; Energy Studies in Buildings Laboratory, University of Oregon; KPFF Consulting Engineers; SOLARC Architecture + Engineering, paper delivered at ARCC Spring Research Conference, Eugene, Oregon, April 2007

Which strategies interact with **Space Zoning**?

» Building Orientation
» Building Form
» Cool Roofs
» Daylighting
» Efficient Artificial Lighting
» Energy Modeling
» Green Roofs
» Natural Ventilation
» Open, Active, Daylit Spaces
» Passive Solar Collection Opportunities
» Rightsizing Equipment
» Sun Shading
» Windows and Openings

40 Staff Training

What is Staff Training?

Buildings have the potential to engage and enrich their occupants and owners and support their health, safety, and productivity. Buildings must first be designed, constructed, and commissioned in the most effective and efficient ways to be useful to their occupants and perform as intended.

To keep the building functioning properly and optimally over its life cycle, particularly as it relates to energy savings and carbon reduction, educating building owners, occupants, and operators about the operations and maintenance (O&M) practices will also contribute to the building's long-term success. Implementing and sustaining an effective O&M program will require the ability to gather, store, and process large quantities of information related to issues such as energy consumption, asset condition, and asset productivity.

Staff training and development is crucial to improve business performance and to meet the goals established for your building projects. Staff training also provides the opportunity to communicate with and educate owners, operators, and users of a building about the building's intended use and their role in that process. Everyone involved in the process of designing, constructing, maintaining, and using a building can affect the success of the project and help carry out the established goals.

To ensure that appropriate and effective staff training will also be provided, consider these activities:

- Engage the O&M personnel in the initial planning stages and/or during a charrette of a project.
- Include the development and documentation of staff training in the project specifications.
- Document building O&M procedures for use in training materials, such as an O&M manual, video training, and online courses.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible lines of attack. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- Not applicable

Specify energy-efficient equipment and technologies.
- Not applicable

Use renewable strategies and purchase green power.
- Not applicable

Educate building owners, operators, and occupants.
- Develop and support staff training that teaches owners and occupants about the intended use and performance issues of the building.
- Update training programs on a regular basis to keep material current and promote continuous involvement.

Develop educational programs that are interactive and support a wide range of learning styles. Include approaches to staff training that can be applied directly to the building element or issue at hand. Build in communication models that encourage staff to coordinate and communicate with each other, learn from each other, and support new or innovative ideas or approaches to the subject. Create training that is visual and offers daily reminders of the building's goals and functions to stimulate continuous interaction with those goals and with other occupants.

As a building's use or occupants change, consider adding new or expanded training programs to ensure continued effectiveness. If improvements or upgrades to an existing building are made, add these elements to the training programs to make sure the training is up to date.

Staff training should be interdisciplinary and encourage building owners and users to work alone or as a group to apply the training. The training should also be developed with a broad, interconnected approach to the issues.

Consider developing incentives that support the training programs to create momentum and motivate people to participate. Staff training on the building components, energy and environmental goals, health, and safety can be incorporated into larger programs that constitute part of a company's staff development structure. Additional educational opportunities, financial rewards, promotions, certifications, and other incentives might be considered as part of the staff development structure. Competitions that generate renewed interest in the topics should also be considered.

How do I apply **Staff Training?**

Steps That Support the Development of Building Goals and Training

- Define and document the project goals and requirements at the outset of each project phase and update throughout the process.
- Establish and document the commissioning process tasks for delivery team members at each phase of the project.
- Deliver building projects that meet the owners' and occupants' needs at the time of completion and as the building use and occupants change.
- Verify that O&M personnel and occupants are properly trained to understand and interact appropriately with the building elements and goals.
- Maintain facility performance across its life cycle through effective recommissioning and staff training.

Aspects of Effective Staff Training

- Create staff training that increases the owners' and users' awareness and understanding of building elements and environmental and performance goals.
- Provide an introduction to the concepts of architecture, design, environmental issues and/or sustainability, and other building performance goals to ensure that owners and users acquire a basic level of knowledge.

- Assess the learning style of your audience to determine an approach to training that is most effective.
- Create tools for use by owners and users to apply and evaluate the goals outlined for the building project.
- Create an interactive process that encourages the active involvement of the training participants.
- Create a mechanism that allows the owners and users to develop strategies to solve problems before they arise or become unwieldy.
- Provide useful resources and sources of data that support the concepts of the building and training.
- Encourage outreach to other building owners, building users, and even the larger community on the impacts and benefits of staff training.
- Support a "train-the-trainer" approach to promote long-term involvement, ownership, and promotion of the staff training program and goals.

Elements of a Training Program

- Develop and communicate the purpose of the training.
- Identify the potential audiences for the training and develop content accordingly.
- Identify appropriate people to conduct and support the training.
- Consider multiple delivery mechanisms for the training to promote inclusiveness and multiple learning styles.
- Create examples and exercises that support the content of the course and provide opportunities for interaction and problem solving.
- Develop and support the use of tools and resources to implement ideas learned in the training.
- Develop a mechanism for widespread use of the training materials.
- Update the training materials as needed or as building use and occupants change.

Staff Activities/Actions That Can Contribute to Carbon Reduction

Building managers and maintenance staff can only affect those items most directly related to O&M activities. Building occupants tend to be largely unregulated in their daily activities and behavior. Activities that can have a negative effect on the building environment include food crumbs and wrappers left around, liquid spills, plants overwatered or placed on or in front of HVAC vents, boxes or files blocking HVAC vents, cleaning products brought into the office that do not meet green maintenance standards, and fans or space heaters. Some of these items if not addressed immediately can contribute to long-term effects such as mold and mildew growth under the carpet and in the HVAC ducts, plant spores spreading around the offices, and unwanted insect populations. In addition, excessive or unmanaged use of energy can contribute to increased heating and cooling loads and energy costs. Encourage staff to do the following:

- Turn off computers when not in use.
- Turn off lights when not in use.
- Use only equipment issued by the office/company that meets stringent energy-savings criteria.

- Participate in the waste management and recycling programs in the building.
- Reduce the creation of waste by promoting reuse of items such as paper, etc.
- Implement paperless office procedures to encourage the use of electronic communications and reduced paper use and printing.
- Encourage communications with O&M staff to inform them of repairs or items needing replacing and to optimize preventative maintenance.

What are relevant resources for **Staff Training?**

- Building Commissioning: www.wbdg.org/project/buildingcomm.php
- Education and the AIA: www.aia.org/ed_default
- Green Maintenance: http://go.infor.com/greenEAM/?WT.srch=1&cid=AM-NA-ALL-0907-PPC-GOOGLE-EAM-WEPS4&source=google Manage assets and cut CO2 emissions Go Green & Save Green—free report
- How Adults Learn: www.langevinonline.com/wShop.asp?C=HAL&lnk=rec
- Sustainable Facility: www.sustainablefacility.com
- Towards Sustainability—Training, Education, and Resource Centres: www.towards-sustainability.co.uk/infodir/educate.html

Which strategies interact with **Staff Training?**

All 50to50 strategies relate to each other in some way. It is recommended that you consider investigating these selected strategies to gain a comprehensive understanding of the topic.

» Building Monitoring
» Environmental Education
» Systems Commissioning
» Systems Tune-Up

41 Sun Shading

What is Sun Shading?

Light shelf designed for BC Gas Operations Centre in Surrey BC.

Sun shading, or the process of controlling the sunlight entering a building, can be accomplished through a number of methods. The techniques employed generally depend on the climate and the use of the space. For instance, in climates with a high cooling load, sun entering the space can increase cooling energy use, whereas in heating climates, the excess sun may be desirable, but glare and high contrast ratios may make it difficult for occupants to work. In either case, properly designed overhangs and light shelves can enhance daylighting while reducing uncomfortable glare and unwanted solar gain.

There are three basic categories of shading devices: landscaping, roof overhangs, and exterior or interior shading devices. Although each has its benefits, a combination of strategies usually works best, because different strategies may be appropriate for each orientation of the building. For example, an overhang for the west side of the building needs to be far deeper than is desirable. On the other hand, a well-placed deciduous tree with a low, dense crown on the west side of the building might provide all the shading necessary.

Working with an engineer to collaborate on the most cost-effective design system is advisable. They can calculate the cooling load with and without the shading strategies chosen, provide a rough estimate of the energy savings, and help analyze the payback period based on the estimated cost of the shading strategies employed. If shading is considered from the onset of the project, it is more likely to result in a more integrated, attractive design.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Reducing the overall energy use of a building will put less demand on and reduce emissions of the power plant that is providing the energy.

Specify energy-efficient equipment and technologies
- Using energy-efficient equipment and technologies as part of the overall building design process will further decrease the load the local power plant must provide while reducing overall emissions.

Use renewable strategies and purchase green power
- Use of electricity sourced from renewable sources along with the purchase of green power can reduce a building's overall carbon and emission footprint.

Educate building owners, operators, and occupants
- On where their sourced power comes from and its implications.

Effective sun shading is dependent on an understanding of sun angles and solar geometry. Terms to know include

- Azimuth (bearing)
- Altitude (fixing the sun's position in the sky)
- Profile (most important for designing overhead shading devices)
- Angle of incidence, which is building and orientation specific (all angles are dependent on latitude)

How do I apply **Sun Shading?**

Below is a more detailed explanation of the types of shading strategies commonly employed in buildings. Using a combination of strategies usually results in the best control and comfort.

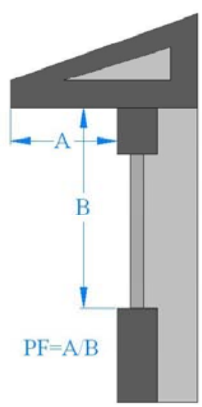
Landscaping

In cooling and heating climates, deciduous trees work best on the east and west sides of the building. They are most effective in these locations if they have a low crown and are placed at a distance from the building. On the south side of the building, deciduous trees with high crowns perform best because the sun is higher in the sky. For hot, dry climates, evergreens are effective in shielding the building from hot winds, and for climates that are hot year-round, evergreens or deciduous trees with dense, long-lasting foliage can be used to shade all windows.

In all cases, shrubbery can be used to shade paved areas, reducing the amount of heat that is radiated to the building; groundcover around the building can help reduce glare.

Landscaping combined with structural elements, such as pergolas, can also be an effective shading strategy for east and west windows, especially when covered with dense growing vines. Not only are these good shading devices, but they can be aesthetically pleasing and can create usable outdoor space for the occupants.

Roof Overhangs



The projection factor (PF) is the overhang projection (A) divided by the distance (B) between the bottom of the window and the bottom of the overhang.

Because overhangs are part of the building shell, they tend to be less expensive and more reliable forms of shading than those techniques that require occupant participation, such as shades and movable awnings. Overhangs must be carefully designed so that they do not block the sun in winter in heating climates if the sun is being counted on to provide heat. When considering using roof overhangs for sun shading, they should be specifically designed for each orientation and for the critical month and time when temperatures are higher and the sun is lower in the sky. For instance, roof overhangs on the south façade can be designed to provide 100 percent of the shading at noon on June 21st or on August 1st when the days are hotter.

Using roof overhangs to provide sufficient shading on east and west façades can result in an overhang that is undesirably large. In this case, a porch could be considered. This would provide the overhang depth necessary while providing a pleasing architectural component, along with usable outdoor space for the occupants.

Exterior Shading Device

In general, fixed shading devices are less expensive than movable devices. Exterior shading is more effective at reducing unwanted solar gain than interior shades because exterior shades stop the sun from striking the building. Exterior devices can be both fixed and operable or moveable (or removable), each with its own advantages and disadvantages. Fixed devises can work well, but you need to understand that the symmetry of sun angles throughout the year often does not align with the climate or heating and cooling cycles for a building. For example, mid-April and mid-August have similar solar geometries, yet often quite different comfort demands. Typical types of exterior shading devices include

- Solar screens
- Roll-down blinds
- Shutters
- Vertical louvers
- Horizontal louvers
- Canvas awnings (fixed or moveable)

The downside to exterior shades is that most require some level of occupant behavior. If the device has to be moved only two times per year, it is usually more acceptable and effective.

Interior Shading Devices

With the exception of awnings, most devices used on the exterior of the building can be used on the interior. They tend to be less effective at reducing the cooling load because they allow the sun to enter the building, trapping the heat between the window and the shading device. The benefits are that such interior devices are low cost and easy to operate. Also, interior shading can be especially effective if designed to provide both sun control and insulation during the day in the cooling season and at night in the heating season.

ESTABLISHED TECHNIQUES

When considering shading strategies, avoid simply copying designs from one project to another. Careful attention should be paid to use of the space, location of the building, and orientation. Control of the sun on the west side of the building is critical in most climates. Because of the lower sun angles, vertical louvers and fins will be important. General rules for good design include

- Minimize the east and west glazing of the building.
- Design projections and/or reveals for the south façade.
- If no exterior shading devices are to be used, specify windows with low solar heat gain coefficients (SHGC).
- For occupant comfort, provide light-colored venetian blinds or light-colored translucent shades on all windows in occupied areas.

EMERGING TRENDS

In response to the growing number of utilities promoting load management programs and the increase in utility costs, a number of sun-shading technologies have emerged over the past several years. A few of these new technologies include motorized shades, switchable electrochromic (in which glazing switches between a

clear and transparent prussian blue–tinted state with no degradation in view, similar in appearance to photochromic sunglasses) or gasochromic (using hydrogen instead of transparent electrodes) window coatings and double-envelope macroscopic window-wall systems that have variable optical and thermal properties and can be changed in response to climate, occupant preferences, and building system requirements. By actively managing lighting and cooling, peak electric loads can be reduced by 20–30 percent in many commercial buildings.

In addition to these, shading strategies involving awnings constructed of sun-tracking photovoltaic (PV) panels have emerged. As the sun rises higher in the sky, the PV array lifts to a more horizontal position allowing the sun's rays to hit the panels at a more direct angle, thereby increasing the efficiency of the system. As the sun lowers, the panels lower. The change in angle of the PV array corresponds very well with the change in the sun's angle, allowing the awning to provide better shading than a typical fixed awning.

Although currently they are pricey options, increases in the cost of energy, coupled with incentives from utility companies, should improve the affordability of these technologies in the future.

What are resources relevant to Sun Shading?

- Whole Building Design Guide (WBDG): www.wbdg.org/design/suncontrol.php
- Shading Strategy, LBL Daylighting Design Guide: windows.lbl.gov/daylighting/designguide/section5.pdf
- *The Passive Solar Design and Construction Guide, Steven Winter Associates Inc., Wiley, 1997*
- Sun Angle Calculator: Society of Building Science Educators (SBSE): www.sbse.org/resources/sac/index.htm

Which strategies interact with Sun Shading?

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Orientation
» Daylighting
» Life Cycle Assessment
» Passive Solar Collection Opportunities
» Renewable Energy Resourcess

42 Systems Commissioning

What is Systems Commissioning?

Systems commissioning is a quality assurance process to ensure that building systems perform as intended. As buildings become more complex, the importance of systematically evaluating their performance has increased. Systems commissioning can be especially critical in the case of innovative buildings that incorporate promising but relatively untested technologies. In recognition of this fact and because systems commissioning has been proven to be among the most cost-effective approaches to reducing energy use in buildings, fundamental commissioning of energy-related systems is a prerequisite in green building standards that have been developed in recent years. Systems commissioning refers to

- HVAC systems and associated controls
- Lighting and daylighting controls
- Domestic hot water systems
- Renewable energy systems

Total building commissioning includes mechanical systems, the building envelope, plumbing, and life safety systems (see also Total Building Commissioning). Total commissioning is therefore broader in scope than systems commissioning. Note that some aspects of total commissioning (i.e., building envelope) can be very critical to building energy performance and carbon reduction, whereas other aspects of total commissioning (i.e., life safety systems) may have less of an impact on carbon reduction.

Systems commissioning includes planning, delivery, verification, and managing risks to critical functions. Deficiencies in design or installation can be identified using peer review and field verification. Systems commissioning typically results in higher

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Reduce the overall energy use in your building
- Systems commissioning reduces energy waste in buildings by ensuring that installed building systems perform as designed and that the design precisely meets the project requirements.

Specify energy-efficient equipment and technologies
- Systems commissioning ensures that the efficiencies promised by premium equipment are actually realized.

Use renewable strategies and purchase green power
- Systems commissioning of renewable energy systems is particularly important because contractors or building operators may be unfamiliar with these systems.

Educate building owners, operators, and occupants
- Educating owners on the requirements and resulting design strategies of their projects is one of the primary focuses of systems commissioning; the development of operations and maintenance manuals as part of the systems commissioning process will ensure persistence in energy savings over time.

energy efficiency, environmental health, and occupant safety and improves indoor air quality. As part of the process, preventive and predictive maintenance plans, tailored operating manuals, and training procedures are developed. Essentially, the commissioning process formalizes review and integration of all project expectations during planning, design, construction, and occupancy phases by inspection and functional performance testing and oversight of operator training and record documentation.

The first step in any commissioning process is to identify a commissioning authority (CxA) for the project. The CxA is a third party, hired by the owner, that is primarily responsible for coordinating the commissioning process and for providing the project with an unbiased perspective, independent of the design or construction team. For smaller projects, it is acceptable for a CxA to be employed by a design team firm but not directly involved in the design of the project itself. For larger projects, the CxA should not be affiliated with the design team. In all cases, the CxA should have experience with projects having similar building systems, size, and budget, and should be brought onboard as early in the process as possible.

How do I apply Systems Commissioning?

ESTABLISHED TECHNIQUES

Commissioning can take place during design, construction, and postoccupancy.

Design Phase Activities for Both Fundamental and Enhanced Systems Commissioning

The first step in any commissioning process is to document the owner's project requirements (OPR). The OPR details the functional requirements of the building systems from the owner's perspective, including facility uses, occupant comfort, and project success. Above all, the OPR should be measurable and verifiable. It is important to note that an owner may not have

Task	Design Phase Commissioning Responsibilities and Tasks	Parties Involved			
1	Overall coordination of the Cx work	Lead			
2	Develop design & operating intent documentation	X	Lead	X	X
3	Perform 60 - 70% Construction Document design review	Lead			
4	Develop draft Cx plan for Construction Phase	Lead			
	a. Review Cx plan		X	X	X
5	Develop Cx specifications for construction	Lead			
	a. Assist with, review & approve all sections		X		X
6	Perform 90 - 100% Construction Document design review	Lead			

Table 1

Task / Activity	Estimated Start Date	Estimated End Date
DRAFT Construction Phase Cx plan		
Begin construction site visits/inspections		
Prefunctional and startup forms developed and distributed Equipment and con trols startup and initial checkout plans		
Startup and initial checkout executed		
TAB Functional performance tests O&M documentation review and verification		
Training and training verification		
DRAFT commissioning report		
Seasonal testi ng		

Table 2

experience formally documenting these requirements. In this case, the CxA can conduct a workshop to facilitate the development of the OPR. In response to the OPR, the design team for the project should develop a basis of design (BOD) document that describes the system configurations and control sequences that will be implemented to meet the OPR. The BOD should include assumptions made by the mechanical engineer to design the HVAC systems, including indoor and outdoor design conditions and occupancy schedules.

The CxA will conduct design reviews in the context of the BOD. As a best practice, a CxA should be designated early enough during the design process to be able to perform an initial review prior to 50 percent construction documents (CDs). The CxA will also develop specifications for the architect to incorporate into the CDs. All of the tasks to be performed during commissioning are described in a commissioning plan developed by the CxA. This plan also describes roles and responsibilities of the entire design team in the process, as illustrated in Table 1.

Construction Phase Activities for Both Fundamental and Enhanced Systems Commissioning

Prior to the end of the design process, the CxA will develop a construction phase commissioning plan. Table 2 presents a sample project schedule taken from the PECI construction phase commissioning plan (www.peci.org). During and immediately prior to the construction phase, a CxA may review contractor submittals related to the systems that will be commissioned. After equipment start-up, the CxA conducts installation inspections, also known as "prefunctional inspections." Once equipment is fully installed, the CxA conducts functional performance testing to evaluate performance at all sequences of operation. The CxA usually develops protocols for functional performance testing during the construction phase on the basis of project specifics and the sequence of operations developed by the controls engineer (CDs often do not provide enough detail). It is important to note that some functional testing can be performed only in certain seasons, which will usually extend the commissioning process beyond the completion of construction. At the end of the commissioning process, the CxA prepares a final report and may also prepare an operations and maintenance (O&M) manual for the project.

EMERGING TRENDS

The high-performance building movement in general and various energy rating prerequisites in particular have brought commissioning more into the mainstream in recent years.

Fundamental Versus Enhanced Commissioning

The United States Green Building Council's Leadership in Energy and Environmental Design (LEED) program also distinguishes between "fundamental" commissioning and "enhanced" commissioning. Fundamental commissioning encompasses the design and construction phase tasks discussed above. Enhanced systems commissioning includes the following additional tasks:

1. Conduct design review prior to the end of design development.
2. Review contractor submittals for energy-related systems.
3. Develop recommissioning manual.
4. Inspect operation of energy-related systems within 10 months of final acceptance and develop plan to resolve outstanding issues.

The additional work associated with enhanced commissioning tends to result in a 15 percent first-cost premium compared with fundamental commissioning.

After Commissioning

Periodic recommissioning is a process intended to ensure persistent energy savings over the life of a building by reapplying previously conducted commissioning tests. Recommissioning may be performed every few years or even continuously, depending on the complexity of the building. Often, a major capital improvement to a building can trigger recommissioning activities. The California Commissioning Guide outlines the following other indicators that can be used to assess when recommissioning is appropriate for a particular building:

- Is there an unjustified increase in energy use?
- Have comfort complaints increased?
- Is building staff aware of problems but without the time or in-house expertise to fix them?
- Has control programming been modified or overridden to provide a quick fix to a problem?
- Are there frequent equipment or component failures?
- Have there been significant tenant improvement projects (buildouts)?

Recommissioning activities can be performed by an independent CxA or by building maintenance staff, if they have the training, time, and resources. The first step in any recommissioning process is to review the OPR developed as part of the original commissioning process for the building. If the requirements of the building have changed, the OPR should be updated to reflect the changes. Functional performance tests of equipment are then conducted to evaluate whether systems are performing as designed. Systems performance over time may be evaluated based on any data collected and stored by the building management system or utility bill tracking.

Commissioning Costs and Benefits

Portland Energy Conservation Inc., Lawrence Berkeley National Laboratory, and Texas A&M University have performed a rigorous analysis of the costs of commissioning. Results from this study are illustrated in Figures 1 and 2. Median commissioning costs were $0.27 per square foot with existing buildings and $1.00 per square foot with new construction. With existing building commissioning, this study documented paybacks of less than one year in the majority of the 100 buildings evaluated. The average payback for new construction commissioning was 4.7 years.

Commissioning costs per square foot tend to be higher in more complex buildings such as hospitals and laboratories. However, as a result of their relatively high energy intensity, paybacks for commissioning also tend to be lowest in these buildings. For existing buildings in this study, the median whole-building energy cost savings associated with commissioning was 15 percent. The carbon reduction potential associated with commissioning in existing buildings is likely to be of the same order of magnitude as this energy reduction: A 15 percent reduction in energy use will translate into (roughly) a 15 percent reduction in carbon. As previously mentioned, fulfilling the LEED enhanced commissioning requirements tends to result in an increase in first cost of roughly 15 percent compared with fundamental commissioning.

Nonenergy benefits of commissioning were also evaluated as part of the above-cited study and are described in the chart below. Although nonenergy benefits will not necessarily translate into carbon reductions, they can be important to convincing decision makers of the value of commissioning to their projects.

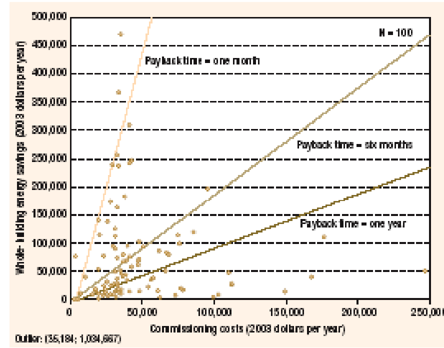


Figure 1. Cost, savings, and payback time of existing building commissioning

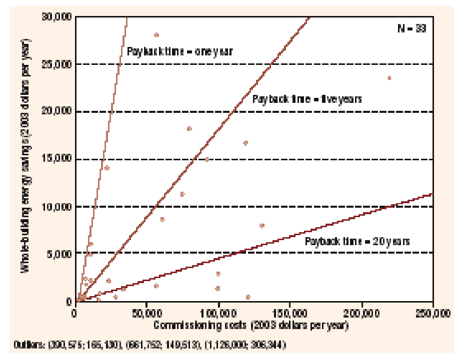
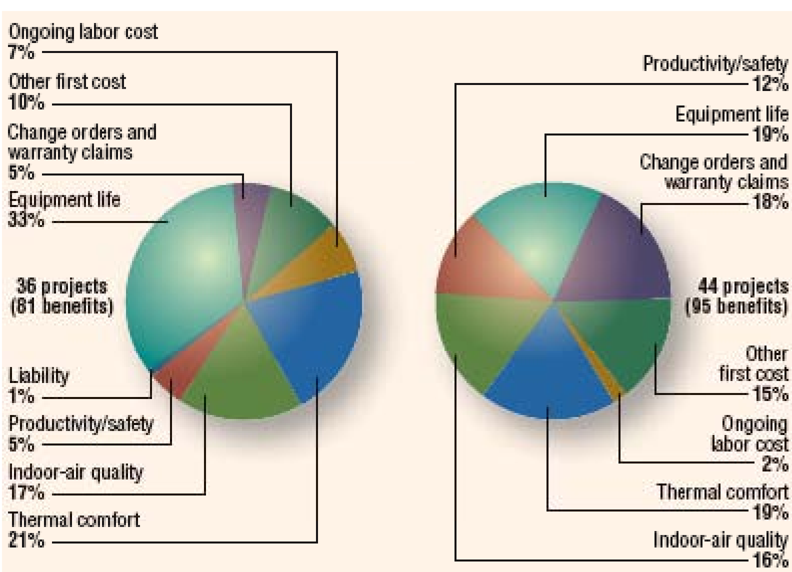


Figure 2. Cost, savings, and payback time of new construction building commissioning



What are relevant resources for Systems Commissioning?

- www.wbdg.org/
- www.peci.org/
- www.cacx.org/resources/commissioning.php
- www.ashrae.org/
- www.usgbc.org/
- www.bcxa.org/

Which strategies interact with Systems Commissioning?

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Monitoring
» High-Efficiency Equipment
» Life Cycle Assessment
» Rightsizing Equipment
» Smart Controls
» Staff Training
» Systems Tune-Up

43 Systems Tune-Up

What is a Systems Tune-Up?

Building systems tune-ups involve identifying and fixing problems in existing buildings. A building tune-up involves establishing contracts with service providers to implement building improvements, making it distinct from commissioning. Although there can be opportunities for energy savings from tuning up nearly all building systems, optimizing control systems tends to result in the largest opportunity for savings. The natural tendency in all buildings is for systems to drift from their original set points as a result of occupants, maintenance staff actions (or inactions), and wear and tear. Although tune ups are usually performed by third party contractors, it is important for building maintenance staff to actively participate in the tune-up process so that operations and maintenance (O&M) practices can be implemented to maintain performance after the tune-up. The frequency with which you tune your building largely depends on the complexity of systems, and varies from system to system. The architect and owner should work with the mechanical, electrical, and plumbing engineers, commissioning agent, or contractor to determine timeframes.

How do I implement a Systems Tune-Up?

Lighting Systems Tune-Up

Both over- and underlighting are common in buildings. Measuring light levels in spaces to assess the effectiveness of lighting is the first step in identifying opportunities for improvement. Often, spaces are underlit as a result of dirty fixtures that should be cleaned as part of a tune-up. It is also

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Reduce the overall energy use in your building
- Systems tune-up reduces energy waste in buildings by ensuring that installed building systems perform as designed and that the design precisely meets the project requirements.

Specify energy-efficient equipment and technologies
- Systems tune-up ensures that the efficiencies promised by premium equipment are actually realized.

Use renewable strategies and purchase green power
- Building O&M staff are typically less familiar with proper O&M procedures for solar and wind energy systems than with conventional systems, making these on-site renewable systems good candidates for tune-up in many cases.

Educate building owners, operators, and occupants
- Educating building maintenance personnel on the requirements and proper O&M procedures will ensure persistence in energy savings over time.

important that lighting controls e calibrated. Photocell sensors may fall into disrepair over time, occupancy sensor control settings may not be configured to result in maximum energy savings, and time clock controls may not result in sufficient precision. Some buildings may also have light-sweeping controls and load-shedding dimmer controls for demand reduction that should be tuned up.


Air sealing at an exterior wall penetration

Envelope Tune-Up

Identifying and sealing air leakage pathways in building envelopes around windows, doors, and wall and roof penetrations can be a very cost-effective means of reducing space conditioning energy costs and can also improve occupant comfort. Holes should be sealed with appropriate (and fire rated as required) materials (i.e., weather stripping on doors, caulk for small cracks, expanding foam for larger holes).


Energy management system

Controls Tune-Up

Building energy management systems are only as reliable as their inputs. Over time, peripheral sensors that provide environmental management systems (EMS) with the information can drift from their original settings.

- Indoor and outdoor temperature and humidity sensors should be calibrated.
- Carbon dioxide sensors associated with demand control ventilation systems should also be calibrated.
- Pneumatic controls should be checked for leaks, and actuators on mechanical valves and dampers should be evaluated.
- Once all peripheral sensors are checked, the EMS should be evaluated to determine whether programmed setback schedules are appropriate for the building occupancy.
- Wall-mounted thermostats and humidistats should be checked to make sure they function properly and have not been adjusted out of normal ranges by occupants.


Motorized damper with draft controller


Burner/boiler

Boiler Tune-Up

A 1/8-inch layer of soot on fire-side surfaces reduces boiler efficiency by approximately 8.5 percent by raising exhaust stack air temperature. Tuning burners for optimum fuel–air ratio can improve combustion efficiency by 5 to 20 percent.

Testing, Adjusting, and Balancing Tune-Up

Improper balancing of air and water distribution systems can result in occupant comfort problems. Testing, adjusting, and balancing contractors can adjust registers and balancing valves for optimal performance.


Flow balancing to a heating coil


Ventilation fan belt adjustment

Heat Exchanger Tune-up

Heat exchanger surfaces can foul over time because of dust or other particle buildup, which can both decrease heat transfer efficiency and unnecessarily increase pumping or fan energy use. The air side of heating coils is usually relatively accessible and can be cleaned with special brushes, compressed air, or power washes.

Chiller/Cooling Tower Tune-Up

There are often opportunities to increase efficiency by adjusting controls to raise chilled water temperature, thereby saving energy.

Cooling tower

What are relevant resources for **Systems Tune-Up?**

- concessions.nps.gov/document/stage2buildingtuneup.pdf
- www.peci.org/library/PECI_TunedUp1_0302.pdf
- www.energytrust.org/bto/
- www.buildingtuneup.com/

Which strategies interact with **Systems Tune-Up?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Monitoring
» High-Efficiency Equipment
» Life Cycle Assessment
» Rightsizing Equipment
» Smart Controls
» Staff Training
» Systems Commissioning

44 Thermal Bridging

What is Thermal Bridging?

Particle deposition due to thermal bridging

Thermal bridging occurs in building envelopes when relatively high thermal conductivity materials such as steel and concrete create pathways for heat loss that bypass thermal insulation. When these materials provide an uninterrupted "short circuit" between the interior and exterior of a building, the resulting impact on envelope R-value can be significant. This effect is most significant in cold climates during the winter when the indoor–outdoor temperature difference is greatest. Thermal bridging can result in localized cold spots on the interior of a wall assembly, which are at risk for condensation. Because it involves the design and installation of the building envelope (including structural components), thermal bridging is best addressed in the design process with new buildings or gut rehabs.

According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1, a 3.5-inch steel stud wall system with R-13 fiberglass batt, 0.5-inch interior gypsum board, and 0.5-inch exterior gypsum board will have a whole wall R-value of only R-8. Even though the steel studs make up a relatively small fraction of the wall area (16 inches on center), thermal bridging through these members greatly reduces the effectiveness of the fiberglass insulation. The images below illustrate computer simulations using THERM modeling software of the heat flow though this type of wall assembly with and without the steel studs. In addition to condensation, cold spots caused by thermal bridging can result in particle deposition, such as the "ghosting" shown in the photo.

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A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Implementing strategies to minimize thermal bridging increases whole wall R-value, which will reduce heating energy use.

Specify energy-efficient equipment and technologies
- Conventional insulation materials designed and specified in the appropriate manner can be used to address thermal bridging in buildings. Heat transfer modeling software is a powerful tool that can be used to inform this process.

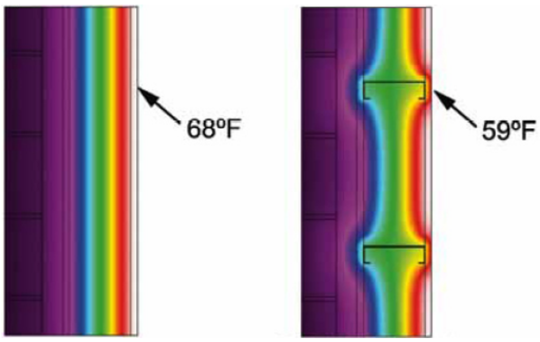
Use renewable strategies and purchase green power
- Implementing strategies to reduce thermal bridging minimizes energy waste and should be addressed before renewable energy systems are considered.

Educate building owners, operators, and occupants
- Education of design professionals on the concept of whole wall R-value (simply R-13 fiberglass batt) is critical.

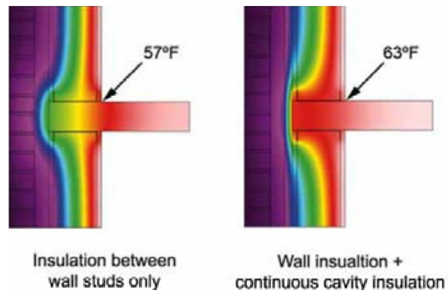
Thermal bridging is also commonly found at the following locations:

- At the edge of uninsulated concrete floor planks that penetrate wall insulation (including slab on grade)
- In curtain walls at locations where walls are fastened to the building (see figure below)
- Throughout metal buildings

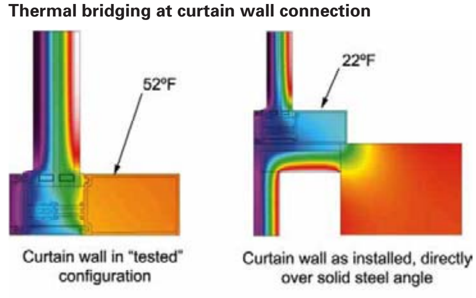
Thermal bridging through light-gauge steel studs



Thermal bridging at floor plank



Thermal bridging at curtain wall connection



Source:
www.carlisle-syntec.com/documents/reslib/ConstructionSpecifier_ThermalBridging.pdf

How do I address Thermal Bridging?

The basic approach to minimizing thermal bridging is to design a wall system with a thermal envelope (insulation layer) that is continuous at all interfaces. This insulation layer must completely cover either the inside or outside of concrete or steel building members. The photos below illustrate continuous layers of insulation installed on the exterior of steel framing that acts as a "thermal break," minimizing bridging though the studs. Note that while the 1-inch mineral wool addresses thermal bridging caused by steel studs, this insulation is interrupted by the concrete plank and therefore does not address thermal bridging at the floor plank edge.

0.5-inch XPS thermal break

For more complex building assemblies, two-dimensional heat transfer modeling should be used to inform the envelope design process. THERM is a 2-D finite element software program developed by Lawrence Berkeley National Laboratory specifically for use in evaluating the thermal performance of building assemblies. This software allows for the calculation of whole wall R-values and surface temperatures and can be used to import

1-inch mineral wool (picture taken prior to steel stud installation)

geometries from CAD. In addition, the software includes a built-in material library with the thermal properties of many common building components.

There are other strategies for preventing thermal bridging. For example, the use of structural insulated panels (SIPs) reduces or eliminates thermal bridging because SIPs are the structural elements and there are no studs or braces to cause breaks in the insulative action. Unlike stick and batt construction, which can be subject to poorly installed insulation, the nature of SIPs is such that the structural and insulative elements are joined as one. There are no hidden gaps, because a solid layer of foam insulation is integral to panel construction.

What are relevant resources for Thermal Bridging?

- www.carlisle-syntec.com/documents/reslib/ConstructionSpecifier_ThermalBridging.pdf
- windows.lbl.gov/software/therm/therm.html
- Evaluating Energy Efficiency Using Whole Building Energy Simulation Tools: www.wbdg.org/pdfs/jbed_sum07.pdf

Which strategies interact with Thermal Bridging?

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 5to50 strategies to assist you in gaining a deeper understanding.

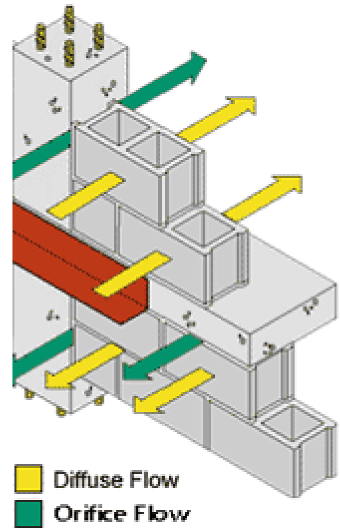
» Cavity Walls for Insulating Airspace
» Energy Modeling
» Life Cycle Assessment
» Windows and Openings

What is Total Building Commissioning?

Total building commissioning (TBCx) is a quality assurance process to ensure that the building as a whole—all of its components and systems—performs as intended. TBCx includes mechanical systems, the building envelope, structural, electrical, control, elevators, plumbing, and life safety systems (see also Systems Commissioning). TBCx is therefore broader in scope than systems commissioning. Note that some aspects of TBCx (i.e., building mechanical systems and envelope) can be very critical to carbon emission reductions associated with building operation, whereas other aspects (i.e., life safety systems) may have less of an impact on carbon reduction. With regard to the building envelope, where an impact on carbon reduction is possible, in addition to analyzing the thermal performance of the building envelope, TBCx includes an evaluation related to air infiltration, moisture diffusion, condensation risk, and rainwater entry. Improving these aspects of building envelope performance can significantly improve the durability and long-term energy performance of building envelopes.

As buildings become more complex, the importance of systematically evaluating their performance has become more important. In fact, TBCx has been proven to represent one of the most cost-effective paths to reducing energy waste in all buildings. Commissioning can be especially critical in the case of innovative buildings that often incorporate promising but relatively untested technologies.

Deficiencies in design or installation can be identified using peer review and field verification. As part of the process, preventive and predictive maintenance plans, tailored operating manuals, and training procedures are developed. Essentially, the TBCx process formalizes review and integration of all project expectations



Building envelope commissioning, a key component of total building commissioning (Source: Whole Building Design Guide

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted in order to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Total Building Commissioning reduces energy waste in buildings by ensuring that all installed building systems – envelope, structural, electrical, control, elevators, plumbing, life safety, and mechanical systems perform as designed and that the design precisely meets the project requirements.

Specify energy efficient equipment and technologies
- Total Building Commissioning ensures that the efficiencies promised by premium products and technologies are actually realized.

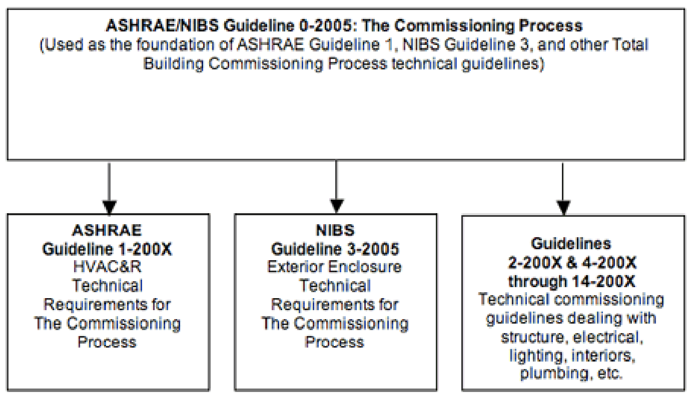
Use renewable strategies and purchase green power
- NA

Educate building owners, operators, and occupants
- Educating owners on the requirements and resulting design strategies of their projects is one of the primary focuses of total building commissioning. The development of O&M manuals as part of the process will ensure persistence in energy savings over time.

during planning, design, construction, and postoccupancy phases by inspection and functional performance testing and oversight of operator training and record documentation.

The first step in any commissioning process is to identify a commissioning team that will determine the commissioning goals, a preliminary commissioning plan, and establish a fee budget for total commissioning of the project. The team then selects the commissioning authority (CxA) for the project. The CxA is primarily responsible for coordinating the commissioning process and for providing the project with a third-party perspective, independent of the design or construction team. For smaller projects, it is acceptable for a CxA to be employed by a design team firm, but not directly involved in the design of the project itself. For larger projects, the CxA should not be affiliated with the design team. In all cases, the CxA should have experience with projects having similar building systems, size, and budget.

The National Institute of Building Sciences (NIBS) Total Building Commissioning Program is currently working with industry organizations to develop commissioning guidelines for various systems and assemblies.



NIBS Guideline 3(Draft Version) Total Building Commissioning (TBC) Process

How do I apply **Total Building Commissioning?**

ESTABLISHED TECHNIQUES

Total building commissioning takes place from project conception and during the planning, design, construction, and postconstruction phases. The U.S. General Services Administration (GSA) has incorporated TBCx into their federal government buildin gprogram. GSA envisions the commissioning process as originating from project conception and initial planning and can incorporate commissioning of all building elements and systems. The following diagram, taken from The Building Commissioning Guide (GSA, 2005), illustrates the steps taken during the planning, design, construction, and postconstruction phases.

Task	Design Phase Commissioning Responsibilities and Tasks	Parties Involved			
1	Overall coordination of the Cx work	Lead			
2	Develop design & operating intent documentation	X	Lead	X	X
3	Perform 60-70% Construction Document design review	Lead			
4	Develop draft Cx plan for Construction Phase	Lead			
	a. Review Cx plan		X	X	X
5	Develop Cx specifications for construction	Lead			
	a. Assist with, review & approve all sections		X		X
6	Perform 90 -100% Construction Document design review	Lead			

Table 1

Design Phase Activities

The first step in any commissioning process is to document theowner's project requirements (OPR). The OPR details the functional requirements of the building systems from the owner's perspective, including facility uses, occupant comfort, and requirements for project success. Above all, the OPR should be measurable and verifiable. It is important to note that an owner may not have experience formally documenting these requirements. In this case, the CxA can conduct a workshop to facilitate the development of the OPR. The process should start as early in the design process as possible. This is a highly integrated process because it should involve all members of the ownership and client team, the A–E design team, and operations and maintenance personnel. All are stakeholders in the performance of the building.

In response to the OPR, the design team for the project should develop a basis of design (BOD) document that describes the system configurations and control sequences that will be implemented to meet the OPR. The BOD should include assumptions made by the mechanical engineer to design the HVAC systems, including indoor and outdoor design conditions and occupancy schedules.

The CxA will conduct design reviews in the context of the BOD. As a best practice, a CxA should be designated early enough during the design process to be able to perform an initial review prior to 50 percent construction documents (CDs). In addition, the CxA will also develop specifications for the architect to incorporate into the CDs. All of the tasks to be performed during commissioning are described in a commissioning plan developed by the CxA. This plan also describes roles and responsibilities of the entire design team in the process, as illustrated in Table 1 (source: Portland Energy Conservation, Inc. [PECI] Design Phase Commissioning Plan).

Task / Activity	Estimated Start Date	Estimated End Date
DRAFT Construction Phase Cx plan		
Begin construction site visits/inspections		
Prefunctional and startup forms developed and distributed Equipment and controls startup and initial checkout plans		
Startup and initial checkout executed		
TAB Functional performance tests O&M documentation review and verification		
Training and training verification		
DRAFT commissioning report		
Seasonal testing		

Table 2

Construction Phase Activities

Prior to the end of the design process, the CxA will develop a construction phase commissioning plan. Table 2 presents a sample project schedule taken from the PECI Construction Phase Commissioning Plan (www.peci.org). During and immediately prior to the construction phase, a CxA may review contractor submittals related to the systems that will be commissioned. After equipment start-up, the CxA conducts installation inspections, also known as prefunctional inspections. Once equipment is fully installed, the CxA conducts functional performance testing that is used to evaluate performance at all sequences of operation. Protocols for functional performance testing are usually developed by the CxA during the construction phase based on project specifics and the sequence of operations developed by the controls engineer (CDs often do not provide enough detail). It is important to note that some functional testing can be performed only in certain seasons, which will usually extend the commissioning process beyond the completion of construction. At the end of the commissioning process, the CxA prepares a final report and may also prepare an operations and maintenance manual for the project.

EMERGING TRENDS

- **The high-performance building movement in general and various energy rating prerequisites in particular have brought commissioning more into the mainstream in recent years. The energy-savings potential associated with minimizing unwanted infiltration through building envelopes is significant, especially in cold climates.**
- **Total building commissioning recognizes and measures interrelationships between individual building components and systems that affect overall performance, occupant satisfaction, and cost.**
- **The concepts of retrocommissioning and continuous commissioning attempt to continue the process into the operational stage of the building to improve reliability and energy performance as intended by design for the life cycle of the building.**

What are relevant resources for Total Building Commissioning?

- www.wbdg.org/
- www.wbdg.org/project/buildingcomm.php
- www.peci.org/
- www.cacx.org/resources/commissioning.php
- www.ashrae.org/
- www.usgbc.org/
- www.bcxa.org/

Which strategies interact with Total Building Commissioning?

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Monitoring
» High-Efficiency Equipment
» Life Cycle Assessment
» Rightsizing Equipment
» Smart Controls
» Staff Training
» Systems Commissioning
» Systems Tune-Up

46 Vegetation for Sun Control

What is Vegetation for Sun Control?

Plants provide a livable atmosphere and moderate climate by regulating the earth's oxygen–carbon dioxide balance and filtering pollutants from air and water. Plants take in carbon dioxide, water, and light to produce carbohydrates (a food for growth) and oxygen—the process of photosynthesis. Vegetation and soil can convert and recycle waste by processing, removing, transforming, and storing pollutants from air and water. Plants can filter gaseous pollutants from the air by absorption through leaf stomata and bark pores. Plants also provide many environmental benefits and improve our quality of life and well-being. Trees especially produce oxygen and provide beauty and shelter (to wildlife). One acre of forest absorbs six tons of carbon dioxide and puts out four tons of oxygen, enough to meet the annual needs of 18 people. In addition to the natural carbon-reducing attributes of vegetation, plants and trees can be used to reduce solar gain in buildings (when not desired), reducing mechanical loads, and thereby further contributing to carbon-reducing strategies.

Using vegetation to augment a building's passive solar and daylighting strategies can also provide valuable shading and cool the surrounding air by evaporation. This process is known as transpiration and draws tremendous amounts of heat out of the air around a building. In addition, an effective landscape plan can reduce the overall energy loads on a building or surrounding community and can provide needed protection from the wind. According to the U.S. Department of Agriculture, the net cooling effect of a young, healthy tree is equivalent to 10 room-size air conditioners operating 20 hours a day. Trees properly placed around buildings can reduce air-conditioning needs by 30 percent and can save 20–50 percent in energy used for heating. Vegetation can also increase a building's value. According to Management

Xeriscaping around a building

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Using varied strategies to reduce the overall energy use of a building will put less demand and reduce emissions of the power plant that is providing the energy.

Specify energy-efficient equipment and technologies
- Not applicable

Use renewable strategies and purchase green power
- Not applicable

Educate building owners, operators, and occupants
- On care and maintenance of plantings.

Information Services of the International City/County Management Association (ICMA), landscaping, especially with trees, can increase property values as much as 20 percent.

How do I apply Vegetation for Sun Control?

Using an integrated approach to landscaping and passive solar design, carefully consider and select plants and vegetation in combination with other building elements to achieve a solution that uses several features to address cooling, shading, and wind protection. The size and location of the trees or plants must be considered in the context of solar access. For example, if you select a tree that grows too large, you may block the solar access or a solar panel that is attempting to generate electricity. If you select a fruit-bearing tree or plant, consider the maintenance and location of droppings that may interfere with patterns of circulation and accessibility.

Orientation

Orientation of the building and the plantings must be considered together. The sun strikes at a low angle early and late in the day on the east and west sides of a building. To shade walls and windows on the east and west, plant bushes or smaller trees. Arbors and trellises can also work well in these locations. Vines tend to grow quickly and can offer an excellent source of shade. Avoid using dark wire for trellis supports because it can acquire so much heat from the sun that it can burn young vines. Trellises should be kept more than one foot from the wall being shaded or heat reflected from the building may injure the plants.

On the south side of a building, planting high-crowned deciduous trees—which grow tall with few low-lying branches—is most effective. These trees can shade roofs and south-facing walls in lower buildings when fully leafed in the summer. They also permit access to ground-level breezes, and when they lose their leaves in the fall, sunlight is able to stream into south-facing windows for passive solar gain.

Grass can also help cool the air around a building by as much as 10° F. Compared with bare dirt, grass absorbs less sunlight and it loses moisture by transpiration through evaporation from the blades.

Evergreens such as pines and spruces can also support a shading strategy. However, because they retain their needles year-round, evergreens planted along the south side of a building can block wintertime solar gain. Along the north, west, and east sides of a building, they can support the shading strategy but may also block breezes that can help passively cool a building. During design, use wind roses to determine which breezes are to be blocked and which can be used for cooling.

Considerations for Selecting Landscape Plants

- Height and width
- Form
- Texture
- Seasonal interest and color
- Insect and disease resistance
- Sun or shade
- Moisture tolerance
- Drought resistance
- Soil type

Tree Selection

To select appropriate trees that will provide shading and evaporative cooling for a building, you must consider the following:

- Growth rate
- Mature height
- Branch spread
- Tree form or shape
- Soil, sun, and moisture requirements
- Fruit-bearing or non–fruit-bearing
- Hardiness zone

I never knew the full value of trees. Under them I breakfast, dine, write, read, and receive my company.
–Thomas Jefferson

Region-Specific Issues

There are also region-specific issues that will need to be addressed. Hot, arid climates, such as the desert Southwest, are characterized by relatively short, warm winters, with temperatures rarely falling below freezing. The rest of the year is hot and dry; therefore, shade is essential to reducing cooling loads. The lack of moisture also means that trees and plants will grow slowly. Shade trees will need to be protected. Walls can be shaded by providing shrubs near the building or vines that drape over trellises or grow against exterior walls or arbors. The use of xeric plants, which are adapted to very low water conditions, is suggested. There are many choices of low-water or xeric plants. Ground vegetation helps to cool a desert building as well. Some cooling will result from transpiration, but certain desert plants also reflect large amounts of sunlight and can contribute to the cooling of spaces around buildings. Nighttime purging of heat is another important passive cooling strategy in desert climates, which in some places is facilitated by cool evening breezes. Vegetation can help funnel breezes to a building. Vegetation and landforms such as earthberms may be necessary to deflect hot winds away from buildings. Trees and shrubs can also support the cooling of driveways, sidewalks, and other paved surfaces.

In hot, humid climates, landscaping with trees and vegetation can address the problem of summertime cooling. Shade trees can cast welcome shadows on roofs, windows, walls, sidewalks, driveways, and large open areas around buildings. The ideal planting consists of tall, high-crowned trees that provide shade but permit breezes to reach the house. Heavy planting may block breezes, trapping warm air near a building.

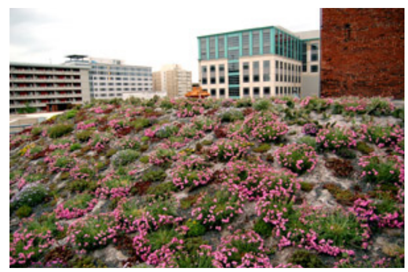
The temperate zone of the United States has a lot of variation in temperature and weather conditions. Summer shade can be provided by planting along the south side of the house but permitting sunlight to warm a building during the colder parts of the year. Trees and shrubs may also be needed to shade a building from early-morning and late-day sun to the east and west, respectively. Wind can also present a design challenge in this zone, but wind can be addressed with proper siting and carefully planted windbreaks, usually consisting of trees.

In cold climates, the dominant force is cold and the primary goal of the designer and landscape architect is to maintain internal building heat during the cooler times of the year. Summers in this climate vary, but in places that are fairly cool throughout the summer, little needs to be done to shade a building. Windbreaks should also be considered and will greatly reduce the demand for fossil fuel for heating or air-conditioning.

Sustainable Vegetation Practices

Disturbing or removing vegetation causes a site to lose valuable ecosystem services such as climate regulation, protection of soil health, provision of habitat for wildlife and pollinators, and filtration of pollutants from water and air. Such disturbance can also restrict the capacity of the landscape to intercept and infiltrate water, which in turn manages stormwater, recharges groundwater, and filters water. Current practices that impair plant health also affect soil health, as vegetation maintains soil structure, prevents erosion, and contributes to organic matter in the soil. Therefore, it is important to minimize erosion and protect natural vegetation during construction.

Protect and conserve existing vegetation. Incorporate healthy native or noninvasive vegetation currently existing on the site into the site design. Encourage a tight disturbance zone to limit construction damage to vegetation.



Silene carolinia plantings on the south side of the ASLA's green roof contribute to the building's overall vegetation strategies.

Use native species. They are easier to establish and keep alive than nonnative species. They are already adapted to the local soil and climate. Nonnative or exotic species of plants and vegetation often require large amounts of water, fertilizer, and pesticides.

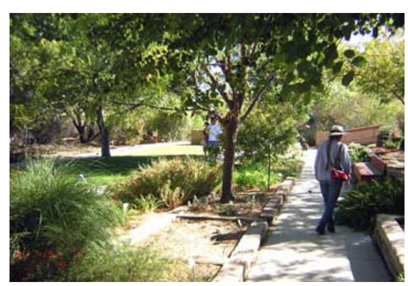
Eliminate the use of invasive plants. An invasive species is defined as "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health."

Specify plants from local growers. Buying locally reduces energy use and other negative environmental impacts of shipping and ensures that plants are adapted to local environmental conditions.

Minimize the amount of time that plants are stored on-site before planting. If plants or on-site transplants must be stored, store them in ways that prevent stress and disease postplanting. Provide adequate water, heal-in root-balls, and nutrients, if needed.

EMERGING ISSUES

Invasive species. Invasive species in landscape design jeopardize native species. Approximately 85 percent of the invasive woody plant species in the United States were introduced for landscape or ornamental uses, and approximately 5,000 plant species are estimated to have escaped to natural ecosystems.



Desert demonstration garden, near Las Vegas, incorporates more than 1,000 species of water-conserving plants set in a water-smart landscape that attracts a variety of resident and migrant bird species.

Sustainable hydrology practices. Under natural conditions, rain falls on vegetation and drips and filters into the soil—which recharges groundwater supplies—and slowly flows into creeks and rivers. In contrast, constructed landscapes are often designed to treat water as a waste product, with the goal of moving it off-site as quickly as possible. Conventional drainage systems typically deliver larger volumes of water to streams in shorter amounts of time, leading to increased downstream flooding, erosion, water quality degradation, and fewer opportunities to enjoy the aesthetic and recreational benefits of streams and lakes. The following strategies outline elements of sustainable hydrology practices that can be incorporated into an effective site and vegetation plan:

- *Incorporate water infiltration into the site design:* Install a rain garden or small vegetated catchment areas that filter rainwater and increase groundwater recharge by capturing excess water.
- *Reuse water:* Use rainwater, gray water, and wastewater for on-site, nonpotable water needs, such as landscape irrigation, cleaning outdoor surfaces, and water features.
- *Clean and slow the flow of water to protect and enhance downstream water bodies:* Water treatment methods for rainwater runoff include dry wells, vegetated swales instead of curb and gutter systems, vegetated filter strips, and infiltration facilities.

What are relevant resources for **Vegetation for Sun Control?**

- American Society of Landscape Architects: www.asla.org
- *Energy Efficient and Environmental Landscaping,* by Anne S. Moffat and Marc Shiler
- National Arbor Day Foundation: www.arborday.org
- The Sustainable Sites Initiative: www.sustainablesites.org

Which strategies interact with **Vegetation for Sun Control?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Orientation
» Carbon Offsets
» Daylighting
» Earth Sheltering
» Green Roofs
» Life Cycle Assessment
» Sun Shading

What are Walkable Communities?

Approximately 30 percent of greenhouse gas emissions in the United States that contribute to rising global temperatures are caused by transportation, and transportation emissions are the fastest rising among all emitting sectors. It is estimated that atmospheric concentrations of carbon dioxide (CO2) will almost double by 2100. Walkable communities, use of public transit, and increased density can lead to efficient energy use while lessening harmful emissions. The most important thing each of us can do to support walkable communities that are also sustainable is limit our use of fossil fuel.

The layout of many existing communities—whether urban, suburban, or rural in scale—does not support pedestrians or bicyclists. Communities need to be planned around people, not cars. Communities should be scaled to ensure that walking and cycling distances are convenient from home to school, work, and services. Necessities such as water, food, and building materials should primarily come from within the community, and waste should be recycled within the community's borders. There is a growing movement among land-use planners, designers, architects, and regulatory agencies to support walkable communities because of the diverse benefits to society and the economy.

Walkability is key to an area's efficient ground transportation. Every trip begins and ends with walking. Walking remains the cheapest form of transport for all people, and the construction of a walkable community provides the most affordable transportation system any community can plan, design, construct, and maintain. Walkable communities are scaled for sustainability of resources (both natural and economic) and lead to more social interaction, encourage physical fitness, and reduce crime and other social problems. Walkable communities are more liveble

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building.
- Reduce the fossil fuel and energy use needed to travel between buildings within the community.

Specify energy-efficient equipment and technologies.
- Rely more on human energy in lieu of fossil fuel-driven vehicles.
- Use renewable strategies and purchase green power.
- Not applicable

Educate building owners, operators, and occupants.
- Consider a charrette to engage a large number of participants and involve the community in the process of creating a walkable community.

communities and lead to whole, happy, healthy lives for the people who live in them.

Walkable communities are also desirable places to live, work, learn, worship, and play. Walkable communities locate goods (such as housing, offices, and retail) and services (such as transportation, schools, and libraries) that a community resident or employee needs on a regular basis within an easy and safe walk. Walkable communities make pedestrian activity possible, thus expanding transportation options and creating a streetscape that better serves a range of users—pedestrians, bicyclists, transit riders, and automobiles. To foster walkability, communities must mix land uses, build compactly, and ensure safe and inviting pedestrian corridors.

As the personal and societal benefits of pedestrian-friendly communities are realized—benefits that include lower transportation costs, greater social interaction, improved personal and environmental health, and expanded consumer choice—many are calling on the public and private sectors to facilitate the development of walkable places. Land use and community design play a pivotal role in encouraging pedestrian environments. By building places with multiple destinations within close proximity, where the streets and sidewalks balance all forms of transportation, communities have the basic framework for encouraging walkability.

How do I design Walkable Communities?

There are a number of approaches to designing a walkable community. The scarcity of land for development has also intensified the use of available land to accommodate future needs. Mixed-use and compact developments have become attractive approaches, especially in places where services and transportation are most available. Mixed-use development refers to the practice of allowing more than one type of use in a building or set of buildings. This can mean some combination of residential, commercial, industrial, office, institutional, or other land uses. However, the process requires the input and support of a wide range of professionals and expertise, implemented through the charrette process. In addition, there are opportunities to revitalize older communities that have existing infrastructure and a layout that already support walkability.

Outlined below are a few elements to consider when designing, constructing, maintaining, or revitalizing a walkable community. Consider and address the following elements:

- Create a clear, understandable, and organized sidewalk, street, and land-use system consistent with the scale and function of the surrounding context.
- Create a pattern of design and use that unifies the pedestrian system.
- Provide a balance among transportation modes that will accommodate and encourage pedestrian participation.
- Protect pedestrians from automobiles and bicycles: Provide adequate time to cross intersections without interference and physical separation from fast-moving cars.

- Provide comfortable, secure, and negotiable paving materials for sidewalks and crosswalks, and unobstructed passage on the sidewalk and at corners. Time signals to enable safe and quick crossings.
- Provide opportunities for social interactions, including sidewalks that support a variety of uses and activities.
- Create the opportunity for all individuals to use the pedestrian environment as fully as possible.
- Incorporate design and functional elements that are simple, efficient, and cost-effective.
- Maintain clean and efficient surroundings with adjacent storefronts and activities that provide sidewalk interest.

ESTABLISHED TECHNIQUES

Elements of a Walkable Community

Sidewalks: Provide sidewalks with added width, buffers to the street, and attractive edges. Reduce the number or setback of driveways and provide nonmountable curbing.

Main Street: Create a main street walk that is wide, attractive, and includes shops and residential units that look over the street. Provide many activities to support the use of sidewalks and the main street area for many hours of the day. Provide good lighting and street furniture and ensure that maintenance is addressed and carried out.

Local Streets: Local streets should be narrow and well landscaped, with on-street parking that acts as a sidewalk buffer. Homes and businesses should be located proximate to the street.

Avenues/Boulevards: Provide sidewalks that are—five or six feet in width. To create essential separation between pedestrians and vehicular traffic, use planter strips, trees, landscaping elements, or medians.

Crossings: Provide crossings that are well marked, accentuated by curb extensions, and allow use by persons with disabilities. Signals may be warranted for heavily trafficked boulevards.

EMERGING ISSUES

A growing number of people think that their suburban lifestyle is becoming more difficult and less appealing because of the amount of time spent in cars. Roadway congestion and dependence on the automobile detract from the livability of communities—especially for seniors, families with children, and persons with disabilities. Therefore, the movement toward walkable, livable communities continues to grow.

Zoning laws are being revised and increasingly address mixed-use zoning. A mixed-use district will most commonly be the "downtown" of a local community, ideally associated with public transit nodes in accordance with principles of transit-oriented development and New Urbanism. Mixed-use guidelines often result in residential buildings with street-front commercial space. Retailers have the assurance that they will always have customers living right above and around them, and residents have the benefit of being able to walk a short distance to get groceries and household items or see a movie.

There is an expanded focus on the economic benefits as well as the environmental benefits of walkable communities. Typical suburban development has become less inviting to investors, who are now expected to evaluate the consequences of low-density development.

A return to community self-reliance, local empowerment, and the rebuilding of traditional commercial districts based on their unique assets—distinctive architecture, a pedestrian-friendly environment, personal service, local ownership, and a sense of community—is becoming more commonplace through initiatives such as the Main Street Program to revitalize older business districts.

What are relevant resources for Walkable Communities?

- AIA Communities by Design: www.aia.org/live_default
- Principles of Smart Growth: Create Walkable Communities: www.smartgrowth.org/about/principles/principles.asp?prin=4&res=1280
- Congress for New Urbanism: www.cnu.org
- Walk Score: www.Walkscore.com
- Sustainable and Livable Communities: www.ecoiq.com/onlineresources/anthologies/sustainable/communities/
- National Trust for Historic Preservation: Main Street Program: www.mainstreet.org/

Which strategies interact with Walkable Communities?

All 50to50 strategies relate to each other in some way.
It is recommended that you consider investigating these selected strategies to gain a comprehensive understanding of the topic.

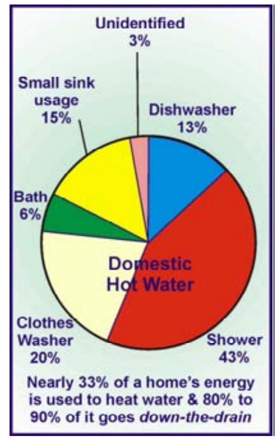
» Alternative Transportation
» Appropriate Size and Growth
» Carbon Offsets
» Space Zoning

What is Waste-Heat Recovery?

Waste heat is heat generated by processes such as fuel combustion (exhaust fumes), a chemical reaction (fuel cells), or a vapor compression refrigeration cycle (refrigerant), which is "dumped" into the ambient environment even though it still has significant useful energy. Waste-heat recovery refers to heat that is discharged as a by-product from one process to provide supplemental energy needed by another process.

How best to recover this energy and how much energy can be recovered depends on the temperature of the waste heat fluid, the secondary processes, and the economics involved. Heat transfer/extraction/recovery takes place as one hot medium, without mixing, passes another cooler medium. By bringing the hotter fluid into indirect contact with a relatively cool incoming load, energy will be transferred to the load, preheating it and reducing the energy that is simply lost to the ambient environment. The amount of transfer depends on the temperature differential between the two fluids and the amount of exposure time.

This recovered energy is typically used for preheating water for domestic or process use. Minimizing active water heating can result in significant environmental and economic savings. According to the U.S. Department of Energy (DOE), water heating in 2000 accounted for 4.2 quads of energy use nationally, or roughly 11.5 percent of the primary energy use by the building sector. In residences, domestic water heating accounts for more than 18 percent of energy consumption. Although water heating is less significant in commercial buildings compared with other building loads, it is a major contributor in some industries: 40.4 percent of energy use in the lodging sector, 26.2 percent in health care, and 21.9 percent in education (1995 data from DOE).



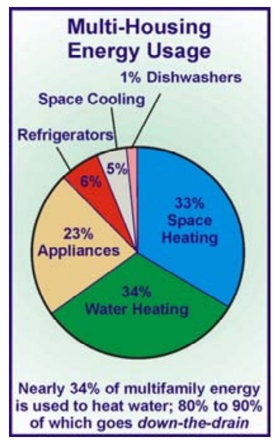


Image from GFX website

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- Waste-heat recovery from the air-conditioning system provides preheated water to the water heater.
- As heat is extracted from the refrigerant more effectively, the air-conditioning system will operate more efficiently.

Specify energy-efficient equipment and technologies
- Desuperheaters provide more condenser capacity, which lowers the compressor head pressure, prolonging the life of the air-conditioning system.
- Heat recovery systems are available for air-conditioning units from two tons up to the largest chillers available.

Use renewable strategies and purchase green power
- Using waste-heat recovery equipment can reduce a building's overall energy load, which would require smaller, more cost-effective, renewable strategies to obtain energy neutrality, and reduce emissions.

Educate building owners, operators, and occupants
- On the environmental and economic benefits of waste-heat recovery systems for new and existing systems.

Typical examples of waste-heat recovery applications are preheating of combustion air, space heating, ventilation, water heating, boiler feed water, or process water.

How do I recover Waste Heat?

There are many potential sources of waste heat in buildings and thus many ways to recover it. An important consideration is the balance between the availability of and demand for recovered waste heat. If the demand is not concurrent with the availability, then storage is required and initial cost and standby energy losses are added. Good candidates for waste-heat recovery are buildings with large hot water loads or large ventilation loads where the heat, or cooling in summer, is recovered from the air as it is exhausted from the building.

ESTABLISHED TECHNIQUES

The most common method of waste-heat recovery for preheating water is extracting heat from the refrigerant prior to rejecting heat via a condenser. A desuperheater is a heat recovery unit (HRU) that recovers the superheat energy from the compressor's discharge line. Under typical conditions, a desuperheater can remove about 10 to 30 percent of the total heat that would have been rejected by the condenser.

Waste-heat recovery is also used to reclaim heat from the hot water after it is used. Domestic hot water is a once-through process that sees most of the energy used to heat water go down the drain. Centralized drainwater heat recovery devices have been developed in an attempt to use this waste energy in homes and commercial buildings. Two products on the market are the Gravity Film Exchanger (GFX) and ReTherm. Both manufacturers claim potential heat recovery percentages as high as 30 percent.

Other types of HRUs and uses for waste heat are

- Recuperator—a gas-to-gas heat exchanger is placed on the stack of the furnace.
- Regenerator—a mass is used for temporary storage of that heat prior to exchange to the secondary process (a heat wheel is a rotary regenerator).
- Absorption chillers—waste heat is used to provide chilled water for cooling.
- Heat pipe exchanger
- Economizers—flue gas heat is used to preheat boiler feed water, or the waste heat is used to preheat combustion air to improve efficiency.
- Heat pumps
- Many other innovative, custom HRUs exist, such as using waste heat from a process to melt snow off a road surface or roof.

EMERGING TRENDS

The increased awareness of the impact of ventilation air requirements on heating and cooling energy loads has promoted greater use of technologies that exchange heat and, in some instances, moisture between the ventilation exhaust and inlet airstreams.

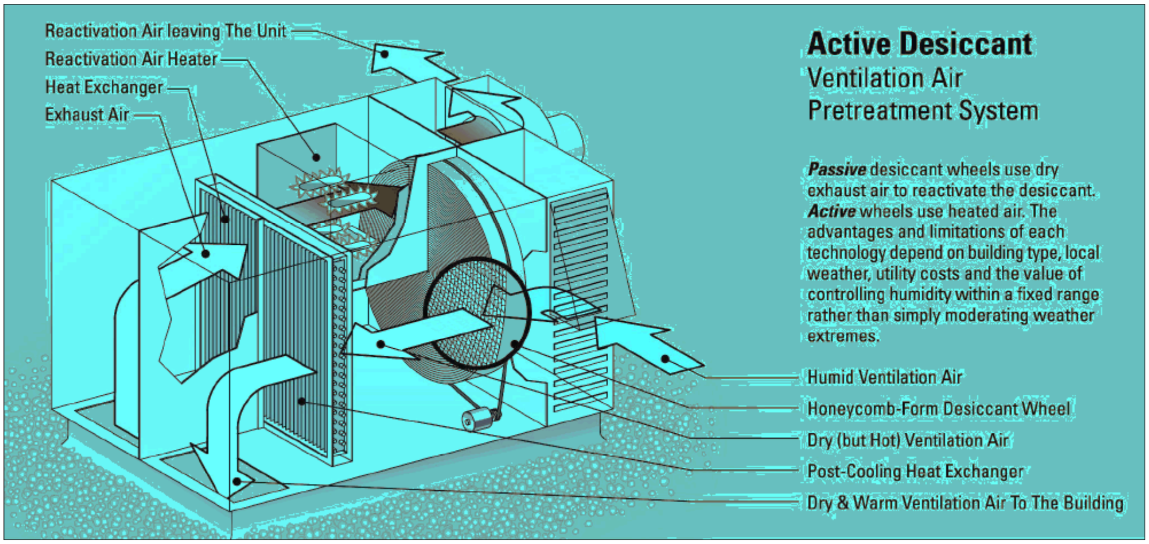
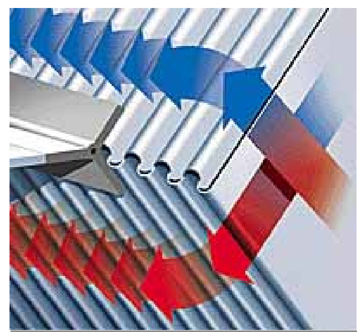


Image from ASHRAE Journal: Evaluating Active Desiccant Systems for Ventilating Commercial Buildings



In commercial buildings in more humid climates, desiccant wheels are a viable option to remove moisture from the incoming ventilation air through the use of a drying agent, or sorbent. Desiccant is impregnated into a lightweight honeycomb-shaped wheel matrix. Supply air passes through one section of the wheel and is dried. As the wheel rotates into a second air stream, that air dries the desiccant and carries the moisture out of the building. The process is repeated as the wheel continues to spin. These units also have a heat-exchange core to transfer heat from the outgoing air to the incoming air.

In more residential applications, heat recovery ventilators and energy recovery ventilators are established technologies that can be used for waste-heat recovery. These units transfer heat and/or moisture to the incoming outdoor air from the indoor exhaust air without mixing the airstreams through the use of a heat-exchange core. In the winter, the outgoing heated air preheats the incoming air. The opposite occurs in the summer, with the outgoing air precooling the incoming air. These systems typically have a total effectiveness of 55 to 85 percent.

What are relevant resources for Waste-Heat Recovery?

- American Society of Heating, Refrigerating and Air-Conditioning Engineers: www.ashrae.org/
- BuildingGreen.com, an independent company committed to providing accurate, unbiased, and timely information designed to help building-industry professionals and policymakers improve the environmental performance and reduce the adverse impacts of buildings: www.buildinggreen.com/auth/article.cfm?fileName=060806a.xml
- www.alabamapower.com/energy_knowhow/desuperheaters.asp
- www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/BuilderGuide3E.pdf
- GFX Web site: gfxtechnology.com/
- ReTherm Web site: www.retherm.com/

Which strategies interact with Waste-Heat Recovery?

All 50to50 strategies relate to each other in some way.
It is recommended that you consider investigating these selected strategies to gain a comprehensive understanding of the topic.

» Co-Generation
» Conserving Systems and Equipment
» Energy-Saving Appliances and Equipment
» Geoexchange
» High-Efficiency Equipment
» Life Cycle Assessment

49 Water Conservation

What is Water Conservation?

Water is one of our most precious natural resources. Potable water is an increasingly valuable global commodity, and the United States is one of the highest per capita water users in the world. Although the United States has an abundant overall supply of water, it is not evenly distributed, leaving many parts of the country undersupplied. Water efficiency programs can be part of any energy management program, a way to even out the imbalance of water supply and save money.

The introduction of water conservation measures (WCMs) is one of the most immediately and technologically available and cost-effective actions we can take.

WCMs can

- Save energy input for supply treatment, water transport and pumping, and disposal treatment
- Save expenditure of energy and money on expanded treatment plants and infrastructure by reducing water volumes, particularly important in localities with combined storm and sanitary systems (conveys both sanitary sewage and stormwater in one piping system)
- Save resources, including water, energy, and labor
- Protect the environment by reducing stormwater runoff, untreated sewage, and use of chemical treatment
- Easily reduce water usage in commercial buildings by 30 percent

Based on 650 occupants using 20 gallons per day (gpd), a typical 100,000-square-foot office building can realize a reduction of 1 million gallons of water per year using low-flow fixtures combined with sensors and automatic controls. Nonpotable water can be used for building systems, toilet and urinal flushing, and landscape irrigation.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible methods. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building

- Water use for site and building systems can be reduced in volume to make way for further energy savings in water treatment, plant, and infrastructure.

Specify energy-efficient equipment and technologies

- Specify water-efficient plumbing fixtures to reduce energy use.
- Specify use of nonpotable water sources for building systems, irrigation, and toilet and urinal flushing to preserve potable water supply.

Use renewable strategies and purchase green power

- Recycle gray water for nonpotable water uses to reduce energy needed to produce and treat freshwater.

Educate building owners, operators, and occupants

- On cost and energy-savings advantages of water conservation measures.

The Energy Policy Act of 2005 mandated use of water-saving standards for water closets, urinals, shower heads, and faucets, saving an estimated 6.5 billion gpd. Toilet flushes account for 4.8 billion gpd, the greatest single water use in residential and commercial buildings. Older water closets used 4.0 to 8.0 gallons per flush; current plumbing codes now require fixtures with 1.6 gallons per flush. Water closets are now available that achieve 1.0 to 1.3 gallons per flush.

Commercial and industrial facilities use large amounts of process water that can be run using gray-water sources, resulting in substantial cost saving and reduction in water supply demand. Businesses such as car washes, industrial cleaning operations, and industrial operations that require equipment cooling use great volumes of water that can be made up with recycled gray water. Gray-water sources may involve wastewater from lavatories, showers, washing machines, and other building activities that do not involve food processing and human waste. This makes sense from the standpoints of energy reduction, environmental good practice, and bottom-line economics.

Consumption of lower volumes of potable water on the supply side, and less need for water treatment, will result in energy savings and carbon reduction. A large quantity of energy must be spent to collect, treat, and distribute potable water and in collection and treatment of wastewater for environmentally safe disposal back into our waterways. If the volume of water used can be reduced, the plant, equipment, and electric power needed to produce the water will be reduced, thereby reducing carbon emissions involved to produce that power.

How do I design for Water Conservation?

Reduce indoor potable water consumption by using fixtures that exceed the performance requirements set by the Energy Policy Act of 2005. Highly efficient fixtures are also available at a cost premium.

- Residential buildings: Employ strategies that use 30 percent less water (combined)
- Commercial buildings: Employ strategies that use 20 percent less water (combined)

Sloan-o-matic Low-Flow Showerhead;
Sloan Automatic Faucet with Infrared Sensor

Plumbing Fixture Selection

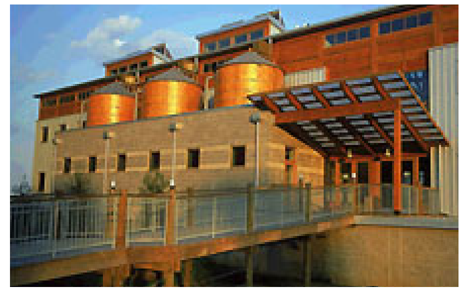
- Install low-flow showerheads (1.75 gallons per minute or less) in all showers.
- Install low-flow sink aerators in all bathrooms (1.0 gallon per minute or less) and kitchens (2.0 gallons per minute).
- Install low-flow toilets (1.3 gallons per flush or less) OR dual flush toilets (these typically have 0.8- and 1.6-gallons-per-flush modes).
- Install low-flow (.125 gallon per flush) or waterless urinals in commercial/public restrooms.
- Install automatic-sensing infrared fixtures on all commercial/public restroom lavatories.
- Reduce indoor water consumption by using water-efficient appliances and equipment.

American Standard ULF Toilet;
The Waterless Company Waterless Urinal

- Specify and install residential and commercial front-loading Energy Star clothes washers with a water factor less than or equal to 5.5.
- Install only Energy Star dishwashers, which save water as well as energy (and generally run quieter because of better insulation).
- Install a domestic hot water recirculation loop system.
- Consider tankless hot water heaters.

Site Use of Water

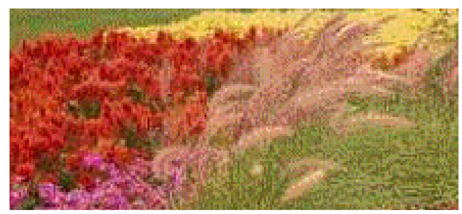
- Reduce potable water used for irrigation.
- Use water-efficient irrigation systems with low-flow sprinkler heads and water-efficient scheduling practices.
- Specify xeriscaping—native and drought-tolerant plant species to minimize the need for watering.
- Consider capturing rainwater to reduce water consumption used for irrigation and building and sidewalk maintenance activities.
- Maximize on-site absorption and filtration of stormwater through the use of nonstructural stormwater management measures.



Rainwater catchment system with cisterns at Philip Merrill Environmental Center, Annapolis, Md.

Building Design

- Use vegetated "green" roofs and/or roof gardens to
  - Reduce impervious areas
  - Reduce peak time discharge
  - Reduce heat island effect
- Reduce negative impacts of construction process:
  - Develop and implement an erosion and sedimentation control plan as dictated by state and/or local requirements.
- Install erosion control measures to prevent any soil or sediment from leaving the site.
- Stockpile and stabilize topsoil, surrounding the area with a silt fence or similar structure, to prevent topsoil from mixing with other soils on-site.



Colorado Springs Utilities, xeriscape demonstration garden, Colorado State University Cooperative Extension

Potable Water Recycling

- Consider capturing gray water from lavatories, showers, sinks, laundry, and dishwashing facilities for treatment and reuse by individual residents for flushing toilets and by the building staff for cooling tower makeup (if applicable), maintenance needs, and irrigation. Review code requirements to ensure that all codes are met.

Mechanical Systems

- Consider conserving water in HVAC systems and cooling towers.

Established Techniques

- Optimize water systems with efficient water systems design, leak detection, and repair.
- Use water conservation measures.
- Use water reuse and recycling systems.
- Educate water consumers and maintenance personnel about appropriate water conservation techniques.

EMERGING TRENDS

- A more highly regulated water conservation environment reflects increased development pressure on limited water supplies.
  - There is limited availability of freshwater in many parts of the country. Vast new building development in California and the Sunbelt states has taxed already highly burdened water supplies. Recent droughts, forest fires, and temperature warming have exacerbated the shortage.
  - Aquifers near shorelines are becoming unable to meet increased demand because of saltwater intrusion.
  - Development pressure is threatening previously pristine watershed areas.

- A relatively new technology on the scene is the Living Machine, which takes blackwater (also known as sewage) and returns it to its natural whitewater state (unpolluted by human waste). Microorganisms are the basis for the process, which includes the following:
  - Anaerobic septic tank
  - Anoxic reactor
  - Closed aerobic tank (with plants to filter gases)
  - Open aerobic tank(s) (with snails, shrimp, and fish)
  - Redirection of sludge to the septic tank (or composting of sludge); redirection of water to a wetland (usually indoor)
  - Further treatment (without chemicals) of water (studies show that the water consumed may be even safer than it was before it became polluted)

- Constructed wetland systems pretreat wastewater by filtration, settling, and bacterial decomposition in a natural-looking lined marsh. Constructed wetland systems have been used nationally and internationally with good results, but performance levels decrease in cold climates during winter.

What are relevant resources for **Water Conservation?**

- American Society of Landscape Architects
- American Water Works Association
  and WaterWiser—the Water Efficiency Clearinghouse
- California Urban Water Conservation Council
- The Irrigation Association
- Xeriscape Colorado!, Inc.
- Low-Impact Development Center, Inc.
- EPA Constructed Wetlands

Which strategies interact with **Water Conservation?**

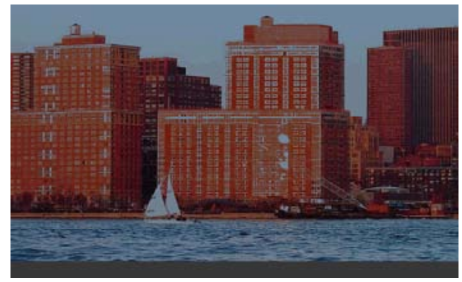
All 50to50 strategies relate to each other in some way. It is recommended that you consider investigating these selected strategies to gain a comprehensive understanding of the topic.

» Earth Sheltering
» Environmental Education
» Green Roofs
» Preservation/Reuse of Existing Facilities
» Staff Training
» Systems Commissioning

50 Windows and Openings

What are Windows and Openings?

A more general question might be, What is fenestration? There is some confusion about the meaning of the word fenestration in connection with windows, perhaps caused by its root fenestra, the Latin word for window. Fenestration, as defined by the National Fenestration Rating Council® (NFRC), is Products that fill openings in a building envelope, such as windows, doors, skylights, curtain walls, etc., designed to permit the passage of air, light, vehicles, or people.



The Solaire, Battery Park City, N.Y.

Windows and openings have always had the greatest impact on building occupants for daylighting, ventilation, thermal comfort, acoustics, and occupant well-being. Many studies have shown that access to windows and daylight has positive effects on occupant health, comfort, and productivity. The negative effects poor window design and construction are thermal discomfort due to unwanted heat loss or gain, drafts, glare, acoustical intrusion, and condensation on interior finishes.

In recent years, windows and glazing have undergone tremendous technological changes. Highly energy-efficient windows and glazing systems are now available, with wide choices of architectural treatments; glazing coatings and films; double and triple layers of glass; double-skin curtain wall façade technology; inert gas and aerogel options between glazing layers; thermally broken window frames and glazing seals/spacers; new glass types to satisfy a variety of functional, security, and aesthetic requirements; and new composite window frame materials.

Use An Integrated Approach To Reduce Carbon Emissions

A new way of thinking must be adopted to meet the goal of reducing carbon emissions associated with buildings. Your solutions can begin by integrating four possible lines of attack. None works alone, and they are not all relevant in considering every strategy. However, considering the following tactics is necessary:

Reduce the overall energy use in your building
- The use of high-efficiency windows and proper design of window openings will result in reduced solar load and air/water infiltration, and thus will reduce energy loads and energy-generation requirements.
- Retrofitting existing buildings with new energy-efficient windows would result in large savings in energy consumption.
- Often the high cost of window replacement results in a longer return-on-investment (ROI) period than other energy-conservation measures. Payback analysis should include the maximum ROI period acceptable to the owner. However, when viewed from a life-cycle perspective, window replacement will be a cost-effective energy-conservation strategy.

Specify high-performance energy-efficient windows and glazing
- The use of high-performance windows will reduce the peak energy use, reduce annual energy use, and lower operating costs, thus reducing energy loads and energy-generation requirements.

Use renewable strategies and purchase green power
- Not applicable

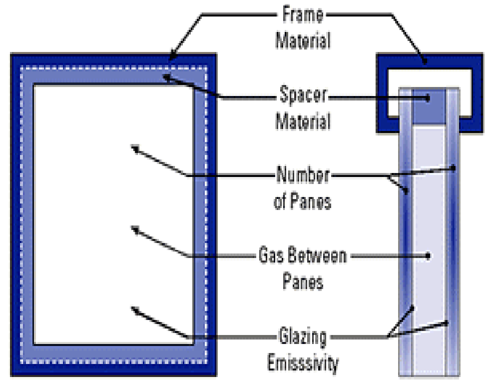
Educate building owners, operators, and occupants
- Educate owners and operations and maintenance (O&M) personnel about proper cleaning and maintenance of glass, perimeter opening seals, daylighting controls, and window operating hardware.
- Educate occupants about proper operation of daylighting controls.

How do I apply Windows and Openings?

Integration with Window/Wall Transitions

Critical to successful window and opening design is consideration of the transition to the surrounding solid wall, proper design and specification of windows and glazing, and then careful construction planning and execution. Integration of all component systems that come together at the windows and wall openings must include consideration of continuity of vapor, water, and air barriers; daylighting control; setback, drip cap, or overhang to provide weather protection of window openings; and sealing and flashing of wall openings against water intrusion. The confluence of these components in design, and the many involved construction trades in execution, represents a formidable challenge to provide desired high performance and energy efficiency over the service life cycle.

Proper continuity of the air, water, and vapor barriers and placement of full insulation in voids at the window perimeter will reduce loss of energy and drafts around the windows. Good detailing of flashing for water protection is also critical because water penetration and condensation trapped within the wall around the window will affect energy performance in addition to causing building damage and mold. Designers should not assume that sealants can satisfactorily perform the first and only line of envelope defense, but should provide redundant barrier protection in the envelope detailing. Other resources listed below discuss these design issues in detail, and some include CAD details.



Factors affecting window performance (courtesy Energy User News)

Window Energy Performance Ratings

The energy performance of individual components can be obtained from the NFRC window label or related product literature. Less well known is how the combination of window and wall envelope components performs as a total system. Acoustical performance for windows is often difficult to establish, especially for custom windows.

For windows, the NFRC label contains ratings for the following attributes relating to energy performance:

U-Factor: U-factor measures how well a product prevents heat from escaping. The rate of heat loss is indicated in terms of the U-factor (U-value) of a window assembly. U-factor ratings generally fall between 0.20 and 1.20. The insulating value is indicated by the R-value, which is the inverse of the U-value. The lower the U-value, the greater a window's resistance to heat flow and the better its insulating value.

Solar Heat Gain Coefficient: Solar heat gain coefficient (SHGC) measures how well a product blocks heat caused by sunlight. The SHGC is the fraction of incident solar radiation admitted through a window (both directly transmitted and absorbed) and subsequently released inward. SHGC is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits in the building.

Visible Transmittance: Visible transmittance (VT) measures how much light comes through a product. The VT is an optical property that indicates the amount of visible light transmitted. VT is expressed as a number between 0 and 1. The higher the VT, the more light is transmitted.

Air Leakage: Air leakage (AL) is indicated by a rating expressed as the equivalent cubic feet of air passing through a square foot of window area (cfm/sq ft). Heat loss and gain occur by infiltration through cracks in the window assembly. The lower the AL, the less air will pass through cracks in the window assembly. This portion of the NFRC rating is optional and manufacturers can choose not to include it .

Condensation Resistance: Condensation resistance (CR) measures the ability of a product to resist the formation of condensation on the interior surface of that product. The higher the CR rating, the better that product is at resisting condensation formation. Although this rating cannot predict condensation, it can provide a credible method of comparing the potential of various products for condensation formation. CR is expressed as a number between 0 and 100. This portion of the NFRC rating is optional and manufacturers can choose not to include it .

U-factor and SHGC are determined for the whole opening value — glazed opening and frame. In the northern hemisphere, south-side glass may be shaded from the sun and have high SHGC if winter heat gain is wanted. Specify a low-SHGC glass if cooling loads dominate and heat gain is not wanted. Consider glazing using aerogel or low-emissivity (low-e) inert gas between glass panels to result in the highest insulating and VT values.

Coatings and films are used to enhance performance and visual qualities of windows. Glass coatings may be reflective or color tinted. A film opacifier is often used where an opaque appearance is wanted, such as at spandrel panels. A wide variety of fritted ceramic coatings can be used for various optical and decorative visual effects. Laminated glass with a film interlayer is used as safety glass and security glazing because it has impact resistance. When used with a normal interior glass layer, the combination provides good insulating and security properties.

Regional and Climatic Issues

Before the advent of modern building technology, particularly air-conditioning, buildings tended to be responsive to their natural environments, particularly with regard to providing daylight access and natural ventilation to their occupants. Modern building design has tended to obscure regional differences in architectural design because mechanical and electrical systems have been able to overcome regional environmental conditions.

Sustainability and energy conservation as a means of design expression have always been around, they but were rarely used in major structures. With the necessity to now meet more stringent energy codes and energy-efficiency certification requirements, use of design strategies that incorporate regional best sustainability practices can help reduce loads on mechanical and electrical systems, thus reducing energy use and carbon footprint, and giving architects a modern means of architectural expression. In this process, the designer must create a synergistic balance of the simultaneous objectives for the windows for natural daylight, visible transmittance, color, natural ventilation, passive solar heat and cooling, sun shading, and views for occupant well-being.

Use of energy modeling now gives the building design team an economical and quickly responsive design tool with which to optimize solar gain for heating and cooling, building orientation, daylighting, and size and placement of window openings.

The building energy standard most often referenced in energy codes (for all but low-rise residential buildings)—ASHRAE 90.1, 2004, Appendix B—divides the world into eight climate zones, and A, B, and C subcategories: United States, Table B-1; Canada, Table B-2; and international locations, Table B-3. Prescriptive building envelope performance requirements for roofs, walls above grade, walls below grade, floors, opaque doors, vertical glazing, including percentage of wall area, and skylights are designated by these climate zones in Table 5.5-3.

Sun Shading

In addition to the energy performance of the window unit, additional sun control and shading devices may be necessary for occupant thermal and visual comfort. Use of façade shading devices will depend on the particular façade solar orientation.

Such shading devices may consist of

- Strategically planted shade trees
- Awnings and trellises
- Overhangs
- Grill-like screens

Horizontally placed light shelves may be employed to reflect daylight deeper into the interior space, keeping in mind that reflected glare from the light shelves is not desired. Solar shading strategies should block solar load in the cooling season, but permit solar gain in the heating season, at the same time also controlling glare. Most challenging to manage are eastern and western exposures from low morning sun glare and late-afternoon solar load and sun glare.

Consider Implications of Regional and Site Characteristics on Window Design

- Consider local microclimate and regional climate characteristics, site location, and building orientation.
- Size and place windows and openings to optimize passive and active solar strategies.
- Take advantage of natural ventilation strategies.
- Optimize daylight use and controls.
- Specify appropriate high-performance window materials and hardware to suit local climate and site conditions.

Other Related Considerations for Window Design

- Regional climate differences and building code requirements
- Local views
- Aesthetics of the building façades and of the window units themselves, including from the interior
- Outside noise generation from local highway or aircraft traffic
- Security requirements
- Fire-rating requirements
- Windows as egress requirements
- Window safety guards
- Building code requirements for combustible and noncombustible frame materials
- Durability and life-cycle performance
- Ease of maintenance
- Use of recycled materials
- Distance to manufacturing site

ESTABLISHED TECHNIQUES

- Design and specify windows to enable U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) program certification, specifically for credits EQ cr 2, for natural ventilation, and EQ cr 8.1 and 8.2 for daylight and views.
- Specify windows that are Energy Star certified.
- Use energy modeling as a design tool to optimize window sizing and specifications.
- Specify mock-up testing prior to production for entire window and adjacent wall assemblies to ensure quality control of windows, leakage, and air, water, and vapor barrier continuity.
- Specify windows with low SHGC for east-west facing orientations for better control of solar heat gain.

EMERGING TRENDS

- The need for more secure windows and openings has generated new products and technologies. Building codes in hurricane-prone areas now require greater wind and water resistance, as well as the ability to withstand damage from large and small projectiles. Government agencies and some private clients now require U.S. Department of Defense–compliant blast-resistant protection for glass, windows, and openings.
- Building information modeling (BIM) technology will enable three-dimensional visualization of window condition and details. This has the potential to reduce the chance of design flaws and can enable the contractor to understand the way all components fit together at the window-wall assembly.
- BIM technology has the capability to automatically develop window schedules and associated product information data, thus reducing the design time needed and potential for coordination errors.
- Glass and window technology is currently advancing at a rapid rate, and there is no evidence this trend will abate, resulting in more exciting product developments from industry.
- The savings on HVAC load gained from the reduced difference between outside and inside temperatures on thermal-adjusted windows and curtain walls using electrical heating elements is supposed to offset the additional electricity use.

What are relevant resources for **Windows and Openings?**

- Whole Building Design Guide, Building Envelope Design Guide, Fenestration Systems, Nik Vigener, PE, and Mark A. Brown, Simpson Gumpertz & Heger,Inc.: www.wbdg.org/design/env_fenestration.php
- Whole Building Design Guide, Resource Pages, Windows and Glazing, Gregg D. Ander, FAIA, Southern California Edison: www.wbdg.org/design/windows.php?r=env_fenestration-i
- Whole Building Design Guide, Building Envelope Design Guide, Fenestration Systems, Windows, Nik Vigener, PE, and Mark A. Brown, Simpson Gumpertz & Heger Inc.: www.wbdg.org/design/env_fenestration_win.php. Includes details such as dwg, dwf, or pdf drawing files.
- *Energy-Efficient Design and Construction for Commercial Building*s, Steven Winter Associates, Inc., Adrian Tuluca, McGraw-Hill, 1997
- U.S. Department of Energy, Building Technologies Program, Building Toolbox, Building Envelope, Integrated Design for Building Efficiency, Building Envelope: www.eere.energy.gov/buildings/info/design/integratedbuilding/buildingenvelope.html
- National Fenestration Rating Council: www.nfrc.org

Which strategies interact with **Windows and Openings?**

All 50to50 strategies relate to each other in some way. However, we recommend that you consider investigating these selected 50to50 strategies to assist you in gaining a deeper understanding.

» Building Orientation
» Daylighting
» Energy Modeling
» Natural Ventilation
» Open, Active, Daylit Spaces
» Sun Shading
» Thermal Bridging