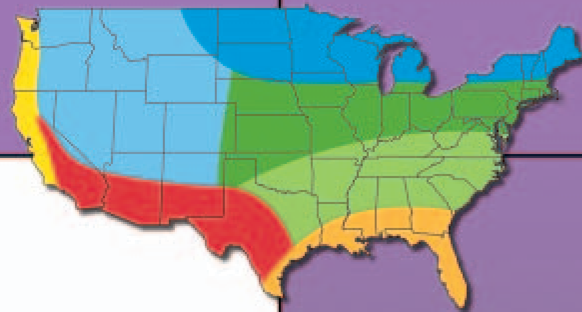
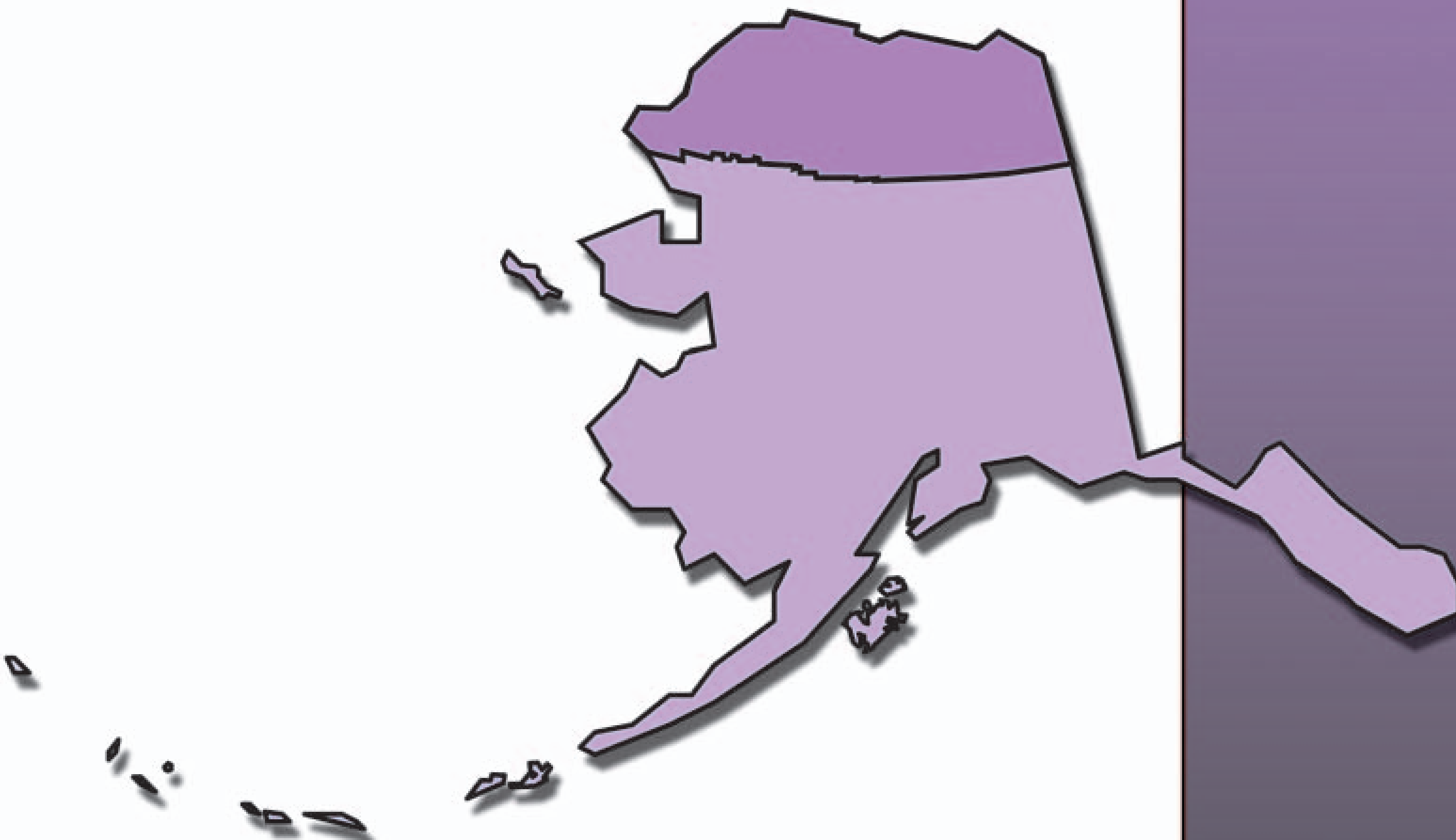
Arctic and Subarctic Climates





Energy Design Guidelines for High Performance Schools

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

CHANGE FOR THE BETTER WITH ENERGY STAR

DEPARTMENT OF ENERGY UNITED STATES OF AMERICA

This document was developed by the National Renewable Energy Laboratory with subcontractors Architectural Energy Corporation and Innovative Design. Technical Assistance came from Krochina Architects: Patrick Krochina, AIA; Jensen Yorba Lott, Inc.: Tony Yorba, AIA; Design Alaska: Jack Wilbur, Jr. PE; Padia Consulting; BuildingGreen; and the Sustainable Buildings Industry Council. Appreciation is also extended to Minch Ritter Voelckers Architects and Bezek Durst Seiser for their assistance with case studies for this document.

Acknowledgements

The U.S. Department of Energy would like to acknowledge the help and assistance of the EnergySmart Schools team and the many reviewers who provided input and feedback during the process of developing this document as well as the other design guidelines in this series. Those include:

U.S. Department of Energy
Rebuild America National Program Manager, Daniel Sze and **EnergySmart Schools National Federal Coordinator,** Margo Appel. **Office of Building Technology**, David Hansen, George James, Arun Vohra, Greg Andrews; **Chicago Regional Office:** John Devine, Peter Dreyfuss; **Seattle Regional Office:** Richard Putnam; **State of Connecticut Office of Policy and Management:** John Ruckes; **EnergySmart Schools Team:** Pat Courtney, Scott Igoe, Jennifer May, Larry Schoff, Blanche Sheinkopf; **Rebuild America Products and Services:** Ken Baker, Bill Mixon; **Idaho State Energy Office**: Sue Seifert; **U.S. Environmental Protection Agency:** Elisabeth Freed, Marti Otto, Melissa Payne; **Lawrence Berkeley National Laboratory:** Dariush Arasteh, Doug Avery, Rick Diamond; **National Renewable Energy Laboratory:** Kimberly Adams, Ren Anderson, John Brown, Victoria Healey, Molly Miller, Patricia Plympton, Susan Sczepanski, Roya Stanley, Kara Stevens; **Oak Ridge National Laboratory:** Sherry Livengood, Ron Shelton; **Pacific Northwest National Laboratory:** Michael Baechler, Kim Fowler, Eric Richman, David Winiarski

The following reviewed this Arctic and Subarctic document: **Alaska Energy Authority**: Rebecca Garrett; **Alaska Housing Authority:** Cary Bolling, Robert Brean; **Architects of Alaska:** Stuart F. Smith; **Architectural Energy Corporation:** Charles Eley; Kimberly Gott, Zelaikha Akram; **D & R International:** Bill Zwack; **Kumin Associates:** John Kumin; **Koonce, Pfeffer, Bettis:** Steve Bettis, Leo McGlothlin

The following reviewed the other documents in this series: **Advance Transformer Co.:** Gary Sanders; **AndersonMasonDale Architects:** Peggy Kinsey; **Ashley McGraw Architects, PC:** David Ashley; **Atelier/Jilk:** Bruce Jilk, AIA; **Austin Independent School District:** Dan Robertson; **Building America:** Mark Halverson; **Building Science Corporation:** Joseph Lstiburek, Betsy Pettit; **Cutler-Hammer:** David DePerro; **Donald Aitken Assoc.:** Donald Aitken; **Energy Design & Consulting:** Ed Mangan; **Environmental Support Solutions:** Dana Johnson; **Facility Improvement Corp.:** John Phillips, PE; **Hickory Consortium:** Mark Kelley; **Horst, Terrill & Karst Architects, P.A.:** Mark E. Franzen, AIA; **IBACOS Inc.:** Brad Oberg; **Innovative Design:** Mike Nicklas, Pascale Rosemain; **John Portman & Associates:** Jeff Floyd, AIA; **Kansas State University:** Bruce Snead; **Kinsey Shane and Assoc.:** William T. Traylor, AIA; **Lithonia Lighting Co.:** Richard Heinisch; **Margo Jones Architects:** Margo Jones; **National Institute of Building Sciences:** Bill Brenner; **Noack Little Architects:** Chris Noack; **NORESCO:** John Rizzo, PE; **Northeast Energy Efficiency Partnerships Inc.:** Jim Rutherford; **Oregon Office of Energy:** Greg Churchill; **Poudre School District:** Mike Spearnak; **Power Correction Systems:** Brahm Segal; **SAFE-BIDCO:** Mary Jo Dutra; **Sarnafill Inc.:** Peter D'Antonio; **Sherber Assoc. Inc.:** Michael S. Sherber; **SHW Group:** Gary Keep; **Stanley Architects:** Lars Stanley; **TechBrite:** Michael Boyd; **Texas State Energy Office:** Robin Bailey; **TRACO:** Tony Bartorillo, Scott Roy; **University of Wisconsin–Madison:** Jeffrey Lackney; **WaterLess Co. LLC:** Klaus Reichardt; **WattStopper:** Dorene Maniccia; **Weller and Michal Architects Inc.:** Charles J. Michal, AIA

In addition to the reviewers, many participated in the roundtable discussions leading to the publication of this document:

Association of School Business Officials, International: Don Tharpe; **Burr Lawrence Rising + Bates Architects:** Tom Bates; **California Energy Commission:** Darryl Mills; **Charles Michal AIA PE LC:** Charles Michal; **CMD Group:** Michelle Hesler; **Council on Educational Facility Planners International:** Elisa Warner; **Dry Creek Elementary Schools:** Kelvin Lee; **Energy Center of Wisconsin:** Abby Vogen; **Estes McClure & Assoc. Inc.:** James McClure; **Florida Solar Energy Center:** Danny Parker; **Hanson Design Group LTD:** Henry Hanson; **Heschong Mahone Group:** Lisa Heschong; **HL Turner Group Inc.:** Harold Turner; **Loudon County Public Schools:** Evan Mohler; **Manheim Township School District:** David Arnstrad; **National Association of State Energy Officials:** David Terry; **New York State Energy Research and Development Authority:** Don LaVada; **Padia Consulting Inc:** Harshad Padia; **Portland Public Schools Environmental Services:** Patrick Wolfe; **Public School Construction Program:** Yale Stenzler; **Simon and Assoc.:** Lynn Simon; **Southern California Edison:** Gregg Ander; **Sustainable Buildings Industry Council:** Deane Evans and Ellen Larson; **U.S. Department of Energy:** Mark Bailey; **U.S. Department of Education:** Tom Corwin; **U.S. Environmental Protection Agency:** Bob Thompson; **Washington State University Energy Program:** Michael McSorley

This document was produced by the U.S. Department of Energy's Energy Efficiency and Renewable Energy under the direction of the Office of Weatherization and Intergovernmental Program.

Available electronically at www.osti.gov/bridge

Creating High Performance Schools

School districts around the country are finding that smart energy choices can help them save money and provide healthier, more effective learning environments. By incorporating energy improvements into their construction or renovation plans, schools can significantly reduce energy consumption and costs. These savings can then be redirected to educational needs such as additional teachers, instructional materials, or new computers.

The U.S. Department of Energy's (DOE) EnergySmart Schools Program provides school boards, administrators, and design staff with guidance to help them make informed decisions about energy and environmental issues important to school systems and communities. These design guidelines outline high performance principles for the new or retrofit design of your K-12 school. By incorporating these principles, you can create an exemplary building that is both energy- and resource-efficient—a school that is a teaching tool.

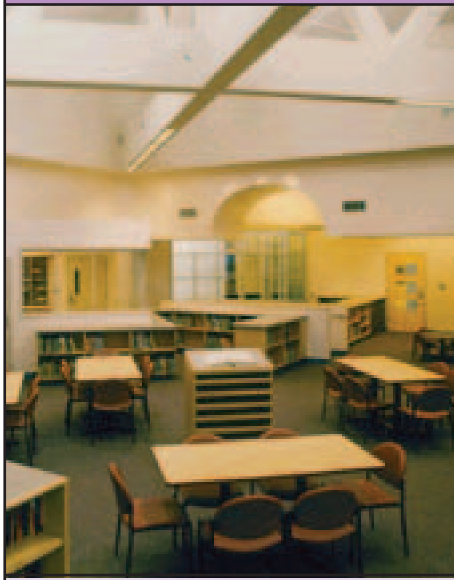


Photo: Ken Graham Photography

"Good teachers never teach anything. What they do is create conditions under which learning takes place."
— S.I. Hayakawa

By implementing the high performance practices included in these guidelines, you will be taking a significant step forward in creating the physical conditions in which the learning process can thrive.

The Importance of Connecting Energy and Environmental Issues

Throughout the arctic and subarctic climate, energy demands are on the rise. Energy costs—already higher in Alaska, especially in the rural areas of the state, than in other parts of the U.S.—continue to increase as demand outpaces supply. While building decisions in Alaska have always been influenced by energy and water availability, these factors will only become more critical as development and population growth continues. There is growing concern about the environmental and societal implications of energy. Today, energy costs over the life of a school will far exceed the initial cost of the building. As prices continue to rise, comprehensively addressing this issue will become even more critical.

This guide was developed to promote long-term thinking and to build our schools in ways that reflect values that support our planet. Our schools can make a strong statement that saving energy and resources protects our environment and benefits students. The message we give to future generations should be embodied in the buildings we use to teach them.

For more information, visit the EnergySmart Schools Web site:
www.energysmartschools.gov

Help Your School Meet National Energy Criteria: ENERGY STAR®, LEED, ASHRAE

Many national and regional programs exist that provide standards and criteria for building high performance schools. The information in this document is intended to work collaboratively with these programs to achieve a common goal: high performance schools.

One prominent national program is ENERGY STAR. The ENERGY STAR label on a school building wall tells an important story. The label not only identifies a school building whose energy performance is in the nation's top 25%—but it also lets taxpayers know you're using money wisely, spending the resources on education instead of high energy bills. The label tells students that their school cares about the environment, that you're doing your part to reduce energy-related pollution. And it indicates that your school has the great lighting, comfortable temperatures, and high-quality air that go hand in hand with smart energy use.

ENERGY STAR, a registered trademark of DOE and the U.S. Environmental Protection Agency (EPA), is the mark of excellence in energy performance. It is a trusted national brand that symbolizes superior energy performance in more than 30 categories of consumer electronics and appliances, as well as office buildings, schools, supermarkets, hospitals, and homes. The ENERGY STAR benchmarking tool is a powerful way to manage building energy performance and to earn recognition for excellence in building energy performance. The rating system measures the energy performance of each building on a scale of 1 to 100 and shows how a building compares with other buildings in your portfolio or nationwide. The rating system provides useful baseline information to help organizations set energy performance targets and plan energy efficiency improvements. Buildings whose energy performance places them in the top 25% among similar buildings nationwide, and that meet industry standards for indoor environment, are eligible to apply for the ENERGY STAR label, a large bronze plaque that can be displayed on the building.

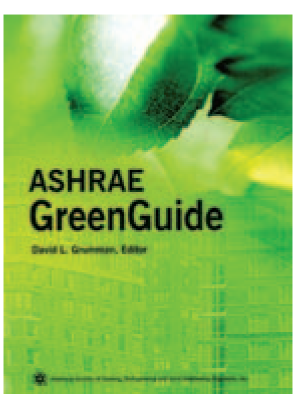
Determining whether your buildings qualify for this label is easy. You need data about your school's energy use over the past 12 months, the square footage of your buildings, and the number of students enrolled. You can then establish an account for your school district and enter your energy data into the ENERGY STAR computer analysis tool available on the Internet. Each school building that scores 75 or higher, while maintaining indoor air quality that meets industry standards, can apply for the ENERGY STAR label.

By incorporating the energy design guidelines detailed in this document into your school's construction or renovation plans, you can take the first essential steps toward earning the ENERGY STAR label for your school.

The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) program is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings. The LEED criteria address strategies for site development, water conservation, energy efficiency, materials selection and indoor environmental quality. To earn LEED certification, the building must satisfy all of the prerequisites and a minimum number of points to attain a LEED rating level – silver, gold, or platinum.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) publish mechanical systems standards for the industry. These guidelines also serve as the foundation for many state and local energy codes. In addition to the standards, ASHRAE also produces the ASHRAE GreenGuide, a manual that provides information to design teams on incorporating sustainable and efficient mechanical and ventilation strategies into buildings.

The LEED (Leadership in Energy and Environmental Design) Green Building Rating System™ is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings.



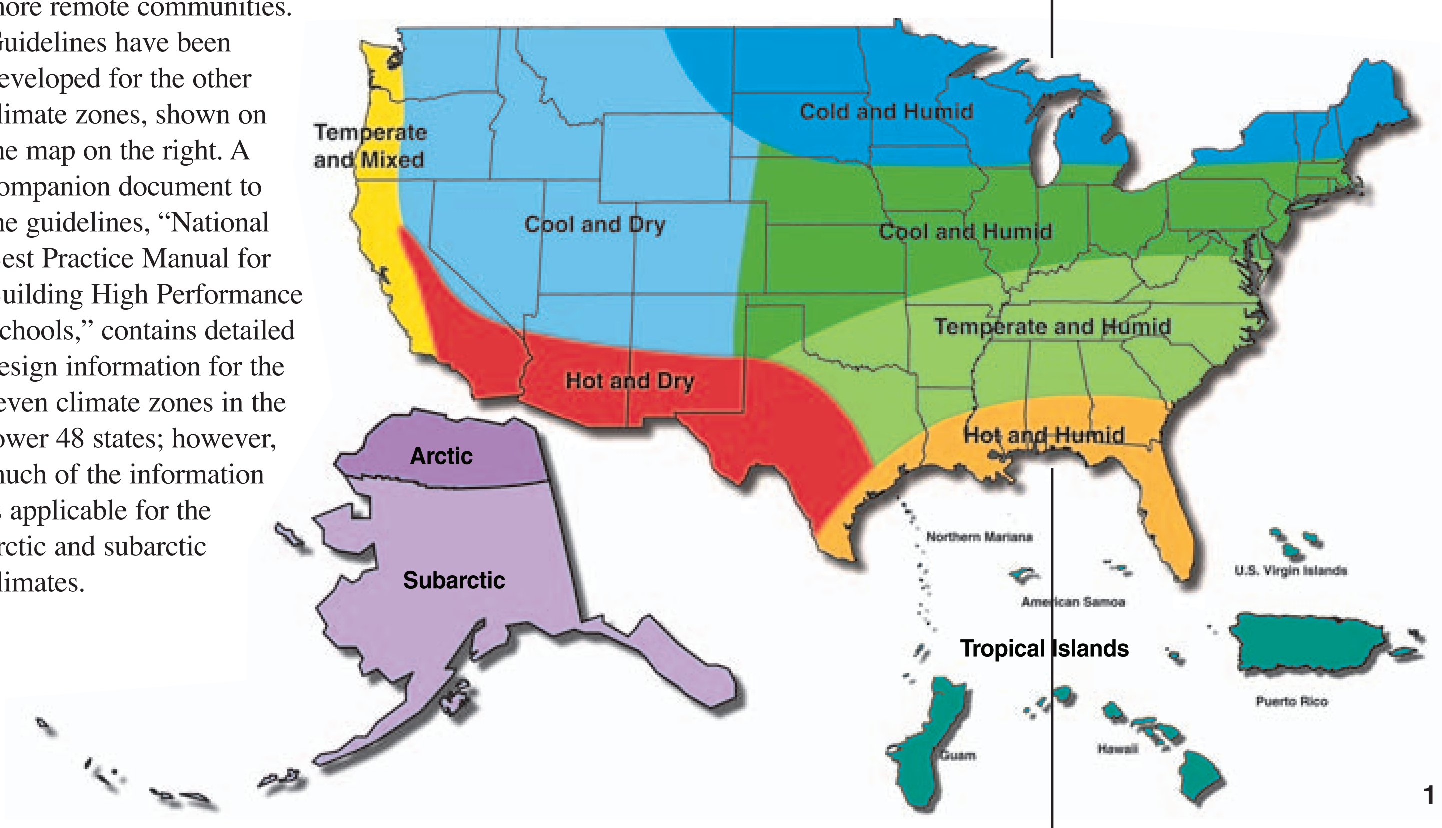
An Introduction to the Energy Design Guidelines

This document presents recommended design elements in 10 sections, each representing a key interrelated component of high performance school design. To effectively integrate energy-saving strategies, these options must be evaluated together from a whole building perspective early in the design process. A "high performance checklist" for designers is located at the end of the document. The checklist is a quick reference for key architectural and engineering considerations. Case studies can also be found at the end of the document, as well as Web sites with additional information.

Climate Zones for Energy Design Guidelines

These guidelines contain general recommendations for the arctic and subarctic climates, which are represented by Alaska. While several sub-climates exist within Alaska, the region is separated into two major zones for the purposes of this document. The climate zone includes Barrow and other villages within the Arctic Circle, as well as some of the more extreme areas of western Alaska. The subarctic zone encompasses the central and southern parts of the state. A sub-set of the subarctic climate is the maritime region around Juneau and Anchorage. Design considerations related to the increased precipitation in this area are noted within the manual.

Within these climate zones, schools can generally be divided into two types: urban and "bush" or village schools. Most urban schools are found in Anchorage, Fairbanks, Juneau, and their immediate surrounding areas, while the "bush" schools are found in the smaller, more remote communities. Guidelines have been developed for the other climate zones, shown on the map on the right. A companion document to the guidelines, "National Best Practice Manual for Building High Performance Schools," contains detailed design information for the seven climate zones in the lower 48 states; however, much of the information is applicable for the arctic and subarctic climates.



Establishing High Performance Goals

Cost-effective energy- and resource-efficient schools start with good planning. Working closely with the school's design and planning staff, the architects and engineers should develop objectives that reflect local conditions and priorities, balance short-term needs and long-term savings, and address environmental issues. Goals can include:

- Reduce operating costs.
- Design buildings that teach.
- Improve academic performance.
- Protect the environment.
- Design for health, safety, and comfort.
- Support community values.
- Consider emerging solutions.

Reduce Operating Costs

To ensure that your school is water- and energy-efficient, you must first work with the school system to establish clear consumption goals. Given your climatic region and building type, this "energy budget" must be realistic, and it must be based on the potential of current, proven energy-saving technologies.

An energy budget can be established by simply setting the goal at a level equal to that achieved by the best 25% of the schools in the district. Many energy- and resource-saving options have very good financial value. Some of these solutions do not add to installation costs.

Design Buildings That Teach

When designing the school, consider the importance of incorporating high performance features that can be used for educational purposes. Some may be harder to rationalize financially but from an educational standpoint are still important. Solar electric systems (photovoltaics), for example, are not cost effective in northern latitudes, but if installed properly, can be very powerful educational tools.

A 1999 study conducted by the Heschong Mahone Group shows that students with the best daylighting in their classrooms progressed 20% faster on math tests and 26% faster on reading tests in one year than those with the worst daylighting.

Improve Academic Performance

During the past decade, studies have indicated a remarkable correlation between school design and student performance. You can maximize student performance by setting air quality objectives that:

- Define a desired level of outdoor air ventilation during occupied times.
- Limit the use of materials, products, or systems that create indoor air quality problems.
- Require monitoring equipment.

Establishing daylighting objectives will also improve classroom conditions and can help improve performance if you:

- Develop intentional visual connections between the indoor and outdoor environments.
- When feasible, include controlled daylighting in all classrooms, administrative areas, the gymnasium, and other significantly occupied spaces.

Protect Our Environment

High performance school design considers the economic, academic, and environmental impacts of design. Environmentally sound design elements:

- Use renewable energy systems and energy-efficient technologies.
- Incorporate resource-efficient building products and systems.
- Promote water-conserving strategies.
- Use less polluting transportation alternatives.
- Establish recycling systems.
- Incorporate environmentally sound site design.

Designing for Health, Safety, and Comfort

You cannot design a high performance school without including design strategies that address health, safety, and comfort issues. Goals should include:

- Implement daylighting and indoor air quality solutions to make the school a healthier place to teach and learn.
- Address acoustical and thermal comfort.

Support Community Values

Incorporating high performance strategies in your school's design results in a win-win situation for the community and the school. Implementing energy saving strategies save the school money. Additionally, the energy dollars saved stay in the community and help build a stronger local economy.

Practically all building materials in Alaska except concrete aggregate and concrete masonry units are imported from the lower 48 states. The cost and environmental impact associated with the transport of building materials are high and can be significant logistical challenges in rural areas. Therefore school designs should use durable equipment and materials. When possible, material use should be minimized.

Implementing energy-efficient, environmentally sound practices also has a direct impact on the local air and water quality. By establishing goals to positively address these issues, you are taking the first step toward creating a better community.

Photo: Joe Manfredini

The common area at New Craig High School in Craig, Alaska, uses daylighting strategies to provide students a connection to the outdoor environment.

Photo: Krochina Architects, AIA

Noorvik K-12 School is a bush school that features a 9,000 ft^2 gymnasium with retractable seating.

"We will insist on protecting and enhancing the environment, showing consideration for air and natural lands and watersheds of our country."

National Energy Policy, 2001

Consider Emerging Solutions

The recommendations in this document reflect proven technologies that have been successfully incorporated into school applications in this climate zone and other climate zones in the U.S. However, every year, new solutions are developed that can make your facilities even more energy efficient and environmentally sound. As these new systems, materials, and products become commercially available, designers should exercise care in selecting those that are viable but should not be discouraged from implementing technologies just because they are not commonplace. Although emerging solutions should be evaluated, school districts should consider district-wide standards for lamps, ballasts, filters, controls, and other consumables to minimize the cost of maintenance and replacement.

Because of their dynamic nature, these emerging solutions will be addressed and updated on the EnergySmart Schools Web site, which provides cost information and examples of projects where the solution is already in use.

"Whole Building" Energy Analysis

Determining the relative merits of one energy strategy versus another can only be accurately determined by analyzing the specific measure in the context of the "whole building." Each component or system is continually affected by changing climatic conditions and occupancy demands. Each component has an effect on another.

When evaluating energy options, the design team must use computer energy analysis programs that can simulate the impact the specific measure has on the overall energy consumption and peak load. The program must be able to provide hourly, daily, monthly, and yearly energy profiles and accurately account for the benefits associated with daylighting. The DOE has two programs to assist with this analysis: DOE-2 and EnergyPlus. More information can be found on these programs in the Web Resources section on page 78. And of course, commissioning is important for ensuring that the school's energy saving strategies actually perform as designed. A commissioning plan should be included as part of the school design and construction process.

Site Design

By orienting your school effectively, you can maximize solar access, which is particularly crucial during the short days of winter. Designing the site to reduce vehicular traffic through closer integration with the surrounding community and its transportation resources helps to reduce fuel use and emissions and improve air quality around the school. Maintaining as much of the natural landscape as possible, and planting native species when needed, will preserve the school's connection to its surrounding environment and reduce water use.

Decisions made early in the design can often have a significant impact on many other aspects of the design. Buildings should be positioned such that the primary windows face south and east. Operable blinds or shades will be needed to control glare, but the benefits of direct morning sun into the building (even in the classrooms) is extremely important in high latitudes with short winter days.

Entrances should also be located in southeast facing pockets to provide a warm, sunny, and shielded outdoor space.

When considering the location for a school site, the initial cost, environmental implications, health and safety, integration into the the community must be considered.

Photo: Roy Beaty

Retaining ecosystems and wildlife habitat around schools and incorporating them into outdoor learning activities enhances student interest in the environment.

Photo: Jensen Yorba Lott

Riverbend Elementary School in Juneau, Alaska, maximizes solar access because of its orientation along an east-west axis.

LEED

LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN

Many recommendations made in these guidelines assist with meeting LEED standards.

Photo: Architectural Energy Corporation

The transformation of a former supermarket into Highland Tech High serves as a prime example of how a site rehabilitation project can result in significant cost savings.

Guidelines for Site Design

Selecting a Site

When selecting a school site, the highest priority should be given to locations that enable the school to be built cost effectively and resource efficiently.

- **Cost**
  - Consider rehabilitating an established site or an urban in-fill area before choosing an undeveloped site.
  - Select a site that where most windows can have south, southeast, or southwest exposures.
  - Consider the wind resources at the site and the potential for implementing wind energy systems.
  - Consider the availability and cost of utilities.
  - In urban areas, analyze mass transit and pedestrian accessibility as well as potential bus routes.
- **Environment**
  - Avoid selecting sensitive ecosystems.
  - Consider geological, micro-ecological, and micro-climatic conditions.
  - Evaluate the potential implications of erosion control and rainwater management.
  - Determine the presence of historic landmarks or archeological features.
  - Conduct an assessment of the impact the school will have on the local environment.
  - Consider the ability to protect and retain landscaping.
- **Health/Safety**
  - Determine the current and projected air, soil, and water quality.
  - Evaluate the physical relationships to industries or utilities that may pollute the air.
  - Alaska schools are required to have fire sprinkler systems if the school population is more than 50 people. For schools in more remote areas, consider using an on-site tank to ensure the required quantity of water is available at all times.
- **Community**
  - Work with community leaders to determine multi-use needs for the school buildings.
  - Determine how the site will connect to bike and pedestrian paths, as well as public and private transportation, especially during heavy winter snow.
  - Evaluate the potential for recycling programs in the area.

Protecting Local Ecosystems

The protection of local ecosystems is critical to an environmentally sensitive site design.

- Integrate the school into the surrounding landscape. For instance, if the site is naturally wooded, consider designs that will minimize the amount of tree removal.
- Protect and restore local ecosystems and wildlife habitats.
- Develop nature trails through preserved wildlife habitats and ecosystems.
- Use explanatory signage for plants and trees.
- Consult with local elders and naturalists about the surrounding ecosystems, how to protect them, and strategies for maximizing their educational value.

Water Conserving Strategies

More remote or bush areas may have a variety of soil conditions, including tundra. Usually, landscaping and irrigation needs are minimal. For most of the climate, the following techniques will help reduce water use.

- Use xeriscaping and native planting materials.
- Consider using synthetic gravel instead of grass for playing fields.

Erosion Control and Off-Site Impacts

Developing on-site erosion control and stormwater management strategies will minimize off-site impacts.

- Use site contours to create natural drainage and water retention.
- Use an underdrain system to deal with stormwater runoff.
- Minimize surfaces that are impervious to water.
- Determine strategies to reduce the likelihood of automobile-related pollutants that affect the watershed.

Photo: Architectural Energy Corporation

Employing native plants and xeriscaping principles reduces landscaping costs by lowering water and pesticide needs.

Photo: Joe Manfredini

Maximize solar potential by incorporating view windows and natural lighting opportunities in order to cut down lighting costs.

Building Orientation

Maximize solar potential by siting the school correctly.

- Develop a floor plan to maximize south, southeast, and southwest exposures.
- Maximize view window and natural lighting opportunities. Daylight hours are brief in the winter and school children come to school and leave in the darkness. The children need a visible connection to the outdoors during daylight hours.
- Use skylights and south-facing roof monitors for daylighting in single-story buildings and on the top floor of multi-story buildings.
- Analyze seasonal variations in wind speed and direction and locate entrances so they are protected from the elements.

Renewable Energy

When evaluating site design issues, investigate renewable systems early in the process. It is essential to evaluate the specific climate conditions to determine feasibility. Solar systems are most applicable in the southern part of the state.

- If applicable, consider installing building-integrated solar thermal systems for domestic hot water and space heating. Consider building-integrated photovoltaic systems for electricity production if solar radiation is sufficient.
- Consider wind energy systems for electricity.
- Consider ground source heat pumps.

Maximize the Potential of the Site

Understanding and using the ground conditions at the site will determine, to a great degree, the economic and environmental success of the design.

- Establish floor grades that least affect site grading.
- Use site contours to minimize grading and, where appropriate, to create berming opportunities to earth-temper walls.
- Stockpile rock from site development for later use as ground cover.

Photo: Ken Graham Photography

Understanding ground conditions was important for the Buckland K-12 School in Buckland, Alaska, which is located on a river flood plain.

Safe walkways connecting the school to the surrounding neighborhoods help reduce air pollution from cars and buses, avoid air pollution and traffic congestion, and decrease the cost of operating buses.

Connecting the School to the Community

One measure of success is the degree to which the school is a vital part of the community. In smaller communities in the arctic and subarctic climates, the school is the cornerstone, and is used for meetings, parties, weddings, and more when class is not in session. If you address these needs early in the site selection and design phases, the school can easily meet all these needs.

- Analyze accessibility issues for local residents.
- Consider requirements related to multi-use of kitchen facilities, libraries, media centers, athletic fields, etc.

Daylighting and Windows

Of all the high performance features typically considered, daylighting is often most significant because of its energy saving potential and its effect on learning environments. Studies have shown a correlation between daylighting in classrooms and increased attendance and higher learning scores. Daylighting—and particularly view windows—are especially crucial in the arctic and subarctic environments where winter days contain an average of 5-7 hours of functional daylight (even fewer in the northern parts of the region). These short days make a visual connection to the daylight from within the classroom vital for staff and students alike.

When properly designed, windows, clerestories, skylights, and roof monitors can provide some lighting needs without excessive heat loss or glare. Good daylighting design can reduce the need for electric lighting for part of the day. High performance windows can reduce heat loss during the winter months and help lower overall energy use.

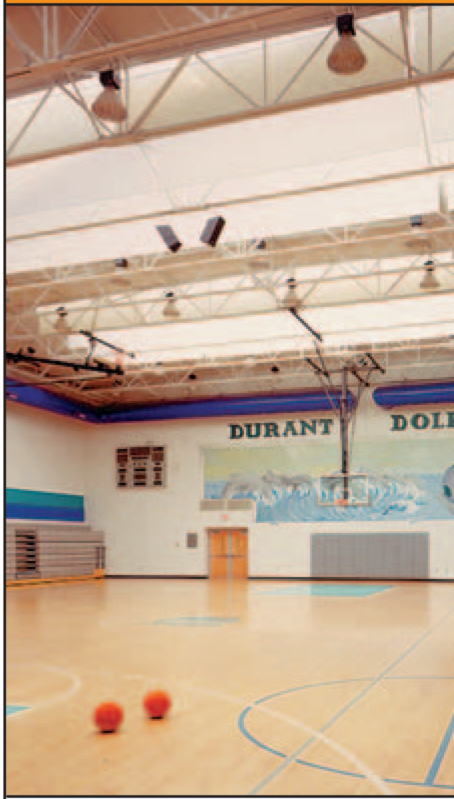


Photo: Robert Flynn

Implement effective daylighting strategies to create significant cost and energy savings by reducing lighting and cooling loads.

Photo: Krochina Architects

This Anchorage middle school provides large view windows to connect students and faculty to the outside environment.

Design Guidelines for Daylighting and Windows

Courtesy of Architectural Energy Corporation

Elongating the school design maximizes the potential for daylighting.

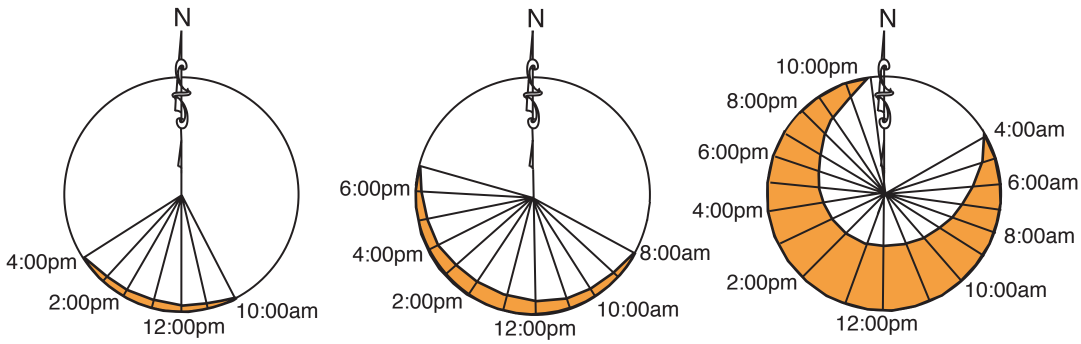
Building Orientation and Solar Access

Elongating the school design on an east-west axis maximizes the potential for cost-effective daylighting.

- Consider daylighting strategies that primarily use south-facing glass and secondarily incorporate southeast- or southwest-facing glass. An elongated building that has its major axis running east-west will increase the potential for capturing winter solar gain through south glass. Kitchens, gymnasia, lockers, and other spaces where daylighting is less important should be located on the north side of the building.
- Verify that other exterior design elements or exterior site features do not negatively affect the lighting design.
  - Make sure that other building elements do not unintentionally shade glazing areas that are designed as daylighting elements.
  - Consider the reflectance of materials in front of the glazing areas. Lighter roofing colors can reduce the glass area needed for roof monitors; a light-colored walkway in front of a lower window may cause unwanted reflections and glare inside the classroom.

Photo: Architectural Energy Corporation

The view windows in this Anchorage high school not only provide daylight to the classroom, but provide students and staff with a visual connection to the outdoors.



January 21
Winter Sun Angles

March/October 21
Spring/Fall Sun Angles

June 21
Summer Sun Angles

Sun angle data for Anchorage, Alaska

Sun angle charts indicate the location (azimuth of the sun at various times of the year).

South-facing roof monitors and windows provide natural light in classrooms and help reduce overall utility costs.

Daylighting Strategies

Lighting accounts for a significant component of a school's energy consumption, and daylighting can significantly offset electricity needs. And perhaps an equally important reason for including daylighting strategies in the arctic and subarctic climates is to provide staff and students with a visual connection to the outside environment during the short winter days.

- Properly designed daylighting can help lower the electricity needed for lighting during certain parts of the year. Although the reduced daylight hours will limit the applicability of using daylighting to supplement electric lighting (particularly in the northernmost areas), daylighting can help reduce electricity use during the longer daylight hours of late spring and early fall. For schools that operate year round, good daylight design could eliminate the need for electric lighting during the summer months.
- Develop a daylighting design with primary emphasis on south-facing windows and roof monitors. Use high ceilings and position windows as near as possible to the ceiling. Consider light shelves inside the window. Snow removal makes exterior light shelves impractical.

Using roof monitors to optimize solar access can significantly lower costs by reducing lighting and cooling needs.

Translucent baffles block direct beam radiation and diffuse the sunlight throughout the space.

Skylights, Roof Monitors, and Clerestories

Skylights, roof monitors, and clerestories provide uniform light within the room and minimize glare.

- Design daylighting strategies to meet the lighting needs of each major space, accounting for:
  - differing lighting level requirements by time of day.
  - the ability to darken particular spaces for limited periods of time.
- If south-facing roof monitors are employed, they should:
  - employ baffles within the light wells to totally block direct beam radiation from striking people, reflective surfaces, or computers.
  - block high summer sun with exterior overhangs.
  - reduce contrast between very bright surfaces and less bright areas.
- Optimize the design of roof monitors to enhance their benefits.
  - Minimize the size and maximize the transmission of glass to reduce conductive losses and gains.
  - Develop an overall building structural design that integrates daylighting strategies and minimizes redundant structural elements.
  - For south-facing monitor glass, select clear, double high, solar low-e glazing.
  - In roof monitor/lightwell assemblies, incorporate white (or very light-colored) translucent baffles that run parallel to the glass and are spaced to ensure that no direct beams can enter into the space. These baffles should be fire-retardant and UV-resistant. Use light-colored translucent baffles because they reflect the sunlight into the space and eliminate contrast from one side of the baffle to the other.
  - At the bottom of the lightwell, provide a transition between the vertical plane surface and the horizontal by introducing either a 45° transition or, if possible, a curved section. This will decrease the contrast between the higher light level inside the lightwell and the horizontal ceiling.
  - Ensure that the walls and ceiling of the roof monitor are well insulated and incorporate infiltration and moisture barriers.

Light Shelves

A south-facing (also southeast and southwest) window can be easily transformed into a well-controlled lighting source by adding a light shelf a couple of feet below the top of the window. The light shelf, made of a highly reflective material, will bounce the sunlight that strikes the top of the surface deep into the building. The reflected sunlight will hit the ceiling and, in turn, provide light for the room. This effective strategy can be employed in multi-story schools or where roof monitors are not possible.

- Select durable materials for interior light shelves.
- Design light shelves to be interior only to eliminate snow accumulation.
- Design so the light shelf may not be used for storage.
- Incorporate white painted gypsum board on top of interior light shelves. However, aluminized acrylic sheets applied to the top of a shelf allows light to bounce farther back into spaces and can improve performance in deeper rooms without top daylighting.
- Use blinds to enhance performance. Even with a combination of interior and exterior light shelves, direct beam light can, at times, enter into the space and create unwanted glare. If the light shelves are located close to perpendicular interior walls and are not deep enough to eliminate this problem (which is the typical case), vertical blinds can provide an excellent option. By using vertical blinds for the window section above the light shelf, the light can be directed toward the walls to eliminate glare and enhance the bouncing of light deep into the space. White blinds are preferred to increase reflectance. If the light shelf windows are located near the middle of the space and farther away from perpendicular walls, horizontal blinds (flat or curved but turned upside-down) would allow the light to be reflected toward the ceiling and deep into the space.
- Control the windows above and below the light shelves independently. To enhance daylighting on the south facade:
  - Incorporate vertical blinds that can focus radiation to the perimeter walls within a space and away from people within the space.
  - Use horizontal blinds that can be installed to reflect the light up toward the ceiling and back farther into the space.
- Don’t use light shelves on northern exposures. They are not cost effective or necessary. However, using clear double high solar low-e glass on high non-view windows on the north is still advisable.
- When calculating daylighting contribution, don’t consider the low north and south view windows in your calculation, as these windows are often closed or covered.

Courtesy of the Collaborative for High Performance Schools

Position light shelves on the inside to prevent snow and ice from lodging in the space between the shelves.

Lighting Controls

Lighting controls can ensure that students and teachers always have adequate light and that energy efficiency is maintained. It is important to keep control systems simple for ease of use and maintenance, particularly in more remote areas where resources are limited. Be sure to train staff on the system operation. Systems that are too complex or difficult to maintain will likely be disabled.

- Specify occupancy sensors for most spaces. Be sure the motion sensors are calibrated properly to prevent disabling.
- Consider photosensors for outdoor lighting to shut off or dim fixtures when daylight levels are sufficient.
- In situations where daylight sensors are feasible for indoor spaces, enhance the economic benefits and provide for smoother transition between varying light conditions by using multi-staged or dimmable lighting controls. The success of these controls relies on:
  - having the sensors mounted in a location that closely simulates the light level (or can be set by being proportional to the light level) at the work plane.
  - implementing a fixture layout and control wiring plan that complements the daylighting strategy.
  - providing means to override daylighting controls in spaces that are intentionally darkened to use overhead projectors or slides.

Light-colored interior finishes help the uniform distribution of natural light in the classroom.

Interior Finishes

The color of interior finishes will have a dramatic impact on the lighting requirements within each space.

- Use white (or very light-colored) paint inside the lightwell area. Colors inside the room can be slightly darker, but the lighter colors will help the light to reflect deeper into the space. Accent colors (with most still white) and beige colors are acceptable inside typical rooms. The tables in the “Energy-Efficient Building Shell” section of this document provide additional information on the recommended reflectance ranges for different interior finishes.
- Apply carpet or other floor coverings that are as light as practical for maintenance. This will greatly enhance reflectance and require less glazing to produce the same light levels. If the floor finish is dark, more glass or electric lights are required to effectively daylight the space.
- If there are television monitors, computers, or whiteboards in the classrooms, locate them perpendicular to windows or light sources to minimize glare.
- Enhance the daylighting by placing south-facing windows with light shelves close to perpendicular interior north-south walls. The color of the walls immediately inside the window should be light to enhance this reflectance. (See page 22 for reflectance values of interior paint and wood.)

Skylights

The potential glare and heating problems from skylights at lower latitudes are less significant in this climate, because of the low elevation angle of the sun and the cool temperatures. Modest white-painted light wells below the skylights can prevent direct beam glare year-round at high latitudes, and deliver daylighting into the space regardless of sun altitude and azimuth. However, skylights must be carefully designed and installed to perform well with minimum maintenance.

Windows—Appropriate Choice

Windows have a significant impact on energy consumption. The characteristics of the windows and their locations, designs, and purposes will determine, to a great degree, the level of energy efficiency.

In all cases, windows should be made of high-quality construction, incorporate thermal breaks or nonmetallic construction, and include clear, high solar, low-e glazing for the particular application. Windows should be designed to meet the overall objective and not be oversized. To determine the optimum glazing area for each application, the designer should ideally conduct computer simulations that compare options. The DOE-2 program is one of the better analytical tools available for this purpose. You'll find more information on the DOE-2 program in the Web Resource section.

Analyze and select the right glazing for each orientation, location, and purpose. Generally speaking, polyvinyl chloride reinforced windows with high solar low-e coating are recommended in these climates. Consider operable windows, especially if the school does not have mechanical cooling.

Photo: Joe Manfredini

Windows made of durable, high-quality construction can significantly reduce energy consumption. Polyvinyl chloride reinforced windows with high solar low-e coatings are recommended in arctic/subarctic climates.

Solar (Heat) Transmission Values for Typical Glass Types

Glazing Type	Solar Transmission	Equivalent U-Value
Clear, Single	75%–89%	1.11
Clear, Double	68%–75%	0.49
Low-e, Double, Clear	35%–55%	0.38
Low-e, Tinted, Gray	30%–45%	0.38
Low-e, Argon	45%–55%	0.3

Considering the transmission values of glass by orientation can greatly reduce cooling loads. Low-e glass reduces the amount of heat gain through the window, which can lower cooling needs.

Window Selection Considerations

Application	Exposure	Type: Shaded	Type: Unshaded
View Glass (Non-Daylighting Apertures)	North	Single or Double Clear	Double Low Solar Low-e
	South	Single or Double Clear	Double Low Solar Low-e
	East/West	Double Low Solar Low-e	Tinted Double Low Solar Low-e
Windows above Lightshelves	South	Single or Double Clear	Double Low Solar Low-e
High Windows above View Glass	North	Single or Double Clear	Single or Double Clear
Roof Monitors	South	Single or Double Clear	Double Low Solar Low-e

The intended application and exposure determines appropriate window selection.

Light Transmission Values

0.9	Standard Double Glazing
0.5–0.9	Internal Venetian Blinds Drawn
0.4–0.8	Internal Curtains Drawn
0.4–0.8	Internal Roller Blinds Drawn
0.7	Heat-Absorbing Glass
0.6	Tree Providing Light Shade
0.5	Internal Blind Reflective Backing
0.4	Solar Control Glass
0.2	External Blinds Drawn
0.2	External Shutters Closed

Light transmission is greatly affected by the type of window treatments used.

Exterior Window Treatments

- Use properly sized overhangs on east, west, and south windows to block the summer sun.
- Consider the advantages of using seasonally adjustable shading devices such as solar screens or vertical louvers when fixed overhangs are impossible or impractical.

Interior Window Treatments

If exterior window treatments cannot effectively control the seasonal and daily variations in radiation (and resulting glare), or if darkening the particular space is desirable, blinds or shades provide better control.

If blinds or rolling type dark-out shades are employed, install types that are either motorized or easily accessible and made of durable construction materials and components.

Clear glass for south-facing roof monitors and low-e glass for view windows are two daylighting and energy-efficient features.

Energy-Efficient Building Shell

Because the building shell is typically responsible for 10%–20% of the total energy consumed in a school, focusing on this area of design can help you reduce energy consumption in your school buildings. Increased insulation in the walls and ceiling helps to reduce heat loss and improve comfort. These factors also contribute to reducing the size and cost of the heating, ventilation, and air conditioning (HVAC) system you will need. The useful lives of building materials, systems, and equipment incorporated in schools can vary considerably, so the building shell decisions you make as a designer will affect the first cost of the school as well as the long-term costs associated with operation, maintenance, and replacement.

Because of the extreme climate conditions, designing for durability in the building shell is important. Wall insulation should be selected based on the likelihood that it will never be replaced. When selecting your wall and roof systems, that you must choose the best for the life of the facility. Specify interior and exterior finishes that are durable and low maintenance, and integrate insulation levels that are appropriate for the life of the facility. Also, incorporate durable strategies that address air infiltration.

If specified correctly, energy-efficient building shell elements can effectively reduce our impact on the environment, and they will never need to be replaced.

Photo: Architectural Energy Corporation

South Anchorage High School, Anchorage, Alaska. Durability is key when designing a building shell in this climate.

Photo: Sara Farrar, NREL/PIX07358

SIPS panels (left) are an excellent option for increasing energy efficiency and thermal comfort in this climate.

Design Guidelines for an Energy-Efficient Building Shell

Wall, Floor, and Roof Construction

Wall

Durability is a key concern in Alaska, and walls should be designed to withstand the extreme conditions with no loss of performance and without deterioration. Wood-framed walls are traditional for construction in the area and should last indefinitely if the wood is kept dry or allowed to dry after it gets wet. If steel-framed walls are used, insulation should be installed continuously on the exterior of the wall, since the thermal conductivity of the steel studs significantly reduces the effectiveness of any insulation placed in the cavity.

Structurally insulated panel systems (SIPS) are a good option in the arctic and subarctic regions. SIPS consist of rigid foam insulation sandwiched between two panels of oriented strand board or plywood. SIPS have no thermal bridges and provide a continuous layer of insulation. SIPS panels are available in thicknesses ranging from about 6–12 inches.

Floor

Slab-on-grade floors may be used in the southern areas of the subarctic climate zone provided that they are insulated below grade with extruded polyurethane or other insulation that will not deteriorate when exposed to moisture.

Elevated floors are common for arctic and subarctic regions because of soil conditions and flood planes. Insulation should be continuous and installed with moisture protection. Wood is a traditional construction material, but needs to be kept dry.

If metal framing is used, the insulation should be installed continuously; if it is installed between framing members, the thermal bridging through the metal framing members will significantly deteriorate performance. SIPS should be considered as an option.

Photo: Ken Graham Photography

Increasing access to natural light was an important building envelope design consideration at Buckland K-12 school, located on the western coast of Alaska. Because of the short days during the winter, providing natural light is a crucial health issue for students and staff.

Roof

Roof construction is critical in Alaska climates. Roofs should be designed to shield the rain and snow, last indefinitely, and provide a good weather and thermal barrier. Sloped roofs should have a uniform exterior temperature to prevent ice dams and other problems related to snow and ice accumulation. This means that pitched roofs with eaves should be designed so full insulation thickness can be maintained over the entire ceiling area.

Flat roofs may also be used for school design. In these cases, single-ply systems should be considered as they provide a good weather barrier and are extremely durable.

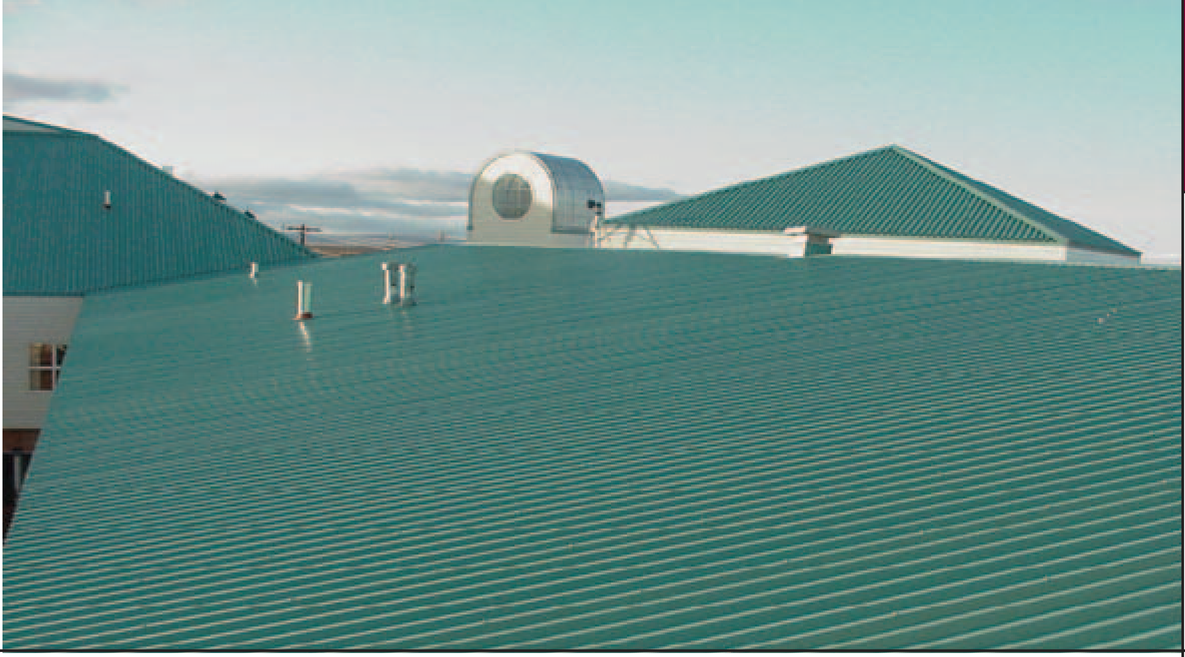


Photo: Ken Graham Photography.

Buckland K-12 School, Buckland, Alaska. A roof should be designed to be durable and provide a good thermal barrier.

Moisture and Infiltration Strategies

In arctic and subarctic climates walls, roofs, and floors must be designed with air barriers and vapor retarders. These may be the same or separate. The air barrier reduces infiltration through the building envelope; the vapor retarder blocks moisture migration through building envelope components.

In arctic and subarctic climates, the vapor retarder should be located on the interior of the insulation. Moisture tries to move from warm humid conditions (indoors in winter) to cold dry conditions (exterior). If the movement is permitted, it will reach the dew point temperature inside the wall, roof, or floor construction and condense into water molecules. The accumulated water can freeze during cold weather. Reported roof and wall leaks are sometimes not leaks at all but ice melting when the weather becomes warmer.

If the vapor retarder is proposed for a location other than the inside surface of the construction assembly, the temperature profile of the construction should be calculated to make sure that the vapor barrier is installed on the warm side of the dew point position. The vapor retarder should be impermeable to water vapor and be continuous. Careful inspection is needed before closing walls and ceiling surfaces.

Windows and doors should be tested and rated to have low rates of infiltration. In general, infiltration rates should be less than 0.3 cubic feet per minute per square foot of door or window. The National Fenestration Rating Council includes infiltration ratings as part of its testing procedure.

Ensure that windows, doors, penetrating pipes, ducts, and any other building shell penetrations are properly caulked at the vapor retarder.

In the areas along Alaska's coast that receives significant moisture throughout the year, use building overhangs to protect the building walls and windows from rain.

Photo: Brian Allen.

In the extreme climate areas in the north and west of this region, elevate schools off the ground. If not elevated, the heat from the building will melt the tundra and cause the school to sink.

Photo: Krochina Architects

Light-colored finishes will significantly reduce lighting demands within interior spaces.

Insulation Strategies

Energy-efficient building design starts with implementing optimum insulation levels. High levels of wall and ceiling insulation are particularly important in the arctic and subarctic climates.

- When selecting insulation levels, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1. R-values should be considered a minimum. In general, exterior insulating sheathing should be used with both wood and steel framed construction.
- When designing insulation systems, you should consider energy efficiency, initial cost, and long-term performance. Ensure that the vapor retarder is properly located and continuous. This will provide for stability of R-value over time and provide a long service life. In addition to traditional insulation materials, several new insulation products made from soy-based polyurethane foam or recycled denim are available.
- Vapor retarders are important for preserving the life of your insulation as well. Faulty vapor retarders can cause water to condensate within the structure. This reduces the effectiveness of the insulation and may lead to structural damage and mold and mildew growth within the wall and on the surface.

Interior Finishes

By properly selecting interior finishes, lighting energy demands can be reduced and visual comfort can be improved for no additional cost.

- Select light colors for interior walls and ceilings to increase light reflectance and reduce lighting and daylighting requirements.
- Consider the color and finish of interior walls and ceilings. When placed incorrectly, light-colored, glossy finishes can create glare problems that negatively affect visual comfort.

Reflectance Table: Paints

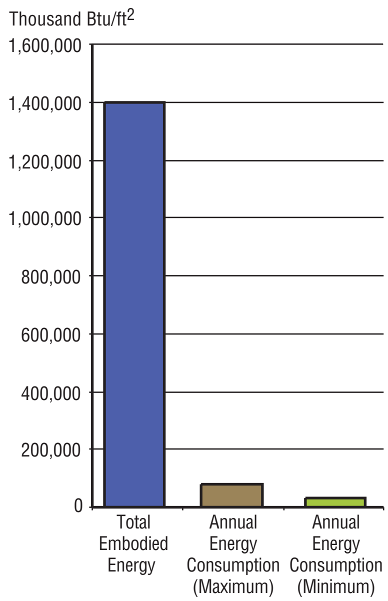
Color	Reflectance
Semi-Gloss White	70%
Light Green*	53%
Kelly Green*	49%
Medium Blue*	49%
Medium Yellow*	47%
Medium Orange*	42%
Medium Green*	41%
Medium Red*	20%
Medium Brown*	16%
Dark Blue-Gray*	16%
Dark Brown*	12%

Reflectance Table: Woods

Type	Reflectance
Maple	54%
Poplar	52%
White Pine	51%
Red Pine	49%
Oregon Pine	38%
Birch	35%
Beech	26%
Oak	23%
Cherry	20%

* These values are estimated for flat paints. For gloss paints, add 5%–10%. Source: SBIC, Passive Solar Design Strategies

Careful consideration of interior finishes based on reflectance values can reduce lighting demands.



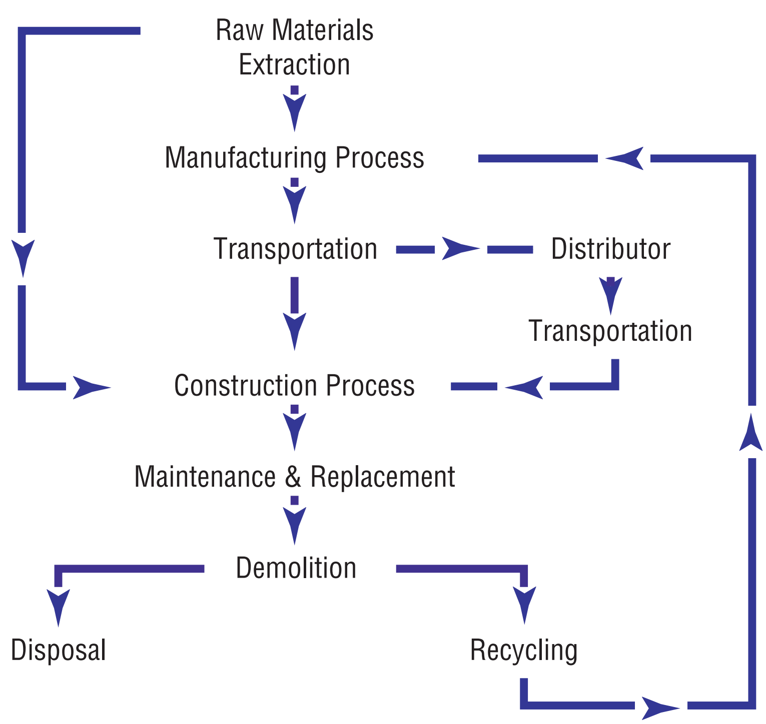
Total embodied energy per square foot for educational buildings

The embodied energy of a school building exceeds the annual energy consumption of the school.

Embodied Energy

When selecting the building materials, consider that, in many cases, the amount of energy embodied in constructing the school is equal to more than two decades of a school's energy consumption. This is especially true in the arctic and subarctic climates, where distance and weather restrictions add time and cost constraints to the school construction process. To seriously address the overall impacts of energy consumption, consider the energy involved in making each product, transporting the product to the site, and implementing the component into the school.

- Minimize costs and energy related to the transport of building materials.
- Consider the energy intensity of the manufacturing process involved in making materials and products incorporated in the school.
- Encourage the use of recycled products.
- Evaluate the recyclability of products once the building has passed its useful life.
- If structures on the school site are to be demolished, consider how the materials could be used in the new construction.



Total embodied energy diagram

Products, materials, equipment, and processes incorporated into construction

Lighting and Electrical Systems

The design of your school's lighting system has direct bearing on the performance of your students and teachers. The ability to read comfortably and perform visual tasks is strongly affected by the type and quality of the lighting systems. Lighting strategies that reduce glare and produce the required lumen levels are essential components of a high performance school.

Lighting represents 25%–40% of a typical school's energy costs. An energy-efficient lighting system that uses occupancy sensors and other controls can save thousands of dollars annually.

Your design team can create an energy-efficient, high-quality lighting system by following two key strategies.

- Select efficient lamps, ballasts, and fixtures that address the needs of each space and achieve the highest output of lumens per input of energy.
- Provide occupancy sensors, time clocks, and other controls that limit the time the lights are on to only hours when the space is occupied and the light is needed. If feasible, provide automated daylighting controls that reduce the electrical lighting when sufficient daylighting is present.

Photo: NREL/PIX03045

Indirect lighting can provide excellent uniform lighting in a classroom by eliminating glare and contrast between bright and dark areas.

Photo: NREL/PIX03047

Indirect lighting systems provide high-quality artificial lighting in classrooms.

Design Guidelines for Lighting and Electrical Systems

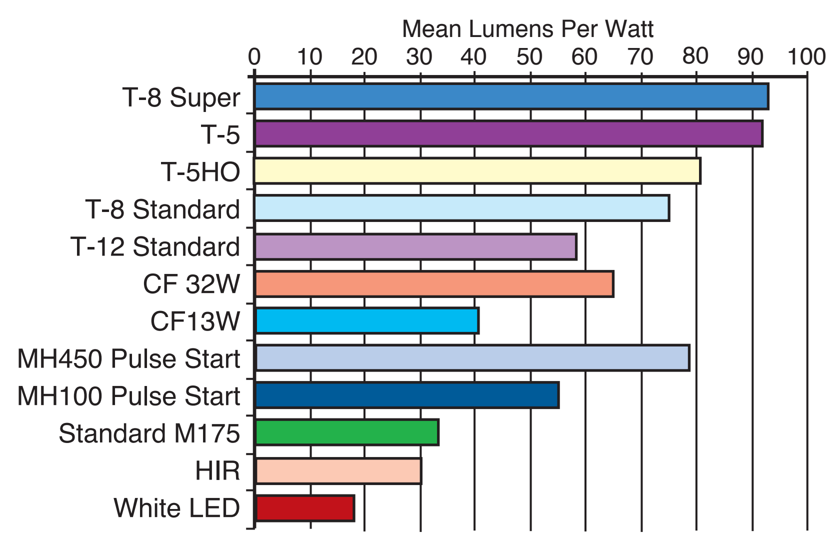
Lighting Strategies

In non-daylit spaces, the objective should be to implement the most energy-efficient system possible that minimizes glare and provides the proper level and quality of light. In naturally lit spaces, the artificial lighting design should be compatible with the objectives of the daylighting.

- In non-daylit spaces, incorporate lamps with high color rendering.
- Maximize the illumination by considering the geometry and reflectance of finishes in each space.
- Implement indirect lighting strategies to complement daylighting.
- Select fixtures that are designed to minimize glare. This is particularly important for rooms with computers.
- Verify the lighting requirements for each space function.
- Consider providing low-level ambient lighting supplemented by task lighting in administrative areas and the library.
- Explore photovoltaic lighting systems for remote exterior applications such as parking areas or walkways. Using a localized photovoltaic system with its own battery storage can be more cost effective than providing underground electrical service.
- Design switching circuits to allow lightly used spaces to be switched off.
- In Alaska, many lighting designers prefer to design for illumination levels that exceed the recommendations of the Illuminating Engineering Society of North America to compensate for short days and scarce sunlight during the winter. Although there is no technical or physiological evidence that additional electrical lighting (at least at the levels possible with conventional systems) will replace the health benefits of sunlight, the practice is widespread. When systems are designed for higher lighting levels, controls should be provided so that the lighting systems may be operated to provide typical illumination during the fall, summer, and spring.

Graphic courtesy of the Collaborative for High Performance Schools

The table to the right outlining comparative lamp efficacies shows that T-8 Super tubes are rated best.



High-Efficacy Lamps

Efficacy is an important measure for energy efficiency in light output per unit of energy used. High-efficacy lamps can provide the same illumination and color rendition as incandescent lamps but at two to six times the efficiency.

- Minimize the use of incandescent fixtures.
- When selecting lamps, consider the maintenance and lamp replacement costs. School districts should standardize their use of lamp and ballast types.
- Select the lamp ballast system with the highest lumens of output per watt of input that addresses the specific need.

Fluorescent Lamp Technologies—Efficacy Comparisons

Lamp Type	Lamp Life (hours)	Lumen/ Watt	C.R.I.*	Lumen Maint.**	Ballast Factor	Description and Comments
T-5 Fluorescent (28 W/4 Ft)	20,000	104	85	0.95	1	5/8” dia. tube; high lamp and ballast efficiency, high CRI, similar output to second generation T-8
T-5 HO Fluorescent (54 W/4 Ft)	20,000	93	85	0.93	1	5/8” dia. tube; high lumen output, high CRI; 61% higher lumens than standard 4 ft T-8
T-8 Fluorescent (32 W/4 Ft)	24,000	97	85	0.95	0.88	1” dia; standard for efficient fluorescent lamps; 24% efficiency improvement for second generation over T-12
T-12 Fluorescent (34 W/4 Ft)	20,000	78	62	0.86	0.87	1 1/2” dia. tube, still used on existing ballasts where efficiency is not considered

Developed by Padia Consulting from manufacturers' literature (Philips, Osram Sylvania, General Electric)

* Color Rendering Index
** The lumen maintenance percentage of a lamp is based on measured light output at 40% of that lamp’s rated average life. For T-5, after 8,000 hours of lifetime, the lumens/watt will be 98.8 lumen/watt (104x0.95).

Fluorescent lamp selection should be based on the illumination needs of the area and lamp replacement frequency and cost.

Compact Fluorescent Lamps

Efficacy is an important measure for energy efficiency in light output per unit of energy used. High-efficacy lamps can provide the same illumination and color rendition as standard lamps, but at two to six times the efficiency.

- When selecting lamps, consider the maintenance and lamp replacement costs. Because the transportation and labor costs are much higher in the arctic and subarctic climates, highly specialized lighting systems and lamps may not be cost effective, particularly in remote areas.
- Minimize the use of incandescent fixtures.
- Select the lamps with the highest lumens of output per watt of input that address the specific need.

Photo: NREL/PIX07071

LED exit signs last 10–50 times longer than fluorescent ones and use less energy.

Fluorescent Lamps

- Choose the smaller diameter, higher efficacy T-8 and T-5 fluorescent tubes over the traditional T-12s. The T-8 system produces 97 lumens per watt compared with 78 lumens per watt for the T-12 system. The T-5 system produces 25% more lumens per watt than the T-12 system.
- Specify fixtures that are designed to enhance the efficacy of the T-8 and T-5 lamps by incorporating better optics in the luminaire design. In gyms, multi-purpose, and other high-ceiling spaces consider T-5 or T-8 luminaries instead of metal halide.

Metal Halide and High-Pressure Sodium Lamps

- Consider metal halide and high-pressure sodium lamps for exterior lighting applications.
- Use metal halide and high-pressure sodium lamps only in areas where the long warmup and restrike time after a power outage will not affect the safety of students, visitors, and staff.

LED Exit Lights

- Select light-emitting diodes (LEDs) for exit signs that operate 24 hours per day, 365 days per year. LED exit signs offer energy savings of 80 kilowatt hours/year and 330 kilowatt-hours/year per fixture with little maintenance. LED exit lights have a projected life of 700,000 hours to more than 5 million hours, and the standby battery requires replacement about every 80,000 hours. Typical fluorescent lamps will last only 15,000 hours.

High-Efficiency Reflectors

High-efficiency fixtures employ two main strategies to minimize the blockage or trapping of light within the housing: high-efficiency lensed troffers and fixtures with parabolic reflectors.

- With troffers, select the shape and finish of the inner housing to minimize inter-reflections and maximize the luminaire efficiency. A high-efficiency troffer with two or three lamps can produce the same illumination as a standard four-lamp fixture.
- Select fixtures with parabolic reflectors for administrative areas to improve the optics and increase the performance of the light fixtures.

Ballasts

Solid-state electronic ballasts are available in rapid-start and instant-start models. The instant-start ballasts have a very high efficiency, but should not be used with occupant sensors.

- Select high-efficiency electronic ballasts because they save energy, attract little dust, incorporate a minimum a few materials, and operate at a cooler temperature.
- Select electronic ballasts because they minimize the characteristic humming from fluorescent lamps.

- Consider that conventional ballasts cycle at 60 hertz and create a perceptible flicker, whereas electronic ballasts cycle faster and reduce eye strain.
- Dimming ballasts are generally not recommended for the arctic and subarctic climate zones. However, if the daylighting strategy warrants a dimming ballast, employ electronic ballasts designed specifically for dimming and controlled by photosensors. Magnetic ballasts will dim to only about 40% of full power before the flicker becomes problematic, whereas electronic ballasts may be dimmed to near zero output with no perceptible flicker. Electronic ballasts also have a higher lumen output than magnetic ballasts at reduced power levels.

Lighting Controls

Because of changing use patterns in schools throughout the day, occupancy sensors and photosensors for outdoor lighting can save considerable energy by simply turning off unneeded lights. There are two commonly used occupancy sensors: infrared and ultrasonic. Infrared sensors detect occupants by sensing changes in heat as occupants move; ultrasonic sensors detect movement of solid objects. Sensors that combine both technologies are recommended for classrooms. Consider lighting controls for storage rooms, mechanical rooms, equipment rooms, closets, locker rooms, and similar areas.

Photosensor controls should be used for outdoor lights to ensure that the fixtures are off or dimmed during the hours when daylight levels are sufficient.

Ensure that all types of lighting controls are properly calibrated. This will reduce the likelihood that the controls will be disabled.

Electrical Systems

An inefficient electrical distribution system in a school can result in degraded power quality, the introduction of wasteful harmonics, and line losses as high as 3% or 4%.

- Evaluate the merits of a high-voltage distribution system, taking into consideration the initial cost and operational savings that result from reduced line losses. Analyze the costs of delivering power at 208/120 volts versus 480/277 volts.
- Correctly size transformers to fit the load, keep losses to a minimum, and optimize transformer efficiency. The correct sizing of a transformer depends on the economic value and size of load losses versus no-load losses, and consideration of expected transformer life.
- Consider more efficient transformers that operate at lower temperatures. Most transformers are 93%–98% efficient. Some states have transformer efficiency standards, others require them. Check with your state energy office.
- Consider using K-rated transformers to serve nonlinear equipment. K factor is a constant developed to take into account the effect of harmonics on transformer loading and losses. A K-rated transformer may initially cost more, and may be less efficient, but should last longer.

Motion sensors are used to turn lights off if the space is unoccupied. If applicable, combine the motion sensor with a daylight sensor to turn off lights if natural light in the space is sufficient.

ESTABLISH ENERGY PERFORMANCE GOALS

For new school design (K-12), the EPA recommends setting a design target and monitoring progress throughout the design process.

The ENERGY STAR label can also be used to identify energy-efficient office equipment, exit signs, water coolers, and other products. By choosing these products, your school can save energy and money.

- Evaluate the distribution system to determine whether power factor correction is justified. Utilities usually charge users for operating at power factors below a specified level. In addition to causing unnecessary line losses, low power factors create the need for a larger energy source. If power factor correction is necessary, a common method is to place power-factor-corrective capacitors or three-phase synchronous capacitors (motors) in the system, close to the load.
- In some situations, disconnecting the primary sides of transformers that do not serve active loads can save energy. Disconnecting the primary sides of transformers is safe provided that critical equipment such as fire alarms and heating control circuits are not affected.
- Where possible, minimize long runs of wire from power distribution panels to electrical equipment. Where equipment would be likely to operate at a low voltage because of distance from the distribution panel, install larger wire to reduce voltage drop.

Because appliances, motors, fans, and other electrical equipment are responsible for a high percentage of building electrical consumption, equipment that is properly sized, energy efficient, and environmentally sound must be selected.

- Don't oversize the equipment. It will add to the peak electrical loads, and often does not operate as well at part-load conditions.
- Use high-efficiency motors and, where appropriate, variable frequency drives. Compare motors using No. 112, Method B, developed by the Institute of Electrical and Electronic Engineers, http://www.ieee.org.
- Select fans and pumps for the highest operating efficiency at the predominant operating conditions.
- Set temperatures on electric water heaters based on use requirements.
- Use timers to limit the duty cycle of electric water heaters when they are not in full use.
- Most rural and/or remote schools in the arctic and subarctic climates feature full kitchen facilities, which should be considered when looking at energy load and equipment selection.
- Select energy-efficient food service appliances.
- Specify ENERGY STAR-rated appliances when applicable.

Photo: Ken Graham Photography.

Select energy-efficient food service appliances. Most schools in the remote areas have full-service kitchens.

Mechanical and Ventilation Systems

Mechanical and ventilation systems are typically responsible for 50%–60% of the energy consumed in schools. By using the "whole-building" approach—looking at how all the building's design elements work together—your design team can factor in energy-saving choices that reduce heating loads and downsize the mechanical system needed. By not over designing the mechanical system, you can reduce initial equipment costs as well as long-term operating costs.

More importantly, mechanical and ventilation systems have a significant effect on the health, comfort, productivity, and academic performance of students and teachers. A 1994–1995 study by the U.S. General Accounting Office found that half of the more than 90,000 public schools in the country are facing noise control problems, lack of adequate ventilation, poor indoor air quality, and comfort issues. A 1999 U.S. Department of Education study found that 26% of the country's schools had unsatisfactory levels of outside air. Most of these issues are directly or indirectly linked to mechanical system design and operation and can be corrected with improved mechanical and ventilation systems.

The best mechanical and ventilation design considers all the interrelated building systems and addresses indoor air quality, energy consumption, and environmental benefit. Optimizing the design and benefits requires that the mechanical system designer and architect address these issues early in the schematic design phase and revise subsequent decisions throughout the design process. You must also implement thorough commissioning processes and routine preventative maintenance programs.

Control strategies like occupancy and pollutant sensors are essential to improve efficiency in the school's energy system management.

Providing visual access to the energy efficient mechanical system provides a teaching tool for students to see energy conservation in action.

EnergyPlus

EnergyPlus is a new-generation building energy simulation program designed for modeling buildings with associated heating, cooling, lighting, and ventilation flows. EnergyPlus builds on the most popular features and capabilities of BLAST and DOE-2 and includes many advanced and innovative simulation capabilities.

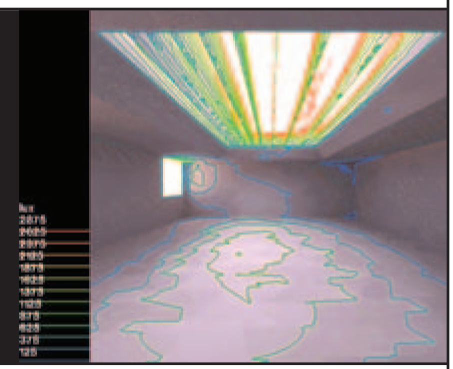
Design Guidelines for Mechanical and Ventilation Systems

Energy Analysis

To optimize the selection of efficient, cost-effective mechanical and ventilation systems, perform an energy analysis early in the process. System optimization also improves indoor air quality and allows better humidity control. Also, smaller mechanical and electrical systems may reduce construction costs. Several computer programs can provide hourly building simulations to predict the energy behavior of the school's structure, air conditioning system, and central equipment plant.

An energy analysis considers the school's key components—the building walls and roof, insulation, glazing, the lighting and daylighting systems, as well as the mechanical systems and equipment. The analysis program can simultaneously assess and predict the results of choices associated with each component. For buildings in the design phase, computer models are generally useful for comparing alternatives and predicting trends.

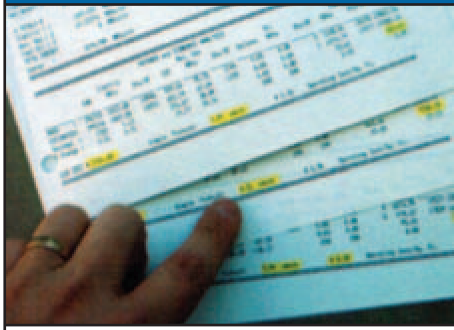
Energy analysis computer programs that simulate hourly performance should include a companion economic simulation to calculate energy costs based on computed energy use. This model can estimate monthly and annual energy use and costs. Some models allow the user to input estimated capital equipment and operating costs so that the life-cycle economics of the design can be evaluated and compared.



Computer simulations of daylighting are essential to achieving a clear understanding of how this energy strategy impacts mechanical loads and the "whole building" performance.

- Before starting work on the design, establish an "energy budget" for the project that exceeds the minimum building code standards. Consider setting an energy budget that might qualify the school for an ENERGY STAR buildings label. An ENERGY STAR designation places the school in the top 25% of energy performance.
- Develop a clear understanding of how the school system wants to balance initial cost versus life-cycle cost, and point out the long-term advantages of investing in more energy-efficient and environmentally friendly approaches.

Communication among members of the school system, architects, and engineers early in the predesign process is critical for establishing the most energy-efficient "whole-building" strategy.



The energy budget and goals should be established before the start of the schematic design phase.

- When evaluating life-cycle costs, take into account:
  - – the initial cost of equipment
  - – anticipated maintenance expenses
  - – projected annual energy costs
  - – projected energy and labor cost escalation rates
  - – replacement costs.
- Optimize the mechanical system as a complete entity to allow for interactions between system components.
- In the schematic design phase, determine the mechanical system implications of all related site, building shell, daylighting, and lighting elements.

When energy use and operating expenditures are considered at the outset of the design process, energy- and resource-efficient strategies can be integrated at the lowest possible cost.

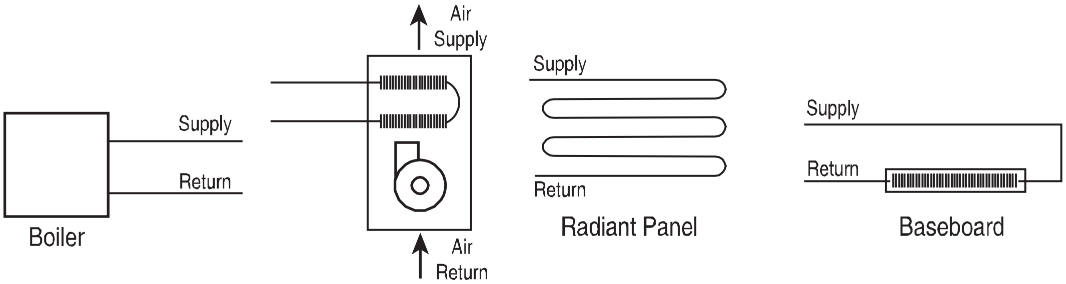
Cooling Systems

Mechanical cooling systems are generally not necessary for high performance design schools in the arctic and subarctic climate zone. Specify some operable windows at the school for cooling and ventilation purposes. Consider mechanical cooling only if the school will be used regularly during the summer months.

Hydronic Heating Systems

Consider hydronic heat loop systems with baseboard heating for schools in this climate.

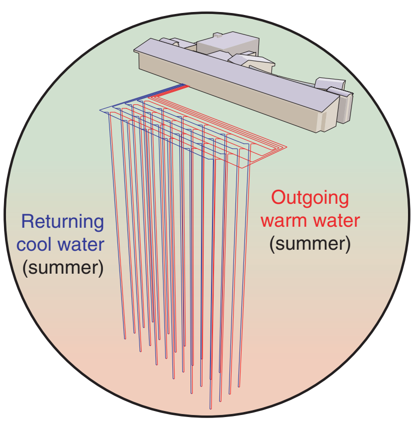
Although packaged rooftop systems are being used in more schools because of their attractive cost, many school districts do not consider these systems feasible because of maintenance concerns.



Components of a hydronic distribution system. Proper design can result in significant economic and energy savings.

Photo: Eddie Bell/PIX10669

These energy efficient, fully condensing pulse boilers were installed as part of a district-wide energy upgrade that significantly reduced overall utility costs.



This closed loop GSHP system is more common than the open loop GSHP. Closed loop systems circulate an anti-freeze fluid through a subsurface loop of pipe to a heat pump. When used in the heating mode, this circulating water is pumped through the cold heat exchanger, where its heat is absorbed by evaporation of the refrigerant. The refrigerant is then pumped to the warm heat exchanger, where it is condensed, releasing heat in the process.

Boilers

Boilers are commonly used as the primary heating sources for schools in the arctic and subarctic climate zones. Although these have traditionally been conventional, oil-burning boilers, be sure to evaluate the most efficient heating for the particular need when considering centralized systems.

- Consider condensing boilers. They are typically 10% more efficient than conventional boilers.
- Consider multiple, modular boilers that are more efficient at partial load.
- Employ draft control devices that reduce off-cycle losses.
- Design a water reset control that is keyed to the outside air temperature.
- Incorporate burner flame controls.
- For small renovation projects, install time clocks to control night and weekend setbacks.
- Consider self-contained boiler and sprinkler water modules located separate from the building for added fire safety.

Alternative Technologies: Ground Source Heat Pumps

Ground Source Heat Pumps (GSHPs) use the moderately tempered ground as a source of heat in the winter and as a tool for heat removal from the building in the summer. They tend to be most applicable and cost effective in areas with considerable heating and/or cooling loads, or where heating fuel is expensive. GSHPs can operate in low temperatures as found in this climate zone, but may not be cost-effective at every location. As with any climate, a detailed site survey is highly recommended if a school/design team is interested in using GSHPs.

Ventilation Strategies

ASHRAE Standard 62 addresses the criteria necessary to meet ventilation and indoor air quality requirements. The outside air requirements for ventilating an occupied school are considerable and can greatly affect energy load and system operating costs, especially in an extremely cold climate. The strategy employed to achieve proper ventilation must be carefully considered.

- Implement ventilation strategies that will ensure outside air by complying with ASHRAE Standard 62-1999.
- For smaller schools, consider a constant volume ventilation system with economizer to provide temperate outside air.
- For larger schools, variable volume systems (versus constant air systems) are more effective for proper ventilation. They allow you to capitalize on reduced fan loads during times of reduced demand.

- Consider heat recovery ventilator systems, which use exhaust air to warm incoming fresh air. Such systems may include run around coils or enthalpy wheels.
- Separate and ventilate highly polluting spaces. Provide separate exhaust from kitchens, toilets, custodial closets, chemical storage rooms, and dedicated copy rooms to the outdoors, with no recirculation through the mechanical system.
- Locate outdoor air intakes at least 7 feet vertically and 25 feet horizontally from polluted and/or overheated exhaust (e.g., cooling towers, loading docks, fume hoods, and chemical storage areas). Consider other potential sources of contaminants, such as lawn maintenance. Separate vehicle traffic and parking at least 50 feet from outdoor air inlets or spaces that use natural ventilation strategies. Create landscaping buffers between high traffic areas and building intakes or natural ventilation openings.
- Locate exhaust outlets at least 10 feet above ground level and away from doors, occupied areas, and operable windows. The preferred location for exhaust outlets is at roof level projecting upward or horizontally away from outdoor intakes.
- Provide filters capable of 60% or greater dust spot efficiency, and install them in a location where all make-up and return air can be intercepted. In dusty areas, use a higher efficiency filtration system (80%–85% by ASHRAE standards with 30% efficient pre-filters).

Distribution Systems

Design an air distribution system that is energy efficient and protects against poor indoor air quality.

- Where individual room control is desired or diverse loads are present, employ variable air volume (VAV) systems (versus constant air systems) to capitalize on reduced fan loads during times of reduced demand.
- Use constant volume systems where the load is uniform and predictable (e.g., kitchen).
- If a particular mechanical system serves more than one space, ensure that each has the same orientation and fulfills a similar function. Consider independent mechanical rooms and systems on separate floors to reduce ductwork and enhance the balance of air delivered.
- Consider a design that supplies air at lower temperatures to reduce airflow requirements and fan energy.
- Specify ductwork that has smooth interior surfaces and transitions to minimize microbial growth. Design ductwork and plenums to minimize the accumulation of dirt and moisture and to provide access areas in key locations for inspection, maintenance, and cleaning. Use mastic to seal metal ductwork. Where possible, locate ductwork in conditioned or semi-conditioned spaces.

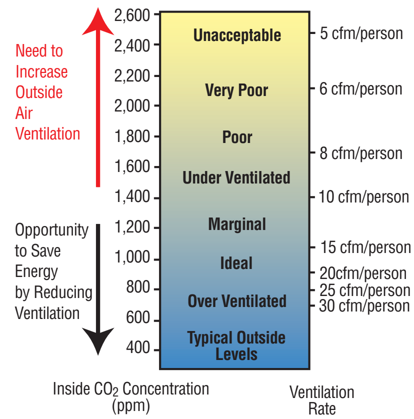
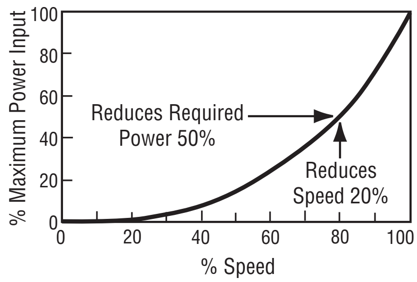


Diagram: TelAir, Goleta, CA

Conditions of Indoor Air Quality

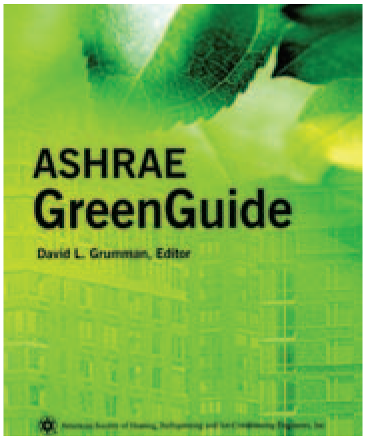
Carbon dioxide concentration may be measured and used to control indoor air quality.



Graphic: Padia Consulting

VAV Fan Speed vs Input Power

Controlling motor speed to control air flow is the more energy-efficient strategy. Variable frequency drive control offers a distinct advantage over other forms of air volume control in variable air volume systems.



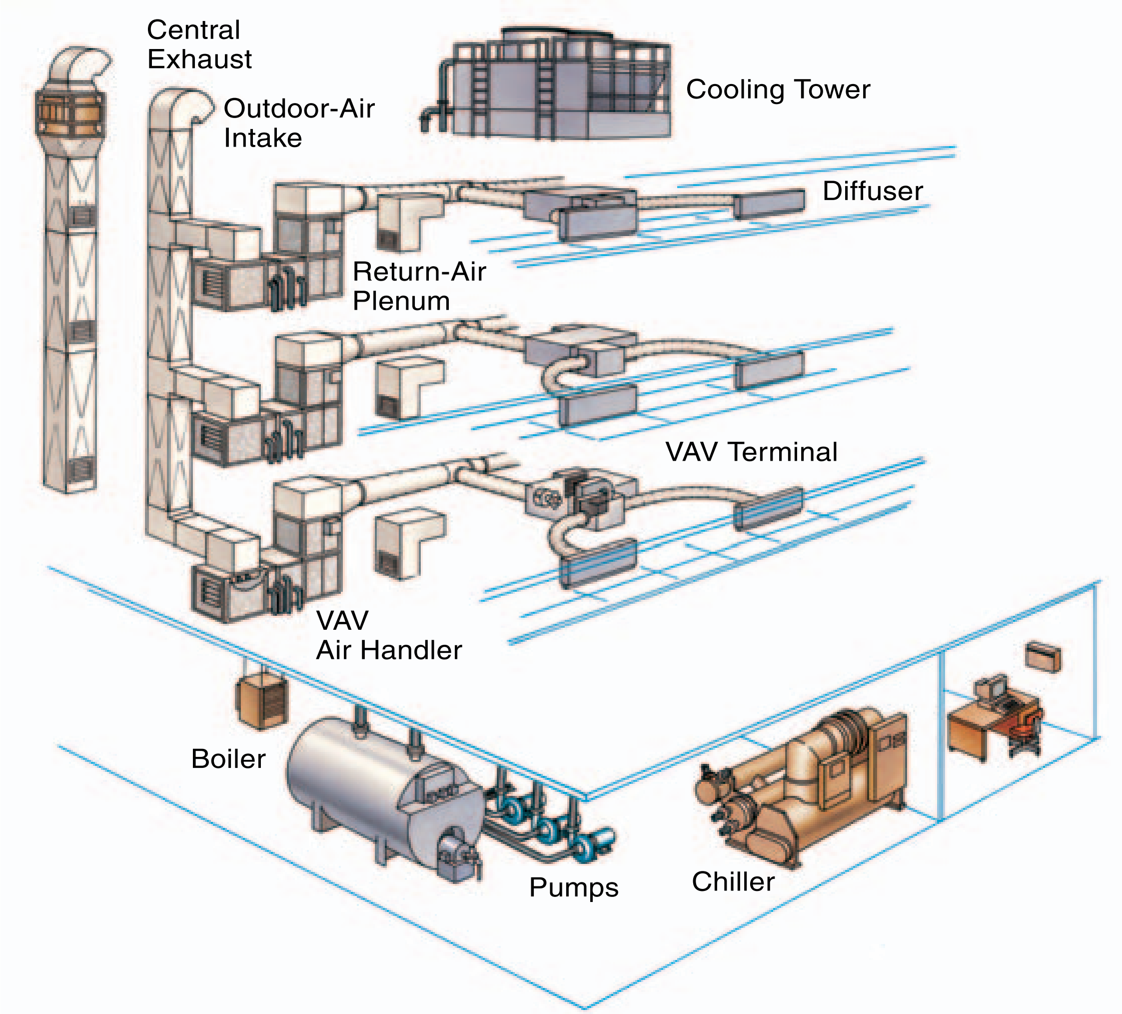
ASHRAE sets the industry standards for mechanical and ventilation systems, as well as providing continuing education for design professionals on the latest strategies and techniques for mechanical system design. ASHRAE also produces the ASHRAE GreenGuide, a manual that provides information to design teams on incorporating sustainable and efficient mechanical and ventilation strategies into buildings.

- Specify duct leakage tests.
- Make sure that air handling units and filters are easy to access and maintain.
- Reduce duct pressures to minimize the amount of fan energy used to distribute the air. Use low-velocity coils and filters.
- To minimize energy consumption, select fans for the highest operating efficiency at predominant operating conditions, and use lower fan speeds to reduce noise levels. Consider direct-drive fans for their improved efficiency.
- Use filters that meet at least 60% ASHRAE Dust Spot Method Standards.

Controls

To ensure proper, energy-efficient operation, implement a control strategy that is tied to key energy systems. Include system optimization, dynamic system control, integrated lighting, and mechanical and ventilation control.

- Analyze the applicability of direct digital control (DDC) for the specific site. These systems generally have the highest benefit in larger schools. DOC systems will result in greater accuracy, performance, and energy savings. However, in smaller and/or more remote schools feasibility may be limited. Be sure to weigh these factors with specifying a DDC system.
- Set up the mechanical and ventilation control system to operate according to need. Limit electrical demand during peak hours by turning off (or rotating) nonessential equipment.
- Establish temperature and humidity set points based on occupancy patterns, scheduling, and outside climatic conditions.
- Install carbon dioxide sensors to reduce ventilation air requirements for unoccupied spaces.
- Make owners aware that they should periodically verify the accuracy of the sensors and control functions and calibrate if necessary.
- Notify owners of the need to periodically audit all computer-controlled mechanical systems to verify performance and calibration.
- If using VAV systems, set supply-air temperature reset controls based on occupancy of space. Specify VAV controls to ensure that the proper amount of outdoor air is maintained, even when the total air supply is decreased.
- In small schools, consider time clocks with night and weekend setbacks.
- Work with the school system to establish a means to monitor and document the performance of the energy management control system and provide training of future maintenance staff.



System Control Schematic—Variable Air Volume System

Variable air volume (VAV) central air handling units with VAV terminal units and/or fan powered boxes equipped with hot water reheat coil.

The hot water for heating is provided either by a condensing boiler or a conventional non-condensing boiler.

Hot Water Distribution

- Carefully select heat exchangers with a low approach temperature and reduced pressure drops.
- In large systems with multiple heat exchangers, designate a separate pump for each heat exchanger to maintain high efficiency at part-load operating conditions.
- Consider primary pumping systems with variable-speed drives because of their effects on part-load energy use.

Indoor Air Quality: Tools for Schools

This program is designed to give schools the information and skills they need to manage air quality in a low-cost, practical manner. The kit is published by the EPA and co-sponsored by the American Lung Association.

Photo: NREL/PIX09214

An energy management system optimizes mechanical and lighting system operation to increase energy- and cost-savings.

Water Heating

- Consider tankless (instantaneous) water heaters in remote areas that require small hot water amounts.
- Consider localized versus centralized hot water equipment by evaluating the types of loads served. A remote location may be best served by localized equipment.
- If adequate solar access is available, consider a solar assisted hot water system.
- Minimize the standby heat losses from hot water distribution piping and hot water storage tanks by increasing insulation levels, using anti-convection valves, and using heat traps.

Renewable Energy Systems

There is no shortage of renewable energy. And renewable energy can contribute to reduced energy costs and reduced air pollution. More importantly, the renewable energy systems that you design into your school will demonstrate to the students the technologies that will fuel the 21st century.

Over the past two decades, the costs of renewable energy systems have dropped dramatically. According to the Department of Energy's Office of Power Technologies, wind turbines can now produce electricity at less than 4 cents per kilowatt-hour—a sevenfold reduction in energy cost. Concentrating solar technologies and photovoltaic costs have dropped more than threefold during the past 20 years. And, with improvements in analytical tools, passive solar and daylighting technologies can be implemented into schools with less than a two-year return on investment.

Incorporating renewable energy options into your school design helps students learn firsthand about these cost-effective and energy-efficient options. Input from teachers early in the design process helps to ensure that energy features are incorporated in a way that optimizes the learning experience. Buildings that teach offer students an intriguing, interactive way to learn about relevant topics like energy and the environment.

Photo: Glen Bair, by State of Texas Energy Conservation Office

In adequately sunny regions of these climates, implementing photovoltaic-powered school zone warning signals can serve as an energy-efficient alternative to traditional electric traffic signals.

Photo: Warren Gretz, NREL/PIX00006

These flat-plate photovoltaic arrays are most cost effective in remote areas of the maritime region.

Photo: Green Mountain Power Corporation

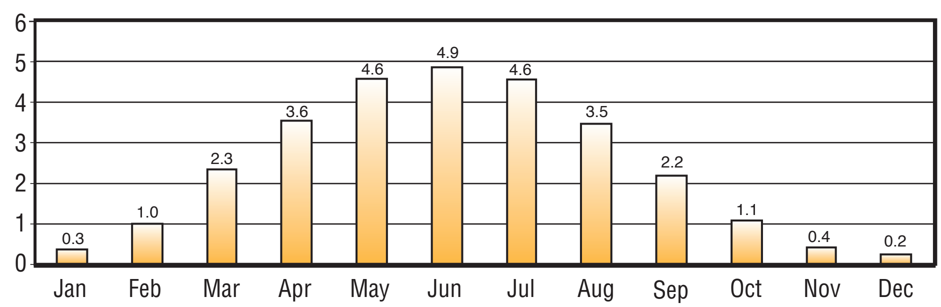
Schools can implement wind turbines to save energy and, in some cases, even make money.

Design Guidelines for Renewable Energy Systems

Available Renewable Energy Resources

When evaluating potential renewable systems, use the best available historic climatic data, closest to the school site.

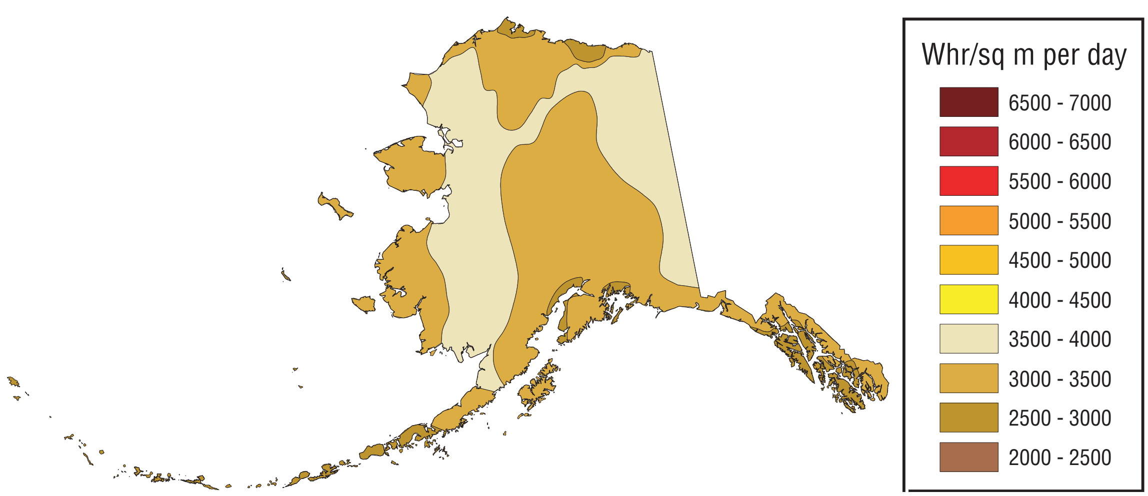
- Even though the solar radiation levels in the arctic and subarctic climates are much lower than in the lower 48 states, you should still evaluate the potential for solar systems in this region. The following data show that the region's solar resources are most viable in the southeast part of the state. You can find additional state specific information on the State Energy Alternatives Web site (http://www.eere.energy.gov/state_energy/).



Average solar radiation data for flat plate collectors with a fixed-tilt in Anchorage (Btu/square foot/day)

NOTE: Watts/Square Meter x .317 = Btu/Square Foot

Source: University of Alaska Fairbanks Cooperative Extension, "Anchorage, Alaska Solar & Weather Information Fact Sheet." EEM-01356, Revised July 2000. http://www.uaf.edu/coop-ext/publications/freepubs/EEM-01356.pdf

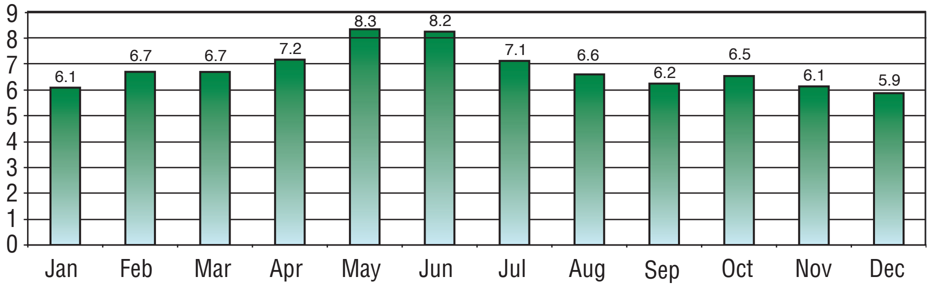


Available solar resources in Alaska for a flat-plate collector

Photo: NREL/PIX08884

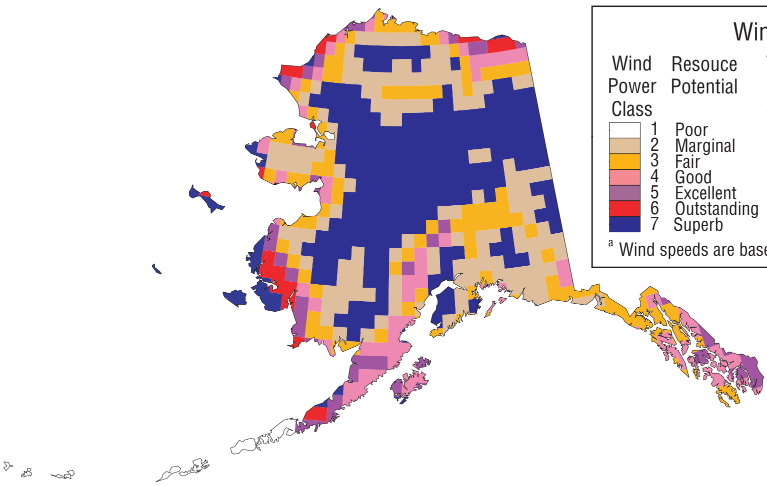
This building-integrated photovoltaic system covers the roof of this school's cafeteria.

- Wind generation becomes cost effective in most areas when the average wind speed exceeds 10 miles per hour. In locations where the wind is marginally below this amount, you should still consider wind systems for their educational value.



Annual mean wind speed (MPH) in Anchorage

Wind resources are substantial in much of the arctic and subarctic climates. The largest areas of class 7 wind power in the United States are located in Alaska. Data from some of the Aleutian Islands indicate an annual average wind power over 1000 W/m^2 at 10 m, which corresponds to about 2000 W/m^2 at 50 m.



Wind Power Classification

Wind Power Class	Resouce Potential	Wind Power Density at 50m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m m/s
1	Poor	0 - 200	0.0 - 5.6	0.0 - 12.5
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	> 800	> 8.8	> 19.7

[a] Wind speeds are based on a Weibull k value of 2.0

Average annual wind power in Alaska

Building Orientation and Solar Access

Employing renewable energy strategies cost effectively requires the school to be sited to maximize the locally available natural resources.

- Establish the building on an east-west axis that maximizes southern exposure for daylighting and other solar systems.

- Ensure that adjacent buildings or trees do not block the intended solar access.

This solar domestic water system was added to the school's kitchen roof area and provides most of the hot water required by the cafeteria.

Building-Integrated Approaches

If considering solar thermal and/or photovoltaic systems, integrate these features into the building shell to maximize cost effectiveness and improve aesthetics.

- Integrate solar systems into the overall design to allow the system to serve multiple purposes (e.g., a photovoltaic array that can also serve as a covered walkway).
- Eliminate the additional costs associated with a typical solar system's structure by designing the building's roof assembly to also support the solar components.
- Incorporate building-integrated approaches to save valuable land.

Renewable Energy Applications for Schools

Several renewable energy systems are applicable or partially applicable in the arctic and subarctic climates. Consider photovolatics, solar hot water heating, wind, and geothermal as energy-saving strategies that also teach students about energy technologies.

Photovoltaics and Solar Water Heating

In the arctic and subarctic climates, solar radiation levels are much lower than in other parts of the United States. Flat-plate solar collectors—flat panels that collect sunlight and convert it to electricity or heat—are sometimes applicable in this climate. A rule of thumb is that a flat-plate collector gets the most sun if it is tilted toward the south at an angle equal to the latitude of the location. Based on available solar radiation patterns, the best area in the climate for their use is southeast Alaska. Although the applicability for technology is lower in this climate than in the lower 48 states, some applications may be feasible in the maritime area.

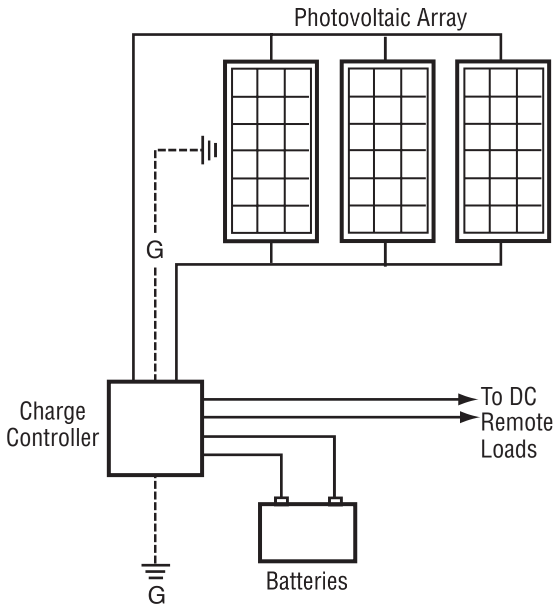
Photo: Bluffsview Middle School

Photovoltaic systems can serve as excellent science teaching tools about how energy works. Their impact on energy and related cost savings can also be a great lesson in conservation and economics.

Photovoltaic systems can be either "stand-alone" or "grid-connected."

- Select stand-alone photovoltaic systems to address small, remotely located loads. They tend to be more cost effective than the conventional approach, which requires extensive underground wiring. Applications include parking and walkway lighting, caution lights at street crossings, security lights, emergency telephone call boxes, and remote signage.

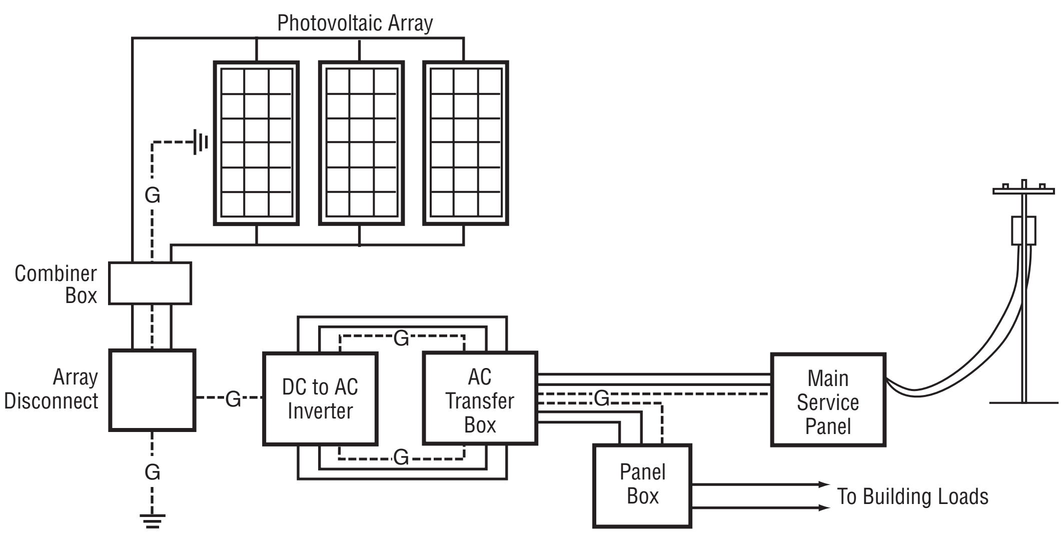
  Because these systems are not connected to the utility grid, battery storage is required. Depending on the device being powered, a DC to AC inverter may or may not be installed.



Stand-alone photovoltaic system diagram

Stand-alone systems are ideal for remote loads located away from electrical lines.

- Choose grid-connected systems in large applications where peak load pricing is high or where first cost is an issue. Because these systems typically rely on the utility to provide power when the sun isn't shining, battery cost is eliminated and long-term maintenance is reduced greatly. This strategy is typically advantageous to both the utility and the school because peak demand will occur when the sun is shining. In these applications, a DC to AC inverter is required. Additionally, in the event of a utility power failure, protection must be provided to ensure that the system does not feed back into the utility grid.



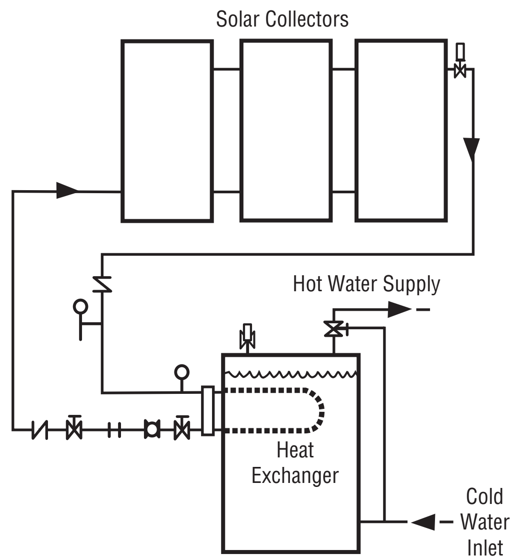
Grid-connected photovoltaic system diagram

Grid-connected systems work well for large loads located near electrical service.

Photovoltaic systems in schools provide substantial energy savings and are educational tools for sustainability.

These stand-alone photovoltaic systems powered parking lights are an energy-saving alternative to traditional electric-powered lights in areas with adequate solar resources.

- Solar water heating also has a limited applicability in this climate. These systems are not recommended for areas where the risk of freezing is high and solar radiation is low, as in the northern part of Alaska.



Closed-loop solar hot water system diagram

Closed-loop systems use a controller to shut the system down when the temperature differential becomes too small or when the tank reaches a set peak temperature.

Photo: /PIX05629

The wind turbines at Kotzebue, Alaska, have innovative foundations designed to protect the tundra and its underlying permafrost.The foundations work like camper refrigerators and keep the ground around them frozen, even in the middle of summer.

Wind

Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used directly (e.g., water pumping), or it can be converted into electricity.

- Consider wind electric generators in areas where the sustained wind speed exceeds 10 miles per hour. Many parts of Alaska have excellent wind resources. High winds are common over the Aleutian Islands and the Alaska Peninsula; most coastal areas of northern and western Alaska; the offshore islands of the Bering Sea and Gulf of Alaska; and over mountainous areas of northern, southern, and southeastern Alaska. Schools in these more remote areas may be able to cost-effectively generate some of their power with wind turbines.
- Consider wind systems for well water pumping.
- Address potential noise problems by properly siting wind installations.
- Consider the educational benefits of installing a windmill or a wind generator on the school site.

Water Conservation

Every day the United States withdraws 340 billion gallons of fresh water from streams, reservoirs, and wells—an amount equal to 1,000 gallons per person per day. And as the population grows, so does that demand for water. Combine the impacts of rising population with the demographic shift to more arid regions, and the pressure of providing clean water becomes more critical every year.

Water conservation is not a big problem in Alaska; however, conservation practices should be enforced as a preservation measure. You can make a considerable difference at your school by reducing community water use. By using water-conserving fixtures, implementing graywater or rainwater catchment systems, and using xeriscape practices, schools can easily reduce their municipal water consumption 25%–75%.

Photo: NREL/PIX00653

This water-conserving sink uses infrared sensors.

Design Guidelines for Conserving Water

Water-Conserving Landscaping Strategies

The demand for water will be greatly affected by the amount of site irrigation required. Because of this climate's long winters and minimal landscaping, irrigation has traditionally not been a big source of water consumption for schools. However, various landscaping strategies must be integrated to ensure water consumption for landscaping stays at a minimum.

- Minimize disruption to the site conditions, and retain as much existing vegetation as is practical.
- Incorporate native and drought-resistant plants and xeriscape principles to minimize irrigation requirements.
- In-ground, automatic irrigation systems are generally not recommended. Consider service sprinklers to efficiently meet irrigation needs.

Photo: Architectural Energy Corporation

Employing water-saving strategies, such as the integration of native and drought-resistant plants, can achieve significant water cost savings.

Conservation of Water during Construction

You can save a considerable amount of water during your construction projects by including specifications that address water conservation during construction.

- Include disincentives in specifications to the general contractor for excessive water use and incentives for reducing consumption during construction.
- Specify that the general contractor is responsible for water cost during construction.
- Minimize watering requirements by specifying times of year when new landscaping efforts should occur.
- At pre-bid meetings, stress to the general contractor and subcontractors the importance of water conservation.

Water-Conserving Fixtures

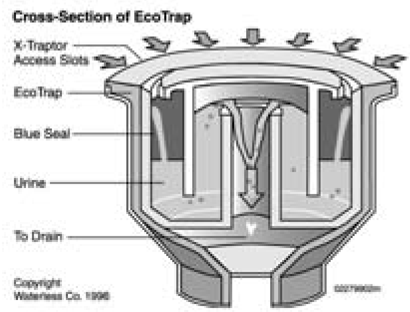
One of the most effective means to limit demand for water is to reduce the requirements associated with necessary plumbing fixtures. Depending on your site's location and transport requirements, consider cost and availability when specifying low-flow fixtures.

- Consider the standards of the 1992 Energy Policy Act as a minimum. Specify low-flow toilets that use less than 1.6 gallons per flush.
- Consider showerheads that require less than 2.5 gallons per minute and incorporate levers for reducing flow 2.1–1.5 gallons per minute.
- Use aerators to reduce flow in lavatory faucets to as low as 1 gallon per minute.
- Specify self-closing, slow-closing, or electronic faucets in student bathrooms where faucets may be left running.
- Consider waterless urinals or 1-gallon-per-flush urinals.

Projected Water Savings by Installing Waterless Urinals in Schools

	School with Regular Urinals	School with Waterless Urinals
Number of Males	300	300
Number of Urinals	10	10
Use/Day/Male	2	2
Gallon/Flush	3	0
School Days/Year	185	185
Water Saved/Year		222,000 Gallons

Waterless urinals are one way to reduce water use in your school.



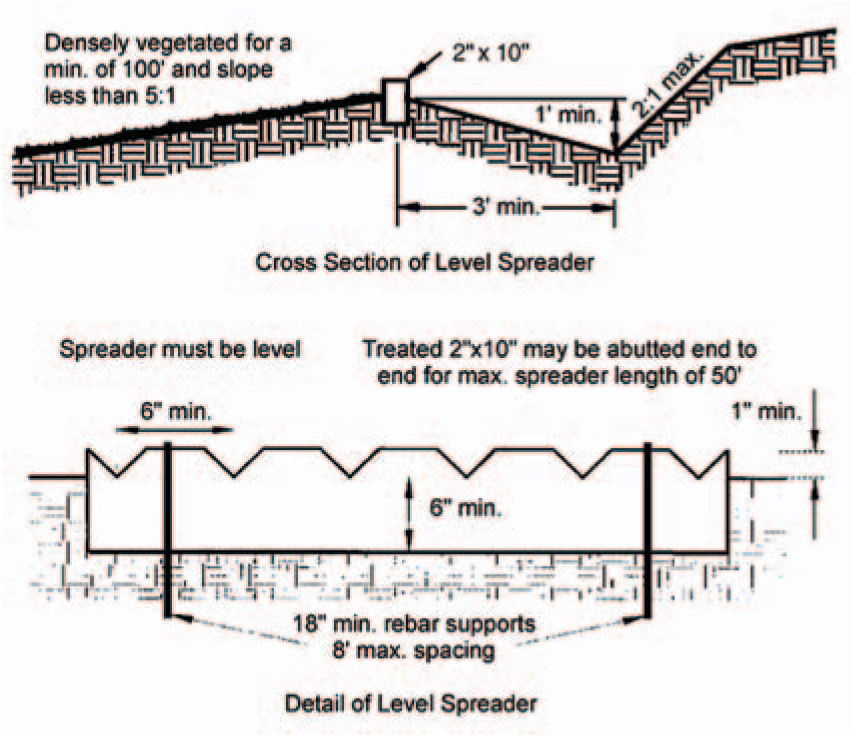
Waterless Urinals

Waterless urinals require no water as the traditional water-filled trap drain is replaced with an oil based trap.

Stormwater Management

Stormwater management is vital to the safety and ecological health of a school site. Stormwater management strategies need to be considered in the arctic and subarctic climates, especially in the southeast areas around Juneau, which receive significant rainfall.

- Manage stormwater with systems that slow water velocity, maximize its use for irrigation, and filter pollutants.
- Use material-efficient options for on-site drainage systems, such as:
  - Ifor fill: recycled-concrete aggregate, crushed concrete, glass
  - Ifor pipes: EPS with recycled content.
- In areas where the water table is high, construction can cause groundwater to seep to the surface. Use level spreaders to pipe the discharge from curtain drains to trickle discharge onto vegetation.
- Natural boulders can be effective as energy dissipaters or checkdams, creating riffles and pools in the channels.
- Groundwater should be managed separately from surface water to prevent contamination.



Level spreader, cross section and detail

Source: Washington State Department of Ecology, Stormwater Management Manual for Western Washington, Volume II, Construction Stormwater Pollution Prevention

Recycling Systems and Waste Management

Waste management is a significant concern in the arctic and subarctic climates. According to Alaska's Division of Environmental Health, every day the average Alaskan throws away six pounds of garbage, which adds up to more than 3.5 million pounds per day—nearly twice the daily average of the rest of the United States. Poor waste management leads to high densities of mosquitoes and rodents around landfill areas. Improperly handled garbage leads to increased bear and fox attraction, as well as increased potential for air and water pollution.

Just like schools in the lower 48 states, schools in this climate are significant contributors to the billions of pounds of municipal solid waste each year. You can help reduce much of this waste by recycling or composting. In a compilation of studies of waste generation in Washington State and New York City schools, reported by the EPA, paper accounted for as much as half of waste in schools, organic (compostable) materials as much as one-third, plastic about 10%, and glass and metals about 7%. To the extent that school buildings can be made more recycling and composting friendly, very high percentages of this material can be kept out of the waste stream. In fact, if every school system implemented aggressive recycling efforts, landfills would have 1.5 billion pounds less solid waste each year.

Recycling programs are becoming more commonplace in urban areas, but costs, particularly in the more rural areas, are higher than in other areas of the United States because of transportation costs. However, by creating schools in which comprehensive waste recycling can be carried out, your design team has an opportunity to instill the practice of recycling. Hundreds of schools throughout the country have embarked on exciting and highly successful hands-on programs to encourage recycling. Often, the students design and manage these programs—and see the fruits of their labors as they quantify waste reduction or recycling. The most successful recycling and waste management programs are integrated into classes, where students make use of mathematical, investigative, and communication skills to implement these programs.

For efficient recycling collection, the recycling bins must be labeled and located in areas easily accessible by students and staff.

Photo: Chittenden Solid Waste District

Teaching students the benefits of recycling improves the overall success rate of a school's waste reduction program by reinforcing the importance of minimizing waste.

Photo: Huntsville High School East

Signage can encourage students and staff to actively recycle major waste materials in the school.

Photo: Mount Baker School District

In Deming, Washington, the Mount Baker School District's recycling effort is in its eighth year and is now saving $25,000 annually. Successful because of its outstanding student participation, the award-winning program has a long list of recyclable or reusable materials. The program is totally self-supporting, and last year the students saved $18,000 through recycling and reuse and an additional $7,000 from avoided disposal fees. In 1999, through the school's efforts, 89,700 pounds of materials were recycled or reused and not put into a landfill.

Design Guidelines for Implementing Recycling Systems and Waste Management

Paper, Plastics, Glass, and Aluminum Recycling

Students are able and eager to participate in recycling programs. Successful recycling programs teach students recycling skills and save money through reuse of materials and avoided disposal fees.

Paper represents one of the largest components of a school's waste stream. Glass, aluminum, plastic bottles, cans, and even styrofoam can now be recycled.

- Allocate space within each classroom, the main administrative areas, and the cafeteria for white and mixed paper waste.
- Provide central collection points for paper and cardboard that are convenient to custodial staff and to collection agencies or companies.
- Place the receptacles for all recyclables where the waste is generated. The best places are in the cafeteria and administrative areas. Receptacles should be made available in public spaces, gymnasia, and hallways for plastic and aluminum in schools with soda machines.
- Locate convenient bins for other materials being recycled. If bins are located outdoors, consider strategies to protect the bins from the weather and to prevent access by wildlife.

In implementing a comprehensive approach to recycling, consider all the aspects needed to make recycling easier and more educational.

- Integrate containers into cabinetry, or have free-standing stations that do not disrupt other functions in the spaces.
- Design bins to be easily dumped into a cart that will be taken by custodial staff to a central collection point.
- Incorporate chutes to accommodate recycling in multi-story facilities.
- Establish a color coding system, and use clearly labeled dispersed containers and centralized bins to distinguish the recycled material.
- Use dispersed receptacles and centralized bins that are easy to clean and maintain.
- Coordinate with a local recycling agency or waste hauler to obtain important information regarding its trucks and how it prefers to access the recycling bins.

Safe Disposal of Hazardous Waste

- Provide a secure space in the school to temporarily store hazardous materials (e.g., batteries, fluorescent lights, medical waste) until they can be taken to a recycling center or safe disposal site.

Composting

About one-third of the average school's waste stream is food and other organic materials. Composting is one environmentally friendly way of handling this waste, but is more challenging in the arctic and subarctic climates.

- Design a conveniently located composting bin. Because of the cool soil and air temperatures, the breakdown of materials needed for good composting occurs slowly. Decomposition will take one to three years.
- Vermicomposting is workable only if you locate the box where you can control the temperature and moisture. Use vermicompost bins in classrooms as educational tools. The bins use worms to dramatically accelerate decomposition.

Composting, although environmentally beneficial, poses great challenges in the arctic/sub-arctic climate, due to the tendency of outdoor bins attracting bears and foxes.

Photo: Chittenden Solid Waste District

Vericomposting can be a good teaching tool for students on the science of decomposition and reducing waste.

Photo: NREL/PIX05289

Recycling by the contractor during construction should be encouraged to decrease the amount of waste sent to landfills.

Construction Waste Recycling and Waste Management

Recycling efforts should begin during the construction of the school and engage the general contractor and all subcontractors.

- Specify the specific job site wastes that will be recycled during construction (corrugated cardboard, all metals, clean wood waste, gypsum board, beverage containers, and clean fill material).
- Require the contractor to have a waste management plan that involves everyone on the site.
- Stockpile topsoil and rock for future ground cover.
- Monitor the contractor's and subcontractor's recycling efforts during construction.

To minimize the impacts from any hazardous materials or waste used in construction, require that the contractor use safe handling, storage, and control procedures, and specify that the procedures minimize waste.

Photo: Craig Miller Productions and DOE/PIX03494

Construction waste materials, including corrugated cardboard, metals, clean wood waste, gypsum board, and clean fill material like concrete or brick can be recycled or reused.

Transportation

In many school districts across the country, more energy dollars are spent transporting students to and from school than in meeting the energy needs of their school buildings. As much as 40% of morning traffic congestion at schools is a result of parents driving children to school.

Incorporating a network of safe walkways and bike paths that connect into the community's sidewalks and greenways can reduce local traffic congestion, minimize busing costs, and reduce air pollution. And, by incorporating natural gas, biodiesel, or methanol into a district's vehicle fleet, you can help to reduce fuel costs and harmful emissions—lowering fuel costs and contributing to reduced operating and maintenance costs.

Today, nearly 60% of all school buses in Alaska run on diesel. Alternative fuel buses and school fleet vehicles can be used to provide environmentally friendly alternatives to high-polluting vehicles. Options for alternative fuel buses include electric, hybrid electric, compressed natural gas, ethanol, and biodiesel—all of which are available today. In addition to long-term energy savings, these vehicles serve as great educational tools for the students and the community. DOE's Clean Cities Program can help you determine the best alternative fuel vehicles for your fleet.

Driving students one at a time to school each day is responsible for 0.5–3.3 tons of carbon dioxide per student being emitted into the air each year. Providing safe pedestrian walkways throughout the surrounding neighborhood allows students who attend a school in their community to walk, reducing busing and single car traffic.

Photo: Krochina Architects

Evaluate transportation strategies for winter use. Four-stroke snowmobiles and all-terrain vehicles are commonly used for transportation during these months.

Design Guidelines for Integrating Transportation Considerations into School Design

Connecting the School to the Community

One measure of school success is the degree to which the school is a vital part of the community. In some of the more remote areas in the arctic and subarctic climates, the school is the true center of the community. It is used for town meetings, weddings, and other gatherings. Community needs for the school site must be addressed early in the site selection and design phases.

- Design the school so that the athletic fields, gymnasium, media center, and special classrooms are accessible and can be shared at appropriate times with the community.
- Provide good access to public transit.
- Evaluate transportation strategies for winter use. In more remote areas, people commonly use snowmobiles and all-terrain vehicles (ATVs) for transportation.
- Incorporate convenient parking for alternative transportation at the school to discourage single car traffic. In growing areas, more schools are being built in conjunction with the construction of large subdivisions by local developers. This situation offers the school system and the community an excellent opportunity to coordinate with developers to make the school a more integral part of the community.
- Work with the developer to implement new, safe walkways and bike paths that link the neighborhood to the school.
- Develop a master plan with the community so that the main pedestrian ways to the site do not cross over busy roads. Or, if that cannot be avoided, provide safe and handicap-accessible pedestrian overpasses or underpasses.
- Develop recreational facilities that can be shared with the community.

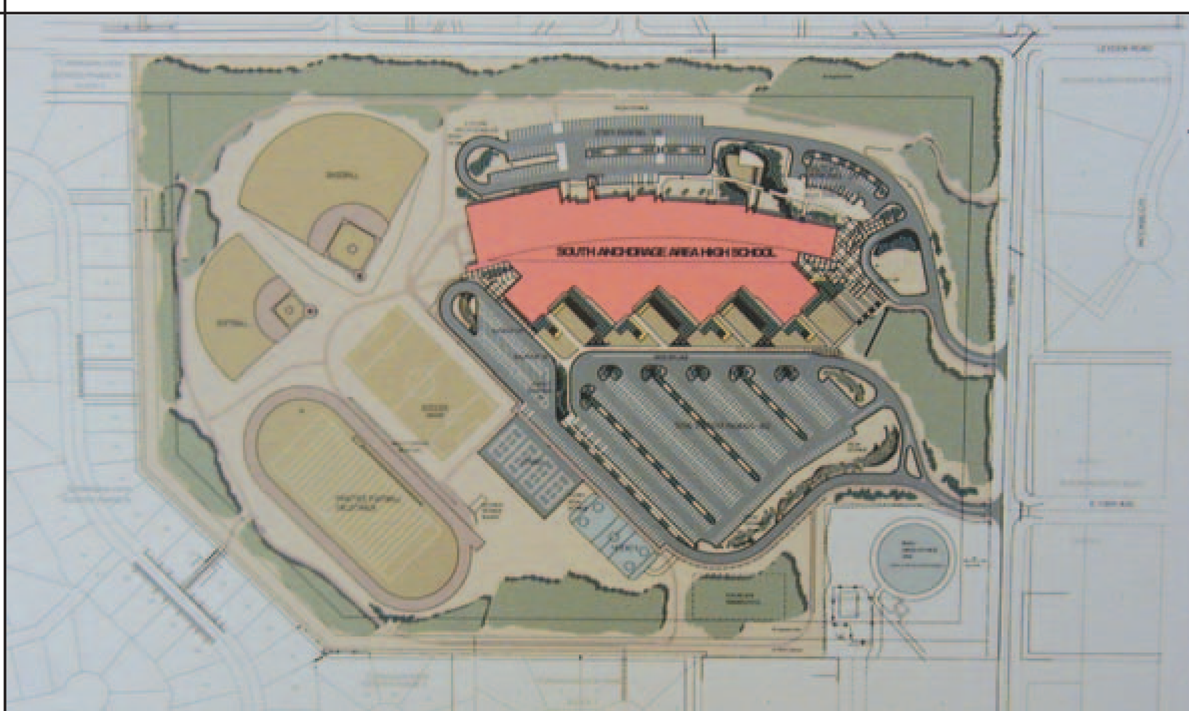


Photo: Architectural Energy Corporation

At South Anchorage High School, the athletic fields are located for easy access by community members.

Walkways and Bike Paths

Transportation alternatives such as pedestrian and bike paths (cross country skis in winter) are effective solutions to easing air pollution and traffic problems.

For schools in the urban areas, the design team should work with the adjacent developers and local planning officials to implement strategies to enhance safe pedestrian paths that connect the school and the community during the early planning of the school.

- If sidewalks provide the main pedestrian access to the school, encourage the developer and/or local planning department to separate them a safe distance from the road.
- Use walkway surfacing materials that are appropriate for handicap access.
- Provide path lighting with photosensors to ensure adequate illumination along the pathways.
- Incorporate caution lights throughout the community to warn drivers of the likelihood of student pedestrian travel.
- Provide controllable crossing lights at the intersections of student pedestrian paths and roadways.
- Provide underpasses or overpasses at the intersections of high-traffic roads and main pedestrian paths.
- On school property, minimize potential conflicts by separating students and vehicular pathways.

High-Efficiency and Low-Emission Vehicles

In addition to incorporating safe and traffic-reducing elements into your site design, consider the use of high-efficiency and low-emission vehicles in your fleet. Electric vehicles, hybrid electric vehicles (HEVs), and vehicles that use alternative fuels like compressed natural gas (CNG) are cost-effective and proven options.

Electric Vehicles

Consider the typical temperature conditions an electric vehicle will be operating in when exploring purchasing such vehicles for this climate zone. Battery performance can sometimes be reduced in extreme cold temperatures. However, electric and hybrid vehicles are available in Alaska and should be considered for feasibility on a project-specific basis.

- To ensure availability, the school or school system should provide a charging station for electric vehicles. These charging areas can be viewable by students to assist with teaching about renewable energy and can include displays to indicate to students the contribution the station is providing.

CLEAN CITIES PROGRAM

The Clean Cities Program, sponsored by DOE, supports public-private partnerships that help put alternative fuel vehicles (AFUs) into the market and build supporting infrastructure.

Unlike traditional command and control programs, the Clean Cities Program takes a unique, voluntary approach to AFV development, working with coalitions of local stakeholders to help develop the industry and integrate this development into larger planning processes.

Currently there are 80 Clean Cities coalitions dedicated to putting AFVs on the road. The Clean Cities Program helps educate fleets across the country on which AFVs and fuel types are right for each fleet. Coalitions also help fleets understand incentives and legislation related to AFVs. More information on the Clean Cities Program can be found in the Web resources section.

Photo: Medford Township Board of Education

Medford Township Schools, in Medford, New Jersey, converted 22 of their school buses to run on a fuel consisting of 20% soybean-derived biodiesel. According to Joe Biluck, director of operations for the school system, their goal of reducing pollution has been achieved. Particulate emissions have been reduced by 35%–40%.

Hybrid Electric Vehicles

HEVs have the same power as conventional vehicles and do not have the reduced driving range that electric vehicles have. There are several options for HEV buses available today, and there are two HEV automobile models that can be used as school fleet vehicles. HEVs can be produced in a variety of ways, but typically the battery pack helps supplement the vehicle's power when accelerating and hill climbing. During stop-and-go driving, the traditional gasoline engine and batteries work together. For extended highway driving, the engine does most of the work because that is when it is operating most efficiently.

Ethanol

Ethanol is typically produced from domestic-grown, plant-based materials such as corn or other grains. Ethanol is a promising alternative fuel for this climate due to the fact that it can be produced locally from materials such as sugarcane molasses and agricultural waste, once production facilities are established. Ethanol buses and vehicles are good options for school districts because several vehicle choices are available.

Vehicles using ethanol as a fuel perform as well as typical conventional vehicles. Under current conditions, the use of ethanol-blended fuels such as E85 (85% ethanol and 15% gasoline) can reduce the net emissions of greenhouse gases by as much as 37%.

- To ensure availability, the school or school system should provide a storage tank for ethanol fuel.

Compressed Natural Gas Vehicles

CNG vehicles operate like any conventional vehicles. Drivers can't tell the difference in performance. CNG buses are being used by many school districts across the nation. CNG is a great option for schools because the vehicles are readily available and the fuel is considerably less expensive than gasoline. Several CNG sedans and trucks are produced by auto manufacturers that would be good options for use in school fleets. Exhaust emissions from natural gas vehicles are much lower than those from gasoline powered vehicles.

- To ensure availability, the school system should provide a CNG fueling station.

Photo: NREL/PIX04152

This school bus looks and operates like a standard diesel bus but runs on CNG.

Resource-Efficient Building Products

A school, like any building, is only as good as the sum of the materials and products from which it is made. To create a high performance school, your design team must choose the most appropriate materials and components and combine these components effectively through good design and construction practices.

Typically, architects and engineers primarily consider the performance of materials and components in terms of how they serve their intended functions in the building. Material function should be a top consideration, but your design team should also consider the materials from a broader environmental perspective. For instance, in the arctic and subarctic climates, durability is a vital consideration. Also, you should evaluate embodied energy costs when selecting building products.

Indoor air quality can also be greatly affected by the selection of indoor materials. For example, eliminating or minimizing volatile organic compounds (VOC) in paints, carpet, and adhesives and formaldehyde in plywood, particleboard, composite doors, and cabinets will help to improve the air quality of the classroom.

The best resource-efficient products and systems improve the indoor air quality, energy efficiency, and durability of a school, and help protect the natural environment by minimizing use of limited resources and promoting reuse and recycling.

Photo: NREL/PIX03049

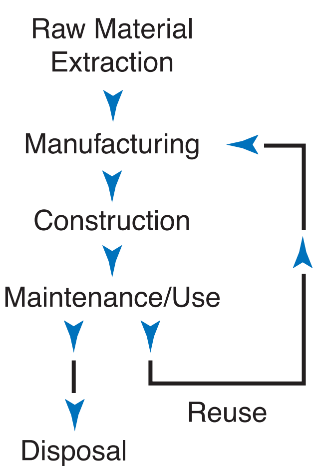
Choosing durable, low-maintenance flooring will significantly reduce labor and replacement costs, and are especially recommended in high-traffic areas.

Photo: NREL/PIX03050

True linoleum is made from wood flour, cork, and linseed oil. It hardens over time, and makes for an attractive, durable surface.

Photo: NREL/PIX02213

These ceiling beams are made from recycled wood products.



Life-cycle analysis

The life cycle of a building product can have significant environmental implications.

Design Guidelines for Resource-Efficient Building Products

The Life-Cycle Approach

To select environmentally preferable products, environmental impacts must be considered from all phases in the product's life cycle. This approach is called life-cycle analysis. A product's life cycle can be divided into the following phases:

- Raw material extraction
- Manufacturing
- Construction
- Maintenance/use
- Reuse or disposal.

Environmentally important impacts associated with the transportation of raw materials and finished products are included with each phase.

Unlike many consumer products, in which the "use" phase is very short (a soft-drink bottle, for example), building materials are typically in place for a relatively long time. As a result, any ongoing environmental impacts associated with the use phase often outweigh those from other phases.

Following are descriptions of key issues to consider at each phase of the life cycle and some examples of products that have environmental advantages.

Phase 1: Raw Material Extraction

Building materials are all made from resources that are either mined from the earth or harvested from its surface. The most common materials are sand and stone to make concrete, clay for bricks, trees for wood products, and petroleum for plastics and other petrochemical-based products.

- Eliminate component materials from rare or endangered resources.
- Determine whether there are significant ecological impacts from mining or harvesting the raw materials.
- Specify that wood products must be harvested from well-managed forests. Require that suppliers show credible third-party verification of environmentally sound harvesting methods.
- Determine the origin of the primary raw materials, and select options close to the site.

Photo: NREL/PIX03048

Cork is harvested from the cork oak. The bark can be removed from the tree about every 9 years without adversely affecting the tree. Cork is used to make cork and linoleum flooring.

Phase 2: Manufacturing

Manufacturing operations can vary considerably in their impacts on the environment. The manufacturer of one product may rely on numerous outsourcing operations at separate locations or obtain raw materials from another country. Another, less energy-intensive product may be produced in a single, well-integrated operation
at one site with raw materials and components coming from nearby locations. Likewise, a particular manufacturer may use a process that relies on toxic chemicals while a competing manufacturer may incorporate environmentally friendly technologies to accomplish the same end.

- Determine whether the manufacturing process results in significant toxic or hazardous intermediaries or by-products. Most petrochemical-based processes involve some hazardous ingredients, so plastics should be used only when they offer significant performance advantages.
- Specify products that are made from recycled materials.
- Select products that are made from low-intensity energy processes. The manufacture of some materials, such as aluminum and plastics, requires a lot of energy; the "embodied energy" to make other materials is considerably less.
- Select products manufactured at facilities that use renewable energy.
- Consider the quantity of waste generated in the manufacturing process and the amount that is not readily usable for other purposes.

Phase 3: Construction

To a great degree, the energy and environmental impacts of products and materials are determined by the way they are implemented.

- Avoid products containing pollutants by:
  - excluding high VOC paints, carpets, and adhesives
  - not incorporating products with excessive formaldehyde
  - using the least toxic termite and insect control.
- When pesticide treatments are required, prefer bait-type systems over widespread chemical spraying and soil treatments.

Photo: NREL/PIX03041

This environmentally sound, no-VOC carpet line is leased and maintained by the manufacturer, which reduces waste by recycling and reusing the carpet tiles. The up-front and maintenance costs are lower, and the environmental and health benefits are substantial.

Photo: NREL/PIX03051

Choose carpet backings with low or no formaldehyde to avoid indoor air contamination.

Photo: BuildingGreen Inc.

Cement manufacturing is very energy intensive. The cement kiln is the largest piece of moving industrial machinery in common use, and temperatures inside it reach 2,700°F.

Photo: Barry Halkin Photography

Recycled tiles installed in school hallways and cafeterias are very low maintenance.

- Separate materials that out-gas toxins (e.g., plywood with formaldehyde) or emit particulates (e.g., fiberglass insulation) with careful placement, encapsulation, or barriers.
- Require the contractor to recycle construction materials.
- Ensure that unconventional products are installed properly.
- Require proper handling and storage of toxic materials at the job site.
- Require that the packaging of products, materials, and equipment delivered to the site be made of recyclable or reusable materials, and discourage unnecessary packaging.
- Ensure that product and material substitutions during construction contain the same energy and environmental benefits.
- Avoid materials that are likely to adversely affect occupant health. Interior furnishings and finishes and mechanical systems all have the potential to affect the indoor air quality for better or worse. Material Safety Data Sheets can provide useful information on the contents of various products.

Phase 4: Maintenance/Use

How easily building components can be maintained—as well as their impact on long-term energy, environmental, and health issues—is directly linked to the quality of the materials, products, and installation.

- Select materials, products, and equipment for their durability and maintenance characteristics. Pay particular attention to selecting roofing systems, wall surfaces, flooring, and sealants—components that will be subject to high wear-and-tear or exposure to the elements.
- Avoid products with short expected life spans (unless they are made from low-impact, renewable materials and are easily recycled) or products that require frequent maintenance procedures.
- Provide detailed guidance on any special maintenance or inspection requirements for unconventional materials or products.

Phase 5: Disposal or Reuse

Some surfaces in the school, such as carpets, may need to be replaced regularly. The building will eventually be replaced or require a total renovation. To minimize the environmental impacts of these activities, designers have to choose the right materials and use them wisely.

- Select materials that can be easily separated out for reuse or recycling after their useful life in the structure. Products that should be avoided include those that combine different materials (e.g., composites) or undergo fundamental chemical change during the manufacturing process.
- Avoid materials that become toxic or hazardous at the end of their useful lives. Preservative-treated wood, for example, contains highly toxic heavy metals that are contained within the wood for a time but will eventually be released when the wood decays or burns.

Checklist of Key Design Issues

The following checklist can be used by school designers, planners, and administrators when considering comprehensive high performance strategies for new and renovated schools.

The format follows each of the 10 critical and suggested design components and cross-references issues for the school decision makers.

Legend

- ■ Critical Design Element
- □ Suggested Design Element

Photo: Warren Gretz, NREL/PIX07071

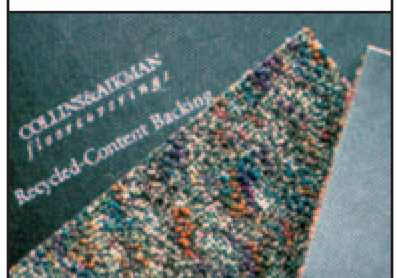


Photo: Finelite/PIX03045

Design lighting systems that employ high-efficiency lamps and ballasts in order to realize the most cost-and energy-efficient system possible.

Checklist of Key Issues for Site Design

Site Design

	Reducing Operating Costs	Designing Buildings That Teach	Improving Academic Performances	Protecting Our Environment	Designing for Health, Safety, and Comfort	Supporting Community Values
• Take advantage of your site's natural resources by:						
– orienting the building to optimize solar access and daylighting	■	■	□	■	□	
– using vegetation and earth formations to your advantage.	■	■		■	□	
• Incorporate xeriscape landscaping to save water.	■	■		■		■
• Retain and add site features that could become educational resources for teachers to incorporate into their instructional programs.		■	■	■	■	
• Include outdoor teaching and interpretive areas.		■	■	□		
• Provide diverse natural environments for exploration.		■	■	□		
• Showcase local natural features.		■				
• Maximize the educational opportunities of the pedestrian pathways from residential areas to the school.		■	■			
• Provide the school with information on environmental design features.		■	■	□		
• Develop the site in a manner that protects landscaping, ecosystems, and wildlife habitat.		■		□		□
• Employ energy-saving strategies, and use renewable energy to reduce air pollution.	■	■		■		■
• Create earth berms to provide sound barriers.				□	■	
• Develop on-site erosion control and stormwater management strategies.		■		■		■
• Connect the school's walkways and bike paths directly into greenways and sidewalks around residential areas.	□	■		□	□	□
• Design the school as a part of the community by:						
– providing easy, safe pedestrian access to surrounding communities and mass transit	■	■		■		■
– allowing for shared recreational facilities.				■		■

Checklist of Key Issues for Daylighting and Windows

Daylighting and Windows

	Reducing Operating Costs	Designing Buildings That Teach	Improving Academic Performances	Protecting Our Environment	Designing for Health, Safety, and Comfort	Supporting Community Values
• Account for all the financial and environmental benefits associated with daylighting, including:						
– reduced electrical lighting	■	■	□	■	□	
– increased visual connection to the outside environment	■	■	■		■	■
– decreased electrical service to the site	■	■		■	□	
– fewer lamp replacements.	■	■		□	□	
• Evaluate and avoid negative impacts associated with window treatments, placement, and types, including:		■	■	□		
– glare and direct beam radiation entering teaching areas		■				
– comfort problems and unnecessary heat loss caused by the lack of thermal breaks, poorly insulated windows, and the choice of solar transmission values of glazing	■	■	■	■		
– maintenance.	■	■		□		□
• Make daylighting strategies obvious to the students.	■	■		■		■
• Incorporate daylighting strategies that could be enhanced through student participation and understanding.	□	■	□	□		□
• Recognize the importance of daylighting as a strategy to create superior learning environments that:						
– have a positive physiological impact on the students and teachers	■	■	■	■	■	
– provide better quality light	■	■	■	■	■	
– increase the performance of students and teachers.	■	■	■	■	■	
• Reduce building materials and cost by integrating daylighting into the overall structural design and roofing system.	■			■	■	
• Incorporate controlled daylighting strategies.	■		■		■	
• When climatic conditions allow, install operable windows to improve indoor air quality.	■		■		■	
• Use daylighting and high performance windows to reduce long-term energy costs, shift more financial resources to critical educational needs, and keep more energy dollars in the community.	■		■	■	■	

Checklist of Key Issues for Energy-Efficient Building Shell

Energy-Efficient Building Shell

	Reducing Operating Costs	Designing Buildings That Teach	Improving Academic Performances	Protecting Our Environment	Designing for Health, Safety, and Comfort	Supporting Community Values
• Carefully evaluate building shell issues. Many of these components are likely to go unchanged during the life of the facility.	■	■			■	
• Consider the wide range of building systems that can improve energy consumption, reduce maintenance requirements, and improve comfort. These include:						
– optimum wall and roofing insulation	■		■	■	■	
– infiltration and weather-resistive barriers	■		■	■	■	
– light-colored interior walls and ceilings.	■	■	■	■	■	
• Incorporate artwork and graphics in the building that will help to educate students about energy and environmental issues.		■	■			
• Design energy-efficient building components to make their purposes and functions obvious to the students.		■	■			
• Highlight different wall and glass treatments on each facade to emphasize the appropriateness of different design responses.		■				
• Consider building shell issues that directly affect comfort and health and indirectly affect the performance of students in the classroom.		■	■		■	
• Consider the embodied energy of optional building components and implementation strategies.	■			■		
• Consider the colors and finishes of interior surfaces in controlling glare and improving visual comfort.		■	■		■	
• Employ energy-saving strategies that will keep more energy dollars in the community.	■	■				■

Checklist of Key Issues for Lighting and Electrical Systems

Lighting and Electrical Systems

	Reducing Operating Costs	Designing Buildings That Teach	Improving Academic Performances	Protecting Our Environment	Designing for Health, Safety, and Comfort	Supporting Community Values
• Select high-efficiency lamps, ballasts, lenses, and lighting fixtures that address the specific task requirements.	■	■	■	■	■	■
• Specify high-efficiency appliances and equipment.	■	■		■		■
• Use long-life lamps to reduce maintenance.	■	■		■		■
• Develop the primary lighting strategy around a daylighting approach.	□	■	□	□	□	□
• Incorporate controls, occupancy sensors, and dimmable or staged lights to automatically reduce electric lighting during times of adequate daylighting.	■	■	□	■	■	■
• Provide photocell controls on exterior lights to ensure lights are not operating during adequate daylight.	■	■		■	■	■
• Consider LED exit lights.	■	■		■		■
• Minimize electrical line losses by installing a high-voltage distribution system.	■	■		■		■
• Conduct a commissioning process that verifies the proper operation of equipment and systems.	■	■		■		■
• Implement a regular maintenance schedule to ensure proper operation.	■	■		■		■
• Use ASHRAE Standard 9.01 to establish maximum lighting power densities for each space within the school.	■					
• Incorporate photovoltaic and solar thermal-electric systems where appropriate.	□	■		□	□	□
• Monitor total building energy use and renewable energy system contribution.	■	■		■		
• Design lighting to uniformly light each space, minimize glare, and reduce overheating from light fixtures.	■	■	■		■	
• Select low mercury lamps.		■		■	■	■
• Design site lighting in a manner that will minimize "light pollution" by:						
– using fixtures with cutoff angles that prevent light from going beyond the specific area to be lighted		■	■		■	■
– optimizing the height of luminaries for pathways to improve illumination and prevent light from straying onto adjacent properties	□	■		■	■	■
– limiting exterior lighting to critical areas only.	■	■		■	■	■

Checklist of Key Issues for Lighting and Electrical Systems

	Reducing Operating Costs	Designing Buildings That Teach	Improving Academic Performances	Protecting Our Environment	Designing for Health, Safety, and Comfort	Supporting Community Values
• Minimize glare and eye strain by:						
– incorporating indirect lighting, particularly in computer areas		■	■		■	
– using lenses that shield the lamp from direct view and help disperse light more evenly		■	■		■	
– evaluating the location of the lighting sources in relationship to the occupants and what the occupants will be viewing		■	■		■	
– avoiding reflected glare commonly experienced when viewing a computer screen and seeing the light fixtures		■	■		■	
– minimizing situations of “transient adaptation” in which the eye cannot properly adjust when going from one space to another with drastically different light levels.		■	□		■	
• Employ energy-efficient lighting and electrical systems that will keep more energy dollars in the community.	■	■				■
• Consider life-cycle costs to ensure that the best long-term solutions are implemented.	■	■				■

Checklist of Key Issues for Mechanical and Ventilation Systems

Mechanical and Ventilation Systems

	Reducing Operating Costs	Designing Buildings That Teach	Improving Academic Performances	Protecting Our Environment	Designing for Health, Safety, and Comfort	Supporting Community Values
• Implement the most energy-efficient mechanical and ventilation strategies to save energy.	■	■		■	■	■
• Consider the initial cost of equipment, anticipated maintenance expenses, and projected operating costs when evaluating the life-cycle benefits of system options.	■	■		■		
• Use a computer energy analysis program that simulates hourly, daily, monthly, and yearly energy consumption.	■	■				
• Optimize the mechanical system as a complete entity to allow for the interaction of various building system components.	■					
• Employ the most energy-efficient mechanical systems by:						
– not oversizing equipment	■	□		■	□	■
– matching the air supply to the load, without adding a reheat penalty	■	□		■		■
– zoning air handling units so that each unit serves spaces with similar orientation and use patterns.	■	□		■		■
• Implement a strategy that energy efficiently ensures adequate outside air by incorporating economizer cycles.	■	■	■		■	■
• Provide safe visual access to mechanical systems to explain how they work.		■			■	
• Use energy monitoring stations as teaching aids.		■				
• Improve student and teacher performance by ensuring adequate fresh air is provided by:						
– complying with ASHRAE ventilation standards	■	□	■		■	
– incorporating pollutant sensors	■	□	■		■	
– installing ductwork that has smooth internal surfaces and transitions to minimize the collection of microbial growth	■	□	■		■	
– designing ductwork and plenums to minimize the accumulation of dirt and moisture and providing access areas in key locations for inspection, maintenance, and cleaning	■	□	■		■	
– locating outdoor-air intakes a safe distance from polluted and/or overheated exhaust grills and away from parking or traffic.		■	■		■	
• Implement mechanical and ventilation strategies that address all physical, biological, and chemical pollutants.			■		■	

Checklist of Key Issues for Mechanical and Ventilation Systems

	Reducing Operating Costs	Designing Buildings That Teach	Improving Academic Performances	Protecting Our Environment	Designing for Health, Safety, and Comfort	Supporting Community Values
• Incorporate renewable energy systems to provide for space heating, hot water, and electricity.	□	■		□		□
• Implement indoor air quality strategies that can provide for healthier learning environments.		■	■		■	
• Design the mechanical and ventilation systems to maximize the comfort of the students and teachers.		■	■		■	
• Employ energy-efficient mechanical and ventilation systems.	■	■				■

Checklist of Key Issues for Renewable Energy Systems

Renewable Energy Systems

	Reducing Operating Costs	Designing Buildings That Teach	Improving Academic Performances	Protecting Our Environment	Designing for Health, Safety, and Comfort	Supporting Community Values
• Consider the wide range of renewable options, including:						
– daylighting	□	■	■	□	■	■
– solar hot water and space heating	□	■		□		□
– photovoltaics	■	■		■		■
– wind.	■	■		■		■
• Consider daylighting your highest priority.	□	■	■	□	■	■
• Incorporate solar systems.	□	■		□		□
• Employ photovoltaic and wind systems as educational tools that demonstrate the opportunities for converting sunlight and wind into electricity.	■	■				
• Incorporate solar hot water, and provide a view that will illustrate how sunlight can be converted into thermal energy.	■	■				
• Use daylighting and passive ventilation strategies to show students the importance of working with, instead of against, nature.	■	■		■	■	
• Integrate displays showing total energy use at the school and the percentage of energy being provided by renewable energy sources.	■	■				
• Use renewable energy systems as stimulating, educational tools involving multiple subject areas.	■	■				
• Use on-site, renewable energy systems to help make the link between saving energy and helping our environment.	■	■				
• Use renewable energy systems in conjunction with battery storage to provide for emergency power.	■			■		
• Use photovoltaic systems to reliably power:						
– parking and walkway lighting	■	■		■	■	■
– caution lights at street crossings and remote signage	■	■		■	■	■
– security lights	■	■		■	■	■
– emergency telephone call boxes	■	■		■	■	■
– electric charging stations.	■	■		■	■	■
• Employ renewable energy and energy-saving strategies that will result in more energy dollars staying within the community.	■	■				■
• Install renewable energy systems at schools to serve the community in times of natural disasters and utility outages.	■	■				■

Checklist of Key Issues for Water Conservation

Water Conservation

	Reducing Operating Costs	Designing Buildings That Teach	Improving Academic Performances	Protecting Our Environment	Designing for Health, Safety, and Comfort	Supporting Community Values
• Encourage the general contractor to conserve water during construction.	■			■		■
• Incorporate indigenous vegetation to minimize irrigation requirements.	■	■		■		■
• Install water-conserving fixtures.	■	■		■		■
• Provide more localized water heaters, closer to the loads in the school, to avoid wasting water and energy.	■	■		■		■
• Use educational signage and graphics to help inform students and staff about the need to conserve water, and instruct them on what they can personally do to save water.	□	■	■	□		
• Install monitoring devices, sight glasses in storage tanks, and energy management systems that can be used by students to monitor school usage and see the benefits of using graywater.		■	■	□		
• Adequately insulate hot water supply piping.	■	■		■		■
• Ensure that the water is clean and lead-free.		■	■		■	
• Implement water-conserving strategies that will reduce the need to provide water from nonsustainable aquifers and water sources not within the immediate region.		■		■		■
• Consider installing an on-site biological wastewater treatment system.	■	■	□	■		■
• Check the condition of all plumbing lines and fixtures for sources of potential contamination, particularly lead.		■		□	■	
• Use only lead-free materials in the potable plumbing system to avoid lead-related impacts such as lower IQ levels, impaired hearing, reduced attention span, and poor student performance.		■	■	□	■	
• Verify the condition of the potable water supply.					■	

Checklist of Key Issues for Recycling Systems and Waste Management

Recycling Systems and Waste Management

	Reducing Operating Costs	Designing Buildings That Teach	Improving Academic Performances	Protecting Our Environment	Designing for Health, Safety, and Comfort	Supporting Community Values
• Implement a comprehensive recycling strategy that involves all major recyclable waste materials in the school.	■	■		■		■
• Allocate space throughout the building for recycling receptacles to reduce waste hauling and disposal costs.	■	■		■		■
• Provide outdoor recycling bins accessible to collection agencies or companies. Protect bins from weather and wildlife.	■	■		■		□
• Allocate space for yard waste composting to further reduce landfill tipping costs.	■	■		■		■
• Ensure that recycling receptacles are designed and labeled so as not to be confused with trash receptacles.	■					
• Design recycling receptacles as attractive components, well-integrated into the overall design but still obvious to the students.		■				
• Incorporate recycling receptacles that are easily accessible to students and custodial staff and designed to be used by students.	■	■		■		
• Develop a recycling system that allows students to monitor their waste stream and that teaches them about waste reduction.		■	■	□		■
• Require a detailed waste management plan from the contractor to minimize the disposal of recyclable or reusable construction waste.	■			■		■
• Monitor construction waste management throughout the construction process to minimize the landfilling, incineration, or improper disposal of recyclable materials.				■		■
• Design recycling systems that will enable the school to recycle as much daily waste as possible.	■	■		■		■
• Consider incorporating a compost center that allows food waste to be used in gardens or landscaping.		■		■		
• Select recycling containers that are made of recycled materials.	■	■		■		
• Ensure that recycling receptacles are designed and installed so as not to create a physical hazard.		■			■	
• Design recycling receptacles for easy cleaning.		■			■	
• Provide documentation on cleaning procedures and maintenance requirements associated with the recycling receptacles.					■	
• Locate local companies or services that can benefit from the use of recycled materials or construction waste.		■		■		■

Checklist of Key Issues for Transportation

Transportation

	Reducing Operating Costs	Designing Buildings That Teach	Improving Academic Performances	Protecting Our Environment	Designing for Health, Safety, and Comfort	Supporting Community Values
• Work with developers and local planning departments to design easy, safe pedestrian access throughout the community to the school site.	■	■		■	■	■
• Use high-efficiency buses and service vehicles.	■			■		■
• Use graphics and signage to help educate students and the community about the environmental benefits of the energy-efficient and low-emission approaches to transportation implemented by the school.		■	■			
• Give high priority to the placement of bicycle racks, and use personalized nameplates for regular bikers.		■				
• Incorporate a highly visible solar electric and/or wind-powered charging station for electric buses and service vehicles.	■	■		■		■
• Design sidewalks and bike paths throughout the community and school site to help reduce air pollution associated with busing and single car drop-offs.	■	■		■	■	■
• Use low-emission methanol, biodiesel, natural gas, and solar electric buses and service vehicles to reduce air pollution.	■	■		■	■	■
• Stress safety when designing walkways and bike paths.		■			■	
• Use photovoltaic systems to reliably power:						
– parking and walkway lights	■	■		■	■	■
– caution lights and street crossings	■	■		□	■	■
– electric charging stations.	■	■		□	■	■
• Allow for handicap access.		■			■	■
• Encourage recreational activities by providing access to athletic facilities that can be shared with residents of the local community.		■				■
• Provide pedestrian ways to and a mass transit stop at the school site so that the school is more easily accessible to the community.	■	■				■
• Implement energy-efficient transportation options that keep energy dollars in the community, strengthening the local economy.	■	■				■
• Choose high-efficiency and low-emission vehicles as the best long-term solution to protect against future energy cost escalation.	■	■				■

Checklist of Key Issues for Resource-Efficient Building Products

Resource-Efficient Building Materials

	Reducing Operating Costs	Designing Buildings That Teach	Improving Academic Performances	Protecting Our Environment	Designing for Health, Safety, and Comfort	Supporting Community Values
• Use products that are energy-efficient.	■	■		■		■
• Choose fixtures and equipment that conserve water.	■	■		■		■
• Specify building systems, components, and materials with low maintenance requirements.	■	■		■		■
• Incorporate less-polluting materials to reduce the need for mechanically induced fresh air and increase energy efficiency.	■	■	□	□	■	
• Incorporate pollutant sensors to reduce ventilation air exchange during non-occupied times.	■	□		■	■	■
• Design environmentally sound building components to make their purpose and function obvious to students.		■				
• Use products and systems that save water in explicit, visible ways.		■				
• Incorporate locally harvested or mined materials as prominent design elements.	■	■		■		■
• Avoid materials containing toxic or irritating compounds that negatively affect the indoor air quality.	□	■	■	■	■	
• Specify products, materials, and equipment that can be maintained in an environmentally friendly way.		■		■	■	
• Select products made from renewable energy and low-polluting processes.		■		■		■
• Specify products harvested from well-managed forests.		■		■		□
• Avoid products harvested or mined from environmentally sensitive areas.		■		■		□
• Select products that are made from recycled materials and/or are recyclable.		■		■		
• Specify products made with a minimum of process (embodied) energy.		■		■		
• Evaluate the environmental life-cycle impacts to minimize the environmental impact of the building's operation .		■		■	□	■
• Incorporate energy-efficiency and renewable energy systems.	■	■		■		■
• Avoid products that produce indoor air pollution.	■	■	■	■	■	
• Separate polluting materials from exposed surfaces.		■	■		■	
• Incorporate indoor planting strategies.		■	■		■	

Checklist of Key Issues for Resource-Efficient Building Products

	Reducing Operating Costs	Designing Buildings That Teach	Improving Academic Performances	Protecting Our Environment	Designing for Health, Safety, and Comfort	Supporting Community Values
• Avoid equipment that requires toxic or irritating maintenance procedures.		■	■		■	
• Provide detailed guidance on preferable maintenance procedures to minimize exposure of staff and students to toxic and irritating chemicals.		■	■		■	
• Work with the school system to develop an indoor pollutant source assessment and control plan.		■	■		■	■
• Choose products and materials that are locally produced or made from readily available materials.	■	■		■		■
• Choose products and building procedures that maximize local labor.	■	■				■
• Select indigenous materials, and implement designs that enhance the connection to "place."		■				■
• Select materials that can be reused or recycled, to minimize impacts on landfills.		■		■		■

Case Studies

The following case studies demonstrate successful applications of high performance solutions for arctic and subarctic climates. Contact information is provided to allow you to gain firsthand knowledge from schools that have successfully implemented many of the design strategies included in this guideline.

To find additional case studies around the country, visit the EnergySmart Schools Web site:

www.energysmartschools.gov

or call the EERE Information Center:

1 (877) 337-3463

Photo: Krochina Architects

When properly designed, windows can provide daylighting without excessive heat loss or glare. View windows, like these at Fairview Elementary School in Anchorage, are extremely important to provide students with access to daylight during short, winter days.

Photo: Ken Graham Photography

Buckland K-12 School, Buckland, AK. Sloped roofs should have a uniform exterior temperature to prevent problems with ice and snow accumulation.

Photo: Joe Manfredini

Contact:

Richard Ritter, Architect
Minch Ritter Voelckers Architects
800 Glacier Ave, Suite A
Juneau, AK 99801
(907) 586-1371

Benefits:

✔ *Locally manufactured building materials*

✔ *Daylighting strategies*

New Craig High School, Craig, Alaska

Located to the north of Juneau, the 38,000 ft^2 school in Craig, Alaska, emphasized the use of local building materials to enhance the resource efficiency of the facility, which increased the connection to the local community and economy. The main exterior materials—stone, shingles, and exposed heavy timber—were not only manufactured locally, they allow the school to integrate well with the surrounding wooded environment.

The school design also emphasized the importance of using daylighting strategies to provide a visual connection to the outdoor environment. The school's library/media center features large windows and a cathedral ceiling.

This school was awarded an American Institute of Architects Merit Award and a Council of Educational Facilities Planners Award for sustainable design.

Photo: Krochina Architects

Contact:

Pat Krochina, Architect
Krochina Architects
3501 Denali St., Suite 303
Anchorage, AK 99503
(907) 561-2241

Benefits:

✔ *Collaborative design process with the community*

✔ *Designed for joint-use with the surrounding community*

Fairview Elementary School, Anchorage, Alaska

An extremely small school site (4.5 acres) posed unique challenges to this school project. Because of the small site and the 12 modular classrooms, this K-3 school became Anchorage's first two-story elementary school. This school is sited in opposition along the north-south axis. The two main entrances create a large circulation atrium that separates the gymnasium and multi-purpose room from the administrative offices and classrooms. By consulting the community members and integrating these shared-use concepts into the design, the school can be used for public functions after school and maintain security in areas where the building is not being used.

Buckland K-12 School, Buckland, Alaska

Designing for extreme weather conditions was a major challenge for this K-12 school, located in the northern part of Alaska, just south of Barrow. This combined renovation/new construction project—11,000 ft^2 renovated secondary classroom area and 30,000 ft^2 new elementary wing with library and administrative offices—was planned as an integrated design.

Because of flood danger from the nearby Buckland River, the school is elevated off the ground. The school was designed with aerodynamic features to minimize snow drift, and the reduced surface area reduces total building heat loss. Mechanical, electrical and communications systems are located within easily accessible, heated cases for ease of maintenance.

Because of the school's remote location, this facility is a true community center. The school emphasizes its connection to the Native American community by housing an Inupiat Cultural Center to allow the community to teach cultural traditions. The school is zoned for day/night year-round use to provide direct after-hours access to the library/computer room, cultural center, and community kitchen/gymnasium.

Contact:

Holly Thorne
Bezek Durst Seiser
3330 Centre Street, Suite 200
Anchorage, AK 99503
(907) 562-6076

Benefits

✔ *Aerodynamic building design reduces heat loss*

✔ *Designed for joint use with the surrounding community*

Photo: Ken Graham Photography

Elevating this school off the ground helps protect it from flood danger and other extreme weather.

EnergySmart Schools is part of the Rebuild America program, a national DOE initiative to improve energy use in buildings. This means that if your school is part of a Rebuild America community partnership, you're ready to benefit from EnergySmart Schools.

Be sure to ask about energy improvements and educational materials for your bus fleet as well as your buildings. Rebuild America focuses on buildings, but its representatives can also direct you to resources for buses. After all, the goal of EnergySmart Schools is a comprehensive one: a nation of schools that are smart about energy in every way.

Web Resources for More Information

EnergySmart Schools Web Site: **www.energysmartschools.gov**

Comprehensive Sources

www.ase.org/greenschools/newconstruction.htm — Alliance to Save Energy's Green Schools Program

www.eere.energy.gov/EE/buildings.html — DOE's Energy Efficiency and Renewable Energy Network buildings site

www.advancedbuildings.org/ — Advanced Buildings Technologies and Practices

www.edfacilities.org/rl/ — National Clearinghouse for Educational Facilities

http://208.254.22.7/index.cfm?c=k12_schools.bus_schoolsk12 — EPA's ENERGY STAR for Schools K-12

www.usgbc.org/leed/leed_main.asp

www.ashrae.org

www.nyserda.org/schools/schoolprograms.html

www.chps.net/

Introductory Section

www.rebuild.gov — DOE's Rebuild America program, with energy-efficient solutions for communities

www.eere.energy.gov/buildings/energy_tools/doe_tools.html — DOE energy simulation software

www.usgbc.org — U.S. Green Building Council

Site Design

www.epa.gov/glnpo/greenacres/ — EPA's site on native landscaping

www.water.az.gov — Arizona Department of Water Resources

Daylighting and Windows

windows.lbl.gov/daylighting/designguide/designguide.html — Lawrence Berkeley National Laboratory's "Tips for Daylighting with Windows"

www.eere.energy.gov/erec/factsheets/windows.html — DOE's "Advances in Glazing Materials for Windows"

www.nfrc.org — National Fenestration Rating Council

www.daylighting.org — Daylighting Collaborative

aa.usno.navy.mil/data/docs/AltAz.html — U.S. Naval Observatory's sun or moon altitude/azimuth table

Energy Efficient Building Shell

www.nrel.gov/buildings_thermal/ — National Renewable Energy Laboratory's Center for Buildings and Thermal Systems

www.ornl.gov/roofs+walls/index.html — Oak Ridge National Laboratory's Building Envelopes Program

gundog.lbl.gov/dirsoft/d2whatis.html — Lawrence Berkeley National Laboratory's DOE-2 energy simulation software

Renewable Energy Systems

www.eere.energy.gov/state_energy/ — DOE's State Energy Alternatives

www.eere.energy.gov/greenpower/ — DOE's Green Power Network

www.nrel.gov — National Renewable Energy Laboratory

www.schoolsgoingsolar.org — The Interstate Renewable Energy Council Schools Going Solar program

Lighting and Electrical Systems

www.iaeel.org — International Association for Energy-Efficient Lighting

eetd.lbl.gov/btp/lsr/ — Lawrence Berkeley National Laboratory's Lighting Systems Research Group

Mechanical and Ventilation Systems

www.epa.gov/iaq/schools/ — EPA's Indoor Air Quality Design Tools for Schools

www.eere.energy.gov/buildings/energyplus/ — DOE's EnergyPlus Building Energy Simulation software

epb.lbl.gov/thermal/ — Lawrence Berkeley National Laboratory's information on Resource Efficient Building Conditioning

Resource-Efficient Building Products

www.sustainable.doe.gov/buildings/rescon.shtml — DOE's Smart Communities Network site

www.ciwmb.ca.gov/GreenBuilding/Materials — California Integrated Waste Management Board's Green Building Materials site

www.ciwmb.ca.gov/RCP/ — California Integrated Waste Management Board's Recycled-Content Building Product Directory

Water Conservation

www.epa.gov/ow/ — EPA's Office of Water

www.water.az.gov/adwr/ — Arizona Department of Water Resources

www.amwua.org/conservation-school.htm — Arizona Municipal Water User Association's "Water in Our Desert Community," an instructional resource for middle school students

Recycling and Waste Management

http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterToolsGHGCalculator.html — EPA's Waste Reduction Model to calculate greenhouse gas emissions

www.p2pays.org/ref/01/00626.htm — North Carolina Division of Pollution Prevention and Environmental Assistance's "Solid Waste Management in North Carolina—A Curriculum Resource Guide for Teachers"

Transportation

www.ccities.doe.gov — DOE's Clean Cities Program

www.nrel.gov/vehiclesandfuels/ — National Renewable Energy Laboratory's Advanced Vehicles and Fuels Web site

This publication and additional information are available online at:

www.energysmartschools.gov

Photo Credits: All photographs not specifically credited were taken by Innovative Design.

Graphics Credits: All graphics not specifically credited were supplied by NREL.

For helpful resources or more information:

Call the EERE Information Center: 1-877-337-3463

Ask a question about saving energy in your school or request information about the EnergySmart Schools program. You may want to inquire about the availability of the following EnergySmart Schools resources:

Publications and Videotapes

- Design Guidelines for New Schools and Major Renovations
- Portable Classroom Guidelines
- Decisionmaker Brochures
- Designing Smarter Schools, a 30-minute videotape that originally aired on the CNBC television network
- Educational CD-ROM featuring teaching and learning materials
- The High Performance Schools 30-minute video is also available by calling one of these three numbers: (303) 443-3130 Ext. 106, (202) 628-7400, or (202) 857-0666

Services

- Technical assistance
- Regional peer exchange forums
- State-based forums for school decisionmakers
- Financing workshops
- Technology workshops

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. By investing in technology breakthroughs today, our nation can look forward to a more resilient economy and secure future.

Far-reaching technology changes will be essential to America's energy future. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a portfolio of energy technologies that will:

- Conserve energy in the residential, commercial, industrial, government, and transportation sectors
- Increase and diversify energy supply, with a focus on renewable domestic sources
- Upgrade our national energy infrastructure
- Facilitate the emergence of hydrogen technologies as vital new "energy carriers."

The Opportunities

Biomass Program
Using domestic, plant-derived resources to meet our fuel, power, and chemical needs

Building Technologies Program
Homes, schools, and businesses that use less energy, cost less to operate, and ultimately, generate as much power as they use

Distributed Energy & Electric Reliability Program
A more reliable energy infrastructure and reduced need for new power plants

Federal Energy Management Program
Leading by example, saving energy and taxpayer dollars in federal facilities

FreedomCAR & Vehicle Technologies Program
Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle

Geothermal Technologies Program
Tapping the Earth's energy to meet our heat and power needs

Hydrogen, Fuel Cells & Infrastructure Technologies Program
Paving the way toward a hydrogen economy and net-zero carbon energy future

Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

Solar Energy Technology Program
Utilizing the sun's natural energy to generate electricity and provide water and space heating

Weatherization & Intergovernmental Program
Accelerating the use of today's best energy-efficient and renewable technologies in homes, communities, and businesses

Wind & Hydropower Technologies Program
Harnessing America's abundant natural resources for clean power generation

For more information contact:
EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov

U.S. Department of Energy

Energy Efficiency and Renewable Energy

Office of Weatherization and Intergovernmental Programs

EnergySmart Schools
Rebuild America Schools
U.S. Department of Energy

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 20% postconsumer waste.

November 2004 DOE/GO-102004-1789