Guidelines for Sustainable Building Designs And Understanding Moisture Management

Guidelines used for Developing AIA/CES Sustainable Design & HSW Courses

THIS DOCUMENT HAS BEEN PREPARED BY VAPROSHIELD BASED ON INFORMATION OBTAINED FROM THE AMERICAN INSTITUTE OF ARCHITECTURES WEBSITE. VAPROSIELD TECHNICAL SEMINARS WERE DEVELPOED TO PROVIDE EDUCATIONAL INFORMATION ON THE BUILDING SCIENCE BEHIND COST EFFECTIVE DESIGN SOLUTIONS TO MANAGEMENT THE MOVEMENT OF AIR AND MOSITURE FOR THE BUILDING ENCLOSURE.

Sustainable Design Intent and Innovation
Sustainable design is an inherent aspect of design excellence. Projects should express sustainable design concepts and intentions, and take advantage of innovative programming opportunities.

Sustainability has been a focus of architecture practice for more than 30 years, and the AIA has provided resources and tools to assist its members in better serving their clients and communities through environmentally responsible projects. The AIA Board of Directors recognized the need to again help prepare their colleagues and fellow practitioners respond to the latest challenge and opportunity facing the profession. The issue of climate change and the impact of buildings on carbon emissions created a new expectation among clients and the public to look to the expertise of architects for solutions that can help them leave a greener footprint. The AIA is responding to this growing demand for our members to assume greater leadership in addressing the challenges facing our planet.

Energy Flows and Energy Futures
Sustainable design conserves energy and resources and reduces the carbon footprint while improving building performance and comfort. Sustainable design anticipates future energy sources and needs.

Energy Flows and Energy Futures addresses:

- How the building design reduces energy loads for heating, cooling, lighting, and water heating
- How the design and integration of building systems contributes to energy conservation and reduced use of fossil fuels, reduces green house gas emissions and other pollution, and improves building performance and comfort
- Techniques for systems integration, use of controls and technologies, efficient lighting strategies
- Use of on-site renewable and alternative energy systems
- Anticipation of future and carbon neutral fuel sources
- Strategies to reduce peak electrical demand
- How the building or parts of the building provide "passive survivability": the ability to function in the event of power outages or interruptions in fuel supply.

Materials and Construction
Sustainable design includes the informed selection of materials and products to reduce product-cycle environmental impacts, improve performance, and optimize occupant health and comfort.

Materials and Construction addresses:

- Efforts to reduce the amount of material used on the project
- Materials selection criteria, considerations, and constraints, such as optimizing health, durability, maintenance, and energy use, and/or reducing the impacts of extraction, manufacturing, and transportation
- How the building enclosure will perform in relationship to air, moisture, water and thermal characteristics
- Consideration given to impacts on the environment over the full life cycle and the results of life cycle assessment if available
- Description of any "green lease" program
- Construction waste reduction plans and any strategies to promote recycling during occupancy

Long Life / Loose Fit
Sustainable design seeks to enhance and increase ecological, social, and economic values over time.

Long Life / Loose Fit addresses:

- How the project was designed to promote long-term flexibility and adaptability
- Anticipated service life of the project, and description of any components designed for disassembly

- Materials, systems, and design solutions developed to enhance versatility, durability, and adaptive reuse potential

Collective Wisdom and Feedback Loops
Sustainable design strategies and best practices evolve over time through documented performance and shared knowledge of lessons learned.

Collective Wisdom and Feedback Loops addresses:
- How you modeled and evaluated the design during the programming and design phases
- How you evaluated the performance of the built results
- Collaborative efforts between the design team, consultants, client, and community
- How the process enhanced the performance and success of the building
- Lessons learned during the design, construction, and occupation of the building
- How these lessons would change your approach to this project if starting over, or to future projects
- Commissioning and any on-going monitoring of building performance and occupant satisfaction.

Cavity Walls for Insulating Airspace

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.

Definition

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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 rain screen 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.
- 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.

Use / Application

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.
- 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.

Codes, Regulations and Incentives

Regulation of the built environment takes many forms in order to achieve many ends. However all aspects of the planning, design and construction of the built environment have environmental consequences. The future of building, zoning, plumbing, mechanical, electrical, and other codes as well as local and federal regulations governing development and redevelopment are likely to revolve around the goal of sustainability. Proactively seeking this outcome through the development of codes and regulations that minimize detrimental environmental consequences is a significant strategy with an enormous potential impact on the emission of greenhouse gases, as well as habitat preservation, protection of the water cycle, and quality of life.

Definition

Codes and Standards
Codes regulate the way specific aspects of the development and construction processes occur, whether the aspect is land use (zoning codes), construction materials (building codes), energy use (energy conservation codes), ventilation rates (mechanical codes), or waste water recycling (plumbing codes). Codes are typically adopted at the state level

and enforced at the municipal level. While locally written codes continue to be used the trend is towards the adoption of nationally developed model codes. Codes are intended to require minimum levels of life-safety, and national code development attempts to involve all stakeholders (building, fire and other code officials, designers, builders and industry) in a process that strives for openness and balance. The adopting jurisdiction may amend a code either to achieve a higher level of life-safety or performance, or to bring the code into alignment with applicable laws and regulations. Environmental impacts are currently only explicit in the requirements of energy conservation, and, to a lesser extent, zoning codes. However all codes have environmental impacts and can be used to prioritize and minimize these impacts. Standards are detailed descriptions of the design of systems that do not typically contain scoping or administrative provisions. Standards are referenced in the appropriate codes and are not subject to amendment or modification by local bodies.

Regulations

Regulations can impose additional requirements on the design and construction processes, and are likely to be developed through different methods and enforced by different parties. Regulations can dictate transportation policy, environmental impact requirements, emissions standards, wetlands conservation, and a host of other environmental policies. Because regulations are developed at a closer proximity to the legislative process they are typically the preferred approach taken by lawmakers, who are remote from and generally unfamiliar with the code adoption process. A regulation is likely to be enforced by a specific agency, whether local or state, with jurisdiction over the matter in question, whereas zoning, building, plumbing and access codes tend to all fall under the jurisdiction of the local building department. Sorting out jurisdiction, coordinating enforcement, and avoiding conflict are all critical to the success of regulations that may overlap or coincide with applicable codes and standards.

Use / Application

It is the legal responsibility of the licensed design professional to adhere to all applicable codes, regulations and standards. As a result the design profession has come to view itself as a consumer of codes. However architects are in a position to document and communicate the environmental impacts of code requirements, positive and negative, to the adopting jurisdiction and national code development process. Architects also have the knowledge and motives to advocate for codes and regulations that implement the most effective strategies for reducing carbon emissions and achieving other environmental goals. Each of the 50 strategies can benefit from codes and regulations that encourage their use. For instance, as described under "Alternative Energy", "local and national policies should be enacted that encourage geothermal development", and, under "Building Orientation", "in urban settings orientation may be strongly determined by local regulation, view easements, and urban design regulations". The impact of continuous commissioning on building energy consumption provides a strong argument for a code requirement in this area. However advocating for codes and regulations that embody the values of sustainability is only one way that architects can employ these requirements to reduce carbon emissions. A more immediate approach is to proactively utilize existing requirements for sustainable ends. Energy conservation codes are increasingly incorporating performance-based approaches that allow the designer to exercise a high degree of creativity in achieving code compliance. A performance-based design amenable to innovation can employ many of the strategies described in 50/50. Also, as described in the "Appropriate Size and Growth" strategy, promoting density through maximum build-out of the allowed zoning envelope results in numerous environmental benefits. Approaching each design decision with a thorough analysis of both code requirements and environmental impacts can reveal surprising opportunities.

Established Techniques

<u>Zoning Code</u>

Initially intended to direct development, control density and segregate uses, zoning codes have evolved to promote mixed-uses, and can be powerful tools in the development of sustainable communities.

<u>Building Code</u>

While intended to establish minimum standards for life-safety in building design and construction, building codes also have significant environmental impacts. Recognition of these impacts is growing and building codes will inevitably evolve towards sustainable goals in response to this recognition.

<u>Energy Conservation Code</u>

Energy conservation requirements were first introduced into the building code in the 1970's in response to the first energy crisis brought on by the oil embargo. These requirements, governing the thermal resistance of the building envelope and energy consumption by building systems, have evolved to form a separate code.

<u>Plumbing Code</u>

Although the connection to greehouse gas emissions is less direct than with other codes, plumbing codes provide an important area of regulation with sustainable consequences. Alignment of plumbing code requirements with sustainability goals will contribute to resource conservation and reduction of carbon emissions.

Mechanical Code
HVAC equipment, installation and operation, regulated by mechanical codes, are major contributors to energy consumption in buildings. Mechanical codes can evolve towards greater utilization of computer modeling and more sophisticated understanding of air movement and user comfort.

Sustainability Codes, Regulations and Standards
As public awareness of the impact of building construction and operation on environmental quality and integrity increases the demand for requirements tailored to the goals of sustainability grows. Several codes and standards have been recently introduced or are under development. This is an area of building regulation that is in its infancy and will experience rapid growth in scope and influence in the near future.

Emerging Trends

ICC Smart Codes
Automated code compliance checking for code compliance intended to facilitate enhanced communication, knowledge and collaboration and more timely design acceptance and approval.

Computer Modeling The complex variables impacting energy performance in the built environment are increasingly best explored through the use of computer modeling. Various tools can explore building form, daylighting, thermal loss, ventilation and air movement, artificial lighting, projected energy use, and embodied energy while integrating the design processes of all design disciplines.

Green Codes
The emergence of codes specifically targeting the goals of sustainability represents a new era in code development. Green codes typically combine areas of jurisdiction from zoning, building, energy conservation, plumbing, and mechanical codes to provide a comprehensive set of regulations for all aspects of the design and construction process.

Smart Growth Zoning
Cutting edge land-use policy is generally described under the title of "Smart Growth". Goals include the creation of walkable communities, construction of a range of housing opportunities and choices, creation of communities with a strong sense of place, mixed land use, preservation of environmental resources whether environmental, aesthetic, or historic, and provision of a variety of transportation choices.

Municipal Regulations
Municipalities have only begun to experiment with local regulations, by-laws, and ordinances as tools for promoting sustainable development. Washington, D.C., Boston, MA, and Salt Lake City, Utah are among many major cities that have adopted or are adopting sustainable requirements that may tie in with existing zoning or other regulations. The actual environmental and economic impacts of these regulations should be assessed carefully in order to guide future developments

Commissioning

Commissioning is a preparatory process whereby a building is readied for operation. This includes 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.

Definition

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Systems commissioning refers to:

- HVAC systems and associated controls
- Lighting and daylighting controls
- Domestic hot water systems
- Renewable energy systems

Total building commissioning (TBCx) includes mechanical systems, the building envelope, plumbing, and life safety systems. 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. 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.

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 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.

Use / Application

Commissioning can take place during design, construction, and post occupancy.

Established Techniques

Design Phase Activities for Both Fundamental and Enhanced 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 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 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.

Total building commissioning recognizes and measures interrelationships between individual building components and systems that affect overall performance, occupant satisfaction, and cost.

The additional work associated with enhanced commissioning tends to result in a 15 percent first-cost premium compared with fundamental commissioning. The owner should be encouraged to assess the life-cycle implications of enhanced commissioning as part of the decision-making process.

After Commissioning

Periodic re-commissioning is a process intended to ensure persistent energy savings over the life of a building by reapplying previously conducted commissioning tests. Re-commissioning 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 re-commissioning activities. The California Commissioning Guide outlines the following other indicators that can be used to assess when re-commissioning 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.

Use an Integrated Approach

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
- Specify energy-efficient equipment and technologies
- Use renewable strategies and purchase green power

- Educate building owners, operators, and occupants

Cost 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.

Integrated Project Delivery

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

Definition

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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 by are prioritized, optimized, and balanced through an integrated project delivery process.

Integrated Project Delivery utilizes an Integrated Design Approach in an Integrated Team Process in order to achieve high-performance buildings.

Use / Application

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 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 and so 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 upon 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 from being "value engineered" out later in the project.

Examples of the Integrated Process for Energy Conservation

- The investigation to use 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 facades 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 to variations of swing days and seasons. It has been demonstrated that occupants have tolerance for greater thermal comfort range under natural ventilation conditions with adequate air movement as compared to total air conditioning. If all parties can come together, significant savings in operating cost and energy usage can result - on initial cost of HVAC equipment, on operating cost for cooling, on reduction of potable water for cooling towers, and on overall energy use.
- Optimize daylighting with proper building orientation, shading, and glare control. Along with daylighing, 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 building can be all shapes, sizes, budgets, building types, and functions; and 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 decisions, and ensuring that all important and complex issues are addressed and explored.

The integrated project delivery process draws from the knowledge pool of all the 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, the mechanical and electrical systems, the controls, etc. Total building commissioning helps ensure the agreed upon design intent is fulfilled – 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 to make unforeseen design changes in later phases of the design process, thus 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 BIM 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.

Use an Integrated Approach

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 with buy-in from building stakeholders.
  - By better coordinating various building systems and design decisions.
  - By incorporating 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 utilize 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 a 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.
  - On function and initial/long term cost effectiveness of available energy efficiency design methods and technology.

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.

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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 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.

ASSEMBLY	PER EMBODIED ENERGY MJ/M^2
WALLS	
Timber frame, timber weatherboard, plasterboard lining	188
Timber frame, claybrick veneer, plasterboard lining	561
Timber frame, aluminium weatherboard, plasterboard lining	403
Steel frame, claybrick veneer, plasterboard lining	604
Double claybrick, plasterboard lined	906
Cement stabilized rammed earth	376
FLOORS	
Elevated timber floor	293
110 mm concrete slab on ground	645
200 mm precast concrete T beam/infill	644
ROOFS	
Timber frame, concrete tile, plasterboard ceiling	251
Timber frame, terracotta tile, plasterboard ceiling	271
Timber frame, steel sheet, plasterboard ceiling	330

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.

Use / Application

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.

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

Use an Integrated Approach

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
  - 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 high-performance energy-efficient windows and glazing
  - 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

Materials and Assemblages

When building or renovating residential and commercial buildings, the choice of materials and how they are assembled 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 and assemblage techniques.

Definition

When building or renovating residential and commercial buildings, the choice of materials and how they are assembled 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 and assemblage techniques. When selecting materials and their assemblage 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?
- Is the assemblage and construction sequencing efficient and effective?
- Does the construction allow for ease of dis-assemblage and material re-use?

Use / Application

The selection of building materials greatly and how they are assembled 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.

Emerging Trends

Advanced Building Materials
Many types of new and environmentally friendly building materials and products are now available. In addition, new methods and techniques for improved and more efficient assembly processes are emerging; These include products for insulation, load-bearing systems, and 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, and designing for disassembly and re-assembly is an important consideration. 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.

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, and those that are manufactured locally.

Use an Integrated Approach

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- 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 support the reduction of the overall energy use of the building over its lifecycle.
- Specify energy efficient equipment and technologies
  - Specifying low embodied energy materials along with energy efficient equipment for a building will further reduce energy usage and overall emissions of the structure.
- 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 lifecycle 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

Preservation/Reuse of Existing Facilities

Preservation is the saving from destruction or deterioration of 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.

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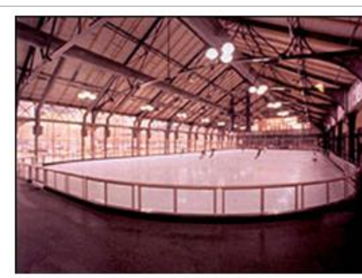
The seminal book about how cities really function by Jane Jacobs, *The Death and Life of Great American Cities*, in 1961, and newspaper columns by Ada Louise Huxtable, former architecture critic of the New York Times, slowly raised national consciousness of the need for preservation of our older urban 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 is inherently sustainable. Although potential for conflict can arise between these two objectives, they are sympathetic on many levels:

- Reuses existing materials and infrastructure, and conserves the energy and resources need for demolition and total replacement.
- Reduces the amount of demolition and construction waste going to landfills.
- Preserves the historic character of older communities, towns and cities, and provides an historical context for new buildings and sustainability technologies.
- Preserves the embedded energy in an existing building which can be 30% of the embedded energy of maintenance and operations for the entire life of the building.
- Older buildings were traditionally designed to respond to climate



Indoor ice arena: Audrey Tepper (Courtesy of National Park Service) and site and to provide daylight and natural ventilation, qualities that can now supplement new sustainable design strategies at far lower cost than to create them from scratch, and to do so without compromising unique historic character.

- When existing buildings are effectively restored, reused, and combined with modern technologies and materials, they can bring about substantial energy savings.

Preservation is also sustainable beyond the level of physical development, and sustains us 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, helps stimulate local community revitalization and viability of existing buildings and neighborhoods.
- Cultural – helps to conserve local cultural resources and make them available for the education of future generations.

LEED® Silver Rated Balfour-Guthrie Building, Portland Oregon

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 invested. Under the Economic Recovery Act of 1981 [36 CFR Part 67] the U. S. Department of the Interior published the *Standards for Rehabilitation,* form 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 measure 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 ten 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.

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, 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 creates 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 (http://www.nps.gov/history/hps/tps/standards_guidelines.htm)

Use / Application

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 non-surviving portions of a property for interpretive purposes.
- Additional Standards and Guidelines for the Treatment of Cultural Resources - landscapes, archaeological and maritime resources, etc. are maintained by the National Park Service.

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)

While 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 if 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.

This former rail station depot was converted to a hotel with reception areas.

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 to 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 mind-set

prescribes forethought and respect for historic materials. For example, design systems efficiently enough to fit into existing openings or be accessible off site.

- Life-Cycle Benefit: Long-term preservation emphasizes life-cycle benefits of reusing historic properties and planning for changing needs. 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, of 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;

Use an Integrated Approach

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- 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
  - On functional and energy savings advantages of historically appropriate and sympathetic technologies

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 that are at risk for condensation. Since 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.

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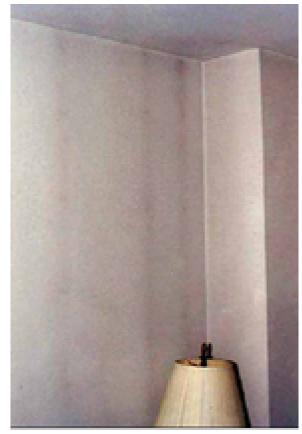
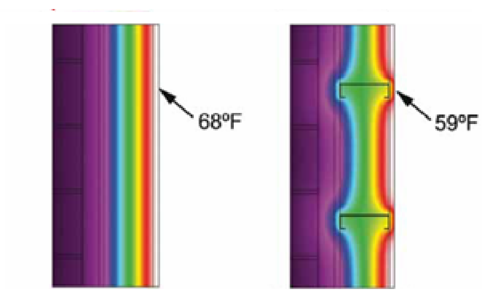
According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1, a 3.5” steel stud wall system with R-13 fiberglass batt, ½” interior gypsum board, and ½”exterior gypsum board will only have a whole wall R-value of R-8. Even though the steel studs make up a relatively small fraction of the wall area (16” on-center), thermal bridging through these members greatly reduces the effectiveness of the fiberglass insulation. The images below illustrate computer simulations of the heat flow though this type of wall assembly with and without the steel studs using THERM modeling software. In addition to condensation, cold spots due to thermal bridging can result in particle deposition such as the “ghosting” depicted in the picture below.



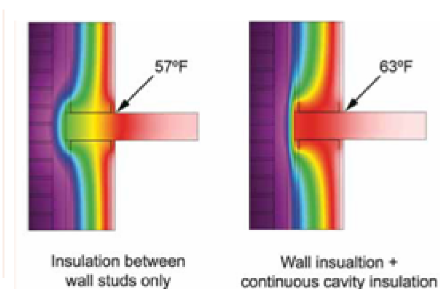
Particle Deposition due to Thermal Bridging

Thermal bridging is also commonly found at the following locations:

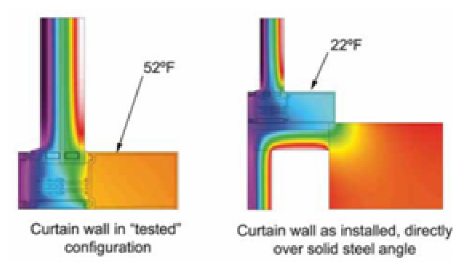
- At the edge of un-insulated concrete floor planks that penetrate wall insulation (including slab on grade).
- In curtain walls at locations where walls are fastened to the building (see figure below).
- Throughout metal buildings.



Thermal Bridging through Light Gauge Steel Studs



Thermal Bridging at Floor Plank



Thermal Bridging at Curtain Wall Connection

Use / Application

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 therefore completely cover either the inside or outside of concrete or steel building members. The images 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” mineral wool addresses thermal bridging due to steel studs, this insulation is interrupted by the concrete plank and therefore does not address thermal bridging at the floor plank edge.

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 (LBNL) 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 geometries from CAD. In addition, the software includes a built-in material library with the thermal properties of many common building components.

1" Mineral Wool (picture taken prior to steel stud installation)

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.

Use an Integrated Approach

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- 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 which 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 (versus simply "R-13" fiberglass batt) is critical

Windows and Openings

A more general question might be: What is Fenestration? There is some confusion about the meaning of the word *fenestration* 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 opening in a building envelope, such as windows, doors, skylights, curtain walls, etc., designed to permit the passage of air, light, vehicles, or people..

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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 of poor window design and construction are thermal discomfort due to unwanted heat loss or gain, drafts, glare, acoustical intrusion, and condensation on interior finishes.

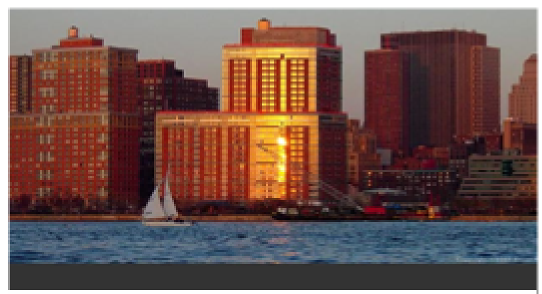
In recent years windows and glazing have undergone tremendous technological changes. Highly energy-efficient windows and glazing systems are now available with wide choices of architectural treatments; glazing coatings and films; double and triple layers of glass; double skin curtain wall façade technology; 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 / Application

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 the component systems that come together at the windows and wall openings must include consideration of continuity of vapor/water/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 all 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/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, since 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.



The Solaire, Battery Park City, NY

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 visible transmittance 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[1] - Air Leakage (AL) is indicated by an air leakage 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.
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. While 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.

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 highest insulating and visible transmittance values.

Coatings and films are used to enhance performance and visual qualities of windows. Glass coatings may be reflective and/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 as regional environmental conditions were able to be overcome by mechanical and electrical systems.

The use of sustainability and energy conservation as a means of design expression has always been around, but was 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 sub-categories; 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, trellises
- overhangs
- grille-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 facades 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/non-combustible frame materials
- durability and life-cycle performance
- ease of maintenance
- use of recycled materials, and
- distance to manufacturing site

Established Techniques

- Design and specify windows to enable LEED® certification, specifically for credits EQ cr 2 for natural ventilation, and EQ cr 8.1 & 8.2 for Daylight & Views.
- Specify windows that are ENERGY STAR certified.
- Utilize 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/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, and the ability to withstand damage from large and small projectiles. Government agencies and some private clients now require U.S. Department of Defense (DoD)-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 presently advancing at a rapid rate, and there is no evidence this trend will abate, resulting in more exciting product developments from industry.
- Thermal adjusted windows and curtain walls using electrical heating elements. The savings on HVAC load gained from reduced difference between outside and inside temperatures on the glass is supposed to offset the additional electricity use.

Use an Integrated Approach

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 use of high-efficiency windows and proper design of window openings will result in reduced solar load and air/water infiltration, and thus 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 (ECM's). 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
  - NA

- 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.

HEALTH, SAFETY & WELFARE

The following is a compilation of HSW subject areas as defined by the various state licensing boards with HSW requirements. (An individual state may not accept all subject areas. Be sure to check your state licensing board's HSW definition and requirements.)

Accessibility
Acoustics
Building design
Code of ethics
Construction administration
Construction contract laws, legal aspects
Construction documents, services
Construction functions, materials, methods, and systems
Energy efficiency
Environmental: asbestos, lead-based paint, toxic emissions
Environmental analysis and issues of building materials and systems
Fire: building fire codes—flame spread, smoke contribution, explosives
Fire safety systems: detection and alarm standards
Insurance to protect the owners of property and injured parties
Interior design
Laws and regulations governing the practice of architecture
Life safety codes
Materials and systems: roofing/waterproofing, wall systems, etc.
Material use, function, and features
Mechanical, plumbing, electrical: system concepts, materials, and methods
Natural hazards (earthquake, hurricane, flood) related to building design
Preservation, renovation, restoration, and adaptive reuse
Security of buildings, design
Site and soils analysis
Site design
Specification writing
Structural issues
Surveying methods, techniques
Sustainable design

HSW: Further Details about Qualifying Subjects

The AIA definition for health, safety, and welfare (HSW) is based on the Architect Registration Examination (ARE). The accompanying excerpt from the Architectural Design Portable Handbook,* by Andy Pressman, AIA, provides more detailed information about subject matter that can be used to earn HSW credit:

*Reprinted with permission from Stephen Schreiber, AIA, "The Architect Registration Examination" in Andy Pressman, NCARB, AIA, Architectural Design Portable Handbook: A Guide to Excellent Practices (McGraw-Hill, 2001), pp. 515-20.

The Architect Registration Examination and it's Ties to HSW Definition

Stephen Schreiber, AIA

The Architect Registration Examination is designed to determine whether applicants for architectural licensure posses' sufficient knowledge, skills, and abilities to provide professional services while protecting the health, safety, and welfare (HSW) of the general public. An understanding of HSW is a focus of the ARE. The following is information useful for ARE students, that may also be useful for those trying for a better understanding of HSW.

The **Pre-design division** focuses on environmental analysis, architectural programming, and architectural practice, including:

Evaluation of existing structures
Impact of sociological influences on site selection and land use

Effect of physiographic and climatic conditions on land use
Ability to develop construction cost estimates and budgets
Development of design objectives and constraints for a project
Effect of human behavior, history, and theory on the built environment
Interpretation of land surveys and legal restrictions
Principles of practice, including office management
Consultant coordination

The **General Structures** division covers structural systems and long-span design, including:

Basic structural analysis and design
Selection of appropriate structural components and systems
Calculation of loads on buildings
Incorporation of building code requirements
Identification and selection of various structural connections
Analysis of soils reports

The **Lateral Forces** division concentrates on effects of lateral forces on the design of buildings, including:

General concepts of lateral loads
Identification and calculation of wind loads and seismic loads
Incorporation of code requirements
Requirements for non-structured building components related to lateral forces

The **Mechanical/Electrical Systems** division addresses mechanical, plumbing, electrical, and acoustical systems (and their incorporation into building design), including:

Incorporation of code requirements
Evaluation, selection, design, and incorporation of appropriate plumbing, HVAC, electrical, and sound control systems
Determination of heating and cooling loads
Selection of building envelope elements
Evaluation of costs of mechanical and electrical systems

The **Materials and Methods** division addresses the evaluation and selection of materials and methods of installation and the development of building details, including:

Evaluation of site conditions
Incorporation of environmental and cultural issues
Identification and ability to detail concrete, masonry, wood, structural metal, and miscellaneous metal construction
Analysis, selection, and ability to detail moisture and thermal protection systems, door and window systems, finish materials, specialties, and conveying systems
Evaluation of costs of systems
Incorporation of code requirements

The **Construction Documents and Services** division covers the conduct of architectural practice, including:

Preparation and review of working drawings and specifications
Coordination of contract documents
Preparation of bidding instruments
Evaluation of substitutions and preparation of cost estimates
Interpretation of general conditions
Review of standard agreements
Observation of the progress of work and material testing
Preparation and review of documents for change orders, progress payments, and project closeout

The **Site Planning** division focuses on the relationship between site use and environment; the consideration of topography, vegetation, climate geography, and law on site development; and the synthesis of programmatic and environmental requirements. Six vignettes test the candidate's understanding of specific areas:

Site design—general site planning principles
Site zoning—cross-sectional building area limitations imposed by zoning and other setback requirements
Site parking—requirements and limitations that influence the design of parking areas and driveways

Site analysis—requirements and limitations that influence subdivisions of land and delineation of building limit areas
Site section—influence of site design requirements on sections
Site grading—understanding of requirements affecting topographic changes

The **Building Planning** division covers the synthesis of programmatic and environmental issues into coherent designs through the process of schematic design. Three vignettes test the candidate's understanding of specific areas:

Block diagram—development of a diagrammatic floor plan from a bubble diagram
Interior layout—principles of design and accessibility that govern interior space planning
Schematic design—understanding of the planning process involved in schematic design

The **Building Technology** division also concentrates on the synthesis of programmatic and environmental issues into coherent designs at the design development level. The six vignettes test candidate's understanding of specific areas:

Building section—impact of structural, mechanical, and lighting components on the vertical form of buildings
Structural layout—basic structural framing concepts through development of a framing plan for a simple building
Accessibility/ramp—accessibility requirements related to ramp and stair design
Mechanical/electrical plan—integration of mechanical, lighting, and ceiling systems with structural and other building components
Stair design—the three-dimensional nature of stair design and code issues
Roof plan—basic concepts related to roof design through the development of a roof plan for a small structure.