HIGH PERFORMANCE DESIGN GUIDE

TO ENERGY-EFFICIENT COMMERCIAL BUILDINGS

VERMONT & THE NORTHEAST REGION

KELLY A. KARMEL, AIA
What you’ll learn

The High Performance Design Guide is a tool to help architects, designers and building owners create better performing, more energy-efficient commercial buildings in Vermont and the Northeast region. Organized by design phases rather than by system, the guide makes it easy to integrate performance goals into the design process. You’ll learn to:

► Integrate energy efficiency into the design process: The best results come from setting energy efficiency goals before conceptual design begins, rather than later in the design process.

► Manage the high performance design process: Educating the client, selecting the right consultants, promoting teamwork, assessing fee and schedule impacts and designing creatively are all critical to the success of high performance design projects.

► Take advantage of daylight in building design: Natural light improves aesthetics, energy efficiency and occupant productivity. Establishing daylighting as a design priority also profoundly affects building orientation, plan, form, exterior expression and material selection.

► Improve electric lighting effectiveness: Electric lighting accounts for as much as 50% of commercial building energy costs. Improving lighting effectiveness requires setting task-specific goals, incorporating daylight and controls, selecting more efficient fixtures, and choosing colors and surfaces that help diffuse and reflect light.

► Increase the efficiency of existing buildings: Energy-efficient renovations have excellent paybacks and can reduce energy use by as much as 50%.

► Protect the environment: High performance design reduces global warming and ozone depletion, reduces reliance on fossil fuels, incorporates renewable energy systems, reduces indoor and outdoor pollution and reduces damage to the natural environment.
Concerns about energy costs, environmental damage and depletion of non-renewable resources have increased the pressure to design and build more efficiently without losing comfort or quality. The guide was created because:

- **Buildings are major energy users:** The energy needed to light, heat, cool and ventilate buildings in the United States uses 38% of the total national energy production and nearly 60% of electricity production. Most of this energy comes from fossil fuel combustion, which in turn contributes to greenhouse gas emissions and global warming.

- **Architects can make a difference:** Simple steps taken during the design process can yield buildings that use **20 to 50% less energy**. High performance buildings cost much less to operate and maintain. They benefit the client, the occupants of the building, the environment and the economy.

- **The regional climate is challenging:** Vermont and the Northeast region have cold, cloudy winters and humid summers. High performance buildings are better at providing comfortable interior spaces at lower operational cost.

- **The need to overcome barriers to high performance:** There are many reasons architects, building owners and their teams don’t fully incorporate high performance design concepts in their buildings. Reasons include apprehension about a design process that may be different, not knowing if additional time or money is involved, concern about working with new consultants, being unfamiliar with how high performance can change building design, not knowing about resources that can provide technical assistance and the lack of a management tool that is organized the way architects design. The **High Performance Design Guide** has been developed to remove many of these barriers and to promote best practice design.
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**HIGH PERFORMANCE GUIDE**
PREFACE

Vermont is known, among other things, for common sense, independence, deep community spirit and residents who have a great appreciation of their natural environment. The act of building, while necessary and useful, can be disruptive and destructive. It’s time we think and work in more holistic and restorative ways. This includes the more fundamentally conservative and common sense concepts that are presented in this guide.

As a longtime student of environmental building issues, I believe that the most significant environmental impacts of development are related to energy use. This does not need to be the case, as many examples in this guide demonstrate. We should be seeking to develop more efficient, high performance buildings that also protect our rural, working landscape and our natural ecology.

The beauty of this guide is in both its generality and its clarity. The guide is organized around the way we all go about designing and building. Its structure and basic organization might well serve as a primer for students, building owners, developers and contractors, as well as architects. The guide includes enough depth to help the most experienced of us with ideas, details, management tools and inspiration to take on the leadership challenges of innovation.

The guide is especially useful because of its regional focus. It directly addresses some of the challenges and specifics of our climate - cold, dark winters and warm, sometimes humid summers, and varied cloudy conditions throughout the year. Comprehensive enough to be applied to large new projects, it is also very well suited to the small-scale, adaptive reuse and historic preservation projects that are so prevalent in our region. I love that it dwells deeply on building form and daylighting, and in this it is fundamentally architectural.

On behalf of AIA Vermont, I would like to thank Efficiency Vermont for facilitating this collaboration, working so hard to establish a dynamic support organization, and helping make Vermont a leader on the path to environmental and economic prosperity.

Jeff Schoellkopf, AIA
Warren, Vermont
FUNDAMENTALS

How to:

▶ Define high performance building characteristics and benefits
▶ Reduce greenhouse gas emissions and global warming by increasing energy efficiency and renewable energy use
▶ Assess the energy efficiency potential of high performance buildings
▶ Use the guide and checklists efficiently
Resources:
In Vermont the following organizations provide technical assistance and financial incentives:

Efficiency Vermont
888/921-5990
www.efficiencyvermont.com

Burlington Electric Department
802/658-7342
www.burlingtonelectric.com

Vermont Gas
802/863-4511
www.vermontgas.com

Chapter cover photo:
Society for the Protection of New Hampshire Forests
© Thomas Ames Jr.

Introduction
High performance buildings step significantly beyond minimum code and standard practices for commercial buildings. They are designed, built and operated for better economic, social and environmental results compared to conventional buildings. High performance buildings are:

- **Healthy** to live and work in, and conducive to greater productivity and human performance.
- **Efficient** in use of energy, water and material resources.
- **Cost-effective** to operate and maintain.
- **Durable** and adaptable.
- **Sustainably designed** to protect the natural environment and the economic and social health of our communities.

High performance buildings are not difficult to achieve, nor are they dependent on exotic equipment or difficult methods. Designing and constructing a high performance building does require new skills, some modifications to the design process and a strong focus on teamwork. This guide’s purpose is to illustrate how to approach high performance building design. There is an emphasis on design process, when key performance decisions should be made and how architectural elements, such as the exterior envelope and lighting, affect performance of the building. The high performance building process includes:

- **Setting performance goals** early in the design process, preferably before Schematic Design begins.
- **Assembling a team** that has the skill and commitment to carry out the goals.
- **Using an integrated “whole building” design process** that involves team consultants during early design phases and optimizes the architectural and building system design. The process includes consideration of operational and life-cycle costs, daylighting, and efficient mechanical and lighting systems. The team often includes commissioning and energy consultants to review design concepts and recommend alternatives.
- **Monitoring** the project during design and construction to make sure the goals and design concepts are realized.
- **Verifying the goals** were met via commissioning the building and conducting a building performance review.
High performance buildings offer advantages to building owners, design teams and the general public. High performance buildings:

- **Save money:** The building owner and tenants will pay less for electricity, oil, propane and other fuel sources. High performance designs can also reduce costs by avoiding demand charges and other penalties for energy use during peak times. High performance buildings reduce maintenance costs because of selection of durable and efficient equipment, optimization of building systems and building commissioning prior to occupancy. These buildings are more fine-tuned than their less energy-efficient counterparts.

- **Improve health and productivity:** A growing number of studies confirm that buildings with high performance features contribute to better human performance. These features improve thermal comfort and control, reduce building-related illnesses and create well-lit interiors and views to the outside. These features are linked to improvements in attitude and productivity of office workers, increased sales in retail stores, and improved learning performance among students in daylit classrooms.

- **Strengthen the economy:** High performance buildings strengthen local, state and national economies. Improved efficiency saves the U.S. economy more than $150 billion in energy costs every year compared with 1973 efficiency levels. Savings created by energy-efficient design can be reinvested in economic development, creating growth and jobs with far less environmental impact.

- **Protect the environment:** High performance buildings conserve energy and water, and reduce pollution and greenhouse gas production. High performance buildings also conserve raw materials by using recycled content and rapidly renewable materials.

- **Improve design quality:** Design for daylighting and sun control creates opportunity for attractive building orientation and detailing on the exterior, as well as improved visual and spatial quality in the interior. High performance design features are less likely to be cut at the last-minute by “value engineering” because removing or altering them decreases energy savings and performance.

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**The Daylighting in Schools study by Heschong Mahone Group** analyzed student performance in classrooms in California, Washington and Colorado. Study results show students with the most daylighting in their classrooms progressed 20% faster on math tests and 26% faster in reading tests over the course of one year compared to those in classrooms with the least daylight.

Refer to www.h-m-g.com for a copy of the 1999 report and 2002 updates.

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**Rocky Mountain Institute Newsletter,** Volume XIV, Number 1, Spring 1998, p. 5. www.rmi.org
There are many web sites with excellent information about the causes of global warming and steps that can be taken to reduce greenhouse gas emission. Examples include:

- **National Oceanic and Atmospheric Administration (NOAA)**
  www.ncdc.noaa.gov

- **Worldwatch Institute**
  www.worldwatch.org

- **Department of Energy**
  www.eia.doe.gov
  www.energy.gov

- **Environmental Protection Agency**
  www.epa.gov


**Rocky Mountain Institute Newsletter**, Volume XIV, Number 1, Spring 1998, p. 5.
www.rmi.org

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**Buildings and Global Warming**

Scientific observation over several decades indicates that average global temperatures are rising. Predicted weather extremes, ecosystem disturbance and rising sea level are cause for concern. Human activity contributes greatly to "global warming." The building industry is significantly tied to global warming: It is responsible for almost 40% of greenhouse gas emissions in the United States (Figure 1.1). These are facts every building professional should know:

**The bad news:**

- **Greenhouse gases** include water vapor, carbon dioxide, methane, nitrous oxide and ozone, chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorinated carbons (PFCs) and sulfur hexafluoride. These gases are emitted during product manufacturing, transportation, building construction and operation.

- **Fossil fuel combustion**, such as burning coal to make electricity, is the source for 99% of greenhouse gas emissions.

- **Carbon dioxide** is the most common greenhouse gas (85% of the total). The United States produces 25% of the world’s total carbon dioxide.

**The good news:**

- **Energy-efficient buildings** reduce greenhouse gas emissions.

- **Renewable energy technology** is readily available to reduce reliance on fossil fuel combustion.

- **Economic benefit:** Eight Nobel Prize winners and 2,500 economists have declared that “policy options exist that would slow climate change without harming American living standards, and that these measures may in fact improve U.S. productivity in the longer run.”

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**Figure 1.1 - Greenhouse Gas Emissions**

Source: U.S. DOE/EIA, Annual Energy Review 2001

- 38% Buildings
- 32% Industrial
- 29% Transportation
- 1% Other
Renewable energy represents a small (7%) but growing source of energy in the United States (Figure 1.2) and in the Northeast region. The region has excellent technical and industrial capabilities to support renewable energy systems. This guide gives many examples of designs that have integrated energy from natural, renewable sources in Chapters 2 - 4.

Displacing fossil fuel-based energy with renewable energy is an important consideration for every project, whether new construction or renovation. Renewable energy applications appropriate for commercial buildings in Vermont and the Northeast region include:

- Daylighting (“daylight harvesting”)
- Passive or active solar domestic water heating
- Passive or active solar space heating
- Building integrated photovoltaic systems (BIPV)
- Nighttime cooling and air flushing
- Natural ventilation
- Wind power
- Wood and biomass heating
- Ground water cooling
- Hydroelectric power
- Biodiesel fuel

Figure 1.2 - U.S. Energy Sources

Source: U.S. DOE/EIA, 2001 Annual Energy Review

Resources:
- Northeast Sustainable Energy Association (NESEA)
  50 Miles Street, Suite 3
  Greenfield, MA 01301
  413/774-6051
  www.nesea.org
- Center for Renewable Energy and Sustainable Technology (CREST)
  www.crest.org
- Renewable Energy Resource Center
  www.rerc-vt.org
- National Renewable Energy Laboratory
  1617 Cole Boulevard
  Golden, CO 80401
  303/275-3000
  www.nrel.gov
- Yestermorrow
  Waitsfield, VT
  www.yestermorrow.org
The Energy Benchmark for High Performance Buildings (E-Benchmark™) is an excellent tool for tracking energy efficiency. The prescriptive approach is simple to use and a good option for projects that won’t be using energy simulations. E-Benchmark documents are available on the New Buildings Institute web site: www.newbuildings.org/ebenchmark/index.htm

Other resources:

www.doe.gov

www.usgbc.org

E-Benchmark Prototype Building Study showed the following energy cost savings beyond ASHRAE 90.1 - 2001 for projects in the Northeast region:

- 29 - 37% for office
- 18 - 19% for schools
- 20 - 24% for retail

How much energy can be saved by designing for high performance? Relatively simple steps can save 20 to 50% compared to the national energy standard ASHRAE/IESNA 90.1 - 2001. An emerging program for high performance buildings, E-Benchmark™ lists two levels of energy efficiency targets:

- **Prescriptive approach** to reach target efficiency of 30% better than ASHRAE/IESNA 90.1.
- **Simulation approach (energy modeling)** to reach target efficiency 50% better than ASHRAE/IESNA 90.1.

E-Benchmark contains performance criteria for most commercial building types. Efficiency Vermont used E-Benchmark prescriptive criteria for a typical two-story, 20,000 square foot project in Vermont. The results, compared to an ASHRAE/IESNA 90.1 base case, are shown in Figure 1.3:

- **31% reduction** in lighting energy cost due to more efficient lighting and daylight harvesting.
- **50% reduction** in heating costs due to better envelope insulation and higher-efficiency boiler and controls.
- **30% reduction** in annual energy costs, or $8,000 per year.

Similar reductions are possible for other project types. Payback periods for these types of efficiency improvements are usually in the one to five year range.

**Figure 1.3 - Office Building Savings Potential**

Source: Efficiency Vermont 2003
Checklists
The chapter cover page lists learning objectives, followed by a two-page checklist. At a glance, the checklist shows actions or information needed to keep the energy design process on track. Checklist topics vary for each chapter but usually contain:

- **At the Very Least**: Easy actions or steps that will improve building performance.
- **Process Management**: Meeting planning, consultant selection, teamwork suggestions, schedules and other management concerns.
- **Design**: Building siting and orientation issues, massing, exterior envelope, glazing, material selections and other design details.
- **Technical Tips**: Reducing heat loads, allowing space for energy-efficient equipment, consultant coordination, energy analysis choices, efficient mechanical and lighting systems, renewable energy options.
- **Renovation Issues**: Analyzing existing buildings, historic designation impacts, lighting upgrades and envelope efficiency.

Icons
The margins and body of the guide use icons to alert readers to important points and available resources. The three icons used are:

- **Caution**: A problem, uncertainty or classic mistake.
- **Learn More**: Web sites, reports, research, organizations, books, programs and built projects that have more information on the particular topic.
- **Good Idea**: A tip or example that can improve energy efficiency and management of the design process.

Case in Point Studies
Case studies, titled “Case in Point,” illustrate energy-efficient projects and concepts. The projects come from Vermont or the Northeast region, and many are public buildings that can be visited. Sources and design team information for the Case in Point studies are listed in Chapter 7.
Resources:
For information on the most current energy efficiency requirements and recommendations, contact the local building department, utility or the state energy office.

In Vermont:

Efficiency Vermont
888/921-5990
www.efficiencyvermont.com

Burlington Electric
Department
802/658-7342
www.burlingtonelectric.com

Vermont Gas
802/863-4511
www.vermontgas.com

Vermont Department of Public Service
800/842-3281
www.state.vt.us/psd

In Northeast Region:

Northeast Energy Efficiency Partnership (NEEP)
www.neep.org

Guide Assumptions

This guide was prepared with the input of architects, energy experts, government representatives, engineers and other consultants. Their input helped to establish guide content and to the development of several underlying assumptions that are implicit in the guide:

Best practice emphasis: An ideal, integrated design process is presented in this guide, where the appropriate decisions are made at the best time. Modifications may be needed to respond to different project needs, goals or schedules.

Content: This guide makes extensive references to other publications and web sites that contain more detailed information about specific systems, equipment and standards. This keeps the guide more succinct and maintains the focus on process, management and design.

Indoor air quality and comfort: A high performance building does not sacrifice indoor air quality or the comfort of the occupants in the pursuit of energy efficiency.

What architects should know: Architects need to rely on consultants for many of the technical aspects of high performance design. However, at the minimum, architects should possess the skills and knowledge to:

- Communicate the benefits of high performance buildings to the client and the team.
- Anticipate the ramifications of high performance to building form, orientation, systems and materials.
- Find resources and technical assistance.
- Facilitate goal setting and major system selection.
- Manage the high performance design process.

Sustainable design: Energy efficiency is a critical element of ecologically sustainable design. This guide includes sustainable principles and topics where possible, and refers to other resources and publications that provide more comprehensive coverage of sustainable design issues and practices.

Base case: The base case for energy efficiency refers to a design that is minimally-compliant with ASHRAE/IESNA 90.1. Local or state codes should be used for the base case where they exceed ASHRAE requirements.
How to:

- Set preliminary performance goals
- Select the team
- Assess cost and schedule ramifications
- Develop a performance-based program
- Analyze site energy characteristics
- Evaluate existing buildings
CHECKLIST

AT THE VERY LEAST . . .

- **Goals**: Develop and prioritize preliminary energy performance and sustainable design goals.

- **Local codes**: Research the energy code requirements of the local or state jurisdiction.

- **Assemble the team**: Determine what combination of team expertise is needed to meet the goals.

- **Utility rates**: Review the utility rates and available fuel sources for the project. Check the availability of utility programs that may provide technical assistance, incentives and financing.

PROCESS MANAGEMENT

- **Strategic planning**: Talk to the client about the strategic benefits of a high performance building and secure the client’s commitment to performance goals.

- **Consultants**: Select consultants with the experience and enthusiasm for high performance design, and who will work interactively with the team.

- **Gather reference information**: Collect goals, program data, energy costs and site information. Give this data to the team before Schematic Design.

- **Schedule**: Allow time in the schedule to gather energy-related information and synthesize the results.

PROGRAMMING

- **Goals**: Summarize energy and sustainable design goals in the programming document.

- **Assess real needs**: Evaluate the actual needs for space and look for opportunities for space efficiency and time-of-use synergies that allow spaces to perform multiple functions.
- **Content**: Determine task types, visual acuity needs, times of occupancy and occupant control needs.

- **Site**: Gather local climate data and site energy attributes such as solar access, shading, and wind directions. Find “true south” on the site.

### Technical Tips

- **Daylight**: Assess which programmed space functions are compatible with natural daylight.

- **Renewable energy**: Identify potential renewable energy applications with the client and consultants. Check to see if these applications qualify for tax credits or other financial incentives.

- **Commissioning**: Select the commissioning agent and determine the scope of commissioning needed for the project.

- **Cost analysis**: Establish project investment criteria, such as the number of years needed for payback, that are consistent with the project goals.

### Renovation Issues

- **Energy records**: Assemble utility bills and other energy records for the previous three years.

- **Walk-through**: Look for evidence of original daylighting and ventilation systems that may have been covered up. Review the condition of the exterior envelope and glazing. Estimate the current R-value of the walls, roof and foundation.

- **Historic status**: Determine if the building has landmark status, such as local or national Register of Historic Places. Historic buildings require sensitivity to the context and some compromises about energy-efficient upgrades, such as new windows.
Pre-Design and Schematic Design are critical to the high performance design process. The best results occur when the focus on high performance starts in these early phases. Many architects believe building performance concerns can wait until Design Development or later. This thinking leads to application of energy efficiency measures to a design that is already fixed. While some improvement in efficiency might result, this approach doesn’t yield the best results. High performance design is an integrated, collaborative process that optimizes the design from the very beginning. Without this process, important design qualities and cost savings can be lost, especially those involving building orientation, form and daylighting. Figure 2.1 shows that energy savings potential peaks during Schematic Design, when the effort to make revisions is low. Making modifications in Design Development or Construction Documents requires much more design time for relatively small cost savings.

The most important tasks during Pre-Design are:

- Setting goals and priorities as early as possible.
- Building a committed team.
- Identifying resources that can help the team.
- Understanding the energy-related challenges and opportunities of the site and program.
- Gathering all the information together and using it to identify opportunities for improved performance.
Goals for high performance design should be tailored to each project, reflecting the building type and use, client expectations, site and climate. Goals determined in Pre-Design will be used in Schematic Design to create specific targets and guide the development of high performance strategies and design concepts. In the process of setting goals, the design and client team should ask questions such as:

- **What level of energy performance should we set?** The energy goal is usually stated as a certain percentage better than a design compliant to ASHRAE/IESNA 90.1 in terms of energy cost, rather than energy use. This guide recommends a minimum of 30% better than ASHRAE 90.1 as the performance goal. There are a number of prescriptive tools available to meet this goal for commercial buildings. Projects that have access to energy consultants and building simulations often target 50% or better than ASHRAE 90.1.

- **Does the client have particular goals for design and performance?** Many clients have interest in high performance benefits such as lower operating costs, good indoor air quality and lighting, occupant comfort and aesthetics. Clients may also be interested in reducing the environmental impact of their building project.

- **Are there funds available for energy simulations and technical assistance?** All building types benefit from modeling energy performance, but not all project teams have the funding or expertise available. Check with the local or state energy agencies and utilities for programs that may offer assistance during design and construction. Refer to p. 1.1 for a list of Vermont agencies and utilities that can provide technical assistance or incentives.

- **What is the investment criteria that would make a first cost investment worthwhile to the client?** Many high performance buildings can incorporate higher-cost efficient systems at the same or lower cost because of savings in other systems. For example, more efficient lighting and a better envelope reduce HVAC loads and equipment cost. However, some high performance concepts may cost more initially, especially in renovations, and it is important to know ahead of time what the client considers a reasonable return on investment. Cost savings from lower utility bills pays for higher initial investment over time and will continue to return “dividends.” Make note of the number of years acceptable to the client.
LEED has been developed by the U.S. Green Building Council. The voluntary rating program can be downloaded for free from www.usgbc.org. The rating system is increasingly used as a national “benchmark” for high performance, sustainable design practices. The main categories are:

- Sustainable Sites
- Energy and Atmosphere
- Water Efficiency
- Materials and Resources
- Indoor Environmental Quality
- Innovation

CHPS is organized into the same five categories as LEED but with points and recommendations tailored to schools. Unique points include acoustical performance and natural ventilation. CHPS is available at no charge from www.chps.net.

**Preliminary Goals**

- **Who will commission the project?** High performance buildings involve a commissioning agent during design as well as during construction to ensure that building systems function efficiently and as designed. The particulars of commissioning will be determined later. For now, make sure a decision has been made about who the agent will be and who hires the agent (client, contractor or construction manager). Recommend that the project budget includes adequate funds for the commissioning process (refer to Chapter 3 for more information).

- **Will the team use a rating system to measure performance?** Having a means to track goals is important to a successful high performance building. Choices include the LEED™ (Leadership in Energy and Environmental Design) Green Building Rating System, the E-Benchmark program and other state and local initiatives. A rating program is also available for schools (CHPS - Collaborative for High Performance Schools). If no rating system is used, determine how the goals will be tracked.

Goals can be general at this stage. For example, goals for an office building might include “optimize the use of natural daylight for illumination.” In Schematic Design, that goal will be refined so that the design can respond to it, for example:

- **Building orientation** will maximize south- and north-facing glazing, and minimize east- and west-facing glazing.

- **Daylight** provided through windows and skylights will provide a target illumination level of 30 foot-candles to perimeter and top-floor spaces.

- **Electric lighting** in perimeter zones will include dimming ballasts controlled by photocells. The average lighting density during the day will not exceed 0.5 watts/sf.

Document the preliminary goals and include them with the programming document, the energy and site information gathered during the Pre-Design phase (refer to p. 2.9 - 2.12). The goals will be used throughout the project to guide the design and the efforts of the team.
High performance building design is a process that relies on effective, collaborative teamwork among all the building disciplines. Team composition can vary depending on the project’s complexity, the architect’s in-house expertise, energy goals and available fees (Figure 2.2). High performance design requires selecting consultants and getting their input before design begins. Since building systems are interactive, the teams that design them need to be interactive too. Assess consultants’ experience by asking questions, including:

**Goals**

- Have you participated in setting high performance goals for projects?
- Have you documented the performance of your projects? What were the results?

**Energy simulation tools**

- What software or modeling tools does your firm use to improve and document energy efficiency? Which tool(s) do you recommend for this project?
- Does your staff routinely use these tools?

**Daylighting**

- What is your experience with daylighting design? Which projects have you designed that incorporate daylighting?
- What tools do you use to optimize and integrate daylighting into the design?

**Commissioning**

- Have you worked with commissioning agents during design and construction?
- What were the commissioning agents findings?

“Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed it’s the only thing that ever has.”

- Margaret Mead, Anthropologist, 1958

Energy consultants should have a broad understanding of building energy technology and be skilled at energy simulations and life-cycle cost analysis.

Mechanical engineers usually run trade software to size equipment, but these programs are not always appropriate for providing design assistance to the architect. Many electrical engineers do not have experience with daylight and lighting simulation software that is standard practice for daylighting and lighting consultants.
Integrated design

- Do you have experience with the integrated design process and working with other team members in the early design phases?
- Which projects have you worked on that followed an integrated design process? What did you learn that would help us with this project?

Mechanical

- Does your firm specify high efficiency HVAC systems as standard practice?
- What tools do you use to optimize the performance of the mechanical systems?
- What energy-efficient strategies do you usually suggest to improve the performance of commercial buildings in the Northeast region?

Renewable energy

- Have you successfully incorporated renewable energy into your projects?
- Which types of renewable applications were used?

Life cycle cost analysis

- How do you estimate the annual utility costs for systems you design?
- Do you have experience calculating the payback or return on investment?

Lighting

- Does your firm have experience with integrating lighting and daylighting systems?
- What tools does your firm use to analyze and optimize daylighting and lighting performance?

Indoor air quality

- What strategies do you suggest this project employ to protect indoor air quality?

Rating systems

- Are you familiar with E-Benchmark, ENERGY STAR, LEED or other rating systems for energy efficiency and sustainable design?
- On which projects have you used a rating system? What was their level of performance?
High performance design can impact schedule, fee structure and construction cost, especially when the team is learning a new process. The impact can be greatly minimized through proper management by the architect and consultant team.

Construction Cost: The project first cost does not necessarily increase as a result of high performance design. Construction cost can remain the same if the team follows a well-planned and well-executed design process. First cost is more likely to increase if energy efficiency efforts come late in the design phases. Life-cycle costs are of concern to most clients, and the team should be prepared to do this analysis.

- The sooner energy efficiency is included in the design process, the lower the potential impact on construction cost.

Design Fees: Architect and consultant fees may not need to be increased for small or uncomplicated projects if the performance goals are modest and the team is using a prescriptive rating program. If the project is complex or the goal is high performance design, fees may need to increase to cover the additional time for design and energy simulations. The financial returns of energy-related fees are usually very attractive, often showing payback within a few years. Occasionally a third party, such as a local utility, will help fund a portion of the additional fees associated with energy simulations.

- Additional design fees for creating high performance building are an investment with an attractive financial return.

Design Schedule: If the project is complex or the energy goal is high performance, the design schedule needs additional time during Pre-Design and Schematic Design. Between 5 - 25% more time may be needed for the team to organize, gather and synthesize information, conduct and review energy simulations and identify efficiency measures and design concepts with the best performance.

- Allow time in Pre-Design and Schematic Design for an integrated energy design process.

Project Management

Life-Cycle Cost Tool: Building life-cycle cost (BLCC) software is available for download from the following website: www.eere.energy.gov

Check with the local utility and energy agencies for the availability of technical assistance or funding that could help offset additional fees.
Gathering project energy reference information during Pre-Design is an important, but often overlooked, step toward creating a high performance building. This data can affect building orientation, daylighting, lighting, envelope and mechanical design. Utility rate data will suggest the types of energy-efficient measures that can reduce operating costs.

Energy reference information can be gathered from a number of sources, including the mechanical consultant, energy consultant, ASHRAE/IESNA 90.1, the state energy code and utility companies. Collect and organize energy reference information such as (Table 2.1):

- **Energy code requirements of the jurisdiction.**
- **Submittal requirements for energy code compliance.**
- **Site latitude and longitude** determines sun angles and position within the time zone. Both are important factors in building orientation, daylighting and shading design.
- **Design conditions** represent the exterior and interior temperature extremes that are used to size the building’s heating and cooling loads.
- **Utility rates for electricity, gas, oil or propane**, or other fuel sources that are available to the project.
- **Demand charges for electricity or other utilities** that the owner will be charged during peak times. Demand charge structure varies greatly among utility providers.
- **Utility company technical assistance or other incentive programs.**

### Table 2.1 - Energy Reference Summary - Vermont

<table>
<thead>
<tr>
<th>Location</th>
<th>Burlington, Vermont</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>44 degrees north</td>
</tr>
<tr>
<td>Longitude</td>
<td>73 degrees west</td>
</tr>
<tr>
<td>Elevation</td>
<td>334 feet</td>
</tr>
<tr>
<td>Heating Degree Days</td>
<td>7771</td>
</tr>
<tr>
<td>Cooling Degree Days</td>
<td>2228</td>
</tr>
<tr>
<td>Winter Design Temp (dry bulb)</td>
<td>-11 F (99.6% condition)</td>
</tr>
<tr>
<td>Summer Design Temp (dry bulb)</td>
<td>84 F (1% condition)</td>
</tr>
<tr>
<td>Summer Design Wet Bulb</td>
<td>69 F (1% condition)</td>
</tr>
<tr>
<td>Wind Velocity</td>
<td>22 mph (1% condition)</td>
</tr>
<tr>
<td>Electric Rate</td>
<td>in $/kWh</td>
</tr>
<tr>
<td>Demand charge</td>
<td>in $/kw over base use</td>
</tr>
<tr>
<td>Fuel Rate</td>
<td>in $/therm</td>
</tr>
</tbody>
</table>
If the building type serves a large percentage of older people, such as an assisted living center, the lighting design should give attention to the needs of aging eyes. The IESNA Design Guide does not include specific criteria for lighting based on age, but it does acknowledge the differences between older and younger eyes. The description of differences between younger and older eye function comes from the IESNA Design Guide. www.iesna.org

2.10

Whether the space program is complete or the programming process is just starting, be sure to gather energy-related functional and aesthetic information from the client and user groups. The resulting data should be included in the programming document, along with the preliminary performance goals, energy references and site energy characteristics. The following functional and aesthetic information can have energy and building performance impacts:

- **Hours of operation** for each space or type of occupancy.
- **Functions or tasks** that will occur within each space.
  Make note of any functions that may need extra design attention for lighting, ventilation, thermal comfort or visual comfort (reduced glare).
- **Lighting requirements**, such as the desired “feel” of the space and areas that require greater levels of illumination. Many high performance buildings have relatively low ambient light levels and use task lighting where needed. For more detail on developing criteria for lighting design, refer to Chapter 3.
- **Age** of the occupants may affect the daylighting and lighting design. The retinal illuminance of a person 60 years old is only about one-third the retinal illuminance of a typical 20-year-old because of smaller pupil size and thicker corneal lenses. Older eyes are also more sensitive to glare and react less quickly to large lighting contrasts (especially when adjusting from dark to light spaces).
- **Control** that occupants want over lighting, temperature and ventilation, to the extent that the client is willing to provide individual controls. This type of control offers more thermal comfort and is often an energy-efficient strategy.
- **Daylighting opportunities** that are consistent with the program. Identify areas that will benefit from daylighting, such as offices and public spaces. Also identify areas where daylighting may be problematic or must be designed with extra care, such as computer lab classrooms or gymnasiums used for competitive sports.
- **Types of equipment** to be plugged in, such as computers, faxes, printers, etc.
- **Multiple functions** that could happen in one space, allowing reduction in building size. Ask questions about times of use and look for synergies to allow spaces to have multiple functions and increase space efficiency.
Draw or write all gathered data onto a site plan for a convenient graphic record of the site issues. Include an aerial photograph if the site is large. Shading patterns of land forms and vegetation can be determined by measuring shadow lengths. (See AIA Energy Design Handbook, Don Watson, ed.: The American Institute of Architects, Washington, D.C.: 1993, p. 28.)


Site Energy Characteristics

High performance design relates very closely to the building site and its location, climate, topography and other physical characteristics. During Pre-Design, in addition to the site-related energy references listed on p. 2.9, gather other site characteristics such as:

- **Topography, landscape and vegetation:** Note the site slope direction and steepness, the type and location of vegetation, height of trees near the building site, and the location and height of existing buildings on or near the site.

- **True south:** Show true and magnetic north on the preliminary site plan. When on the site, determine true south by using a compass as shown in Figure 2.3. A sun path chart can be used to confirm solar availability and identify areas with too much or too little shading.

- **Renewable energy potential:** In addition to solar energy, review wind, hydroelectric, geothermal and biomass renewable energy sources.

- **Zoning restrictions:** Identify any zoning regulations that could limit solar access or solar equipment. Some urban areas and planned developments have zoning regulations that prevent new construction from blocking solar access to existing buildings.

- **Wind conditions:** Wind direction and speed vary greatly in the Northeast region. Knowing wind conditions helps to inform location of intake and exhaust vents, natural ventilation systems and exterior envelope choices. Check with local sources as well as NOAA's monthly summaries of nearby weather stations.

**Figure 2.3 - True South Determination**

To confirm true south when on site:

1. Use a compass to determine the location of magnetic north.

2. Using a USGS map, survey or isogonic chart showing lines of magnetic declination, determine the declination nearest to the site. In the Northeast Region, the compass needle will point west of true north. Declination is 15 degrees in the Burlington area.

3. Turn the compass dial from magnetic north to the east by the amount of the declination. This is true north, opposite of true south.

Source: The Passive Solar Energy Book
A well-planned energy renovation program can reduce energy use by 30 to 50%. Performance can be improved through replacement of lighting systems, controls, mechanical systems and glazing and insulating and sealing the envelope.

Figure 2.4 illustrates energy savings for typical existing commercial buildings. The left chart shows energy use documented by utility bills. The right chart shows the improvement for the same buildings after energy-efficient renovation. Note the lighting, heating and cooling energy reductions after the renovation.

During Pre-Design, assemble existing building data that will be used in Schematic Design to determine energy-efficient strategies. Valuable data or documents include:

- **As-built drawings.**
- **Three years of utility bills** for electricity, water and fuel.
- **Maintenance records for large equipment.**
- **Historic or landmark status.**
- **Evidence** of original daylighting and ventilation systems that may have been covered up by previous renovations. Look for light wells, skylights, windows, vents and chases.
- **Moisture problems** anywhere in the building.
- **Ceiling height and condition.**
- **Exterior envelope condition** including exterior walls, structure, insulation, sealant, flashing, windows and frames.
- **Age** and condition of the existing HVAC, lighting and electrical equipment and controls.
Renovation

The McFarland State Office Building in Barre, Vermont, was built in 1914 as a four-story hospital. The renovation reclaimed the deteriorated structure and provided a new energy-efficient building envelope and modern mechanical system while retaining the historic character of the original building. Renovation of the 52,000 square foot building was completed in December 2002 at a cost of $7 million.

Analysis of the existing conditions yielded a list of concerns about the envelope, as well as heating and cooling systems. The renovation design included energy-efficient measures that cost $45,000 and yielded an annual energy savings of $15,000. Incentives paid by Efficiency Vermont, the State’s energy efficiency utility, lowered the payback to just 2.2 years. The high performance features include:

- **Premium efficiency chiller.**
- **Premium efficiency oil-fired boilers.**
- **Envelope improvements** such as increased insulation and reduced air infiltration.
- **Heat recovery** ventilation system.
- **Premium efficiency motors** on pumps and fans.
- **Efficient lighting** and controls.

**Insulation:** The original building envelope was un-insulated and leaky. New perimeter spray-on wall insulation acts as a vapor retarder and air infiltration barrier and provides a high R-value and a thermal break. A total of three different insulation systems were used for walls, roofs and floors.

**Glazing:** The existing single-pane, double-hung window sashes were reglazed with insulated low-E units.

**Other sustainable design features:** In addition to the energy upgrades, the team included sustainable design features such as low-flow toilets and showerheads, demolition waste recycling and reuse, a built-in recycling program, low-toxicity finishes and materials, new light wells to bring daylight into lower levels and replacement of existing skylights to restore daylight in corridors.

**Energy savings:**
Approximately 150,000 kWh saved with higher efficiency equipment and envelope upgrades. Annual savings is $15,000.
How to:

- Organize the design team
- Refine the energy goals
- Orient buildings efficiently
- Create daylighting and lighting criteria
- Set glazing and envelope criteria
- Set mechanical criteria
- Approach conceptual design
- Evaluate upgrades to existing buildings
CHECKLIST

AT THE VERY LEAST...

☐ Goals: Secure the client’s commitment to the high performance goals.

☐ Daylighting: Design to allow daylight into spaces and balance it with efficient lighting systems.

☐ Consultant input: Identify systems that could have an impact on building form or orientation.

☐ Set criteria: Use Pre-Design goals to set efficiency criteria (or targets) for lighting, envelope and mechanical systems.

PROCESS MANAGEMENT

☐ Team meeting: Organize a team meeting to kick off the conceptual design, exchange information and identify opportunities to save energy and improve performance.

☐ Team roles: Clarify team roles and confirm that the team is committed to the project goals. Emphasize teamwork and respect for new or different ideas about design and energy.

☐ Energy modeling: Determine if building will be evaluated with modeling software and who will do it.

☐ Iterations: Plan on several design iterations to test the energy and economic performance of the design.

CONCEPTUAL DESIGN

☐ Orientation: Gain the best daylighting potential by orienting the building’s long axis in the east-west direction.

☐ Renewable energy: Evaluate use of renewable energy sources and incorporation of renewable energy systems.
Site design: Incorporate needs for shading, solar access and ventilation into the site design.

Building form: Develop structural and envelope systems together to maximize daylighting potential.

TECHNICAL TIPS

Mechanical: Reduce loads and improve comfort first, then select the most efficient mechanical system. Facilitate the selection of the mechanical system and confirm enough space is allocated for equipment and distribution.

Daylighting: Create conceptual daylighting and lighting schemes in consultation with the team.

Commissioning: Review the commissioning agent’s preliminary commissioning plan.

Analyze energy performance: Analyze proposed energy efficiency measures to test the performance.

RENOVATION ISSUES

Assess equipment: Conduct an energy audit and operational assessment of the existing building systems if they are not planned for replacement.

Upgrades: Assess potential energy savings and costs for upgrades, especially lighting and HVAC, and the feasibility of replacing inefficient equipment.

Lighting: Include a lighting designer on the team if significant lighting upgrades are anticipated.

Envelope: Evaluate the potential to add insulation and to replace glazing. Estimate the costs of glazing options and compare to cost savings in the mechanical system.
The Schematic Design (SD) phase needs to be especially well managed and executed in order to coax the best performance out of the building design. At the beginning of SD, the full design team should meet to plan the phase and the design effort. The purpose is to build team rapport, make sure the goals are clear and secure team members’ commitment to achieving the goals. Create an agenda for this “kick off” meeting that allows time for brainstorming and team interaction.

Organize the Team

- **Goals:** Ask the team to help refine the Pre-Design goals to more specific performance targets. The team can set its own targets or rely on programs such as E-Benchmark or LEED for setting lighting, envelope, and mechanical efficiency targets.

- **Roles:** Clarify the team roles and the design process that will be used.

- **Teamwork:** Emphasize the need for collaboration and openness to new ideas about design and energy.

- **Systems:** Ask the consultants to brainstorm energy-efficient systems appropriate for the project and the energy goals. Include discussion of potential building envelope systems and structural systems, as these choices have an impact on energy performance.

- **Design requirements:** Discuss space and building form requirements needed to accommodate mechanical and lighting systems, such as adequate room for mechanical equipment and minimum floor-to-floor height.

- **Iterations:** If the project will be using energy modeling, the team should plan on several design iterations during Schematic Design to fine-tune building orientation and configuration.

- **Rating programs and incentives:** Identify rating programs that the project is expected to meet. Discuss any incentives or design assistance that may be available from local utilities. Identify a point person in the architectural firm to coordinate and track the programs or incentives and ask the consultants to assign an individual from their firms who will be responsible for meeting the objectives.
Efficient Design Process

High performance design is as much art as science; as much a way of thinking as it is specific skills. Artful solutions to energy and cost challenges are more likely if the team is savvy about how to approach the process. It is possible to spend too much time on a single system or strategy that may not make a large difference. Concepts for making the design process efficient are:

Solve many problems with one expenditure:
- **Optimize** a room type or function that is repeated many times in the building such as a hospital room, classroom or typical office.
- **Orient** the building for the best daylighting performance, which will also reduce energy costs and improve comfort.

Prioritize the savings:
- **Find large energy savings** by finding many smaller savings. Evaluate any system that is on continuously, develop envelope upgrades and lighting strategies that reduce the load on the mechanical system.
- **Target** areas with high energy use, such as lighting in galleries and retail spaces and hot water for kitchens.

Sequence the decisions:
- **People before hardware**, quality before quantity, passive before active, shell before contents, and load reduction before supply. For example, efficient lighting design might start with improved seating arrangements (people before hardware), reduction of glare (quality before quantity), and incorporation of daylight (passive before active) with better glazing (shell before contents). After that, consider the technical efficiency of the light fixtures.

Optimize the whole building:
- **Look for components** that interact significantly with others. Higher-performance glazing and walls can often eliminate perimeter heating systems. This moves mechanical distribution off the exterior and toward the interior, which results in first cost and operational savings.
- **Use energy simulations** to run "what if" scenarios with combinations of energy efficiency measures to discover how building energy use changes. The synergy of combined efficiency measures may result in significant first cost and energy savings.
Site design can have a large impact on the relative efficiency or inefficiency of the building design. To improve the performance of the site and building, consider the following:

- **Orient** the building for the best daylighting and energy performance. The best choice is along the east-west axis (Figure 3.1), as this provides the best access to controllable daylight on the south and north facades. East- and west-facing facades have more variety in low and high sun angles throughout the year, making them harder to control and prevent glare or heat gain. The major facades (north and south) should be within 15 degrees of true south for best daylighting and thermal performance. Second choice is within 45 degrees of true south, and last choice is at 90 degrees off true south.

- **Locate the entrances** to provide safety, ease of access and protection from the elements. Entrances on the south, southeast or southwest sides benefit from solar gain in winter and avoid north/northwesterly winter winds.

- **Use buffers** such as natural landforms or other buildings to shade the building from unwanted solar gain or wind.

- **Employ landscaping features** to moderate weather conditions. For example, using trees to shade the east and west facades reduces heat gain and glare. Shading the south facade with deciduous trees is an option if it does not impact the daylighting or active solar systems.

- **Plan for comfort:** Incorporate shading and natural ventilation. Look for opportunities to provide comfortable outdoor spaces by moderating the sun and wind.

- **Minimize environmental damage** by reducing site disturbance, conforming the building to natural contours, reducing impervious paved areas, treating stormwater runoff on site, protecting undisturbed land and restoring native landscape where land has been disturbed by construction or previous owners.

- **Select sites with good access to public transit** and provide for transit options not dependent on fossil fuel combustion (walking, bicycling, etc.). Provide bicycle racks and changing rooms to facilitate non-car commuting. Allow space for car pools and provide plug-in for electric vehicles if appropriate.
Daylighting is simply the controlled use of natural light in a building. When paired with an efficient electric lighting system, daylighting can become a powerful tool in high performance buildings to reduce energy use and to increase comfort and productivity. Electric lighting accounts for 30 to 50% of total building energy costs, and daylighting is the most cost-effective strategy to reduce operational costs. Well-designed daylighting systems also reduce space cooling loads by reducing waste heat generated by lamps and ballasts. Factors that affect daylighting design include the following:

- **Building orientation** determines what the daylighting potential is for each project. Optimal orientation along the east-west axis allows better control of sun angle.

- **Envelope design** also has a large impact on the availability of daylight, as well as properly controlling and diffusing light inside the building.

- **Floor-to-floor and ceiling height** affect the height of windows and how much light is reflected into the interior.

- **Glazing type and location** control how much visible light and glare enter the space.

- **Electric lighting** should be designed to balance and supplement the daylighting design. Location and type of fixture, spacing, photocell controls and lamp color all contribute to daylighting effectiveness.

- **Climate**, including cloudiness or bright sun conditions, light duration and intensity should be considered. The high overcast conditions in the Northeast region during some seasons are actually very conducive to daylighting in buildings.

- **Site characteristics**, such as shading from vegetation or other buildings, can greatly reduce available daylight.

- **Tasks and space function** determine the illumination needed and degree of glare control required.

- **Floor plan configuration** can hinder daylight penetration. For example, private perimeter offices with opaque, full height partitions prevent daylight from reaching corridors or other offices.

Daylighting reduces energy costs only if the electric lighting system is designed to turn off or dim in response to daylight levels.
Effective daylighting directs light onto ceilings and other surfaces that diffuse and distribute the light. Daylighting systems can be simple or complex, depending on the energy goals, budget and availability of a daylighting specialist to help. Since daylight is harvested at the building envelope, building configuration affects how much daylight can enter. Key building form issues include:

**Building footprint:** Spaces intended for daylighting should be arranged nearest to an exterior surface such as walls, roof, daylit atrium or courtyard.

  - **Building depth:** The ideal building depth is limited by the penetration of reflected light. Frank Lloyd Wright defined this ideal as 13 meters (about 42 feet) for side-lighting from windows on both sides. Figure 3.2 shows a library footprint before (Initial Design) and after (Improved Daylight Design) daylighting modeling was completed. All public spaces were effectively daylit by making the wings more slender and adding clerestories to the wings and the central lobby. “Effective” means that lights are off whenever daylight provides enough illumination to meet the targeted light level.

  - **Room depth:** If using simple side-lighting, the maximum room depth should not exceed 2.5 times the height of the window wall to maintain a minimum level of illumination (Figure 3.3). Incorporation of light shelves (Figure 3.6) can greatly increase daylight penetration into interior spaces.

**Ceiling height:** Effective daylighting requires higher ceiling heights (nine feet or higher).

**Light control:** Any direct sunlight needs to be diffused or blocked from reaching work surfaces. Devices such as light shelves, louvers, mesh blinds and other exterior and interior devices can accomplish this requirement.

**Windows:** Place the majority of the windows on the south and north faces. Large windows facing east or west can cause discomfort from glare and heat gain. Windows are often divided into a daylight zone and a view zone as shown in Figure 3.6.

**Reflectivity:** The higher the reflectance of the ceiling, wall and floor surfaces, the less light (daylight or electric light) will be needed to achieve the desired illumination level.
Top-lighting: Skylights, roof monitors and clerestories introduce daylight into spaces.

- **Skylights** can be an effective means of daylighting in the Northeast region as long as the skylight area is controlled (usually 3% or less of roof area). Use software, such as SkyCalc (see p. 3.11,) to optimize the skylight area that achieves the maximum energy savings.

- **Roof monitors/clerestories** are stepped roof forms that allow light from one or more directions (Figures 3.4 and 3.5). The adjacent roof can be used to reflect light through the monitor if the roof material is light in color.

Side-lighting: Windows can be designed to distribute daylight deep into the space from the perimeter (Figure 3.6).

- **Daylight glazing** has a high visible transmittance (70% or higher) and low solar heat gain coefficient (30% or less) and is often paired with an exterior or interior light shelf to maximize the light diffusion and projection into the space.

- **View glazing** provides a visual connection to the outdoor environment. The glazing has a visible transmittance of about 50% to reduce brightness and glare. View glazing can be paired with shading devices on the exterior or diffusing shades on the interior to reduce glare and heat gain (see p. 3.9).
Shading devices are essential to control glare and reduce solar heat gain in daylit buildings. The orientation of the facade determines the most effective type of shading devices (Figure 3.7). If exterior shading devices are not cost-effective or advisable due to snow conditions, consider interior shading devices and higher performance glazing to reduce solar heat gain. Refer to Chapter 4 for more detail about glazing performance in daylit buildings.

- **Projection and shape** should be determined by calculating the sun angles that need to be blocked. The projection should be at least enough to block summer sun, but can be extended to cover spring and fall angles.

- **Shading devices** do not have to be solid. They can be made of perforated materials, slats, angle or channel shapes or translucent materials.

- **Glazing** protected by shading can admit a higher proportion of visible daylight with less glare.

- **Interior shades** should be selected to diffuse direct sun, such as woven or mesh shades. Blocking daylight is not usually necessary unless the function of the space requires this level of control.

Light shelves reflect and diffuse daylight, and also reduce glare and block solar heat gain (Figures 3.6 and 3.8). Advanced light shelves maintain illumination as far as four times the window wall height, greatly reducing electric lighting requirements. Components of effective light shelves are:

- **Glazing**: Daylight glazing above the light shelf.

- **Reflector**: High reflectance materials on the top surface of the light shelf (90% or more), such as painted surfaces, light-colored metals or specular films.

A light-colored underside to light shelves will help decrease contrast between the shelf and light coming through the window.
Daylight Optimization

Northern Power Systems (NPS) in Waitsfield, Vermont, designs, builds and installs on-site power systems including co-generation and renewable energy systems. For the construction of its new 30,000 square foot office headquarters and engineering testing laboratory, NPS sought a design that would minimize energy use and demonstrate its own technologies.

Orientation and plan: The NPS building is curved around true south and uses shading devices on the southern side (Figure 3.9). This orientation minimizes the glazing facing east and west, reducing solar gain and glare. This design keeps most of the glazing facing north and south, optimizing daylighting potential.

Daylighting system: The south wall contains an insulated, translucent fiberglass curtainwall to diffuse light and triple-glazed windows elsewhere. Both systems reduce heat transfer through the glazing while permitting significant daylight into the building. Photocell controls were linked to the electric lighting to turn lights down or off when light levels from daylighting met the goals. Lighting power density is only 1.1 watts/sf.

Energy savings: The approximate added cost of the fiberglass system and daylighting control was $40,000. The design is estimated to save 14 kW and 72,400 kWh per year compared to the base case of 207,000 kWh per year.

Energy status: 39% better than ASHRAE 90.1, not including credit for the co-generated electricity made on site. Projected energy savings is $16,300 per year.

Software type: Carrier’s Hourly Analysis Program (HAP) 4.0 was used to model energy performance.

Figure 3.9 - NPS Orientation Plan

Solar Meridian (True south)

Wings are 50' deep, offices along perimeter, computer lab along north wall

Source: Efficiency Vermont
During Schematic Design it is common to encounter any number of challenges to the best daylighting design. Resources such as the list to the left can help. Examples of problems and their possible solutions are:

**Orientation can’t be on east-west axis:** Perhaps the building footprint is complex, or the site orientation or setbacks preclude this orientation.

- **Review the conceptual design room by room** to determine if individual spaces can make use of clerestories or skylights that do face in the north or south direction.

**East or west-facing windows:** If the predominant views face east or west, decrease the potential for glare or unwanted heat gain.

- **Reduce the size of window openings.**
- **Lower the visible transmittance** and the solar heat gain coefficient of the windows (refer to Chapter 4 for more information).
- **Include light-diffusing interior shades.**

**Limited construction budget:** If funds are not available for daylight modeling or daylighting improvements such as roof monitors, there are less expensive solutions.

- **Orient the building** for the best daylight potential.
- **Incorporate daylight with side-lighting** through south- and north-facing windows.
- **Incorporate photocell controls** with efficient electric lighting.
- **Investigate the availability of incentives** or technical assistance programs through utility programs.

**Not every space can be daylit:** Either due to cost or function, daylight is not appropriate for every space.

- **Focus on spaces where occupants spend productive time,** such as offices and classrooms. These spaces will benefit greatly from daylighting.
- **Be inventive about options** for dimming and controlling daylit spaces. Some spaces can be daylit as long as there is an option to darken them, such as during an audio-visual presentation.
- **Control direct sunlight** in all spaces, unless direct sun is part of the design concept.
Schematic Design is a good time to develop renewable energy options for the project. Building forms can be affected by renewable energy systems, and if the forms are not established now the renewable option may be lost. Active solar strategies include direct gain for supply air or domestic hot water pre-heating and building-integrated photovoltaics (BIPV) for electricity generation (Figure 3.10).

- **Significant areas of south-facing wall and roof are basic requirements for solar-based strategies.**

The development of thin-film BIPV modules has improved cost-effectiveness. BIPV can be incorporated into spandrel panels, skylights and awnings. In addition to producing electricity, commercial BIPV systems can offset electrical demand during peak hours, thus saving additional energy costs. The angle at which BIPV panels are set depends on the purpose (Figure 3.10):

- **Flat - 30 degrees** if maximizing output during the summer, late spring and early fall is the goal.
- **35 - 45+ degrees** if winter optimization is desired.
- **Vertical** if integrated into spandrel panels and the purpose is to shave afternoon peak electrical use.

Using the sun to warm supply air can be accomplished by placing air collectors on the south side of the building. Since it can interfere with window placement, this system is most frequently used on warehouses and manufacturing facilities that do not require significant south windows. An example is the Ford Motor Company Stamping Plant in Buffalo, New York. To meet indoor air quality standards, the facility required a high ventilation rate. The company installed 50,000 square feet of south-facing air collectors that cost $615,000, but save $194,000 each year.

Assess building energy demands and climate to decide upon the most appropriate renewable energy application. Other renewable applications that are viable now in the Northeast include wood for heating (cordwood, chips, pellets) and micro-hydroelectric and wind for electricity.

Determine the financial feasibility and payback of the application. Some applications may have paybacks of over 10 years but offer other life-cycle cost benefits, such as better indoor air quality and less greenhouse gas emission. Contact utilities and state agencies for grant programs or incentives.
Luminance is what we see: Brightness, or how much light is reflecting off a surface. Luminance has direction and is greatly affected by the color and reflectance of a surface.

Illuminance: How much light is falling on a surface. Illuminance is measured in foot-candles (fc) or in lux (lumens per square meter).

Lumen Micro is an industry-standard software program. www.lighting-technologies.com

Visual Basic is available free of charge from the Lithonia web site: www.lithonia.com/software

Many architects begin lighting design thinking that the palette consists of only electric lighting. Light is already present in the form of daylight, but it’s blocked by the building envelope. The high performance approach begins lighting design by looking for ways to decrease barriers to natural light. Envelope design, building orientation and configuration are the precursors to electric lighting design.

In SD the high performance lighting process includes:

**Establish target lighting power allowance:** The target is based on the overall goal set at Pre-Design and can be determined by using the whole building occupancy or by each type of space or activity within the building. The target is expressed as “interior lighting power density” in watts/sf. Refer to E-Benchmark for targets set at 30% better than ASHRAE/IESNA 90.1. The team can also set targets with the assistance of the electrical engineer or lighting designer.

**Set illuminance and luminance values:** Architects are generally more familiar with designing to illuminance targets (fc) rather than luminance. Refer to the newest IESNA recommendations. Make a distinction between the ambient lighting target and the target for task surfaces such as desks. Also include preliminary surface brightness ratios (see p. 3.14) and the lighting mood or purpose of each space. This information will be invaluable when reviewing fixture layout and lighting product options during Design Development.

**Set conceptual goals for control strategies:** Lighting control strategies include:

- **Daylighting tied into the electric lighting** system with photocell sensors and dimming or switching ballasts.
- **Individual control** for occupants.
- **Occupancy sensor** switches in areas with intermittent use.
- **Time controls** to turn lights off when the building is closed.

**Make preliminary physical or computer models:** Test the lighting and daylighting concepts of primary spaces and room types that are repeated, such as offices. Examples of lighting modeling software are Lumen Micro and Visual Basic.
In spaces such as libraries, the ambient space illumination can be between 20 - 22 foot-candles if task lighting is made available at desks and reading areas.

Resources: Advanced Lighting Guidelines
www.iesna.org
IESNA Lighting Handbook, IESNA.
www.iesna.org

Brightness Ratios

- 3-1 brightness ratio will not result in excessive contrast or glare. Most people cannot tell the difference between ambient space illumination of 25 foot-candles and 30 foot-candles. This allows an energy-efficient strategy of lowering ambient illumination and providing supplemental lighting where additional light is needed for specific tasks.

- 5-1 brightness ratio is the threshold for most people to perceive an object or surface as being brighter or more luminous than the surrounding environment.

- 10-1 brightness ratio creates a spotlighted object or surface, such as in a retail window display or architectural feature.

The Illuminating Engineering Society of North America (IESNA) suggests the following strategies for optimizing the performance of the lighting design:

- **Tasks**: Group together tasks that have the same illumination requirements, if the architectural program allows. When determining the ambient illumination level, be aware that the IESNA tables list requirements for illumination at the task.

- **Adjacency**: Group spaces where lighting can be turned off after hours using time controls.

- **Highlighting**: Use accent lighting to highlight what is needed instead of using general overhead lighting.

- **Open space**: Favor open-space plans in lieu of partitioned spaces. Solid partitions block efficient distribution of light and require additional lighting for the same amount of space. If partitions are needed, consider integrating clear or translucent glass into the top part of the wall system.

- **Exterior windows**: Locate the work areas requiring the most illumination nearest the windows, but be conscious of the need to control glare and direct sun.

- **Controls**: Incorporate occupancy sensors in intermittently occupied spaces such as offices, storage areas and conference rooms. Include daylight sensors and time controls where feasible.
Thermal bridging effects are critical when making an R-value determination for a system. According to ASHRAE 90.1, a steel-framed wall with R-19 batts at 16 inches o.c. has an actual effective R-value of only R-7.1. Steel stud walls with fiberglass batts (without exterior insulation) is not a recommended wall system for the Northeast region because of the thermal bridging potential.

Roof types that meet the ENERGY STAR® requirements are usually white, gray or other light color roof materials that have reflectance of 0.65 and emissivity of 0.9.

Thermal performance characteristics of the exterior envelope should be set during Schematic Design. The goal is to optimize the thermal envelope before developing mechanical system loads for heating and cooling. Selection of specific materials is not as important as determining the basic qualities of the envelope. Important tasks in Schematic Design are:

Establish thermal performance of the envelope:

- **R-value**: Set preliminary R-value targets for wall, floor and roof assemblies. These values must at least meet ASHRAE/IESNA 90.1 requirements, and would ideally meet the prescriptive level of the E-Benchmark program. If the project is using energy simulations, a base case will be created using minimum envelope performance using ASHRAE 90.1 or local code, whichever is more stringent.

- **Location of thermal insulation**: Plan to place the air barrier and thermal insulation outside the structural walls.

- **Air leakage**: Control of air infiltration is critical to comfort, thermal performance and moisture control in the Northeast climate. Consider wall configurations that are easier to seal, such as exterior insulation systems, or set a strategy for how air sealing will be achieved.

- **Shading and glazing strategy**: Identify size and location of glazing and determine the shading strategy for east-, south- and west-facing windows. Set preliminary glazing characteristics based on E-Benchmark recommendations. Refer to Chapter 4 for more information about glazing selection and specification.

- **Roof performance**: Consider requiring an ENERGY STAR® “cool” roof that will reduce heat gain. This is particularly important for one-story buildings or other buildings whose roofs are a significant percentage of the total exterior envelope.

Review ramifications for other systems:

- **Mechanical**: Determine if the building will incorporate operable windows or other natural ventilation systems and whether perimeter heating can be eliminated because of an enhanced envelope design.

- **Cable, electrical and phone**: These systems can cause penetrations in the exterior wall that are hard to seal. Bring these systems in under floors or through uninsulated walls where feasible.
The Boscawen Elementary School in Boscawen, New Hampshire, was built in 1996 to replace an old, inefficient school. Though the funding for the new school was limited ($65 - $80/sf), the district wanted to create a high-quality, healthy and social learning environment for the students. The school district, architect and construction manager worked together from the beginning of Schematic Design. The goals included creating a high performance school that was energy-efficient and had good acoustics, indoor air quality, lighting quality and ventilation. The concepts they came up with during Schematic Design included:

Configuration: The plan features classrooms off a double-loaded corridor wrapped in a “u” shape around a courtyard. This gives all classrooms access to natural light and views.

Envelope: The team selected an exterior insulation system installed over a continuous air infiltration barrier. Any systems requiring penetrations, such as cable, electrical and plumbing, were zoned to interior walls instead.

“Advantage Classroom”: The prototypical classroom has good acoustics, visual comfort and fresh air. The classrooms have peaked ceilings, angled corners and valances to break up and absorb sound; the window concept included sizing and selecting performance to balance the electric lighting (lighting budget was 1.1 watts/sf); the ventilation concept was to provide 100% fresh air at all times through either operable windows or the mechanical ventilation system.

Displacement ventilation: After optimizing the room configuration, lighting and envelope, the team selected a mechanical system to maximize the indoor air quality. Outside air is filtered, passed through heat exchangers and sent at low velocity to classrooms, where it is delivered through diffusers near the floor. Warm air is removed and passed through heat exchangers before it is exhausted. This system required some changes in building configuration, such as running ductwork down walls and installing air handling equipment suited to moving high-volume, low-velocity air.
Reducing the plug load for cooling load calculations **does not mean the power supply is reduced**; it means cooling systems are not over sized.


The nation’s 7 million copying machines would use 60% less power if they turned themselves off after a period of inactivity.

ENERGY STAR program
www.energystar.gov

Download free ENERGY STAR "sleep" software
www.efficiencyvermont.com

Mechanical

The choice and sizing of the mechanical system has a big impact on the overall performance of the building. Schematic Design is the right time to review alternatives and to select the system.

**Think in terms of load reduction and “right sizing”:** Oversized mechanical systems increase first cost, use more energy, cycle more frequently, reduce comfort and shorten equipment life. High performance buildings avoid these problems by taking several steps early in Schematic Design:

- **Plan to use all the tools of an integrated design:** Good orientation with daylighting tied into an efficient lighting design, an envelope with good thermal performance and shading devices.

- **Ask engineers to use actual internal gains:** Mechanical engineers often assume 2 - 5 watts/sf for plug loads in building cooling load calculations. Recent research shows that power drawn is only 0.44 - 1.05 watts/sf in modern office buildings, an average of 46% of the UL label listing.

- **Specify ENERGY STAR equipment:** The EPA certifies products that sleep when not in use. For example, flat screen computer monitors use 50% less energy than standard computer screens.

- **Set the number of building occupants:** Ask engineers to use the actual number of people in the building and not the occupant load calculated for exiting.

- **Identify efficiency strategies:** Reduce loads further with nighttime ventilation, air-side economizers, increased thermal mass, heat recovery ventilation, demand control ventilation and renewable energy systems. Brainstorm other strategies applicable to the project and climate with your engineering team.

Select the mechanical system: Investigate the HVAC alternatives with the team and choose systems based on efficiency, comfort and fuel costs. Equipment and controls selection happen in the next design phase. Discuss issues such as:

- **Heating system alternatives:** What are the available fuels (solar, wood, oil or gas)? Should the heating system be hot water or hot air? Condensing boilers are more efficient than non-condensing boilers and both are more efficient than the heating side of roof top units (RTU).
Effective daylighting requires higher ceiling heights. In order to avoid an increase in building height, designers often squeeze the area above the ceiling. This can have adverse impacts to comfort and mechanical system efficiency. Carefully analyze the trade-offs in cost and performance between ceiling heights, building height and mechanical systems.

### Cooling system alternatives:
Should cooling happen through DX or chilled water? If DX, ask the engineers about split systems which can be nearly 50% more efficient than the best RTU. If chilled water, should the system be air-, water- or evaporatively-cooled? Water-cooled can be twice as efficient as air-cooled, with evaporatively-cooled water roughly in between.

### Distribution alternatives:
Should the air delivery be conventional overhead ductwork or an under floor air distribution system? UFAD systems provide significant energy savings and comfort benefits (see Figure 3.11). Should the air system be constant volume or variable air volume (VAV)? VAV systems are generally much more efficient than constant volume, and UFAD systems are more efficient than overhead VAV. Should the water system be 2-pipe or 4-pipe? Can the envelope be improved enough so that no perimeter distribution is necessary?

### Provide adequate physical space:
Some efficient systems require additional space or different configurations:

- **Ductwork:** Ducts may be larger in diameter or placed in walls to deliver air properly.

- **Floors:** Systems such as displacement ventilation and under floor air distribution require different floor configurations. See Figure 3.11 and p. 3.20 for examples. If the design concept calls for raised floor construction for other reasons, UFAD can be integrated into the system.

- **Ceilings:** Higher ceilings that are needed to optimize daylighting performance can have an impact on the ventilation system, duct location and mechanical system chosen for the project.

### Figure 3.11 - Under Floor Air Distribution

<table>
<thead>
<tr>
<th>Component</th>
<th>Floor-based System (UFAD)</th>
<th>Ceiling-based System (Typical VAV system)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply air temp.</td>
<td>63 degrees F</td>
<td>55 degrees F</td>
</tr>
<tr>
<td>Return air temp.</td>
<td>82</td>
<td>75</td>
</tr>
<tr>
<td>Chilled water supply</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>Chiller efficiency</td>
<td>0.37 kW/ton</td>
<td>0.60 kW/ton</td>
</tr>
<tr>
<td>Chiller power draw</td>
<td>160 kW</td>
<td>260 kW</td>
</tr>
</tbody>
</table>

Based on analysis of the same commercial building with two different systems. Low pressure drop and fan efficiency saves additional energy in floor-based systems.
The energy models should be developed during Schematic Design - before the building footprint and design concept are fixed. Energy efficiency options are more limited once the project enters Design Development, unless fee and construction cost budgets can be increased to cover additional costs.

The programs that require little training are inexpensive. eQUEST is available for download free of charge.

Another way of looking at building performance is to evaluate life-cycle costs. The Building Life-Cycle Cost (BLCC) computer program was developed by the National Institute of Standards and Technology (NIST). It was developed to clarify energy conservation investment choices in buildings required to meet the ASHRAE/IESNA 90.1 standard. BLCC is available through NIST, along with a video and workbook. www.eere.energy.gov

Evaluate Energy Efficiency

After the performance criteria are in place and a first pass at a floor plan is available, it is a best practice to run an energy simulation. This is an opportunity to check the design concepts against the performance goals and to identify system improvements that reduce energy cost. Some consultants recommend using energy simulation software during Pre-Design to assist with building orientation decisions. The model is built simply using the square footage, use and location. This model would then be modified during Schematic Design.

There are many energy modeling software programs available. For the purposes of this guide, they fall into two categories:

Programs that require little training: Simpler programs that give reasonable estimates of energy use.

- **eQUEST**: An easy-to-use DOE-2-based program with wizards for building model creation and energy efficiency measures. The program displays graphical results and gives good estimates of the potential energy benefits of different efficient options. www.energydesignresources.com

- **ENERGY-10**: A conceptual design tool for making whole-building decisions early in the design phases for buildings of less than 10,000 sf and two zones. The program includes integration of daylighting and generation of energy-efficient alternatives. www.sbicouncil.org

- **System Analyzer** permits a quick evaluation of any building, system and equipment combination. This program can be used to decide what systems are appropriate and how one compares to another in performance. www.trane.com/commercial/software

Programs that require more training: Sophisticated programs that are more accurate and can model more complex systems. They require more expertise.

- **DOE-2**: A widely used program that requires detailed model construction and can accurately predict energy use and cost for all types of buildings.

- **PowerDOE**: Uses a DOE-2 simulation engine for energy and cost calculations with a 2-D or 3-D graphical interface.

- **TRACE**: A building simulation program that compares up to four HVAC systems and estimates life-cycle cost and payback for combinations of systems and controls.

- **HAP**: Like TRACE, HAP is designed to estimate HVAC loads and compare systems. It is an hourly simulation with good correlation to DOE-2 results.
Mechanical/Energy Evaluation

The Mascoma Savings Bank Operations Center is a 40,000 square foot bank and office building in White River Junction, Vermont. The owner and design team were committed from the start to maximize the efficiency of the design. The project enrolled in Efficiency Vermont’s Comprehensive Design Track, which provided some technical assistance and energy simulation services to compare proposed energy efficiency measures to an ASHRAE/IESNA 90.1-compliant base case. One of the most notable measures is the incorporation of an under floor air distribution system (UFAD) into the building.

Efficiency results: The energy efficiency measures resulted in a 43% reduction in energy costs compared to the base case. Lighting power density was reduced to 1.2 watts/sf from 1.4 watts/sf under the base case.

Best EEM package: The following package of energy efficiency measures resulted in an estimated $13,600/year savings in energy and maintenance costs. The payback, after factoring in an incentive from Efficiency Vermont, is less than four years:

- **Improved exterior wall insulation** from 3/4 inch to 2 inches of rigid foam sheathing (R-16.7 to R-29.4).
- **Added roof insulation** (R-15 to R-30).
- **Improved glazing performance** with thermally-broken aluminum frames with double-glazed low-E and argon gas fill.
- **Increased lighting system efficiency** included daylight controls with dimming ballasts to perimeter offices.
- **Revised cooling plant from DX to high efficiency chiller** and reduced cooling loads.
- **Added carbon dioxide-based demand-controlled ventilation.**
- **Changed traditional duct distribution system to UFAD system**, improving occupant comfort and reducing energy costs in fan and HVAC equipment.

Modeling info: The project was modeled with Carrier’s Hourly Analysis Program (HAP). Efficiency Vermont provided some design incentives to cover a portion of the modeling costs and provided technical and logistical support under the Comprehensive Design Track.

Energy status: 43% better than ASHRAE 90.1. Projected energy savings is $13,600 per year.
The windows for the National Resources Defense Council (NRDC) in New York were replaced with operable double-hung windows in keeping with the historic character of the building and the client's preference for natural ventilation.

Infrared thermography pinpoints heat losses quickly. Thermographs are taken at night, preferably in cold conditions. High heat loss areas show as white, low heat loss areas as dark gray or black.

Assess upgrades
Using the results of the energy survey made in Pre-Design, assess the potential performance upgrades or replacement of components, such as:

- **Windows**: Improve daylighting and decrease heat loss with efficient replacement windows, awnings and additional windows. Make sure there are no historic building issues to prohibit this. Window refurbishment, application of low-E films or low-E storm windows to existing windows can improve thermal and air leakage performance if full replacement is not possible.

- **Sealing and testing**: Plan to caulk and seal existing joints that are visible, and use blower door tests or infrared thermography to find other joints and cracks.

- **Insulation**: Increase the R-value of walls, roofs and floors above unconditioned spaces to significantly reduce envelope heat gain and losses, improve comfort and reduce energy costs.

- **Lighting**: Redesign the lighting system to improve lighting quality and energy efficiency. Incentives may be available from utilities and state agencies to accomplish the redesign. As a second choice, replace old fluorescent lamps and magnetic ballasts with more efficient lamps and electronic ballasts. Include a lighting designer if the renovation goes beyond basic replacement. The NRDC office renovation in New York reduced ambient light levels from 50 - 75 foot-candles to 25 - 30 foot-candles, lighting power density from 2.0 watts/sf to 0.4 watts/sf, saving $12,500 per year in electrical costs.

- **HVAC**: If a natural ventilation system was discovered in the existing building, restore it by removing any covered-up elements and replacing operable vents and windows. Replace HVAC equipment with premium energy efficiency models sized according to the performance improvements to the envelope and lighting systems. Increase ventilation rates if needed to meet or exceed current code levels.
Renovation

The Green Mountain Seminary is a century-old building that was unoccupied for several years except for the portion used for the library in Waterbury Center, Vermont. The seminary was purchased by a tax credit partnership headed by two nonprofits and renovated into 16 living units. Because equity was raised through syndication of historic tax credits, the exterior and interior of the building needed to be treated with sensitivity. The project goals included creating a safe, comfortable place to live with low energy costs while maintaining the historic integrity of the building.

The energy-efficient features cost approximately $30,000 and yielded $15,000 energy savings per year in reduced oil and electricity costs. The energy-efficient features include:

**Envelope upgrades:** 8 - 10 inch wall cavities were insulated with densepack cellulose, and the attic was filled with 12 inches of loose fill cellulose. Air-sealing work was done throughout the building with expanding foam and a two-part urethane spray system. The large single-pane windows had to remain, but approved triple-track storm windows were installed to improve glazing performance.

**Lighting upgrades:** Hallway lighting included compact fluorescent fixtures that matched the historic look of the building. Apartments had both linear and compact fluorescent lighting installed to reduce the resident’s bills.

**Ventilation upgrades:** Each unit has a dedicated “exhaust only” vent fan on a 24-hour timer (8 hours minimum) to ensure adequate fresh air and ventilation. The fans are quiet and use a very low wattage split capacitor motor.

**Heating upgrades:** The central heating system consists of several ENERGY STAR boilers with ducted combustion air. Control systems start only the number of boilers needed to meet demand. The boilers also provide domestic hot water and shut down in warm weather. Each unit has its own zone controlled by non-mercury thermostats.

Historic issues: If the building had not been required to follow historic preservation requirements, the team would have recommended that the existing single-pane windows be replaced with double pane low-E argon-filled windows with a warm edge spacer.
Energy professionals interviewed for this guide noted opportunities frequently missed or overlooked by design teams in early design phases. Don’t leave Schematic Design without reviewing this list:

- **Orientation:** Orient the long face of the building within 15 degrees of true south if possible.

- **Energy goals:** Document what the high performance goals are for the building before moving on to the next phase.

- **Energy strategy:** For most commercial buildings, reduce the cooling load by planning a better envelope and better lighting design. Don’t miss the opportunity to increase comfort and decrease ductwork and piping by improving the glazing and envelope so perimeter heating is not needed.

- **Daylighting:** Check the daylighting concept and be sure there is a plan to diffuse or block direct sun.

- **Lighting level:** Reduce the ambient light level wherever possible and supplement with task lighting. The recommended illumination levels from IESNA apply to the task surface and do not apply to ambient conditions.

- **Glazing:** Tailor glazing characteristics to the performance needed. Designate high visible transmittance for daylighting glazing, but lower visible transmittance for vision glazing.

- **“Overglazing:”** Avoid having too much window area compared to wall and floor area, especially on the east and west facades.

- **Shading and light shelves:** Incorporate shading and light shelf devices to reduce heat gains, improve daylighting, reduce glare and improve the exterior appearance of the building.

- **Thermal bridges:** Avoid structural systems and building configurations that inherently create thermal bridging. Examples include cantilevered steel or concrete for decks and metal stud construction without exterior insulation.

- **Load assumptions:** Before engineers size the HVAC equipment, they assemble cooling and heating load assumptions. Ask the engineers to explain their assumptions and question any that don’t make sense. Require that the systems be “right-sized” for the loads.
DESIGN DEVELOPMENT

HOW TO:
- Develop daylighting design
- Select envelope and glazing systems
- Refine lighting systems
- Select mechanical systems
- Review energy performance
- Integrate building systems
AT THE VERY LEAST...

- **Goals:** Compare the design to the performance goals and targets developed in Schematic Design.
- **Envelope:** Confirm all wall, floor and roof assembly R-values against target performance.
- **Develop daylighting system:** Determine projection of shading devices and light shelves, and select daylight and view glazing.
- **Infiltration control:** Review preliminary wall sections and details for airtightness.

PROCESS MANAGEMENT

- **Systems:** Hold frequent coordination meetings to facilitate integration of systems.
- **Specifications:** Request that all consultants add the performance goals to their parts of the specifications.
- **Energy review:** Run the energy simulation with selected systems and material selections. Test efficiency measures that improve performance.

DESIGN ISSUES

- **Daylighting:** Confirm the daylighting strategies used for the project. Integrate glazing location, light shelf design and shading concepts with the exterior design.
- **Glazing:** Select whole window U-factor, solar heat gain coefficient, visible transmittance and tint.
- **Interior choices:** Select color, surface reflectance and ceiling heights that work with the daylighting and lighting system.
- **Mechanical:** Select the HVAC equipment on the basis of input from the consultants and client.
T E C H N I C A L  T I P S

❑ **Commissioning:** Provide design documentation requested by the commissioning agent.

❑ **IAQ:** Request indoor air quality (IAQ) information from the consultants, including which rooms are exhausted to the outside, ventilation rates, air intake locations, filtration efficiency, carbon dioxide sensor locations and relative humidity levels.

❑ **Lighting:** Work with the electrical engineer or lighting designer to locate lighting controls and confirm switching strategies. Include photocells to link the electric lighting with the daylighting system.

❑ **Internal loads:** Confirm that mechanical systems have been “right sized” to meet realistic heating and cooling loads.

❑ **Mechanical optimization:** Review control options with the consultant team in order to select the most appropriate controls. Optimize the systems for performance and comfort by considering natural ventilation, nighttime cooling, heat recovery, etc.

R E N O V A T I O N  I S S U E S

❑ **Restoration:** Incorporate existing light wells, skylights, and other original energy-related features into the design.

❑ **Glazing:** Determine the economic feasibility of replacing glazing, adding interior or exterior low-E storm windows or applying a low-E film.

❑ **Envelope:** Refine the envelope design to accommodate new construction such as insulation, sealing and glazing.
During this phase, the design team should work closely together to refine and integrate the energy concepts. The architect has a critical role that includes organizing the coordination effort, refining the design, providing feedback to the technical consultants and tracking the performance goals.

- **SD summary:** Kick off the Design Development (DD) phase with a summary of what was learned in Schematic Design. Include any revised goals, findings from the energy simulation model, results of cost analysis and potential efficiency measures that need to be evaluated.

- **Systems coordination:** Ask team members to alert the rest of the team when design refinements have a positive or negative performance impact.

- **Iterations:** Some systems or components may need several iterations to be refined properly. Light shelf design, for example, may necessitate computer simulations or physical models to determine whether it will function as assumed during SD.

- **Indoor air quality:** Review ventilation rates, filtration and outside air intake location with the consultants. Develop criteria for material selection that includes reduced air pollutants. Confirm whether the project will have an IAQ plan during construction and, if so, include it in the DD specification.

- **Commissioning coordination:** The commissioning agent usually reviews the system selection at the DD phase. Provide the information the agent needs and carefully review the resulting report and incorporate the recommendations.

- **Life-cycle costing:** Review the cost-effectiveness of the proposed design and systems with the client and team.

**Confirm performance**

During Design Development, the energy design is refined and major systems and materials are selected and specified on the basis of the Schematic Design goals and targets. Confirm performance one of two ways:

- **Running additional energy simulations** with the refined design. Additional efficiency measures usually come to light during the energy analysis.

- **Reviewing the prescriptive E-Benchmark guidelines** to confirm the project exceeds 30% of the baseline design.
Development of the daylighting system requires coordination between the envelope design, materials, electric lighting, controls and mechanical design. Refinements include:

**Shading devices**

- **Exterior shading:** Overhangs, louvers, awnings and other devices block the sun. Shading devices do not have to be solid or flat, though it is common conceptually to show them that way. For example, the exterior shading for Harmony Library is accomplished via curved awnings over windows (sketch at right). The awnings are perforated metal to preserve a view of the sky and allow about 1/3 of the light to pass through. The devices are curved downward to shed snow and rain. In the Northeast region, snowy conditions may require the exterior devices to be sloped, partially open and firmly attached.

- **Projection determination:** The size of the overhang depends on the latitude, facade orientation, energy goals, design concept and budget. Side projections block solar radiation from the east and west. Overhead projections are most effective on the south. The ideal projection can be determined by using solar mask plotting (shading mask protractor over a solar path diagram), tables or nomographs. Figure 4.1 shows examples of projections and the shading pattern they project. E-Benchmark recommends glazing characteristics depending on how much projection is provided.

![Figure 4.1 - Horizontal Projections and Shading Masks](source)

**Source:** U.S. DOE/EIA, 1996

**Daylighting**

Light shelves and other daylight distribution

Light shelves add to the first cost of the project, so it’s important that the design show significant reduction of lighting or cooling loads to offset first cost. If for some reason light shelves are not economically feasible, the team may want to consider other means of daylighting the building, for example:

- The design team for a high-rise mixed-use building in New York City reviewed light shelves and found both cost and maintenance problems. Instead, the daylighting design focused on larger windows, high visible transmittance glazing, interior diffusing shades and daylight-controlled dimming systems. The perimeter of the floor plate (25% of the total area) was effectively daylit. The upgraded glazing and controls saved substantial energy, resulting in a simple payback of 14 months.

If mechanical distribution is in the ceiling, rather than in the floor or walls, ask the mechanical consultant to lay out the distribution to accommodate the light shelves. This includes thinking through the location of access panels and diffusers so they do not conflict with interior light shelves.

**Floor-to-floor height**

Confirm the ceiling height and floor-to-floor heights assumed during Schematic Design. Increasing floor-to-floor height typically impacts the structural and envelope costs. Those costs can be balanced by reduction in mechanical and electrical systems or by simplifying the ceiling design.

**Surface reflectance**

Light colors on interior daylit surfaces greatly improve the efficiency of the daylighting design. Establish minimum percent reflectance for surfaces and specify paints and finishes that meet the goals. For examples of surface reflectance goals, refer to Figure 4.3 on p. 4.8.

**Daylighting controls system**

Lighting controls are crucial to both energy savings and visual comfort. Photocells and time controls are two common daylighting controls for commercial buildings. Photocells measure the incoming daylight and dim or shut off electric lighting when daylight provides adequate illumination. Time controls turn lights off at pre-set times of day.
**Daylighting Integration**
The Society for the Protection of New Hampshire Forests in Concord is the first LEED-certified building in northern New England and one of only a few in the nation to receive a Gold level designation. This innovative office building reflects the conservation focus of the SPNHF and the other nonprofit organizations that are housed in the new addition. The building also has excellent indoor air quality, a graywater system, composting toilets and renewable energy systems. The two-story building was completed in April 2001 at a cost of $107/sf.

**Daylighting analysis:** The building orientation and building form were modeled by both computer and physical models to optimize performance. The model was constructed with interchangeable roofs to allow testing of the daylight performance. The original “sugarhouse” monitor roof did not meet the energy goals. A “butterfly roof” performed better, but the most energy-efficient option was a combination of south clerestory monitors and north-facing skylights. The south clerestory windows provide “sunny day” daylight and the north skylights provide consistent diffuse light. Each office has two large windows placed close to the interior dividing partition in order to bounce daylight off the high-reflectance wall surface.

**Electric lighting design:** Each office has two one-lamp fixtures designed to provide 30 foot-candles of illumination. High quality task lighting is provided in each office to increase the light level for critical tasks. Ambient light in the atrium is balanced by three suspended metal halide fixtures on high-low (100 to 50 %) ballast controls.

**Other innovative features:** The heating system is baseboard hot water provided by a wood-chip boiler. The radiators are exposed and architecturally integrated into the spaces. Each radiator has a separate thermostat to increase the thermal comfort of occupants. Winter ventilation is accomplished by an air-to-air heat exchanger. Summer ventilation is accomplished by natural ventilation from operable windows and transoms (stack effect) and, after hot days, by mechanical ventilation during nighttime. The cupola over the atrium has an exhaust fan that is activated when the outdoor air is cold enough to cool the building.

**Energy Status:** Energy costs are 60% less than the ASHRAE 90.1 baseline. The building attained all the available energy efficiency and renewable energy points in the LEED Green Building Rating system.

**Software type:** ENERGY-10 was used to model energy performance, and physical scale models were also created to test daylighting concepts. For more info: [www.eere.energy.gov/buildings/highperformance/case_studies/](http://www.eere.energy.gov/buildings/highperformance/case_studies/)
As a general rule, efficient lighting uses more fluorescent, metal halide and LED sources and fewer halogen and incandescent sources. During Design Development, the tasks are to refine the lighting design, make fixture selections and check the performance against the goals.

**Refine lighting design**

**Efficacy:** Design for lamps with higher efficacy (lumens per watt) compatible with the desired light source color and color-rendering capabilities:

- **Incandescent:** 16 - 20 lumens/watt (low efficacy).
- **Compact fluorescent:** 60 lumens/watt.
- **T8 with electronic ballasts:** 85 lumens/watt.
- **Metal halide:** 65 - 110 lumens/watt.

**Special conditions:** Review all of the "typical" lighting cases and special cases such as reception counters, display windows, stack lighting, kitchen areas, etc.

**Exterior lighting:** Follow the E-Benchmark requirements for site and exterior lighting. These requirements include: light sources must have a minimum of 60 lumens/watt, lamps of 175 watts or greater must have cutoff features, and all lighting must turn off during the day and meet the lighting power densities (0.06 watts/sf in parking areas, for example).

**Applications:** Discuss best fixture type for each application with the consultants.

- **Parabolic luminaires** vary in design, cutoff and ability to reduce glare. They are not usually the best choice for office areas or classrooms with computer screens. Also, the cutoff features of parabolics don’t light upper part of walls and ceilings, creating the sense of a dark space.

- **Indirect lighting** is an efficient source if the illumination goals are relatively low and the ceiling heights are not unusually high. Indirect lighting reflects light off wall and ceiling surfaces. Illumination of an office area with 10 foot ceilings to 30 foot-candles is very appropriate use of indirect lighting.

- **Direct/Indirect lighting** sends most of the light down but also keeps the ceilings and upper walls bright. This type of lighting creates the feeling of a brighter space at the same foot-candle level as parabolics. Direct/indirect lighting is an excellent choice for offices, schools and other environments with computer screens.
Tune surface reflectance

The efficiency of illumination is controlled in part by surface reflectance and ceiling height. The most important light-reflecting surface is the ceiling. This is true for both daylighting and electric lighting design. A ceiling plane tilted toward the light source will reflect more light. The rear wall is the next most critical surface (across from the window wall or across from the entry door if not a daylit space). The side walls, followed by the floor, have less impact on the reflected light in the room or space. Refer to figures 4.2 and 4.3 for examples of reflectance values.

- **Light-colored**, diffusely reflecting surfaces and furnishings facilitate the distribution of light.
- **Ceiling reflectance** should be 80% or higher.
- **Wall reflectance** should be 50% or higher.
- **Floor reflectance** should be no less than 20%.
- **Furnishings reflectance** should not be less than 25%.
- **Ceiling height/reflectance**: The higher the ceiling and the lower the reflectance, the more light is required to achieve the same illumination at the floor or desk. Figure 4.3 shows that a room with a 17 foot ceiling with 20% wall reflectance has one-third the illumination of a room with a 9 foot ceiling with 50% wall reflectance. Check the reflectance of the paint colors as they are selected. Many paint companies now show the percentage reflection on the back of color chips.

### Figure 4.2 - Reflectance

<table>
<thead>
<tr>
<th>Color</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>80-85</td>
</tr>
<tr>
<td>Ivory white</td>
<td>70-80</td>
</tr>
<tr>
<td>Pearl gray</td>
<td>70-75</td>
</tr>
<tr>
<td>Pink</td>
<td>50-70</td>
</tr>
<tr>
<td>Azure blue</td>
<td>50-60</td>
</tr>
<tr>
<td>Light gray</td>
<td>45-70</td>
</tr>
<tr>
<td>Buff</td>
<td>40-70</td>
</tr>
<tr>
<td>Dark gray</td>
<td>20-25</td>
</tr>
<tr>
<td>Tan</td>
<td>30-50</td>
</tr>
<tr>
<td>Green</td>
<td>25-50</td>
</tr>
<tr>
<td>Brown</td>
<td>20-40</td>
</tr>
<tr>
<td>Red</td>
<td>20-40</td>
</tr>
<tr>
<td>Olive</td>
<td>20-30</td>
</tr>
<tr>
<td>Cardinal red</td>
<td>20-25</td>
</tr>
</tbody>
</table>

Source: AIA Energy Design Handbook

### Figure 4.3 - Ceiling Heights and Reflectance

<table>
<thead>
<tr>
<th>Height</th>
<th>Illuminance w/ 50% wall reflectance</th>
<th>Illuminance w/ 20% wall reflectance</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 ft</td>
<td>1.0 fc</td>
<td>.74</td>
</tr>
<tr>
<td>11 ft</td>
<td>.82</td>
<td>.59</td>
</tr>
<tr>
<td>13 ft</td>
<td>.68</td>
<td>.47</td>
</tr>
<tr>
<td>15 ft</td>
<td>.57</td>
<td>.39</td>
</tr>
<tr>
<td>17 ft</td>
<td>.48</td>
<td>.32 fc</td>
</tr>
</tbody>
</table>

Source: Luminous Design
High performance mechanical systems are the result of teamwork and an integrated design process. Architects don’t always get involved with mechanical selection and refinement, but they should. They can provide a valuable service to the client by facilitating a four-step process:

- **Mechanical system selection**, preferably accomplished during the Schematic Design phase (see p. 3.17 - 3.18).
- **Equipment selection** involves selecting equipment efficiency and capacity, as well as refining the distribution system for water or air.
- **Advanced controls selection** for systems such as ventilation and hot water.
- **System optimization** by looking for strategies to reduce energy use, improve comfort and reduce first cost of equipment and distribution.

### Equipment selection

The mechanical systems in most commercial buildings consist of a combination of standard and custom components designed for each building’s requirements. The efficiency of the parts and the degree of integration are critical to the total efficiency. Discuss equipment and distribution sizing and selection criteria that the mechanical engineer plans to use for the design:

- **Request premium efficiency equipment**: Ask that the equipment meet or exceed the criteria listed in E-Benchmark. The criteria cover air conditioners, chillers, heat pumps and boilers.

  - **Documentation**: Ask that equipment, fan and distribution capacity be based on interior load assumptions developed in Schematic Design, or those recommended by E-Benchmark.

### Advanced controls selection

Discuss controls that will help the equipment or distribution work more efficiently. Control systems that work for most commercial buildings include variable frequency drives (see p. 4.10), economizers, upgraded economizers (dual enthalpy), demand controlled ventilation (carbon dioxide sensors or occupancy on/off sensors), DDC controls and water temperature controls on chilled water, hot water and heat pump loops.
System optimization

After equipment and controls are preliminarily selected, high performance design practice includes optimizing how the equipment and controls work together, equipment upgrades, and brainstorming to improve efficiency even further. Discuss strategies with the team, especially the mechanical engineer and energy consultant, to determine what additional steps can be made to reduce energy use and potentially reduce the first cost. The following strategies taken individually or together can make a large impact on energy use and comfort:

- **Night flush or nighttime cooling**: Eliminate excess heat and remove pollutants by bringing in cool air at night and exhausting via natural or mechanical ventilation.

- **Natural ventilation**: Operable windows and using stack effect to cool certain spaces or the whole building. Use where consistent air temperature is not critical (stair towers, hallways, gymnasiums, etc.).

- **Energy recovery ventilation**: Sensible or latent heat recovery (heat or heat and moisture) to pre-heat incoming ventilation air. Cost-effective for most building types.

- **Variable frequency drives** on supply and return fans, hot and chilled water circulation pumps and cooling tower fans and pumps.

- **Thermal envelope improvement**: Upgrades in R-value for walls and roof, U-factor and SHGC for windows can reduce the need for perimeter heat and reduce cooling loads.

- **Under floor (or near floor) air distribution**: Keeps the tempered air near building occupants and warmer air toward ceiling (see Figure 3.11). Uses high volume, low velocity air system that is more energy efficient than the equivalent ceiling-based VAV distribution system.

- **Multiple boilers or chillers**: Using several smaller units in lieu of one larger unit. Only the boilers or chillers needed to meet the required temperature are on at any given time. These smaller units usually have better part-load efficiency and will cycle on and off less, extending life expectancy of the equipment.

Other strategies discussed elsewhere in the guide include involving a commissioning agent during Design Development, including occupancy controls for ventilation, DDC controls and premium efficiency equipment.

If possible, run energy simulations during DD to test the effectiveness of the strategies, especially packages of strategies that could have a synergistic effect on energy. An example is combining envelope upgrades with night flush and natural ventilation and then review the effect on the cooling loads.
Recent advances in glazing and frame technology for doors, windows and skylights have given architects more choices and much more control over the performance and appearance of glazed openings. Energy efficiency is just one benefit of the new technology. Other benefits are improved thermal comfort for building occupants, better daylighting designs, more connection to the outside and a choice for more or less heat gain.

The most reliable sources of window performance criteria are:

- **National Fenestration Rating Council** (NFRC), which has developed a rating system based on whole product performance. The NFRC label makes comparing and verifying products easier.

- **ASHRAE Handbook of Fundamentals**.

- **WINDOW** computer software program from Lawrence Berkeley National Laboratory.

When developing the design of glazed openings and specifying products, review the aesthetic and performance goals set in Schematic Design. Ask questions such as:

- **Heat gain**: Does the design need to prevent heat gain through glazing or allow it, as in passive solar strategies?

- **Glare control**: On east, west and south faces, what is the glare control strategy? Will there be shading or diffusing devices on the exterior or interior?

- **Insulating value**: Can perimeter heating be eliminated if the window system has superior insulating performance?

- **Ventilation**: Will the building be naturally ventilated and require operable windows?

- **Daylighting support**: Where are the daylit spaces, what direction do the windows face and does the glazing performance support the concept? Review the visible transmittance and solar heat gain coefficient (see p. 4.12) for each glazing under consideration.

- **Thermal breaks**: Do the window frames have effective thermal breaks? Many commercial frame manufactures have more than one type of thermal break, including those with superior detailing. The better the thermal break, the lower the U-factor of the assembly.

- **Detailing**: Do the details show low-expansion foam insulation between windows and wall construction? This eliminates air leakage better than stuffed fiberglass.
**Glazing Terminology**

**U-factor (U)** represents the insulative properties of the entire window, including glazing system and frame. **Total window U-factors range from 0.18 to 1.2.** The lower the number, the better the insulating performance.

**Solar Heat Gain Coefficient (SHGC)** measures how well a product blocks heat caused by sunlight. **The SHGC is a value between 0.0 and 0.87.** The lower the number, the less solar heat the glazing transmits. The solar heat gain coefficient for a window (glazing and framing) is always lower than the center-of-glass value. The type of glass (clear, tinted, coated, etc.), glass thickness and low-E coating surface location all affect solar heat gain properties. For example, the closer the coating is to the outside, the more solar heat gain is blocked.

**Visible Transmittance (VT)** measures how much light comes through a window. Visible transmittance is influenced by glazing type, number of layers, coatings and internal shading devices. **VT varies from 0 to 100%.** Some tinted glass used to reduce solar heat gain also reduces the VT, which adversely affects daylighting. New spectrally selective tints and coatings have made it possible to reduce solar gain while keeping visible transmittance higher. Generally daylit buildings use a high percentage of light transmittance (70 - 90%). If vision glazing and daylight glazing can be separate (daylighting glazing on top of vision glazing), this allows a lower VT in the vision glazing. Refer to Figure 3.6 on p. 3.8 for an illustration of daylighting and vision glazing location.

**Ultra-violet Light Transmittance (UV)** is the fraction of UVA and UVB radiation that passes through the glazing. Limiting UV transmission may be desirable where fading of finishes and furnishings is of concern, but not desirable if the client wants plants to thrive in daylit areas.

**Air Leakage (AL)** is expressed as the equivalent cubic feet per minute of air passing through a square foot of the whole window area (cfm/sf). The lower the AL value, the less the air infiltration or exfiltration. Energy-efficient buildings control leakage with tight window construction and use of revolving doors or double door vestibules at heavily used entrances.
Wall, roof and floor systems

Design Development is a critical period for selection and preliminary detailing of the envelope systems. The following issues should have attention during this phase:

- **Thermal resistance:** Determine R-value or U-factor for each major assembly prior to finalizing the system. If unsure how to calculate R-value of an assembly, refer to one of the resources listed or ask the mechanical consultant for assistance. The assembly R-value should be no less than allowed by ASHRAE 90.1 or the local code.

- **Thermal bridging:** Envelope areas that have significantly higher rates of heat transfer than other areas are said to have thermal bridging. Steel framing causes thermal bridging through the wall system. For example, a wall with 6 inch steel studs at 16 inches o.c. with R-19 insulation has an effective R-value of only 7.1 due to thermal bridging effects. If only one inch of polyisocyanurate foam insulation is applied to the exterior of this assembly, the effective R-value increases to R-16, in large part because of reduced thermal bridging effects.

- **Moisture and condensation control:** Condensation can occur in wall cavities if the temperature within the cavity falls below the dew point of the inside air or because of thermal bridging effects. Use of exterior insulation has the effect of keeping the interior of the wall above the dew point temperature. This is generally a better approach than using a polyethylene vapor retarder. Refer to the ASHRAE Handbook of Fundamentals and HVAC Applications Handbook for more information about condensation and moisture diffusion.

- **Air leakage:** All joints and penetrations in the envelope are potential sources of air leakage. Refer to Chapter 5 (p. 5.5 - 5.6) for more information. For this phase, be aware that some wall and window types allow more leakage than others. For example, brick-on-stud walls are more difficult to seal than stucco-on-block, and may require an air/vapor retarder membrane.

- **Intersections and changes in material:** Think through the intersections of the wall, floor, ceiling and roof systems and detail them to maintain continuous R-values, air leakage and water control. Cavities, floor/wall or wall/roof intersections and foundation/ground conditions all deserve attention at this phase to identify systems that maintain envelope continuity.

---

**Resources:**

ASHRAE/IESNA Standard 90.1 User’s Manual
www.ashrae.org

E-Benchmark Advanced Building Guidelines
www.newbuildings.org

Information taken from ASHRAE 90.1 Table A-10 Assembly U-factors for steel framed walls.

High performance buildings in the Northeast region are beginning to use exterior insulation (polyisocyanurate, mineral fiber board, etc.) and skipping the batt insulation between studs entirely. Three inches of polyisocyanurate provides a true R-20. The Leahy Center used four inches of continuous recycled, semi-rigid mineral fiber (no insulation between the studs) over a fluid-applied waterproof membrane to create a wall system with a high R-value and an integral air barrier, vapor retarder and drainage plane. (Refer to p. 4.4)
Glazing and Envelope Integration

The Leahy Center for Lake Champlain in Burlington has an exemplary envelope design. The design team worked together to create a well-integrated and efficient shell that allowed them to reduce the size of the cooling and heating system. The team also employed daylighting in some spaces, an efficient lighting design, an energy recovery system and efficient equipment. The design saves the Center $15,000 per year in energy costs.

High performance glazing system:

- **Thermal efficiency:** Windows are triple pane with one low-E coating and argon fill. The frames are thermally broken and the system has a thermal efficiency of R-4 (U-0.25).

- **Operable:** Windows in the glass rear exit stair tower automatically open and close in response to temperature changes. This allows natural ventilation of the stair tower with a fan system as backup.

- **Continuity:** The exterior shell is detailed to allow the thermal break in the windows to be in line with the exterior insulation of the wall. Placing the windows in this way ensures continuity of the thermal and air leakage barrier systems of the envelope.

- **Thermal comfort:** Because of the high efficiency of the glazing and envelope systems, no perimeter baseboards or radiant panels are needed under the windows to keep the occupants comfortable. This saved the first cost of the baseboards as well as future operation and maintenance costs.

- **Lighting:** The sophisticated daylighting and lighting design features T5 lamps, occupancy sensors, time controls and photocells that turn off metal halide fixtures in the atrium whenever possible. The lighting power density is about half the code-suggested level for this building type.

Energy Status: Energy costs are 30% less than the ASHRAE 90.1 - 2001 baseline.

The team on this project included a lighting consultant, energy consultant and commissioning agent who helped them achieve this integrated and efficient design. Refer to Chapter 7 for more information about the team.


**Indoor Air Quality**

Refinement of the mechanical and envelope design should include development of an indoor air quality plan. Enough is known about the mechanical equipment and distribution system to move on to ventilation, filtration, and pollutant source control. These are the fundamental elements of an indoor air quality plan.

Ask the mechanical consultant to review ventilation rates for each type of space and other requirements of ASHRAE Standard 62, *Ventilation for Acceptable Air Quality*. High performance projects further protect IAQ by reviewing:

**Materials:** Identify finish and insulating materials with low or zero Volatile Organic Compound (VOC) content. This includes wall and ceiling insulation, carpeting, paint, sealants, adhesives and other finish materials. The LEED rating system has a checklist of IAQ requirements for materials. This list can be used to benchmark IAQ performance even if the project is not pursuing LEED certification.

**Ductwork insulation:** Discuss using ducts insulated on the outside instead of the inside with the mechanical consultant. Outside insulation simplifies periodic duct cleaning and prevents microbial growth in the duct liner over time.

**Filtration:** Review the filtration options with the mechanical consultant. Ask for recommendations for appropriate filtration for the selected air distribution system. LEED recommends certain filter effectiveness (refer to the Indoor Environmental Quality section of the LEED system) and to change filter media prior to occupancy.

**Avoid airborne pollutants:** Consider only sealed combustion equipment, and exhaust spaces such as copy rooms and janitor closets to the outside. The LEED system also recommends extending the walls of all exhausted spaces to underside of structure and placing walkoff mats at all main entrances to remove particulates from shoes.

**Air intakes:** Confirm air intakes are not near loading docks, exhaust fans or other sources of outdoor air pollutants.

**Construction IAQ:** The construction process generates high volumes of particulate matter and VOCs that affect IAQ during and after construction. Consider requiring an IAQ plan for construction to protect ductwork, equipment and the health of workers. Refer to the LEED system and p. 5.8 for more information.
Some projects that use energy simulations in SD don’t continue to run them in Design Development. Since the time-consuming part of creating the building model has already been accomplished, additional runs are usually inexpensive but valuable. DD simulations can assess the effectiveness of alternative mechanical systems, glazing changes and calculation of paybacks and life-cycle costs.

The Building Life-Cycle Cost (BLCC) computer program was developed by the National Institute of Standards and Technology (NIST) to clarify energy efficiency choices.

www.eere.energy.gov

If the project is participating in the LEED Green Building Rating System, the end of Design Development is an important time to check on the status of each credit identified for certification.
System Integration

The Leahy Center for Lake Champlain assembled a complete team, including a lighting designer, energy consultant, construction manager and commissioning agent. This team structure enabled a high level of system integration and energy savings. To help defray the costs of this process, the team secured incentives from Burlington Electric Department and Vermont Gas.

System integration results:

- **Downsizing:** The mechanical, electrical and envelope design saved 15 tons of cooling capacity and 300,000 Btu/hour of heating capacity. This reduced the first cost for mechanical and electrical equipment.

- **Efficient envelope:** The roof, floor, walls and windows all exceed ASHRAE 90.1 requirements.

- **Energy recovery:** Ventilation air comes through a unit that recovers the energy in heat and moisture from air exhausted from the building.

The incentives and funding support helped the Center achieve energy savings estimated at $15,000 per year compared to a code-compliant base design.

**Commissioning:** Rigorous commissioning started in the design phases, continued during construction and after the building was complete. Inclusion of a third-party commissioning agent made the process smooth and eliminated any apparent conflict of interest. The commissioning agent was involved with all major building systems (see p. 5.10 for more information).

**Air leakage control:** Details at joints and material transitions were carefully detailed to minimize air leakage. Sprayed-on wall membrane outside the stud wall and behind the mineral fiber exterior insulation also served as an air barrier and vapor retarder. Blower door testing showed only 0.2 winter air changes per hour, verified by blower door tests.

**Innovative ideas:** High efficiency heat pumps provide cooling for the exhibit fish tanks in winter when the main chiller is not running, and the high efficiency chiller cools through an evaporative cooling tower but has a provision to connect to the lake for heat rejection.
CONSTRUCTION DOCUMENTS

CHAPTER 5

How to:
- Coordinate systems
- Document efficient envelope design
- Specify windows, doors and skylights
- Explain commissioning benefits
- Specify energy performance
- Participate in commissioning
AT THE VERY LEAST . . .

❑ **Architectural**: Meet the envelope insulation, glazing and infiltration requirements of ASHRAE/IESNA 90.1, or better yet, the minimum prescriptive criteria of the E-Benchmark program.

❑ **Lighting**: Review lighting design efficiency and maintain the integrity of the lighting concept.

❑ **Mechanical**: Ask the consultant team to provide a status report of mechanical and plumbing system energy efficiency half way through Construction Documents.

❑ **Infiltration control**: Review exterior details for potential air infiltration problems. Review effective placement of flashing, sealant, foam or caulking.

MANAGEMENT ISSUES

❑ **Coordination**: Hold a consultant meeting mid-phase and discuss whether the building systems are on track to meet the performance goals.

❑ **Budgeting**: Suggest that the owner or contractor develop a contingency budget that will cover “fine-tuning” of design or equipment during construction.

❑ **Energy modeling**: Make an integrated run of the energy simulation to capture the final selections of mechanical and electrical equipment and systems.

TECHNICAL TIPS

❑ **Schedules**: Create master window, door and skylight schedules with thermal and daylighting performance shown for each assembly.

❑ **Thermal breaks**: Detail and specify thermal breaks in exterior window and wall systems.
Insulation: Check that details show continuous insulation at all joints and envelope transitions. Confirm all R-values for assemblies.

Daylighting: Finalize detail development of light shelves, sun shades and other daylighting features.

Coordination: Review the lighting design with other systems that impact luminaire and photocell placement, such as partitions, furniture, mechanical diffusers and fire protection devices.

Lighting review: Ask the lighting consultant to run photometric plots and check that light levels are consistent with the goals. Check task areas in particular, and that non-task areas are not over-lit.

Mechanical systems: Ask mechanical consultants to confirm that equipment efficiency and indoor air quality measures meet the performance goals.

Specifications

Documentation: Review specifications and make sure they include efficiency and performance requirements for all major systems. Include commissioning requirements in the specifications.

Energy goals: Include explanation of the high performance goals in Division 1 of the specifications.

Renovation Issues

Envelope: Review details to confirm insulation levels, thermal breaks and air sealing.

Commissioning: Tailor the commissioning requirements both to existing systems that will remain and to new systems.
Most of the major decisions about energy efficiency have been made by the time the Construction Documents (CD) phase begins. This phase is spent refining, documenting the design and checking for consistency with the performance goals.

Review of 50% complete CDs is a common milestone for projects. This review is an appropriate time to confirm the performance of each major system, particularly if the project has not been checked during previous phases. Review of the site, envelope, glazing, lighting and mechanical systems can help teams avoid performance problems at the end of the CD phase, when there is neither time nor budget to make fundamental changes. Consider holding a coordination meeting with the consultants to discuss the system integration. At the coordination meeting:

► **Review the design implications** of any needed changes, such as improved glazing or deeper shading devices.

► **Identify and resolve space constraints** that impact efficiency, such as limited space for mechanical systems.

► **Confirm the efficiency** of mechanical and lighting systems and equipment by asking consultants to check for compliance with the performance goals.

► **Brainstorm ideas** to improve building performance.

► **Encourage the team** to remain vigilant about saving energy and improving building performance.

► **Review documents** for conflicts and coordination problems between systems, especially between lighting and other ceiling-based systems.

► **Include the commissioning representative** and ask for a focused review of the major building systems based on the 50% drawings and specifications prior to the meeting.

► **Request an update to the energy simulation** if significant changes have occurred to the envelope or mechanical or lighting systems.

“Value Engineering” at this stage is especially onerous for high performance buildings. Changes or reductions in performance in one system usually adversely affect other building systems and operational costs. Use the investment criteria established early in the project to identify the cash flow implications of changes. Steer clients away from evaluating changes only on first cost and show them the long term cash impacts.
Refine the lighting design and maintain the performance goals with the help of the consultant team:

**Photometric plots:** Ask the consultant responsible for lighting to run photometric plots for all public and primary spaces. The photometric plot will show foot-candle (fc) distribution within the room. Make sure the task area lighting meets the illumination target and look for good distribution. Identify areas that are too bright or dark or that have too much contrast. Also review the light distribution on walls that are design elements or that affect tasks, such as teaching walls in classrooms.

**Controls strategy:** Ask the consultants to confirm which rooms receive controls, such as occupancy sensors, photocells and time controls. The types of occupancy sensors are:

- **Dual technology:** The most commonly used and reliable occupancy sensor includes both infrared and ultrasonic technology. It is appropriate for any space.

- **Infrared:** An infrared-transmitting lens creates horizontal and vertical detection zones (Figure 5.1). Motion across one or more zones within a specified time period keeps lights on. Infrared is suitable for exterior use and for rooms that have good air mixing and little stratification of warm air.

- **Ultrasonic:** High-frequency sound waves from the sensor are reflected by the room. Motion changes the reflected sound wave pattern and the sensor turns lights on (Figure 5.2). Lack of motion turns lights off. Avoid use if people with hearing aids will be using the space.

**Coordination issues:** The lighting design is often altered to accommodate other systems, such as mechanical supply and return diffusers. Energy-efficient lighting usually has geometric constraints that are almost as stringent as those for fire protection. Give high priority to life safety, lighting location and illumination levels, then the needs of other building systems. If the building is designed to harvest daylighting, make sure photocell controls are shown on the electrical drawings and located in the daylit zone.

**Control “Value Engineering”:** There is usually very little slack in a well-designed energy-efficient lighting system. Review product performance of less-expensive fixtures before agreeing to include them. If lighting changes are suggested, ensure that lighting quality, purpose and operational costs are included in the decision making.
Document energy performance by showing thermal performance on the drawings and in the specifications. Sources for thermal performance include ASHRAE/IESNA 90.1 (or local code), the E-Benchmark program and the National Fenestration Rating Council (see p. 5.7). The following information should be included in the Construction Documents:

**Exterior walls**
- **Caulking**, gasketing, weatherstripping and other sealing of joints, cracks and holes.
- **Wall insulation R-value** on wall sections, including below-grade walls and those adjacent to unconditioned spaces.
- **Door U-factor or R-value** on door schedule.
- **Details on the insulation method**, whether between studs or an exterior system. Dense-pack cellulose and spray-applied foam are effective between studs. A very effective system for the Northeast climate is three inches of rigid exterior insulation with no batts between studs. Check that details show all joints and transitions between exterior materials.
- **Specifications on glazing U-factors**, solar heat gain coefficient and visible light transmittance for overall assembly on window schedule (see p. 5.7).
- **Specifications on window frame type**, glazing layers, gap width, low-E coatings and gas fills.

**Roofs**
- **Insulation R-values** on roof sections/assemblies.
- **Baffle vent openings** for eave vents to deflect incoming air above insulation. Avoid fiberglass batts in steel roof rafter construction.
- **Insulation of parapet walls** and extend vapor retarders, if any, to prevent condensation within the parapet cavity (Fig. 5.3).

**Skylights**
- **U-Factors** for overall assembly on skylight schedule.
- **Specifications on frame type**, glazing layers, gap width, low-E coatings, gas fills, etc.
- **R-value** of skylight curb insulation (Figure 5.4).
- **Specification of maximum infiltration rates** (cfm/sf).
Air leakage

- **Window air leakage rates** on window schedule.
- **Door air leakage** rates on door schedule.
- **Details on sealing at joints** around window and door frames; joints between wall panels; and openings in walls or floors for plumbing, electrical or mechanical penetrations with caulking or sealant.
- **Overall leakage rate** for smaller buildings (no more than 0.35 natural air changes per hour), usually confirmed by blower door test.

Slabs on grade

- **Perimeter insulation R-value** on building sections.
- **Insulation position**, depth and length.
- **Above-grade** exterior insulation protected from damage from ultraviolet light, moisture or impact.
- **Continuous vapor barrier** provided under slabs.

Floors over unconditioned spaces

Conditioned floor space above parking garages, crawl spaces or other unconditioned spaces should be insulated and air-sealed for energy efficiency, comfort and indoor air quality. The insulation should be installed without an air space between it and the floor underside (insulation value is poor because of high air infiltration in garages). Be sure to document:

- **R-value for floor assembly**, making sure that insulation is in substantial contact with the floor.
- **Air barriers** are essential between unconditioned and conditioned space to prevent air leakage and eliminate transmission of harmful gases or mold from these spaces.

Thermal breaks

Review all exterior details for thermal bridging potential. A steel stud wall without exterior insulation creates a thermal bridge, as do uninsulated slab edges (Figure 5.5) and under-insulated parapet walls. Any metal or concrete construction not insulated on the exterior is subject to thermal bridging, increasing heat loss and the potential for condensation within the wall cavity.↑

Refer to the ASHRAE HVAC Applications Handbook, Chapter 43 - Building Envelopes for more information.
The National Fenestration Rating Council (NFRC) develops national energy-performance rating systems for windows and doors. All NFRC-rated windows are tested to measure energy transfer through the entire window unit. The temporary NFRC label (below) is affixed to certified windows and provides a means to compare windows and to verify that products installed are consistent with the specifications. The permanent NFRC label is a serial code etched on an inconspicuous part of the window, such as a spacer or metal strip.

www.nfrc.org

G L A Z I N G  S P E C I F I C A T I O N

Windows and doors

Include energy performance criteria in the window and glazed door schedule to better integrate energy efficiency into the documents and make it easier to evaluate submittals during construction. Refer to the ASHRAE Handbook of Fundamentals, E-Benchmark program, ENERGY STAR program or the National Fenestration Rating Council for window performance data. An appropriate schedule includes the following:

- **Dimensions** for the frame or rough opening.
- **U-factor** of the window assembly, not the center of glass. Include any warm-edge spacer requirements.
- **Solar heat gain coefficient**.
- **Visible transmittance** for daylighting glazing and view glazing.
- **Low-E coating** or film emittance.
- **Tint color** and location (outer or inner glass).
- **Frame type** (material, fixed or operable, thermal break).
- **Infiltration limits**, often met by referring to ASTM E283-89 for windows and doors, and by specifying less than 0.05 cfm/sf for skylights.

Skylights

Skylight schedules include the same information as the window and door schedule, plus the following:

- **Curb size and material**.
- **Curb U-factor or R-value**.
- **Presence of louvers or light-diffusing glass**.

Check the percentage of skylight area compared to roof again at this phase to make sure the design balances the potential heat loss and solar gain with the daylighting benefit (the optimum skylight area in Vermont is approximately 3%). Coordinate with the mechanical consultant, energy consultant or use SkyCalc software (see p. 3.11). Consider adding a requirement to the specifications that the architect or commissioning agent review the first skylight installation for adherence to the construction document intent.
Review the mechanical design with the consultants to confirm that performance targets have been met and that mechanical systems are properly coordinated with architectural and lighting systems.

**Equipment efficiency:** Ask the mechanical consultant to document that the specified equipment meets the performance goals for the project. If the team is using a prescriptive method, ask the consultant to provide the minimum requirements along with the actual performance for boilers, furnaces, domestic hot water, chillers, air conditioning units, pumps, fans and controls. If using energy simulations, request a final run incorporating the most recent information about the building (see energy modeling below).

**Indoor air quality:** Specify the indoor air quality (IAQ) requirements during and after construction. Consider including best practice IAQ measures such as:

- **IAQ during construction:** Use Sheet Metal and Air Conditioning Contractors’ National Association (SMACNA) guidelines for IAQ, including protecting ductwork, avoiding moisture damage during construction and replacing filters prior to occupancy.

- **Building flush-out:** Ventilate with 100% outside air for at least two weeks prior to occupancy.

- **Ventilation standards:** Meet or exceed the provisions of ASHRAE Standard 62 for quantity of ventilation, filtration and air quality requirements.

- **Reduce indoor pollutant sources:** Specify low-toxicity, low volatile organic compound (VOC) materials and finishes, exhaust copy rooms to the outside and limit particulates coming into the building.

**Energy modeling:** If the project is using energy simulations to document building performance, ask the modeler to make a last run using the final selections for insulation, glazing, plumbing, mechanical and lighting systems. This is especially critical if there have been any significant changes since the last energy simulation.

**System coordination:** Review locations of lighting, mechanical diffusers, thermostats, controls and other equipment. Prepare sections of the space above the ceiling at cross-over points and other areas crowded with systems to ensure adequate space for each.
A commissioning agent can be most helpful if involved throughout the design process, but preferably no later than midway through the CD phase. A focused review is required by the LEED program and highly recommended as a best practice for high performance design. The results of the review are usually included as a report issued by the agent.

**Who specifies commissioning?**

The specifications should spell out the extent of the commissioning effort, who does the commissioning, when certain activities will take place and what documents need to be produced. The specifications should also clearly state the requirements for contractor participation in commissioning activities. The specification should require that each system meet the detailed performance specification prior to final acceptance. The commissioning agent can provide the specification language, or the design team can tailor one of the available commissioning “boilerplate” specifications. Develop a formal plan to manage potential conflicts of interest if members of the design team participate as commissioning agents. To avoid the conflict, clients may prefer to employ a third party to prepare the specifications. Third parties might be:

- Independent mechanical and electrical engineers with commissioning experience.
- Commissioning specialists.

**Cost benefits**

Commissioning typically improves the operating efficiency and equipment longevity. Energy savings alone result in paybacks of less than three years in most cases. A study conducted by Portland Energy Conservation, Inc. reported energy savings due to commissioning of up to $0.42/sf (based on new construction of greater than 25,000 sf).

**Renovation commissioning**

Owners of existing buildings can benefit from commissioning to optimize building performance. Another PECI study showed that if 1% of all existing U.S. commercial buildings greater than 25,000 sf were commissioned each year:

- 285 million sf would be commissioned; at a cost of $48.4 million ($0.17/sf); saving 3,370 billion Btu (12% energy savings); and saving $46 million per year (providing a simple payback averaging about one year).
**Commissioning**

A high performance building relies heavily on the proper functioning of its systems. This in turn relies on the proper design, installation and calibration of the equipment, lighting, ductwork, plumbing, sensors and controls that direct each system. Problems in the installation or calibration of these systems results in buildings that are less comfortable and more expensive to operate.

The Leahy Center for Lake Champlain in Burlington, Vermont, benefited from the involvement of a commissioning agent during design and construction phases. The agent conducted a focused review during design and made suggestions that helped reduce energy use or avoid duplication. The suggestions included:

- **Reduce the chiller energy use** 50% by resetting cooling tower water cooler as outside temperatures moderate.
- **Reduce fan energy use** by connecting room occupancy sensors to the VAV controllers, avoiding unnecessary airflow to vacant rooms.
- **Close heating vent** in the stair tower when the high windows open to vent excess solar gain.

During construction the commissioning agent methodically applied a quality assurance program, noted any problems and made sure modifications were made. The agent found control system deficiencies or omissions that might otherwise not have been found because some of them did not impact occupant comfort, only system performance:

- **Water treatment systems were omitted** for the cooling tower. This would have resulted in corrosion inside the chiller and cooling tower.
- **Central exhaust fan used excessive energy** due to a closed damper.
- **Boilers were short-cycling** which would have reduced energy performance and equipment life.
- **Heat tracing for cooling tower piping was missing,** which would have eventually caused pipe rupture.
- **The heating plant didn't meet the required heating water temperature** because of poor coordination between building controls and startup technicians.

**LEED certified:** The Center is a LEED-certified Green Building, one of the first in the Northeast region. The project excelled in energy efficiency, indoor air quality and gained extra points for its thorough commissioning process.

Remote monitoring from the commissioning agent’s office identified and corrected several post-occupancy problems without inconveniencing the operations staff.
The end of the Construction Documents phase is an opportune time to document the performance of the building design. Assemble information that includes comparisons between the early Pre-Design goals and the final design. The information may include:

**Goal status:** A checklist or matrix that lists the goals from Pre-Design and the performance of the final design. If using the LEED or E-Benchmark programs, fill out the checklists and compare them to the original goals. If targeted points were lost during design, identify the reasons they were lost, so that the same problems can be avoided in future projects.

**Commissioning CD phase report:** The report from the commissioning agent who reviewed the Construction Documents that highlights particular suggestions or recommendations that are relevant for the Construction Administration phase.

**Photometric plots:** The illumination studies done to confirm the lighting level and lighting design.

**Controls strategy:** The control type, location and integration with lighting and mechanical systems. Ask the mechanical consultant to provide a narrative of the controls strategy in plain language so that the information can be shared with the client and later with building occupants (refer to Chapter 6).

**Final energy model:** If energy simulations have been conducted for the project, include the earliest and latest run. This data may be required, depending on the rating or evaluation system the project is using, and it is always educational for designers to see how energy performance is affected by design decisions.

**Specifications:** Be sure that the project goals are listed in Division 1 of the specifications so potential bidders know about the performance expectations. Explain commissioning activities and documentation the contractor is expected to keep to track performance for the client or for a rating program. Refer to Chapter 6 for suggestions for submittal and substitution review procedures.
POST-DESIGN

CHAPTER 6

P O S T - D E S I G N

How to:
- Include contractors on the energy team
- Review submittals and substitutions
- Observe energy-related construction
- Coordinate with commissioning agents
- Review performance during construction
- Conduct a building performance evaluation
CHECKLIST

AT THE VERY LEAST . . .

❑ Coordination: During the pre-bid meeting with potential contractors, include an agenda item about the energy-efficient design and goals for the project.

❑ Substitutions: Be prepared to deny substitution requests if the proposed product or system is less energy-efficient than what is specified.

❑ Submittals: Review submittals carefully to make sure the product or system is as specified.

PROCESS MANAGEMENT

❑ Presentation: Enlist the contractors’ help in realizing the performance goals. Present the high performance features to the contractor and subcontractors during bidding and show them how they are documented.

❑ Meetings: Include the status of building performance and energy goals in construction meeting agendas.

❑ Commissioning: Confirm the construction team’s participation in the commissioning process.

CONSTRUCTION ADMINISTRATION

❑ Glazing: Review windows, doors and glazing for NFRC labels and compare with specified performance. Review the first complete installation to ensure the design intent is being followed.

❑ Skylights: Review skylight, flashing and sealant installation and specified thermal performance. Look for potential problems for air or water leakage.

❑ Envelope: Confirm the R-value of specified materials on site and look for voids and other installation problems. Review potential air-sealing problems such as joints without proper caulking or sealant.
COMMISSIONING

❑ Lighting: Walk through the project with the electrical or lighting designer and ensure that fixture location, lamp color (CRI), light levels, controls and switching are consistent with the documents.

❑ Shading: Fine-tune the shading system to prevent direct sunlight from reaching work surfaces or creating glare.

❑ Mechanical & Electrical: Ask the consultants to brief the rest of the design team about the findings of M&E system commissioning. Use the results to improve the next project.

POST-OCCUPANCY

❑ User manual: Provide a user manual for occupants that explains how the high performance, energy-efficient building works, how to make minor adjustments and who to call if there are problems. Include occupant training on complex systems.

❑ Evaluation: Conduct a building performance evaluation one year after construction. The evaluation should include energy use and utility costs, and may include water use, occupant comments and financial performance.

RENOVATION ISSUES

❑ Evaluation: Evaluate the renovated building’s energy use and utility costs at least one year after completion.

❑ Commissioning: Conduct commissioning on the envelope and mechanical/electrical systems similar to new construction.
The goal during the bidding and construction phases is to maintain the design intent of the project. For a high performance building, this means being vigilant about systems or materials that contribute to the overall performance. This requires teamwork and commitment to the goals all the way through construction and post-occupancy.

**Pre- and post-bid coordination:** Let the contractors know from the beginning, starting with the pre-bid conference, that they are important members of the performance team. Design team members who are familiar with the high performance design should make a presentation to the contractor and subcontractors soon after award of the contract. Review the whole project and point out high performance design features and systems. Share any evaluation systems that will be used on the project, such as the LEED program, or minimum performance requirements, such as airtightness or ENERGY STAR rating.

**Construction meetings:** Include energy and performance goals and questions as a standing part of the construction meeting agenda. This helps keep the focus on the design intent and creates a forum for ideas to improve system performance or to avoid problems.

**Substitutions and submittals:** Building performance can be compromised during the substitution process. Unless the contractors understand the energy goals, they may make suggestions to save money or time by substituting a product that has less-efficient qualities. A good example is glazing. Suppose the building design has been fine-tuned for specific performance and a substitution request comes in for a similar product with a higher solar heat gain coefficient. Review a change like this with the specification and with the design team. It may be that an apparently simple change in glazing can adversely affect the cooling loads and the size of the mechanical equipment. When reviewing substitutions:

- **Look for energy-related and building performance features** in addition to other criteria that are used to review substitutions or change order requests.
- **Ask the consultants** to alert the architect if any substitutions or submittals in their area of expertise appear to have lower than specified energy efficiency.
- **Be prepared to reject** products or systems that do not meet the energy goals.
Field Observation
In addition to other field observation duties that the architect may have, review building components to verify that construction is consistent with the documents and design intent for high performance, such as:

Envelope

- **Insulation R-values** meet the minimum and no voids or compressions are apparent. Blown or sprayed insulation may be tested for installed thickness, settled thickness, and coverage.

- **Air leakage control** measures have been implemented. Smaller buildings can use blower door testing to confirm air leakage rates. Infrared photography can pinpoint missing joint sealant and other potential leaks.

- **Moisture and water control** measures are properly installed and have good continuity.

- **Shading devices and light shelves** are mounted with the correct projection and use the specified materials.

Glazing and Skylights

- **NFRC labels** for windows are checked, preferably prior to installation, for confirmation of U-factor, solar heat gain coefficient, visible light transmittance and other important glazing attributes such as tint, low-E coatings and gas fills.

- **Glazing and skylight openings** are properly flashed and sealed. Skylight curb R-value meets the specifications.

Lighting

- **Controls, switching and dimming** function as designed. Daylight control settings turn the appropriate lights off or dim them.

- **Light fixture** type, number, location, lamp type and color (CRI) are per the design documents.

- **Visual quality problems** such as glare or direct sunlight penetration in inappropriate places, such as offices or classrooms are solved. Propose solutions such as diffusing shades or other means to reduce or reflect light.

Mechanical

- **Thermal controls** function properly and the spaces are comfortable. Ask the consultants or commissioning agent to confirm that efficiency of HVAC equipment, control functions and sensor locations are per the documents.
The commissioning process for high performance buildings starts during the design and construction documents phases, then continues through construction and post-occupancy. If the commissioning process does not start until the construction phase, important benefits can still be achieved in the final building performance. Confirm with the client what types of systems the commissioning will cover:

- **Whole building, including the exterior envelope.**
- **HVAC, controls, electrical and lighting systems.**
- **HVAC and controls only.**
- **Electrical power/lighting systems and controls only.**

The commissioning process is not rigid and can be tailored to individual building types and available budgets. The architect’s role in commissioning varies depending on the extent of commissioning and whether a third-party commissioning agent is part of the team. Whoever oversees the commissioning effort during construction can be more effective by organizing prior to beginning construction:

- **Set a kickoff meeting:** Assemble the commissioning team members to confirm the scope, process and end result of the commissioning effort. The team may include an owner representative, project manager, design architect and engineers, contractor, mechanical and electrical contractors and commissioning agent.

- **Confirm the systems** that will be commissioned.

- **Review the requirements** of the specifications and any certification programs that the project is trying to meet. Examples are E-Benchmark, LEED and ENERGY STAR rating systems. Refer to the Chapter 7 Resources section for more information.

- **Establish a record-keeping process** that tracks information that will be needed for certification programs, the commissioning report and the operations and maintenance manual.

- **Encourage communication** between members of the commissioning team. Foster teamwork and focus on making the adjustments necessary to the materials, systems and controls without assigning blame or creating an atmosphere where design professionals or contractors fear full participation. 

Recent focus group studies have found that building owners and their representatives repeatedly stressed lack of communication between the design and construction teams as a major impediment to building performance. *CHPS Best Practices Manual, 2002.*
Commissioning agent activities during construction include:

- **Review submittals** for equipment and the operation and maintenance manuals prepared by the contractor.
- **Visit the construction site** periodically and note conditions that might affect system performance or operation.
- **Review construction checklists** or other pre-functional documentation prepared by the general contractor and the subcontractors. Any problems noted are brought to the attention of the contractor at this stage. This procedure can significantly cut contractor call-backs after construction is complete.
- **Coordinate with building operations staff** so they better understand the proper operation of equipment and systems.
- **Write progress reports**, if required, to document results of reviews that may adversely affect future building performance.
- **Document and verify** the proper operation of equipment and systems per the design documents and any change orders. Most often, the contractors and subcontractors conduct the tests and the commissioning agent oversees and documents. Acceptable performance is reached when equipment or systems meet specified design parameters under full load and partial load conditions in all modes of operation.
- **Write a final commissioning report** and submit it to the building owner for review. The report can be as comprehensive as the building owner specifies. The report is usually combined with as-built documents, system descriptions, sequence of operation descriptions, locations of all controls, seasonal startup and shutdown procedures and a list of recommended maintenance procedures.
- **Recommend systems** that would benefit from re-commissioning after the one-year warranty phase and two to five years after completion to maintain the savings gained in the initial commissioning process.
- **Recommend training** needed for building staff who will be operating and maintaining the building.

**Commissioning costs** vary considerably depending on the scope. “New Construction Commissioning Costs,” PECI, is a good source for cost of commissioning services. It is available as a PDF on www.peci.org.

If the whole building is being commissioned, it is a best practice to include evaluation of the performance of the exterior envelope. A review by the architect or commissioning agent should include thermal performance, air and water leakage assessment of walls, roofs, windows, skylights and joints between dissimilar materials. This improves the performance of the building and also reduces contractor call-backs.

Review the commissioning report findings with the design team. It can be used as a quality assurance program that leads to changes in specifications or design of future projects.
Near the end of the warranty period, usually one year after construction is complete, it is a best practice for designers to conduct a post-occupancy review to determine how well the building is performing. This review covers many of the qualitative factors of how humans interact with buildings that don’t come to light during commissioning. A traditional post-occupancy review focuses exclusively on the perspective of the building users. High performance buildings benefit from a broader review that also includes energy use and costs, durability, even financial performance. This type of review is termed “building performance evaluation.”

Prior to commencing the evaluation, confirm what questions the design team and client want to answer and then devise the method to answer them. There are multiple benefits to conducting a building performance evaluation:

- **Short-term** modifications or repairs can be made to fix problems or poorly performing systems and materials, thus improving occupant experience and client satisfaction.
- **Mid-term**, designers and clients can use the feedback to improve subsequent projects.
- **Long-term** evaluation results help generate criteria that can improve building design and construction practices.

Components of a building performance evaluation usually include:

**Survey occupants:** The input from occupants is an important, and cost-effective, way to find areas that need more detailed review. An example is lighting levels that are perceived as problems, or areas that are too hot or too cold. Personal interviews, focus groups and paper or e-mail surveys are all effective.

**Review problem areas:** Target any system, architectural, mechanical, lighting, etc. that has had less-than-expected performance. Some systems may need to be re-commissioned if maintenance has not been effective. Others may need modification or repair to work properly.

**Review utility bills for water, electric and fuel:** The time period is usually one year. This data can be compared to design estimates of performance and can be used to apply for the ENERGY STAR building rating program.
• Acknowledgments
• Case in Point Credits
• References
• Resources
• Continuing Education Questionnaire
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Chapter 2
Renovation
McFarland State Office Building
Barre, Vermont
Architect: Freeman, French, Freeman
Photo: Jim Westphalen
Source: Efficiency Vermont

Daylight Optimization
Northern Power Systems
Waitsfield, Vermont
Architect: Bast & Rood Architects
Energy Consultant: GWR Engineering
Mechanical Contractor: Carlson Mechanical, Inc.
Electrical Contractor: Lamberton Electric, Inc.
Contractor: DEW Construction, Inc.
Photo: Jim Westphalen
Source: Efficiency Vermont

Envelope and Lighting Optimization
Boscawen Elementary School
Boscawen, New Hampshire
Architect: The H.L. Turner Group, Inc.
Mechanical and Electrical: The H.L. Turner Group, Inc.
Construction Manager: The MacMillin Company
Photo: Joseph St. Pierre

Mechanical/Energy Evaluation
Mascoma Savings Bank Operations Center
White River Junction, Vermont
Architect: Banwell Architects
Energy Consultant: GWR Engineering
Photo: Jim Westphalen
Source: Efficiency Vermont

Renovation
Green Mountain Seminary
Waterbury Center, Vermont
Architect: NBF Architects
Photo: Jim Westphalen
Source: Efficiency Vermont

Chapter 3
Daylight Optimization
Northern Power Systems
Waitsfield, Vermont
Architect: Bast & Rood Architects
Energy Consultant: GWR Engineering
Mechanical Contractor: Carlson Mechanical, Inc.
Electrical Contractor: Lamberton Electric, Inc.
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Photo: Jim Westphalen
Source: Efficiency Vermont

Glazing Integration
The Leahy Center for Lake Champlain
Burlington, Vermont
Architect: Smith, Alvarez, Sienkiewycz Architects
Mechanical Engineer: Yeaton Associates
Electrical Engineer: WV Engineering
Contractor/CM: HP Cummings Construction Company
Photo: Jim Westphalen
Source: Efficiency Vermont and SAS Architects

System Integration
The Leahy Center for Lake Champlain
Burlington, Vermont
Architect: Smith, Alvarez, Sienkiewycz Architects
Commissioning Agent: Cx Associates, Ltd.
Photo: Jim Westphalen
Source: Efficiency Vermont and SAS Architects

Chapter 4
Daylighting Integration
Society for the Protection of New Hampshire Forests
Concord, New Hampshire
Architect: Banwell Architects
Energy Consultant: Energysmiths, Inc.
Lighting Consultant: J & M Associates
Photo: Thomas Ames, Jr.
Source: Efficiency Vermont

Glazing Integration
The Leahy Center for Lake Champlain
Burlington, Vermont
Architect: Smith, Alvarez, Sienkiewycz Architects
Mechanical Engineer: Yeaton Associates
Electrical Engineer: WV Engineering
Contractor/CM: HP Cummings Construction Company
Photo: Jim Westphalen
Source: Efficiency Vermont and SAS Architects

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The Leahy Center for Lake Champlain
Burlington, Vermont
Architect: Smith, Alvarez, Sienkiewycz Architects
Commissioning Agent: Cx Associates, Ltd.
Photo: Jim Westphalen
Source: Efficiency Vermont and SAS Architects

Chapter 5
Commissioning
The Leahy Center for Lake Champlain
Burlington, Vermont
Architect: Smith, Alvarez, Sienkiewycz Architects
Commissioning Agent: Cx Associates, Ltd.
Photo: Jim Westphalen
Source: Cx Associates, Inc.
Energy Efficiency


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Operations, Maintenance and Commissioning


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1001 Connecticut Avenue, NW, Suite 801
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www.aceee.org

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1662 Mill Brook Road
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www.aiavt.org

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www.ashrae.org

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National Fenestration Rating Council
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www.nfrc.org

National Renewable Energy Laboratory (NREL)
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www.nrel.gov

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www.nesea.org

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Vermont Gas
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Burlington, Vermont 05402
802/863-4511
www.vermontgas.com
More Helpful Web Sites

www.crest.org
Comprehensive source of energy efficiency information for buildings. Includes an extensive listing of web sites.

www.eerc.und.nodak.edu
EERC is expert in scientifically advanced energy systems and the prevention and cleanup of air, water and soil pollution. The site contains extensive information on renewable energy resources.

www.efficientwindows.org
Sponsored by the U.S. Department of Energy’s Windows and Glazing program in collaboration with the industry members of the Efficient Window Collaborative (EWC).

www.eia.doe.gov
U.S. Energy Information Center publishes annual energy reports, energy trends and energy production and environmental indicators.

www.energydesignresources.com
Tools for designers and owners. Comprehensive list of links site to energy-related organizations.

www.energy.gov
Energy and environmental quality information and extensive information on climate change.

www.energysearch.com
An Internet search engine for the energy industry on global energy topics.

www.eere.energy.gov/buildings/tools_directory
Programs and software tools to help architects, engineers, and code officials evaluate and rank potential energy-efficient technologies and renewable energy strategies in new or existing buildings.

www.energystar.gov
Review ENERGY STAR-qualified equipment and appliances, use the online worksheets to review building energy efficiency and apply for ENERGY STAR building certificates.

www.nfrc.org
National Fenestration Rating Council provides glazing performance criteria, testing and approved product lists.

www.nrdc.org/nrdcpro
Natural Resources Defense Council provides information about global warming, publications and environmental responsibility.

www.peci.org
PECI is a nonprofit offering energy and commissioning information, including DOE’s "Model Commissioning Plan and Guide Specifications" downloadable from the web site.

www.solaraccess.com
Clearinghouse for information on solar and renewable energy.

www.state.vt.us/psd
Vermont Department of Public Service has extensive information about energy efficiency programs and resources, renewable energy, and free downloads for energy and life-cycle cost calculation.

www.sustainable.doe.gov
Helps design and implement innovative strategies that enhance the local economy as well as the local environment and quality of life. The home page offers a Sustainability Toolkit.

www.yestermorrow.org
Based in Vermont, Yestermorrow offers courses in energy-efficient and ecological design and construction. Courses include LEED workshops, integrated design, passive solar and photovoltaic systems.
This questionnaire has been designed to test readers’ understanding of the key points of the High Performance Guide. Completion of the questionnaire entitles AIA members to up to eight AIA/CES Learning Units (LUs), all of which contribute to the Health, Safety and Welfare CES requirement.

Please photocopy the questionnaire, then circle the correct answers and add your name, address and membership number, then mail to AIA Vermont.

1. What percentage of the United States’ total energy production is used to heat, cool and ventilate buildings?
   a. 25%  b. 28%  c. 35%  d. 45%

2. What percentage of the total energy production in the United States is provided by renewable energy sources?
   a. 2%  b. 7%  c. 10%  d. 15%

3. The benefits of energy-efficient buildings include:
   a. Reducing pollution
   b. Reducing greenhouse gas emissions
   c. Conserving natural resources
   d. All of the above

4. Fossil fuel combustion is the source of what percentage of greenhouse gas emissions?
   a. 50%  b. 65%  c. 87%  d. 99%

5. The building industry is responsible for what percentage of greenhouse gas emissions in the United States?
   a. 30%  b. 38%  c. 45%  d. 63%

6. The E-Benchmark program prescriptive approach for energy efficiency is targeted at what percentage above ASHRAE/IESNA 90.1?
   a. 10%  b. 20%  c. 30%  d. 50%

7. A high performance building does not sacrifice indoor air quality in the pursuit of energy efficiency.
   a. True  b. False

8. The ratio of the potential for energy savings to the effort required to attain the energy savings is highest during Pre-Design and Schematic Design.
   a. True  b. False

9. High performance goals should be set no later than:
   a. Early Schematic Design
   b. Schematic Design
   c. Pre-Design
   d. Design Development

10. Latitude of the project site is needed to determine the length of shading devices.
    a. True  b. False

11. Energy-related programming data that should be gathered includes:
    a. Functions or tasks in each space
    b. Hours of operation
    c. Individual controls
    d. All of the above

12. Magnetic north is how many degrees west of true north in the Burlington area?
    a. 5 degrees  b. 10 degrees  c. 15 degrees  d. 20 degrees

13. The most effective building orientation to reduce energy use and promote daylighting is when the long axis of the building is aligned with the:
    a. East-west axis
    b. North-south axis
    c. Neither of the above

14. Daylighting schemes are most effective if they are within how many degrees of true south?
    a. 5 degrees  b. 10 degrees  c. 15 degrees  d. 20 degrees

15. Factors that affect daylighting design are:
    a. Building orientation
    b. Glazing type and location
    c. Shading devices
    d. HVAC system type
    e. All of the above
    f. a, b and c
16. Ceiling height is not a factor in daylighting design.
   a. True   b. False

17. The skylight area must carefully balance the potential heat loss and solar gain with daylighting benefit.
   a. True   b. False

18. Daylight glazing should have a minimum visible transmittance of what percentage or greater?
   a. 30%  b. 50%  c. 70%  d. 90%

19. To maintain a relatively even distribution of light from sidelighting, the room depth should not exceed:
   a. 1.5 times the height of the window wall
   b. 2.5 times the height of the window wall
   c. 30 feet
   d. 50 feet

20. Electric lighting accounts for up to 50% of total building energy costs.
   a. True   b. False

21. “Interior lighting power density” is measured in:
   a. Watts
   b. Watts/square foot
   c. Lumens
   d. None of the above

22. Good air quality depends on:
   a. Adequate ventilation
   b. Low VOC materials
   c. Exhausting copy rooms and janitor closets
   d. All of the above

23. The ASHRAE Standard that governs ventilation, filtration and air quality is:
   a. ASHRAE Standard 55
   b. ASHRAE Standard 62
   c. ASHRAE Standard 90.1
   d. None of the above

24. Light shelves can be designed to both distribute daylight in the interior and shade adjacent work surfaces.
   a. True   b. False

25. When approaching early mechanical design decisions, the architect should:
   a. Think in terms of load reduction first
   b. Ask engineers to use realistic plug loads and safety factors
   c. Discuss the range of energy-efficient strategies
   d. All of the above

26. Incandescent lamps have higher efficacy (lumens per watt) than compact fluorescent lamps.
   a. True   b. False

27. Parabolic luminaires are the best fixture choice in an open office area with lots of computer screens.
   a. True   b. False

28. Ceiling reflectance in daylit spaces should be at least:
   a. 80%  b. 70%  c. 50%  d. Doesn’t matter

29. Wall reflectance in daylit spaces should be at least:
   a. 80%  b. 70%  c. 50%  d. Doesn’t matter

30. The higher the ceiling and the lower the surface reflectance of the room, the more light is required to achieve the same illumination at the floor or desk.
   a. True   b. False

31. For U-factor, the lower the number the better the insulating performance.
   a. True   b. False

32. The effective R-value of a wall with 6” steel studs @ 16 inches o.c. with R-19 insulation in between studs is

33. Solar Heat Gain Coefficients range in value from 0.0 to 0.87. The closer the SHGC is to 0.87, the
   a. More solar heat gain is transmitted through the glazing
   b. Less solar heat gain is transmitted through the glazing
   c. None of the above

34. Thermal bridging effects in a wall system result in:
   a. Higher rates of heat transfer in some parts of the wall
   b. Reduced overall R-value
   c. Condensation within the wall cavity
   d. All of the above
35. Thermal bridging can be prevented by:
   a. Adding foam insulation to the exterior of the bridging materials
   b. Adding an air/vapor retarder to the warm side of the insulation
   c. All of the above
   d. None of the above

36. A comprehensive lighting controls and switching strategy usually reduces cooling loads.
   a. True   b. False

37. Lighting controls often used in energy-efficient buildings include:
   a. Occupancy sensors
   b. Photocells
   c. Time controls
   d. All of the above

38. Dual technology occupancy sensors include both infrared and ultrasonic technology.
   a. True   b. False

39. When reviewing substitution requests and submittals, the architect should:
   a. Review energy efficiency compliance with the design intent
   b. Ask the contractor to resubmit a product or system that does not meet the energy performance criteria
   c. Assume the contractor will meet the energy performance criteria
   d. a and b

40. What percentage cost savings would building owners receive if 1% of all existing commercial buildings were commissioned each year?
   a. 5%  b. 8%  c. 12%  d. 14%

41. Commissioning the building after construction:
   a. Provides the owner with a facility that operates in accordance with the design intent
   b. Reduces energy and operating costs
   c. Reduces the number of contractor callbacks
   d. All of the above