

MATERIALS AND RESOURCES OVERVIEW

In this chapter, you've been challenged to consider where materials come from and where they go. From their extraction on through their sale, use, and disposal, materials have extensive impacts on our lives and the environment.

Green building focuses on two primary categories when considering materials and resources:

- Selection of sustainable materials (life-cycle impacts); and
- Waste management.

Material Selection—Considering Life-Cycle Impacts

So What?

Obviously the development of buildings requires the use of materials ... a lot of materials! In fact, 40% of raw stone, gravel, and sand and 25% of all virgin wood that is extracted is used for the construction of buildings.

Environment: Given the sheer amount of resources that go into buildings, it is easy to see the environmental consequences of their use, including air and water pollution, destruction of native habitats, and depletion of natural resources.

Economy: Many of the readily available materials used in the construction industry are extracted or manufactured in a way that historically has focused solely on economic profit. In this model, the environment and people are completely left out of the picture.

Community: The extraction, manufacturing, application, and disposal of many of today's materials pose serious health risks to the human population, many of which are not clearly understood.

Strategies

So what exactly does it mean when you hear the term “life cycle” in regard to material selection? Basically, it means you are considering all the environmental impacts associated with a material from the beginning (i.e. its extraction) through its processing and use in manufacturing, its transportation, and its end use, all the way to its eventual disposal. A life-cycle assessment, or LCA, is a “cradle-to-grave” approach for assessing materials. Cradle-to-grave begins with the gathering of raw materials from

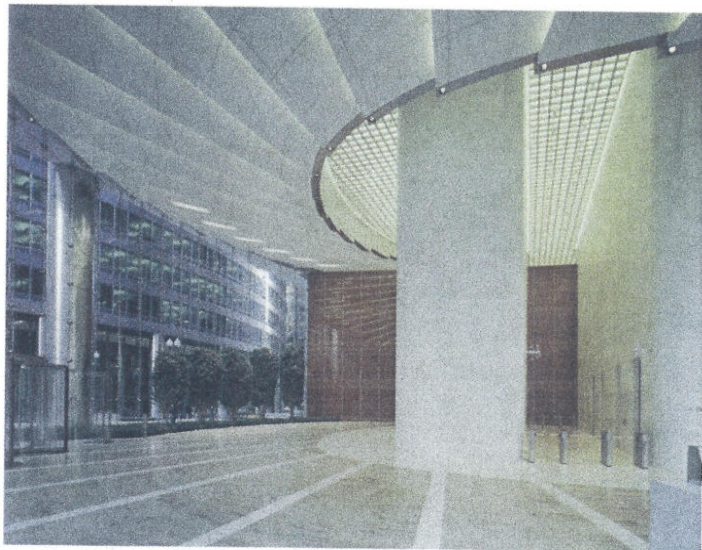


Photo courtesy of the John Buck Company

the earth to create the product and ends at the point when all materials reach disposal. While you may not be able to complete a formal LCA on all the products and services you use on a project, the framework itself can be extremely useful when weighing various options.

Strategies

Develop a construction purchasing policy.

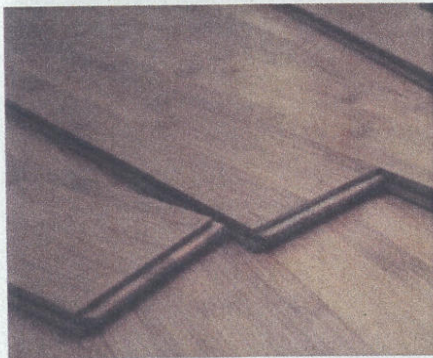
There are a lot of people involved in the design and construction of a project, and not all of them necessarily understand your goals. Put all these goals into a construction purchasing policy so that there is no question about what products you'd like to see selected for the project.



Specify green materials.

Specifications are the written documents that an architect issues along with drawings to describe the quality of materials to be used on a project. It is in the specifications that you can let the contractor know to buy wood from the region or not to use PVC, for example. The specifications are a legally binding document, so it is the most solid way to ensure that green materials make it into the project.

Photo by Jonathan Leys



Specify green interiors.

The inside of a building is one of the most critical areas for human health to specify green. As noted above, you can use the specifications to make sure only low- or no-VOC paints are used or bamboo floors, for example, are installed.



Develop a sustainable purchasing policy.

The word "policy" is enough to scare a lot of people off, but really a purchasing policy can be a simple checklist that documents the types of products you want to be used in your project. It ensures that everyone from the top down understands what your goals are and how these translate into purchases so that the paper with 100% recycled content makes it to the copier instead of virgin paper.

Specify green electronic equipment.

There are already countless choices when it comes to electronic equipment, but thinking about energy use and material selection is something you can't forget about. Find electronics and accessories that use less energy, are made with recyclable and recycled materials, and are easier to upgrade, fix, and recycle.

Waste Management

So What?

The funny thing about throwing something away is that there is no “away.” The three necessary components for decomposition—sunlight, moisture, and oxygen—are hard to come by in a landfill. Although we’re not sure, since we haven’t been paying attention long enough, scientists estimate that plastic could take 500 years or longer to decompose in a landfill.

And where is all this garbage coming from? Construction and demolition of buildings account for about 40% of the total waste stream in the United States.

Environment: Current construction and disposal practices introduce highly hazardous toxic materials into the soil, air, and water when such materials are disposed of in landfills. Landfills fail and leak contaminants into ground and surface water.

Economy: The cost of building and maintaining landfills is astronomical. Because landfills have the potential to substantially harm the environment, they are highly regulated and therefore costly. Even after a landfill is “closed,” it must be monitored and tested for decades to determine its impact on local air, soil, and water resources.

Community: Landfill gas emissions and contaminated groundwater sources have the potential for devastating impacts on human health.

Strategies

OK, so you’ve heard enough. But what’s the answer? Well, you know the three R’s, right? Reduce, reuse, recycle. But did you know that they’re in that order for a reason? It’s a hierarchy, and it’s best to start at the top with reduce. That’s because reducing the amount of materials minimizes the environmental impacts throughout each phase of the materials life cycle. Next comes reusing, which means that instead of building a new building or buying new cabinets, you look at reusing existing products that may just need to be fixed up. Last of the R’s is recycling, which means taking waste to recycling facilities that break down the materials and turn them back into “new” materials.

Good waste management can reduce the amount of waste and toxins hauled to and disposed of in landfills or incineration facilities. With that in mind, consider the strategies below, each of which fits into either the reduce, reuse, or recycle category.

Strategies

Size the building appropriately.

Bigger isn't always better. Buildings that are smartly designed meet the needs of their occupants without wasting space. Using less means you inherently waste less.



Reuse existing buildings or portions of existing buildings.

Given the number of existing buildings in this country, we need to get more creative about repurposing them. Consider an old manufacturing facility that has sat unused for years. It could have great "bones," and some creative design decisions could transform it into a unique office space.

Photo by Melva P. Calder



Reuse building materials.

Certain salvaged materials simply cannot be duplicated in today's manufacturing system. Looking for architectural gems or repurposing a product such as old lockers is a great way to keep materials out of the landfill and give a space character.

Photo by Dale Photographic



Develop a construction waste management policy.

During construction, it is important to write down your goals so that you can hold everyone on-site accountable for the goals and processes you put in place. A construction waste policy should outline the three R's and spell out for all the trades how they can contribute to reducing the amount of waste headed to the landfill.

Photo by Jim Gallop/ Gallop Studio

Strategies



Consider new technology, design, and construction decisions.

Every day, designers and engineers are coming up with new ideas for addressing the myriad of issues associated with waste. Such strategies might include a stained concrete floor (design strategy), advanced wood framing (construction strategy), or carpet tiles (new technology strategy).



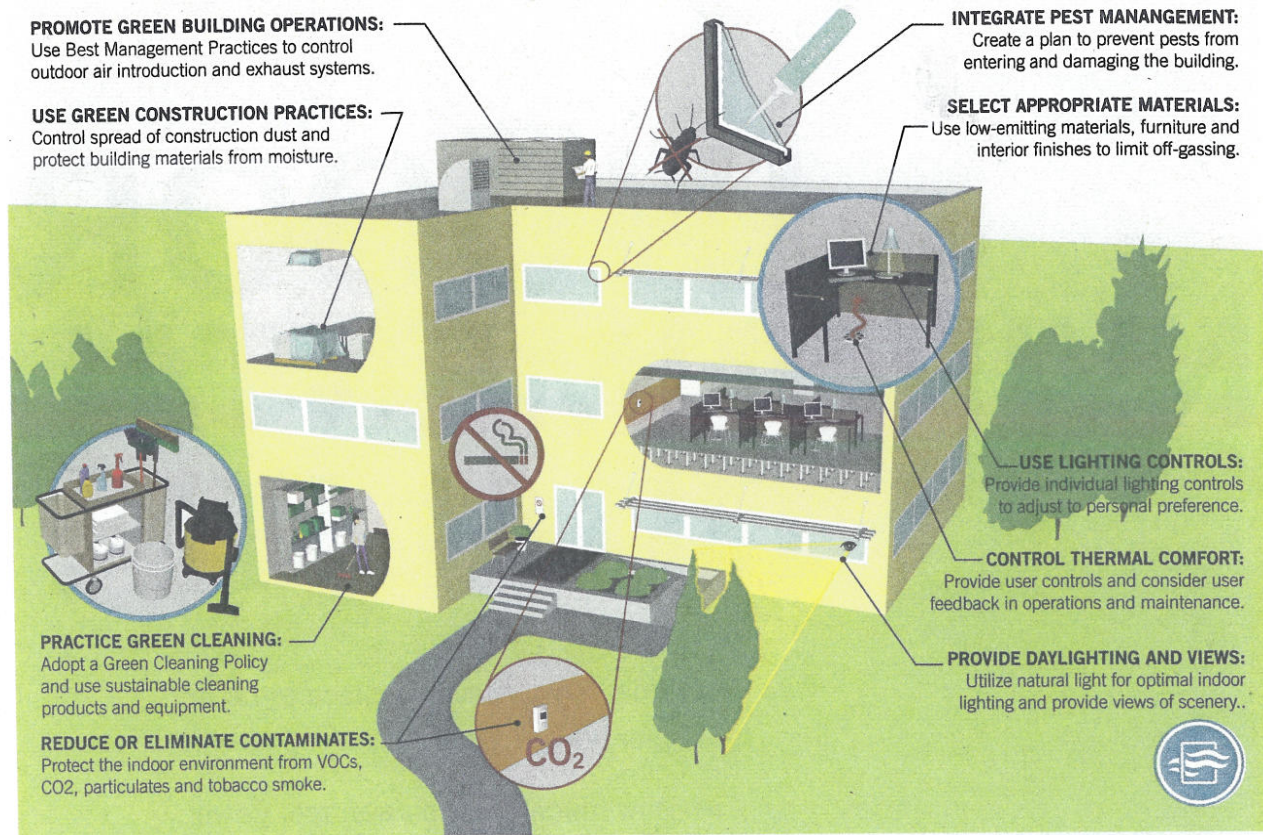
Compost.

One person's waste is another person's meal ... er, another plant's meal. Food and landscaping waste can easily be transformed into mulch for garden beds.



Encourage recycling.

It's pretty basic, but make sure it's as easy for building occupants to recycle as it is for them to throw something away. This means not only dedicating spaces for recycling but educating occupants on what goes where.



INDOOR ENVIRONMENTAL QUALITY OVERVIEW

In this chapter, you've learned about the importance of maintaining high-quality indoor environments by controlling pollutants, introducing daylight and views, and putting some control into the hands of the occupants. Additionally, acoustics and thermal comfort were noted as critical to overall occupant satisfaction.

To summarize, the critical components of the Indoor Environmental Quality section are as follows:

- **Indoor air quality;**
- **Thermal comfort;**
- **Lighting; and**
- **Acoustics.**

Indoor Air Quality

So What?

Most of the air that building occupants breathe is delivered through the building's ventilation system (naturally or mechanically), and the quality of this air can be compromised by contaminants within the building. Indoor air quality is known to affect human health and can directly influence productivity and quality of life.



Photo courtesy of Exelon

Environment: Improving indoor air quality specifically benefits the places where Americans spend most of their time: indoors. Providing ample, but not excessive, ventilation strikes the right balance between energy use and human health. Too much air is wasteful in terms of energy use, and too little air can contribute to poor-quality indoor environments.

Economy: The potential annual savings and productivity gains from improved indoor environmental quality in the United States are estimated as follows¹:

- \$6 billion to \$14 billion from reduced respiratory disease;
- \$1 billion to \$4 billion from reduced allergies and asthma;
- \$10 billion to \$30 billion from reduced sick-building-syndrome symptoms; and
- \$20 billion to \$160 billion from direct improvements in worker performance unrelated to health.

1 IAQ Fact Sheet (Environmental Health, Safety and Quality Management Services for Business and Industry, and Federal, State and Local Government, March 9, 2006).

Community: Locations with high-quality indoor air are desirable places to live, play, and work and are ideal as community gathering spaces. Additionally, improvements to indoor air quality can reduce the incidence of diseases and ailments, directly improving the health of community members.

For schools and schoolchildren, good indoor environmental quality is even more urgent, due to the heightened sensitivity of young people to contaminants.

Strategies

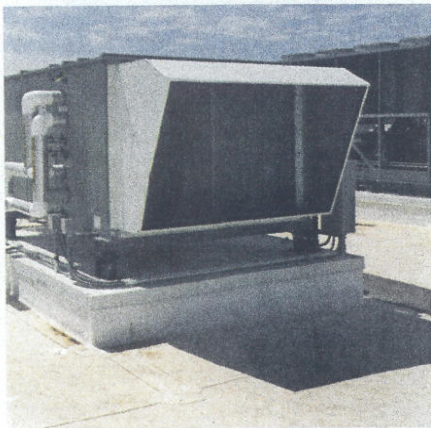
Some strategies that project teams consider in addressing indoor air quality, along with examples of each, are as follows:

Strategies



Prohibit smoking.

The writing is on the wall—smoking causes lung disease, cancer, and heart disease as well as a host of other health problems. Secondhand smoke is no better. Project buildings can prohibit smoking within the building and restrict outdoor smoking to designated areas that won't cause smoke to irritate building occupants.



Ensure adequate ventilation.

We all know how draining it is to sit in a stuffy room. Well, it doesn't have to be stuffy and stale just because you're inside. Mechanical designers should ventilate with ample outdoor air to help ensure that indoor air contaminants are sufficiently diluted within the space.

Strategies



Monitor carbon dioxide.

Monitoring carbon dioxide levels within spaces, especially spaces where the number of people changes, can allow for demand-control ventilation strategies in which the amount of air delivered to the space is controlled based on the needs of the users.



Install high-efficiency air filters.

High-efficiency air filters continually remove contaminants from the air and contribute to cleaner, healthier indoor air.



Specify low-emitting materials.

Low-emitting materials should be used rather than conventional products because of their reduced off-gassing of harmful contaminants.

Photo by Dale Photographic

Use integrated pest management.

Integrated pest management uses strategies that minimize or eliminate the potential for human exposure to pest-control chemicals by prioritizing nonchemical strategies, such as monitoring and baiting, rather than taking a "pesticide first" approach.

Strategies



Protect air quality during construction.

Project teams can implement an indoor air quality management plan during construction to improve the air quality for construction professionals as well as reduce the buildup of dust and other contaminants within the building's HVAC system. Additionally, projects that carefully protect absorptive materials from moisture damage reduce the potential for future mold growth.

Photo by Jennifer L. Owens

Conduct a flush-out.

Once construction is complete, before occupants move into the building, the space can be flushed with large quantities of outside air to remove residual contaminants from construction activities.



Employ a green cleaning program.

Green cleaning policies can greatly reduce the introduction of harmful chemicals during building operation and encourage best practices by custodial staff.

Thermal Comfort, Lighting, and Acoustics

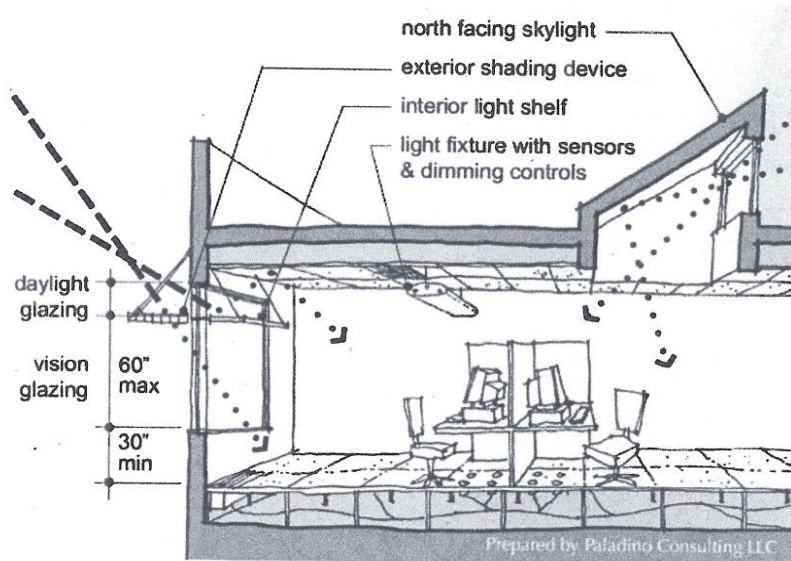
So What?

Providing a high degree of thermal comfort and enabling occupants to play a role in controlling their environmental conditions lead to greater productivity and increased occupant satisfaction. Additionally, spaces that provide ample daylight, access to views, and high-performance acoustics further enhance the user experience.

Environment: Increased controllability fosters a partnership between the occupants and the building, and increases the likelihood that occupants will be advocates for operational practices such as turning off lights when they're not in use. Further, increased access to daylight can reduce the need for electric lighting during daytime hours, thereby decreasing energy use.

Economy: Personnel costs are a significant percentage of operating costs—much greater than energy or maintenance costs—thus, actions that affect employee retention, attendance, and productivity are significant for the bottom line.

Community: Most people prefer to live, work, and play in spaces where they have a degree of control over the indoor environment, are thermally comfortable, have access to daylight and views, and can communicate effectively due to good acoustics. Buildings that provide these comforts, especially if they openly accommodate public gatherings, are ideal as centers for the community they serve.



Strategies

Strategies to increase occupant comfort indoors, along with examples of each, are provided below.

Strategies



Use daylighting.

Projects should be designed to introduce ample natural light into the space while providing glare-control devices to minimize the unwanted effects of unfettered sunlight. Areas that are not regularly occupied should be designed in the core of the building, while spaces such as offices and classrooms should be located along the building perimeter to take advantage of greater access to windows.

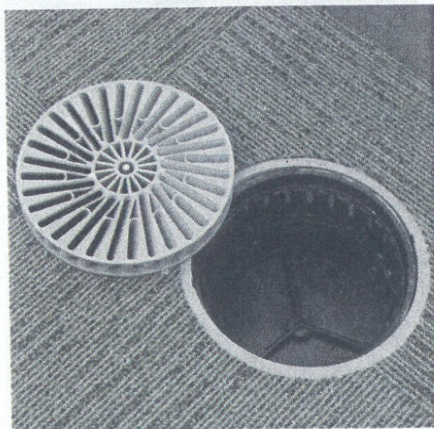
Photo by Eric Laignel



Install operable windows.

There is nothing quite like opening a window to get some fresh air. Operable windows provide occupants control over their environment so that on a mild day they can enjoy a breeze.

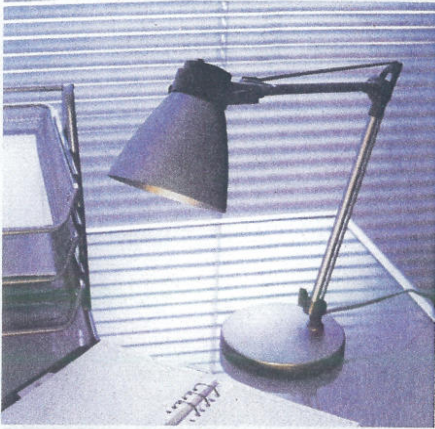
Photo by Anthony Semonti



Give occupants temperature and ventilation control.

Where operable windows are infeasible, occupant control over mechanically supplied heating, ventilation, and air conditioning should be provided.

Strategies



Give occupants lighting control.

Task lighting at individual workstations and group lighting controls for shared spaces should be incorporated into the building to allow occupants to adjust the light levels to suit their needs and preferences. This also enables occupants to actively participate in energy savings by turning off lights when they're not needed.



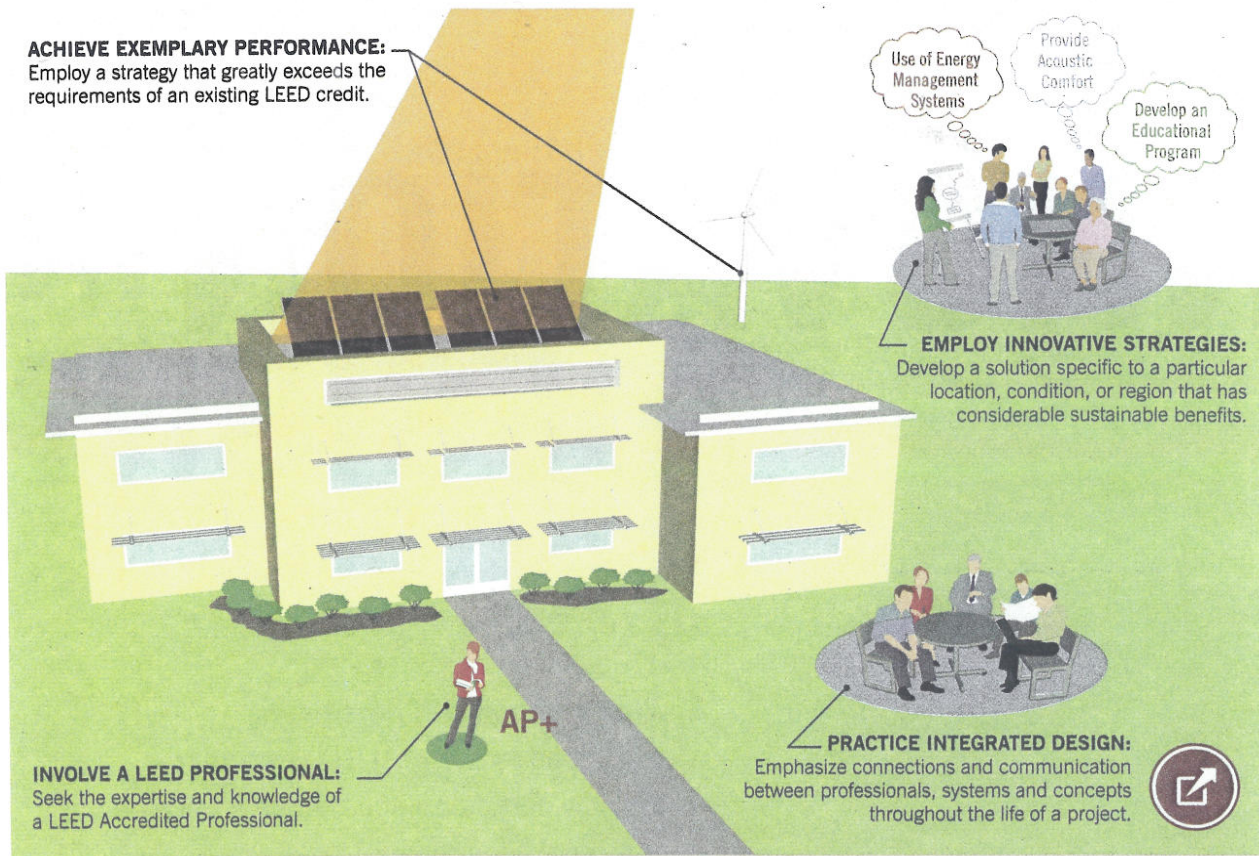
Consider acoustics.

Effective verbal communication is integral to the way we live, work, and learn within buildings. Projects can make use of acoustical finishes, building geometry, duct insulation and other strategies to facilitate this critical component of human interaction.

Photo by Phil Weston

Conduct occupant surveys.

It's amazing how much you can learn just by asking a few questions. Asking occupants about their comfort within the space, and addressing thermal conditions, lighting, acoustics, and other elements contributing to their overall satisfaction, can help identify areas for improvement and foster occupant engagement in the operation of the building.



INNOVATION IN DESIGN OVERVIEW

Now that you've finished reading through all of the LEED categories and green building strategies, hopefully you're excited and thinking about what's next. Green building and sustainable design are all about evolving, learning, and improving. That's exactly why the Innovation in Design category exists—to reward projects that go above and beyond what a credit requires or that incorporate a strategy that's not addressed by any prerequisite or credit.

There are two primary ways to earn an Innovation in Design credit:

- Innovation in Design; and
- Exemplary performance.

Lastly, a project team can earn one point for involving LEED Accredited Professionals in the project.

Innovation in Design

As the building design and construction industry introduces new strategies for sustainable development, opportunities for additional environmental benefits will continue to emerge. Opportunities that are not currently addressed by LEED may include environmental solutions specific to a particular location, condition, or region.

With all sustainable strategies and measures, it is important to consider related environmental impacts. Project teams are encouraged to pursue opportunities that provide benefits of particular significance and should be prepared to demonstrate the environmental benefit of their innovative strategies.



Photo by Jenny Poole

Exemplary Performance

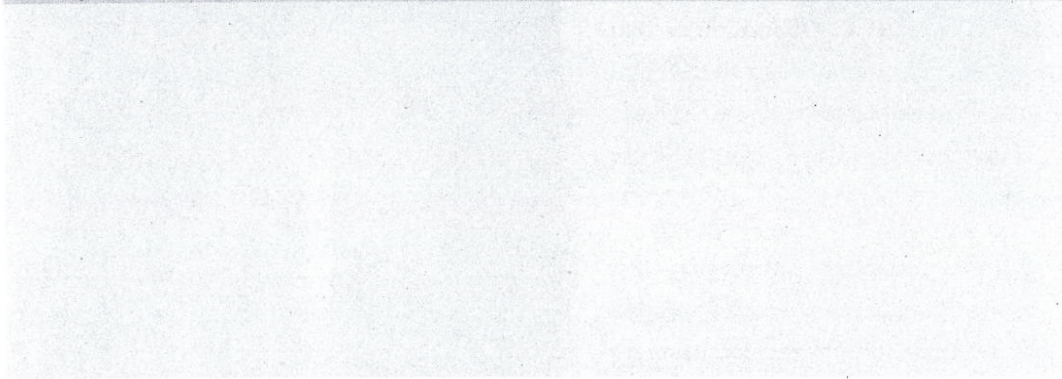
Project teams can earn exemplary performance points by implementing strategies that result in performance that greatly exceeds the level or scope required by an existing LEED prerequisite or credit. Exemplary performance opportunities are noted throughout the LEED reference guides. For example, if a project demonstrates a 45% reduction in potable water use, it is eligible for an Innovation in Design credit.

LEED Accredited Professionals

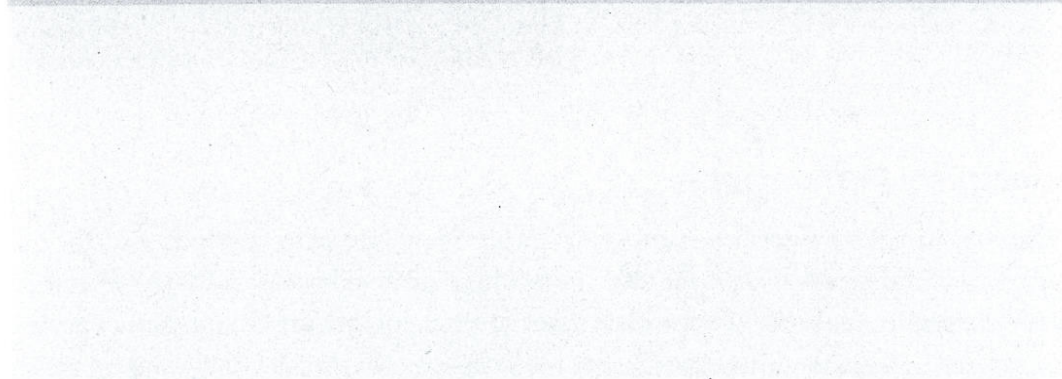
Multidisciplinary expertise in sustainable building principles and operational practices is recognized by the LEED Accredited Professional designation. LEED Accredited Professionals have the knowledge required to integrate sustainability into building operating and upgrade practices. The LEED Accredited Professional understands the importance of considering interactions between the LEED prerequisites and credits and their respective criteria. Building owners, facility managers, engineers, technicians, groundskeepers, purchasing staff, consultants, contractors, and others who have a strong interest in sustainable buildings are all appropriate candidates for accreditation.

ID CATEGORY REVIEW

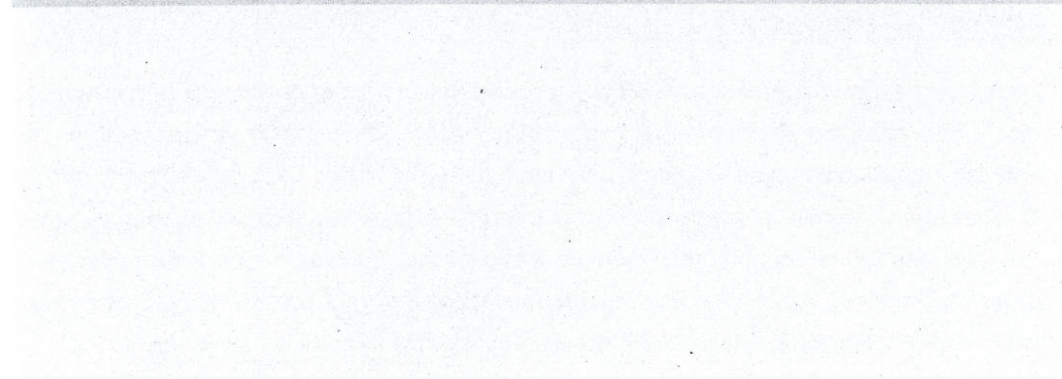
How can involvement of a LEED Accredited Professional enhance a project?



What are some examples of today's innovative building methods that weren't in use five or 10 years ago?



What innovative strategies are on the horizon for five or 10 years from now?



LEARNING ACTIVITIES

THINK ABOUT IT

What strategies that might positively impact building performance aren't included in the current LEED Rating System?

If a project utilized a new technology that allowed them to drastically reduce the amount of materials that went into the construction of a building would it qualify for an Innovation Credit? What type of information would you need to know in order to document the benefits?

FIND OUR MORE

Visit the GBCI website (www.gbci.org) and research what is required to become a LEED Professional. Identify what the expectations are of the LEED Professional within an active LEED project. What role does the LEED Professional play?

INVESTIGATE

Investigate a couple of LEED projects in your area or in the USGBC case studies and identify which ID strategies were used.

PRACTICE QUESTIONS

1. An Innovation in Design credit for exemplary performance would be available for ___?

- a.) Implementing a comprehensive green building education program
- b.) Significantly diverting construction waste beyond the requirement of 75%
- c.) Achieving carbon neutrality
- d.) Providing 75% more spaces with daylighting
- e.) Developing a green housekeeping policy

2. Projects can identify which credits have regional priority by ___?

- a.) Checking the USGBC website
- b.) Researching locally pertinent environmental issues
- c.) Submitting a Credit Interpretation Request (CIR)
- d.) Calculating the net environmental impact

3. An Innovation in Design credit for innovative strategies is likely available for projects that ___?

- a.) Issue a press release to announce their LEED project registration.
- b.) Include two LEED Accredited Professionals on the project team.
- c.) Develop an educational outreach program.
- d.) Plan to enroll the project in LEED for Existing Buildings: Operations and Maintenance.

4. A project team is considering pursuing an Innovation in Design credit for a strategy that will require a large capital expense. The team decides that it will implement the strategy only if the strategy will be eligible for an Innovation in Design credit. What steps should the team take to determine whether its strategy will be eligible for the credit?

- a.) Research existing CIRs to see whether the strategy has been previously addressed.
- b.) Calculate the strategy's overall environmental impact and self-evaluate whether it is significant.
- c.) Draft a compelling narrative for the LEED submittal.
- d.) Check the LEED rating system.

Answer Key on Page 138

PRACTICE QUESTION ANSWER KEY

GREEN BUILDING ANSWERS

1. **b.** According to the U.S. Department of Energy's Energy Information Administration, 38% of all energy used within buildings is used for space heating. Lighting is the second largest user, at 20%.

2. **c.** In a conventional linear design, disciplinary boundaries can lead to inefficient solutions. Integrative design, conversely, brings together owners, operators, architects, engineers, and other stakeholders to identify cross-disciplinary opportunities to improve the environmental performance of building projects.

3. **a.** The conventional bottom line evaluates only economic prosperity. The triple bottom line, in contrast, is a way to evaluate performance relative to overall impact, including the human and environmental effects associated with performance.

4. **b.** Life-cycle assessment is a method used to analyze the environmental aspects and potential impacts associated with a product, process, or service. (LEED Reference Guide for Green Building Operations & Maintenance, 2009 Edition, page 499)

5. **a.** The predesign period of an environmentally responsive design process is the first phase in the development of a project. Bringing professionals together as early as possible in the process decreases the barriers to implementing innovative strategies such as passive thermal comfort and links between the site and the building.

6. **b.** LEED credits are weighted based on their relative importance. Credits that most directly address the most important environmental impacts and human benefits are given the greatest weight.

7. **c.** Life-cycle cost analysis considers the long-term costs of building materials and design strategies.

8. **b & c.** Reducing the flow of water at hand-washing stations results in less water used per minute, thereby decreasing the total water used when washing hands. This in turn results in less hot water use, thereby decreasing the energy used to heat water.

U.S. GREEN BUILDING COUNCIL AND ITS PROGRAMS ANSWERS

1. **d.** GBCI recognizes three tiers of professional accreditation. Green Associate is the first level, followed by LEED AP with a specialty. Beyond LEED AP with a specialty, professionals can achieve the LEED Fellow designation.

2. **d.** USGBC is a nonprofit, member-driven body whose mission is "to transform the way buildings and communities are designed, built, and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life." Its primary responsibilities are to develop and maintain technically robust building certification programs and educational offerings.

3. **a.** LEED for New Construction and Major Renovation addresses buildings, and

although furniture and appliances can be included within the scope of the program, it is not required to do so.

4. **a.** The carbon overlay is used to weight LEED credits based on the carbon footprint impact within a “typical” LEED building. The carbon overlay considers the impact of direct energy use, transportation, and the embodied emissions of water, solid waste, and materials.

5. **a.** Projects must first register with GBCI and pay the registration fee. Then, the LEED submittal documentation is compiled and submitted along with the certification fee. Once the review process is completed for both the design and construction credits, a final point tally (and achievement of all prerequisites) dictates the final LEED rating.

6. **d.** Once construction is complete, the project team can submit its construction phase credits (design phase credits may be submitted earlier). Only once the certification review is complete, and the project achieves the minimum number of points and all prerequisites, is the project certified.

7. **c.** The licensed-professional exemption allows registered professionals to forgo some of the documentation requirements.

8. **a, c, & d.** From the Guidelines for CIR Customers, the three correct answers should be tried before submitting a CIR. While LEED customer service representatives may be able to assist users in determining whether an issue is of appropriate technical complexity to be a CIR, they do

not advise applicants as to whether a CIR is likely to be successful. Likewise, local chapters do not play a role in the CIR process. Finally, only one concise question or a set of related questions may be addressed within a single CIR, so it is not appropriate to include other issues within the same CIR.

SUSTAINABLE SITES ANSWERS

1. **c.** Vehicle miles traveled is a measure of transportation demand that estimates the travel miles associated with a project.

2. **c.** Decreasing impervious surfaces permits an increase in pervious surfaces. Pervious surfaces allow water to infiltrate the ground, thereby reducing stormwater runoff.

3. **d.** Nonpoint source pollution is caused by many sources, such as oil leaks in cars or fertilized landscape plantings, and is exacerbated by impervious hardscapes during heavy rainfall.

4. **a.** The solar reflectance index represents how well a surface rejects solar heat. Using materials with high solar reflectance indexes reduces the trapping of heat in site hardscapes, in turn reducing the heat island effect.

5. **a & d.** Increasing the floor-to-area ratio results in a smaller building footprint, thereby increasing the available site area to use as open space. Additionally, locating parking underground eliminates surface parking, likewise increasing the available site area that can be dedicated to open space.

6. **a & b.** Providing a carpooling incentive increases the percentage of occupants who co-commute, thereby reducing the total vehicle miles traveled. Upgrading the company fleet to hybrids or other low-emitting/fuel-efficient vehicles reduces the transportation impact per mile traveled, further lessening the environmental harm associated with automobile use.

7. **d.** Light trespass is the unwanted spillage of light onto adjacent properties. To minimize its impact on nocturnal environs, light trespass must be controlled.

8. **a.** The Sustainable Building Technical Manual: Part II recommends developing green design criteria before selecting the project site, in order to use the criteria to evaluate potential sites and guide the overall design effort.

WATER EFFICIENCY ANSWERS

1. **b.** Many water-using fixtures follow the Energy Policy Act (EPA) requirements for baseline water use. Other water-using fixtures adhere to standards such as the Universal Plumbing Code (UPC).

2. **a.** Projects that use reclaimed water for process uses reduce their demand on municipally supplied potable water.

3. **a & b.** Submeters and locally adapted plantings both contribute to water use reduction. Submeters ensure that water use can be tracked and leaks or overwatering quickly mitigated. The use of locally adapted plantings allows further reduction, because these plants are suited to the local climate and, once established, can be

sustained with little or no ongoing irrigation.

4. **c.** Blackwater doesn't have a single definition that is accepted nationwide, although in all cases, water containing human waste is considered blackwater.

5. **d & e.** Nonpotable water is, by definition, not suitable for consumption, so although it is often acceptable to use for plant watering and waste transport, it is not usable for drinking, ice making, or bathing.

6. **c.** The Energy Policy Act (EPA) establishes the baseline of 1.6 gallons per flush for all water closets.

7. **b.** Many municipalities supply both potable water (treated for human consumption) and nonpotable water (typically treated, but not to the same standard as potable water). This nonpotable water is often reclaimed from sources such as stormwater.

8. **a & d.** Process water is used for industrial systems such as HVAC, as well as for certain business operations, such as clothes washing and dish washing. Submetering can track consumption and allow for the early identification of inefficiencies or leaks. ENERGY STAR-certified clothes washers have low water factors, thereby ensuring that they use water efficiently.

ENERGY AND ATMOSPHERE ANSWERS

1. **b.** To reduce energy use, project teams should first reduce energy demand, followed by implementing energy efficiency measures such as installing high-performance equipment. Only then should renewable energy systems be considered. Finally, submetering equipment is used to maintain building performance.

2. **d.** Passive design strategies are used to reduce energy consumption by utilizing natural thermal processes (convection, absorption, radiation, and conduction) and sunlight to condition and light spaces.

3. **b.** RECs are tradable environmental commodities representing proof that a unit of electricity was generated from a renewable energy source. RECs are sold separately from the electricity itself.

4. **a.** The Lawrence Berkeley National Laboratory study found that commissioning for existing buildings has a median cost of \$0.27 per square foot and an average simple payback of 0.7 years. For new construction, the study found that the median cost was \$1 per square foot and had a payback of 4.8 years based on energy savings alone.

5. **a & c.** A refrigerant is weighted by its global warming potential and its ozone depletion potential.

6. **b & c.** Energy performance is a primary factor in determining how much energy is used per unit of cooling, thereby influencing the environmental impact of the HVAC

system. Expected life is also a large driver of environmental impact, as systems that last longer need to be replaced less often, thereby decreasing the impacts associated with system replacement over the life of the building.

7. **c.** Process energy is defined as energy used to run office equipment, computers, elevators and escalators, kitchen cooking and refrigeration units, laundry washing and drying units, lighting that is exempt from the lighting power allowance, and miscellaneous items.

8. **b & c.** Renewable energy comes from sources that are not depleted by use. Examples include energy from the sun, wind, and small (low-impact) hydropower, plus geothermal energy and wave and tidal systems.

MATERIALS AND RESOURCES ANSWERS

1. **b.** Rapidly renewable resources, defined by LEED as having a planting/harvest cycle of 10 years or less, are replenished more quickly than conventional materials.

2. **c.** Waste reduction should be the first consideration of a waste management policy, followed by exploring opportunities for reuse. Recycling should then be considered for waste streams that can't be eliminated or repurposed.

3. **c.** The 50 tons sorted off-site are 60% diverted, resulting in 30 tons recycled. The 40 tons separated on-site are 100% diverted, resulting in 40 tons recycled. The

remaining 10 tons are incinerated, resulting in 0 tons recycled. The total recycled is 70 tons, which is 70% of 100 tons.

4. **c.** LEED has established 500 miles as the threshold for a regionally sourced material.

5. **b.** The EPA estimated greenhouse gas emissions from waste materials and found that the United States currently recycles approximately 32% of its solid waste. Even a small increase in the overall recycling percentage could have enormous environmental benefits.

6. **b.** Postconsumer recycled content comes from consumer waste, contrasted with preconsumer recycled content, which comes from manufacturing processes.

7. **c.** Ongoing consumables are goods with a low cost per unit that are regularly used and replaced in the course of business (for example, paper, batteries, and soap).

8. **a, b, & d.** LEED addresses many environmental attributes of building materials, including their recycled content, regional harvest and manufacture, and reuse. LEED doesn't currently recognize materials based on their nation of origin or potential customizability.

INDOOR ENVIRONMENTAL QUALITY ANSWERS

1. **c.** The EPA estimates that Americans spend 90% of their time indoors, where concentrations of harmful contaminants may be dangerously high.

2. **a.** ASHRAE Standard 55 defines the environmental factors of thermal comfort as humidity, air speed, and temperature (air temperature and radiant temperature).

3. **a.** Volatile organic compounds (VOCs) are volatile at room temperature. Many of them are harmful to humans.

4. **f.** Delivering high volumes of outside air into the building interior dilutes indoor air contaminants, thereby improving indoor air quality.

5. **b & d.** Studies show that improved daylight in classrooms increases student learning, with one study showing 20% faster progression in math and 26% faster progression in reading. High-performance acoustics foster effective teacher-student and student-student communication.

6. **b.** Operable windows allow occupants to make adjustments to the air speed and temperature within the building, thereby controlling multiple environmental conditions for thermal comfort.

7. **c.** Demand-controlled ventilation modulates the delivery of outdoor air into the building based on occupancy. In many cases, outdoor airflow is increased when the building automation system detects increased carbon dioxide concentrations.

8. **b & c.** Smoking near building entrances or near building air intakes allows infiltration of environmental tobacco smoke into the building interior, thereby exposing occupants to harmful airborne chemicals.