Sustainable Design Guidelines

For the

construction of

new facilities

and the

renovation of

existing structures

June 2005

Operations

POUDRE SCHOOL DISTRICT

Foreword from the Superintendent - 2005

In 2000, Poudre School District developed the original Sustainable Design Guidelines to inspire and challenge our design partners to help us build better, more sustainable schools. Five years later the shift from conventional design to sustainable design is largely behind us, but now the new test begins: to institutionalize what we have learned while pushing ourselves to do even better.

Recognizing sustainability as a process rather than an endpoint, the Poudre School District is renewing its commitment to sustainable design with these updated guidelines. In an effort to institutionalize the success of the last 5 years, we are also implementing a board resolution and policy for sustainability. Our aim is to ensure that sustainable design outlasts the careers of the individual champions that were so instrumental in getting us started.

In an effort to achieve the next level of successful sustainability, the Green Team has worked diligently to update and distribute the 2005 Sustainable Design Guidelines. In addition, it is important to thank the numerous partners that helped us achieve our goals of designing, building, and learning from sustainable schools and invite them to continue on the path with us.

Sincerely,

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Superintendent of Schools

Foreword from the Superintendent - 2000

Poudre School District is committed to being a responsible steward of our natural resources and believes that public education should provide leadership in developing an ethic of sustainability in all of its practices. In Poudre School District, we have both Energy Conservation and Waste Management policies that espouse these values, making environmental stewardship an integral part of the physical plant operation. The purpose of the Sustainable Design Guidelines is to provide direction for applying these policies to the construction of new facilities and the renovation of existing schools.

As stewards of the natural environment, Poudre School District challenges the design community to help us build better schools. We believe that by working together in an integrated approach, we can build higher performance schools that provide a superior learning environment, while reducing life cycle costs through conservation of energy and natural resources.

We recognize that sustainable design may require a fundamental shift from certain aspects of conventional design and construction. However, we stand committed to sustainable design and are confident it will yield positive outcomes for our students and the community. Poudre School District is excited about this new direction. We look forward to working with you to achieve our goals of designing, building, and learning from sustainable schools.

Sincerely,

Don Unger, Superintendent of Schools

Acknowledgements

This second edition of the Sustainable Design Guidelines was developed by the Poudre School District Green Team. Judy Dorsey and Julie Sieving of The Brendle Group, Inc. facilitated the Green Team process and completed the actual revisions and enhancements to the document.

The 2004-2005 Green Team members include:

- Jeff Arnold, Facilities Information Specialist
- Norm Bastian, Security Manager
- Alan Boatright, Custodial Supervisor
- Bill Franzen, Executive Director of Operations
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- Ed Holder, Construction Manager
- Jim Knauer, Maintenance Supervisor
- Jim Norgard, Master Electrician
- Frank Rayder, Outdoor Services Supervisor
- Stu Reeve, Energy Manager
- Chris Rock, Director of Food Services
- Chris Romero, Operations Office Manager
- Russ Richardson, Outdoor Services Area Supervisor
- Mike Spearnak, Director of Planning, Design, and Construction
- John Waldo, Head Plumber
- Tom Weatherly, Head HVAC Technician

The original 2000 Green Team included the following additional members:

- Ellyn Dickmann, Security and School Operations Director
- Tracy Hoffman, Capital Funds Accountant
- Donna Kramer, Custodial Supervisor
- Gary Schroeder, Energy Services Engineer (City of Fort Collins Utilities)
- Roger Smith, Technical Foreman

As a first step for the second edition, the Green Team solicited feedback from its designers; general contractors; subconsultants; building occupants; peer organizations; and local, state, and national experts on the original guidelines developed in 2000. The Green Team would like to thank and acknowledge the following organizations for their valuable feedback on how the guidelines are being used and their recommendations for improvements included in this second revision:

- Corky Bradley, A.I.A., LEED™ AP, RB+B Architects, Inc.
- Brian Dunbar, Institute for the Built Environment
- Gary Schroeder, Fort Collins Utilities
- Doug Seiter, U.S. Department of Energy
- Jim Walsh, Energy Service Associates

How to Use this Guide

Rather than prescribing what is required for Poudre School District (PSD) facilities, these guidelines present the desired performance outcomes from employing sustainable design and suggested approaches for attaining them. Many of the sustainable design strategies described in these guidelines require further analysis to determine feasibility on a project-by-project basis. The guidelines are meant to illustrate sustainable design strategies and concepts, providing a starting point for further research.

This guide summarizes the product and technology research conducted by the Green Team (see Acknowledgements for a description of the Green Team), and describes those products and technologies that will likely be the most useful for and relevant to school buildings. It also provides numerous case studies and references to further investigate opportunities on specific projects. The case studies are intended for illustrative purposes only; they are not a prescription that must be followed by Poudre School District.

There are many purposes for which the Sustainable Design Guidelines may be used. The following table organizes the contents of the Sustainable Design Guidelines in terms of these purposes:

To Read About…	**Go To…**
The basic tenets of sustainable design.	Chapter 1
Poudre School District's philosophy regarding sustainable design.	Chapter 2
PSD strategies for integrating sustainable design into procurement and project management practices.	Chapter 2
Key features of sustainable schools.	Chapter 3
Case studies and lessons learned	Throughout the text in call out boxes

What's New in This Revision

While all of the topics of the original guidelines have been reviewed and updated, there are several new topics added to this second revision.

Chapter 1: Introduction to Sustainable Schools

- Awards illustrating successful sustainable design

Chapter 2: The Sustainable Design Process

- Role of performance-based contracting for renovations
- Building performance goals
- Building modeling

Chapter 3: The Sustainable Design Product

- Acoustics
- Security
- Kitchen design
- Total moisture control
- Construction indoor air quality
- Design for maintainability
- Building controls systems

In addition to these new topics, lessons learned have been added for each major section and case studies have been updated.

The guidelines will continue to be updated periodically. Consultants, suppliers, contractors, or other stakeholders who wish to comment may direct their remarks in writing to **Poudre School District, Planning, Design, and Constrcution Services, 2407 LaPorte Avenue, Fort Collins, Colorado 80521-2297**.

Contents

1.0 Introduction to Sustainable Schools

The word "sustainable" means meeting the needs of the present without jeopardizing the ability of future generations to meet their own needs.[1] Sustainable design is the systematic consideration, during design, of a project's life cycle impact on environmental and energy resources. By definition, the overarching tenet of sustainable design is to use resources efficiently and within their renewable limits.[2] While responsible stewardship of the environment is important, sustainable design also provides a better physical environment for students and staff at lower life cycle costs for the school district.

"…sustainable design provides a better physical environment for students and staff at lower life cycle costs for the school district.."

Goals for a typical sustainable building include the following:
(adapted from footnote 2)

1. Increase energy and water conservation and efficiency.
2. Increase use of renewable energy resources.
3. Reduce or eliminate toxic and hazardous substances in facilities, processes, and their surrounding environment.
4. Improve indoor air quality and interior and exterior environments, which will lead to increased human productivity and performance and better human health.
5. Use resources and materials efficiently.
6. Select materials and products that will minimize safety hazards and life cycle environmental impact (e.g., local materials and lowest embodied energy materials).
7. Increase use of materials and products with recycled content and environmentally preferred products.
8. Recycle and salvage construction waste and building materials during construction and demolition.
9. Generate less harmful products during construction, operation, and decommissioning/demolition.
10. Implement maintenance and operational practices that reduce or eliminate harmful effects on people and the natural environment.
11. Reuse existing infrastructure, locate facilities near public transportation, and consider redeveloping contaminated properties.
12. Consider off-site impacts such as storm water discharge rates and water quality

A Pressing Concern

Every new structure that is constructed without sustainable principles is a lost opportunity for the lifetime of that building. The lost opportunity is staggering considering that design and construction are estimated to account for only 20 percent of a building's total life cycle cost, yet decisions are made during design that commit up to 80 percent of the building's life cycle cost. In other words, design decisions determine how a building will perform throughout its operational life from a resource consumption and waste generation standpoint, substantially affecting annual operating costs. Savings in operating costs can be

[1] Report by the World Commission on Environment and Development (Bruntland Commission). 1987. *Our Common Future*.
[2] Peterson, K.L. and J.A. Dorsey. 2000. "Roadmap for Integrating Sustainable Design into Site-Level Operations." Pacific Northwest National Laboratory (PNNL).

redirected into the core business of curriculum delivery. This is significant considering the U.S. Department of Energy estimates that schools in the United States spend more than $6 billion per year on energy, which exceeds the cost of computers and books combined, and is second only to salary expenses.

Since the motivating premise of sustainability is to meet the needs of the present without jeopardizing the ability of future generations to meet their own needs, what better way to ensure sustainability than to educate the next generation about their role in a sustainable future? Furthermore, Colorado school districts are experiencing first hand the effects of growth, requiring them to build new schools to accommodate increasing enrollments. For these reasons, schools are an ideal application for sustainable design in Colorado.

Buildings That Teach

Although schools are an ideal application for sustainable design, the full benefits are lost if the building itself is not used to help teach students about sustainability and their role in a sustainable future. In science, for example, students are expected to *know and understand interrelationships between science, technology, and human activity and how they can affect the world*. Despite this fact, schools and classrooms continue to be designed and built that are inadequate vehicles for teaching these principles. Spaces for learning can be embedded with subject matter from native materials to daylighting to visually accessible building systems to dynamic technologies. School buildings can provide practical applications of science, math, and art principles.

For example, according to Professor David Orr, Director of Environmental Studies at Oberlin College, "Their [school buildings] design is thought to have little or nothing to do with the process of learning or the quality of scholarship that occurs in a particular place, when in fact buildings and landscape reflect a hidden curriculum that powerfully influences the learning process. The curriculum embedded in any building instructs as fully and as effectively as any course taught in it."[3] For these reasons, sustainable schools should give consideration to eco-education[4], incorporating the environmentally sound building into the educational program.

Diverse Benefits

Beyond the opportunity for buildings that teach, other important benefits of sustainable design in schools are improved indoor air quality and cost savings from decreased energy consumption and other conservation practices. Ninety percent of our time is spent inside buildings and only 10 percent of our time is spent outdoors. The built environment should and can be as healthy as the outdoors when sustainable design principals are used.

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[3] Orr, David W. Spring 1999. "Architecture as Pedagogy." Orion *Afield*.
[4] SHW Concepts. Fall 1998. *www.shwgroup.com.*

Students learn more, perform better, and attend more often, when they are schooled in a sustainable building.

Furthermore, over a 30-year period for a commercial building, it is estimated that only 2 percent of life cycle costs are spent on construction and 8 percent on building energy and maintenance. Ninety-two percent is spent on salaries.[5] Therefore, one of the biggest cost savings from sustainable design stems from improved worker productivity. Similarly, perhaps the most significant benefit of sustainable design for Poudre School District (PSD) is that students learn more, perform better, and attend more often when they are schooled in a sustainable building. Students simply do better when their school is full of daylight, fresh air, and comfortable temperatures.

PSD's success integrating sustainability into its normal operations is evident not only from the increased comfort and productivity of its building occupants, but also from the various awards with which PSD has been honored.

2001

- **Environmental Achievement Award, U.S. Environmental Protection Agency** - Awarded to PSD for superior leadership and commitment to energy conservation, environmental performance, and responsible use of tax dollars.
- **Waste Saver Award, North Front Range Solid Waste Action Group** -
- **Recognition Award, Colorado Renewable Energy Society** - Awarded to PSD in recognition of developing sustainable schools.

2002

- **Design Merit Award, AIA Colorado North Chapter** - Awarded to Zach Elementary School for design excellence.
- **Recognition Award, Colorado Renewable Energy Society** - Awarded to the Operations Center in recognition of excellent use of renewable energy in buildings.

2003

- **Citation Award, American Association of School Administrators/Council of Educational Facility Planners International/American Institute of Architects** - Awarded to Zach Elementary School.
- **Sustainable Design Award, American Society of Interior Designers** – First Place awarded to Zach Elementary School.
- **Media Center Design Award** - American Society of Interior Designers – Second Place awarded to Zach Elementary School.

2004

- **Annual Award, The Wirth Chair in Environmental and Community Development at the University of Colorado, Denver** – Awarded to a Bacon Elementary School student group.

[5] Sustainable Building Technical Manual. *www.sustainable.doe.gov.*

Case Study: Fossil Ridge High School

Fossil Ridge High School is the latest sustainability showcase for PSD, which challenged its design team to exceed the achievements of the award-winning Zach and Bacon Elementary Schools.

FRHS projects energy savings of 61 percent compared to a similar-sized conventional building, translating to approximately $150,000 per year. Energy optimization was achieved through a highly integrated design effort that includes the following:

- Super insulated envelope and white reflective roof
- High efficiency/condensing boilers and heat recovery wheels
- High performance glazing, daylighting, dimming systems, occupancy sensors

Other exceptional features include:

- 100 percent of the building's electricity from wind power
- Over 50 percent of the building's materials regionally manufactured
- Over 20 percent of the building's materials harvested locally
- Nearly 70 percent of the construction waste diverted from the landfill
- A thermal energy storage system shifting over 40 percent of peak cooling demand
- A highly efficient irrigation system that uses a weather station, computer monitoring, and moisture sensors
- Drought-resistant and tolerant plants where possible
- A pond for raw water used for the xeriscaped grounds and nearby properties
- A preserved 1930s farm building for maintenance equipment storage
- Recycled, pervious materials that require no maintenance or water for the football field
- Photovoltaic paneled canopies for shading and electric generation
- Shared recreation facilities and infrastructure with the City of Fort Collins

Even with all these innovations that will provide long-term benefits to the community, the environment, and PSD's economic condition, Fossil Ridge High School was built within budget and at an equal price range to a conventional high school. Above all, the building's inviting feeling and high degree of comfort delight building users and visitors alike.

2.0 The Sustainable Design Process

2.1 Overview of PSD Sustainable Design Philosophy and Policy

PSD's philosophy is to use sustainable design as a lever for realizing a superior learning environment characterized by long-term cost savings.

In 2000, the subtitle to this chapter was "Business is NOT as Usual in Poudre School District." Five years later, PSD can honestly assert that the district has undergone a cultural transformation where sustainability IS business as usual. The purpose of this chapter is to describe how PSD's philosophy translates into routine project management methods both for new construction and renovations.

PSD believes that sustainable design offers an opportunity for superior learning environments *and* long-term cost savings in building operations and maintenance. These are not competing interests, but goals that can be achieved simultaneously through schools that accomplish the following:

- Enhance student performance and attendance
- Teach principles of sustainable design
- Harmonize with the natural landscape
- Provide higher quality lighting
- Consume less energy
- Conserve materials and natural resources
- Enhance indoor environmental quality
- Safeguard water[6]

In 2000, PSD's sustainable design guidelines stated that, "sustainable design may require a fundamental shift from certain aspects of conventional design and construction. The initial shift to sustainable design may take more time and cost more money for design services, but not necessarily increased construction costs, and certainly lower building life cycle costs." Five years later, PSD has seen the bulk of this shift occur and believes that any incremental costs for sustainable design and construction are becoming competitive with conventional design. Meanwhile, the lower life cycle costs are significant based on results of actual schools built within the district in the same time period. For these reasons, PSD's philosophy remains the same: to use sustainable design as a lever for realizing a superior learning environment characterized by long-term cost savings. These cost savings will continue to be reinvested into education, rather than building operations and maintenance.

[6] "Sustainable Design: An Integrated Approach" workshop. March 14, 2000. Jointly sponsored by the PSD and the City of Fort Collins Utilities.

To balance the short-term, albeit shrinking, costs and risks of sustainable design with its long-term benefits, PSD intends to:

- Build schools that are state-of-the-art without being experimental.
- Use exemplary buildings as precedents, rather than reinventing previous work in sustainable design.
- Share risk and rewards by collaborating with other benefactors of sustainable schools, such as the City of Fort Collins and state and federal agencies.
- Use performance agreements, where appropriate, to further share the risks and rewards with contractors.

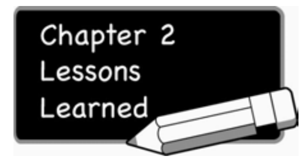
In implementing this philosophy, PSD will advocate an integrated, multi-disciplinary design approach with review and input by all stakeholders. Only through an integrated approach will PSD significantly reduce energy consumption and conserve resources for a whole building. For example, efficient lights and windows may require smaller and less expensive mechanical systems.

Keeping with the desire to use resources wisely, PSD's philosophy is to design schools for durability, functional flexibility, maintainability, and ease of deconstruction/recycling after a useful life.

2.2 Integrated Design

PSD believes the key to achieving a sustainable school is to employ an integrated design approach. This has been misinterpreted by some to mean putting together a good team that works well together. Integrated design extends beyond this meaning in two ways: 1. holistic, rather than systems-based design, and 2. collaboration that extends beyond the design team and beyond traditional perspectives.

Although the total costs for an integrated design project are expected to be equivalent to that of a traditional approach, PSD has found that the expenditures of the design phase of such a project can be elevated. Generally, PSD's costs for designing integrated projects have been approximately 2 percent higher than traditional design costs. This experience correlates closely with a number of existing case studies on integrated design projects nationwide. PSD anticipates this minimal design premium to decrease as sustainable practices become more commonplace. When considering that the increase in design costs still yields equivalent total project costs and significant utility savings for the building, an integrated design approach is a clear value.



Project Management:

- ✓ Shift funding to front load projects for additional design and less construction costs.
- ✓ Further integrate commissioning into project management, including budget for commissioning and communication about commissioning.
- ✓ Actual building performance and energy modeling typically differ, yet energy modeling is useful to predict energy use and influence design.

Whole Building Design

In the past, the design process largely analyzed individual components and subsystems of each building, optimizing them separately. Whole building design not only looks at how materials, systems, and products of a building connect and overlap, but also considers how the building and its systems can be integrated with supporting systems on its site and in its community. A successful whole building design is a solution that is greater than the sum of its parts. The fundamental challenge of whole building design is to understand that all building systems are interdependent.

Through a systematic analysis of these interdependencies, a much more efficient and cost-effective building can be produced. The choice of a mechanical system might, for example, affect the quality of the air in the building, the ease of maintenance, global climate change, operating costs, fuel choice, and whether the windows of a building are operable. In turn, the size of the mechanical system will depend on factors such as site development, the type of lighting used, how much natural daylight is brought in, how the space is organized, and the facility's operating hours.

Whole building design also extends the perspectives, or criteria, for evaluating the design as it progresses. The design is evaluated for cost, quality-of-life, future flexibility, efficiency, overall environmental impact, productivity and creativity, and how the occupants will be enlivened. These factors are evaluated and optimized by examining the building as a whole system, recognizing and maximizing the interplay between components.

Case Study: Seeing is Believing – The Integrated Design Difference

Comparing the site development of a traditional PSD prototype school with the new prototype design illustrates the benefits of an integrated approach.

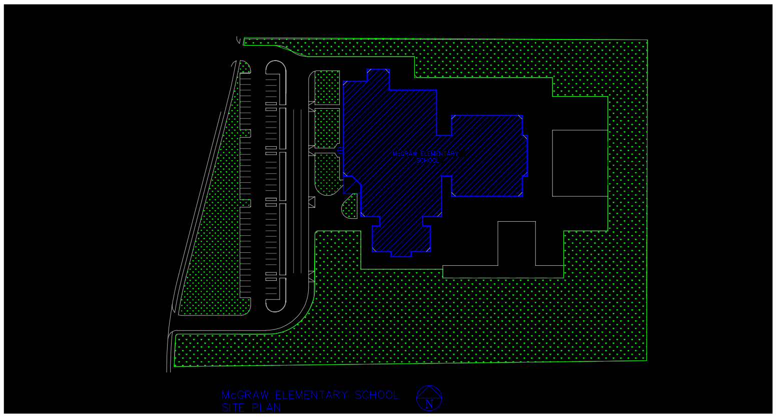


Figure 1:Traditional Prototype Site Development

The traditional approach to site development was focused on one customer – teachers. The result was a lot of asphalt, making it easier for teachers to let students out for recess, drive vehicles to the room for materials transportation, etc. This approach did not consider wider impacts of the site for all customers (e.g., the heat island effect of the asphalt – compromising occupant comfort and increasing the building's cooling load).

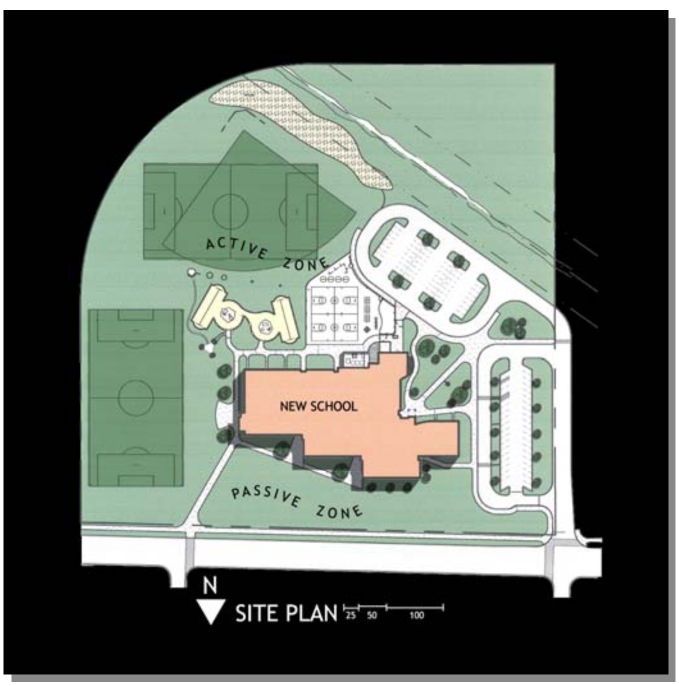


Figure 2: Integrated Design Prototype Site Development

A Collaborative Approach

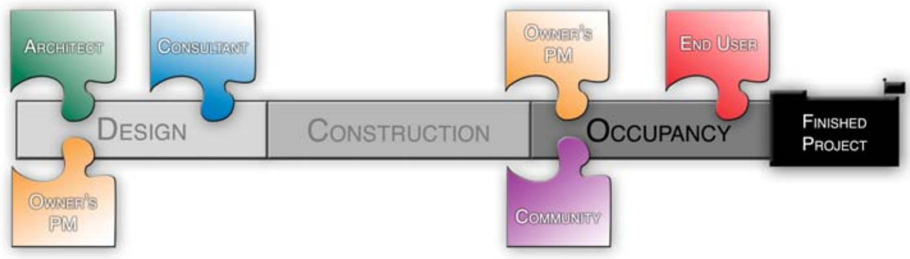
To create a successful high-performance building, an interactive approach to the design process is required. It is necessary for the people responsible for the building design to interact closely throughout the design process. This does not mean that PSD staff members, architects, engineers, contractors, and consultants simply need to talk or attend their traditional meetings. It means everyone involved in using, operating, constructing, and designing the facility must fully understand the issues and concerns of all the other parties. The graphics on the following page illustrate this collaborative approach.

In traditional design, parties have limited or non-existent interaction during design and construction. Often, the end user doesn’t know what will be built until move-in day.

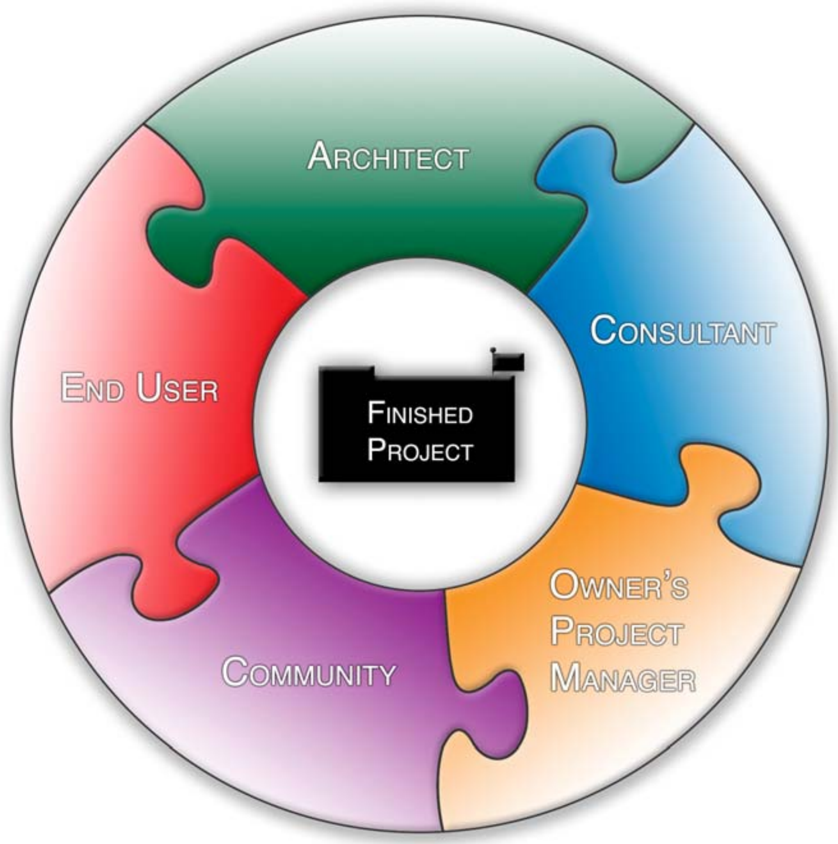
In integrated design, parties have multiple face-to-face meetings, allowing for a better opportunity to make sure the project outcome meets the need it was created for.

PSD involves the end users up front, uses post-occupancy notes to inform the next project and completes an 11-month (following substantial completion or opening) walk and visitation with the users.

Traditional Design Approach



Integrated Design Approach



Project Management Strategies for Achieving Integrated Design

In order to achieve the integrated design goals of whole building design and a collaborative approach, PSD intends to implement some or all of the following project management steps[7]:

1. Clearly define sustainable design goals in requests for qualifications (RFQs), requests for proposals (RFPs), and bid review criteria (see Section 2.3).

2. Select team members who are experienced with or interested in using sustainable design strategies.

3. Establish contracts that encourage collaboration and excellence in sustainable design and construction practices (see Section 2.3).

4. As soon as the project is established, review similar projects with exemplary results for resources and lessons learned. Numerous case studies have been researched and included throughout these guidelines in easy-to-read callout boxes from the main text. Additional case studies can be found in the resources described in Chapter 4.

5. Conduct one to two design charrettes (at conceptual design and/or schematic design) with stakeholders and specialists (see Section 2.4).

6. Establish an electronic conference site. Post goals and results of charrettes. Invite feedback and require consultants to evaluate/monitor responses.

7. Set standards and measurable goals for sustainable building performance (e.g., lighting power density in watts per square foot, energy consumption in British thermal units (BTUs) per square foot, percent of material that will be reused, recycled, recycled content, etc.)

8. Develop an energy model that evolves with and informs the design.

9. Look for design opportunities that provide multiple benefits and cost tradeoffs.

10. Evaluate costs and conduct value engineering only from a whole building perspective.

11. Expand the timeline for normal design development and construction phases, allowing time to evaluate new systems and products and to perform building simulations.

[7] Berkebile, Nelson, Immenschuh, McDowell Architects. "Ten Steps to Sustainable Design Management." Kansas City, MO. INFO@BNIM.COM.

12. Establish instrumentation for monitoring and evaluating building performance, including commissioning and post-occupancy evaluation (see Section 3.13).

13. Perform post-occupancy inspection (1 year minimum), with recommendations as appropriate for operational improvements.

Charrettes

A Sustainable Design Charrette is a process advocated by the American Institute of Architects (AIA) in which a multi-disciplinary team works together to envision alternative design solutions for a building program with an emphasis upon long-term economic, social, and environmental sustainability.[8]

The term charrette is adopted from the practice of *Ecole des Beaux Arts* students in nineteenth century Paris. Charrette, in its modern day adaptation, refers to an intensive design workshop involving people from various disciplines working together under compressed deadlines. The AIA Committee on the Environment endorses the Sustainable Design Charrette process as a preferred alternative to the traditional linear process of designing and constructing built environments.

Typically, a Sustainable Design Charrette is a workshop held over 2 or 3 days. PSD will consider holding one to two charrettes during the design phases of a new school (during conceptual and/or schematic design).

The charrette participants would operate as an expanded design team, providing expertise and input to the core design team in an integrated fashion. The participants may include PSD project management, facilities staff and educators, contracted design and professional service firms, as well as outside expertise and other project stakeholders, such as the City of Fort Collins Utilities, Colorado State University design and engineering faculty, and U.S. Department of Energy buildings specialists.

Building Performance Goals

A sustainable school can be an evasive goal. It is not enough just to tell your design team that you want a high performing or energy efficient building. There are many examples of recent school buildings nationwide that fall short of district expectations regarding performance despite an interest in energy efficiency or sustainability. That is why these guidelines address both the content of what a sustainable school entails as well as the steps for getting there. One of the steps new to this second version of the Sustainable Design Guidelines is to articulate that PSD will set quantitative building performance goals for its construction projects. The specific performance goal values will be set on a case-by-case basis, but could include the following:

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[8] Watson, Donald. FAIA. 1996. American Institute of Architects, Committee on the Environment, Environmental Design Charrette Workbook. ISBN #1-879304-86-04.

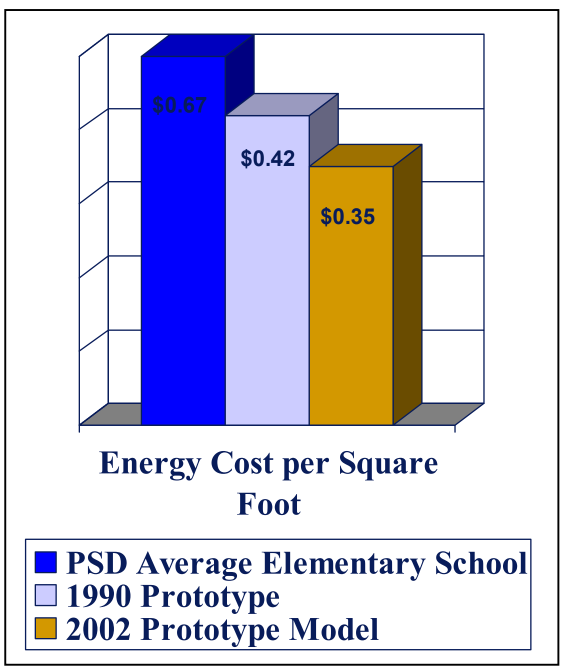
- ENERGY STAR™ rating
- LEED™ rating
- Energy use (e.g., kBtu/ft^2/yr)
- Electric demand limits for peak periods
- Water use and uniformity
- Construction recycling diversion rate
- Lighting load and electric plug load densities
- Lighting and heating, ventilation, and air conditioning (HVAC) occupancy schedules
- HVAC occupied/unoccupied set points

For example, the building performance goals initially set for Zach Elementary School included:

- ENERGY STAR rating: 80
- Energy use: 22 kBtu/yr/ft2
- Exceedance of ASHRAE 90.1 by 50 percent
- Construction recycling diversion rate: 75 percent

The following graph comparing Zach to PSD's previous elementary prototype and the District's average elementary school clearly displays the energy cost benefits of aggressive performance goals and the overall sustainable design process.

Adjust graph relative sizes



Building Modeling

Energy modeling is an important tool to use during the design and construction phase of a building to predict energy use and to influence design. Models can be used to inform the design process by evaluating the impacts of various strategies on the performance of the building. Typically, the first energy model is established based on schematic design information. The model informs and evolves with the design. A base model reflecting a minimally code compliant building is established to calculate overall energy savings and to document benefits of the energy design. Final “as-built” and baseline models are completed to document total expected integrated savings.

A modeling specification is useful for establishing expectations between the modeler and design team. The specification clearly spells out deliverables and their due dates relative to the design process. For example, a specification might call for a simple schematic model in early schematic design to inform building shape and orientation. Then, a well established base model along with models showing combinations of energy efficiency measures (e.g. HVAC options, glazing, exterior shading, electric lighting, etc.) at some point in design development.

Modeling reports are an important tool for the entire project team and should also be specified as to what type of report and when it is expected. They include information such as:

- Summary of annual projected utility costs and savings
- Performance graphs (e.g., monthly energy use for gas and electric, monthly facility peak kW, etc.) in comparison to the baseline
- Input parameter information (e.g., internal load specifications, building envelope characteristics, HVAC system definitions, etc.)
- Assumptions of building characteristics (e.g., schedules, HVAC setpoints, etc.)
- Notations of changes from previous modeling versions (e.g., changes made between schematic design and design development, etc.)
- Interpretation of results
- Software input and output files (electronic)

2.3 Hiring the Right Design Team

Experience and Expertise in Sustainable Design

PSD will seek out demonstrated experience in applying sustainability concepts and principles to the design of schools through an integrated design approach.

To ensure implementation of its sustainable design philosophy, one approach PSD intends to take is to select design and related professional services on the basis of their knowledge and demonstrated experience in applying sustainability concepts and principles in designing schools using an integrated design approach.[9]

PSD will specify that contractors demonstrate this knowledge in both RFQs and RFPs. Specifically, design teams will be asked to demonstrate experience in these areas:

- Environmentally responsible or sustainable school design
- Integrated design methodologies
- Projects that use less heating and cooling energy than conventional standards require
- Projects that use less electrical energy and less energy for lighting than industry standards require
- Projects with Leadership in Energy and Environmental Design (LEED™) or other green building ratings
- Projects that specifically address ensuring good indoor air quality by using less toxic materials, integrated pest management, etc.
- Site planning that sustains and enhances the natural environment by maximizing solar energy potential and use of natural light, maximizing the potential for natural ventilation, and minimizing off-site storm water runoff
- Specifications writing that requires waste management and recycling plans for construction and demolition
- Life-cycle analysis techniques to select building materials that minimize environmental impacts
- Client references for previous sustainable design work

[9] Naval Facilities Engineering Command Planning and Design Policy Statement - 98-03.

If the sustainable design expertise resides with a consultant rather than a contractor, priority will be given to teams that have had success working together on prior sustainable design projects. PSD will give priority to submittals containing at least one sample of a sustainable project previously designed by the firm, including an explanation of the following:

- Increased energy conservation and efficiency
- Increased use of renewable energy resources
- Application of daylighting strategies
- Reduction or elimination of toxic and harmful substances
- Efficiency in resource and materials use
- Selection of materials based on life-cycle environmental impacts
- Recycling of construction waste and building materials after demolition
- Metered performance and post -occupancy evaluation data

2.4 The Role of LEED™ and Other Standards

PSD recognizes there are several existing and emerging green building standards that are applicable to schools. Our philosophy is to keep apprised of relevant standards and to determine which will be employed on a project-by-project basis. For example, at the time the original sustainable design guidelines were developed, LEED™ for New Construction and Major Renovations (LEED-NC) was in its pilot phases. Five years later, PSD is seeking LEED™ certification for the Fossil Ridge High School. The costs and benefits of that experience will play into future decisions about LEED™ on an individual project basis. Meanwhile, new standards, certifications, and design guidelines continue to emerge. The rest of this section summarizes these resources that PSD recognizes as potentially valuable design aides for future projects.

LEED™

LEED-NC is a green building rating system that was designed to guide the construction or major renovation of commercial and institutional buildings. It has been successfully applied to numerous K-12 schools, including PSD's Fossil Ridge High School.

The following score sheet highlights the points-based LEED™ system as applied to the Fossil Ridge High School (see case study, Chapter 1 for additional details).

Fossil Ridge High School Preliminary LEED™ *Scorecard*

Revised 3/15/04

Yes	?	No			Points
7	0	7		**Sustainable Sites**	**14** Points
Y			Prereq 1	**Erosion & Sedimentation Control**	Required
		1	Credit 1	**Site Selection**	1
		1	Credit 2	**Urban Redevelopment**	1
		1	Credit 3	**Brownfield Redevelopment**	1
		1	Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
1			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
		1	Credit 4.3	**Alternative Transportation**, Alternative Fuel Refueling Stations	1
		1	Credit 4.4	**Alternative Transportation**, Parking Capacity	1
		1	Credit 5.1	**Reduced Site Disturbance**, Protect or Restore Open Space	1
1			Credit 5.2	**Reduced Site Disturbance**, Development Footprint	1
1			Credit 6.1	**Stormwater Management**, Rate or Quantity	1
1			Credit 6.2	**Stormwater Management**, Treatment	1
1			Credit 7.1	**Landscape & Exterior Design to Reduce Heat Islands**, Non-Roof	1
1			Credit 7.2	**Landscape & Exterior Design to Reduce Heat Islands**, Roof	1
1			Credit 8	**Light Pollution Reduction**	1
Yes	?	No			
1	0	4		**Water Efficiency**	**5** Points
1			Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
		1	Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
		1	Credit 2	**Innovative Wastewater Technologies**	1
		1	Credit 3.1	**Water Use Reduction**, 20% Reduction	1
		1	Credit 3.2	**Water Use Reduction**, 30% Reduction	1
Yes	?	No			
12	0	4		**Energy & Atmosphere**	**17** Points
Y			Prereq 1	**Fundamental Building Systems Commissioning**	Required
Y			Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**CFC Reduction in HVAC&R Equipment**	Required
2			Credit 1.1	**Optimize Energy Performance**, 20% New / 10% Existing	2
2			Credit 1.2	**Optimize Energy Performance**, 30% New / 20% Existing	2
2			Credit 1.3	**Optimize Energy Performance**, 40% New / 30% Existing	2
2			Credit 1.4	**Optimize Energy Performance**, 50% New / 40% Existing	2
1			Credit 1.5	**Optimize Energy Performance**, 60% New / 50% Existing	2
		1	Credit 2.1	**Renewable Energy**, 5%	1
		1	Credit 2.2	**Renewable Energy**, 10%	1
		1	Credit 2.3	**Renewable Energy**, 20%	1
1			Credit 3	**Additional Commissioning**	1
		1	Credit 4	**Ozone Depletion**	1
1			Credit 5	**Measurement & Verification**	1
1			Credit 6	**Green Power**	1
Yes	?	No			
5	0	8		**Materials & Resources**	**13** Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
		1	Credit 1.1	**Building Reuse**, Maintain 75% of Existing Shell	1
		1	Credit 1.2	**Building Reuse**, Maintain 100% of Shell	1
		1	Credit 1.3	**Building Reuse**, Maintain 100% Shell & 50% Non-Shell	1
1			Credit 2.1	**Construction Waste Management**, Divert 50%	1
		1	Credit 2.2	**Construction Waste Management**, Divert 75%	1
		1	Credit 3.1	**Resource Reuse**, Specify 5%	1
		1	Credit 3.2	**Resource Reuse**, Specify 10%	1
1			Credit 4.1	**Recycled Content**, Specify 25%	1
1			Credit 4.2	**Recycled Content**, Specify 50%	1
1			Credit 5.1	**Local/Regional Materials**, 20% Manufactured Locally	1
1			Credit 5.2	**Local/Regional Materials**, of 20% Above, 50% Harvested Locally	1
		1	Credit 6	**Rapidly Renewable Materials**	1
		1	Credit 7	**Certified Wood**	1
Yes	?	No			
5	0	10		**Indoor Environmental Quality**	**15** Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
		1	Credit 1	**Carbon Dioxide** (CO_2) **Monitoring**	1
		1	Credit 2	**Increase Ventilation Effectiveness**	1
		1	Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
		1	Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
1			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
1			Credit 4.2	**Low-Emitting Materials**, Paints	1
1			Credit 4.3	**Low-Emitting Materials**, Carpet	1
		1	Credit 4.4	**Low-Emitting Materials**, Composite Wood	1
1			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
		1	Credit 6.1	**Controllability of Systems**, Perimeter	1
		1	Credit 6.2	**Controllability of Systems**, Non-Perimeter	1
1			Credit 7.1	**Thermal Comfort**, Comply with ASHRAE 55-1992	1
		1	Credit 7.2	**Thermal Comfort**, Permanent Monitoring System	1
		1	Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
		1	Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1
Yes	?	No			
5	0	0		**Innovation & Design Process**	**5** Points
1			Credit 1.1	**Innovation in Design**: Locally Manufactured	1
1			Credit 1.2	**Innovation in Design**: Locally Harvested	1
1			Credit 1.3	**Innovation in Design**: Green Power	1
1			Credit 1.4	**Innovation in Design**: Shift Peak Demand	1
1			Credit 2	**LEED™ Accredited Professional**	1
Yes	?	No			
35	0	33		**Project Totals**	**69** Points

Certified 26-32 points **Silver** 33-38 points **Gold** 39-51 points **Platinum** 52-69 points

Relatively new by comparison to LEED-NC, the LEED™ Green Building Rating System for Existing Buildings (LEED-EB) is a set of performance standards for sustainably operating existing buildings. The LEED-EB criteria cover building operations and systems upgrades in existing buildings where the majority of interior or exterior surfaces remain unchanged. LEED-EB is applicable to existing buildings that are seeking LEED™ Certification for the first time, as well as projects previously certified under LEED™ standards for new construction. LEED-EB provides the opportunity for building owners and operators to meet their sustainable operations goals and to reduce the impacts of their buildings on the environment and occupant health over their entire life cycle. http://www.usgbc.org/LEED/leed_existing.asp

The LEED™ Application Guide for Schools should be completed in fall 2005. It is designed to complement the LEED™ Green Building Rating System and the LEED™ Reference Guide. The purpose of the application guide is to provide direction in applying the LEED™ Green Building Rating System to K-12 educational facilities. It serves as a checklist of suggested steps and is designed to make the process easier to understand and more user friendly. The LEED™ for Schools Application Guide, based on LEED™ Version 2.1 for New Construction, is currently under development. Several schools have successfully been certified using LEED™ Version 2.1 for New Construction. Several more are currently in the certification process. The U.S. Green Building Council (USGBC) serves as the educational entity and third party verification authority that supports the implementation and review of the LEED™ submission process. www.usgbc.org

Collaborative for High Performance Schools

The Collaborative for High Performance Schools (CHPS, often pronounced "chips") aims to increase the energy efficiency of schools in California by marketing information, services, and incentive programs directly to school districts and designers. CHPS's goal is to facilitate the design of high performance schools - environments that are not only energy efficient, but also healthy, comfortable, well lit, and contain the amenities needed for a quality education. www.chps.net

Washington State High Performance Schools Pilot Program

The Washington State High Performance Schools Pilot Program is based on the CHPS Protocol model, but explicitly defines a high performance school for the State of Washington. The criteria, which are voluntary, were created by a joint committee established by the Washington Chapter of the Council for Educational Facility Planners International (CEFPI). This program enables Washington school districts to construct and/or modernize all schools, regardless of size or other variables. The program's goal is to achieve and measure sustainability that enhances the learning environment and that is climate responsive, affordable, inspirational, and integrates well into the school construction process. http://www.k12.wa.us/SchFacilities/SustainableSchools.aspx

Technical Specification and LEED™ Guidance for Colorado Schools

In 2004, Falcon School District 49, located in Falcon, Colorado, developed two resources for sustainable design with broad applicability to other school districts state-wide: 1) a specification for standards that go beyond code organized into the 16 divisions of the Construction Specifications Institute (CSI) master format; and 2) LEED™ guidance on a point-by-point basis, including spreadsheets for developing LEED™ scorecards. These documents were developed with support from the Governor's Office of Energy Management and Conservation (OEMC) and included input from other school districts statewide, including PSD. The documents are available through OEMC.

Minnesota Sustainable Design Guide <web link>
The Minnesota Sustainable Design Guide is a web-based tool that assists architects, building owners, occupants, educators, students, and the general public concerning sustainable building design. It can be used to set sustainable design priorities and goals, develop appropriate sustainable design strategies, and determine performance measures to guide the sustainable design and decision-making processes. The guide's strategies are an adaptation of the LEED™ scorecard. To ensure that sustainable design is thoroughly integrated into the project process, the guide outlines project management practices and corresponding deliverables for each step in the project lifecycle: pre-design, design, construction, and occupancy.
http://www.sustainabledesignguide.umn.edu/

ASTM Subcommittee on Sustainability and Associated Standards
Each main committee of the American Society for Testing and Materials (ASTM) International is composed of subcommittees that address specific segments within the general subject area covered by the technical committee. In 2001, ASTM sub-committee E.06.71 on Sustainability was established as a sub-committee of technical committee E.06 on Building Performance. The sub-committee is working on numerous standards relevant to sustainable building design and construction (http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E0671.htm?L+mystore+fpsn6329+1106346501). The standards of most interest to schools are listed below:

- E1971-98 Standard Guide for Stewardship for the Cleaning of Commercial and Institutional Buildings
- E1991-98 Standard Guide for Environmental Life Cycle Assessment of Building Materials/Products
- E2114-04 Standard Terminology for Sustainability Relative to the Performance of Buildings
- E2129-03 Standard Practice for Data Collection for Sustainability Assessment of Building Products

In addition to existing standards, the sub-committee is working on additional standards, such as a standard for green roofs, and a Standard Guide for General Principles of Sustainability Relative to Buildings (WK5566).

2.5 Remodels and Additions

Effectively the same principles of sustainable design for new construction apply to remodels and additions as well. Actively considering sustainable design is perhaps even more important for remodels and additions considering that the vast majority of the projects within PSD are remodels and additions versus new construction.

Although the principles are the same, remodels may present some specific challenges with respect to applying sustainable design such as:

- More restrictive budgets
- Design contraints based on existing building and building systems
- Less resources and expertise from partnering organizations

Budgets and financing

Remodels may have more restrictive budgets than new construction because the scopes (and therefore budgets) are more specifically defined. This can also limit design options and project approaches. Where project budgets are limited, PSD recognizes that performance contracting may be a useful tool for achieving sustainable design. Performance contracting allows capital equipment to be purchased and paid for from future savings, usually from reduced utility bills. PSD feels this type of financing mechanism can be an antidote to traditional value engineering. In value engineering, building components are weighed for their individual merits and eliminated where possible and necessary to meet project budgets. This can conflict with the integrated design approach described above. Performance contracting can be an answer to value engineering because it allows for incremental or new project costs at the component level so long as the overall whole building performance will realize a reduced operating cost to pay for the purchase.

Although it has not been exercised to date, PSD entered into a master lease agreement with Platte River Power Authority (PRPA) in 1997. Under the agreement, PRPA can purchase up to one million dollars in capital equipment and lease it back to PSD. PSD in turns meets the lease payments with energy savings associated with the equipment purchase. The term for the master lease agreement is indefinite.

Remodels:

- ✓ Remember remodels, they make up the majority of our projects.
- ✓ Look for retro commissioning opportunities

Interface with existing buliding and building systems
On the one hand, PSD advocates an integrated whole-building approach to design, yet the majority of projects are for remodels or additions where a whole building already exists. First and foremost, it's important to ensure that the existing building is properly operated and maintained for peak performance relative to its design. That is why the energy management program is such an important complement to PSD's sustainable design efforts.

Under the leadership of its energy manager and energy efficiency team, PSD has completed over 108 energy efficiency upgrades to existing schools since 1994. As a result, the district has saved a total of over $1,500,000 with ongoing annual savings over $378,000. These upgrades have helped 10 existing schools and one office building to be recognized with the prestigious ENERGY STAR label – meaning that the labeled school performs better than 75% of schools nation-wide from an energy standpoint. Example projects include:

- Conversion of old steam heating systems to modern hot-water heating systems
- Upgrade of old roof-top units to higher efficiency modern units
- Lighting upgrades throughout schools, including gym lighting and exit signs
- De-lamping of over-designed lighting systems
- Installation of automated building energy management systems
- Boiler insulation
- Conversion of electric heating systems to efficient natural gas systems
- Installation of energy-efficient insulation during re-roofing projects
- Pilot project to evaluate solar tubes for daylighting
- Optimizing HVAC controls on existing units

The district also looks for re-commisioning and retro-commissioning opportunities. Re-commisioning is the process of restoring the operation of systems (e.g. HVAC) as intended in the original design. Retro-commissioning is taking that a step further and optimizing the system with today's knowledge and technology.

Beyond modernization of energy-consuming systems, there are many other maintenance and operating considerations that contribute to a school's sustainable performance. The California High Performing Schools Program (CHPS) offers a comprehensive guide for Maintaining and Operating schools to ensure schools buildings continue to operate as intended in their design—providing optimal health, efficiency, and sustainability. The manual is available for download at www.chps.net.

Well-maintained and operated buildings still undergo a series of remodels and sometimes additions over their life time to accommodate changing functional needs. The majority of projects within PSD fall into this category. Because they're relatively small compared to new construction, it can be easy to forget about sustainable design. It can also be frustrating trying to apply integrated systems thinking to a smaller scope project.

As an example, Weld County School District 6 had bond funding to install air conditioning in several of its elementary schools. An integrated design approach would first look for ways to reduce cooling demand and then to design the most effient cooling system at the right size. But the remodel scope was limited to simply adding air conditioning. Under separate grant funding, Weld 6 was able to install energy efficient lighting to reduce the cooling load, while also saving electric energy.

Less Resources and Expertise from Partnering Organizations

PSD has been fortunate to receive funding and direct technical expertise from numerous partnering organizations on its new construction projects. This has included grants for design assistance, commissioning, and drywall recycling as well as staff technical review from partner organizations. This type of assistance is less available on smaller profile projects with less energy and environmental impacts. Therefore, its incumbant upon PSD project management and design staff to ensure that the lessons learned from new construction, in terms of buildings systems, materials, and technologies, are transferred to the smaller projects.

Case Study: Sustainable Design in the Remodel of Harris Bilingual Elementary School

Sustainable design principles were applied to the remodeling of Poudre School District's Harris Bilingual Elementary School. This project, completed in 2002, remodeled significant portions of the building and added just over 5,000 square feet to the total building size.

Sustainable design applications at Harris include:

- Natural daylighting provided by existing windows
- New doors and windows prior to new construction
- Updated lighting fixtures in all areas including electronic ballasts and higher efficient T8 light technology
- Fluorescent/multilevel switching lighting fixtures in the gym
- High efficiency boilers
- Energy management system
- Increased insulation in newly constructed areas
- Artificial turf playground, reducing irrigation needs

Prior to the remodeling project, Harris' ENERGY STAR score was 85. As of a result of the sustainable design, the school's energy star score increased to 89.

3.0 The Sustainable Design Product: Features of Sustainable Schools

While Chapter 2.0 focused on how sustainable design impacts the project management *process*, Chapter 3.0 addresses what physically will be different about the design *product*. That is, what features will characterize sustainable new schools, as well as renovations to existing schools.

The following features collectively represent a comprehensive, sustainable school:

1. Sustainable site planning and landscape design
2. Use of renewable energy sources
3. High quality and energy efficient lighting
4. Energy efficient building shell
5. Energy efficient HVAC systems
6. Indoor environmental quality, including eenvironmentally preferable building materials, indoor air quality, acoustics and total moisture control
7. Water conservation
8. Security
9. Kitchen operations
10. Recycling and waste management
11. Construction waste reduction and recycling
12. Commissioning
13. Maintainability
14. Buildings that Teach

Each of these features is developed in more detail in the remaining sections of this chapter. As noted earlier, these guidelines do not necessarily reflect requirements for new schools. Rather they illustrate possible features that should be developed in further detail during the design phases of specific projects.

3.1 Site Planning and Landscape Design

Site planning is critical to the success of a sustainable building. Careful planning, building orientation, and landscaping can cut energy consumption levels and monthly utility expenses considerably. An analysis of a site should consider all existing features, both natural and human made, to determine the inherent qualities that give a site its personality. A topographical analysis of existing features is advised. Emphasis should be placed on the site's relationship to the larger environment and its special values. This analysis should include natural, cultural, and aesthetic factors that affect the site.[10] The site also should be viewed as a valuable resource for education, not just a building site.

[10] Rubenstein. 1996. *A Guide to Site Planning and Landscape Construction.*

At least seven features characterize a sustainable school site[11]:

1. Includes bio-diversity

2. Requires low input after establishment
   (e.g., water, mowing, labor, fertilizers, etc.)

3. Relates to and is connected to the area's natural systems

4. Uses green materials where possible

5. Visible from the indoors

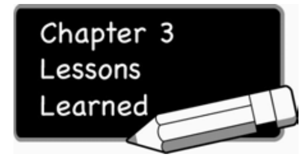
6. Modulates heating and cooling of the building (e.g., wind buffers, shading)

7. Reinforces the health and welfare of the local community and economy and engages the community in its construction and use

In site planning for the built environment, the designer must be aware that any structure will inevitably, by virtue of its physical presence and functioning, affect not only the site's ecosystem but the ecosystems around the site. The structure's possible influence on surrounding ecosystems must be included as part of the set of design considerations.[12] The well designed building site lets natural energy sources work for it, such as solar heating and natural cooling breezes.

Natural water features, such as small streams or ponds, are some of the most powerful elements in landscape design. They also lower the temperature by contributing to cooling breezes, which may enter the building. When designing open spaces, it is important to pay particular attention to natural drainage patterns. These patterns can act as a design determinant and can produce beautiful landscaping features that serve as a wildlife habitat, reduce off-site water flow; are incorporated into a city's storm water quality criteria (by improving the quality of storm water runoff)[13], supply water for landscaping, and cost substantially less to build and maintain than conventional storm drainage systems.[14]

In designing water features, consult the City of Fort Collins Stormwater Quality WaterSHED Program (Stormwater, Habitat, Education, Development). This program works in conjunction with local elementary school science curriculum to provide outdoor educational opportunities. Experiences from the WaterSHED Program that involve working with school students should be consulted during site planning of future schools.



Site Planning:

- ✓ Limit turf to playable areas and increase overall site landscaping diversity.
- ✓ Consider appearance and cultural practices in landscape design.
- ✓ Maintain concepts of drought tolerance even during non-drought periods.
- ✓ Limit impervious surface materials where possible.

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[11] Schaal, Herb. EDAW, Inc. March 14, 2000. "Sustainable Design: An Integrated Approach" workshop. Fort Collins, Colorado.
[12] Yeang. 1995. *Designing with Nature.*
[13] Urban Drainage and Flood Control District. Drainage Design Manual, Volume 3.
[14] Rocky Mountain Institute. 1995.

Case Study: Northern Colorado Water Conservancy District
Information provided by BHA Design, Inc., Fort Collins, Colorado

The Northern Colorado Water Conservancy District (NCWCD) governs water distribution that spans 1.5 million square miles in Northern Colorado. Water conservation is one of the organization's major focuses. In 1999, the NCWCD elected to build a new headquarters in Berthoud, Colorado, on a 35-acre parcel of land.

The project was to model agricultural and domestic water conservation, as well as to educate the public about the mission of NCWCD. The landscape architects were asked to create a landscape that was drought tolerant and attractive, as well as to develop an interpretive area educating the public about NCWCD's major projects.

Planted with Aspen, Ponderosa Pine, Colorado Spruce, and thousands of native perennials and shrubs, the project is a delightful place to sit and listen as the information officer explains the history of water in Colorado. A small Xeriscape garden provides information for visitors on the many kinds of plants and grasses, such as Blue Gramma, suitable for the Colorado landscape that can exist on indigenous rainfall. Planted with native and drought tolerant plants, the garden, after several years of establishment, will be able to live on native rainfall alone, as will most of the vegetation on the site.

Overall, the project is a model of water conservation. The landscape achieves an 80 percent savings over the typical bluegrass lawn approach. Additionally, the site uses raw water for irrigation and does not rely on a potable city supply. As part of the final project, the NCWCD water conservation officer will monitor actual water used in the landscape and document typical water savings over time. The results will be conveyed to the NCWCD constituents and will be available to the public. Once fully established, the NCWCD campus will be a living example of water conservation.

3.2 Renewable Energy Sources

Currently, 98 percent of Colorado's energy is produced from fossil fuels — coal, oil, and natural gas.[15] Predictions vary widely, but fossil fuel supply is finite, and fossil fuel combustion produces air pollutants and contributes to global warming. In contrast, renewable energy sources are constantly replenished and do not have the environmental consequences associated with combustion. Renewable energy also provides an educational opportunity for students to understand the earth's natural processes and how to put them to work for humans. For these reasons, PSD is interested in investigating the potential for using renewable energy sources in schools.

Renewables:

- ✓ Renewables cost more, but PSD encourages their use as the right thing to do.

3.2.1 Using Solar Energy in Schools

The sun serves as a pollution-free source of energy for schools. The technologies to capture the sun's energy range from inexpensive options that can be easily incorporated into new buildings, such as daylighting (see Section 3.3.1), to more expensive options, such as photovoltaic systems.

Passive solar heating relies on the design of the building to capture and hold the sun's heat. Passive solar often goes hand-in-hand with daylighting, which uses natural sunlight to supplement or replace indoor electric light. In this part of the country, too much solar heat can be a problem; therefore, solar gains must be controlled. Passive solar heating can be incorporated into new school designs at little or no cost.

"A building should be like a tree, it should thrive on the sun's energy while enhancing its surroundings" WILLIAM McDONOUGH, ARCHITECT, 1993

Ventilation preheating is an inexpensive and efficient means of using solar energy to supplement space heating in a school. It requires a south-facing wall without windows. The system involves a black metal sheet heated by the sun mounted against the wall. The intake air for the ventilation system is drawn through holes in the metal sheet and heated. The systems are incorporated into new schools or added as a retrofit to existing schools.[16]

Solar hot water systems use various collector technologies to collect sunlight for heating water. Although solar hot water systems have higher initial costs than other water-heating technologies, the energy savings will pay back the cost of the system.

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[15] U.S. Department of Energy National Renewable Energy Laboratory. April 2000. "Colorado's Clean Energy Sources" pamphlet. Available from the Governor's Office of Energy Management and Conservation, 303-620-4292.

[16] see *www.eren.doe.gov/solarbuildings/tech-transpired_bib.html* and *www.buildinggreen.com products/solarwall.html*

Solar photovoltaic systems generate electricity directly from the sun. They are currently a more expensive source of electricity than utility power. However, photovoltaic systems serve as a useful teaching aid and provide a true hands-on experience with solar energy. American Electric Power, for instance, has created a web site that displays the power generation from a photovoltaic system on Bluffsview Elementary School in Worthington, Ohio.[17]

Another consideration for photovoltaic systems owners is the ability to sell excess power back to a utility, preferably at the same price system owners pay for electricity (as opposed to the much lower wholesale cost of power). This concept is often referred to as net metering or parallel generation. According to the City of Fort Collins Utilities, larger customer-owned parallel generation systems may be connected to the utilities distribution system. Any parties considering parallel generation are asked to contact Utilities staff for more information on the applicable provisions and to discuss details.

Case Study: Photovoltaics at Fossil Ridge High School

One of the more innovative and groundbreaking elements of the Fossil Ridge High School integrated design is its photovoltaic, or solar electric, system. Generating electricity from sunlight, the installation is the largest of its kind in Northern Colorado. The system is 5.2 kilowatts (kW) and is comprised of thirty 175-watt panels. These panels are mounted near the main building entrance and double as canopies for window shading (an excellent example of truly integrated design). Used extensively for demonstration and educational purposes, the photovoltaic system is tied to the utility grid, but does not have electrical storage capacity. The cost of the project, including monitoring equipment, was just over $42,000.

Fossil Ridge High School also has a 1-kW photovoltaic system installed on the maintenance equipment storage building, which is a historic 1930s farm building. This system is not connected into the utility grid. In addition, PSD's Operations Center has a photovoltaic array, and designs are being completed to include photovoltaic as part of Kinard Junior High School. Infrastructure for a system sized to be at least 10 kW is planned for this school.

[17] *www.aep.com/environment/solar/graphs/index.html*.

3.2.2 Wind Power and Other Renewable Energy Purchases for Schools

Wind energy employs a turbine for converting wind into either electric power or mechanical power, such as for pumping water. While PSD would be willing to consider wind energy if a compelling engineering case was developed by the design team, the current focus is toward purchasing wind power through Fort Collins Utilities.

Case Study: Wind Energy Purchases at Poudre School District

To demonstrate commitment to renewable energy, Poudre School District (PSD) purchases 100% wind power for all electrical loads at four buildings:

- Zach Elementary School,
- Bacon Elementary School,
- Fossil Ridge High School, and
- PSD Operations Center.

The source of PSD's wind power purchased is the Medicine Bow Wind Project near Medicine Bow, Wyoming. Zach was the first of PSD's schools to subscribe to Fort Collin's Utilities Wind Power Program. At that time, wind power were a premium purchase of 2.5 cents per kilowatt-hour (kWh). Due to an increased subscribers to the wind program and other City initiatives, unit costs for wind power decreased by 60% in June of 2004. Wind power is available for only 1 cent more per kWh re than standard electric rates. This premium is small compared to the significant energy savings in these four sustainably-designed buildings.

3.3 High Quality, Energy Efficient Lighting

Lighting:

- ✓ Include manual overrides on lighting controls.
- ✓ Be judicious with design and location of occupancy sensors.
- ✓ Be sensitive to occupant needs for room blackouts.
- ✓ Design work areas without direct sunlight.
- ✓ Northern daylight is preferable.
- ✓ Keep lighting controls simple and commission them

Lighting is a critical aspect for both a high-quality learning environment and an environmentally sustainable building. There are numerous opportunities to improve the quality of light while significantly reducing the energy used by lighting. Lighting approaches should rely primarily on well-designed daylighting systems, complemented as needed by energy-efficient electric lighting systems. For both daylighting and electric lighting, the design should begin by carefully assessing the tasks to be performed. Controls may be needed to provide different lighting for different tasks in the same space. Daylighting and electric lighting should be designed only in the context of a whole-building design approach, starting with decisions on orientation and shape of the building.

3.3.1 Daylighting

Daylighting is defined as using natural light for illumination. Well-designed daylighting provides a superior quality of light, contributes to productivity, reduces energy costs, and improves the health of the occupants. Daylighting is more than simply installing a few skylights; it must be designed within the context of a whole building approach. In this regard, it can be an organizing principle for design. Daylighting involves consideration of heat gain, glare, variations in light availability, and sunlight penetration into a building. A successful design must address details, such as shading devices, aperture size and spacing, glazing materials, and surface reflectance characteristics.[18] In large measure, the art and science of daylighting is not so much how to provide enough daylight, as how to do so without undesirable effects, such as excessive heat gain, brightness, and glare. Daylighting also can contribute to transparency, which increases the connection between occupants and the outdoor environment.

Benefits of Daylighting in Schools

In 1992, an Alberta Department of Education (Canada) study found that students enrolled in schools where daylighting was the principal source of internal light had the following advantages:

- Increased attendance by 3.5 days a year
- Student growth an average of one centimeter more than their peers enrolled in schools operating under electronic light
- Better scholastic performance resulting from more positive moods induced by natural light
- Increased concentration levels and significant reductions in library noise
- One-ninth the rate of tooth decay

[18] Ander, Gregg D. AIA. 1995. *Daylighting Performance and Design.* International Thompson Publishing.

A 1999 study found that PSD students show a 7 percent improvement in test scores in classrooms with the most daylighting, and a 14 - 18 percent improvement for students in classrooms with the largest window areas.[19] A 2003 re-analysis of this study affirmed that daylight has a positive and highly significant association with improved student performance.[20]

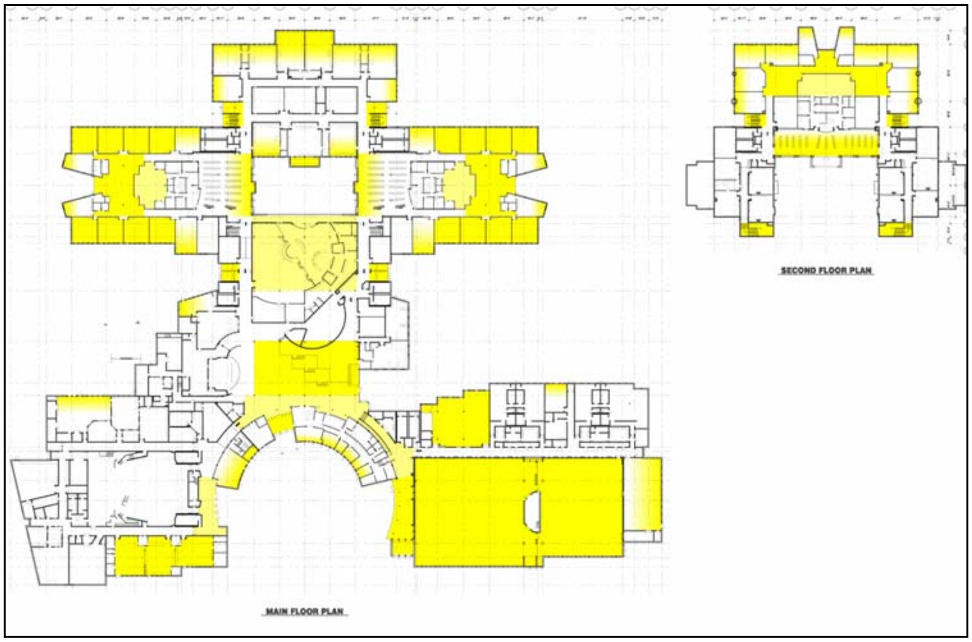
To achieve the best building spaces with maximized productivity at the least cost, the Green Team has identified the following specific sustainable design goals for daylighting systems in PSD schools:

- Select daylighting spaces from the north.
- Strive for uniform daylighting of every space from an exterior wall.
- Where daylighting comes from the south, design for the worst case (December 21) and assume full shading at this point.
- Use supplemental daylight from the north and south, if possible.
- Follow principles of Cool Daylighting™ regardless of orientation.
- If southern exposure daylighting strategies are employed for a building, use strategies (e.g., exterior shading, blinds, lightshelves, wing walls, etc.) to keep out direct light.
- Integrate landscaping with daylighting strategies.
- Employ equally illuminated ceiling planes.
- With the exception of solar tubes, de-emphasize penetrations (e.g., skylights).
- Avoid sloped glazings and motorized blinds.
- Daylight gyms, but allow for darkening capability and control using building automation system (versus local control).
- Maximize transparency of buildings, allowing for views of the outdoors from anywhere in the building.
- Balance contrast ratios

[19] Daylighting in Schools: An Investigation into the Relationship Between Daylighting and Human Performance. Condensed Report, August 20, 1999. Prepared by Heschong Mahone Group, 11626 Fair Oaks Blvd. #302, Fair Oaks, CA 95628. *www.pge.com/pec/daylight/valid4.html*

[20] Summary of Daylighting in Schools: Reanalysis Report. October 2003. Prepared by New Buildings Institute based on research by Heschong Mahone Group. *www.newbuildings.org/pier*

A number of these daylighting strategies were successfully employed at Fossil Ridge High School. As shown in the following figure, significant areas of the building are daylit, including the majority of classrooms and the gymnasium.



Common Pitfalls

Daylighting is challenging to do well. To be successful, daylighting involves a systems approach to design. There are many examples of buildings where good intentions but limited expertise or lack of communication resulted in less than desirable outcomes. Some common pitfalls to avoid are listed below:[21]

- Add-on approaches: Attempts to add daylighting to a building that is already largely designed are usually not successful – economically, aesthetically, or functionally.

- Too much direct sun: Direct sun is unpleasant in many settings because of excessive light levels, glare, and heat.

- Too much light: Even when direct sun is excluded, daylighting can provide too much light. This happens when apertures are too large and/or the visible transmittance of glazing is too high. It makes it hard for people to see and can reduce productivity.

- Poorly balanced light: If daylight illuminates only parts of a space adequately, and electric lighting is poorly integrated, parts of the space will appear too bright and other parts will look underlit and gloomy in contrast.

- Dark-colored interior surfaces: Dark-colored interior finishes reduce the amount of reflected light, thereby wasting daylighting potential.

[21] Harmony Library web-site. *www.light-power.org/harmonylib/ lev3/daylighting/fr3pitfalls.html.*

- Uncontrolled electric lighting: If electric lighting is left on, even when daylighting provides sufficient illumination, there will be no energy savings and the lighting will produce unnecessary heat that the cooling system must remove.

- Too much solar heat: Daylight can bring solar heat with it, adding to the demands on the cooling system and increasing energy bills rather than decreasing them. Problems can result from poor placement (east- and west-facing glass, horizontal glass, and glass set at an angle), lack of shading, or poor choice of glass type.

- Too much contrast between windows and the adjacent wall(s).

Tips for Daylighting

The Harmony Library web site (see footnote 21), as well as other resources referenced in Chapter 4, provides numerous tips and design details for overcoming these pitfalls. Some of the main strategies are outlined here:

- Work with diffuse light from the sky rather than direct sunlight.

- Design for all seasons and times of day. This requires understanding the sun's path and how the energy puzzle varies throughout the year.

- Bring light deep into the building.

- Provide multiple sources of daylight, preferably from at least two sides of every space, to reduce glare and shadowing problems.

- Distribute the daylight by directing it toward ceilings, walls, and floors for gentler and more diffuse light with fewer shadows.

- Use light-colored interior surfaces to reflect daylight and brighten the space.

- Use vertical glass, facing north or south, for best results with daylighting and keeping solar heat out of the building.

Daylighting and Visual Comfort

Visual comfort results from a well-designed, well-integrated combination of daylighting and electric lighting systems. For both students and teachers, performing visual tasks is a central component of the learning process. Students spend much of their day engaged in visual tasks – writing; reading printed material; reading from visual display terminals; or reading from blackboards, whiteboards, and overheads. Furthermore, they must constantly adjust their vision from heads-up to heads-down positions and back again. Inadequate lighting and/or glare can seriously impact a student's ability to learn. A high performance school should provide a rich visual environment – one that enhances rather than hinders learning and teaching. These environments are achieved by carefully integrating nature and artificial lighting strategies, by balancing the quantity and quality of light in each room, and by controlling or eliminating glare. A comfortable, productive visual environment is one that takes into account more than simply the amount of light hitting the desktop.[22]

Visual Comfort Strategies

1. Integrate natural and artificial lighting strategies

    - Take the amount of daylight entering a room into account when designing and sizing the artificial lighting system for that room.

    - Provide controls that turn off lights when sufficient daylight exists.

2. Balance the quantity and quality of light in each room

    - Avoid excessively high horizontal light levels.

    - Design for uniformity with flexibility.

    - Develop individual lighting strategies for individual rooms or room types (e.g., classrooms, hallways, cafeterias, libraries, etc.). Avoid one-size-fits-all approaches.

3. Control or eliminate glare

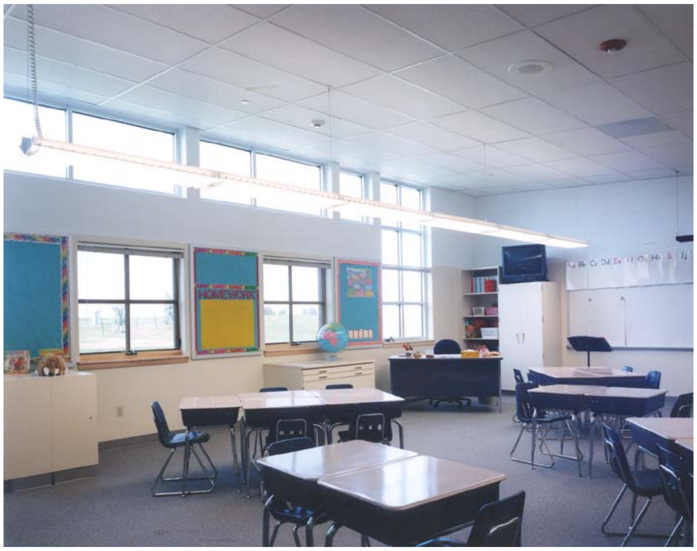
    - Consider how light sources in a room will impact work surfaces.

    - As methods of control, consider increasing the brightness of surrounding surfaces, decreasing the brightness of light sources, or both.

    - Consider interior (shades, louvers, blinds) or exterior (overhangs, trees) strategies for filtering daylight and controlling glare from sunlight.

[22] Sustainable Building Industry Council. *High Performance School Buildings*.

Case Study: Zach Elementary School Daylighting
Information provided by the Lighting Center of New York



Zach Elementary School opened in 2002 and features classrooms designed around daylighting principles. Classroom daylighting technology includes:

- Roof-mounted photosensors
- Tinted view and clerestory windows
- External overhangs providing shade on the south clerestory windows
- Perforated roller shades on south view windows
- Venetian blinds on select windows
- Sloped ceilings to increase reflectivity

Lighting for each classroom consists of a bank of windows on one wall and, parallel to this wall, four rows of OSI T8/841 lamps. These lamps contain perforated metal reflector wings that direct uplight to the ceiling. The lamps are operated by a two-stage photosensor control and two switches, allowing for bi-level control of each fixture. One switch operates the manual lamp rows; the other switch operates the photo-controlled lamp rows. The photosensors will turn off the exterior row upon sensing an adequate amount of daylight and the interior row as daylight increases.

Monitoring and human factors studies of the daylighting system at Zach Elementary were completed by third-party organizations in 2004. A number of interesting findings were noted:

- Operator behavior is an extremely significant factor in determining the magnitude of energy savings.
- Eighty percent of interviewed teachers stated that the system provided sufficient light and reacted appropriately to changes in weather.
- Seventy percent of interviewed teachers stated that the lighting levels were appropriate for white board use.
- Eighty percent of surveyed students found the room windows comfortable to look at.
- Seventy percent of surveyed students never found the room to be too dark or too light.
- Fifty-five percent of surveyed students found the lighting to be better than other schools.

3.3.2 Electric Lighting

> ***"Efficient lighting is not just a free lunch; it's a lunch you are paid to eat."***
>
> ***AMORY LOVINS, CO-FOUNDER OF RMI, 1987***

Electric lighting directly accounts for approximately 20 to 25 percent of the total electrical energy used in the United States. Lighting also has an indirect impact on total energy use because the heat generated by electric fixtures alters the loads imposed on mechanical equipment. During the cooling season, reduced electric lighting loads also lower air conditioning energy use. [23]

More importantly, electric lighting affects the quality of the building spaces and the productivity of its occupants. It has the potential to enhance or detract from the goal of a superior learning environment. Lighting design is the starting point; skillfully done it can enhance quality while reducing lighting power density. Energy efficient lighting equipment is the second, companion strategy that can lower connected load and energy use still further.

Some primary strategies for designing electric lighting systems are included below: [24]

- Carefully define the required lighting.
- Put the right amount of light where it is needed, when it is needed.
- Avoid glare.
- Light the ceiling and walls.
- Blend electric lighting and daylighting with proper orientation of fixtures and selection of color temperatures nearest to daylight.
- Eliminate lighting flicker and noise.
- Provide good color rendition.
- Simplify controls.

Additionally, the Green Team has further identified the following sustainable design attributes for lighting systems in PSD schools:

- Standardize when possible (including lamps, ballasts and controls).
- Consider ease of maintenance (including fixture locations and access, fixture cleaning requirements, and re-lamping efforts).
- Maximize potential of proven technologies.

[23] *www.uofs.edu/admin/greenlight.html.*
[24] See the Harmony Library web-site for descriptions of technologies and resources for further assistance: *www.light-power.org/harmonylib/lev2/strategies/ fr2strategieselectriclighting.html.*

Implementing these strategies requires up-to-date lighting design skills and knowledge of available energy efficient lighting equipment and its performance. There are numerous resources available to assist with equipment selection (see footnote 27). Sustainable lighting also should include careful consideration of outdoor lighting from the standpoint of visibility, energy use, and light trespass and pollution.[25]

Finally, it is important to emphasize that commissioning lighting systems, particularly controls, as well as educating occupants, becomes very important in obtaining the maximum energy benefits.

Case Study: Efficient Electrical Lighting

Information provided by Clanton & Associates, Inc., Boulder, Colorado

To achieve high performance, classrooms must successfully integrate daylighting with efficient electric lighting and fenestration controls. Southern California Edison (SCE) is demonstrating the latest high performance practices at its demonstration classroom of the Customer Technology Application Center in Irwindale, California.

The SCE demonstration is a 960 foot^2 classroom with an 11-foot ceiling. The classroom's window wall faces south. The north interior area has three solar tubes.

The classroom demonstrates two energy-efficient electric lighting systems:

(1) Super T8 configuration with an open-loop photo sensor

- Two 20-foot semi-indirect luminaries suspended in 2 rows of 5 lamps each
- Luminaries that employ 2 high-lumen T8 lamps powered from high-ballast-factor electronic ballasts
- Whiteboard task light: 12-foot-long linear wall washer with 3 Super T8 lamps
- Average illuminance: 45 footcandles

(2) T5 high output configuration with a closed-loop photo sensor

- Two 20-foot direct/indirect luminaries suspended in 2 rows of 5 lamp each
- Luminaries employ 1 high-lumen T5 HO lamp powered from high-ballast-factor electronic dimming ballast
- Whiteboard task light: 12-foot-long linear wall washer with 3 Super T8 lamps
- Average illuminance: 33 footcandles

The second system proved to have the simplest controls, use less energy, and require the least number of lamps and ballasts (important for maintenance).

[25] See *www.darksky.org.*

3.4 Energy Efficient Building Shell

> ***The building envelope isn't a barrier, but a selective pathway that takes advantage of natural energy flows.***
>
> ***GREG FRANTA, ENSAR***

The building's shell consists of exterior walls, roof, foundation, doors, windows, skylights, dampers, and other openings. The objectives for a well-designed building shell are described below:

- Minimize infiltration (both outside air leaking in and conditioned air leaking out) to reduce convective heat transfer through the building shell.
- Minimize conductive heat transfer and thermal bridging (e.g., through steel studs).
- Control humidity by maintaining proper movement of water vapor in and out of the building.
- Design and construct a continuous air barrier.
- Seal penetrations, windows, and roof-ceiling-wall intersections.
- Seal gaps between windows and walls.
- Control sunlight to reduce HVAC loads and electric lighting needs.

Strategies for meeting these objectives typically include adding insulation to walls, floors, and roofs; upgrading windows or treatments; construction of a continuous air barrier shell-tightening measures to reduce air infiltration and exfiltration.

Building Shell:

- ✓ Use infrared imaging to identify issues (e.g., thermal leaks, window sealing, etc.) during construction and allow for corrective measures.
- ✓ Bring contractor and subcontractors up to speed on quality control for installing systems during construction.
- ✓ Include the building envelope in the commissioning scope.

Glazing

Design aspects related to glazing — placement, area, shading, types of glass — provide large opportunities to enhance architecture, daylighting, view, heating and cooling, and comfort. Good choices in these areas are critical to a successful building.[26][27]

There have been great advances in high performance glass options over the past two decades that should be investigated during design. Glass with specific properties (u-value, solar-heat gain coefficient, visible transmittance) should be selected for specific applications in order to balance desired outcomes with undesired outcomes (e.g., conductive heat transfer, solar gains, daylighting, and radiant comfort). This may mean selecting different glazing for different faces of the building to account for solar orientation. This becomes very important in Colorado's climate because unwanted solar gains can significantly contribute to cooling loads. The material used for the glazing frame also is important (e.g. the R-value for wood is higher than aluminum, etc.).

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[26] American Institute of Architects, 1997. Glazing Design: Handbook for Energy Efficiency. 800-242-3837.
[27] *www.light-power.org/harmonylig/lev2/strategies/fr2strategiesglass.html*.

High performance glass, on a standalone basis, may not look like a good investment compared with standard insulated glass. But when viewed from a systems standpoint in a well-integrated design, it often becomes the least expensive glazing choice.

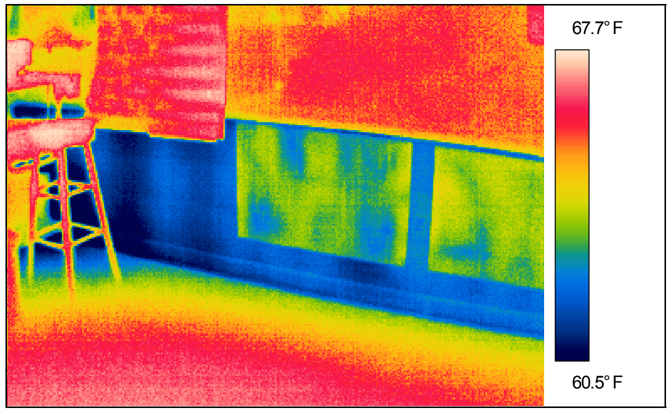
Air Sealing

It is important to find air leaks and concentrate air-sealing efforts on the major sources of air leaks into a building since they can easily account for a large percentage of the air infiltration.

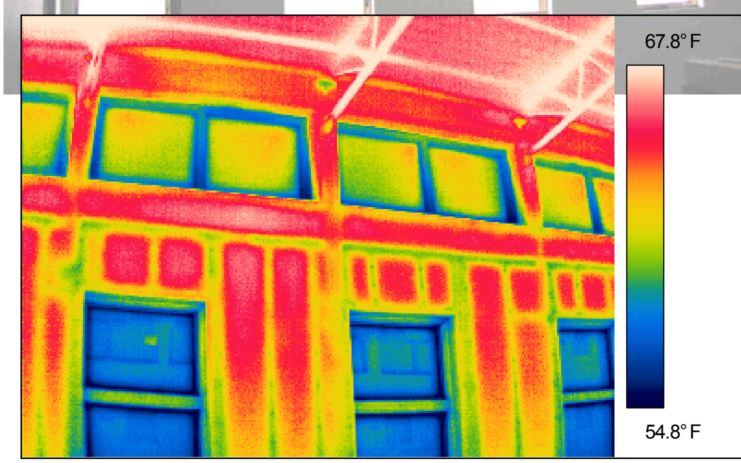
School buildings may use unconditioned ceiling plenum space as the return air path to the heating or cooling system. Routing return air leads to substantial air infiltration since return air plenums are depressurized and will draw in surrounding outside air if not sealed. In these situations, plenum surfaces that have connection paths to the outdoors should be sealed (including areas around pipes and other penetrations) to prevent unnecessary air infiltration. Wall and corrugated roof deck intersections and windows are areas that need particular attention. For flat, unventilated roof spaces, rigid insulation (most cost-effective during new design or a major re-roofing) should be used to maintain return air temperatures, thus saving energy.[28]

Infrared (IR) photos of a building's shell are useful tools. IR photos taken during the construction phase of a project can sometimes help identify and address potential issues. They also inform design and construction of future buildings. The following photos are examples of photos taken during construction at PSD buildings. The first photo is of a Zach Elementary School classroom and depicts an uninsulated concrete wall adjacent to an unconditioned stair well. The second photo shows the IR image, including a temperature gradient graphic, with the wall shaded blue (indicating a cooler temperature).

[28] *www.eren.doe.gov/energysmartschools/elements_shell.html.*



The following photos are of a Fossil Ridge High School art room, indicating interesting effects of the building's steel wall framing, window types, window frames (wood below, aluminum above), and the temperature stratification in the space.



3.5 Energy Efficient HVAC Systems

The sustainable design goal for HVAC systems is to meet occupant comfort needs through the most energy efficient and environmentally sensitive means possible. Although this may sound simple, the HVAC system proves to be a pivotal aspect in the design of a sustainable building. It is pivotal because heating and cooling needs are affected by virtually every other sustainable (or non-sustainable) characteristic of the building. For example, the extent of passive solar design, natural lighting, natural ventilation, insulation and window performance, and even material selection all play a role in the resulting requirements for conditioned air. Therefore, the HVAC system design is a prime example of the importance of integrated, whole building design. In essence, if everything else is done sustainably, the HVAC system should be significantly downsized. Rocky Mountain Institute calls this "tunneling through the cost barrier."[29] With significant downsizing brought about by good whole building design and responsible safety factors, the efficiency of the equipment becomes somewhat less critical. The appropriate HVAC system should therefore be selected only after the entire design team has reviewed the contributing thermal loads of these interrelated systems. One local example occurred during the design of the Value Plastics building in Fort Collins, Colorado. Because of the performance of the glazing selected, the design team was able to eliminate perimeter baseboard heating from the building.

If everything else is done sustainably, the HVAC system should be significantly downsized.

Aside from ensuring proper system size, the Green Team has identified the following sustainable design goals for HVAC systems in PSD schools:

- Simple design
- Easy maintenance
- Minimal number of components
- Energy efficient
- Best life cycle cost (including energy, maintenance, and replacement)
- Configuration that provides optimum air distribution and considers how surfaces affect radiant comfort
- Low noise
- Easy access to equipment (not in classrooms)
- Flexible system for after-hours use
  (e.g., when only certain rooms will be in use)
- Staged chilling/heating

[29] Rocky Mountain Institute. 1998. Green Development: Integrating Ecology and Real Estate. John Wiley & Sons.

HVAC Systems:

- ✓ Right sizing of HVAC equipment is key; avoid oversizing
- ✓ Ease of maintenance using adequately sized closets for geothermal heat pump (versus ceiling mounted units)
- ✓ Consider site influences on HVAC design
- ✓ When considering new technologies, visit existing installations and work with engineering firms familiar with the technologies
- ✓ Consider service life of new and energy-saving technology (e.g., heat wheels, condensing boilers, etc.) and budget for replacement
- ✓ Optimize condensing boiler operations by maintaining the system water at a warm (vs. hot) temperature (e.g., 120°F supply temperature and 90°F return temperature)

As noted earlier, these Sustainable Design Guidelines are not intended to be prescriptive or to state requirements for PSD Schools. However, the Green Team has developed the following list of considerations based upon its process knowledge and the sustainable design goals listed above:

- Traditional computer labs typically need their own independent HVAC systems due to different load requirements and after school use.
- Chilled water should be considered when adding more than 50 tons of cooling to a building.
- Premium efficiency motors should be selected, as defined by the Consortium for Energy Efficiency (CEE), for all motors greater than one horsepower. Consider ECM motors when less than 1 horsepower.
- Consider heat recovery air handlers.
- Avoid HVAC operation during peak electric demand periods using thermal storage or other strategies.

In addition to the guidance from PSD, the Sustainable Building Technical Manual, developed by the U.S. Department of Energy's Center of Excellence for Sustainable Development, offers many practical guidelines for integrating sustainability into HVAC system design:[30]

General Design Guidelines

- Explore non-energy-intensive opportunities that harness natural processes, such as daylighting, natural ventilation, evaporative cooling, thermal mass coupling, and energy recovery systems.
- Recognize that thermal mass can be beneficial in providing a flywheel effect to reduce after-hours environmental conditioning and morning warm-up loads.
- Control the infiltration of unwanted air through sealing leaks and pressurizing the building.
- Consider increased insulation levels to reduce loss factors.
- Use computer-based analysis tools (such as DOE-2.1, ENERGY-10, TRNSYS, and BLAST) to evaluate building load, select equipment, and simulate system performance. Specify equipment that meets the calculations and do not oversize.

[30] The Sustainable Building Technical Manual: available for download from *http://www.sustainable.doe.gov/articles/ptipub.shtml*.

- Design for part-load efficiency and select equipment that remains efficient over a wide range of load conditions.

- Make every attempt to reduce cooling loads by using high performance glazing, overhangs, efficient lighting, etc.

Air Delivery Systems

- Consider using variable-air-volume systems for cooling to reduce energy use during part-load conditions.

- For ducting configurations, emulate displacement ventilation schemes (if supplying air at a high room height, exhaust air at a lower height, or vice versa) to yield better human comfort and improved indoor air quality.

- Reduce duct system pressure losses by using computer-based programs for correct sizing. Strategically locate balancing dampers to improve energy efficiency, and consider using round or flat oval ductwork to reduce energy losses and minimize noise.

- Reduce required fan power through proper duct sizing and good duct layout practices (e.g., minimized number of turns, minimized use of flex duct, etc.).

- Reduce duct leakage and thermal losses by specifying low-leakage sealing methods and good insulation.

- Optimize selection and location of air diffusers to save energy and improve comfort control.

- Use low-face velocity coils and filters to reduce energy loss through components.

- Design equipment and ductwork with smooth internal surfaces to minimize the collection of dust and microbial growth.

Central Equipment

- When selecting chillers, consider high-performance chillers, integrated controls to increase operational flexibility, and open-drive compressors.

- Evaluate a multiple-chiller system with units of varying size.

- Consider absorption cooling, which employs lower cost fuels, such as steam, natural gas, or high-temperature waste heat, to drive the absorption refrigeration process.

- Where simultaneous heating and cooling loads occur, evaluate using heat-recovery chillers.

- Consider thermal energy storage to manage the school's utility use during peak demand (see additional text below).
- Investigate condensing boilers and properly calibrated reset temperatures.
- Consider indirect evaporative and/or evaporative condensing direct expansion (DX) systems.

Energy Efficient HVAC Components

- Use premium efficiency motors (or ECM models for fractional-sized motors) that are properly sized.
- Consider variable-speed drives for reducing energy used by fans, chillers, and pumps under part-load conditions.
- Consider direct-drive equipment options and review actual loss factors on belt- or gear-driven equipment.

Thermal Energy Storage

- Integrate high-performance chillers with thermal ice storage to reduce electrical demand use and costs during the cooling season.
- Reduce chiller size accordingly with thermal ice storage system.
- Fort Collins Utilities' rate structure, including coincident peak demand charges and incentives for peak demand reduction, increases the benefits of thermal storage for PSD.

Water Heating

- Use semi-instantaneous, condensing boilers for more evenly distributed heated water.
- Substitute cartridge pumps designed to match the load for large circulation pumps.
- For smaller buildings, use a central domestic hot water heater with a tempering valve to service both the kitchen and the rest of the building.
- For larger buildings, use two separate water heaters - one dedicated to the kitchen and the second dedicated to the rest of the building.
- Utilize refrigeration heat recovery to heat hot water from walk-in cooler compressors.

3.5.1 Geothermal Heating and Cooling Systems

The popularity of and installations for geothermal heating and cooling systems have increased significantly both nationwide and in Colorado. These systems are known by a variety of names, including ground- or water-source heat pumps, earth-coupled, water-coupled, ground-coupled, geoexchange, etc. In general, PSD is a proponent of geothermal systems, particularly with the success of the system referenced in the case study provided later in this section.

How Geothermal Systems Work

Below the frost line, the earth maintains a relatively constant temperature that is warmer than surface temperatures during winter months and cooler than surface temperatures during summer months. Geothermal heating and cooling systems take advantage of this temperature differential by pumping heat from or to the earth.

Most school installations require one heat pump for every one or two classrooms. The earth connection is either a series of buried pipes (closed loop) or water wells (open loop), often buried beneath parking lots or playing fields.

The U.S. Department of Energy's ESS program offers the following design suggestions for geothermal heat pumps:

- Use closed-loop systems in areas where well water is not present or adequate.
- Use open-loop systems in regions where sub-surface water can be extracted and reinjected into the ground through wells in an environmentally sound manner.
- Conduct a detailed site survey to evaluate the soils and water table of a potential location, and analyze the heat gain and loss to avoid oversizing.
- Specify high-efficiency heat pumps.
- Avoid using excessive amounts of antifreeze.
- Specify thermally fused, high-density polyethylene (HDPE) for all in-ground piping.

Advantages of Geothermal Heating and Cooling Systems

- Lower energy operating costs (up to 25 to 50 percent less than conventional systems) and maintenance costs (up to 30 percent less than conventional systems).
- Potentially lower construction costs because the space required for mechanical equipment is smaller.
- Classroom comfort and user satisfaction from individually controlled units.

- Potentially less indoor air pollutants because there is no combustion of fossil fuels.

- In cooling mode, waste heat can be recovered from the system to heat water.

- Twenty-five to 30 year life expectancy for heat pumps.

- Significant acoustic advantages for classrooms compared to traditional systems (also see Section 3.7.3 on Acoustics).

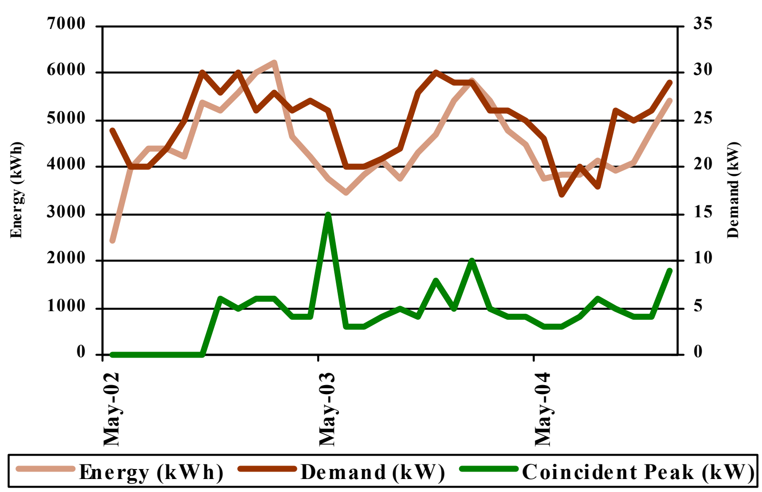
Although more efficient, heat pumps still contribute to peak demand. In some applications it may be worth considering a central heat pump with hot and/or cold thermal storage. The compressor could operate during off-peak periods storing hot and/or cold water which would then be used to satisfy loads without a compressor during peak periods.

Case Study: PSD Operation Services Building Geoexchange System
Information provided by EMC Engineers, Inc., Golden, Colorado and RMH Group, Inc., Lakewood, Colorado

When constructing the Operations Services building, PSD elected to install its first geoexchange system. The following table is the basic defining parameters of the building and the installed system that were determined, in part, using the results of an energy/feasibility study and a load analysis.

Building Footprint	8,900 ft^2
Installed System Capacity	~25 tons
Number of Geoexchange Units	12 heat pumps
Number of Geoexchange Boreholes	15
Individual Borehole Depth	300 feet
Total Feet of Boreholes	4,500 feet

The Energy Star score for the building is 97 due, in large part, to the geoexchange system. Compared to a building with an ENERGY STAR score of 75, the energy intensity (kBtu/ft^2-yr) is nearly 50 percent less, CO_2 emissions are reduced by just over 270 thousand pounds/yr, and cost savings are approximately $3,100/yr. The building's energy use for May 2002 to December 2004 is shown below.



The utility data reflect two key characteristics of geoexchange systems:

- Although some seasonal fluctuation does occur, the system results in generally consistent energy use.
- Operational costs typically vary only 1 to 2 percent from year to year (compared to variations of traditional HVAC systems that can be 10 to 20 percent).

3.6 Building Controls Systems

Controls Systems:

- ✓ Use occupancy sensors with both daylighting controls system and unit air terminals in high school classrooms to take advantage of unoccupied periods.
- ✓ Be judicious with design and location of occupancy sensors.
- ✓ Include manual overrides on lighting controls.
- ✓ Involve controls contractor during design to help streamline the typical hurdles between design and implementation.
- ✓ Consider monitoring and verification of daylighting controls as part of the commissioning process.
- ✓ Continue to standardize controls equipment and optimize integration with HVAC (e.g., variable speed drives, chillers, etc.)

To ensure proper, energy-efficient, and optimized operation, control strategies tied to key energy systems are essential. Key energy systems to be controlled include both mechanical and lighting systems, (including daylighting).

A key PSD controls-related energy saving strategy is participation in Fort Collins Utilities Hot Shot Program. This program was started in the 1980s by the Utility as a residential electric water heater program. The utility sends out a signal to the program participants when peak electric loads are anticipated to allow them to initiate load-shedding procedures. About 10 commercial subscribers participate in the program. The utility supplies PSD with a control box that is triggered by a radio signal. For PSD, this signal is incorporated into the building automation system for the new schools. For older buildings, the district has a procedure through the Customer Support Center to notify key personnel when the signal is received. With this notification, manual load shedding procedures are initiated to avoid peak load charges.

Mechanical Controls

Effective controls are integral to efficient HVAC operations. PSD will continue to use Energy Management System (EMS) for controls, ensuring all applicable equipment is compatible with and controlled by the EMS. Specific strategies include the following:

- Use direct digital control (DDC) systems to offer greater accuracy, flexibility, and operator interface (compared to pneumatic systems).
- Integrate micro switches of operable windows with HVAC operation.
- Integrate occupancy sensors with HVAC operation.
- Consider demand controlled ventilation using carbon dioxide sensors in applicable areas.

Lighting Controls

Effective lighting controls are key to maximizing and integrating daylighting and high-efficiency electric lighting. Guidelines for using controls to integrate both strategies are outlined below:

- Consider the electrical lighting as supplemental to natural light (daylighting) by implementing a complimentary fixture layout and control wiring plan.
- Install controls that dim or turn lights off at times when daylight is sufficient.
- Consider photoelectric controls that are sensitive to levels of daylight.

- Provide manual override switches for daylighting controls only where the need to manually control lighting levels is necessary (i.e., overhead projection).

Other general lighting controls considerations include the following:

- Use occupancy sensors, either infrared (heat detection), ultrasonic (movement detection), or a combination of both, to control lighting in areas that are intermittently occupied (i.e., rest rooms, storage areas, classrooms, etc.).
- Mount sensors in a location that accurately detects light levels representative of the occupants' work surface.
- Implement photocells on exterior lights to ensure they only operate during non-daylight hours.
- Consider incorporating lighting controls into the facility's overall energy management system, as appropriate.

3.7 Indoor Environmental Quality

The average American spends 80 to 90 percent of his or her time indoors. Obviously then, the quality of the indoor environment has a significant influence on the health and productivity of a school's occupants. Indoor environmental considerations enter every step of the design and construction process and often are far less expensive to address through prevention. The topics of indoor environmental quality (IEQ) can range from indoor air quality to acoustics. The following topics related to IEQ are addressed in this section:

- Environmentally preferable building materials
- Indoor air quality
- Acoustics
- Total moisture control
- Construction indoor air quality
- Transparency and local control

3.7.1 Environmentally Preferable Building Materials

Environmentally preferable materials are defined as those materials that have a lesser impact on human health and the environment when compared to products serving the same purpose.[31] Not only do environmentally preferable materials help to improve indoor air quality in schools, they are more ecologically sensitive when analyzed over their entire life cycle. This cradle-to-grave analysis is the tracing of a material from its initial source availability and extraction, through refinement, fabrication, treatment, transportation, use, and eventual reuse or disposal.

As part of its sustainable design philosophy, PSD intends to use environmentally preferable building materials to the maximum extent possible. However, this can be a complex aspect of sustainable design considering the vast number of products available that are claimed to be green, as well as the numerous factors for comparing products on an environmental basis. Using environmentally preferable products requires both a prioritization scheme for comparing products, as well as time to research specific products, their function, cost, and local availability.

Evaluation Criteria for Comparing Products

The following table from the City of Fort Collins Facility Design Standards summarizes factors for choosing building products and materials:[32]

Energy Efficiency	• Energy efficient production methods • Use of renewable energy sources
Resource Responsibility	• Minimal need for other materials • Low maintenance • Durability • Efficient use of material • Recycled content • Recyclable
Social/Public Health	• No harmful chemicals in production • Reduced off-gassing • No harmful chemicals in disposal and reuse
Economics/Functionality	• Initial cost • Cost savings and payback • Availability • Acceptability
Supplier or Manufacturer	• Local supplier • Local economic benefit • Suppliers with in-house environmental programs

[31] EPA Environmentally Preferable Purchasing Guidelines.
[32] City of Fort Collins. City of Fort Collins Facility Design Standards. Prepared by Facilities Division.

IEQ

- ✓ Low volatile organic carbon (VOC) cleaning products can be effective, but are more costly.
- ✓ Response to indoor air quality concerns/ complaints should be taken seriously and promptly.
- ✓ Scheduled maintenance of HVAC systems is important to ensure systems operate as designed and that filters are changed out .
- ✓ Roof inspections are important to monitor roof condition and to minimize potential water intrusion.
- ✓ Awareness by staff at buildings to report any water leaks or suspect sources that may compromise air quality.

When selecting products, it is important to consider the following facts:

- **Natural materials** are generally less energy intensive, less polluting to produce, and contribute less to indoor air pollution than synthetic materials.

- **Local materials** have less energy cost and air pollution associated with their transportation and can help sustain a local economy.

- **Durable materials** can save on maintenance costs, as well as installation of replacement products.

It is also helpful to prioritize products by origin, taking care to avoid materials from nonrenewable sources.

- **Primary Materials -** those found in nature, such as stone, earth, flora (hemp, jute, reed, wool), cotton, and wood.

  - Ensure new lumber is from certified sustainably managed forests or certified naturally felled trees.
  - Use caution that treatments, additives, or adhesives do not contain toxins or off-gas volatile organic compounds (VOCs).

- **Secondary Materials -** those made from recycled products, such as wood, aluminum, cellulose, and plastics.

  - Verify that production does not involve high levels of energy, pollution, or waste.
  - Verify functional efficiency and safety of salvaged materials.
  - Consider the composition of recycled products since toxins may still be present.
  - Consider cellulose insulation.
  - Specify aluminum from recycled material; it uses 80 percent less energy to produce over initial production.
  - Keep alert for new developments; new recycled goods are coming on the market every week.

- **Tertiary Materials -** manufactured materials (artificial, synthetic, nonrenewable) having varying degrees of environmental impact.

  - Avoid using materials containing or produced with chlorofluorocarbons or hydro chlorofluorocarbons that deteriorate the ozone layer.
  - Avoid materials that off-gas VOCs.
  - Minimize using products made from new aluminum or other materials that are resource disruptive during extraction and a high-energy consumer during refinement.

Another method for comparing products is using information available from Green Seal. Green Seal is an independent, non-profit organization that strives to achieve a healthier and cleaner environment by identifying and promoting products and services that cause less toxic pollution and waste, conserve resources and habitats, and minimize global warming and ozone depletion. Green Seal has no financial interest in the products that it certifies or recommends nor in any manufacturer or company. Green Seal's evaluations are based on state-of-the-art science and information using internationally recognized methods and procedures. Thus, Green Seal provides credible, objective, and unbiased information whose only purpose is to direct the purchaser to environmentally responsible products and services. Various organizations, including LEED™, use and recommend Green Seal as a resource for product information. Green Seal information can be accessed at www.greenseal.org.

Case Study: Environmentally Preferable Building Materials at Bacon Elementary School

PSD's second prototype elementary school, Bacon Elementary, included approximately 40 different types of environmentally preferable building materials in its construction. A partial list of the materials and their sustainable quality are given in the table below.

Material	**Sustainable Quality**
Gravel pave	Reinforced, stabilized, porous pavement. Water permeates the soil at a more natural rate.
Rye grass wall panels	A substitute for wood.
Brick and block	Recyclable, made locally from natural materials.
Laminated plastic for countertops	Contains filler paper from non-rainforest timber and water-based resins.
White roofing	Reflective to minimize heat gain.
Rubber floor	Made of 80 percent recycled material from tires.
Plastic toilet compartments	Contain recycled products.
Natural cork	Natural, no vinyl.
Relocateable casework	Reduces cost of future remodels caused by moving classes/grades.
Metal corner guards	Made of scraps from wall panels.
Furniture - computer desks	Recycled content: steel 20 percent, cartons 50 percent, upholstery 40 percent, wood

3.7.2 Indoor Air Quality

Why IAQ is Important to Schools

Environmental Protection Agency (EPA) studies of human exposure to air pollutants indicate that indoor levels of pollutants may be 2 to 5 times, and occasionally more than 100 times, higher than outdoor levels. These levels of indoor air pollutants are of particular concern because it is estimated that most people spend approximately 90 percent of their time indoors. Comparative risk studies performed by the EPA and its Science Advisory Board have consistently ranked indoor air pollution among the top four environmental risks to the public.

> ***"We know that fresh air, proper circulation, and managing humidity is important in our homes. Why should we think it wouldn't also be true in a school?"***
>
> ***CAROL BROWNER-FORMER EPA ADMINISTRATOR***

Being proactive and working to prevent indoor air problems helps to achieve the following advantages for PSD and for school occupants:

- Decreased chances for long-term and short-term health problems for students and staff
- Enhanced student learning environment, student and staff comfort, and student attendance
- Increased teacher and staff productivity by reduced discomfort, sickness, or absenteeism
- Slower deterioration and increased efficiency of the school physical plant and equipment
- Decreased potential that schools will have to be closed or occupants temporarily moved
- Enhanced relationships among school administrators, parents, and staff
- Positive publicity that could enhance a school's or administration's image and effectiveness
- Reduced potential liability problems

Indoor air problems can be subtle and do not always produce easily recognized impacts on health, well-being, or the physical plant. Children are especially susceptible to air pollution. For these reasons, as well as those noted above, air quality in schools is of particular importance. Properly maintaining indoor air is more than a quality issue; it includes safety and good management of PSD's investment in the students, staff, and facilities.[33]

[33] *www.epa.gov/iaq/schools.*

Chemicals, Sources to Avoid

Listed below are some of the most common substances that should be avoided, as well as their reactions.

- ***Benzene*** found in synthetic fibers and plastics: highly toxic to red blood cells
- ***Acetone*** found in masonry, caulking, wall coverings, strippers, adhesives, polyurethane, stains and sealers: flammable and strong odor
- ***Toluene*** found in adhesives, paint remover, paint: flammable and may cause lung damage
- ***Dichloromethane*** found in solvent in paint remover and adhesive paint aerosols: may cause cancer, heart attacks; a known water pollutant
- ***Ethylene glycol*** found in solvent in latex paint: may cause damage to blood and bone morrow
- ***DEHP*** found in plasticizer used in wall covering and floor covering to keep vinyl flexible: known carcinogen
- ***Dioxin*** found in PVC products: very toxic; low levels cause cancer; disrupts endocrine functioning
- ***Formaldehyde*** found in plywood, particleboard, adhesives, fabric finishes, and carpet padding: known carcinogen; may cause allergic reactions or asthma attacks
- ***4-PC,*** the natural result of binding latex to carpet: may cause allergic reactions

Case Study: Environmentally Preferable Cleaning Products Used by PSD

Cleaning programs that minimize the use of toxic materials help to maintain good indoor air quality in school buildings. PSD has experimented with various cleaning products that have very low or no VOCs. These products have proven to be as effective and cost competitive as traditional cleaning products. Example products used by PSD include:

- Soy-based floor stripper
- Citrus/peroxide cleaners
  (used for multipurpose cleaning, everyday mopping, spot cleaner, windows, etc.)
- Water-based gym seals (for leaks)

Options for environmentally preferable cleaning products are continually expanding. For example, PSD is currently researching the use and availability of environmentally preferable disinfectants.

3.7.3 Total Moisture Control

The idea behind total moisture control is to look at the building as an integrated whole, from the top of the roof to the subgrade and drainage, with attention to mechanical systems used, building materials, and hidden construction assemblies, as well as the building envelope.

Some key elements of total moisture control are given below:

- Make the building envelope as seamless as possible, with details and fenestration mechanically flashed in such a way that gravity drains water away. Designers should consider the worst-case scenario of wind-driven rain or heavy snow. In addition, designs should not rely heavily on sealants that inevitably degrade, leak, and become a constant maintenance issue.

- Ensure that inner construction assemblies provide drainage planes or other avenues for any water that does penetrate the envelope to have an unobstructed path back to the outside. Often this involves good construction methods as much as materials. For example, drilling weep holes afterward rather than during masonry assembly could penetrate the vapor barrier.

- Positively drain the landscaping away from the building and do not install irrigation that will spray water on the building or too close to the perimeter.

- Include a strategy for draining excess sub-surface water away from the foundation perimeter. Also include a barrier to prevent sub-slab moisture from penetrating and being drawn into the building due to negative pressure.

- The dynamics of building operation create other opportunities for moisture penetration.

- Give careful attention to the building ventilation, air supply, and exhaust to avoid causing infiltration from such places as building parapets, unsealed wall cavities or floor decks, and unsealed ceiling plenums. Building pressurization helps but can be difficult to achieve due to thermal air movements, wind pressure, and other factors. Building controls need to manage humidity and avoid over-cooling or over-drying that will tend to drive the infiltration of warm, humid air from the outside.

- Consider building assemblies not just for their resistance to moisture penetration but also because of their capacity to hold moisture, their natural resistance to fungi and bacterial growth, and their ability to release held moisture.

- Because buildings do get wet, consider the drying process.

- Certain areas, such as showers, restrooms, art rooms, and kitchens, can generate significant humidity. Warm humid air will migrate toward any colder surfaces where it will condense. Appropriate insulation and ventilation in these areas should prevent this condensation. Designs also should include insulation on cold water pipes to prevent condensation.

3.7.4 Construction Indoor Air Quality

The construction process is traditionally an indoor air polluting activity and often contaminates the building during construction, as well as after the building is occupied. HVAC systems are especially prone to contamination from construction particulate matter that contains dust, VOCs, microorganisms, and other contaminants. The contaminants can remain in HVAC systems for years and have adverse effects on the health of building occupants. Strategies can be instituted during construction and before occupancy to minimize construction contamination and to mitigate any contamination that has occurred.

Construction projects for PSD must achieve the two LEED™ credits related to construction indoor air quality. The two credits involve developing and implementing an IAQ management plant for the construction and post-occupancy phases of the building. Details on achieving these credits are provided by the U.S. Green Building Council at www.usgbc.com.

3.7.5 Acoustics

The negative effects of excessive classroom noise and reverberation on learning have been well documented. The American Speech-Language-Hearing Association published guidelines for optimal acoustics in learning environments in 1995. And as early as 1950, Knudsen and Harris stated that unoccupied noise levels should not exceed 35 decibels (dBA), "in classrooms in which a quiet environment is especially desirable and 40 dBA in ordinary classrooms." Current terminology refers to these enclosures as core learning spaces and ancillary learning spaces respectively. Noise levels greater than 35 to 40 dBA interfere with receptive communication primarily by acoustically masking the phonemes of speech. Sources of noise may be intrinsic to the classroom, such as HVAC

systems, noisy light fixtures, etc, or may be extrinsic in nature, such as noise from adjacent classrooms or even highway/airport noise.
The deleterious effects of background noise are exacerbated by excessive classroom reverberation times. Indeed, noise and reverberation appear to act synergistically to reduce speech intelligibility. Reverberation compromises receptive communication via temporal masking, creating a smearing of the speech signal over time. In a highly reverberant environment, speech sounds do not decay rapidly enough for accurate perception of subsequent speech sounds.

Poor classroom acoustics impact a wide range of learners. Not only are students with hearing impairment negatively affected, but second language learners, students with attention deficit disorder (ADD)/attention deficit hyperactivity disorder (ADHD), students with learning disabilities, and those with other learning challenges find classrooms with poor acoustics to be particularly difficult learning environments. In addition, young children (pre-school and kindergarten age) who are still developing the foundations of receptive and expressive speech are particularly vulnerable to the negative effects of compromised classroom acoustics. There is a higher incidence of vocal strain among teachers in these environments as well.

In response to parent/professional requests, the Acoustical Society of America, under the auspices of the American National Standards Institute (ANSI), developed standards for noise and reverberation in core and ancillary learning spaces. The standards were submitted and approved by ANSI as ANSI S12.6-2002 “Acoustical Performance Criteria, Design Requirements and Guidelines for Schools.” This is the first such standard for classroom acoustics in American history. The complete document is available through the Acoustical Society of America. However, the standards for core learning spaces are summarized below:

Core Learning Space	Reverberation	Noise level (dB)
Vol. up to 20,000 cubic ft.	35 dBA	.6-.7 seconds

*Please see ANSI S12.6-2002 for the complete standard.

Expertise is available within PSD to incorporate appropriate predictive metrics during the design phases of construction, as well as to appropriately measure the acoustical properties of existing enclosures according to the ANSI standard.

PSD has demonstrated itself as a leader in all aspects of educational facility design and construction, and has voluntarily elected to adopt the ANSI S12.6-2002 standard for future construction and building renovation projects. By adopting this standard, PSD continues to strive to provide optimal learning environments for all learners, in all settings, at all times.

3.8 Water Conservation

> ***"When the well is dry, we know the worth of water."***
>
> ***BENJAMIN FRANKLIN- STATESMAN & SCIENTIST 1790***

Water is a precious resource that should be used efficiently indoors and out. Conserving water in schools saves money, but the ramifications of water efficiency go far beyond lower water bills. For example, at the community level it can help to eliminate or defer the need for more dams, treatment facilities, and expensive water rights. Water treatment consumes a great amount of energy. A large percentage of the treated water ends up being flushed in toilets and used to water landscaping. Whenever water can be saved, so can energy. And the energy savings often financially dwarf the water savings. Installing water-efficient appliances and fixtures, using drought resistant plants in landscaping, and changing irrigation practices can reduce water consumption by 30 percent or more.

In order to conserve both water and energy to the extent possible, PSD applies the following steps to the sustainable design process:

1. Minimize the amount of water required to operate the school both indoors and outside.

2. Evaluate the various water uses, distinguishing those that can be performed using raw (untreated) water versus those requiring treated water.

3. Evaluate methods for providing the required raw water supply using on-site resources.

> ***Indoor Water Conservation Strategies***
>
> ***1. Low-flow end-use fixtures (toilets, aerators, and showerheads.***
>
> ***2. Waterless urinals***
>
> ***3. Infrared controls for end-use fixtures.***
>
> 4. Air-cooled (vs. water-cooled) equipment

For Step 3, example methods include harvesting rainwater, collecting and treating storm water runoff via constructed wetlands, and on-site biological wastewater treatment systems. These features are included in case studies of sustainable schools. However, none would be feasible for PSD because of Colorado water rights laws and code restrictions for on-site wastewater treatment. Therefore, the emphasis for PSD should be on water conservation through landscape design and efficient fixtures within school buildings.

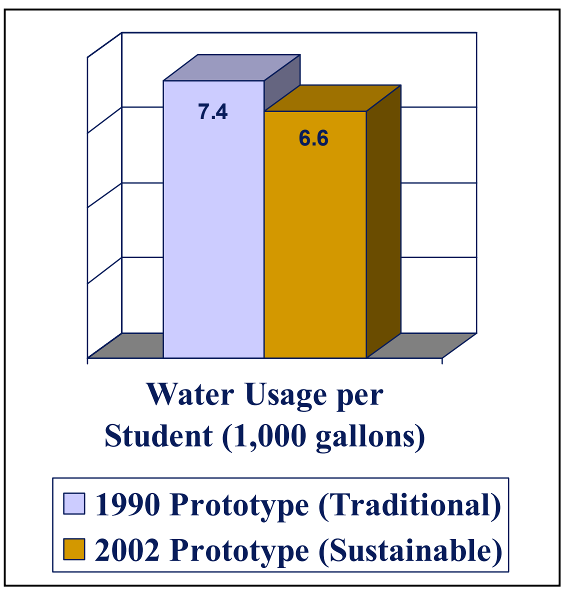
Water-efficient Landscaping

Efficiently using water should be a primary concern in the developing a landscaping plan for a sustainable school. Properly selecting plants, irrigation equipment, and irrigation scheduling can dramatically reduce water waste. Outdoor water use varies widely from place to place and climate to climate, but on average, 50 percent of water use occurs outside. There is a tremendous opportunity to conserve water through appropriate landscaping design, operation, and maintenance.

Several ways to cut down on outdoor water waste in landscaping are outlined below:

- Design to prevent water from running off the property.
- Consider using grasses, trees, bushes, and shrubs that require less water (e.g., wheat grass or buffalo grass instead of bluegrass), with attention to durability and wear.
- Install drip irrigation systems to water trees, shrubs, and bushes.
- Program automatic sprinkler systems correctly to maximize irrigation systems.
- Install and connect buried moisture sensors to irrigation timers to deliver the right amount of water to the root zone and to shut off irrigation systems during rain.
- Preserve natural landscaping during construction.
- Design zone planting for efficient irrigation.

The following graph comparing water usage of PSD's sustainable design elementary schools and traditional design elementary schools displays the water usage benefit of water conservation techniques and the overall sustainable design process. (Note that the data shown in this figure is for schools that do not have access to raw water for irrigation.)



3.9 Safety and Security

Safety and Security:

- ✓ Do not overlook the safety and security aspects of an integrated design.

At first glance, the link between security and sustainability may not be readily apparent. But when you consider that sustainability includes social as well as the economic and environmental aspects, the link becomes a bit more clear. First and foremost, school buildings need to provide a safe and secure environment for students and teachers. Safety includes direct aspects of sustainability, such as healthy building materials and fresh clean indoor air covered elsewhere in these guidelines. But safety also includes providing a secure building that is less susceptible to crime and vandalism.

A sustainable school can and should provide safety and security by incorporating the following design strategies during project development:

- Optimize opportunities for natural surveillance.
- Reinforce a sense of territoriality.
- Control access.
- Employ technology that complements and enhances, rather than substitutes for, security-focused design features.

Crime and vandalism — and the fear they foster — are problems facing school populations throughout the United States. While better buildings alone cannot solve these problems, they can be powerful factors in helping reduce crime and other antisocial behavior. Thoughtful design that builds on basic "Crime Prevention through Environmental Design" principles is the key.

Security-based design strategies will influence a school's basic layout and site plan. If properly integrated from the beginning of the development process, these influences will complement and enhance other sustainable design strategies used in the facility. For example, daylit classrooms can share their natural light with adjacent corridors through windows or glass doors provided primariliy for surveillance purposes. This free natural light can, in turn, be used to offset the need for electrical lighting in the corridors. Security technology strategies will not strongly impact other systems in the school unless they are incorporated into a comprehensive automated control system for the whole facility.

Security and Safety Checklist

Increase opportunities for natural surveillance

- Design landscaping to minimize places that are hidden from view. Ensure that key area, such as parking, bicycle storage, drop-off points, play equipment, entries, are easily observable from inside the building.
- Design exterior lighting to facilitate nighttime surveillance by community residents.

- Consider providing views through glazed doors or windows from classrooms into circulation corridors.

- Minimize areas within the building that are hidden from view.

- Consider open stairwells.

Reinforce a sense of territoriality

- Foster a sense of ownership of the school for students and teachers by clearly defining borders — what is part of the school and what is not.

- Consider decorative fencing and special paving treatments to delineate the boundaries of the school grounds.

- Consider designing common areas, particularly corridors, so that they are less institutional and more room-like.

Design for easy maintenance

- Consider graffiti-resistant materials and finishes.

Control access to buildings and grounds

- Consider decorative fencing to control access to school grounds.

- Limit the number of entries to the building. Allow visual surveillance of all entries from inside the school.

- Provide the capability to lock down parts of the school when the facility is used for after-hours activities.

Integrate security technology

- Consider incorporating interior and exterior surveillance cameras.

- Ensure that all high-risk areas (office, cafeteria, shops, labs, etc.) are protected by high security locks.

- Consider other security technologies as appropriate.

- Consider motion sensors for lighting that provide effective security control.

- Consider access control systems to keep unauthorized persons out.

Traffic safety

- Incorporate separate pedestrian walkways from the street.

- Separate the bus drop off area from general traffic flow.

3.10 Kitchen Operations

Kitchens can be an overlooked or lower priority area during school design, yet they also can be one of the most resource-intensive areas per square foot. Effectively, the same principles of sustainable design that apply to the rest of the school building apply to kitchens. A number of sustainable design strategies specific to kitchens operations are provided below:

- For exhaust hoods, consider variable frequency drives, equipment operation occupancy sensors tied with manual overrrides, heat recovery options, and lower airflow/higher efficiency hoods.
- Consider air-cooled (versus water-cooled) refrigeration compressors and ice makers with environmentally preferable refrigerants.
- Ensure that walk-in coolers are ENERGY STAR certified with lighting controls.
- Purchase high-efficiency dishwashers that are ENERGY STAR certified and include washwater reuse options and higher (versus lower) temperature operation. Additionally, taller units fit more sheet pans.
- Maintain domestic hot water supply at 140^{o}F. Ensure water heating is as efficient as possible and then minimize losses through strategies such as in-line cartridge pumps, semi-instantoues systems, etc.
- Install gas-fired (versus electric) kitchen equipment, such as ovens, booster heaters, and grills. Equipment should ignite electronically instead of using pilot lights.
- Purchase other ENERGY STAR certified commercial food service equipment, including hot holding cabinets, solid door refrigeraters and freezers, and steam cookers. Additional types of commercial equipment also should be considered as new products become ENERGY STAR certified.
- Institute related recycling and waste management pracitces, such as allowing space for kitchen recyclables and composting.
- Include kitchen areas and auxiliary areas (e.g., store rooms, walk-in coolers, etc.) in lighting design strategies, including daylighting and controls. Ensure any lighting lamps are shatterproof.

3.11 Recycling and Waste Management

Sustainable school design should not only involve the building itself, but should foster sustainable practices within the building. For example, one requirement for all LEED™ certified sustainable buildings (see Section 2.4) is that the building be designed for storing and collecting recyclables. Most schools within PSD are already recycling on some level. However, there is room for improving upon and expanding these systems to include additional materials. Furthermore, some schools are having difficulty recycling because they lack storage space.
Part of the sustainable design process should include examining current recycling practices in PSD schools, and designing provisions for continuing and improving upon these recycling systems in new schools. Also, collection systems should be designed to minimize labor costs. For example, chute systems that drop recyclables to central collection areas may save money. The following suggestions are from PSD food services staff members involved with the district's solid waste recycling program.

Ensure that the following areas have space allocated for recycling the specified materials:

- Cafeteria: aluminum cans, glass bottles, plastic bottles, and grease from deep-fat fryers

- Receiving Areas: cardboard and cans (e.g., #10 cans)

- All Areas: Office paper, newspaper, and magazines

- Custodial: packaging and custodial supply containers

There may be special solid waste and recycling requirements for art rooms, science rooms, and the nurse's office. Finally, the design should take into account provisions needed for recycling in areas where public events occur during off hours. The most common spaces used are cafeterias, gymnasiums, athletic fields, and media centers.

In addition to solid waste recycling, PSD has been investigating the feasibility of composting cafeteria wastes, as well as leaves and grass clippings from grounds keeping. One possible strategy is to use containerized compost systems. This would require allocating space for these containers during site planning.

Aside from the benefits of solid waste recycling, another reason for composting in schools is that it provides a rich topic for scientific investigation and discovery. Because it is a process that relies on biology, chemistry, and physics, it can be used for a wide range of scientific projects or experiments and can help students to see the interconnections between various scientific fields.[34]

[34] *www.cfe.cornell.edu/compost/.*

3.12 Construction Waste Reduction and Recycling

Construction Recycling:

- ✓ Construction recycling is becoming a standard practice in the industry
- ✓ Contractor and recycling education is key

As noted earlier, PSD intends to apply sustainability to the design, construction, operation, and ultimate dismantling of its school buildings. This section describes sustainable construction methods and how to incorporate them into the design/build process. Using construction methods that minimize waste generation is critical. It is estimated that construction-related waste accounts for approximately one-fourth of total landfill waste in the United States. Yet many construction materials can be recycled, including glass, aluminum, carpet, steel, brick, and gypsum. It is estimated that 50 to 80 percent of construction and demolition waste is potentially reusable or recyclable, depending on the type of project and local markets for waste materials.[35]

Some strategies for applying sustainability to construction practices are given here:

- Use waste reduction techniques during construction.
- Reuse construction waste material on the construction site.
- Salvage construction and demolition waste material from the construction site for resale or reuse by others.
- Return unused construction material to vendors for credit.
- Recycle construction and demolition waste for remanufacture into new products.

To implement these strategies, PSD needs to communicate its expectations and goals clearly to its design agents, to the construction contractor, and its subcontractors. There are several methods for achieving clear communication through changes to construction specifications:

- ***Use bid alternates*** to evaluate the economic feasibility for undertaking specific recycling measures as an alternative to landfilling waste.
- ***Require recycling to the extent practical*** in specification language, including possible requirements to track what is recycled and where it goes. The specification language could be reinforced in the pre-bid meeting, pre-construction meeting, and regular job-site meetings.
- ***Require a waste management plan*** for PSD approval. The plan requirements could be included in project specifications and may include such items as expected waste volumes, disposal methods, and costs; items to be recycled; arrangements for construction site recycling, and indoctrination of subcontractors.

[35] Triangle J Council of Governments. July 1995. Waste Spec: Model Specifications for Construction Waste Reduction, Reuse, and Recycling. P.O. Box 12276, Research Triangle Park, NC 27709, (919) 549-0551.

- ***Require recycling of specific items*** such as concrete, metal, glass, etc.

- ***Subtract waste costs and substitute a waste manager.*** Under this approach, each contractor would be required to include a line item in its bid for disposal cost. This amount would then be subtracted from the final bid and an independent waste manager would be hired to handle all waste recycling and disposal.

There are precedents for each of these strategies that need to be further investigated and applied within PSD on a project-by-project basis.[36] Selecting the most appropriate strategy depends on project circumstances, as well as changing markets for recyclable construction and demolition materials and local landfill tipping fees.

In addition to these general strategies, the following more specific practices also should be considered for inclusion in construction specifications:

- Design the building to common lumber sizes to reduce waste from cutting custom sizes.

- Verify field measurements before confirming product orders to minimize waste from excessive materials.

- Coordinate product delivery to minimize site storage time and potential damage to stored materials.

- Arrange to return packing materials, such as wood pallets.

- Store and handle materials to prevent loss from weather and other damage.

- Prevent contact with materials that may cause corrosion, discoloration, or staining.

- Use only non-hazardous materials in the final cleanup.

- Use the least toxic sealants, adhesives, sealers, and finishes necessary to comply with the construction specifications.

[36] Triangle J Council of Governments. Using Specifications to Reduce Construction Waste. P.O. Box 12276, Research Triangle Park, NC 27709, (919) 549-0551.

Beyond minimizing construction waste, sustainable construction practices also minimize site impacts. Some suggested approaches to achieve this are given below:

- Protect existing and proposed landscape features from damage or contamination.
- Require that all marketable trees designated for removal be sold.
- Require all other vegetation be chipped for mulching and composting or used for mill pulp or process fuel.
- Provide on-site locations for as much excavated rock, soil, and vegetation as possible.
- Assess suitability of site for applying pulverized gypsum waste as soil amendment or for striping athletic fields instead of using marble dust.

Case Study: Construction Recycling of Drywall at Bacon Elementary

Ground drywall spread across the future site of Fossil Ridge High School.

The recycling program during the construction of PSD's Bacon Elementary School was very successful, achieving an overall recycling rate of 75 percent by weight and reducing the district's construction waste expenditures by at least 50 percent. The typical materials recycled were wood, metal, cardboard, and aggregate materials, such as concrete, blocks, bricks, and rocks. One notable material was included as part of this commercial recycling program for the first time in Colorado: drywall.

With funding from the EPA, PSD embarked on this cutting edge drywall recycling project based on information from a geotechnical engineering report, case studies using drywall as a soil amendment in other states, and the *Guidelines for On-Site Use of New Scrap Wallboard in Georgia Construction*. Material safety data sheets were used to confirm that the drywall was free of hazardous materials. PSD then employed a collection method at the Bacon construction site to ensure that the drywall remained uncontaminated. At the time of the project, no markets existed for recycling drywall in the local area. For this reason, the recycling effort was focused on a land application process to enhance the soil at the site of Fossil Ridge High School (before its construction began). The drywall was ground, spread on the site at a rate of 5 tons per acre, and then tilled into the soil. The total cost to grind and apply the material was just over $2,000 for the estimated 240 yards of waste drywall generated during the construction of the school.

3.13 Commissioning

Commissioning is defined as documented confirmation that building systems function in compliance with criteria set forth in the project documents to satisfy the owner's operational needs. This definition is based on the critical understanding that the owner must have some means of verifying that their functional needs are rigorously addressed during design, construction, and acceptance.[37]

Commissioning can be thought of as the step that bridges the gap between a sustainable school on paper and the fully functional, energy efficient, sustainable school in practice. Essentially, commissioning verifies that building systems perform as intended so that the anticipated benefits of sustainable design become a reality. It also provides a communications conduit from the design team to the facilities staff charged with the day-to-day operation of the school building. Commissioning is a required component for LEED™ certified buildings (see Section 2.4). The District has performed commissioning on its new school construction projects, as well as building remodels and system upgrades.

Divisions 1, 15, and 16 of the technical specifications most commonly define the commissioning elements of a PSD project. Systems that are typically commissioned as part of a PSD construction, remodel, or building upgrade project are listed below:

- Lighting, including daylighting, controls
- Electrical
- Mechanical/plumbing (including test and balance)
- Irrigation
- Kitchen equipment
- Fire/alarm security (limited)
- Test and balance

Commissioning:

- ✓ **More** is not always better.
- ✓ Commissioning agent should represent PSD.
- ✓ Increase internal management of commissioning through meeting facilitation, increased involvement, etc.
- ✓ Dedicated PSD staff for commissioning involvement in each project.

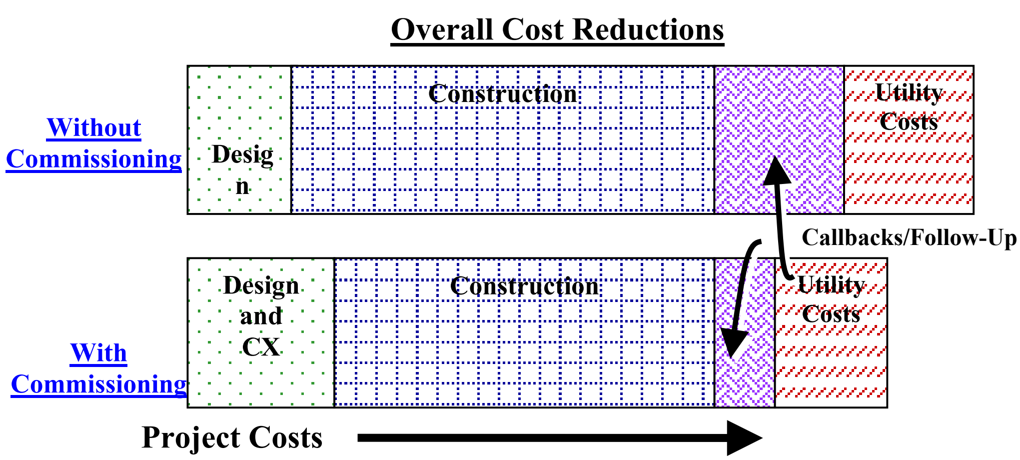
[37] *www.bcxa.org.*

Benefits of Commissioning

- Larger and more sustained energy savings
- Reduced maintenance costs
- Reduced warranty and follow-up
- Fewer construction litigation problems
- Better building systems operation
- Greater budgeting accuracy

Costs of Commissioning

As shown in the figure[38] that follows, commissioning reduces overall project costs by reducing construction costs, follow-up costs, and operational costs. However, there are added costs for commissioning.



Based on the district's experience with commissioning, the cost range for commissioning is as follows:

- New construction: \$0.50/ft^2 to \$1.20/ ft^2 (generally, \$0.80 is considered to be a detailed effort for PSD)
- Existing construction: \$0.05/ ft^2 to \$0.40/ ft^2

[38] Wolpert, Jack. March 2000. Commissioning presentation at the Sustainable Design Workshop: An Integrated Approach, Fort Collins, Colorado. E Cube, Inc. March 2000. Boulder, Colorado, *www.ecube.com*.

Data on energy savings and payback of commissioning from proceedings of 1997 National Conference on Building Commissioning closely tracks the experiences of PSD. These data are summarized in the following table:

Construction	Energy Savings	Payback Period
New	6-12 percent	2 to 6 years
Existing	7-30 percent	Less than 2 years

PSD will determine the level of commissioning appropriate on a project-by-project basis. For new construction, commissioning will likely be integrated into project planning phases so that the project team understands the goals and procedures of commissioning. Elements of commissioning to be considered for integration into project management methods include the following:

- Establish expected outcomes, such as how the building should perform, what the occupants need, and how much it costs.
- Measure or predict the basic functional, energy efficiency, and thermal/environmental performance of the building's automatic control, heating, air conditioning, refrigeration, lighting, and other important energy systems.
- Test building equipment to make sure it works correctly with other equipment and meets the present design and operational specifications.
- Provide building system documentation for future operations and maintenance so the school will continue to perform reliably and reap the expected savings.
- Verify that building and system operators have received appropriate training.

ESS schools encourage school decision-makers to incorporate these components into their construction programs.[39]

[39] U.S. Department of Energy. March 15, 2000. Energy Smart Schools a Campaign of Rebuild America.

3.14 Design for Maintainability

Design for maintainability integrates downstream experience and knowledge regarding cost-effective building operations and maintenance (O&M) into project design with the goal of reducing the costs to operate the facility for its expected life.

> ***"(Sustainable schools) can only work if EVERYONE, including building occupants, knows what's going on."***
>
> ***PSD MAINTENANCE STAFF***

Although O&M issues have been included in the relevant sections of Chapter 3, the topic is of enough importance to re-emphasizing as a unifying theme for the chapter. PSD considers incorporating O&M perspectives during design to be paramount in achieving the lowest life cycle cost school.

Designing for reduced O&M costs provides for an inherently sustainable building because it reduces waste associated with replacing worn or broken equipment, interior finishes, fixtures, etc. Furthermore, it increases the likelihood that expected energy savings are achieved long into the building's life, not just after initial commissioning.

In addition to the environmental benefits, design for O&M is a primary strategy for reducing total building life cycle costs. Life cycle costs include first costs, operating costs, maintenance costs, equipment replacement costs, and ultimately costs to demolish or disassemble the building. Paying close attention to each of these subsequent life cycle stages during design can produce significant cost benefits throughout the life of the school. For example, labor costs associated with operating and maintaining a school (which represents a major part of the O&M budget) can be reduced using the strategies listed in this section. For maximum benefit, involve the people that will maintain and occupy the building by consulting facility O&M personnel early in the design process and educating occupants as part of the construction process.

The following examples illustrate Design for Maintainability strategies to consider during design:

- Select materials, products, and equipment for their durability and maintenance characteristics. Pay particular attention to components that will be subject to high wear and tear or exposure to the elements, such as roofing systems, wall surfaces, flooring, and sealants.

- Avoid products with short expected life spans or products that require frequent maintenance procedures.

- Design and select systems inherently intuitive to operate and maintain. This typically involves simple design with fewer components over complex systems.

- Make provision for systems that are controllable and adjustable by the user without burdensome reliance on outside contractors.

- Design for longevity from all perspectives: component, system, and building. Longevity includes designing for expandability, flexibility, disassembly, recyclability, and durability.

- Consider equipment accessibility, making sure there are adequate clearances for maintenance staff to perform maintenance tasks on equipment. Leave room for staff to visually inspect systems, such as ductwork.

- Standardize, document, and label equipment. Standardized components ease purchases, reduce inventory, improve reliability and maintainability, and minimize vehicle trips for maintenance staff.

- Plan for ongoing education of building occupants. Why was the building designed as it is? How do they (the occupants) use it? How do they support the motivations for the building design intent?

3.15 Buildings that Teach

As noted in Chapter 1, the full benefits of a sustainable school are not realized if the building itself is not used to teach students about sustainability and their role in a sustainable future. Colorado Content Standards have clearly identified concepts related to sustainability as important to a student's education. The full benefits of sustainable design are lost if faculty and students either are unaware of the building's sustainable features or cannot access them. Furthermore, by its very definition (to meet the needs of the present without jeopardizing the ability of future generations to meet their own needs[40]), sustainability implies an imperative to educate students about their role in perpetuating a sustainable future.

"The curriculum embedded in any building instructs as fully and as effectively as any course taught in it."

David Orr,
Oberlin College

[40] World Commission on Environment and Development (Bruntland Commission). 1987. *Our Common Future*.

Case Study: Poudre School District's Learning Wall

Cutout showing hot and cold water pipes, columns, metal studs, conduits and insulation within the walls at Bacon Elementary.

When their Sustainable Design Guidelines were first written in 2000, PSD identified four strategies for accomplishing a building that teaches. All four teaching strategies were implemented at Zach Elementary – the first school built using these guidelines - and Bacon Elementary. The strategies are:

- Make building systems visibly and physically accessible (such as the wall cut out shown above)
- Provide feedback (including real time data) so students can see and measure the impact of their actions on building operations
- Provide students with a connection to the natural environment: better daylighting and site design from past prototypes
- Document sustainable features and their benefits, and share results with faculty, staff, and students

For example, at Bacon Elementary, recycled blue jeans make up the building insulation material. The students can see it through an opening in the wall known as "the truth wall". Virtually no part of this building is tucked away with the intent of teaching the students the methods and reasons for the building construction. According to Bacon's Fifth Grade Teacher Diane Odbert, "[the students] are also very well-versed in the building at this point, because we actually went off into engineering at the beginning of the school year."

How can a sustainable building help deliver science curriculum?

The remainder of this section outlines examples of how a sustainable school can help teach the science curriculum defined in the Colorado Model Content Standards for Science. For each of the six standards listed in the Colorado Model Content Standards, excerpts for grades K-4 are provided, along with examples of sustainable features for demonstrating the standard. These are provided as examples only and are not intended to represent an exhaustive list of possibilities for buildings that teach. The purposes of the outline are given below:

1. Demonstrate the compelling alignment between Colorado science requirements and sustainable design.

2. Stimulate ideas for sustainable features that can help teach the science curriculum.

Because the Sustainable Design Guidelines initially will be used to design the next prototype elementary school, excerpts for grades K-4 only are provided. The possibilities become even more compelling for higher-level grades. Furthermore, it should be noted that the following outline provides a comparison between sustainability and science curriculum only. Sustainability can help deliver virtually every area of curriculum.

Following are examples of sustainable features for teaching Colorado model content standards for science.

Standard 1: Students understand the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations.

Selecting and using simple devices to gather data related to an investigation	⇒	Expose walls and include samples of different insulation, window systems, etc. Provide instruments to measure performance differences.
Using data based on observations to construct a reasonable explanation	⇒	Connect electric and water meter to the computer network; provide LED display of real time energy use.

Standard 2: Physical Science: Students know and understand common properties, forms, and changes in matter and energy.

Making observations and gathering data on quantities associated with energy, movement, and change	⇒	Use different energy sources, including renewables (see above for providing access to data describing system performance).

Standard 3: Life Science: Students know and understand the characteristics and structure of living things, the processes of life, and how living things interact with each other and their environment.

Giving examples of how organisms interact with each other and with nonliving parts of their habitat	⇒	An on-site pond for irrigation can serve dual purpose of learning aquatic biology.
Recognizing that green plants need energy from sunlight and various raw materials to live, and animals consume plants and other organisms to live	⇒	Design landscape for bio-diversity and for native plants.

Standard 4: Earth and Space Science: Students know and understand the processes and interactions of Earth's systems and the structure and dynamics of Earth and other objects in space.

Recognizing that fossils are evidence of past life	⇒	Include fossils in pathways outdoors.
Identifying major features of Earth's surface (e.g., mountains, rivers, plains)	⇒	Design landscapes to reflect bioregions.
Recognizing that the sun is a principal source of Earth's heat and light	⇒	Use solar panels, solar hot water heaters, and daylighting.
Recognizing how our daily activities are affected by the weather	⇒	Real time energy data will show how much more energy the building consumes during cold days.
Describing existing weather conditions by collecting and recording weather data (e.g., temperature, precipitation, cloud cover)	⇒	Incorporate a weather station and periscope into science classrooms.
Recognizing the importance and uses of water (e.g., drinking, washing, irrigating)	⇒	Incorporate water-measuring devices for comparing flow from different fixtures.
Describing the motion of Earth in relation to the Sun, including the concepts of day, night, and year	⇒	Provide a sundial.

Recognizing the characteristics of seasons	⇒	Provide a sundial.
Identifying basic components of the solar system	⇒	Provide to-scale model of solar system on grounds.

Standard 5: Students know and understand interrelationships among science, technology, and human activity and how they can affect the world.

Describing resource-related activities in which they could participate that can benefit their communities (e.g., recycling, water conservation)	⇒	Design schools to facilitate implementation of on-site recycling programs for paper, glass, plastic etc. Consider feasibility of on-site composting operation.

Standard 6: Students understand that science involves a particular way of knowing and understand common connections among scientific disciplines.

Describing and comparing the components and interrelationships of a simple system (e.g., tracking the continuous flow of water through an aquarium, filter, and pump)	⇒	Make building systems accessible so students can study them. For example, design the building so students can trace where air is drawn into the building and how it is heated, distributed, and exhausted from the building. Similarly for water, where does it come from, how is it routed in the building, where does it go?

Mission

Educate...Every Child,
Every Day

Vision

Poudre School District exists to support and inspire every child to think, to learn, to care, and to graduate prepared to be successful in a changing world.

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