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AUTHOR	Nicklas, Michael; Bailey, Gary; Rosemain, Pascale; Olin, Samuel
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ABSTRACT

These guidelines present optional strategies to be considered in designing schools to be more energy efficient and sustainable. The guidelines are organized by the following design and construction process: site selection; selection of A & E design team; programming and goal setting; schematic design; design development; construction documents; bidding and negotiations; construction administration; and commissioning. Each of these areas is further divided into some or all of the following fourteen areas that apply to each phase: general considerations; site planning and landscape design; daylighting; energy-efficient building shell; solar systems; energy-efficient lighting and electrical systems; energy-efficient mechanical and ventilation systems; environmentally sensitive building products and systems; indoor air quality; water conservation; recycling systems and waste management; transportation; commissioning and maintenance; and eco-education. (Contains 19 references.) (GR)

Guidelines For

Energy-Efficient Sustainable Schools

Clark County School District
Clark County, Nevada

Developed by Innovative Design, Inc.

Prepared by:

Innovative Design, Inc.

850 West Morgan Street
Raleigh, North Carolina 27603

8275 S. Eastern / Suite 220
Las Vegas, Nevada 89123

Michael Nicklas, AIA
Gary Bailey, AIA
Pascale Rosemain
Samuel Olin

Technical Assistance by:

Padia Consulting, Inc.

For:

Clark County School District

Although great care has been taken in compilation and preparation of these *Guidelines for Energy-Efficient Sustainable Schools*, no warranties, expressed or implied, are given in connection herewith and no responsibility can be taken for any claims arising herewith.

Comments, criticisms, clarifications, and suggestions regarding the subject matter are invited.

Acknowledgments

The authors would like to thank the Clark County School District for funding our development of these Guidelines for Energy-Efficient Sustainable Schools. The Guidelines have been greatly enhanced by the insight and effort of all those who participated in the process.

The development of these guidelines was a unique process that brought together a wide variety of participants from the design, construction and educational fields. This inclusive approach helped to develop a more comprehensive document that specifically addressed the conditions of Clark County. These guidelines would not have been possible without the dedication and energy of all involved.

Special thanks

Special thanks to E Build, Inc. and Trane for providing technical information that is included in these guidelines. Special thanks to Clark County Facilities Department and the professional community for their participation and support in the development of these guidelines.

Purpose

These guidelines were developed for the Clark County School District for the purpose of presenting optional strategies to be considered in designing our schools to be more energy efficient and sustainable. As voluntary guidelines, they offer architects and engineers numerous suggestions to improve their designs. Over the course of the nest couple of years, these guidelines will be tested in actual schools. Once evaluated, certain elements of these guidelines will be mandatory while others will remain as voluntary options.

Organization

This document, *Guidelines for Energy-Efficient Sustainable Schools*, has been organized by the design and construction phases: Site Selection; Selection of A & E Design Team; Programming and Goal Setting; Schematic Design; Design Development; Construction Documents; Bidding and Negotiations; Construction Administration; and Commissioning. Each of these phases is further divided into some or all of the following fourteen areas that apply to each phase.

- General Considerations
- Site Planning and Landscape Design
- Daylighting
- Energy-Efficient Building Shell
- Solar Systems
- Energy-Efficient Lighting and Electrical Systems
- Energy-Efficient Mechanical and Ventilation Systems
- Environmentally Sensitive Building Products and Systems
- Indoor Air Quality
- Water Conservation
- Recycling Systems and Waste Management
- Transportation
- Commissioning and Maintenance
- Eco Education

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INTRODUCTION

Introduction

The concept of sustainable development reflects an understanding that we must meet the needs of the present without compromising the ability of future generations to meet their own needs. A sustainable school not only embraces the concept of sustainability but is, in itself, a teaching tool for sustainability.

The *Guidelines for Energy-Efficient Sustainable Schools* were developed because of the understanding that it is important to build our schools in a manner that reflects values critical to the sustainable development of our planet. The messages that we give to future generations, through the schools we build for them, should not be under-estimated. Our schools should make a strong statement that saving energy and protecting our environment is important.

Clark County is now experiencing a period of unprecedented growth. This growth is now forcing us to move from a period of less expensive energy and resources with few environmental concerns to a time in which building-related decisions are more strongly influenced by energy costs and there is a deeper appreciation of the environmental and societal implications of construction materials and processes.

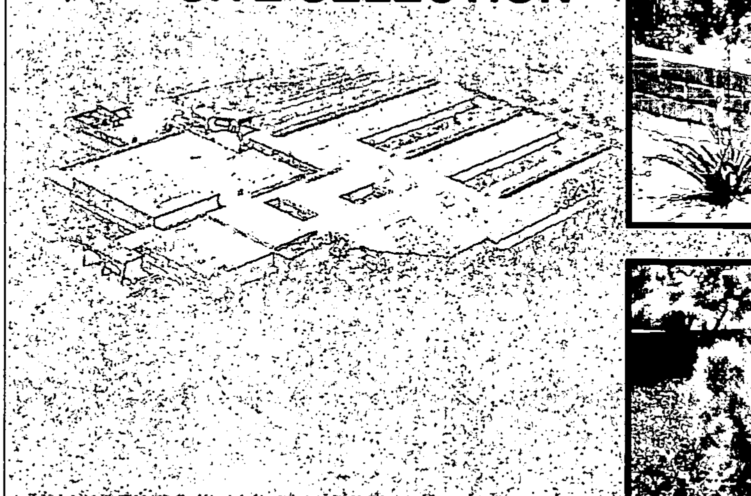
Over the normal life of a school, energy costs will far exceed initial costs. These guidelines, which embrace a philosophy of long-term thinking, are important because they point out numerous options that can drastically reduce unnecessary energy costs. They also point out ways in which the health and productivity of students and teachers can be enhanced. The use of daylighting is a win-win opportunity because, in addition to improving performance, it also can cut energy bills and reduce initial construction costs.

One of the main sustainable design strategies featured throughout this guideline is the use of daylighting. Productivity studies conducted in daylit schools in North Carolina, California, Colorado, and Washington have all indicated the very strong correlation between the use of controlled daylighting and improved student performance.

These *Guidelines for Energy-Efficient Sustainable Schools* offer a detailed listing, by the typical design and construction stages, of key practices and technologies that can help create a sustainable school. It lists literally hundreds of cost-effective, common sense recommendations that can improve the energy performance and environmental quality of school design. It is our hope the designers of our schools will find these guidelines useful and that the inclusion of these sustainable principles will result in our schools being more energy efficient and environmentally sound.

Section 1

SITE SELECTION



1. SITE SELECTION

1.1 General

In selecting a school site, consideration should be given to site characteristics that will enable the school to be designed most cost-effectively and still incorporate concepts of sustainability. The following elements should receive high priority in the site selection process.

1.2 Site Planning and Landscape Design

1.2.1 When selecting a potential site:

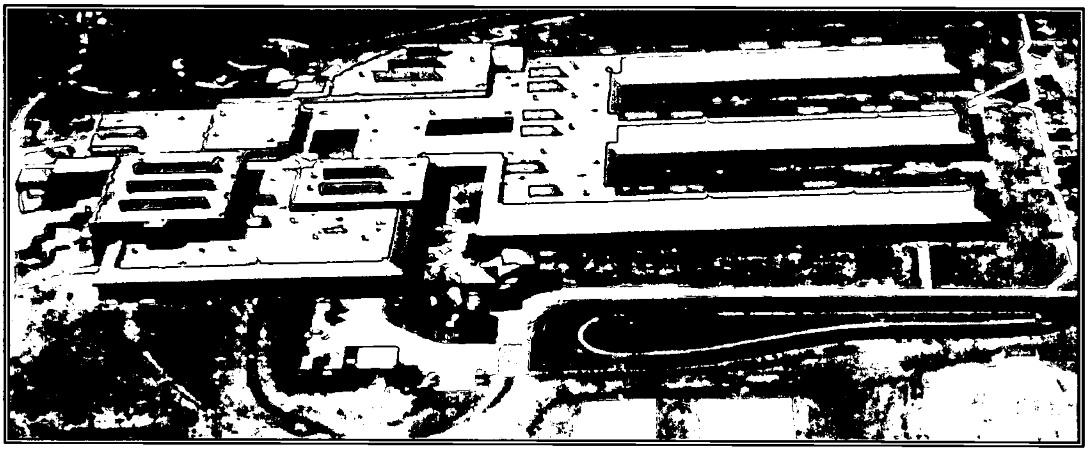
1. Consider rehabilitation of existing sites or urban infill areas versus use of an undisturbed site.
2. Avoid sensitive ecosystems, such as wildlife habitats.
3. Select a site that can maximize orientation for solar access and daylighting.
4. Consider geological, micro-ecological, and micro-climatic conditions.
5. Determine existing air and water quality and impact that the school will have on these conditions.
6. Evaluate noise levels typically experienced at the site.
7. Evaluate flooding and site water issues.
8. Determine presence of historic landmarks and/or archeological features on site.
9. Conduct assessment of impact school will have on wildlife habitats and other sensitive ecosystems.
10. Evaluate the impact the school will have on the local environment.
11. Consider protection and retention of existing landscaping.
12. Evaluate potential for utilizing existing vegetation.

1.3 Daylighting

1.3.1 Evaluate potential for the building to be sited on an east-west axis, maximizing southern exposure.

1.3.2 Determine if the site can accommodate a one-story school, which is considerably easier to daylight than a school with multiple stories.

Aerial view of south facing roof monitors



Durant Road Middle School, Innovative Design Inc.

1.4 Solar Systems

1.4.1 Consider potential solar access for the building, including requirements for integrated active solar and photovoltaic systems.

AVERAGE DIRECT NORMAL INSOLATION			
COLOR KEY	PER DAY (kWh/m²-day)	PER YEAR (MJ/m²)	PER YEAR (quads/100 mi²)
	<3.0	<3,940	<1.0
	3.0 - 3.5	3,940 - 4,600	1.0 - 1.1
	3.5 - 4.0	4,600 - 5,260	1.1 - 1.3
	4.0 - 4.5	5,260 - 5,910	1.3 - 1.5
	4.5 - 5.0	5,910 - 6,570	1.5 - 1.6
	5.0 - 5.5	6,570 - 7,230	1.6 - 1.8
	5.5 - 6.0	7,230 - 7,880	1.8 - 1.9
	6.0 - 6.5	7,880 - 8,540	1.9 - 2.1
	6.5 - 7.0	8,540 - 9,200	2.1 - 2.3
	>7.0	>9,200	>2.3

Source: Texas Renewable Energy Resource Assessment

1.5 Energy Efficient Electrical and Mechanical Systems

1.5.1 Consider the energy options available at the site (electricity, natural gas, LP gas, solar, etc...)

When selecting a site, the design team should evaluate the availability of energy options, the current and projected costs of each energy choice, and service connection charges associated with each energy option. Consider the impact of multiple meters. Multiple meters may have additional costs associated with them which makes it more attractive to combine loads on a single service. Environmental impacts of each energy option should be also considered.

1.6 Indoor Air Quality

1.6.1 Consider outdoor air conditions and physical relationships to industries or utilities which may pollute the air.

1.7 Recycling Systems and Waste Management

1.7.1 Evaluate potential for collection of materials that can be recycled.

1.8 Transportation

1.8.1 Consider mass transit accessibility to high school site.

1.8.2 Consider proximity to neighborhoods and accessibility by foot or bicycle.

Location of the site within Clark County is also critical. A poorly located facility could easily result in transportation related energy expenditures which far exceed the energy consumed by the building. A site that has the potential for safe pedestrian walkway and bikeways to the surrounding communities should be a high priority. Mass transit options, as well as the typical travel distances of workers, clients, students and others routinely going to the facility, also be analyzed.

Whether transportation cost is directly incurred by the County or by those coming to the school, considerable energy and environmental impacts can be reduced when this often overlooked issue is made a part of the early planning process. In some cases, the cheapest land to buy is really the most expensive for the taxpayers in the long term.

SITE SELECTION REPORTING FORM

Project .... **Project #**..................... **Date** ....

Submitted by...

Architect ( ) Clark Co. Schools ( ) Consultant to School System ( ) Other ( )

Site Location & Size..

Building Type	K-5 School	Middle School	High School ....
	Library............................	Gymnasium	Maintenance.......................
	Horizon High Schools......................................		Other..............................

Orientation

	Yes	No
Does the site lend itself to a good southerly orientation?	( )	( )
Are there any adequate buildings or other structures which could block solar access?	( )	( )
Would the proposed building obstruct solar access to any existing buildings?	( )	( )

Energy Options

Check the availability of various utility energy options at the site. If not currently at site indicate distance from site and estimated cost to extend service:

	Yes	No	Distance	Cost to County
Electricity	( )	( )	....	....
Natural Gas	( )	( )	....	....
Water	( )	( )	....	....

List utility company options and current cost of energy:

Energy Option	Company	Cost/Unit
Electricity (kw & kwh demand)	Nevada Power	Oct.-May \$1.11/kw; \$0.04/kwh June-Sept. \$9.10/kw; \$0.06/kwh
Natural Gas	SW GAS	\$0.51783 per therm (1000,000 Btu)
L.P. Gas	Suburban Propane	\$1.40 to \$1.68 per gallon

Transportation

	Yes	No
Is site serviced by local bus system?	( )	( )
If no, distance from site to closest bus route	....	
Would bus system consider stop at site?	( )	( )

Pedestrian Friendly Site

Is the site easily accessible by:	pedestrian walkways	( )	( )
	bikeways	( )	( )

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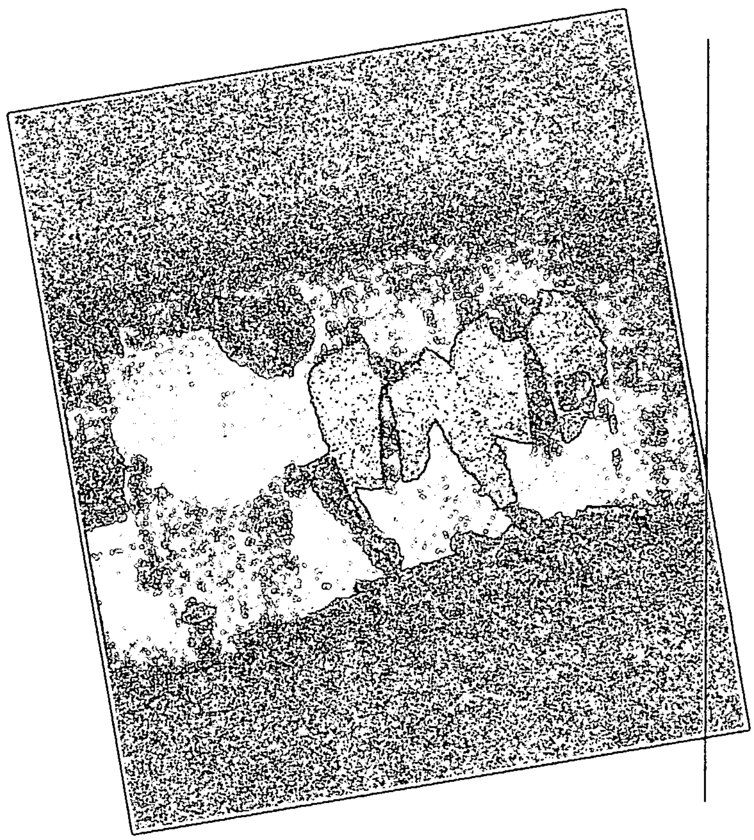
Section 2

SELECTION OF ARCHITECTURAL & ENGINEERING DESIGN TEAM



2. SELECTION OF A&E DESIGN TEAM

2.1 General

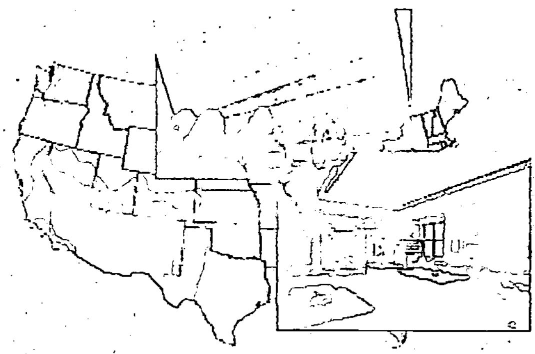
Establish a selection process that will result in an architectural and engineering team with knowledge and experience in energy and sustainable design.

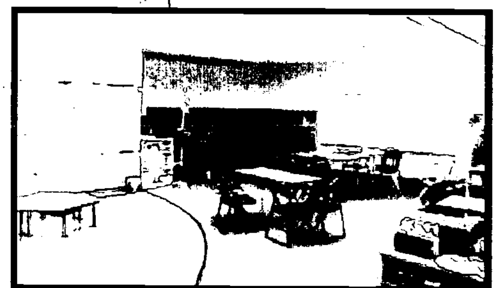
2.1.1 Request for qualifications and proposals should include questions regarding:

1. Issues of sustainable school design
    a. site considerations
    b. daylighting
    c. building shell design
    d. solar design
    e. energy-efficient systems (mechanical, electrical, ventilation)
    f. environmentally sensitive building products and systems
    g. indoor air quality
    h. water conservation
    i. recycling systems and waste management
2. Analytical tools used to evaluate energy
    a. daylighting simulation
    b. energy consumption and peak loads
    c. life-cycle analysis

2.1.2 Interviews should address same issues as above, but also include questions regarding:

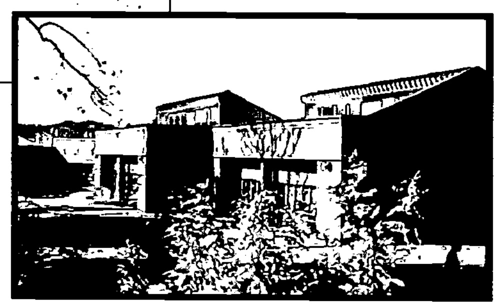
1. how issues of sustainability are addressed as a part of the architectural and engineering team's normal design process;
2. the success of past projects in addressing issues of sustainability; and
3. commitment of the design firms and their principals to energy efficiency and sustainability.

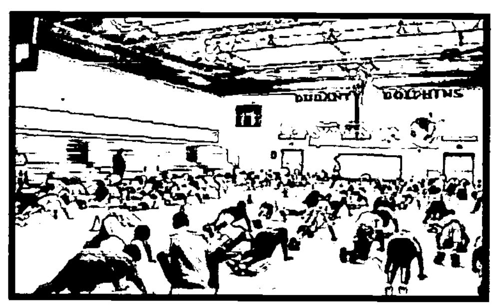




Section 3

PROGRAMMING AND GOAL SETTING





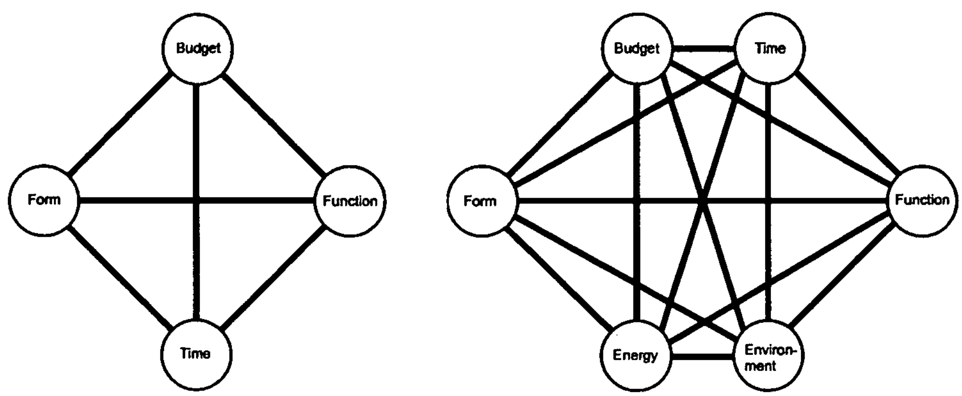
3. PROGRAMMING AND GOAL SETTING

3.1 General

Establish criteria for evaluating sustainability and energy use. The following represents a possible framework for the inclusion of particular systems, products, materials and design elements.

Energy Efficiency and the Environment as a Programming Objective

The overall intent of programming is to clearly identify the design problem and to understand the important criteria by which the County wants the design team to solve the problem. Traditionally, four overriding design determinants have served as the basis for the development of these principles - function, form, budget and time. Because of the importance that Clark County now places upon energy and environmental quality, designers must integrate these factors with the other four, and systematically approach these problems before design commences.



The design team must create a building which is as energy efficient as possible and still remains within the construction budget. The building design must incorporate the best "life-cycle" energy solutions that are available. The facility should also be environmentally sensitive and be a healthy building for teachers, students and visitors.

3.1.1 In evaluating the cost effectiveness of various design options to be implemented in our schools, a "modified" life-cycle analysis shall be used.

Nevada Requirements

Nevada Revised Statutes NRS 338.190 (1): Before it begins to construct or renovate any public building which is larger than 20,000 square feet, each agency of the state or a political subdivision, district, authority, board or public corporation of the state shall obtain a detailed analysis of the cost of operation and maintaining the building for its expected useful life.
Nevada State Public Works Adopted Standards 7.2: In accordance with NRS 338.190, prior to construction or renovation of any public building with a gross floor area greater than 20,000 square feet, a detailed analysis of the cost of operation and maintenance of the building must be completed which shall identify measures for the conservation of energy (and shall identify the use of alternate non-fossil fuels when applicable).

Criteria For Life-Cycle Cost Analysis

Various analytical methods have been utilized by energy analysts to evaluate the appropriateness of incorporating optional energy saving measures. However, only one method totally evaluates what is in the best, long-term interest of the County - life-cycle cost (LCC) analysis. By incorporating life-cycle cost approaches throughout, all reasonable energy options can be compared on an equal basis.

Factors To Consider In Analysis

The following factors should be included in life-cycle evaluation of various energy options.

- Initial cost
- Maintenance cost (over the projected life)
- Energy inflation costs
- Useful life

Typically the County does not finance building projects, however, if bond monies or financing charges are associated with a particular project, they should also be included.

Energy Inflation Rates

The following energy inflation rate will be used between now and 2005 at which time Clark County will provide an updated energy inflation rate to utilize in your assumptions.

Energy Option	Energy Inflation Rate
Electricity	2 ½ % per year
Natural Gas	5 % per year
Propane	5 % per year

Current Energy Costs in Clark County

Energy Options		Cost/Unit (Range In Clark County)	
Electricity Nevada Power Rate		Customer Charge $255 / month Facilities Charge $55 / kw	
Summer – June 1 thru Sept. 30		Demand	Energy
On-Peak	1pm to 7pm	$9.10 / kw	$0.5958 per kwh
Mid-Peak	10am to 1pm, 7pm to 10pm	$1.39 / kw	$0.05567 per kwh
Off-Peak	10pm to 10am	$0.00 / kw	$0.04102 per kwh
Other – October 1 thru May 31		$1.11 / kw	$0.03972 per kwh
Natural Gas		$0.51783 per therm (100,000 Btu)	
LP Gas		$1.40 to $1.68 per gallon	
Renewables		Various	

Timeframe For Life-Cycle Cost Analysis

The "estimated life" of the measure determines the period over which the life-cycle cost analysis is to be run. If the project involves a new building, the estimated life would be longer than that of a renovated structure. Likewise, building shell component decisions should be viewed in a longer context than equipment which is often replaced as new technologies make their way into the marketplace. To provide a guide for the design team, the following timeframes are to be used in the modified life-cycle analysis. This modified approach (which multiplies the projected life of the facility time a factor or percentage) reflects a balance between what is best of the life of the facility and the importance of keeping initial cost low.

Type Of Measure	Projected Life Of Facility	Timeframe For LCC Analysis (% And Years)
New Construction		
Building Shell (Thermal Envelope)		
• Schools, Libraries, Gymnasiums	50 years	50%, 25 years
• Horizon High Schools	50 years	50%, 25 years
• Maintenance	30 years	50%, 15 years
Mechanical Equipment,	30 years	50%, 15 years
Electrical, Lighting and Controls	30 years	50%, 15 years
Renovation		
Building Shell (Thermal Envelope)		
• Schools, Libraries, Gymnasiums	*	50% *
• Sunset High Schools	*	50% *
• Maintenance	*	50% *
Mechanical Equipment,	*	50% *
Electrical, Lighting and Controls	*	50% *

* On renovation projects, Clark County and the design team will determine the projected remaining useful life of the facility or equipment. This projected life figure should be multiplied by the percentages listed above in order to determine the actual number of years to use in the modified life-cycle cost analysis.

3.1.2 Design elements may, sometimes, not be able to be justified economically but should still be included if they:

1. are environmentally preferable and costs no more than 15% more than typically utilized elements;
2. demonstrate an environmentally sound technology that will produce educational benefits;
3. should be incorporated because they are become an integral part of the educational program (e.g., greenhouse for growing plants);
4. provide productivity, psychological, and/or health benefits (e.g., a product substitution that will eliminate out-gassing of volatile organic compounds);
5. result in significantly greater benefit to the local economy (e.g. locally manufactured product or locally available materials);
6. replace an element with a high negative environmental impact; and/or

7. address an increasingly problematic environmental issue (e.g. water conservation).

3.1.3 Gather information on locally available energy options and pricing structures.

3.1.4 Evaluate energy consumption of similar buildings and establish energy performance goals (for building and site energy).

Energy Budget And Energy Goal

The most important energy programming criteria is performance. The following Energy Budgets and Energy Goals were established as benchmarks upon which we will judge the project's success or failure. The Energy Budget numbers, listed by the particular school type, reflect the minimum energy performance that is expected. Achievement of the Energy Goal is considered to be excellent. These numbers were derived by analyzing other standards, applicable to Clark County's climatic area, as well as what has been historically achieved by architects and engineers on Clark County schools.

The following reflects the energy consumption of all the existing schools in Clark County. Note: the following information reflects the annual consumption in 1999.

Schools

Elementary		
20% Above Lowest	40,100	Btu's/ sq. Ft / Yr
Average	55,123	Btu's/ sq. Ft / Yr
Highest	123,800	Btu's/ sq. Ft / Yr
Middle		
20% Above Lowest	47,000	Btu's/ sq. Ft / Yr
Average	58,486	Btu's/ sq. Ft / Yr
Highest	80,600	Btu's/ sq. Ft / Yr
High School		
20% Above Lowest	65,700	Btu's/ sq. Ft / Yr
Average	80,964	Btu's/ sq. Ft / Yr
Highest	158,200	Btu's/ sq. Ft / Yr
Horizon		
20% Above Lowest	37,300	Btu's/ sq. Ft / Yr
Average	61,413	Btu's/ sq. Ft / Yr
Highest	94,200	Btu's/ sq. Ft / Yr

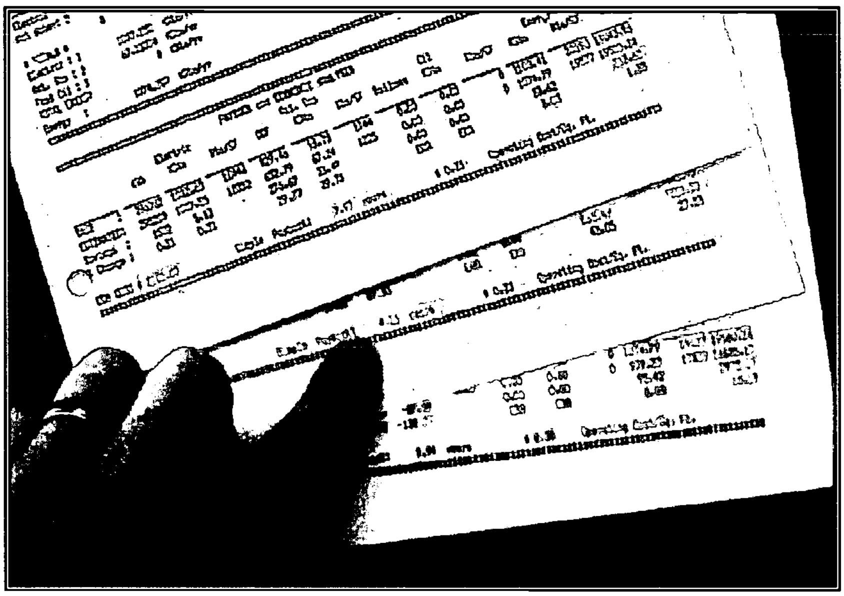
Clark County school Energy Budget and Energy Goals

The following reflects Clark County school's Energy Budget (the minimum expected) and our Energy Goal (considered exemplary performances).

School Type	Energy Budget (Btu's/Sq Ft/Year)	Energy Goal (Btu's/Sq Ft/Year)
K-5	50,000	42,500
Middle Schools	53,000	45,000
High Schools	73,000	62,000
Horizon High Schools	55,000	47,000
Gymnasiums	60,000	51,000
Libraries/Media Centers	65,000	55,000

The Energy Budgets and Goals are based upon normal daytime operations as well as typical nighttime and occasional weekend operation over a 12 month timeframe. The "Energy Budget" approximates a value that is 90% of the current average. The "Energy Goal" represents energy consumption values that are approximately 85% of the Energy Budget amounts.

3.1.5 Determine means of long-term energy use monitoring (e.g., energy bills, sub-metering, etc.).



3.1.6 Determine how non-energy related elements of sustainability will be individually and collectively evaluated.

1. Individually each element should meet evaluation criteria established under each category of sustainability listed below.

2. Collectively the criteria could encompass:

   a. student and teacher attendance relative to other schools (indicator of healthier indoor environment);

   b. levels of improvement in end-of-grade testing relative to other schools' improvement;

Student Performance in Daylit Schools - Summary of Conclusions

Although there are many variables that can alter student performance, it appears that the students attending daylit schools clearly benefit by being in the superior, daylit learning environments.

A 1996 study, conducted by Innovative Design, of daylit schools in Johnston County, North Carolina indicated that students who attended daylit schools out-performed the students who were attending non-daylit schools by 5 to 14 percent in their End-Of-Grade testing.

In 1999 a similar study of daylit classrooms was carried out in California, Colorado and Washington by the Heschong Mahone Group with The Pacific Gas and Electric Company for the California Board for Energy Efficiency Third Party Program. The study of 2000 classrooms and 21,000 students observed improvements in End-Of-Grade tests of 20% in math and 26% in reading for students in the best daylit classrooms versus the worst.

Energy Performance of Daylit Schools - Summary of Conclusions

The most obvious conclusion is that daylighting, even excluding all of the productivity and health benefits, makes sense from a financial investment standpoint. The same study of daylit schools in North Carolina indicated energy cost reductions of between 22% to 64% over typical schools. With paybacks on all the new daylit schools below three years, the long term benefits to a school system are enormous. In North Carolina, a 125,000 square foot middle school that incorporates a well-integrated daylighting scheme showed typical savings of $40,000 per year over what is typically constructed. And, if energy costs go up by 5% per year, the savings on just one school, over the next ten years, would exceed $500,000.

Source: *Strategic Planning for Energy and the Environment, Lilbum, GA 1997*

c. in-school waste recycling rates, relative to other schools;

d. water usage relative to other schools;

e. percentage of construction materials and products purchased locally (county, state);

f. enhanced awareness by students of energy and environmental issues and how the school design addresses these issues (e.g., percent of 1st grade families that recycle versus percent of 5th grade);

g. the influence that the school has on the construction of additional sustainable schools in the school system and state (e.g., the amount of media exposure for the school compared with coverage of other schools, number of visitors to school compared with other schools);

h. the maintenance costs associated with this school compared with the maintenance costs at other schools in the school system;

i. average number of vehicles driven to school each day, compared with that of other schools; and/or

j. comparisons between this school and other schools by foot, bicycle, bus, or mass transit.

3.1.7 Ensure that architectural and engineering selection process will result in firms being selected that have skills (in energy and sustainable design) necessary to meet objectives.

3.1.8 Ensure that architectural and engineering scope of services is adequate to meet objectives.

3.2 Site Planning and Landscape Design

3.2.1 Establish objectives regarding:

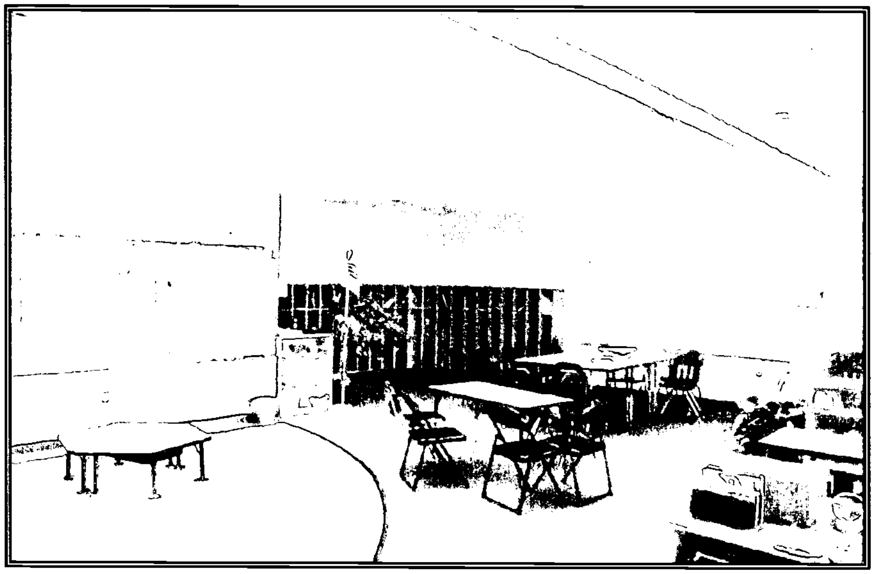
Protection of existing landscaping, Picture Innovative Design, Inc.

1. protection and retention of existing landscaping and natural features;
2. orientation of the building to provide southern solar access for daylighting, use of solar systems, and passive heating/cooling (coupled with a minimization of east-west exposure);
3. protection of wildlife habitats and ecosystems;
4. retention of storm water on the site;
5. protection of historic landmarks and/or archeological features;
6. avoidance of factors contributing to heat islands;
7. protection of the regional and global environment;
8. use of existing vegetation when appropriate; and
9. use native and drought resistant plants and employ xeriscape techniques.

3.3 Daylighting

3.3.1 Establish objectives regarding:

1. inclusion of natural daylighting in typically occupied spaces;

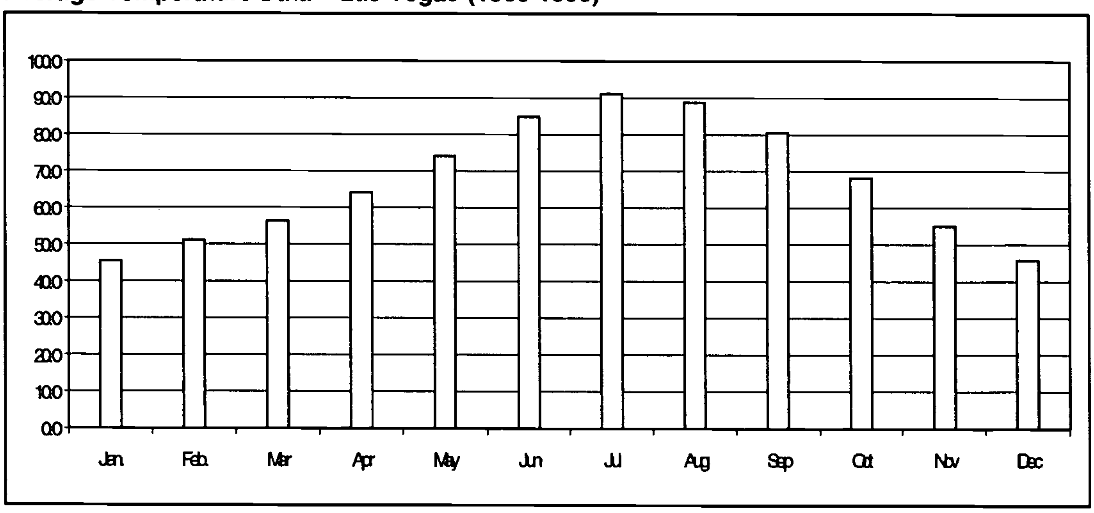


Daylit Classroom, Innovative Design, Inc.

2. inclusion of daylighting as a means of reducing cooling and electrical loads;
3. inclusion of daylighting in creating superior learning environments; and
4. use of a one-story strategy to maximize daylighting potential.

3.4 Energy-Efficient Building Shell

Average Temperature Data – Las Vegas (1969-1998)



	Jan	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	45.5	51.1	56.3	64.1	74.0	84.9	91.1	88.7	80.5	68.2	55.0	45.7
Maximum	57.3	63.3	68.8	77.5	87.8	100.3	105.9	103.2	94.7	82.1	67.4	57.5
Minimum	38.6	38.8	43.8	50.7	60.2	69.4	76.2	74.2	66.2	54.3	42.6	38.9

Source: NCDC Asheville, NC

3.4.1 Establish objectives regarding:

1. level of insulation in relationship to building code requirements;

2. minimization of east- and west-facing glass and maximization of south- and north-facing glass for daylighting;

South facing glazing, Innovative Design, Inc.

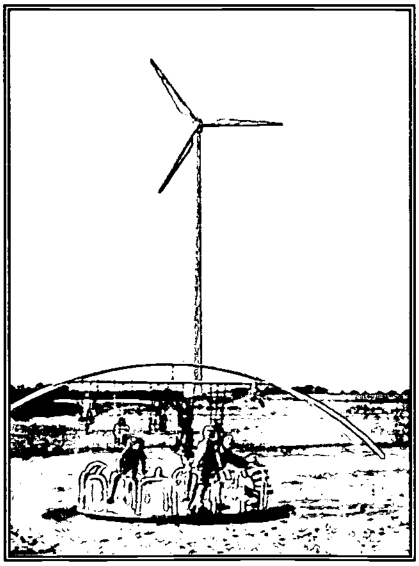
3. inclusion of high-mass construction;

4. incorporation of shading strategies to eliminate overheating and glare;

5. incorporation of infiltration/exfiltration barriers and radiant barriers; and

6. use of light colored roofing and wall materials.

3.5 Solar Systems



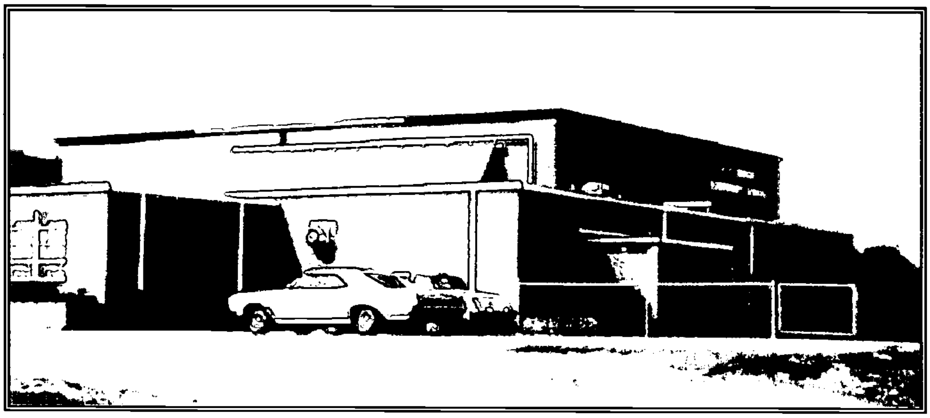
Single turbine providing power to school

Spirit Lake, Iowa School District

Source: American Wind Energy Association

3.5.1 Establish objectives regarding:

1. the use of solar, including daylighting, passive heating/cooling, natural ventilation, solar hot water, solar absorption cooling, photovoltaics, and wind systems;
2. the use of solar in lieu of conventional energy options; and
3. purchase of solar energy (renewable energy) from utilities supplying green power options.



Solar hot water system, Innovative Design, Inc.

3.6 Energy-Efficient Lighting and Electrical Systems

3.6.1 Establish objectives regarding:

1. use of full-spectrum lighting;
2. use of lighting that is compatible with daylighting strategies;
3. energy efficiency of equipment or systems;
4. the minimization of maintenance;
5. use of lighting control systems based on availability of daylighting and occupancy in individual spaces;
6. employment of optimum energy management systems;
7. use lighting strategies that minimize glare and eye strain; and
8. establishment of appropriate light level requirements by space function and time of day.

3.7 Energy-Efficient Mechanical Ventilation Systems

3.7.1 Establish objectives regarding:

1. energy efficiency of equipment or systems;

2. employment of ventilation strategies based upon dilution, filtration, or elimination of pollutants;

3. the minimization of maintenance;

4. use of renewable energy;

5. utilization of natural ventilation when appropriate;

6. monitoring of indoor air quality; and

7. control of outside air supply based on indoor air quality.

3.8 Environmentally Sensitive Building Products and Systems

3.8.1 Establish objectives and a preference for the use of environmentally sound building materials, products, systems, and design features that:

1. are produced with renewable energy;

2. are produced using environmentally sound methods;

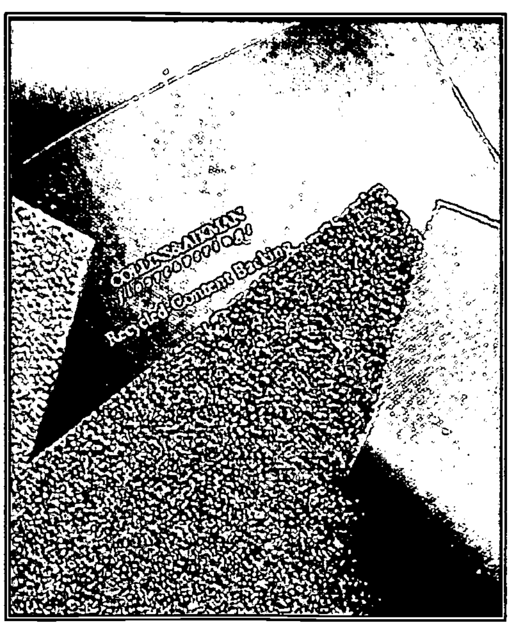
3. are produced locally;

4. employ local labor;

5. can be obtained with a minimum of shipping;

6. are made from recycled material;

100% recycled-content backing carpet



Courtesy of Collins & Aikman Floorcoverings.

7. contain low levels of embodied energy (i.e., do not require a lot of energy for manufacture and transport);
8. contain low-toxic or non-toxic materials;
9. are recyclable;
10. can effectively utilize renewable energy as a power source;
11. are energy-efficient to operate;
12. utilize a minimum of water;
13. have low maintenance requirements; and
14. utilize low- or no-polluting processes to maintain.

3.9 Indoor Air Quality

3.9.1 Establish objectives regarding indoor air quality that:

1. define a level of indoor air quality desired during occupied times;
2. place limitations on the use of materials, products, or systems that adversely affect biological, chemical, or physical aspects of indoor air quality; and
3. employ monitoring equipment.

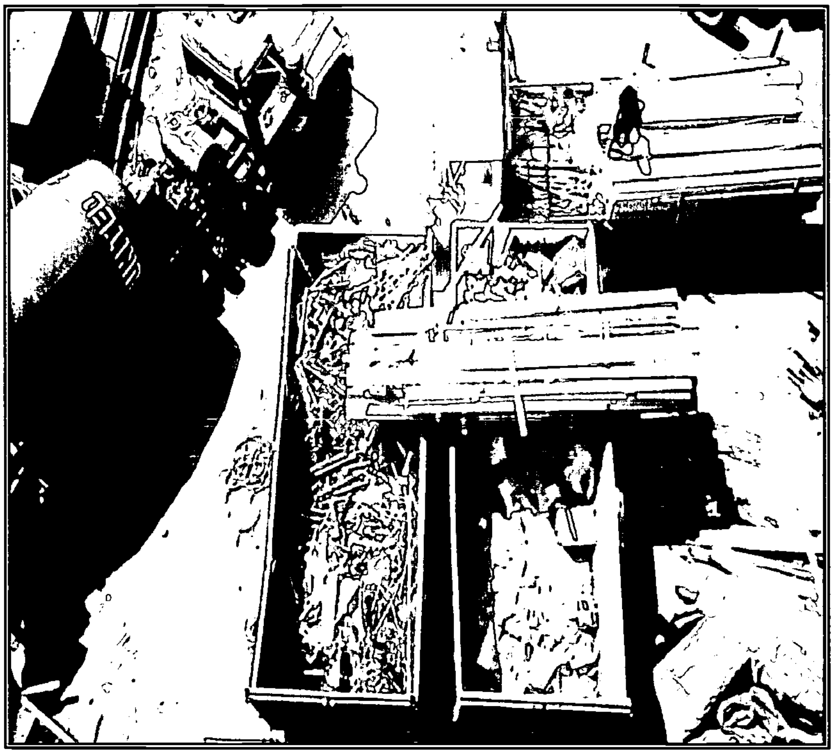
3.10 Recycling Systems and Waste Management

3.10.1 Research local landfill costs and the value of (and markets for) recycled construction materials.

3.10.2 Determine local options for collecting waste materials for recycling.

3.10.3 Establish objectives regarding:

1. the selection of materials (e.g., glass, paper, aluminum, etc.) that will be recycled once the facility is operational;
2. the limitations of certain waste products from going to landfills;
3. the utilization of recycled products or materials in construction;
4. the collection, sorting, and appropriate disposal (including recycling and composting) of waste materials generated on site;
5. the selection of waste materials from construction that will require recycling by contractor; and

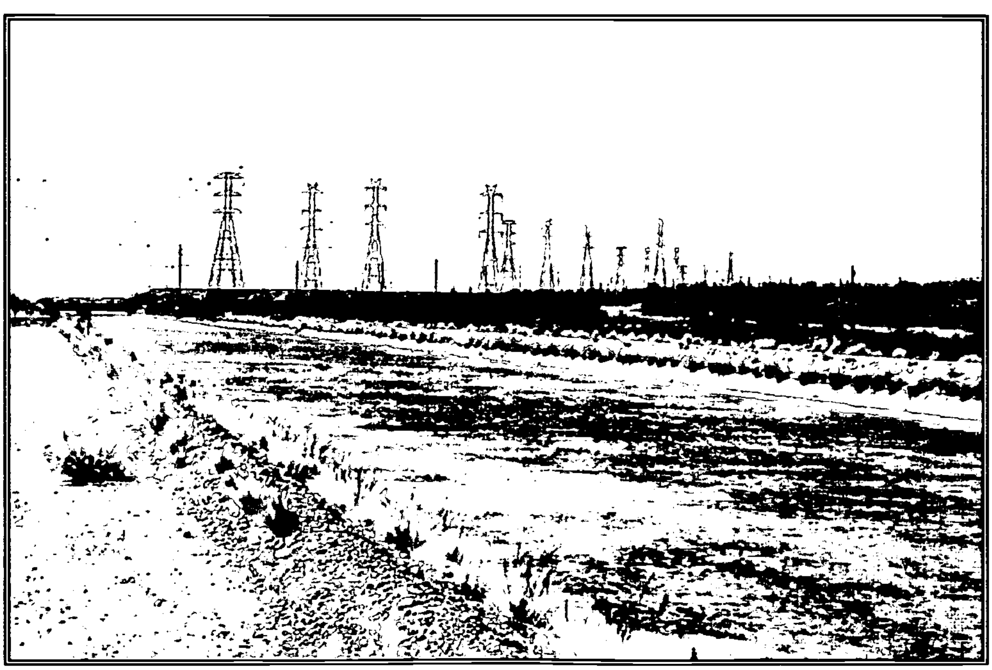


Separation of construction waste for future recycling

Photo: Benchmark Construction, Inc.

6. use of materials and products from demolished schools.

3.11 Water Conservation



California Canal, Picture Innovative Design, Inc.

Cost of Water Inflation Rate

In evaluating water conservation measures, the design team should analyze options based upon a life-cycle cost approach similar to that used in evaluating energy options. In determining the best options, an inflation rate of 10% per year should be assumed. This inflation number will be updated by Clark County Schools in 2005.

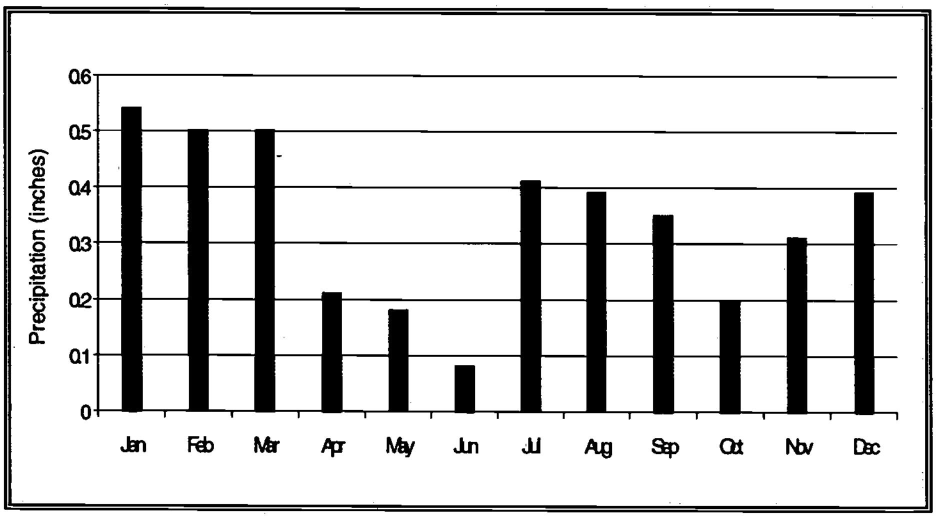
Type of project	**Projected life of Facility**	**Timeframe for LCC Analysis (% and year)**
New Construction	40 years	50%, 20 years
Renovation	*	50% *

* On renovation projects, Clark County School District and the Design Team will determine the projected remaining useful life of the facility or equipment. This projected life figure should be multiplied by the percentages listed above in order to determine the actual number of years to use in the life-cycle cost analysis.

3.11.1 Evaluate information on water, including:

1. seasonal and annual rainfall and frequency of storm events; and

Precipitation Data, Las Vegas, NV (*1969-1998*)



Source: Data published by NCDC Asheville

2. quality and cost of municipal water.

Water Cost : 1999 Annual Average for Clark County Schools

School Type	Average Cost	Average Consumption
Elementary School	$10,966 /school	19, 739,000 gallons
Middle School	$22,590 /school	42,920,000 gallons
High School	$51,939 /school	103,878,000 gallons

Source: Clark County School District

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3.11.2 Gather information on sewage treatment and costs.

3.11.3 Establish objective regarding:

1. graywater usage; and
2. water conservation.

3.12 Transportation

3.12.1 Evaluate locally available transportation options.

3.12.2 Establish objectives regarding:

1. use of mass transit;
2. potential for students and teachers to walk or bicycle to school; and
3. use of low- or zero-emission service vehicles and buses.

Courtesy of: Ballard Power Systems.

3.13 Commissioning and Maintenance

3.13.1 Establish objectives regarding:

1. commissioning process that would allow for:
   a. adequate outgassing of VOC-containing materials to ensure good indoor air quality and
   b. proper testing of all major mechanical, electrical, solar and daylighting control systems;
2. the level of maintenance required; and
3. the environmental impact of maintenance associated with each building component or system including:

a. use of toxic cleaners;

b. use of polluting replacement components;

c. use of replacement components that are made from recycled or renewable produced materials;

d. use of maintenance operations and practices that are inherently polluting (e.g., mowing grass);

e. minimization of energy and water usage in maintenance operations;

f. handling, storage and disposal of toxic materials;

g. the recyclability of replacement parts, components;

h. minimization of packaging of replacement parts, components;

i. use of lease programs that maximize recycling potential (e.g., carpet leasing); and

j. minimizing personal travel associated with maintenance activities.

3.14 Eco Education

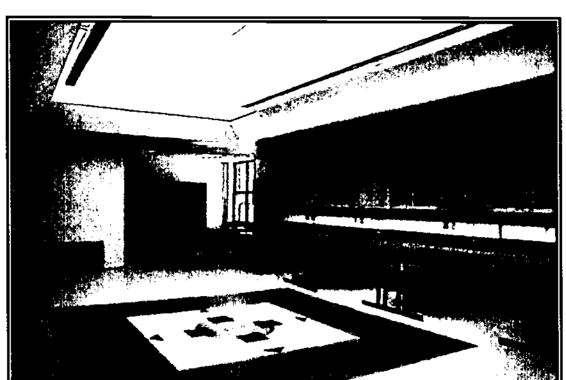
3.14.1 Establish objectives regarding:

1. development of a design which reflects the importance placed on sustainability by the school board;

2. inclusion of renewable energy technologies and energy-efficient and environmentally sound building elements that can serve as instructional aids and teaching tools;

3. inclusion of renewable energy technologies and energy-efficient and environmentally sound building elements which will be an integral part of students' eco education (e.g., greenhouse for growing plants);

4. incorporation of artwork and graphics in design that would help to educate students about the sustainable design elements of the school or provide an environmental message;



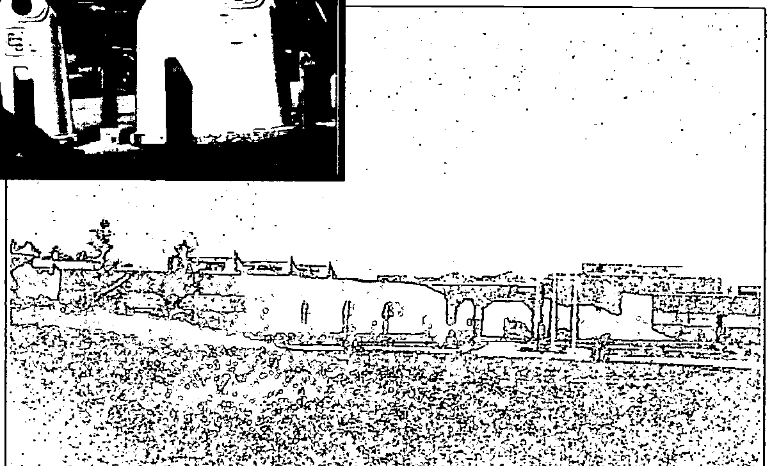
Floor tile compass, Innovative Design, Inc.

5. retention of ecosystems and wildlife habitats surrounding the school for incorporation into learning activities;

Photo: Roy Beaty, Portland Oregon

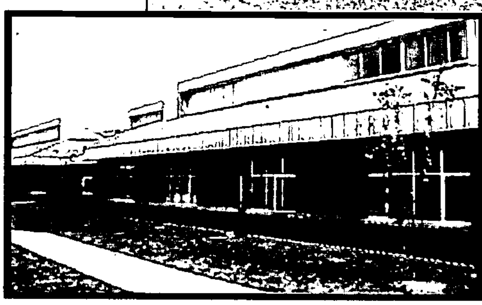
6. integration of recycling systems that encourage student interaction; and

7. development of videos that help explain the sustainable design elements to students and teachers, how to utilize them, why they were incorporated, and what they will save.



Section 4

SCHEMATIC DESIGN



4. SCHEMATIC DESIGN

4.1 General

4.1.1 Conduct energy simulations of the entire school to determine interrelationships of key energy-saving measures being considered.

4.1.2 Conduct life-cycle cost analysis to prioritize energy saving measures and select those with the highest value, while staying within budget. Because of a lack of detail at this stage it is often necessary to make assumptions on costs and benefits that can be verified in later analysis.

4.1.3 Utilize acceptable energy simulation computer software, project the anticipated energy requirements by major categories of use.

1. heating
2. cooling
3. lighting
4. ventilation
5. hot water
6. miscellaneous electrical

4.1.4 Compare this to typical school consumption patterns and compare overall projected consumption to Energy Budget and Goal.

4.2 Site Planning and Landscape Design

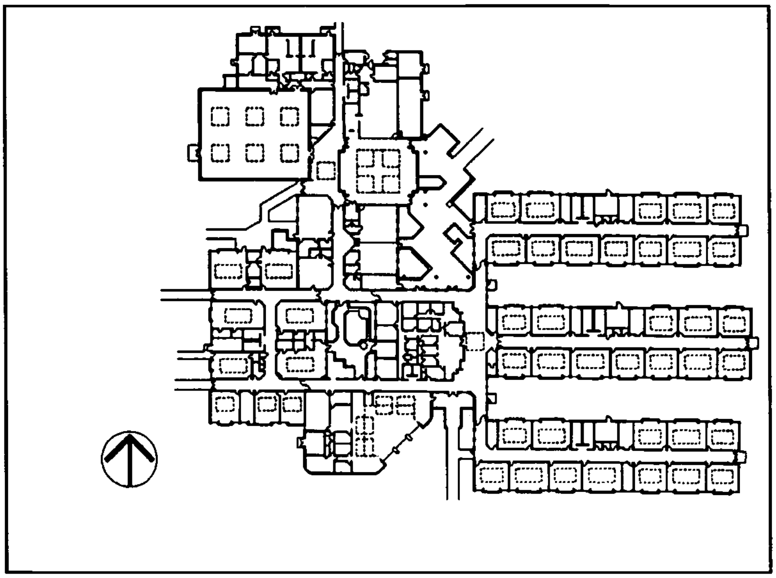
4.2.1 When considering the site during schematic design:

1. Visit site and evaluate existing conditions carefully.
2. Establish building orientation on east-west axis to maximize solar access.

Solar Access and Building Form

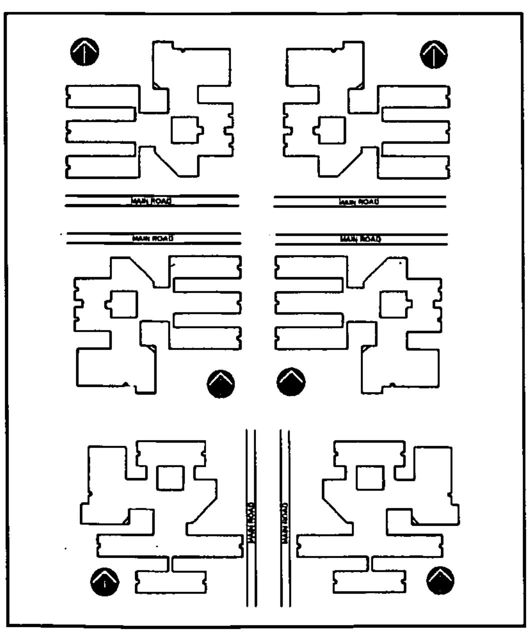
The process should begin by thinking of how the positive aspects of solar energy can be capitalized on while protecting the building in times of unwanted solar gain. The most critical energy decision that is made is building orientation. To maximize daylighting benefits, the building should be properly oriented in relationship to the path of the sun.

Creating a design that maximizes the potential for cost-effective daylighting is greatly enhanced by elongating the school on a east-west axis. Daylighting strategies using south- or north-facing glass are much preferred because unwanted, excessive radiation is much easier to control. An elongated building that has its major axis running east-west will also increase the potential for capturing winter solar gain as well as reducing unwanted summer sun that more often strikes on the east and west surfaces. Open, western exposures should be avoided wherever possible in that they will result in excessive summer cooling loads.



Typical floor plan – Innovative Design, Inc.

Because of site constraints beyond the design team's control the perfect southerly orientation is sometimes not practical or even feasible. In these cases it is equally important to analyze the impacts of the various strategies which could be employed to control solar gain throughout the year. In these less than ideal situations it is almost always feasible to integrate daylighting strategies on a limited basis. For example, windows on the south side of a square building could still be increased in size, while those on the east and west could be reduced.



Optimal orientations of a prototype daylit school
Source: Innovative Design, Inc.

3. Employ one-story design to maximize daylighting.

4. Protect and retain existing landscaping and natural features.

5. Siting should protect or restore ecosystems and wildlife habitats.

Utilizing natural landscape features – Picture: Innovative Design, Inc.

6. Consider erosion control and storm water management issues.

7. Utilize earth-berming where appropriate.

8. Through site design, provide for maximum access to public transit, bicycle routes, and pedestrian pathways from residential areas surrounding the site.

9. Minimize impervious surface area on site.

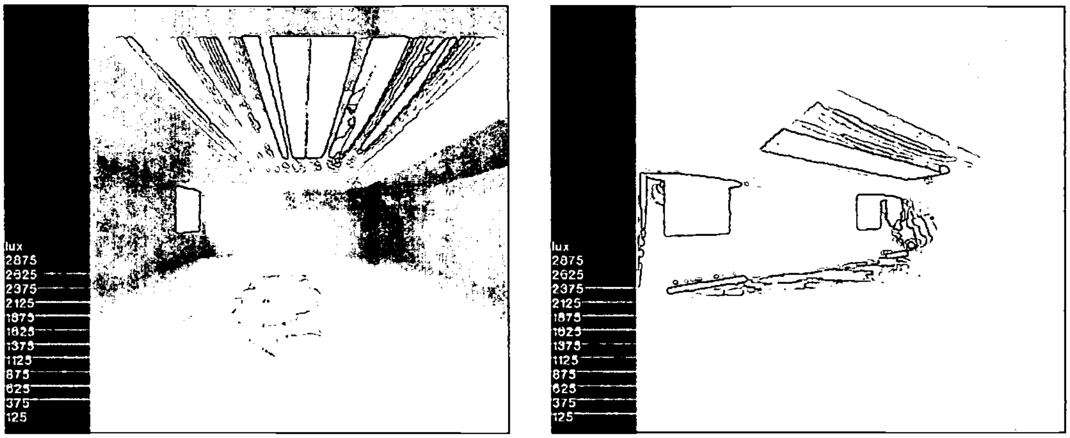
10. Consider wind patterns during site design to maximize positive benefits of natural ventilation in swing months and minimize negative impacts of cold winter winds. During schematic design, a graphic should be developed to illustrate the site planning impacts from wind, sun, and other environmental considerations.

4.3 Daylighting

4.3.1 Develop a plan that is conducive to daylighting all well utilized spaces in a manner that is integrated into the anticipated structural and roof systems.

4.3.2 Design a daylighting strategy that is superior to conventional lighting, providing adequate natural lighting for at least two-thirds of the daylit hours.

4.3.3 Using computer software, conduct daylighting simulations of representative major spaces (e.g., classroom, gym, cafeteria, media center) and incorporate into full building energy analysis to determine overall effectiveness of design.



Classroom daylight "Radiance" simulations - Innovative Design, Inc.

4.3.4 Based upon life-cycle cost analysis evaluate energy savings in relation to anticipated costs (including cost offsets on mechanical and electrical equipment) and determine level of daylighting to be implemented.

Daylighting

Because lighting is a significant component of a school's energy consumption, consideration of various daylighting options should be a high priority. Daylighting not only has positive energy ramifications but has also helps to create a better living environment and, in turn, increased productivity in the school.

Controlled daylighting can reduce both lighting and cooling energy usage. The reason is simple - electric lights actually produce more waste heat energy than light energy. In the warmer months, this heat must be negated through either ventilation or air conditioning. Sunlight, on the other hand, is a cooler light. When properly designed, windows, clerestories and roof monitors can provide a large portion of the lighting needs, without as much undesirable heat or glare.

The following chart, showing the lumens per watt, indicates the strong advantage of utilizing daylighting or more efficient lighting sources. The more lumens per watt, the less heat that enters into the conditioned spaces. One lumen of light per square foot equals one footcandle.

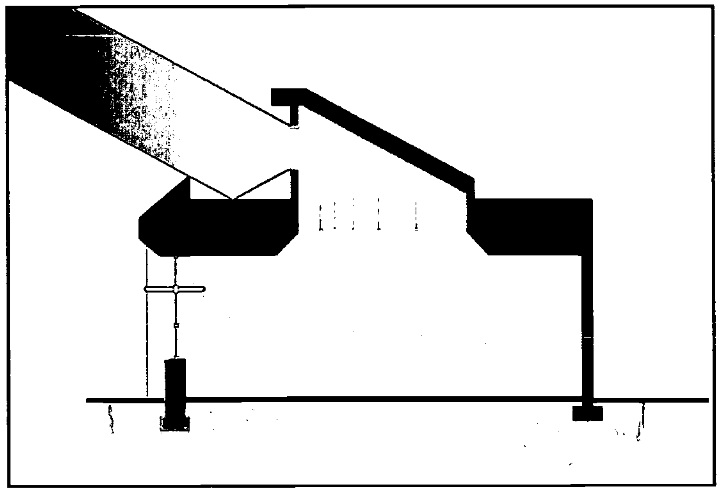
LUMENS PER WATT FOR VARIOUS LIGHTING SOURCES

LIGHTING SOURCE	MEAN LUMENS/WATT APPROXIMATE
Beam Sunlight/Diffuse Skylight	110 – 130
High-Pressure Sodium	32 – 122
Metal Halide	54 – 92
Fluorescent (T-12/T-8/T-5)	82 – 95
Incandescent	13 – 17

Source: Manufacturer's literature (Philips, Osram Sylvania, General Electric)

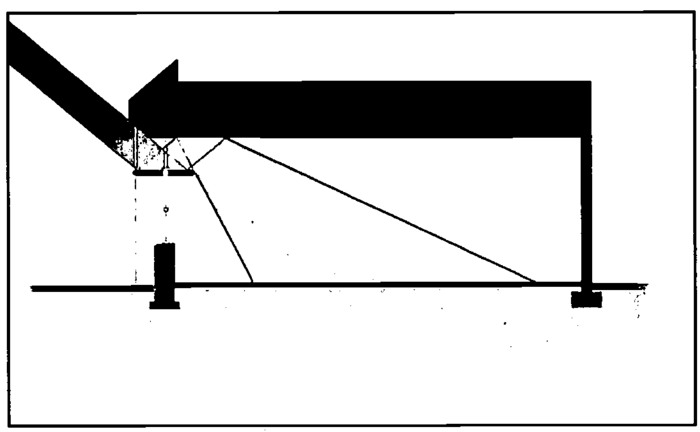
In Clark County, schools are cooling-dominated. But there is still some advantages in also addressing passive heating benefits as long as it doesn't negatively impact summer cooling. Properly designed south-facing monitors, or windows with lightshelves, can accomplish both. By facing the glass south and providing overhangs that maximize winter gain but block the majority of direct solar gain during summer peak cooling times, an optimum solution is possible. Because cooling loads are a greater concern, it is very important to size the glass area so that during times of peak cooling no more solar gain is allowed to enter into the space than is necessary to provide the required lighting levels.

If designed correctly, this entering sunlight will generate less heat for the same amount of light, meaning that in addition to the lights being off, the peak cooling mechanical load will also be reduced.



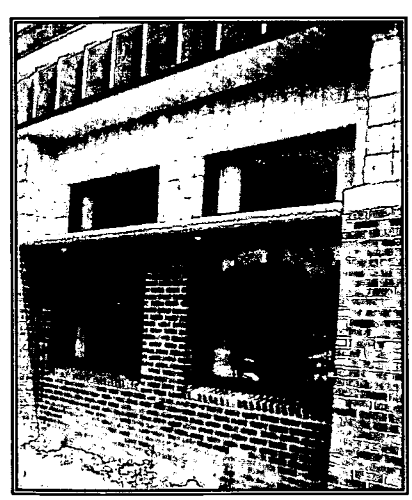
Cross section of south-facing classroom roof monitor - Innovative Design, Inc.

South-facing roof monitors, coupled with interior baffles can provide uniform light within the room while, very importantly, eliminating glare. The baffles block any direct beam light from getting into anyone's face while diffusing and directing the light downward.



Light shelf section – Innovative Design, Inc.

A south-facing window can be easily transformed into a well controlled lighting source by adding a light shelf a couple of feet down from the top of the window. The light shelf, made of a highly reflective material like aluminum, will bounce the sunlight that hits on the top of the surface deep into the building. The reflected sunlight will hit the ceiling and, in turn, provide light for the room. This is a very effective strategy for rooms up to 20 feet deep and can be employed in multi-story schools or where roof monitors are not possible. The light shelf also serves the vital role of shading the window below.



South facing lightshelf - Innovative Design, Inc.

4.4 Energy-Efficient Building Shell

4.4.1 During schematic design, energy analysis should investigate the inclusion of key building shell elements including:

1. radiant barriers in roof;
2. superior insulation levels in excess of code requirements;
3. infiltration and exfiltration barriers;
4. high-efficiency windows (low-e glazings with argon in areas not utilized for daylighting);

Window Types and Locations

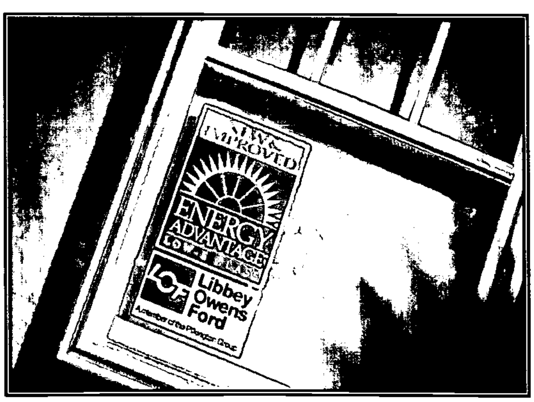
Decisions regarding the type and placement of windows can either dramatically hurt or significantly enhance a building's energy performance and comfort. On the positive side, windows can allow sunlight to enter into a space, helping reduce both the lighting and heating requirements. They can also be effectively used for natural ventilation. But, if not properly designed, increased glass can cause increased problems. Energy inefficient windows can create conductive heat losses in the winter, be a constant source of air infiltration, and cause overheating in the summer months.

Solar Transmission Values For Typical Glass Types

Glazing Type	Solar Transmission	Equivalent U-Valve
Clear, Single	75% - 89%	1.11
Clear, Double	68% - 75%	.49
Low-e, Double, Clear	45% - 55%	.38
Low-e, Tinted, Grey	30% - 45%	.38
Low-e, Argon	45% - 55%	.30

External window shading can be an effective strategy since it stops unwanted solar gain from entering the building. Numerous specialized products are available such as canvas awnings, solar screens, blinds, shutters and vertical louvers.

If properly sized, fixed overhangs on south-facing windows can block a large portion of the summer sun, while still admitting winter radiation. From a practical standpoint, windows on the east and west sides (because of the much lower sun angles) can not be shaded with fixed overhangs and should typically be equipped with vertical louvers or reflective coatings.

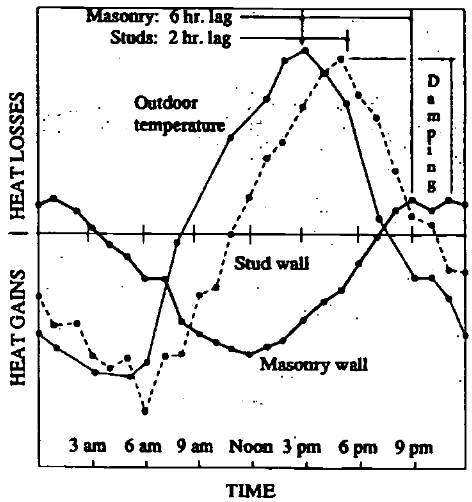


Low E-glass window, courtesy of: Libbey Owens Ford

5. high-mass walls to increase lag time of temperature flows;

Thermal Mass in Walls

Massive wall materials provide significant cooling benefits by retarding summertime heat gain, moderating interior temperature swings, and helping shift heating and cooling loads to off-peak hours when electricity is less expensive. In evaluating building construction techniques, it is appropriate to address the mass issue while also looking at the building shell and insulation levels, the more mass you have, the less insulation you need. Appropriate levels of thermal storage are often available in many typical wall and floor construction techniques (i.e., brick-block cavity walls, concrete floors). In Clark County an important consideration is the relationship between the wall insulation and the mass. To maximize the impacts of massive walls consideration should be given to incorporating cavity walls or masonry walls with exterior insulation systems.



Thermal Storage

Using high- mass wall construction creates a lag time between the outside environment and the inside. This allows for conditioning the interior during off-peak hours (when the high-mass materials release the stored thermal energy).

Proper management of a building's thermal storage has resulted in 10-35% reductions in peak electrical use in commercial buildings; and energy cost savings of from 10-50% have been found with time-of-use utility rates.

Source: *Concrete Masonry Manual, 1997,* Carolinas Concrete Masonry Association

6. internal mass to stabilize temperature fluctuation;

7. light colored wall and roofing materials; and

8. overhangs and exterior shading.

4.4.2 The arrangement of spaces within a floor plan plays a major role in determining how the whole building will perform from an energy consumption and peak load perspective. By understanding the anticipated internal loads and time-of-use characteristics for each major space, individual rooms can be most logically located to maximize the desired natural energy flows

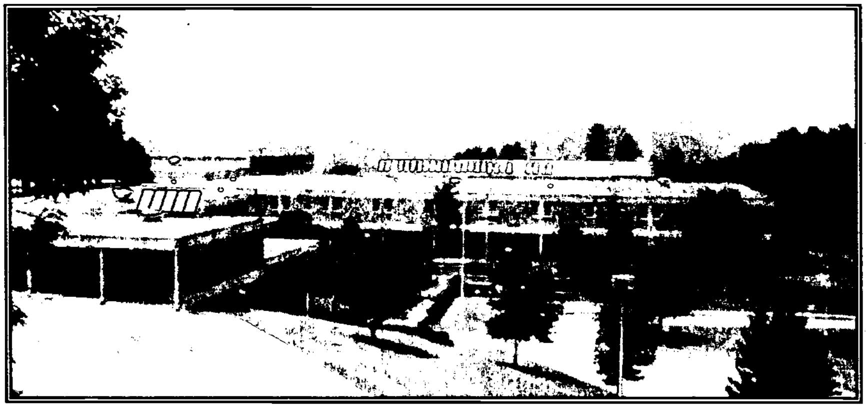
4.4.3 Based upon preliminary costs and generic characteristics of each measure being considered, use life-cycle cost analysis to evaluate the energy savings in relation to anticipated costs and determine measures (and level of energy-efficiency) to be included in design.

4.4.4 Based upon past evaluation, grouping some of the above measures into logical levels of efficiency may help expedite this schematic design evaluation. Final determination on marginal items relative to inclusion into project will be made in construction documents phase.

4.5 Solar Systems

4.5.1 During schematic design, energy analysis should investigate the inclusion of solar systems (note: daylighting included in section above) that would:

1. have a significant impact on the heating and cooling loads (e.g., solar driven absorption cooling systems);
2. be integrated into the building shell design, thus having an impact on the overall design (e.g., building integrated photovoltaics); and



Rooftop solar hot water panels - Innovative Design, Inc.

3. have significant form or functional impact and will be included for educational purposes (e.g., greenhouse).

4.5.2 Systems to be analyzed during schematic design typically include:

1. solar thermal systems utilized for absorption cooling;
2. large solar domestic hot water or space heating systems;
3. building-integrated photovoltaic systems;
4. greenhouses;

Integrated greenhouse – Picture: Innovative Design, Inc.

5. solar electric charging stations for electric vehicles; and

6. wind generators located on site.

4.6 Energy-Efficient Lighting and Electrical Systems

4.6.1 The daylighting analysis in this phase will depend upon the extent to which daylighting strategies could reasonably be incorporated in the overall design.

1. If significant daylighting is to be incorporated, assume that standard back-up lighting systems will be used in the daylit spaces. This is because the amount of time that the electrical lighting is on will be minimal and it will be difficult to justify the more energy efficient, state-of-the-art, lighting strategies.

2. If daylighting is not possible within well-utilized spaces, it will be necessary to compare various lighting and ballast combinations to determine the optimum design.

Energy-Efficient Lighting Systems

In many school buildings the electric lighting often accounts for 30% of the total electric bill, while also adding significantly to the air conditioning requirements. Because it is such a big energy factor, lighting offers some of the best opportunities for energy savings. Because of this, daylighting and energy efficient lighting solutions should be carefully reviewed early in the design process. During schematic design, the various daylighting options should be analyzed in relationship to shell design options. In areas where natural daylighting is not practical or in spaces utilized predominantly during nighttime hours, energy efficient lighting becomes even more important. Lamp selection is critical because of the wide range in the lumens delivered per watt of electricity.

The following table shows the approximate range of lamp/ballast combination characteristics based on data applicable to the most commonly used lamps within each lamp category. Data are provided for general comparative purposes only. Actual performance of a lamp with regard to any of the factors indicated will vary due to the uniqueness of a specific installation. Efficiency of an installation depends on far more than lamp or lamp/ballast efficiency.

Type of Lamp	Typical Wattage	Initial Lumens per watt*	Mean Lumens per watt*	% Lumen Maintenance	Average Rated Life (Hours)	Warm-up/ Restrike (Minutes)	Typical CRI***
Low Pressure Sodium	18-180**	62-150	60-143	100	10-18,000	7-15	-44
High Pressure Sodium	35-1000	35-135	32-122	90-91	10-24,000+	3-4/.5-1	20-70
Metal Halide	50-1500	64-115	50-92	77-80	10-20,000	2-5/10-20	60-90
Mercury Vapor	50-1000	30-60	23-46	75-89	16-24,000+	5-7/3-6	15-30
Fluorescent	20-215	70-104	80-104	82-95	12-20,000+	Immediate	53-98
Incandescent	60-1500	15-20	13-17	85-90	750-2500	Immediate	100

* Includes ballast losses; ** Lamp wattage increases with use; *** Color Rendition Index

Developed by Padia Consulting from Manufacturers of lamps and ballasts (Philips, Osram Sylvania, General Electric).

4.6.2 Conduct a preliminary life-cycle cost analysis on the feasibility of including fiber optic lighting systems in non-daylit spaces where:

1. task lighting is required;

2. lamps are difficult to access; and

3. heat generated by conventional fluorescent lighting and ballasts will result in considerable localized heat build-up.

4.6.3 In conjunction with the daylighting analysis, evaluate staged and dimmable lighting controls (note: This evaluation is integral to routine daylighting analysis programs) including:

1. staged lighting levels tied to a photocell that operates banks of lights in one to four stepped increments; and

2. dimmable lights, individually controlled by dedicated photocells.

4.7 Energy-Efficient Mechanical and Ventilation Systems

4.7.1 During the schematic design phase all major heating, ventilating, and air conditioning (HVAC) system options should be evaluated on the basis of Life Cycle Cost Analysis. This analysis should take into consideration the following:

- Equipment first costs
- Energy and operating costs
- Maintenance/replacement costs
- Time value of money and interest rates
- Inflation rate

This analysis should also incorporate the evaluation of different fuel and energy source options over the life-cycle period. There are many alternative designs that can be used to supply air conditioning to a building. The final selection of an air conditioning system should be primarily based on the option with the least life cycle cost. Other secondary factors like space requirements, degree of control, maintenance factors, flexibility, need for individual zoning, acoustics, reliability, and off-hour operation should also be considered.

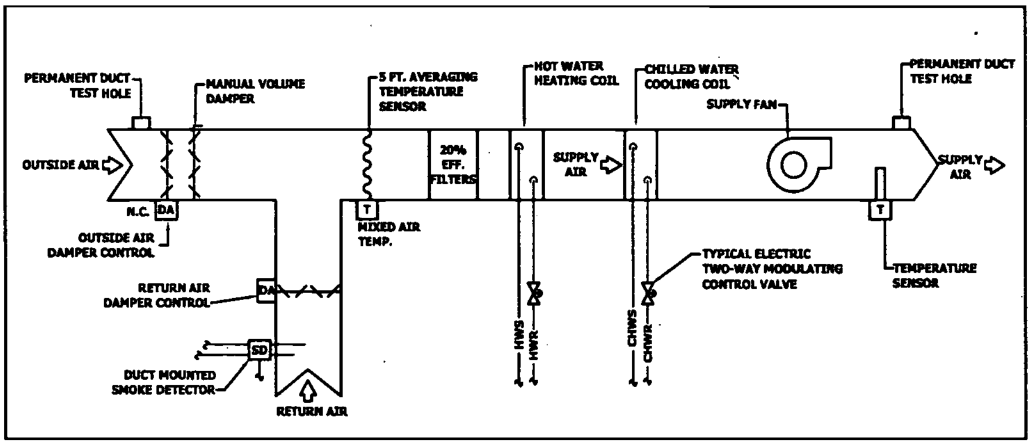
Systems that first cool the air and then reheat it, or mix cold and hot air, are energy wasteful. Systems in this category include: constant volume zone reheat, constant volume terminal reheat, two pipe perimeter induction, constant volume dual duct, and constant volume multizone.

The most efficient systems minimize the energy required during operation by matching their air supply to the load without adding a penalty for reheat. These include: variable air volume for interior air supply with perimeter radiation for heating, interior variable air volume with perimeter constant volume, and interior variable air volume central air handling supplying air to variable air volume terminal units equipped with re-heating coils.

At least four (4) HVAC systems should be identified and life cycle cost analysis performed on them. There are many options available with central plant-hydronic and central plant air delivery systems. These include:

1. Single zone air handling units (AHU's) with chilled water for cooling produced by either an air-cooled screw chiller, a water-cooled screw chiller, a water cooled centrifugal chiller, or a solar assisted with back up natural gas absorption unit and hot water for heating provided by natural gas-fired hot water boiler. Each single zone air-handling unit can serve as many as six classrooms.

Single Zone Constant Volume Air Handling Unit With Chilled Water Cooling Coil and Hot Water Heater Coil



Source: Padia Consulting

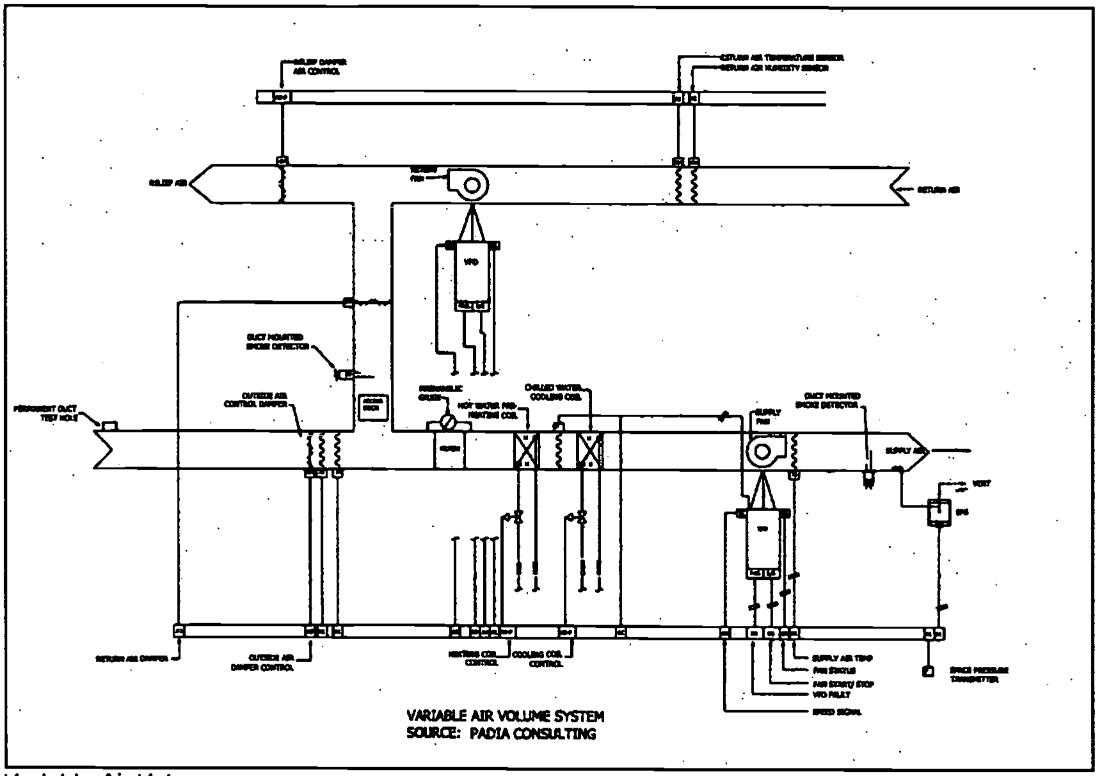
This single zone system utilizes an air-cooled screw chiller, water-cooled screw chiller, or a water-cooled centrifugal chiller for cooling, and natural gas hot water boilers for heating. Standard central station air handling units with chilled water and hot water coils are utilized for constant volume air or variable volume air distribution to classrooms and support areas. A single zone air-handling unit should be used for up to six classrooms.

2. Variable air volume (VAV) central air-handling units with VAV terminal units equipped with reheat coil. The chilled water for cooing produced by an air-cooled screw chiller, a water-cooled screw chiller, a water-cooled centrifugal chiller, or a solar assisted with natural gas back up absorption unit and hot water for heating provided by natural gas-fired hot water boiler.

Variable Air Volume

A modulating variable air volume (VAV) system circulates only the air required under part-load conditions and thus, with proper equipment selection, the fan energy consumed is substantially less than with a constant volume system. Several different types of variable air volume systems are available today and should be investigated prior to selecting one which will be most appropriate.

The economic benefit of the VAV systems will depend, to a great degree, on the cooling and heating load profile. A wide variation in solar transmission and people load and a high ratio of perimeter to interior area are the conditions that will generally require less energy for operation with a variable air volume system than with a constant volume system.

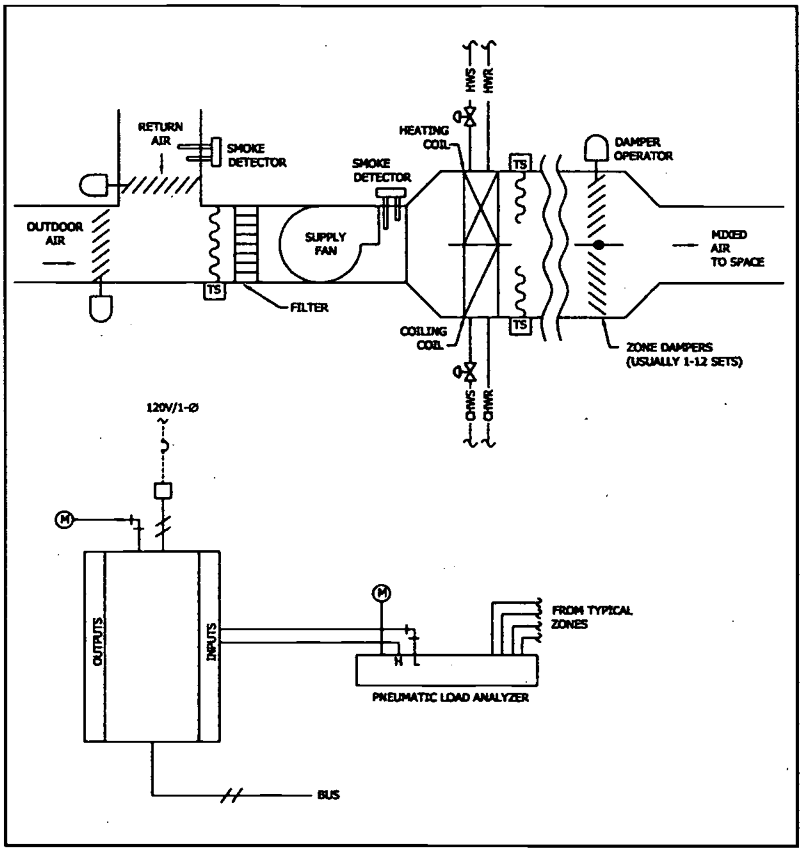


Variable Air Volume
Source: Padia Consulting

3. Multizone air handling units with chilled water for cooling provided by either an air-cooled screw chiller, a water-cooled chiller, a centrifugal chiller, or a solar assisted with natural gas back up absorption unit and hot water for heating coil provided by natural gas-fired hot water boiler.

The multizone system conditions all the air at the central system. One of the basic differences from the single zone system is the location of the final heating and cooling coils. The coils are located one above the other or in parallel and separated by ductwork. This provides a separate hot deck and cold deck. The requirements of the different zones are met by mixing cold and warm air through zone dampers at the central air handler in response to zone thermostats. The mixed conditioned air is distributed throughout the building by a system of single zone ducts. Zone mixing dampers are controlled by individual space thermostats. Multizones are available either as packaged rooftop units, complete with all components, or field fabricated systems.

A three deck multizone unit (cold, hot and recirculated air) is also available to overcome the energy inefficiencies for mixing heated and cooled air to the zones. The control is the same, but the dampers are liked so they mix heated and recirculated air or cooling and recirculated air. They never mix heated and cooled air.



Multizone System

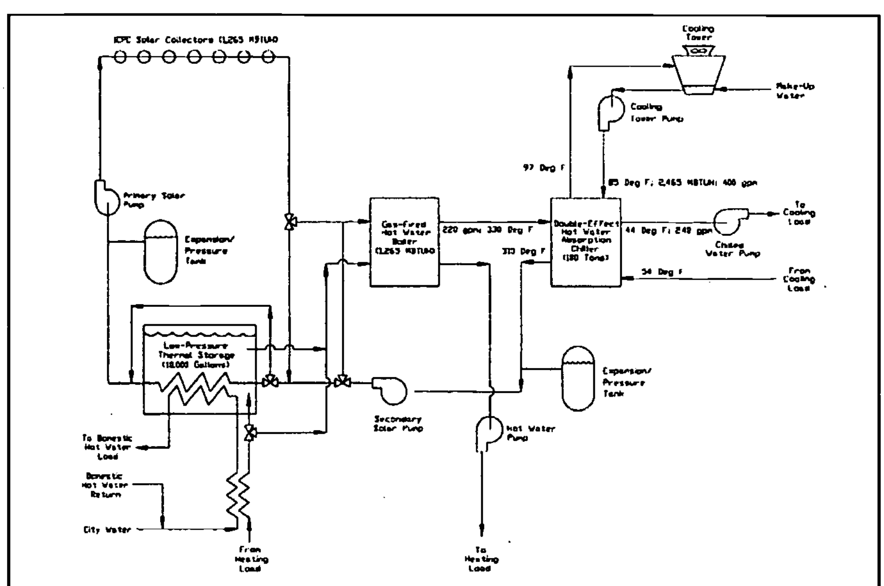
Source:
Padia Consulting

Typical Mulizone DDC Panel

Source:
Padia Consulting

4.7.2 Consider solar assisted, natural gas backup, absorption unit for cooling.

Solar Driven, Absorption Cooling



Source: Duke Solar

Direct-fired absorption (DFA) chillers can use hot water or steam produced by solar energy and natural gas (as backup fuel) to fire an absorption refrigeration cycle. The advanced double-effect reverse cycle used in these chillers can result in the coefficient of performance (COP) exceeding 1.1, including burner losses. This level of efficiency enables direct-fired absorption chillers to compete with electric centrifugal chillers in many parts of the country, where electricity prices have risen dramatically over the last decade and/or where higher than normal amounts of solar energy can be harvested to produce hot water or steam. What makes these units unique is their ability to operate in either a cooling or heating mode. This flexibility is of particular interest for applications that need chilled water for space cooling during the summer and hot water for space heating during the winter.

4.7.3 Direct and indirect evaporative cooling. These systems can be used to reduce the amount of energy consumed by mechanical cooling equipment.

Direct and Indirect Evaporative Cooling

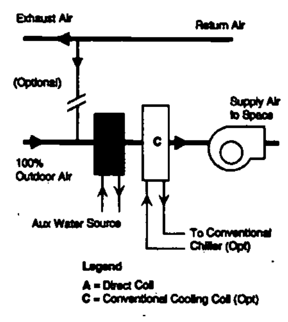


Figure 1
Direct Evaporative Cooling

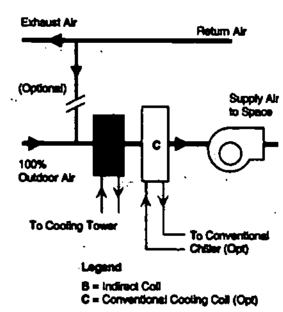


Figure 2
Indirect Evaporative Cooling

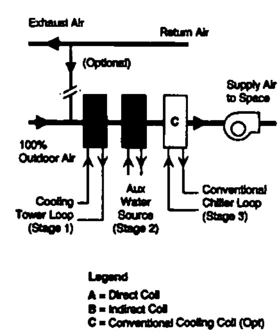


Figure 3
Staged Evaporative Cooling

Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan.1996"

Direct evaporative cooling (Figure 1) introduces water directly into the supply airstream - usually with a spray or wetted media. As the water absorbs heat from the air, it evaporates. While this process lowers the dry bulb temperature of the supply airstream, it also increases its wet bulb temperature by raising the air moisture content. By contrast, indirect evaporative cooling (Figure 2) uses an additional waterside coil to lower supply air temperature. The additional coil is placed ahead of the conventional cooling coil in the supply airstream, and is piped to a cooling tower where the evaporative process occurs. Because evaporation occurs elsewhere, this method of "precooling" does not add moisture to the supply air, but is somewhat less effective than direct evaporative cooling. A third option blends both the direct and indirect evaporative processes. Combined or staged evaporative cooling (Figure 3) systems are arranged so that the indirect coil is activated first partially reducing the supply air dry bulb temperature without increasing its moisture content. The supply air then passes through the direct coil where the dry bulb temperature is further reduced with only a slight increase in moisture content.

4.7.4 Different strategies to ensure adequate fresh/ventilated air and free cooling should be evaluated including:

1. photocatalytic oxidation air treatment;

2. economizer cycles;

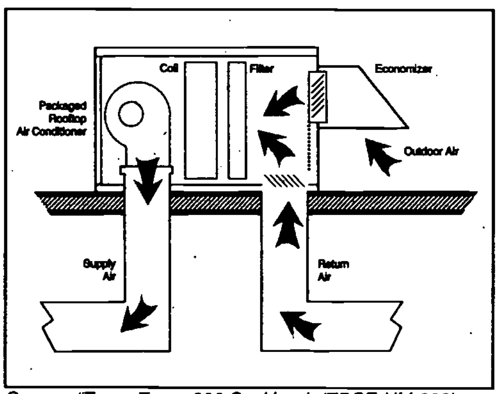
Free Cooling Cycle (Air and Water)

Some cooling without refrigeration can be accomplished when the total heat content of the outside air is less than the total heat content of air at the inside design conditions. Most of the cooling can be accomplished without refrigeration when the dewpoint of the outside air is at or below the dewpoint of air required to offset the internal heat loads.

The basic system for free cooling is to provide for variable outdoor air inlet and variable return air disposal up to the full capacity of the air circulation system. Through the use of a proper control sequence of return and outside air dampers, the return and outdoor air are mixed to produce the required supply air temperature.

In Clark County where design wet bulb is relatively low compared to climate in other states, it is highly beneficial to include the water side economizer in the design of the HVAC system. For single fan multi-zone and dual-duct systems, it should be noted that the free cooling cycle can impose a greater load on reheating some zones than is saved in the free cooling. Care in the design of the control system can minimize this condition. However, other HVAC system options applicable to Clark County Schools are more suited to the economizer cycle.

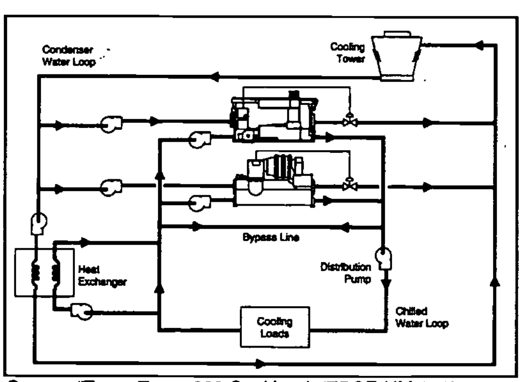
Airside Economizers



Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan.1996"

An airside economizer cycle can lower cooling energy consumption by using as much as 100% outside air. When ambient conditions are such that the outdoor air will provide natural cooling, the economizer introduces this air directly into the building. Control of the economizer cycle is typically accomplished by monitoring the enthalpy of the outdoor air and comparing it with predefined, often user-selected, limits. Once ambient conditions fall below the predefined enthalpy limit, economizer cooling is initiated. As the outdoor air temperature (and enthalpy) drops, the position of the outdoor/return air dampers is modulated to maintain the desired supply air temperature.

Plate-and-Frame Free Cooling



Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan.1996"

This diagram indicates the addition of a plate-and-frame heat exchanger to pre-cool the chilled water before it enters the evaporator. When the ambient wet bulb temperature is low enough, the heat exchanger allows the transfer of heat from the return chilled water to the water returning from the cooling tower. Lowering the temperature of the water entering the evaporator reduces both chiller loading and energy consumption.

3. heat exchanger options, including those with coil to coil heat recovery and enthalpy heat wheels;

Heat Recovery and Waste Heat Systems

Significant energy savings can be achieved through the re-capture of waste heat. Outdoor air can be preheated in the winter and precooled in the summer by the exhaust air, using heat exchangers between the outdoor and exhaust air streams. To provide exchangers to transfer sensible heat only is less costly than for both sensible and latent heat. However, many applications can use both effectively.

Utilization of waste heat or energy rejected at one level can be used for another process. Waste heat is available from many processes rejected heat of compression, refrigeration units, building exhaust air, heat from lights, hot water drains, and solar energy which has been stored in the building mass. A high degree of integration of systems is required to make maximum use of this energy but there is a very high potential for energy conservation.

It is important not to unnecessarily degrade heat which has been stored for later use. Multiple storage tanks are useful to take maximum advantage of the thermodynamic quality of the stored energy.

Coil-to-Coil Exhaust Air Heat Recovery

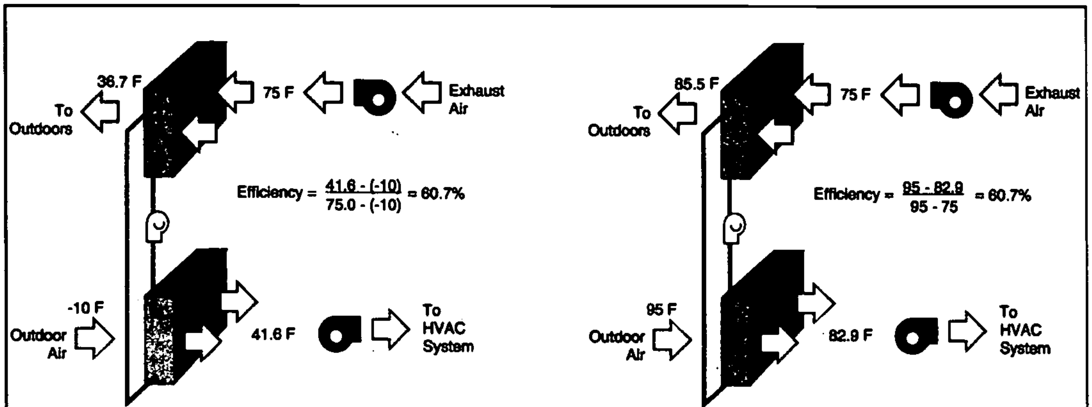


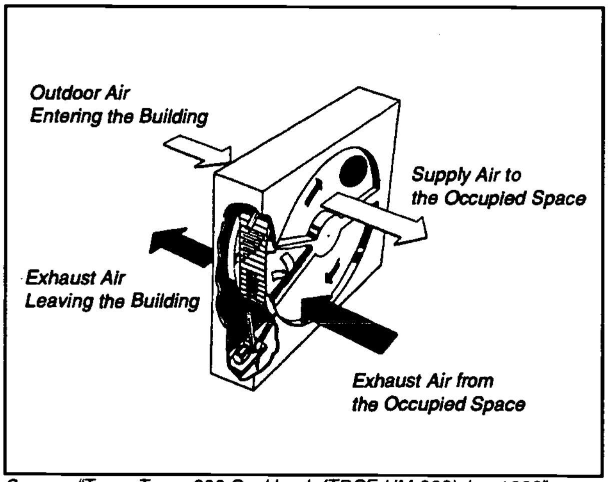
Figure 1
Winter Operation

Figure 2
Summer Operation

Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan.1996"

An exhaust air heat recovery system is used to reduce energy consumption by capturing the energy that would normally be lost to the exhaust airstream. Coil-to-coil exhaust air heat recovery can be applied to pre-cool and pre-heat outside/ventilation air. During "winter" operation (Figure 1), heat extracted from the exhaust airstream is used to pre-heat the temperature of incoming outside air. Preliminary warming of the outside air reduces the heating load placed on the HVAC equipment and, in turn, reduces energy consumption. Summer operation (Figure 2) of the coil-to-coil exhaust air heat recovery is used to pre-cool incoming air and thereby reduces the energy consumption of the cooling equipment.

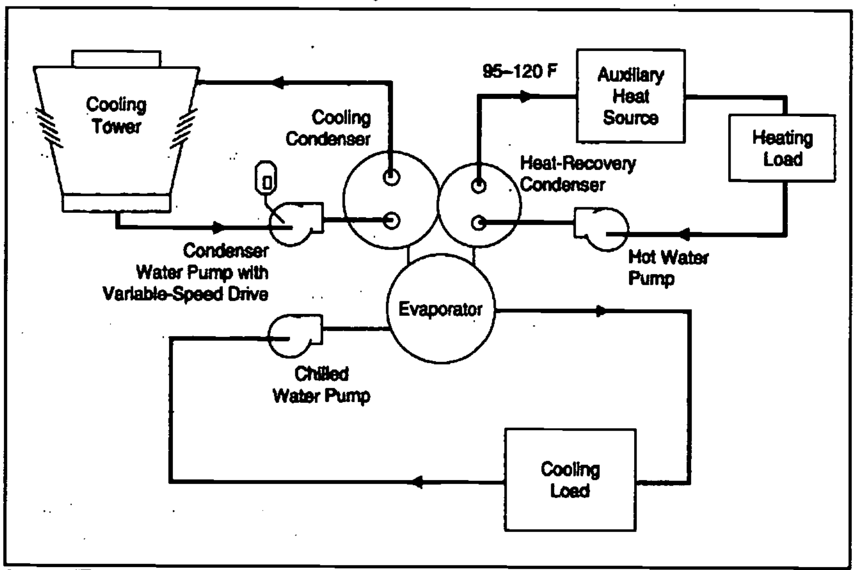
Enthalpy-Wheel Exhaust Air Energy Recovery



Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan.1996"

The increased outdoor/ventilation air requirement mandated by ASHRAE Standard 62-1989R creates the opportunity to use heatwheels to realize significant energy savings. Heat is recovered by passing adjacent supply and exhaust air streams through the wheel in a counter flow arrangement. The exchange medium inside the wheel transfers sensible heat by recovering heat from the hot air stream and releasing it to the cold one. Latent heat transfer occurs as the medium collects moisture from the more humid air stream and releases it, through evaporation, to the drier air stream.

Double-Bundle Condenser Heat Recovery



Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan.1996"

The "waste heat" which is normally rejected to the cooling tower from the chiller's cooling condenser bundle is recovered and used to heat - or preheat – domestic hot water and/or for space heating. An example of a typical heat-recovery chiller application is illustrated above. In this instance, the rejected heat is used to satisfy concurrent cooling and heating loads. When a heating load exists, waste heat is recovered by reducing the amount of heat rejected to the cooling tower. This is accomplished by varying water flow to the cooling tower. Depending on the characteristics of the application and the heat-recovery chiller selected, hot water temperatures ranging from 95 F to 120 F can be obtained.

4. low-grade solar air heating options; and
5. inclusion of pollutant sensors with above options.

4.7.5 Thermal Energy with Ice Storage systems should be considered when there are:

1. high electric demand charges coupled with low electricity pricing during off-peak hours;
2. large, on-peak cooling load conditions and small after hour cooling loads.

Thermal Energy with Ice Storage (TES)

Thermal storage (TES) is the temporary storage of energy for later use. It usually involves storage of coolness that was generated electrically during off-peak hours for use during subsequent peak hours. Reducing electrically generated cooling during on-peak hours by using or supplementing the cooling load with thermal energy storage can reduce the cost of energy and also can save energy.

Conditions that favor TES include:

1. High electric demand charges
2. Low cost electricity during off-peak hours
3. High on-peak loads
4. Small after hours cooling loads like computer rooms, offices, etc.
5. Need for back-up cooling.
6. Need for increased capacity.

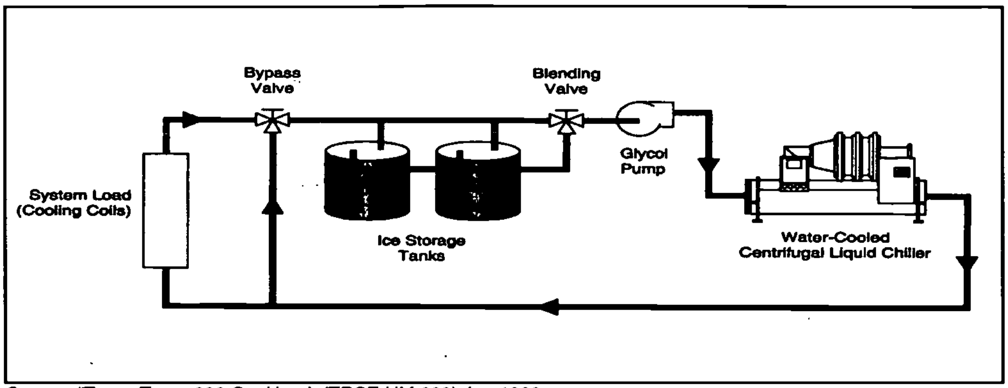
Some of the ways that TES systems can save energy are:

1. During the charging phase, the chiller can be operated at its Best Efficiency Point (BEP)
2. Ambient conditions are normally favorable (lower temperature) during the off-peak hours (typically 9:00 p.m. to 6:00 a.m.) for more efficient chiller operation.
3. Chilled water distribution system can be smaller if ice or low temperature fluid systems are used.
4. Longer energy availability period compared to energy use permits small heating and cooling equipment requirements.
5. Air handling units and their distribution systems can be reduced in their sizes using higher air temperature differential.

Two storage strategies are typically used for TES systems. Full storage systems generate and store the entire cooling (or heating) load at off-peak periods for use during the following on-peak periods. Partial storage systems generate and store only a portion of the daily load at the off-peak period. During the on-peak period, the building total load is supplied by simultaneous operation of the cooling (or heating) equipment and withdrawal from storage.

Thermal Energy Storage (with ice)

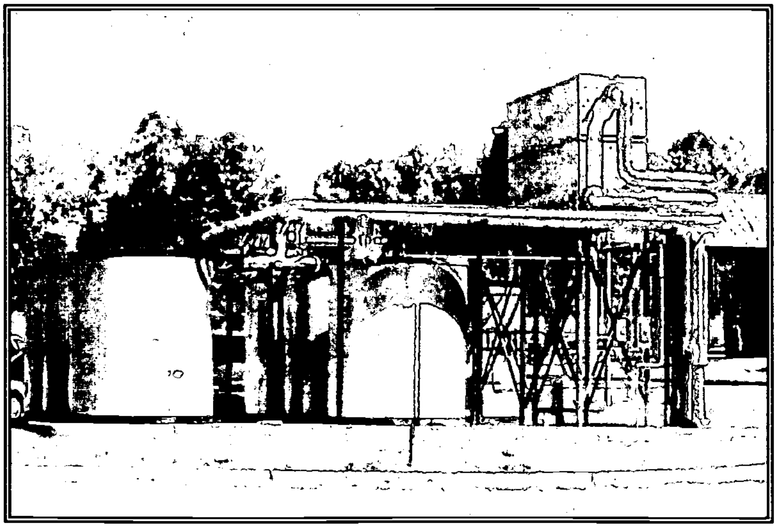
Ice storage tanks, like those shown in the schematic below, are often used as a means of thermal storage. During off-peak (low utility rate) periods, the chiller cools a glycol/water mixture to a leaving temperature of approximately 23 F. This mixture is then circulated through tubes within the ice storage tank, where it freezes the surrounding water.



Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan. 1996

Also, there are many other benefits which can be derived from the low temperature thermal storage concept, particularly when it is used in conjunction with a variable air volume (VAV) fan system:

- Substantial savings in building construction cost through reduction of overall structure height brought about by smaller sized supply air ductwork.
- Significant increase in floor space available through reduction of mechanical room and duct chase area.
- Reduced HVAC construction costs because ducts, fans, coils, filters, and all components associated with air-side systems can be downsized by 40% to 50%.
- Savings of fan energy when compared to conventional all air VAV systems at 55° F supply air temperatures.
- Reduced fan speed sound levels, requiring less sound and vibration treatment to achieve acceptable noise levels in occupied areas.
- Increased indoor comfort because the lower indoor relative humidity allows space thermostats to be set higher than usual.



Ice storage mechanical system

East Clayton Elementary School, Clayton, NC - Innovative Design, Inc.

4.8 Environmentally Sensitive Building Products and Systems

4.8.1 Decisions on most environmentally preferable products and systems will be made during the construction documents phase, but many alternatives are integral to whole system design choices that must be addressed early in the design process. Examples of choices that should be made during schematic design include:

1. fundamental choices about the structural systems and envelope materials, such as the use of locally made masonry products that could be utilized in wall construction, adding thermal capacitance; and

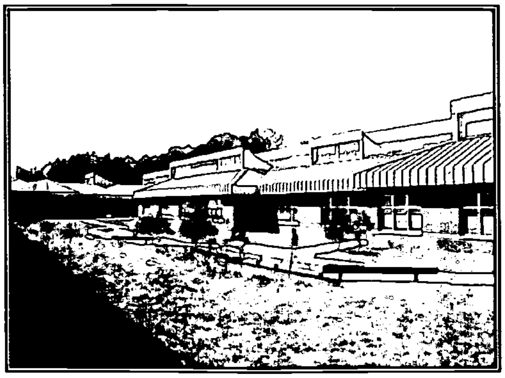
2. restrictions placed upon the use of products containing toxics (e.g. VOCs, formaldehyde, etc.) could help determine ventilation strategies that will logically be determined in the schematic design phase.

4.9 Indoor Air Quality

4.9.1 Key decisions affecting indoor air quality should logically be addressed during schematic design phase if they are to be included in the most cost-effective manner.

These key issues include:

1. natural ventilation strategies in appropriate spaces;
2. separation of vehicle traffic and parking from fresh air inlets or spaces employing natural ventilation strategies;
3. the separation and ventilation of highly polluting spaces (e.g., photocopy room);
4. incorporation of interior planting strategies;
5. the inclusion of photocatalytic oxidation; and
6. the design of conveniently located outside spaces that can be utilized for:
   a. teaching,
   b. breaks and lunch, and
   c. recreation.



Courtyard for outdoor teaching and recreation, Innovative Design, Inc.

4.9.2 ASHRAE Standard 62-1989R (Ventilation for acceptable indoor air quality) should be followed to establish "Design Ventilation Rates" for the times of occupancy. The prerequisites for designing Co_2 Demand Controlled Ventilation System (DCV) controls that reset system ventilation air flow based on sensed carbon dioxide (CO_2) should be reviewed prior to incorporating DCB. Care should be taken to maintain ventilation airflow above the minimum 15 cfm/person required to properly dilute building contaminants during periods of scheduled occupancy or preoccupancy purge.

Ventilation

The term "ventilation air" is that air introduced from outside and processed through either the heating or cooling system or a separate system. The quantity of ventilation air required is determined by the total volume of the building, the number of occupants, the volume of exhaust air for toilets, kitchens, or other exhaust systems, and that required to maintain the pressure within the building slightly higher than outside pressure. Infiltration is that air quantity entering the building through construction cracks and joints around doors, windows, etc., and will not usually be a significant factor if adequate ventilation air is provided and good quality construction technicians are employed.

These should be reviewed for conformance with present day engineering practice recommended by ASHRAE 62-1989R and required by building codes of the State of Nevada. Where codes and standards are deterrents to energy conservation design, the architects and engineers can alternatively utilize fresh air make-up quantities that are tied through pollutant sensors to actual air quality demands. Additionally, air exchangers can be employed to minimize this impact. The designer should incorporate systems which provide for good air quality at the times needed and employ the best strategy to minimize energy losses. Common practice results in use of excessive amounts of outdoor air at all seasons of the year. It is particularly wasteful when spaces are ventilated on weekends and nighttime when the building is sparsely populated or unoccupied altogether. The mode of the building operation and system operation can strongly affect ventilation loads.

Opportunities to reduce the energy demands of ventilation systems include transferring energy from exhaust air to the incoming air stream by heat exchangers that transfer both sensible and latent heat. There are many devices to transfer heat from exhaust air to pre-heat the outdoor air, such as heat exchange coils in each system, heat pipes, thermal wheels, etc. The selection of the particular device depends on the thermodynamic qualities of each air stream, i.e., the exhaust upon the room conditions and the intake upon climatic conditions.

Outdoor air which is used as makeup to replace air exhaust through kitchen hoods imposes a heating and cooling load which can be materially reduced by a direct supply to the hood instead of through the air supply system. Air supplied to a hood need only be tempered in the wintertime and requires no cooling in the summertime.

By comparing enthalpy of the outdoor air with inside design conditions, a determination can be made to operate the free cooling ventilating system during the night to dissipate the heat stored in the building mass during the daytime. A study of the energy thus expended should be compared with the energy of operating the refrigeration compressor, chilled and condenser water pumps, and the cooling tower to accomplish the same result.

In the winter months, consideration should be given to reducing the outdoor air introduced to just equal the general exhaust (toilet & kitchen) at the start of the day if the heat content of the outdoor air is above the heat content of the return air and a satisfactory odor level is not exceeded.

4.10 Water Conservation

4.10.1 Key decisions relating to water conservation, that should be investigated during the schematic design phase, include:

1. the use of graywater (and associated storage) to be utilized for irrigation; and

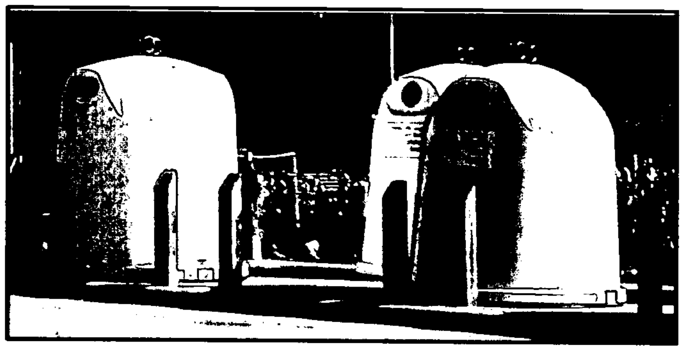
2. the use of alternative fixtures, such as composting toilets, that have different space considerations.

4.11 Recycling Systems and Waste Management

4.11.1 Key decisions relating to recycling and waste management systems that should be investigated during the schematic design phase include:

1. the allocation of space within the design for recycling receptacles and maintenance associated with recycling;

2. access to recycling bins by outside waste collection agencies;



School yard recycling area – Picture: Innovative Design, Inc.

3. space allocated for yard waste and/or composting; and

4. the location of collection chutes in multi-story facilities.

4.12 Transportation

Source: "Renewable Energy, The Infinite Power of Texas"

4.12.1 Key decisions relating to sustainable transportation options that should be investigated during the schematic design phase include:

1. pedestrian friendly site access to community sidewalks leading to residential areas;
2. easy site access for bicycles;
3. secure, protected parking for bicycles;
4. location for solar charging station to service buses or service vehicles; and
5. easy access to public transit stations.

4.13 Commissioning and Maintenance

4.13.1 Maintenance issues to be addressed during schematic design typically are associated with understanding the long-term benefits or liability of one approach versus another and are used in life-cycle cost approaches.

Maintenance team adjusting controls – Picture: Innovative Design, Inc.

4.14 Eco Education

4.14.1 Program decisions regarding design elements that are to become teaching tools or integral aspects of educational programs should be identified and incorporated.

Examples include:

1. greenhouses for growing plants;
2. photovoltaic systems that could serve to educate students about the concepts of solar energy and the conversion of sunlight into electricity;
3. daylighting strategies that could be enhanced through student participation;

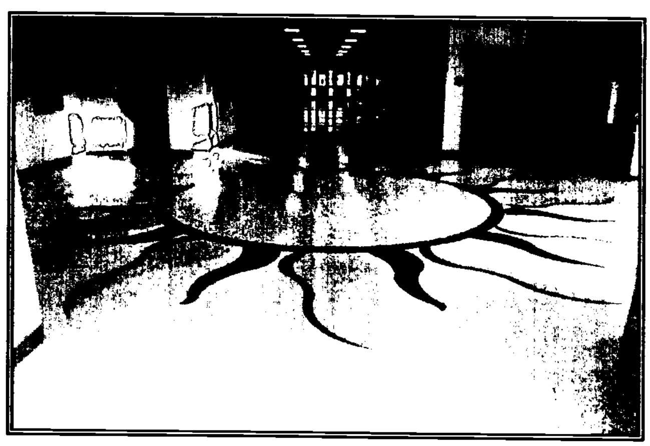
4. use of recycling systems (programs) within the school that the students could participate in;

5. interpretive nature trails through preserved wildlife habitats and ecosystems;

Nature trail for education purposes – Picture: Innovative Design, Inc.

6. the design of environmentally-sound or energy-efficient building components so as to make their purpose and function obvious to students;

7. incorporation of artwork and graphics in the building design which would help to educate students about sustainable design;



Floor tile sun graphic, Dillard Middle School, Raleigh, NC
Innovative Design, Inc.

8. use of outside teaching courtyards and spaces to allow for grouping plants, viewing habitat, and understanding eco-cycle;

9. educational signage about bicycles and other pedestrian-friendly transportation options for getting to and from the school; and

10. interpretive displays showing total energy use at the school and the percentage of energy being provided by renewable sources.

ENERGY STATUS: SCHEMATIC DESIGN REPORTING FORM

Project .... **Project #**.................... **DATE** ....

Submitted By...

Building Type K-5 School .... Middle School .... High School ....
Library .... Gymnasium .... Maintenance.............................
Horizon High Schools...................................... Other ....

Square Footage Conditioned .... Total ....

Project Design Team Architect ....
Lighting / Electrical Engineer ....
Mechanical Engineer ....

Energy Consumption

Energy Budget	....	Btu/Square foot/Year
Energy Goal	....	Btu/Square foot/Year
Energy Projection	....	Btu/Square foot/Year

The analysis of energy consumption is based upon computer simulation of the school facility:

	% of Consumption	Btu/Square foot/Year
Heating	......................%	......................%
Cooling	......................%	......................%
Ventilation/O.A.*	......................%	......................%
Interior Lighting	......................%	......................%
Other Electrical	......................%	......................%
Hot Water	......................%	......................%
Other	......................%	......................%
Total Building	100 %	......................%

* Assume 15 CFM/person ventilation rate

Time Frame for Life-Cycle Cost Analysis

New Construction .... Renovation................ Projected Life Of Facility ....Years

Energy (and Daylighting) Computer Software Program(s) Used

....

....

Anticipated Energy Sources and Systems To Be Utilized

	Fuel/Energy Source	HVAC/Lighting/HW System Description
Heating	....	....
Cooling	....	....
Hot Water	....	....
Lighting	....	....

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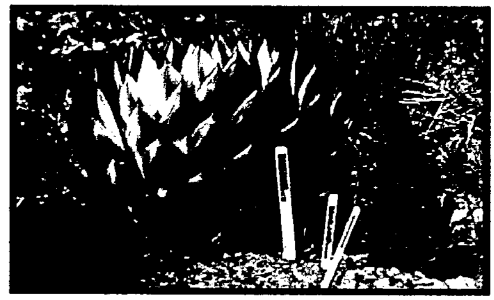
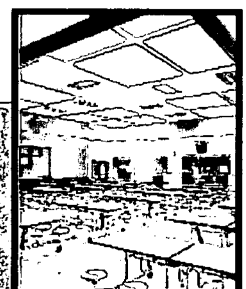
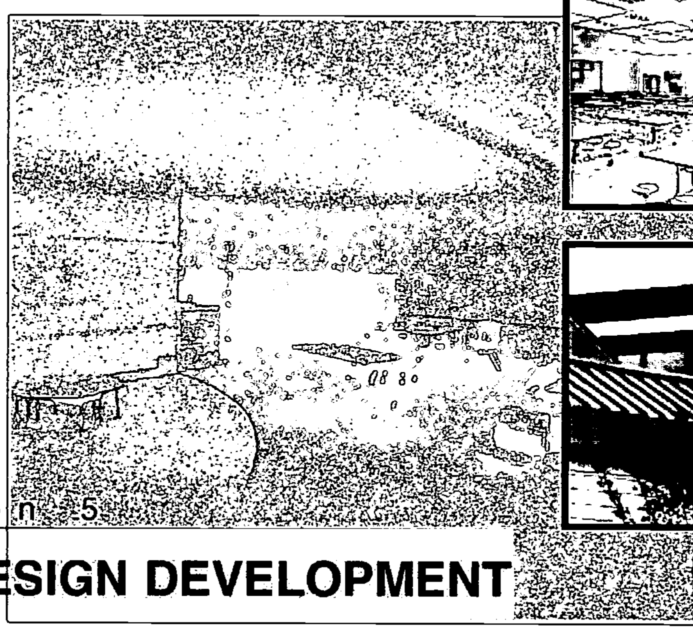






Section 5

DESIGN DEVELOPMENT

5. DESIGN DEVELOPMENT

5.1 General

5.1.1 Verify that energy strategies chosen in schematic design meet the energy budget:

1. If the energy analysis completed in schematic design reflects a projected energy consumption that meets the energy budget, clarify the assumptions that made this possible. Included should be both the primary strategies as well as key secondary measures.

2. If the energy analysis determines that the consumption is close (within 10%) to the energy budget, establish a list of secondary energy saving measures which will enable the objective to be met.

3. If the energy analysis indicates that the primary design strategies selected will not result in the energy budget being met, the primary design strategies should be redesigned.

5.1.2 Using the cost analysis completed in the schematic design phase, and incorporating appropriate modifications, verify that the cost of the green building components including the energy elements are within the overall project budget.

5.1.3 Any significant primary energy strategies or key secondary energy saving measures with major energy impact should be re-evaluated in the context of the total anticipated energy requirements. The total energy analysis should evaluate the following components.

1. heating

2. cooling

3. lighting

4. ventilation

5. hot water

6. miscellaneous electrical

5.1.4 During design development, overall system design should be refined and sub-systems should be clarified. This can be accomplished by analyzing the energy and environmental design considerations listed in this phase.

5.1.5 Evaluate the schematic design to determine if the environmental objectives are being fulfilled by the design strategy and green building components incorporated.

5.2 Site Planning and Landscape Design

5.2.1 Carefully re-evaluate building plan and site plan elements with respect to existing:

1. landscaping,
2. natural features,
3. ecosystems, and
4. wildlife habitats.

5.2.2 Clearly define strategies to utilize existing conditions within the overall design context. Possibilities include:

1. earth-berming to earth-temper the walls where appropriate;
2. contours to better define floor levels and minimize grading; and
3. retain in site features that will enhance eco-educational programs.

Landscape Designer: Ron Mark, The Xeris Group

5.2.3 Refine the on-site erosion control and stormwater management strategies including:

1. employing site contours and natural drainage;
2. minimizing impervious surfaces (i.e., paved areas).

5.2.4 Incorporated into the site plan should be:

1. safe pedestrian pathways leading to residential areas surrounding site and to mass transit;

2. convenient bicycle parking areas for students and teachers; and

3. outdoor teaching and interpretive areas.

5.2.5 The site and building design should reflect a plan that allows for handicapped access.

5.2.6 Site design should allow for maximum energy potential from renewable energy systems that are to be employed including solar and wind.

5.3 Daylighting

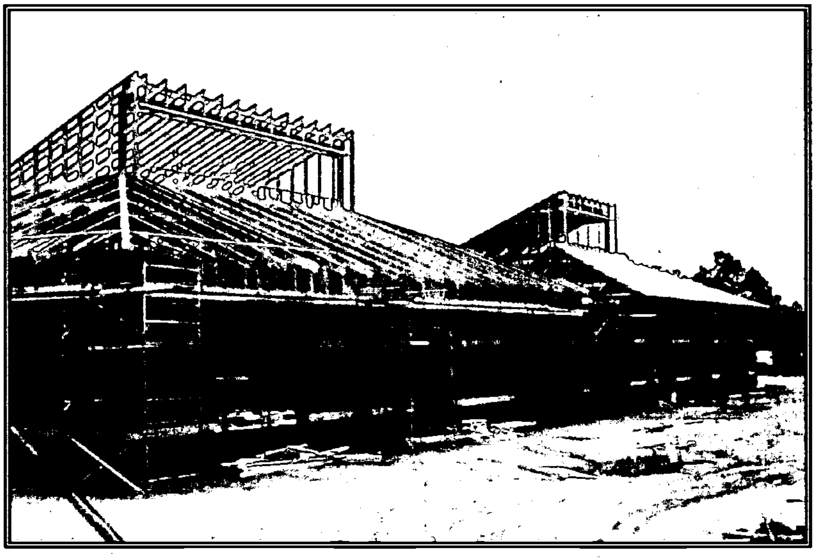
5.3.1 Design daylighting strategies to meet the different program and lighting needs of each major space (e.g., classrooms, gym, cafeteria, media center). Major differences often reflect:

1. differing lighting level requirements;

2. lighting requirements by time of day; and

3. the ability to darken particular spaces for limited periods of time.

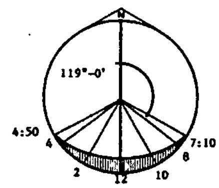
5.3.2 Concentrate on developing an overall building structural design which integrates the daylighting strategies and minimizes redundant structural elements.



Roof monitors under construction, Innovative Design, Inc.

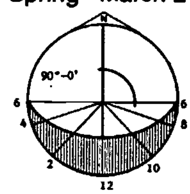
5.3.3 Daylighting apertures should be configured to keep beam radiation off of the glazing during the hottest part of the day during the cooling season. This would mean that east and west glass should be minimized. In Clark County, south facing, vertical glazing is typically better because roof overhangs can be designed to effectively admit low-angle winter radiation for daylighting while still excluding excessive higher angle sunlight, experienced in the warmer months. North glazing is second best in that it doesn't create overheating problems during the cooling seasons but it also doesn't provide any passive heating benefits.

Winter Dec. 22



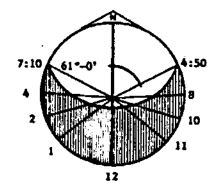
Am	Pm	Azimuth	Altitude
Noon		180° - 0'	31° - 30'
10:00	2:00	149° - 30'	25° -0'
6:00	4:00	126° - 0'	8° - 30'
7:10	4:50	119° - 0'	0° - 0'

Fall Sept 23
Spring March 21



Am	Pm	Azimuth	Altitude
Noon		180° - 0'	55° - 0'
10:00	2:0	135° - 0'	45° - 0'
8:00	4:00	108° - 30'	24° - 0'
6:00	6:00	90° - 0'	0° - 0'

Summer June 22

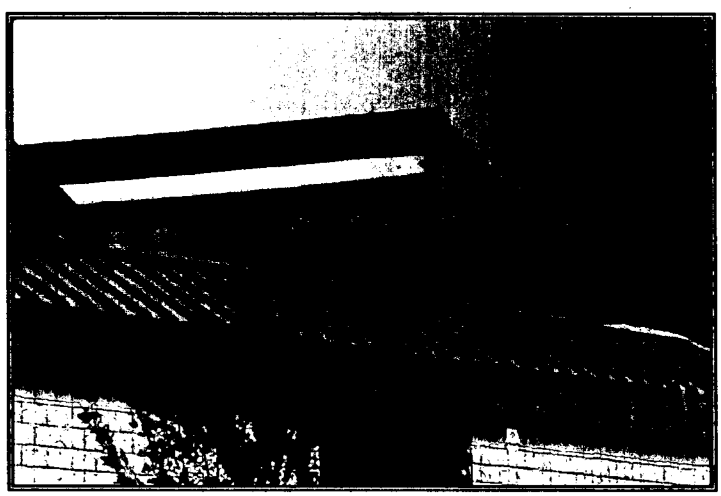


Am	Pm	Azimuth	Altitude
Noon		180° - 0'	78° - 30'
11:00	1:00	127° - 0'	72° - 30'
10:00	2:00	105° - 30'	61° - 30'
8:00	4:00	85° - 30'	37° - 0'
4:50	7:10	61° - 0'	0° -0'

5.3.4 The potential drawbacks of summertime solar gains through south-facing glazing can be mitigated by using a small overhang. An oversized overhang on the south is not recommended on daylighting apertures since it can also block significant amounts of diffuse radiation in addition to the direct beam.

5.3.5 Care should be exercised to not count on low view glass area as being an integral part of the daylighting strategy in that those window may be covered (e.g., with pictures or art work) or closed (with blinds).

5.3.6 Develop a daylighting design with primary emphasis on south- (typically best) or north-facing roof monitors and a secondary emphasis on lightshelves. Lightshelves can significantly enhance the natural lighting uniformity within a space and also provide good lighting in narrow rooms (less than 16 feet to 20 feet).

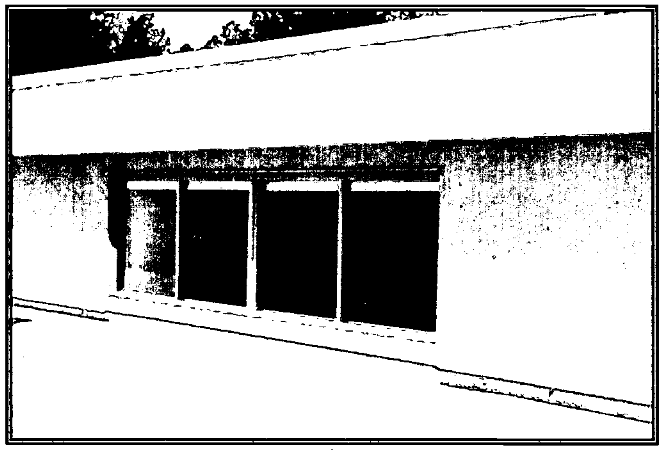


Roof monitor with overhang, Innovative Design, Inc.

5.3.7 Optimize the daylighting strategies by:

1. utilizing roof monitors to evenly distribute light within spaces;

2. using light colored roofing materials in front of roof monitors to reflect light;



White single ply membrane in front of roof monitor, Innovative Design, Inc.

3. reduce glare by preventing direct beam radiation from entering into teaching spaces;

4. filtering, directing, and diffusing radiation;

5. minimizing contrast between light and dark surfaces;

6. minimizing size and maximizing transmission of glass in order to reduce conductive losses;

7. using multi-staged or dimmable lighting controls to enhance the economic benefits and provide for smoother transition between varying light conditions;

8. using light colored finishes in daylit spaces;

9. use photocell controls to turn off exterior lights during daylight hours; and

10. use daylight sensors to dim interior electrical lighting when it is not required.

5.3.8 Vertical windows, located below lightshelves, should be controlled independently of those above the lightshelves. On the south facade daylighting can be enhanced by:

1. incorporating vertical blinds that can focus radiation to the perimeter walls within a space and away from people within the space; and/or

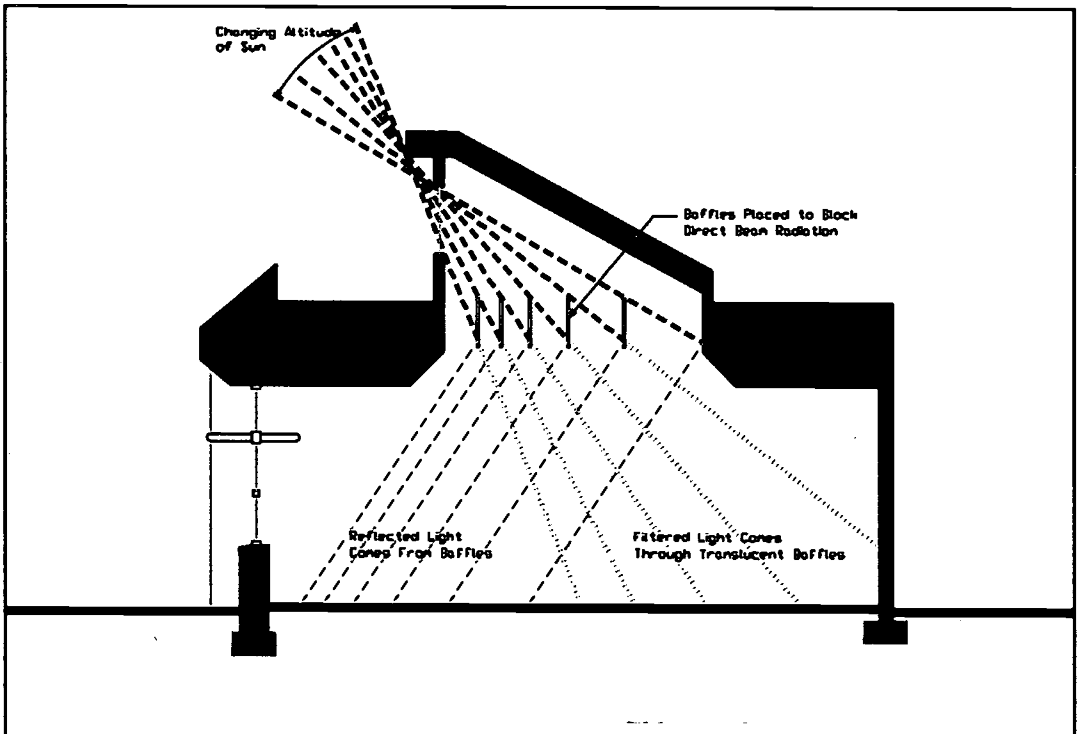
2. using horizontal blinds that can be installed to reflect the light up toward the ceiling, thus reflecting it back further into the space.

5.3.9 The use of blinds, however, should only be used where glare is problematic (e.g., low view glass) or the space requires darkening. Unless the space must be able to accommodate slide presentations (overhead projectors typically do not require darkening) or the use requires darkening (e.g., kindergarten nap time), it is recommended that blinds or other window treatments that could nullify the lighting benefits not be installed at roof monitors (with baffles) or glass areas above lightshelves (that are deep enough to eliminate direct beam implications).

5.3.10 If blinds or rolling dark-out shades are employed it is recommended that they either be motorized or easily accessible and made of durable construction materials and components.

5.3.11 If south-facing roof monitors are employed they should be designed to:

1. employ baffles within the light wells to totally block all direct beam radiation from getting into the face of anyone in the space;
2. block high summer sun with exterior overhangs; and
3. reduce contrast between very bright surfaces and less bright areas.



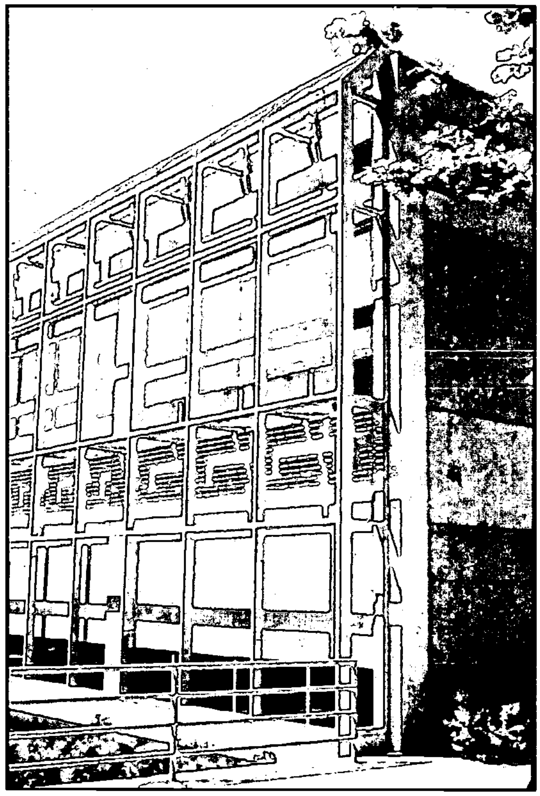
Classroom section, Innovative Design, Inc.

5.4 Energy-Efficient Building Shell

5.4.1 Include building shell elements that will significantly impact energy efficiency, including:

1. radiant barriers in roof;
2. superior insulation levels in excess of building code requirements;
3. infiltration and exfiltration barriers;
4. high-efficiency windows (low-e argon in areas not utilized for daylighting);
5. high-mass walls to increase lag time of temperature flows;
6. internal mass to stabilize temperature fluctuation;
7. light colored wall and roofing materials; and

8. overhangs and exterior shading.



Exterior shading devices, Photo Innovative Design, Inc.

5.4.2 To maximize the benefits of massive walls, cavity walls or masonry walls with exterior insulation systems should be incorporated.

5.4.3 Care should be taken in locating moisture retarders and barriers in order to prevent moisture build-up in wall and ceiling/roof assemblies.

5.4.4 In all cases windows should be of high quality and with thermal breaks. Windows should be designed to meet to overall design objectives but not be oversized. Analyze and select the appropriate glazing choice for each particular application. For example:

1. if windows are oriented east or west and not shaded, the best choices are:
   - tinted, low-e
   - tinted, low-e, and argon
2. if windows are well shaded by the building elements, tinting would not be advised;
3. if windows are physically located close to the floor level (where comfort is a primary concern) and utilized as view glass, the best choice is typically low-e or low-e with argon; or
4. if the glazing is designed for areas above lightshelves or in roof monitors where high light transmission is important, the best option is typically clear, double glazing.

5.4.5 Consider the possibilities for implementing natural ventilation strategies.

5.4.6 Properly size overhangs on roof monitors and above lightshelves to block a large portion of the mid-day summer sun while still allowing the lower winter sun to reach the glass. Other south-, east- and west-facing glass should be either shaded or protected by using tinted glass.

5.4.7 External window shading options are superior to using interior blinds because they block the radiation before it enters into the space. These include:

1. awnings,
2. solar screens,
3. shutters,
4. vertical louvers, and
5. fixed overhangs.

Theoretically, moveable shades perform the best because they can be seasonally adjusted to maximize desirable winter gain while blocking summer radiation.

5.4.8 Radiant barriers should be implemented in roof assemblies. A high-performing roof assembly can also use the radiant barrier as an infiltration/exfiltration barrier with the insulation above the barrier and the ductwork below. This allows the radiant barrier to serve the additional purpose of keeping the ductwork within a semi-conditioned space.

5.5 Solar Systems

5.5.1 Solar systems tentatively determined to be viable during schematic design should be further investigated to determine accurate loading conditions and, in turn, optimum size and space requirements. Start by analyzing:

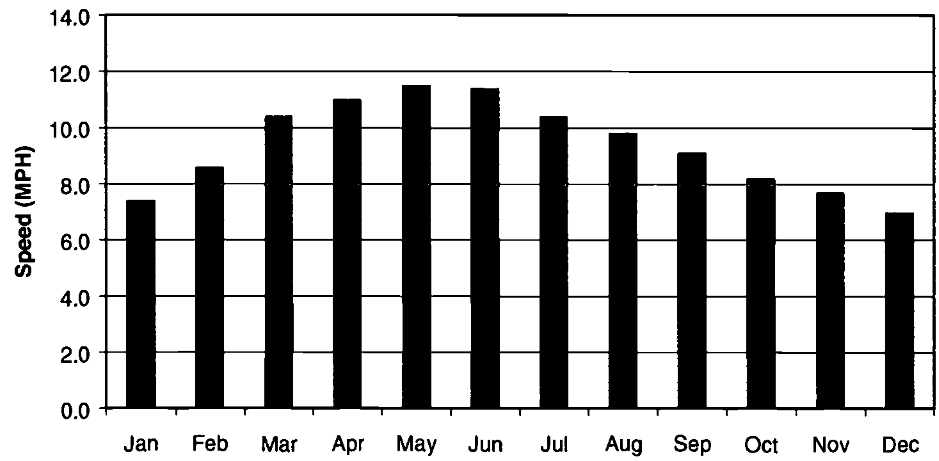
1. the hot water requirement;
2. the space heating load not fulfilled by the mechanical system selected;
3. any fresh air make-up requirement that could be fulfilled with low-grade thermal energy;
4. peak cooling loads having a significant impact on the overall load; and
5. opportunities to reduce peak electrical loads through the utilization of solar and/or wind systems.

Secondly, determine the physical space requirements for solar and/or wind systems by system component. Also address any building code ramifications.

5.5.2 The best available design data (the closest to the site) should be gathered regarding solar radiation and typical wind speeds at the site. The following data shows that Las Vegas's climate is ideal for solar applications and is a relatively good location for wind systems.

Wind Data – Las Vegas, NV

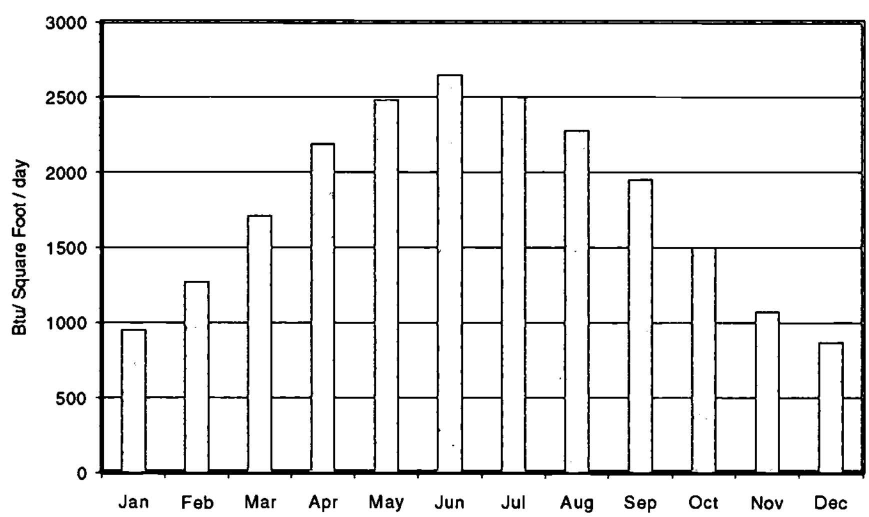
	POR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
MEAN SPEED (MPH)	34.0	7.4	8.6	10.4	11.0	11.5	11.4	10.4	9.8	9.1	8.2	7.7	7.0	9.4
PREVAIL DIR (TENS OF DEGS)	19	25	25	24	22	23	18	18	18	24	24	24	25	24



Source: National Climatic Data Center

Average Incident Solar Radiation (Btu/ft²/day) – Las Vegas, NV

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Solar Radiation	950	1270	1710	2190	2480	2650	2490	2280	1950	1500	1070	870	1790



Source: "Solar Radiation Data Manual for Buildings", NREL

5.5.3 Information should be gathered on the specific program requirements of educational activities that involve renewable energy systems to be employed the building or on the site. This information should be used to maximize the solar or wind system primarily as a teaching tool and, secondarily, as an energy savings measure.

5.5.4 Building-integrated options should be evaluated in terms of detailing and the ability to be incorporated into the other building elements. Particular emphasis should be placed upon:

1. minimizing redundant design elements (e.g., sawtooth photovoltaic array that could serve as the roof of a covered walkway);
2. maximizing non-shaded solar access;
3. placing the system in close proximity to the load or mechanical system servicing the load; and
4. integrating the system into the overall design to improve the aesthetics.

5.5.5 The highest priority systems from an energy savings standpoint typically include:

1. daylighting (see above);
2. solar domestic hot water and space heating systems; and

Solar Hot Water Systems

Solar water heating systems are usually classified by the means of fluid circulation ("passive" or "active"), the means by which heat from the solar collector is transferred to the DHW itself ("direct" or "indirect", or "closed loop"), and the means of protection against freezing.

Passive systems rely on gravity for circulation. Hence, the storage tank usually must be placed above the collector and the number of bends in the collector's supply and return piping minimized, to minimize friction. The advantages of the passive approach include lower cost of components, high mechanical reliability (no pump, etc.) and low operational costs.

Active systems use pumps to force the fluid to the collector. Although this arrangement allows the designer more flexibility in locating the collectors and storage, it introduces the potential of mechanical breakdown, increased maintenance, and the higher cost of the energy needed to run the pump.

Direct systems utilize only one fluid: the water to be heated for use in the building is circulated through the solar collector. Such a system has the advantages of simplicity and efficiency, as it does not require a separate loop of fluid and the attendant piping complications and inefficiencies of heat exchange.

Indirect systems use a closed loop containing a fluid that circulates through the collector and storage tank. The fluid is not mixed with the DHW itself; rather, heat is passed from one fluid to the other through a heat exchanger. One advantage of this system is that it allows nonfreezing solutions to be used in the collector loop. It also allows collectors to be operated at low pressures, rather than at the high pressures typical of urban public water systems. The choice of fluid is determined by its freezing and boiling points, its specific heat, and its level of toxicity.

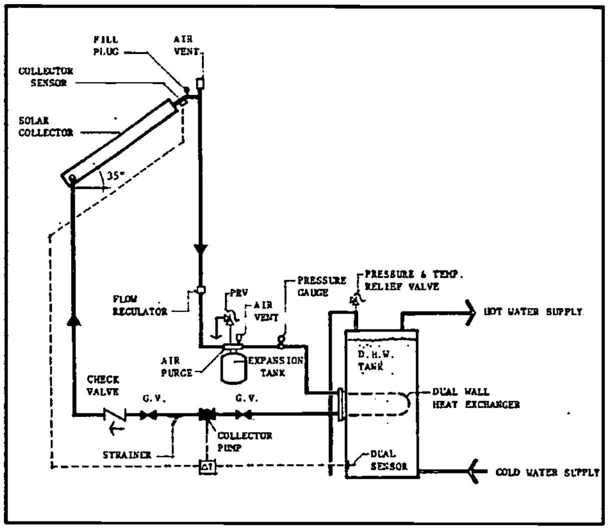
The design elements (passive and active, direct and indirect) are combined in a number of typical solar DHW systems. Brief descriptions of some of the more common systems follow.

Thermosiphon Systems

The sun acts as both the "pump" and the heat source for these systems. With no moving parts, maintenance needs are low. The collector, however, must be lower than the tank, and piping must be kept as simple as possible. Since the coldest water remains in the lower collector at night, the hot water in the upper tank is not threatened with undue heat loss; however, freezing conditions pose a severe threat to the collector. Accordingly, indirect (closed-loop) systems containing a nonfreezing fluid are frequently used; phase-change systems are the cold-winter option for this type of passive system.

Closed-Loop Freeze-Resistant Systems

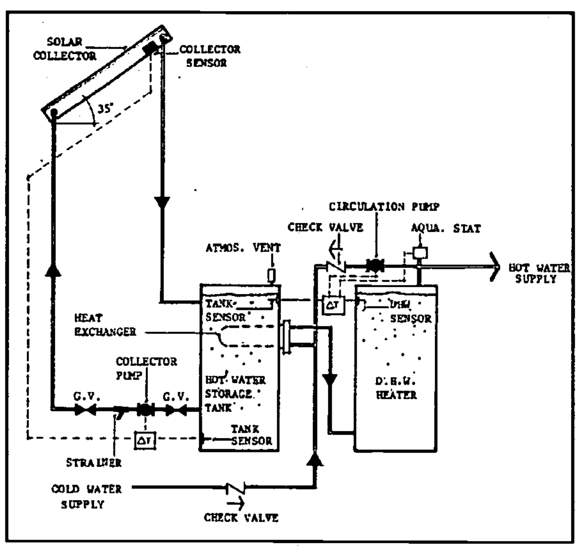
In close-loop systems, small pump circulates non-freezing fluid to the collector when there is sufficient sun. This process is governed by a "differential controller", a device that compares the temperature of the stored hot water to that of the collector. The price of this freeze protection is the inefficiency of the heat exchanger, used between the collector's fluid and the DHW itself. Codes require a double wall between any toxic non-freezing fluid and the DHW, which further reduces efficiency.



Graphic: Innovative Design, Inc

Drain-Back Systems

Although drain-back systems use water as the fluid pumped from tank to collector, the water is not the DWH itself. Instead, the DHW passes through a heat exchanger in the solar storage tank. With the DHW kept out of the collector, the solar collector can operate at lower water pressure. This, however, requires a large heat exchanger. It also requires care in the design and installation of piping between collector and tank, so that the collector will drain thoroughly. When the controller senses that no solar energy can be gathered, it cuts off the pump, and water drains back into the tank. Therefore, the collector will be filled with air, not water, for all nighttime and cloudy-cold daytime hours. This suggests that corrosion inhibitors should be added to the collector/tank's water, because the piping is frequently exposed to air.



Graphic: Innovative Design, Inc

Drain-Down Systems

Drain-down systems are the only active systems that do not utilize heat exchangers; DHW is circulated directly through the collector. Both higher pressure and higher efficiency result. In this system, the collector is usually filled with water that moves only when the differential controller activates the pump. Whenever the outside temperature drops near freezing, the controller activates solenoid valves and the water in the collector is drained down (dumped). Although the lack of a heat exchanger is attractive from the standpoint of cost savings and thermal efficiency, the set of electrically controlled solenoid valves is not foolproof.

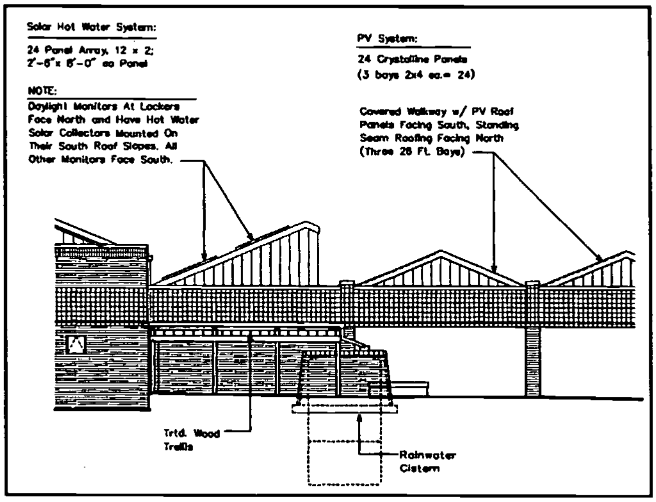
3. passive heating systems including greenhouses.

5.5.6 Systems typically considered to have the a longer payback but, depending upon conditions, could still result in a very good, long-term investment, include:

1. solar thermal systems utilized for absorption cooling;

2. building-integrated photovoltaic systems;

Building Integrated Photovoltaic System, Innovative Design, Inc.



Integration of solar systems in design development, Innovative Design, Inc.

3. solar electric charging stations for electric vehicles; and

4. wind generators located on site.

5.5.7 When evaluating solar systems, analyze any additional heat recovery strategies that could be enhanced through the joint utilization of system component (e.g., thermal storage tanks, control packages, etc.).

5.6 Energy-Efficient Lighting and Electrical Systems

5.6.1 In spaces that incorporate significant daylighting strategies, emphasis should be placed upon an electrical lighting design that:

1. utilizes a relatively energy-efficient lighting strategy that is justifiable as a backup lighting option;

2. is compatible with the quality of daylighting;

3. incorporates staged or dimmable lighting controls tied to photocells located within each space and capable of reading light levels at the appropriate work surface; and

4. minimizes glare.

5.6.2 In spaces that are not daylit, emphasis should be placed upon an electrical design that:

1. incorporates full-spectrum lamps;

2. consists of high-efficiency lamps, fixtures, and electronic ballasts (rapid start ballast);

3. reduces the use of incandescent fixtures;

4. incorporates reflectors within the light fixtures to maximize lumens per watt, and

5. use appropriate lighting controls.

Artificial Lighting and Controls

High-efficiency lighting components save energy by using advanced technologies. However, energy efficiency in lighting does not end with the installation of efficient lamps and luminaries. Lighting control offers as much or more potential for energy savings. Conservative estimates suggest that a comprehensive strategy of lighting control can save 30% of the lighting energy a commercial building consumes.

Use of incandescent lamps should be avoided because they have the lowest efficiency, from 5 to 22 lumens/watt, where about 90% of its energy goes into heat. They also have the shortest useful life, ranging from 750 to 2,500 hours. If there are applications where incandescents must be used, it is recommended that the R-lamp or parabolic aluminized reflector (PAR) lamp be used instead of the A-lamp. Fluorescent lamps consume 70 to 85% less electricity than incandescents and last 9 to 13 times longer. Fluorescent lamp technology has made significant advances by improving efficiency and color rendering index (CRI). Fluorescent lamps, now, also come in many more sizes and styles.

Efficacy Comparisons of Fluorescent Lighting Technology

Lamp Type	Lamp Life	Lmns/ Watt	C.R.I.	Lumen Maint.	Ballast Factor	Description and Comments
T-5 Fluorescent (28Watts/4Ft)	20000	104	85	0.95	1	5/8"dia. tube; High lamp and ballast efficiency, high CRI, similar output to T-8 with a 12% reduction in power usage
T-5 HO Fluorescent (54Watt/4Ft)	20000	93	85	0.95	1	5/8"dia. tube; high lumen output, high CRI. 88% higher lumens than Standard 4Ft. T-8
T-8 Fluorescent (32 Watts/4Ft)	20000	92	82	0.92	0.9	1" dia. standard for efficient fluorescent lamps 23% efficiency improvement over T-12
T-12 Fluorescent (36 Watts/4Ft)	20000	80	72	0.89	0.88	1 1/2" dia. tube, still being used where efficiency is not being considered.

Summary
The recent development of smaller diameter fluorescent lamps has brought significant improvements in lamp life, lumen maintenance, lumens per watt, and color rendering. These characteristics, along with immediate start-up, excellent lumen maintenance, long lamp life and high color rendering, make these lamps ideal for most indoor applications.

Source: Deveoloped by Padia Consulting from Manufacturer's literature (Philips, Osram Sylvania, General Electric)

Electronic ballasts present an opportunity to save over 20% in comparison to the traditional core-and-coil ballasts and the choice of luminaries can also reduce energy needs. When incorporated as part of the daylighting strategy, the savings can be even greater and provide an excellent means of complementing the natural light modulations. Dimming electronic ballasts with adjustable output permit light output from 100% down to 1%. This adjustment is done within the ballast from a low voltage input signal from a daylight sensor or an external potentiometer. By changing from typical recessed fixtures to designs that incorporate indirect, suspended fixtures in conjunction with task lighting, the electrical requirements can often be reduced by over 50%.

There are six basic lighting control strategies for reducing building energy consumption and peak demand: scheduling, daylighting, lumen maintenance, tuning, adaptation compensation and peak demand limiting.

Scheduling strategies turn lights on only when needed, and turn them off when not needed. The controls can be manual (wall switch) or automatic (time clocks and occupancy sensors).

Electric lighting can be dimmed or turned off entirely when natural light from windows or roof monitors is sufficient. Daylighting controls generally require some form of photosensor to signal the lighting control system. Daylighting sensing and task illumination sensing, combined as a lighting control strategy, will insure electrical lighting is only on to the level required, since both techniques focus on providing optimum illuminance.

Control of lights is usually done by time-of-day controls, occupancy sensors, and switches. Time-of-day controls include timers or time clocks, photocells, and energy management system.

Occupancy sensors most commonly used are passive infrared or ultrasonic motion detection devices including photocells. The passive infrared sensors have been very successful. Most of them come with override switches so lights can be turned off even when room is occupied. This feature helps permit showing of movies, videos, etc., in darkened rooms.

Most lighting designs are calculated to produce "maintained" illuminance levels, which account for the depreciation over time of lamps and luminaries. As a result, most lighting systems generally produce an excess of illuminance until they reach the design illuminance level. Automatic lumen maintenance controls employ photocells to monitor illuminance levels and increase the power delivered to the lamps over their life cycle. In this way new, bright lamps are operated at partial power and older, deteriorated lamps are operated at full power. Illuminance levels remain consistent over the life of the lamp and total electric usage is reduced.

5.6.3 Consider indirect lighting strategies that reduce glare. This strategy is particularly beneficial in daylit spaces because indirect lighting often complements natural lighting. It is also an excellent strategy in classrooms and offices with computers there a low, uniform, low-glare light is most desirable.

5.6.4 Check the lighting requirement associated with the specific task. Over lighting classroom or office areas where computer terminals are used causes visual fatigue due to excessive contrast between the VDT and surrounding environment. This has been shown to result in lower productivity and long term health problems.

5.6.5 Provide low-level ambient supplemental task lighting in spaces where the general illumination requirements are lower.

5.6.6 Infrared, ultrasonic, or a combination of infrared and ultrasonic motion detectors (occupancy sensors) should be incorporated in all major spaces to turn off lights when the space is not occupied.

5.6.7 Manual switches are often incorporated to override the automated lighting controls that are normally controlled by the light level within the space.

5.6.8 Fiber optic lighting systems should be considered in non-daylit spaces where:

1. task lighting is required;
2. lamps are difficult to access and maintenance costs would be excessive; and
3. heat from conventional fluorescent lighting and ballasts will result in localized heat build-up.

5.6.9 Photovoltaic lighting systems should receive high priority in exterior applications where light fixtures are more than several hundred feet from the main electrical service. It is often more cost effective to utilize a localized photovoltaic system with its own battery storage than to provide underground electrical service.

5.6.10 When selecting light fixtures and lamps, consider maintenance and replacement costs.

5.6.11 Outdoor lights should be controlled by photocell lighting controls, thus ensuring that lights are not operating during daylight hours.

5.6.12 The merits of a high voltage distribution system should be evaluated, taking into consideration the installed cost and operational savings due to lesser line losses.

5.6.13 Major electrical equipment should be identified and selected based on proper sizing, energy efficiency and environmental soundness. Oversized equipment can add significantly to peak electrical loads and often doesn't operate as well at part-load conditions.

5.6.14 Care should be taken not to significantly oversize the transformer since a fully loaded transformer is more efficient than a partially loaded one. Also, consider more efficient, lower temperature-rise transformers.

5.6.15 Utilize high-efficiency motors and, where appropriate, variable frequency drives. Compare motors based on the consistent method spelled out under No. 112, Method B, developed by the Institute of Electrical and Electronic Engineers (IEEE).

Motor

Alternating current motors vary from low efficiencies at fractional horsepower outputs to higher efficiencies for larger motors. Three phase motors are more efficient than single phase. Recently, higher efficiency motors have been manufactured with improved power factors, but are limited to 25 horsepower. Above 3 horsepower, squirrel cage motors operating at 1/2 to 3/4 part loads are slightly less efficient than at full load rating. Below 3 horsepower, for similar load comparisons, losses in motor efficiency are greater.

Because motor efficiency is presented using various rating methods, it is imperative that they are compared using the same method. The recommended rating should be the Institute of Electrical and Electronic Engineers (IEEE) No. 112 Method B. This method is also recommended by the National Electrical Manufacturer's Associations (NEMA). The cost of energy-efficient motors are only about 20% to 25% higher than the standard motor. Motor specifications should meet or exceed applicable NEMA and Underwriters Laboratories (UL) requirements.

5.6.16 Select fans for the highest operating efficiency at the predominant operating conditions.

5.6.17 Minimize electrical line loss. Line loss can account for 3 to 4% of the total loss.

Line Loss

Line loss can account for 3 to 4% of the total loss. Losses caused by low power factor can account for additional 5 to 10%. Transformer losses can account for further losses of 2 to 3%. These losses combined with motor losses and inefficient lighting systems can account for losses totaling 30 to 35% of the peak demand in a building.

Line loss is the result of current flowing through impedance, namely the wire. Factors directly related to line loss are high current and high resistance. High current can be caused by low power factor and distribution at lower voltages. Long circuits and small diameter wire increase resistance. Harmonics and high temperatures also affect the current and impedance in wiring systems.

Distribution system voltages should be evaluated taking into consideration installed cost and potential operating savings to be realized in higher voltage distribution systems due to reduced line losses. A 480/277 volt distribution system (excluding branch circuits) will have a meaningful reduction effect on I^2R losses as opposed to a 208/120 volt system. The net reduction in I^2R losses can be 50% or more.

Reducing the impedance in a wiring system will reduce the I^2R losses proportionately. Locating the main switchgear room near the center of the load will result in shorter circuit runs and consequently lower I^2R losses.

Use of No. 10 AWG wire in lieu of No. 12 AWG for branch circuits can reduce the I^2R losses in those circuits by as much as 35 to 40%. This concept can be applied to any circuit or feeder, but the larger the wires involved, the smaller the percentage gain. Savings to be realized due to reduced feeder losses should be evaluated in terms of possible higher equipment ratings which may be required due to the increase in available fault currents in larger feeders.

5.6.18 Low power factor is caused by electromagnetic devices that need magnetizing current in order to operate. These include motors, magnetic lighting ballasts, solenoids, and transformers. In addition to causing unnecessary line losses, low power factor also creates the need for a larger energy source than would otherwise be required. An evaluation should be made of the distribution system to determine if power factor correction is justified. If required, the most common approach is to place capacitors in the system close to the load.

5.6.19 Efficiencies of most transformers range from 93% to 98% with core losses from impedance and resistance. When specifying transformers, select those with high efficiency ratings that fit the need. Be sure to obtain all transformer loss information from the manufacturer and match the transformer to the load profile. Manufacturers trade-off coil losses (most significant at full load) and core losses (most significant at low load). Consequently, a low temperature-rise unit that operates very efficiently at high load may be inefficient at low load.

5.6.20 Disconnect the primary side of transformers not serving active loads. Transformers consume power even when loads are switched off or disconnected. Disconnecting the primary side of transformers to serve transformer standby losses is safe provided that critical equipment such as clocks, fire alarms, and heating control circuits are not affected.

5.6.21 Select energy-efficient school electronics equipment and food service appliances. New high-capacity, multistage dishwashing machines save electrical energy, reduce water usage and manpower requirements. Select refrigerators and freezers with highest possible energy efficiency ratings.

5.7 Energy-Efficient Mechanical and Ventilation Systems

5.7.1 Based on conclusions of life-cycle analysis conducted during schematic design, the mechanical systems with the lowest life-cycle cost should be selected.

5.7.2 Optimize the mechanical system as a complete entity in order to allow for the interactions between the system components.

5.7.3 Accurately size and select system components by using computer design tools capable of simulating hourly, daily, monthly and yearly energy use.

5.7.4 Energy analysis should concentrate on not oversizing mechanical equipment. If oversized the owner will pay more initially, pay for higher operating costs and pay for higher maintenance.

Equipment Efficiency

Energy efficiency improvements during the past decade have affected virtually every HVAC component and system. Despite these advances, there is still a great deal of inefficient equipment still on the market which must be avoided. There is also a tendency within the industry to oversize equipment. Oversized equipment wastes energy because when it runs below full capacity it is generally not as efficient. More importantly, oversized equipment increases peak demand and this can significantly raise electric bills. It is critical that you select properly sized equipment.

Equipment selected for the highest operating efficiency at the predominant operating load conditions will minimize energy consumption.

Refrigeration Units

The Coefficient of Performance of refrigeration systems is the ratio of the net heat removal by the evaporator to the total energy input to the compressor.

The following is a table comparing the COP of different refrigeration systems operating at full load.

Type	Size (Tons)	Condensing	Minimum Cop	Best Cop	Average Cop
A/C Package Units	< 5	Air	2.93	4.70	3.50
		Water	2.64	5.30	3.00
	> 5	Air	2.49	4.70	3.50
		Water	2.78	5.3	3.14
Chillers					
Centrifugal:	100-2,000	Water	5.41	7.33	6.40
Screw:	100-750	Air	2.40	3.06	2.80
Centrifugal and Screw:	< 250	Water	4.40	5.90	4.52
	> 250	Water	4.40	7.33	5.87
Reciprocating:	50-250	Air	2.55	3.00	2.78
	10-1,500	Water	3.64	4.20	3.92
Absorption:					
Direct-Fired					
Single-Stage		Water	0.48	0.67	0.58
Two-Stage		Water		1.02	
Indirect-Fired					
Single-Stage		Water	0.68	0.71	0.70
Two-Stage		Water		1.14	

Source: Developed by Padia Consulting from Manufacturer's literature (Trane, Carrier, York, McQuay)

5.7.5 Select equipment that remains efficient over a wide range of operating conditions. Size systems that accommodate multiple stages of capacity.

5.7.6 Reduce duct system pressure losses to minimize the amount of fan energy used to distribute air throughout the building. Most ductwork sizing does not generally take into account the distribution system as a whole. However, computer-based programs for sizing ductwork are becoming widespread. These programs facilitate improved analysis that can reduce energy losses. A good design should strategically locate balancing dampers to improve energy efficiency. The use of round or flat oval ductwork will reduce energy losses and minimize noise.

Air Distribution System

The energy required to operate the air circulating fans in a building is often greater than the energy required to operate the refrigeration compressor and its allied equipment. To minimize the fan horsepower, ductwork should be designed for the lowest practical total pressure and square or round ducts employed with a minimum number of units and offsets. To accommodate larger ductwork may require increasing the depth of the ceiling plenum which, in turn, increases the total area of the building envelope. This additional exterior wall area causes heat loss and gain should be considered in balancing the energy saved by reduced fan horsepower.

Centralizing toilet rooms on a floor and stacking them above each other on multiple floors simplifies the exhaust system which saves total exhaust fan horsepower. Locating air handling rooms in central areas reduces total length of duct runs which reduces total fan horsepower. Low resistance air filters which accomplish the required filtration will aid in reducing fan horsepower.

One of the biggest contributors to energy inefficiency can be found in the duct systems. Typical duct leakage can contribute to high levels of energy loss as well as being a major source of indoor air pollution. In designing a mechanical system, proper duct sizing and mastic duct wrap are critical to good performance. To minimize losses ductwork should be located within conditioned spaces when possible. Duct leakage should be limited to those values established by the Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA)

5.7.7 Consider proper air distribution to deliver conditioned air to the occupied space. Optimal choice and location of air diffusers will save energy and improve comfort control. Select diffusers with high induction ratios, low-pressure drop, and good part-flow performance.

5.7.8 Use low-face velocity coils and filters. Reducing velocity across coils and filters will reduce the amount of energy lost through each component. It will allow more efficient fan selection and reduce noise attenuation need.

5.7.9 Select fans for the highest operating efficiency at predominant operating conditions to minimize energy consumed for air circulation. Centrifugal fans include the air foil, backward inclined, and forward curved types. The air foil and backward inclined types have similar efficiencies, with the air foil more efficient in larger sizes. Efficiency of the forward curved type is lower than the other two centrifugal types.

5.7.10 Vaneaxial fans are available with either fixed or adjustable pitch blades and, at full load operation, efficiencies are comparable to centrifugal fans. At part load operation, the position of adjustable pitch fan blades can be automatically reset to reduce air quantity and maintain high operating efficiency. Variable speed drives used with fixed blade vaneaxial fans can vary the quantity of airflow for efficient part load operation.

5.7.11 Consider a design that supplies air at lower temperatures to reduce airflow requirements and fan energy usage. This offers additional benefits of lower indoor air humidity. Thermal storage offers an opportunity to supply air at lower temperature besides saving electrical demand changes.

5.7.12 Design equipment and ductwork with smooth internal surfaces. This will minimize the collection of dust and microbial growth. Be sure to provide adequate access for inspection and cleaning.

5.7.13 Chiller options are routinely evaluated on larger projects but often overlooked as a component of smaller, packaged equipment. High-performance chiller equipment is available in all sizes. Integrated controls that work with other HVAC components to increase operating flexibility are also available. Advances in the design of air-cooled screw type chillers have made available equipment with an excellent part load efficiency curve for energy savings over the entire cooling season.

The decision to specify chiller efficiency using the full-load or part-load (integrated part-load valve – IPLV) depends upon the application. Full-load is appropriate where chiller loads are relatively constant. IPLV is preferred for highly variable loads, the more common situation.

Product Type	**Recommended Chiller Efficiency**		**Best Available**	
	Full-load ** Kw/ton	IPLV Kw/ton	Full-load Kw/ton	IPLV Kw/ton
Centrifugal	0.60 or less	0.56 or less	0.48	0.42
Rotary Screw	0.65 or less	0.59 or less	0.60	0.52

* This recommendation covers chillers between 175 and 1600 tons. No reciprocating chillers meet these given efficiency levels.
** Values are based on ARI standard reference conditions.

The following example compares the cost effectiveness of a centrifugal to a rotary screw.

	Centrifugal Chiller	Average Base Model	Recommended	Best Available
1	Full Load Efficiency (kw/ton)	0.68	0.60	0.48
2	Annual Energy Use	510,000 kwh	450,000 kwh	360,000 kwh
3	Annual Energy Cost	$ 30,600	$ 27,000	$ 21,000
4	Lifetime Energy Cost	$401,250	$352,500	$281,250
5	Lifetime Energy Cost Savings		$ 48,750	$120,000

	Rotary Screw-Chiller– 250-Ton	Average Base Model	Recommended	Best Available
1	Full Load Efficiency (kw/ton)	0.78	0.59	0.52
2	Annual Energy Use	292,500 kwh	221,250 kwh	195,000 kwh
3	Annual Energy Cost	$ 17,550	$ 13,275	$ 11,250
4	Lifetime Energy Cost	$228,750	$161,000	$153,750
5	Lifetime Energy Cost Savings		$ 56,250	$75,000

* Energy costs based on $ 0.06/kwh

Source: Developed by Padia Consulting from Manufacturer's literature (Trane, Carrier, York, McQuay).

In the example above, the annual energy use for the centrifugal chiller is based on 1,500 equivalent full-load hours per year for a 500-ton chiller. The rotary screw chiller example uses a 250-ton machine operating 3,000 hours per year at 50% of rated load at part-load (IPLV) efficiencies, since rotary chillers are often installed in applications with variable load conditions. The assumed electricity price is $.06/kwh. This average cost figure does not incorporate the disproportionately large portion of demand costs that chillers usually contribute. Therefore, the cost savings figures are conservative.

In the example shown above, the 500-ton chiller with an efficiency of 0.60 kW/ton is cost-effective if its purchase price is no more than $48,750 above the price of the "Base Model". The "Best Available" centrifugal model, with an efficiency of 0.48 kW/ton, is cost effective if its price is no more than $120,000 above the price of the "Base Model". Similarly, the example 250-ton "Recommended" and "Best Available" rotary screw chillers are cost effective if their respective purchase prices are no more than $56,250 and $75,000 above the price of the "Base Model".

5.7.14 Evaluate a multiple-chiller system with units of different sizes to accommodate the predicted load profile. Another good alternative is to provide variable speed drives for improved chiller operation during part-load conditions.

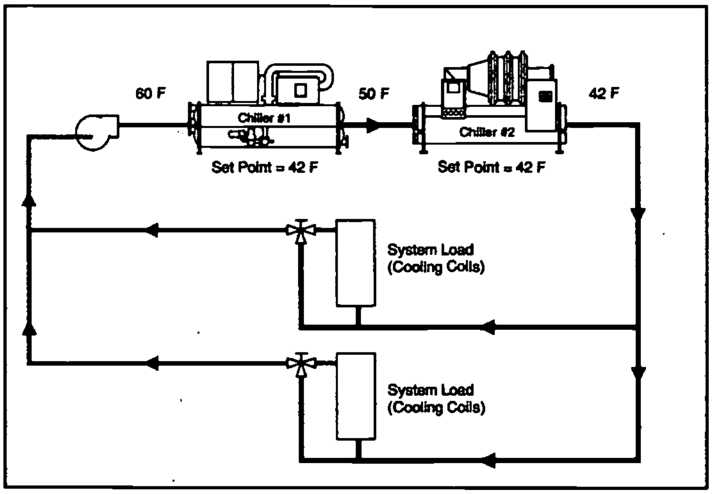
Refrigeration Systems

The efficiency or COP (Coefficient of Performance) of all refrigeration compressors increases when they are operating with lower condensing temperatures.

Several small chillers can operate with higher efficiency than a single large chiller under part load operating conditions.

The piping arrangements of a chilled water system having two or more water chillers affects the system's energy consumption. Chillers which are piped in a series arrangement operate with a greater COP than chillers which are piped in parallel. The first chiller in a series arrangement operates at a higher suction temperature and uses less power per ton. At low loads, the second chiller can be turned off. To reduce pumping resistance through the idle chiller, water can be diverted through a bypass line around the idle chiller. The increased chilled water pumping head from piping chillers in series can be evaluated against the compressor energy savings. Pumping energy can be reduced by a by-pass around the inoperative chiller.

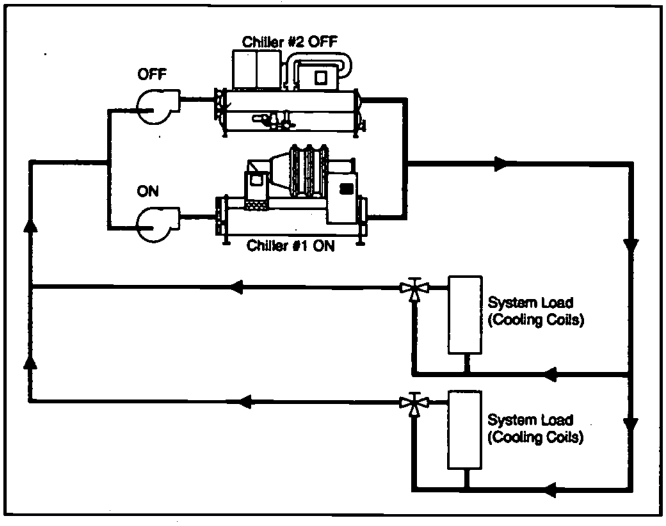
Series Chiller Sequencing



Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan.1996

Sequencing the chillers in series reduces system energy consumption while improving reliability. Because system loads can vary over a broad spectrum, it is possible that a multiple-chiller system can often satisfy the building cooling load with the operation of only one chiller. During these periods, the energy required to operate the second chiller can be conserved. Also, by arranging chiller evaporators in series, it is possible to reduce system flow rate and pumping power by increasing the system's ΔT value.

Parallel Chiller Sequencing



Parallel chiller sequencing with proper control strategy optimizes the match between building load and chiller capacity, enhancing the overall efficiency of the system. Because system loads can vary over a broad spectrum, it is possible that one chiller can often satisfy the building cooling load. Parallel-sequenced chillers are typically piped in either of two pumping arrangements: one arrangement uses a single chilled water circulating pump, while the other uses separate, dedicated chiller pumps (as shown above).

Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan.1996

In multiple chiller installations, the use of a separate chilled water pump and a separate condenser water pump for each chiller, can reduce energy consumption at part load operation by interlocking the pumps to cycle on and off with their respective refrigeration unit. Where high pressure steam is available, the use of two-stage absorption machines will use approximately 40 per cent less energy for the same refrigerating effect than single-stage units.

Power requirements of refrigeration compressors can be minimized at part load by raising the exiting chilled water temperature and reducing the temperature of condenser water to the lowest level acceptable for satisfactory refrigeration unit operation.

Selecting refrigeration units with increased heat transfer surfaces of chillers and condenser beyond standard catalog selections can reduce power input per ton of refrigerating capacity. Possible increased power requirements in pumping heads should be compared to compressor power input.

Increased pipe size for chilled water and condenser water systems will reduce the total dynamic head of the chilled and condenser water pumps and will reduce power input and energy consumption.

Increasing the temperature differential in chilled water systems to reduce the quantity of water circulated can reduce pumping requirements.

5.7.15 Consider the use of environmentally friendly refrigerant alternative. Also, as an alternative to chlorofluorocarbons (CFC's) refrigerants, the design team should consider absorption refrigeration units which are CFC free and use water as the refrigerant and lithium bromide as the absorbent. This option can also be an economical way of cooling and heating large buildings. These compact, high efficiency units are available in models providing from 40 to 1500 tons of cooling and operate on natural gas, propane, oil, exhaust heat or steam. Because they avoid the increasingly expensive use of electricity for air conditioning, these units can cut cooling and heating costs substantially.

CFC Issues

Besides the traditional criteria used to select chillers (efficiency, reliability, service etc.) refrigerant choice is still a major issue. Large tonnage chillers are at least 25-30-year investments and decisions made today will impact owning and operating economy for many years. Three chlorofluorocarbons refrigerants - R123, R-22, and R-134a - are widely available for commercial air-conditioning applications and represent acceptable alternative CFC's. None is perfect from an environmental viewpoint, but all are significantly better than CFCs. Brief comparison of these three refrigerants and discussion of additional alternatives is given as guidance.

The technical issues related to the application of R-123 (an HCFC) have been resolved including material compatibility (both new and retrofit) toxicity testing and safety standards. Environmentally, R-123 is a high efficiency refrigerant with very low ozone depletion potential (ODP). The Montreal Protocol and U.S. Environmental Protection Agency (EPA) policy makes R-123 a viable refrigerant for new retrofit, and replacement chiller applications through the early part of the 21st Century. Adequate production of replacement refrigerant is assured through the year 2030; recycled R-123 would be available beyond that. Available scientific evidence, as well as extensive industry laboratory and field experience, indicate that R-123 is a safe and effective refrigerant. Every installation monitored has operated well below the allowable time-weighted exposure limit of 10 parts per million (ppm). In fact, ambient levels have typically been less than 0.6 ppm during routine maintenance and refrigerant transfers.

Introduced over 50 years ago, R-22 an (HCFC) has been the workhorse of the air conditioning and refrigerant industry and is the predominant refrigerant in use today. R-22 equipment is being specified today in well over one-third of all large tonnage chiller applications. Expanded use of R-22 is the major reason the industry has been able to reduce its usage of CFC in large chillers over this time period. While its relative low cost and high efficiency make it attractive, R-22 has a higher ODP value than R-123, and is scheduled for a somewhat earlier EPA phaseout. The Montreal Protocol and, currently, EPA support R-22 as a viable refrigerant for new and replacement chillers through at least the year 2020. Recycled R-22 should continue to be available after that time.

R-134a an (HFC) is viewed very favorably today because of its zero ODP. Toxicity is not an issue. The theoretical efficiency of R-134a is lower than R-123 and R-22 and this will require more effort by equipment manufacturers to compete in the high efficiency market of large chillers. However there are other advantages to use R-134a. The most fundamental solution instead of the interim HCFCs (R-22 and R-123a) R-134a operates at a positive pressure in both the evaporator and condenser.

This eliminates the need for purge units, additional pressure valves to buck up rupture discs and vacuum prevention system that are required on negative pressure (R-123) chillers. Purge units are another source of refrigerant costs. R-134a technology does not require major change in components.

Safety, efficiency, and environmental impact should be considered in selecting the appropriate refrigerant for the chillers. Also, absorption, desiccant and evaporative cooling units should also be considered as an alternative. The salient characteristics of each of the refrigerants is shown following.

EPA Comparison of Refrigerant Alternatives

Criteria	HCFC-123	HCFC-22	HFC-134a	Ammonia
Ozone Depletion Potential	0.016	0.05	0	0
Global Warming Potential	85	1500	1200	0
Ideal kw/ton	0.46	0.5	0.52	0.48
Flammable	No	No	No	Yes
Occupational Risk	Low	Low	Low	Low

Source: EPA literature (EPA publication titled Refrigerant Properties Comparison, April 1992)

5.7.16 Absorption cooling systems allow changing of the energy source from electricity to gas and can reduce energy costs. Direct-fired gas equipment can also be selected to provide hot water for building needs in addition to chilled water. This type of system is ideal for a solar thermal energy application. Modifications can be made to the chiller by the manufacturer to use the lower temperature solar energy as well as gas for back-up.

5.7.17 The heating and cooling loads of a building vary on a daily and seasonal basis. Thermal energy storage (TES) makes it possible to manage a building's utility usage or conduct "load management." A TES system generates and stores thermal energy on a daily, weekly, or longer basis. It can shift from the use of more expensive peak utility energy to less expensive off-peak energy to save on demand charges. Ice banks and stratified chilled water are the most common examples.

5.7.18 Boilers can be selected for operation at high average efficiency for the predominant load range. Large packaged boilers with modulating burners can operate at constant efficiency down to 25 per cent of maximum rated output. The use of two or more boilers in sequential operation can increase boiler operating efficiency when system loads are below 25 per cent of peak load. Each boiler can operate at its highest average efficiency and be responsible to its incremental portion of the load.

5.7.19 The most efficient boiler arrangement for small boilers with fixed firing rate burners is the modular boiler assembly, consisting of multiple small boilers. Each boiler can respond to a small increment of load and operate at peak efficiency. Under part load operation, boiler modules start and stop in sequence to match the load.

5.7.20 Carefully select heat exchangers with low approach temperatures and reduced pressure drops.

5.7.21 Each heat exchanger can be provided and operated with a separate pump to maintain high efficiency at part load operation in a large system with multiple heat exchanger units.

5.7.22 Consider other heating-system equipment and enhancements. It is advisable to use condensing boilers, match output temperatures to the load, use temperature reset strategies and select equipment with a part-load ability. Specify multiple, staged operations wherever possible.

5.7.23 Where opportunities for heat-recovery from waste streams exists, evaluate the use of such devices. High ventilation loads can be reduced through the use of an air-to-air heat-recovery of both sensible and latent loads.

5.7.24 Primary and secondary pumping systems with variable-speed drives are worth consideration because of their effects on a part-load energy use. Pressure losses in piping can be reduced by selecting pipe sizes with a lower pressure drop factor. The design should optimize total head loss with a minimum of flow-balancing controls. New systems that use hydronic system additives to reduce system friction losses and associated pumping energy are being developed.

Hot and Chilled Water Distribution System

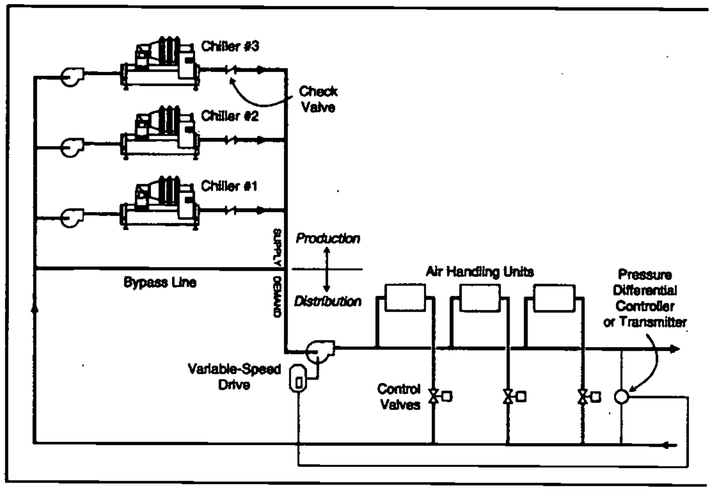
The energy required to power the fluid distributing system is a function of the quantity of fluid distributed and the total system resistance. The fluid quantity required can be reduced by increasing the temperature spread between the inlet and outlet through heating and cooling coils. This must be considered on a total system basis, including the energy economics of the heating/cooling generating plant.

Total system resistance can be minimized by reducing the overall length of the circuit, increasing pipe sizes, reducing the number of sharp offsets and turns, eliminating unnecessary valves, and by selecting equipment with low pressure drop.

Pumps for these systems should be selected to operate at their maximum efficiency. Sufficient instrumentation should be included to determine the actual operating conditions and enable the plant engineer to adjust to the optimum operating conditions.

In many designs, common piping systems are used for both heating and cooling. Since the design would be optimized for the system with the larger demand, it would be oversized for the smaller demand. In lieu of operating the smaller system with oversized pumps, the condition can frequently be avoided by providing separate pumps for each function or providing modular equipment and operating them in parallel. For instance, in a system using common piping circuits for both heating and cooling, the pump requirements in the cooling mode could be 80 horsepower, while in the heating mode it could be 35 horsepower. Normal practice would be to install a 100 horsepower pump motor, and either throttle the flow in the heating mode or circulate more heating fluid than the requirement. By installing two 40 horsepower pumps in parallel, and using both in the cooling mode and one in the heating mode, less energy will be consumed

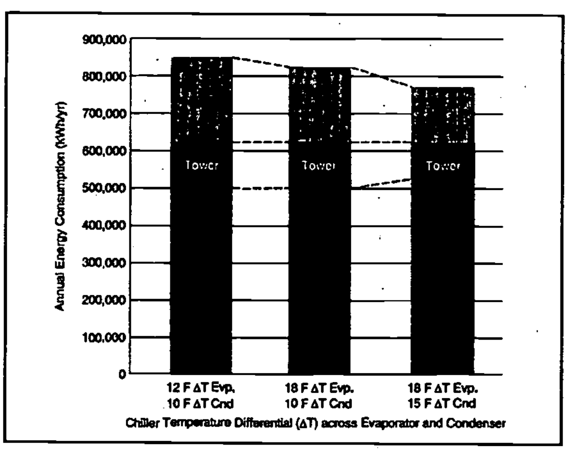
Hydraulically Decoupled Chiller System for Constant Flow Primary and Variable Flow Secondary Systems



Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan.1996

As shown in the illustration above, a supply/demand relationship exists at the tee connecting the supply and bypass lines. Whenever supply and demand flows are unequal, water will flow into - or out of - the bypass line. If demand exceeds supply, for example, water will flow out of the bypass line into the distribution side of the supply line. When the control system senses this change, it will energize the next pump/chiller pair. Flow through the bypass line will reverse when supply exceeds demand. In this instance, however, a specific amount of surplus flow must exist before a pump/chiller pair is de-energized. That is, the amount of surplus flow through the bypass line must exceed the flow through the next chiller to be shut down. Because control of the number of chillers operating at any one time is accomplished simply by noting the direction and amount of flow through the bypass line, decoupler systems can greatly simplify control of large chiller plants. In addition, decoupler system staging of pump/chiller pairs and distribution pump modulation provide a very energy-efficient sequence of operation.

Wider Temperature Differentials (Δ T's)



Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan.1996

To reduce a chilled water plant's pumping energy requirements, apply variable-flow pumps in a decoupled piping arrangement. Additional reductions in pumping energy requirements are achieved by increasing the chilled water and condenser water temperature differentials (i.e., "delta T" or ΔT). The left bar in the graph represents the annual energy consumption associated with a 12 F evaporator water ΔT and a 10 F condenser water ΔT across the chiller. As the middle bar of the graph depicts, increasing the evaporator (chilled water) ΔT to 18 F actually reduces the chiller's yearly energy consumption. The graph's right bar shows the impact of greater-than-"normal" temperature differentials in *both* water loops: though annual chiller energy chiller consumption is slightly higher, raising the condenser water ΔT by 5 F reduces the overall energy consumption of the chilled water plant by nearly 10 percent.

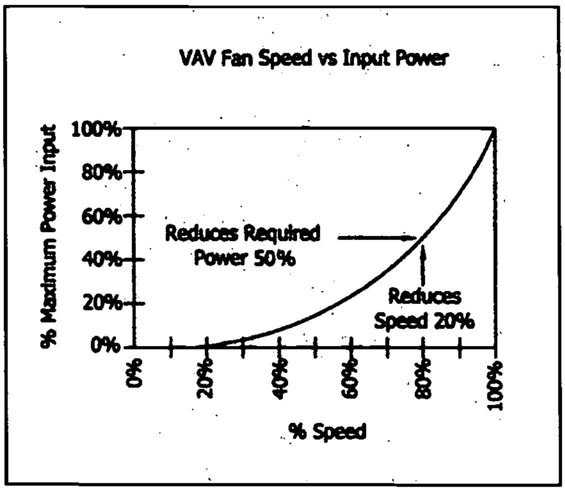
5.7.25 Pumps can be selected for high efficiency at part load operation. The quantity of fluid in circulation can be reduced to match the load and still maintain high efficiency operation, with automatic throttling type control valves and multiple pumps that can be started and stopped in sequence.

5.7.26 Variable-speed drives have advanced significantly over recent years. They offer a proven means of substantially reducing the energy used by fans, chillers, and pumps under part-load conditions. Electronic drives are considered the best option; drive controller and motor selection are also important considerations.

Variable Frequency Drives (VFD)

Much of the power consumed by alternating current (AC) motors can be attributed to the operation of fans, blowers, and pumps. It has been estimated that at least one-half of the motors used are for these applications. Generally fans and pumps are designed to be capable of meeting the maximum demand to the system in which they are installed. However, the actual demand is often much less than the designed capacity.

Fans and pumps follow affinity laws where the flow varies directly with the speed and horsepower is proportional to the cube of the speed. Controlling motor speed to control flow is the more energy efficient strategy. Use of VFD control offers a distinct advantage over other forms of air volume control in variable air volume (VAC) system.



Source: Padia Consulting, Inc.

Advanced electronics can be used to slow the drive system to run in the optimum speed range, providing HVAC system with the most ideal operating conditions. Although other methods of speed control are available, none are as energy efficient or as accurate as VFDs. Supply fans, return fans, and cooling tower fans are all prime candidates for VFD operation. At 50% of rated speed, the VFD system consumes 85% less energy than constant volume systems, 80% less than outlet dampers and 75% less than inlet vanes. Newly designed VFD limits inrush current and normal operating current to a maximum of 110% of motor full load amperes; provides built-in safety features assure operator protection; provides soft-start/stop which reduces maintenance problems.

5.7.27 High-efficiency motors are suggested for all applications because of their energy conserving capabilities, longer life and reduced maintenance costs. Motors should be of the proper size to avoid the inefficiencies of oversized equipment.

5.7.28 Mechanical drive efficiency can be improved to reduce losses in the power transmitted from a motor to the driven equipment. Consider direct-drive equipment options and review actual loss factors on belt- or gear-driven equipment.

5.7.29 Direct digital control (DDC) systems offer greater accuracy which can improve energy efficiency and performance.

5.7.30 Advanced control strategies using DDC systems include system optimization, dynamic system control, integrated lighting and HVAC control, and variable-air-volume (VAV) box airflow tracking.

Automated Controls

Computerized energy management systems should be used in conjunction with the automatic temperature control system to reduce energy consumption by minimizing the system operating time required to satisfy heating and cooling requirements. This is accomplished through automatic computerized analysis of outdoor weather conditions, building response characteristics, and environmental system reactions. Energy consumption should also be minimized through computerized control of:

- Economizer cycles (air and water)
- System start time
- Refrigeration plant optimization
- Chilled and hot water temperature reset
- Lighting system operation.

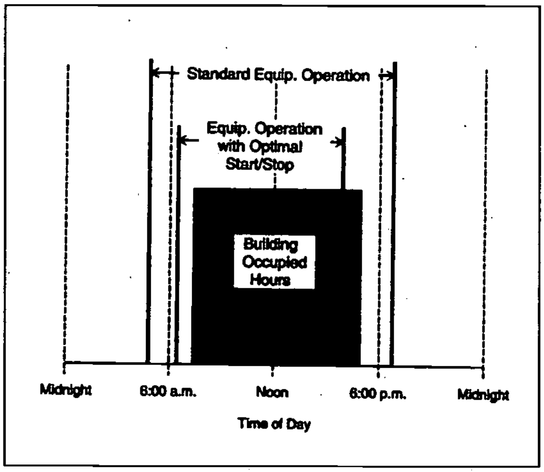
In addition to their primary purpose of maintaining comfort conditions for building occupants, automatic control systems should also be used to reduce the energy consumed by building environmental systems.

The following are some of the energy conserving control applications that should be used.

Deadband Room Thermostats:
Energy conserving deadband thermostats are dual temperature heating and cooling control devices with an inactive temperature band between the heating and cooling load control points and internal limitations to their set points. When the space temperature is within this inactive band, neither heating nor cooling can be supplied to the space until its temperature rises or steadily falls to the cooling or heating control set points, thereby reducing energy consumption. The internal temperature limitations restrict occupants from obtaining higher space temperatures in the winter and lower temperatures in hot weather.

Unoccupied Area Shutoff:
In a building with multiple zones that function at different operating periods, energy should be conserved in the operation of a central air handling system through the use of automatic shutoff dampers in zone supply ducts, and a multispeed fan drive or a volume control damper at the supply air fan. When a zone is unoccupied during system operation, its damper should be closed to avoid heating or cooling the zone for the duration of the unoccupied period.

Optimum Start / Stop:
The optimum start/stop strategy can lower utility costs by reducing the operating time of HVAC equipments, by incorporating CO_2 sensors in the building.



Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan.1996

Often, a building's HVAC equipment is scheduled to start one or two hours before the normal occupied period begins and stop approximately one hour after the occupied period ends. Though this simple equipment schedule does assure occupant comfort, it also consumes more energy than is necessary. The optimum start/stop strategy takes advantage of a building's thermal capacity to minimize equipment run time. Since "light" buildings cool down quickly at startup, the equipment "start" time can be very close to the beginning of scheduled occupancy on a mild day, and somewhat earlier on a hot day. "Heavy" buildings, on the other hand, take longer to cool down, so the equipment "start" time must be early enough to achieve the desired space temperature by the time scheduled occupancy begins.

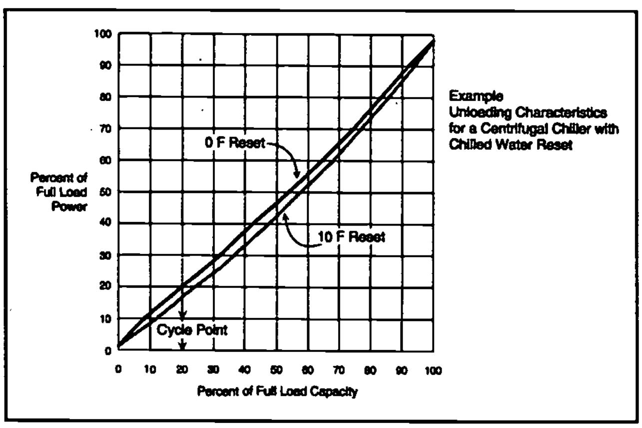
Based on occupancy schedules, ambient conditions and building thermal characteristics, the equipment is started as late as possible - and stopped as early as possible - without sacrificing occupant comfort. By minimizing equipment operating time in this manner, significant energy savings can be realized.

Cycling Fan and Pump Operation:
The operation of fans and pumps should be cycled periodically to reduce energy consumption when systems are functioning under partial load conditions, by means of a 5 to 8 minute shutdown period every half hour. Repeated starting of large motors may adversely affect motor starter operating life, and caution is recommended in applying this energy conserving method.

Supply Air Temperature Reset:
Automatic reset of supply temperature for air and water heating and cooling systems, in response to load fluctuations, should be used to conserve energy in system operation.

The cold deck temperature is reset to the highest level that will satisfy the cooling requirements of the zone or room with the greatest demand, when its cold air damper is wide open and its hot air damper is closed. The hot deck temperature is reset to the lowest level that will satisfy the heating requirement of the zone or room with the greatest demand, when its hot air damper is wide open and its cold air damper is fully closed.

Chilled Water and Hot Water Temperature Reset:
Chilled water and hot water supply temperatures should be reset to reduce energy consumption during partial load operating conditions. Automatically raising the chilled water supply temperature to the highest level that will satisfy cooling load requirements or lowering hot water supply temperature to the lowest level that will satisfy heating load requirements reduces energy input to refrigeration units and boilers. In systems with multiple air handling units, the unit with the greatest cooling or heating demand resets the supply temperature of the chilled water or hot water system to satisfy its load when its control valve is in the wide open position. For each degree increase in chilled water temperature, there is approximately 2 per cent reduction in energy input to the refrigeration system.



Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan.1996

The chilled water reset raises the temperature of the chilled water supply during periods when the building load isn't at, or near, design conditions. This lessens the work required of the chiller's compressor, reducing energy consumption. As a "rule of thumb," every 1F of chilled water reset reduces chiller energy costs by approximately 1 to 1½%, which can result in major operating cost savings. For example, consider a chiller with design leaving and entering water temperatures of 44 F and 54 F, respectively, and a maximum reset value of 4 F. If the building load is approximately 80% of design, the leaving-evaporator chilled water set point is reset upward by 2 F to 46 F. If the building load continues to drop, this set point is adjusted upward until the maximum reset point of 48 F (i.e., 44 + 4) is attained.

Humidity Controls:
In the wintertime, raising the relative humidity permits lowering the dry bulb temperatures for the same degree of comfort, but more energy may be required to produce humidification than may be saved by the reduction in temperature. However, when outdoor air quantities are reduced, the opportunity for saving energy through humidification is increased.

Fan Volume Reset:
Automatic reset of supply and return air fan volume, in response to load variations, can be used to conserve energy in variable air volume system operations.

5.7.31 Once the type of HVAC system and related controls have been decided upon, a detailed sequence of operation should be written for each component of the HVAC system (air handling units, boilers, chiller, cooling tower, flat plate exchanger, pumps). This sequence of operation should describe the desired operation of the HVAC system components during the day, night, weekend, holiday periods, and season of the year.

5.7.32 Select plumbing fixtures and appliances that conserve water.

Toilet & Urinal Water Consumption by Type

Option	Pre-1970 Models, Water Usage (gal)	Traditional Model Retrofits	Modern Model Water Usage (gal)
Toilets			
Gravity flow	5 - 7	Save up to 2 gpf	1.6
Flush valve	5	Save up to 3.4 gps	1.6
Pressurized tank	1.6	----	1.6
Urinals			
Siphonic jet	Continuous flow	----	1.0
Blowout	2 - 3	----	1.0
Washout	2 - 3	----	1.0
Wireless	-----	----	0

Source: Developed by Padia Consulting from Manufacturers' literature (American Standards, Kohler)

5.7.33 In remote locations within the building, where the hot water load is small, consider localized heaters with high-energy recovery rates.

5.7.34 Consider energy efficient water heating options that are enhanced/supplemented by:

1. solar,
2. heat pumps,
3. heat recovery processes,
4. tankless water heaters, and
5. combination hot water and space heating systems.

5.7.35 Reduce losses from distribution piping and hot water storage tanks by:

1. increasing insulation,

2. using anti-convection valves, and

3. using heat traps.

5.7.36 Consider solar hot water systems to provide for domestic hot water and, potentially, space heating needs and absorption cooling (see solar systems).

5.8 Environmentally Sensitive Building Products and Systems

5.8.1 Decisions on many specific environmentally preferable products and systems will be made during the construction documents phase, but the selection of generic alternative approaches are often integral to whole system design choices that must be addressed by the design development phase.

5.8.2 By the design development phase, the design team should assemble a listing of locally produced materials and products. Products made locally will help the local economy and resources use from indigenous materials will reduce transportation cost (and associated energy) and enhance the connection to place.

5.8.3 Clear choices need to be made on whether or not specific polluting materials will be eliminated or minimized. This will help define the ventilation strategy employed.

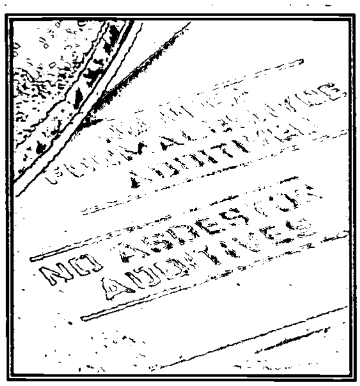
Specifically address:

1. VOCs in paints, carpets, carpet backing, floor base materials, and adhesives;

2. products that may release particulates;

3. formaldehyde in plywood, particleboard, composite doors, and cabinets; and

4. toxic termite control.



Courtesy of: The Homasote Company

5.8.4 In addressing sitework and landscaping, consideration should be given to:

1. the use of local stone or recycled-content surfacing materials;

2. the specification of playground surfacing materials made from recycled rubber;

Elementary school playground

3. landscaping designs that rely on native planting materials; and

4. the inclusion of utilizing graywater systems.

5.8.5 In selecting structural wall and roof systems, the merits of environmentally-sound building components should be considered, including:

1. the use of locally made brick and concrete masonry products for exterior and interior wall construction;

2. concrete masonry units that contain recycled materials;

3. steel joists and beams with recycled content and efficient use of material;

4. integral masonry wall insulation systems; and

5. interior masonry serving as thermal capacitance while also enhancing fire ratings and structural capabilities.

5.8.6 Exterior material finishes should be selected for:

1. maximum durability and minimum maintenance;

2. color (light colored material will help reflect radiation and reduce cooling loads);

3. massiveness (masonry wall construction will increase thermal lag time and improve cooling energy loads); and

4. dual functionality, examples of which are:

   a. a light colored single-ply roofing material can also enhance the performance of a daylighting roof monitor and reduce unwanted heat gain;

   b. a photovoltaic or solar thermal system could also serve as the roofing material.

5.9 Indoor Air Quality

5.9.1 Eliminate four main sources of indoor air pollution (see previous section on Environmentally Sensitive Building Products and Systems).

5.9.2 Provide for adequate and effective ventilation systems with control concentrations of indoor pollutants as outlined in ASHRAE Standard 62-1989R.

5.9.3 Locate outdoor-air intakes a minimum of 7 feet vertically and 25 feet horizontally from polluted and/or overheated exhaust (e.g., cooling towers, loading docks, fume hood exhausts, chemical storage areas, etc.).

5.9.4 Carefully locate (separate) ventilation air intakes and exhaust fans to avoid air quality problems.

5.9.5 Consider natural ventilation strategies in appropriate spaces.

5.9.6 Separate vehicle traffic and parking a minimum of 50 feet from fresh air inlets or spaces employing natural ventilation strategies.

5.9.7 Separate and ventilate highly polluting spaces (e.g., photocopy room). Reduce diffusion of pollutants by isolating potential sources which include kitchens, equipment rooms and janitorial closets. Provide an isolated and adequately ventilated, locked room for designated hazardous materials storage.

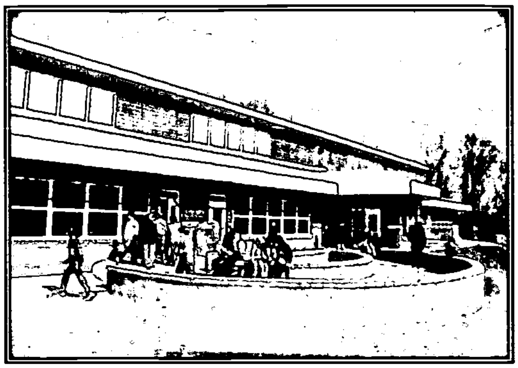
5.9.8 Incorporate interior planting strategies.

Innovative Design, Inc.

5.9.9 Consider the inclusion of photocatalytic oxidation as a means purifying air and reducing energy consumption.

5.9.10 Design outside spaces that can be utilized for:

1. teaching,
2. breaks and lunch, and
3. recreation.



Entry "Sundial" courtyard, Innovative Design, Inc.

5.9.11 Locate exhausts in such a way that prevailing wind carries exhausts away from building.

5.9.12 Ductwork should have smooth internal surfaces and transitions to minimize the collection of dust and microbial growth.

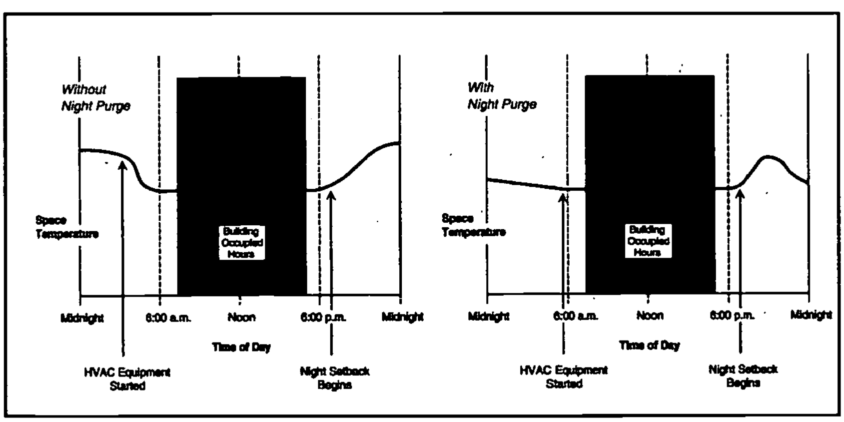
5.9.13 Design ductwork and plenums to minimize accumulation of dirt and moisture and provide access areas in key locations for inspection, maintenance (i.e., filter changing) and cleaning.

5.9.14 Monitor conditions within the building with carbon dioxide sensors and VOC sensors. These could ideally be used in conjunction with ventilation-demand-based systems to insure adequate fresh air while still allowing less outside air to be introduced during low-occupancy times.

5.9.15 Use nighttime ventilation strategies in the cooling season to flush out stale air prior to morning occupancy.

Night Purge

In many climates, ambient temperature during nighttime hours is low enough to precool the building. When this temperature reaches a predefined value during unoccupied hours, the control system activates the supply fans to introduce outdoor air directly into the building; the fans remain on until space temperature falls to a specified level. Using the unoccupied ventilation cycle in this manner can provide energy savings by reducing or eliminating the morning "pull-down" load that often develops in buildings during the cooling season.



Source: "Trane Trace 600 Cookbook (TRCE-UM-606) Jan. 1996

5.9.16 Develop an indoor pollutant source assessment and control plan.

5.9.17 Maximize IAQ and energy efficiency together by using heat recovery devices to pre-condition incoming ventilation air with air that is exhausted from the building.

5.10 Water Conservation

5.10.1 If graywater usage is to be employed it is essential that key components of these systems are integrated into the design at this stage.

5.10.2 Determine non-potable water needs (i.e., toilets, irrigation, cooling tower water) and determine viability of meeting these needs with graywater.

5.11 Recycling Systems and Waste Management

5.11.1 Verify that consideration has been given to:

1. the allocation of space within the building design for recycling receptacles and maintenance associated with recycling;

Recycling station at eating area

2. access to recycling bins by outside waste collection agencies;
3. space allocated for yard waste and/or composting; and
4. collection chutes in multi-story facilities.

5.11.2 Coordinate with recycling organizations servicing the school to determine specific requirements or limitations regarding:

1. current and anticipated recycled materials collected;
2. methods of collecting materials and requested access requirements including:
    a. turning radius of trucks, and

b. means of transferring material from school's bins to trucks;

3. desired storage bin sizes and type;
4. whether bins are provided by agency or school;
5. collection schedule; and
6. any associated health- or code-related issues.

5.12 Transportation

5.12.1 Final decisions should be made regarding key site-related issues including:

1. pedestrian friendly site access to community sidewalks leading to residential areas;
2. easy site access and convenient racks for bicycles;
3. location for solar charging station to service buses or service vehicles;
4. easy access to public transit stations; and
5. shower facilities for staff who choose to bicycle.

5.13 Commissioning and Maintenance

5.13.1 Materials, products, equipment or building systems should be considered with an emphasis on the long-term maintenance issues associated with the design options.

5.13.2 Plan a commissioning process to document that the completed building meets the original design intent and the owner's objectives. This process should begin in the early stages of design and continue throughout construction at a level which corresponds to the projects complexity.

Major systems that require commissioning include:

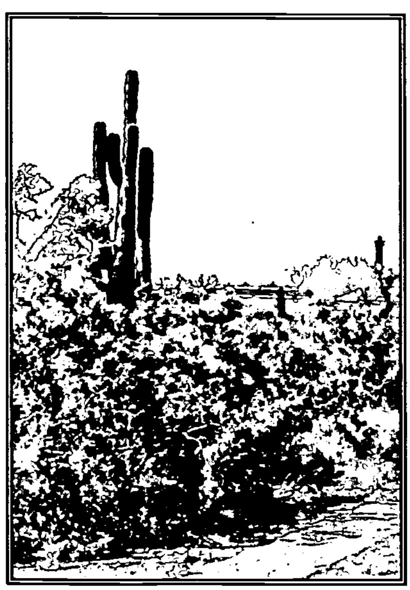
1. water heating systems,
2. pumps,
3. cooling towers,
4. air handling systems,
5. refrigeration systems,
6. HVAC control systems,
7. energy management systems,

8. daylighting/lighting control systems,
9. emergency systems,
10. ventilation systems,
11. solar domestic hot water systems,
12. wind systems,
13. photovoltaic systems,
14. daylighting systems, and
15. graywater collection and distribution systems.

5.14 Eco Education

5.14.1 Once programmatic decisions are made regarding the integration of environmentally sound and energy efficient components as educational tools it is important to start to incorporate these elements in the design development documents. As previously pointed out during schematic design, examples would include:

1. greenhouses for growing plants;
2. photovoltaic systems that could serve to educate students about the concepts of solar energy and the conversion of sunlight into electricity;
3. daylighting strategies that could be enhanced through student participation;
4. use of recycling systems within the school that the students could participate in;
5. interpretive nature trails through preserved wildlife habitats and ecosystems;



Natural habitat area

6. the design of environmentally-sound or energy-efficient building components so as to make their purpose and function obvious to students;

7. incorporation of artwork and graphics in the building design which would help to educate students about sustainable design;

8. use of outside teaching courtyards and spaces that allow for grouping plants, viewing habitat, and understanding eco-cycle;

9. educational signage about bicycles and other pedestrian-friendly transportation options for getting to and from the school; and

10. interpretive displays showing total energy use at the school and the percentage of energy being provided by renewable sources.

ENERGY STATUS: DESIGN DEVELOPMENT REPORTING FORM

Project .... **Project #**..................... **Date** ....

Submitted By...

Building Type K-5 School .... Middle School .... High School ....
Library .... Gymnasium .... Maintenance ....
Horizon High Schools...................................... Other ....

Square Footage Conditioned: .... Total: ....
Project Design Team Architect ....
Lighting / Electrical Engineer ....
Mechanical Engineer ....

Energy Consumption Energy Budget .... Btu/Square foot/Year
Energy Goal .... Btu/Square foot/Year
Energy Projection .... Btu/Square foot/Year

The analysis of energy consumption is based upon computer simulation of the school facility:

	% of Consumption	Btu/Square foot/Year
Heating	......................%	......................%
Cooling	......................%	......................%
Ventilation/O.A.*	......................%	......................%
Interior Lighting	......................%	......................%
Other Electrical	......................%	......................%
Hot Water	......................%	......................%
Other	......................%	......................%
Total Building	100 %	......................%

* Assume 15 CFM/person ventilation rate

Time Frame for Life-Cycle Cost Analysis

New Construction .... Renovation............... Projected Life of Facility ....Years

Energy (and Daylighting) Computer Software Program(S) Used

....

....

Anticipated Energy Sources and Systems to be Utilized

	Fuel/Energy Source	HVAC/Lighting/HW System Description
Heating	....	....
Cooling	....	....
Hot Water	....	....
Lighting	....	....

Analysis Completed During Design Development

Briefly describe the energy-efficient design features that you will anticipate being included:

Daylighting and Controls ....

Electrical Lighting and Controls ....

Electrical Systems Line Loss, Low Power Factors, Transformer Loss ....

HVAC System Design and Zoning ....

Equipment Efficiency Refrigeration Units, Motors, Fans, Pumps, Boilers ....

Air Distribution System
- Variable Frequency Drive ....

Refrigeration Systems ....

Hot and Chilled Water Distribution Systems ....

Analysis Completed During Design Development (continued)

Automatic Controls ....

Computerized
Energy Management System ....

Plumbing Systems ....

Domestic Hot Water Systems ....

Energy Conservation
Opportunities in
Plumbing System ....

Solar Hot Water Systems ....

Maintenance

Please explain the building maintenance ramifications of any particular energy-savings feature which characteristically requires high maintenance.

....

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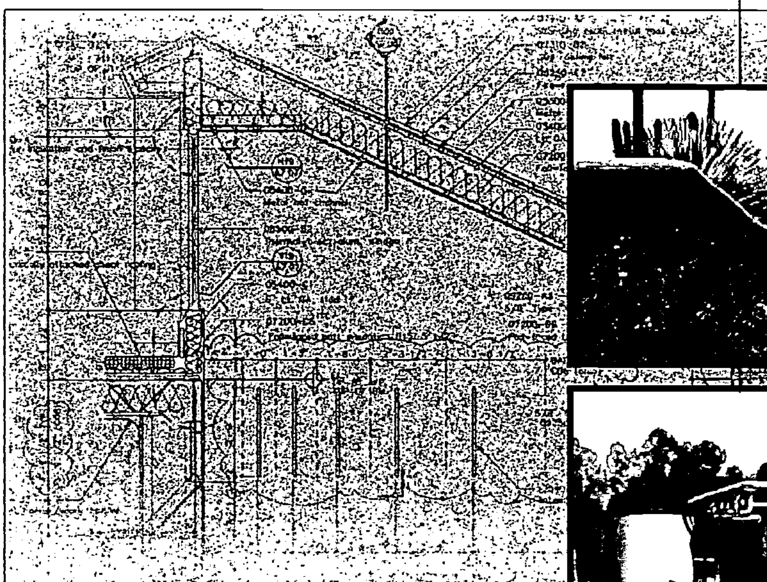
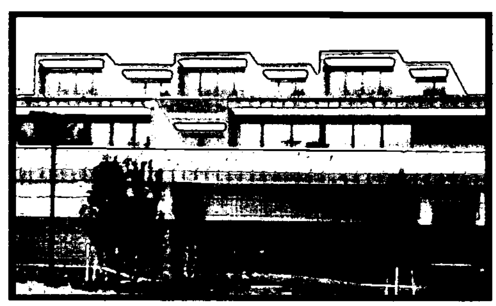
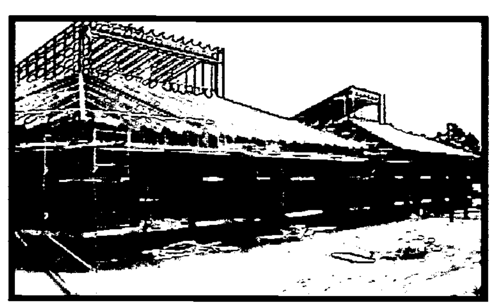
Section 6

CONSTRUCTION DOCUMENTS







6. CONSTRUCTION DOCUMENTS

6.1 General

6.1.1 Verify that energy strategies developed in Design Development are consistent with the energy budget. At 50% completion of construction documents, an updated energy analysis should be conducted, encompassing all major elements influencing energy consumption. This should be coupled with a final cost analysis on key components (which should at this point be well identified) to verify cost effectiveness.

1. During this phase energy analysis of key individual zones and the building in entirety should be conducted.

2. If primary energy strategies developed during the last phase were successfully integrated, it is unlikely that the overall energy budget will vary by more than a couple of percent. However, it may be important to further analyze degrees of efficiency (e.g., efficiency of mechanical system components) or the extent certain energy strategies are implemented (e.g., size of solar hot water system).

3. If the energy analysis indicates that the overall design will not result in the energy goals being met, it is likely that implementing these higher levels of efficiencies (explained above) should be adequate to achieving the objectives.

4. Look at the breakdown of projected energy consumption to determine areas where additional improvement can still be made.

   a. heating

   b. cooling

   c. lighting

   d. ventilation

   e. hot water

   f. miscellaneous electrical

6.1.2 Evaluate the design to ensure that all of the original environmental objectives are being fulfilled.

6.1.3 Using the cost analysis conducted at 50% completion of construction documents, each key green building component should be identified and again assessed against the component's merits and contribution in meeting sustainability goals.

6.1.4 Unlike many of the major energy decisions which take place in schematic design and design development, this phase will be the most significant for many of the green building components. If sustainability is to be meaningfully addressed at all levels, the specifications must reflect that intent with clear and consistent language.

1. The overall environmental objectives should be reflected in the specifications in a very

clear manner.

2. Each division should begin with a note about any unconventional requirements for environmental performance, recycled content, or construction waste management.

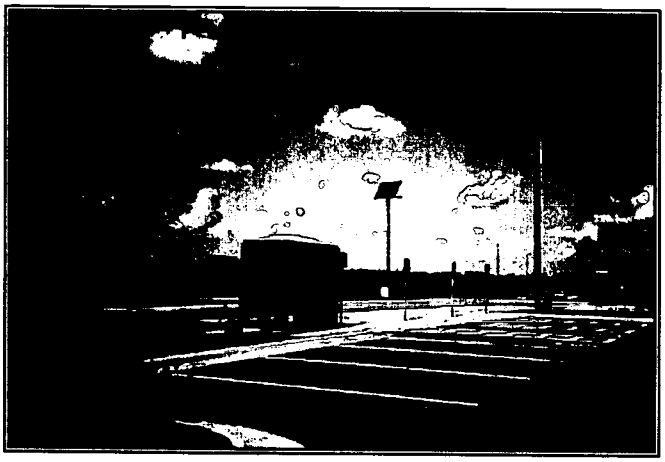
6.2 Site Planning and Landscape Design

6.2.1 Protect the existing environment.

1. Specify the manner in which significant vegetation, natural features, ecosystems, and wildlife habitats will be protected during construction.
2. If located in watershed areas, protect from polluted surface water runoff both during and after construction.
3. Minimize and control air pollution from dust and dirt during the construction.

6.2.2 Incorporate environmentally-friendly design solutions.

1. Minimize impervious surfacing materials, allowing rainwater to soak into the ground.
2. Employ environmentally-sound erosion control and storm water retention.
3. Stockpile appropriate rock from site for later use as ground cover.
4. Use organic fertilizers in lieu of petroleum-based products.
5. Use photovoltaic lighting for parking areas and exterior walkways.



Photovoltaic lighting for parking area, Photo: NC Solar Center

6. Distinguish between light, heavy and pedestrian traffic when designing paving thickness and stone base requirements.
7. Aggregate location of utility piping and conduits servicing building to minimize site disturbance.

6.2.3 For locations in the Clark County School District, utilize native and drought resistant planting materials and xeriscape principles to minimize need for site irrigation.

1. Based upon the findings of previous site analysis, develop a landscape design in a manner that insures compatibility of new and existing plants.

2. Select native trees including:

   a. Catclaw Acacia, *Acacia greggi*

   b. Blue Palo Verde, *Cercidium floridum*

Native species: Blue Palo Verde

"Native Plants for Southwestern Landscapes", by Judy Mielke, © 1993
Courtesy of the University of Texas Press

   c. Joshua Tree, Yucca brevifolia

Native species: Joshua Tree

"Native Plants for Southwestern Landscapes", by Judy Mielke, © 1993
Courtesy of the University of Texas Press

   d. Western Redbud, *Cercis occidentalis*

   e. Desert Willow, *Chilopsis linearis*

   f. Arizona Ash, *Fraxinus velutina*

   g. Texas Honey Mesquite, *Prosopis glandulosa*

   h. Canyon (Scrub) Oak, *Quercus turbinella*

3. Consider drought resistant trees including:

a. Of U.S. origin:

- Modesto Ash
- Honey Locust
- Fan-Tex Ash
- Thornless and Colorado Mesquite
- Valley Oak
- Heritage Oak
- Chitalpa

b. Of Asian origin:

- Raywood Ash
- Lacebark Elm
- Chir Pine
- Silk Tree
- Eldarica Pine
- Chinese Pistache

c. Of Mediterranean origin:

- Stone Pine
- Chaste Tree
- Pomegranate
- Holly Oak
- Aleppo Pine
- Olive

4. Select native shrubs including:

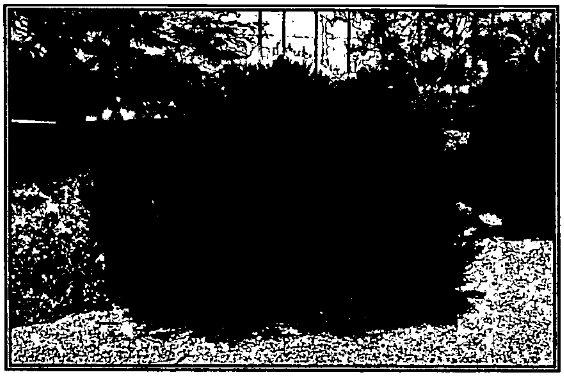
a. Desert Milkweed, *Asclepias subulata*

b. Quail Bush, *Atriplex lentiformis*

c. Desert Broom, *Baccharis sarothroides*

Native species: Desert Broom

"Native Plants for Southwestern Landscapes", by Judy Mielke, © 1993
Courtesy of the University of Texas Press



d. Golden Rabbit Bush, *Chrysothamnus nauseosus*

e. Cliff Rose, *Cowania stansburiana*

f. Brittlebush, *Encelia farinosa*

g. Morman Tea, *Ephedra viridis*

h. Flattop Buckwheat, *Eriogonum fasciculatum*

i. Apache Plume, *Fallugia paradoxa*

j. Creosote Bush, *Larrea tridentata*

k. Desert Sage, *Salvia dorri*

5. Consider low water, drought resistant shrubs including:

a. Desert Honeysuckle
b. Wormwood
c. Fairy Duster
d. Alderleaf Mountain Mahogany
e. Bush Morning Glory
f. Little-Leaf Cordia
g. Turpentine Bush
h. Chuparosa
i. Bush Lantana
j. Texas Ranger
k. Sugar Bush
l. Blue Sage
m. Autumn Sage
n. Arizona Rosewood
m. Mexican Flame
n. Wooly Butterfly Bush
o. Silver Leaf Cassia
p. Purple Rockrose
q. Texas Olive
r. Silver Dalea
s. Gregg Ash
t. Mexican Honeysuckle
u. Silver Cloud Sage
v. Red-Flame Sumac
w. Evergreen Sumac
x. Mealy-Cup Sage
y. Yellow Bells

6. Select native ground covers and vines including:

a. Dahlberg Daisy, *Dyssodia pentachaeta*

b. Blackfoot Daisy, *Melampodium leucanthum*

c. Gooding Verbena, *Verbena gooddingii*

d. Prairie Zinnia, *Zinnia grandiflora*.

7. Consider low water, drought resistant covers and vines including:

Native species: Trailing Indigo Bush

"Native Plants for Southwestern Landscapes", by Judy Mielke, © 1993
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a. Creeping acaccia
b. Bush Morning Glory
c. Trailing Indigo Bush
d. White Primrose
e. Centennial Broom
f. Groundcover Junipers
g. Cat's-Claw vine
h. Arizona Grape

8. Select native cacti including:

   a. Compass Barrel Cactus, *Ferocactus acanthodes*

   b. Strawberry Hedgehog, *Echinocereus engelmannii*

   c. Mojave Prickly Pear, *Opuntia phaecantha*

9. Select hardy cacti including:

   a. Saguaro
   b. pancake Prickly Pear
   c. Grizzly Bear Prickly Pear
   d. San Pedro
   e. Beehive Cactus
   f. Old Man Prickly Pear
   g. Coastal Prickly Pear

10. Select low water, drought resistant accent plants including:

   a. Octopus Agave
   b. Soaptree Yucca
   c. Beaked Yucca
   d. Pindo Palm
   e. African Aloe
   f. Ocotillo
   g. Bigelow Nolina
   a. Banana Yucca
   b. Weeping Yucca
   c. Guadalupe Island Palm
   d. Aloe Vera
   e. Toothless Sotol
   f. Red-flowered Hesperaloe

11. Select low water, drought resistant ornamental grasses including:

   a. Pampas grass
   b. Bigelow's Bear Grass
   c. Red Fountain Grass
   d. Deer Grass
   e. Fountain Grass

12. Select native perennials including:

   a. White Bursage, Ambrosia *deltoidea*

   b. Desert Marigold, *Baileya multiradiata*

   c. Winterfat, *Ceratoides lanta*

   d. Angel Wing Primrose, *Oenothera caespitosa*

   e. Paper Flower, *Psilostrophe cooperi*

   f. Globe Mallow, *Sphaeralcea ambigua*

   g. Palmer Penstemon/ Scented Penstemon, *Penstemon palmeri*

Native species: Penstemon

"Native Plants for Southwestern Landscapes", by Judy Mielke, © 1993
Courtesy of the University of Texas Press

13. Select low water, drought resistant perennials including:

a. Spurge
b. Guaura
c. Bearded Iris
d. Four O'Clock
e. Russian Sage
f. Lavender Cotton
g. Stonecrop
h. Hummingbird Flower
i. Blanket Flower
j. Hybrid Daylily
k. Lantana, Grayfeather
l. Catnip
m. Black-eyed Susan
n. Green Santolina
o. Mountain Marigold

14. Consider using native Annual Wildflowers including:

a. Modesto Ash
b. Esteve's pincushin Desert Sunflower
c. Goldfields
d. Arizona Lupine
e. Desert-dandelion
f. Mojave Desert Star
g. Birdcage Primrose
h. Rock Daisy
i. Cream Cups
j. Valley Oak
k. Pale Blue Trumpets
l. Arizona Poppy
m. White Tidy Tips
n. Desert Lupine Purple Aster
o. Monkeyflower
p. Purple Mat
q. Chinchweed
r. Wild Heliotrope
s. Desert-chicory

6.2.4 Develop landscaping designs that minimize potable water use including:

1. utilization of graywater from sinks and water fountains for irrigation supplement; and

2. use of soaker hoses and drip irrigation techniques that minimize evaporative losses and concentrates water on plants.

6.2.5 Understand and maximize natural conditions at the site.

1. Maximize site features that could be utilized in eco educational programs.
2. Provide or retain vegetation and landscaping buffers to protect against traffic noise.
3. Finalize grading plan that will maximize natural drainage systems.
4. Verify that the locations of any wind energy systems are not adversely affected by building design or landscaping (planned or existing).
5. Verify that the locations of solar systems are not shaded by buildings or landscaping (planned or existing).

6.2.6 Design for easy accessibility.

1. Provide conveniently located bicycle parking area that encourages bicycling to school.
2. Use photovoltaic powered caution and crossing signal lights.
3. Comply with all ADA and handicap requirements.

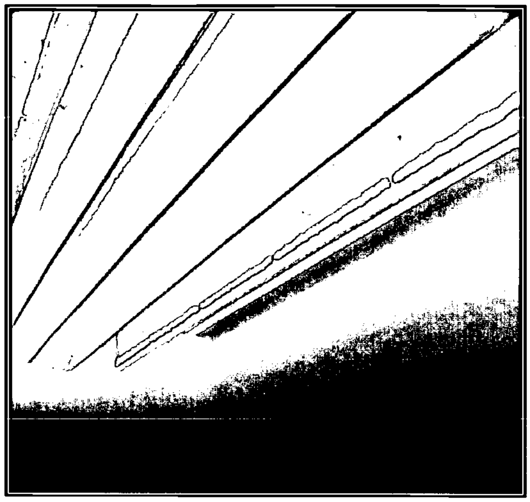
6.3 Daylighting

6.3.1 It is most important to verify that other, often unrelated, exterior design elements or existing site features are not negatively affecting the daylighting design.

1. Make sure other building elements are not shading the glazing areas designed as daylighting elements.
2. Consider the reflectance of the materials in front of the glazing areas to ensure that they correspond with the original assumptions in the daylighting analysis. The use of lighter roofing colors can reduce the glass area in roof monitors while a light colored walkway in front of lower view glass may cause unwanted reflections and glare inside the classroom.

6.3.2 In designing roof monitors, specify the specific daylighting components to ensure that the design has been optimized.

1. Choose light colored roofing materials in front of roof monitors to reflect light.
2. In roof monitor/lightwell assemblies, incorporate white (or very light colored) baffles that will run parallel to the glass and be spaced to ensure that no direct beams can enter into the space. These baffles should be fire-retardant and UV resistant. Use light colored, translucent baffles because, in addition to reflecting the sunlight down into the space, they also eliminate contrast from one side of the baffle to the other.
3. At the bottom of the lightwell it is best to transition the surfaces from the vertical plane to the horizontal by either introducing a 45 degree transition or, better yet, a curved section that will decrease the contrast between the higher light level inside the lightwell to the horizontal ceiling.



Curved transition from lightwell to ceiling plane

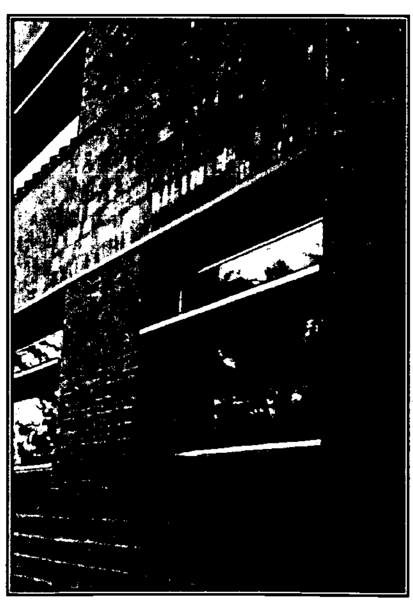
Innovative Design, Inc.

4. Ensure that the walls and ceiling of the roof monitor are well insulated and incorporate appropriate infiltration and moisture barriers.

5. Only use blackout shades in the monitors if it will be necessary to darken the space. Select high-quality, durable products that are easy to operate remotely.

6. For the monitor glass, select clear, double glazing or clear, double glazing with argon. Do not use low-e or tinted glass in these windows because it has lower visible light transmission, which (typically) adversely affects the daylighting and requires more glass area to achieve the same results.

6.3.3 In designing lightshelves, specify the specific daylighting components that will ensure that the design has been optimized.



Lightshelves on two story building

Innovative Design, Inc.

1. Select durable materials for both interior and exterior lightshelves, capable of carrying the weight of a person.

2. Aluminum exterior lightshelves provide a very good compromise between good reflectance, little or no maintenance, and cost.

3. Interior lightshelves can be finished with nothing more than white painted sheet rock. However, aluminized, acrylic sheets applied to the top of the shelf would allow light to bounce further back into spaces and could improve performance in deeper rooms without top lighting.

4. Even with a combination of interior and exterior lightshelves, direct beam light can, at times, enter into the space creating unwanted glare. If the lightshelves located close to perpendicular interior walls and are not deep enough to eliminate this problem (which is the typical case), vertical blinds can provide an excellent option. By using vertical blinds for the window section above the lightshelf the light can be directed towards the walls, thus eliminating glare and enhancing the bouncing of light deep into the space. White blinds would be preferred in order to increase reflectance.

   If the lightshelf windows are located near the middle of the space and further away from perpendicular walls, horizontal blinds (flat or curved but turned up-side-down) would allow the light to be reflected up toward the ceiling and deep into the space.

5. Separate blinds or shades should be provided for the view glass section, below the lightshelf, on southern exposures.

6. Lightshelves are not cost effective nor necessary on the northern exposure. However, it is still advisable to use clear, double glass or clear, double glass with argon (if possible) on high, non-view glass windows on the north.

7. The view glass on both the north and south side rooms should not be counted on in analyzing daylighting contribution, as these windows are often closed or covered. Because of this, these windows should be considered only view glass and should be double glazed, low-e with argon. Their sizing should be dictated by the requirement for views (providing a visual connection to the outdoor environment). By adding the low-e component to this lower glass comfort will be improved and the daylighting will not be affected.

6.3.4 Make sure those decisions on interior finishes or design elements are not detracting from the design, but enhancing it.

1. Use white (or very light colored) paint inside the lightwell area. Colors inside the room can be slightly darker but the lighter colors will help the light to reflect deeper into the space. Accent colors (with the majority still white) and beige colors are acceptable inside typical rooms.

2. Carpet or other floor coverings should be as light as is practical for maintenance. This will greatly enhance reflectance and require less glazing to produce the same light levels. If the floor finish is darker than anticipated, increased glass may be required for effective daylighting.

3. If television monitors are incorporated within the classrooms, locate them so as to minimize glare.

4. By placing southern exposed windows, with lightshelves, close to perpendicular interior north-south walls, the daylighting is improved into the space. The color of these walls, immediately inside the window, should be light in order to enhance this reflectance.

6.3.5 Use photocell controls to turn off exterior lights during daylight hours.

6.3.6 Specify lighting controls that maximize the impact that daylighting can have but ensure that students and teachers always have adequate light.

1. Multi-staged or dimmable lighting controls will enhance the economic benefits and provide for smoother transition between varying light conditions. The success of these controls relies on:

   a. having the sensors mounted in a location that closely simulates the light level (or can be set by being proportional to the light level) at the work plane and

   b. being programmed and tied to the central energy management system in a manner that will not allow the final stages of lighting to come on if occurring during times of peak load (note that this is highly unlikely since the peak occurrence will be when it is the hottest and this is when the sun is the brightest, which is when the daylighting is the best).

6.4 Energy-Efficient Building Shell

6.4.1 Most of the key decisions regarding the building shell will have been made by this time but care must be taken to investigate details to ensure that the intent has been carried out. Areas where conflicts often arise include:

1. roof assemblies where anticipated insulation levels are reduced because structural members are not as deep;
2. cavity walls where the insulation level is reduced because the cavity thickness is reduced;
3. roof assemblies where exposing one side of the radiant barrier becomes difficult because of details (resulting in an ineffective radiant barrier);
4. soffit and ridge areas where ventilation is restricted or eliminated;
5. wall assemblies where moisture barriers/retarders are difficult to install as intended;
6. overhangs (particularly on east or west windows) that do not extend far enough to provide proper shading;
7. walls and, particularly, roof finishes that have been changed from light colors, thus increasing uncontrolled absorption of solar radiation through building surfaces;

Reflectance Factor

New Snow	75%
White Painted Surfaces	70%
Concrete	40%
Old Asphalt	35%
New Asphalt	7%
Grass	6%

Ground surfaces differ widely in their light reflectance properties, which should be accounted for lighting design.

Source: Outdoor Lighting Manual for Vermont Municipalities

8. windows where the thermal breaks have been specified;

9. glass types that are not accurately specified for each location; and

10. radiant barriers in roof assemblies (where installed below the insulation and above the ductwork, as is recommended) that are not adequately detailed to insure a good infiltration/exfiltration barrier.

6.4.2 Verify that the appropriate glass choice has been specified for each particular application.

Application	Exposure	Type
View glass	South	clear double, low-e with argon
	North	clear double, low-e with argon
	East/West unshaded	tinted double, low-e with argon
	East/West shaded	clear double, low-e with argon
Windows above lightshelves	South	clear double or clear double with argon
High windows above view glass	North	clear double or clear double with argon
Roof monitors	South	clear double or clear double with argon

6.5 Solar Systems

6.5.1 In selecting and specifying solar systems (both thermal collection systems and photovoltaics), specify total "systems".

6.5.2 Integrated solar systems reduce cost by saving materials and labor. Detail integration to:

1. minimize redundant design elements (e.g., sawtooth photovoltaic array that could serve as the roof of a covered walkway);

2. provide non-shaded, solar access;

3. place the system in close proximity to the load or mechanical system servicing the load; and

4. improve the aesthetics.

6.5.3 Specify adequate warranty periods for solar systems and evaluate the need for including service agreement costing as an alternate in the bid documents.

6.5.4 Re-evaluate the extent to which these solar systems are serving as teaching tools and important components of the eco educational programs and specify components that will enhance that possibility.

1. Include graphical displays of the technologies including readouts that show the solar contribution.

2. Locate the systems for high visibility.

3. Where appropriate, design the system and its operation to have an interactive component.

6.5.5 Verify that there is little or no shading of solar systems created by building elements.

6.5.6 Verify that there are no conflicts between the landscaping plan and location of wind generators.

6.5.7 Use photovoltaic systems for remotely located applications (more than several hundred feet) that make economic sense and avoid site disturbances including:

1. caution lights for road crossings and school zone signage;

2. parking lot lighting;

3. telephone call boxes;

4. walkway lighting;

5. lighted signage; and

6. (coupled with an uninterruptible power supply) security lighting.

6.5.8 If batteries are provided with a photovoltaic system, insure that the batteries are located in a vented space separate from the main conditioned space.

6.5.9 Like any mechanical system, maintenance is required. In designing location of equipment, ensure that maintenance staff has easy access.

6.6 Energy-Efficient Lighting and Electrical Systems

6.6.1 Where there is energy or environmental benefit, provide lighting and electrical equipment that exceeds common standards.

1. Select electric motors that exceed NEMA & UL efficiency requirements.

2. Specify electric motors with IEEE Standard 112, Test Method B.

3. Verify compliance with the interior lighting design guidelines of the Illuminating Energy Society (IES). Avoid the use of outdated, higher light-level standards. Criteria should include illumination levels and luminance ratios since uniformity plays an important role in perceived lighting quality.

6.6.2 Integrate lighting and electrical systems into the energy management system. Implement an energy management system that allows for optimum energy performance and appropriate monitoring.

6.6.3 Lighting

1. In spaces that incorporate significant daylighting strategies, verify that the emphasis has been placed upon an electrical lighting design that:

    a. utilizes a relative energy efficient lighting strategy that is justifiable as a backup lighting option;

    b. is compatible with the quality of daylighting;

    c. incorporates staged or dimmable lighting controls tied to photocells located within each space and capable of reading light levels at the appropriate work surface; and

    d. employs lighting solutions that minimize glare.

2. In spaces that are not daylit, verify that the emphasis has been placed upon an electrical lighting design that:

    a. incorporates full-spectrum lamps;

    b. consists of high-efficiency lamps, fixtures, and electronic ballasts;

    c. reduces the use of incandescent fixtures; and

    d. incorporates reflectors within the light fixtures to maximize lumens per watt.

3. Verify that the most energy efficient technology for lamp fixtures and control equipment is specified prior to preparing contract documents. Choices in the energy-efficient lamps have greatly expanded during the recent years. Specify high-efficiency:

    a. T8 fluorescent lamps,

    b. compact fluorescent lamps,

    c. lower-wattage, high-color rendering HID lamps,

    d. compact reflector HID lamps, and

    e. halogen lamps with infrared reflectors.

4. Specify fluorescent lamps with a minimum color rendering index (CRI) of 80.

5. In selecting lamps, consider:

    a. the environmental impact associated with lamp disposal and

    b. the maintenance associated with each option.

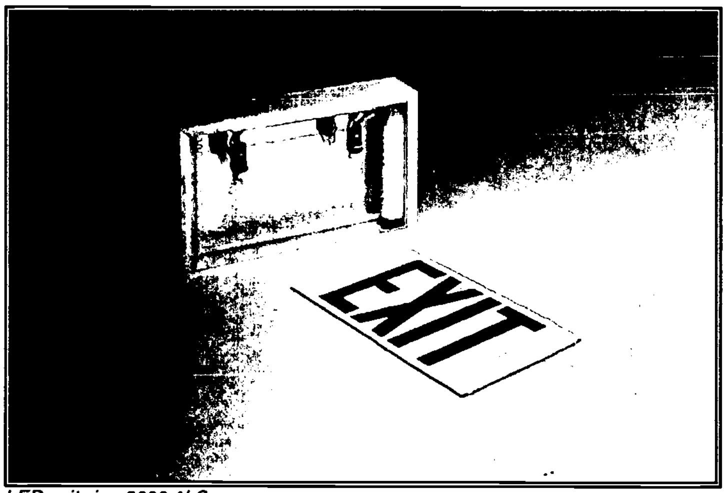
6. Coordinate the lighting plan (reflected ceiling plan) with the daylighting strategy as well as the furniture layout and functional needs of each space. Areas such as corridors or service spaces often achieve adequate lighting by "borrowing" it from adjacent areas requiring higher levels.

7. When designing the lighting in a daylit space, carefully determine if the use within the space changes between nighttime and daytime use. If less light (or task light) is required in the space at night it may be possible to install less lighting. An example may be a classroom that requires 60 footcandles during the day (when, on the cloudiest day, there is typically 15 footcandles of natural daylighting) but only requires 40

footcandles during the evening (when the general use would be for meetings). In this case only 45 footcandles of electrical lighting should be required to supplement the 15 footcandles of daylighting and produce the 60 footcandles required. Other than a few days in December, when it is still dark, the daylighting strategy should be able to provide a certain minimal amount of daylighting.

Note: Teachers may want more than 45 footcandles at night at their own work area but this could be better provided by simply increasing the light above these specific areas.

8. Specify LED exit signs in that they use only one to six watts, compared to 40 watts for older exit signs.



LED exit sign 3000 ALS
Courtesy of Astralite

9. Specify Class-P electronic high frequency instant-start parallel-circuit ballasts.

10. Make electric lighting more efficient by specifying 99% dimmable ballasts.

11. Specify electronic ballast with zero crossing circuitry. This eliminates the in-rush current problem caused by electronic ballasts. This is an important factor in determining the long-term reliability of lighting systems.

12. Direct exterior lighting downward to reduce light pollution and allow the use of lower wattage lamps.

6.6.4 Lighting Controls

1. Specify appropriate occupancy sensors.

    a. Infrared sensors are more suited for spaces where the sensor can have a clear view of the entire area and areas with high mechanical air flows (computer rooms, laboratories, etc.).

    b. Ultrasonic sensors are better suited for larger conference rooms, storage areas with cabinets and shelves, bathrooms, open office spaces, and areas that require 360 degree coverage but can not be viewed by a sensor.

    c. Dual technology systems (which combine passive infrared and ultrasonic technologies) can provide solutions for areas that are typically troublesome for single technology sensors. Dual technology sensors are more appropriate for classrooms, areas with high ceilings and areas requiring 100% cut-off and/or slight motion sensing.

2. Locate the photosensors correctly, so that they are simulating the light level at the work plane. The sensor should "see" a mixture of both natural and electrical light. They should not be located so as to be fooled by movement of occupants or objects in the space. The calibration of the photosensors for the lighting control systems is critical for the energy efficient operation.

3. Include in the specifications a requirement that a representative from the manufacturer participate in setting the sensor levels and participate in a training session of the school maintenance and administrative staff.

4. Consider the use of occupancy sensors and wireless controls not only to reduce power bills, but to also achieve increased productivity. Studies conclude that lighting quality and ability to modify lighting levels to suit the task at hand contribute to performance and accuracy.

5. In addition to controlling lighting so that it can respond to levels of daylight, other lighting control strategies are typically cost effective in reducing needs and subsequently reducing lighting and cooling energy consumption. Make sure that time or schedule controls, occupancy-sensor controls, and lumen-maintenance control programs are included in contract documents.

6. Specify that exterior lighting be controlled on astronomical clocks that are 365 day, programmable.

6.6.5 Energy-Efficient Equipment

1. Verify energy-efficiency ratings on the office equipment and appliances.

2. Specify exterior lighting powered with photovoltaic solar systems containing batteries. The initial cost of such systems is often justifiable by eliminating the need to run underground electric service to the fixture and the life-cycle energy cost savings.

3. The selection of electrical equipment should be based upon proper sizing, energy efficiency and environmental soundness. Oversized equipment can add significantly to peak electrical loads and, often, the equipment doesn't operate as well at part-load conditions.

6.7 Energy-Efficient Mechanical and Ventilation Systems

6.7.1 Mechanical

1. Verify that the mechanical systems servicing each area of the school have been zoned by orientation and use patterns.

2. Avoid oversizing heating and cooling equipment. In significantly daylit spaces, downsize cooling equipment to reflect daylighting benefits associated with the lights being off during peak load conditions. (When the sun is the brightest the daylighting is the best.)

3. Fine tune the selection of equipment to obtain maximum available Cooling Energy Efficiency Ratio (EER) and Heating Coefficient of Performance (COP) of the HVAC equipment.

4. Specify HVAC equipment that uses non-ozone depleting refrigerant in lieu of those containing chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs).

5. Consider photocatalytic oxidation equipment to produce excellent air quality or install a high-efficiency air filtration system to remove particles of airborne dust. The system should consist of two filters. The second or final filter should be 85 or 95 percent efficient or should be a HEPA filter.

6. Either encapsulate fibrous acoustical insulation that is located inside the air-handling units, ducts and variable-air-volume (VAV) boxes, or place duct insulation on the outside of the metal duct. These fibers tend to trap dirt that provides a medium for undesirable microbial growth.

7. Check the design of HVAC system installations to ensure adequate access for inspections and regular housekeeping, maintenance and cleaning.

8. Design the air-distribution system to ensure good air distribution to all locations.

9. Provide proper air distribution to deliver conditioned air to the occupant's work areas. The selection and location of diffusers can save energy and improve operation of the HVAC system control. Select diffusers with high induction ratios, low pressure drop, and good partial-flow performance. Locate diffusers for proper airflow, not on the basis of a simplistic pattern. Coordinate the layout with furniture and partitions.

10. Design dedicated local-air exhaust systems vented to the outside, separate from the general exhaust system in spaces that house specific contaminant sources such as kitchens, janitorial closets, bathrooms, and copy rooms.

11. Specify increased insulation thickness for all HVAC ductwork and equipment. Minimize ductwork in non-conditioned spaces. Locate ductwork in conditioned and semi-conditioned spaces (i.e., below insulation/radiant barrier assembly).

12. Specify sealing of ductwork seams, joints, and connections with permanently pliable water-based mastics or sealants with a volatile organic compound (VOC) content not to exceed 40 g/l.

13. Incorporate variable speed, energy efficient pumps and motors.

14. Minimize long duct runs and unnecessary turns and curves to keep static pressure losses to a minimum and, in turn, reduce the fan's energy consumption.

15. Require in specifications independent professional testing, adjustment, and balancing of the HVAC system to assure proper operation for occupant comfort.

16. Include in specifications the requirement of a building commissioning program to ensure good IAQ and energy-efficiency as outlined in ASHRAE guidelines.

17. Require in specifications that commissioning should be performed by knowledgeable persons either working directly for the School District or with contracted out to commissioning professionals.

6.7.2 Energy-Management Systems and Controls

1. Ensure that building energy-management control systems include the functions of:

    a. comfort control (temperature & humidity);

    b. scheduled operation (time-of-use, holiday & seasonal variations);

    c. sequence mode-of-operation (optimum start-up);

    d. alarms and system reporting;

    e. lighting and daylighting integration (including the elimination of at least the final stage of lighting during peak load conditions);

    f. maintenance management;

    g. indoor air quality reporting (and control of the increase in outdoor air if quality is low);

    h. remote monitoring and adjustment potential; and

    i. commissioning flexibility.

2. At a minimum, the energy management system should be programmed to:

    a. maximize use of economizer cycles;

    b. minimize operating time of all mechanical, electrical and solar systems;

    c. control programmed start and stop times;

    d. control chilled and hot water temperatures;

    e. control and if necessary override lights in daylit spaces to ensure lights are out during times of adequate natural light and simultaneous peak electrical conditions;

    f. control general outdoor and interior lighting; and

    g. control indoor air quality through the use of pollutant sensors.

3. Integrate engineering design strategies to maximize daylighting and integrate with artificial lighting and HVAC controls, to minimize HVAC load (particularly peak load).

6.7.3 Ventilation

1. Design the HVAC system controls to allow the building operator to respond quickly to comfort problems and ventilation deficiencies by providing a building control system with local controls (override switches and timers) where possible.

2. Verify that the design of the HVAC system provides adequate ventilation and appropriate temperature and humidity for human comfort in accordance with building codes and ASHRAE standards and guidelines. Use indoor air quality sensors to sense air quality and adjust outdoor air induction, accordingly.

3. Regulate quantities of ventilation air based according to specific occupancy needs. For example, sensors that detect occupancy, carbon dioxide, and volatile organic compounds (VOCs) can be used to monitor occupancy levels and provide greater fresh-air intake when required most.

4. Verify the design of outdoor-air economizer systems to allow outdoor air to be introduced into the system during times when the outdoor temperature and humidity conditions are acceptable. This outside air can be used to maintain the required inside conditions without the use of the refrigeration cycle and can lead to significant energy savings and improved air quality.

5. Dedicated ventilation fans (separately controlled) and/or dedicated ventilation distribution systems should be installed to insure quantity of air can be regulated, measured, and documented. This provides greater certainty that acceptable air ventilation is maintained. Ventilation air can be separately conditioned for improved energy efficiency.

6. In areas requiring high ventilation rates, air-to-air heat-recovery systems will provide increased energy efficiency and address both the sensible and latent loads. Air that is exhausted from the building can be used to precondition air entering the building, thus reducing energy needs. Run-around hydronic loops and heat pipes are two commonly used heat exchange methods.

7. Incorporate ventilation air cleaning with high-efficiency filtration.

8. Locate outdoor air intakes away from sources of contamination such as cooling towers, plumbing vents, loading docks, parking areas, relief-air louvers, and the dedicated exhausts from contaminated spaces such as toilets and copy rooms.

9. Employ outdoor air intakes with screens and bird guards to reduce animal/pest contamination.

10. Locating airflow monitoring devices on the outdoor air and return air side of the air handling system will allow these devices to better monitor and regulate the mix of outdoor and circulated air needed to provide good air quality.

6.7.4 Plumbing and Water Heating

1. Specify solar hot water systems as the most significant way to reduce hot water energy needs.

2. Use only energy-efficient hot water heaters that are well insulated. Use natural gas or LP gas hot water heaters where possible.

3. Losses from distribution piping and hot water storage tanks can be more than 30% of heating and energy input. Verify the use of tank insulation, anti-convection valves and heat traps where appropriate.

4. Confirm the hot water temperature requirements for each point of use and design system and distribution accordingly. Lowering the hot water supply temperature can significantly reduce the energy requirement.

Domestic Hot Water

Substantial amounts of energy can be saved in building facilities by reducing domestic hot water level and minimizing distribution losses. The hot water level is a function of both the amount of hot water required and the temperature difference between the feed water and the supply water. Lowering the consumption, lowering the supply water temperature, and/or raising the feed water temperature will reduce the hot water load. To lower consumption, reduce flow rate and usage by installing low-flow shower heads, flow restrictions or timers (including sensors) for regular self-closing faucets. Consider setting the thermostat at the lowest temperature at which hot water will meet occupant's needs. If the entire domestic hot water system needs to be set at a higher temperature for a particular service consider reducing the tank temperature and installing a booster heater on that service.

5. Include appropriate controls that will optimize energy use. Time-of-day controls on hot water heaters is a basic function that should be on all hot water heaters. Controls on other equipment (e.g., pumps) may also benefit from on-off scheduling and temperature optimization features.

6. Verify that hot water use is limited to areas specified in the programming phase of the project.

7. Use electronic ignition systems rather than pilot lights on hot water heaters.

8. Specify lead-free solder in the potable water lines.

9. Locate plumbing in close proximity so as to reduce losses due to lengthy pipe runs.

10. Specify that the water heaters are wrapped in an additional insulation jacket.

11. Consider specifying water fountains in lieu of electric drinking fountains.

12. Consider using efficient cooling tower water treatment technology which achieves at least five (5) cycles of concentration. These technologies include ozone, magnetic or well planned treatment.

13. Implement graywater systems that use water for irrigation.

14. The maximum water requirements for each fixture shall be as follows:

    a. tank type and flush valve toilets should not exceed 1.6 gallons per flush

    b. shower heads should not exceed 2.5 gallons per minute

    c. faucets should not exceed 2.2 gallons per minute

    d. urinals should not exceed 1 gallon per flush.

6.8 Environmentally Sensitive Building Products and Systems

6.8.1 Specifications for environmentally preferable products must be explicit about the required environmental performance of each product to ensure that other products, which are functionally equivalent but less appropriate environmentally, are not substituted. In particular, if the phrase "or equal" is used it must be clearly defined to include environmental criteria.

6.8.2 Language relating to the submittal of substitutions by the contractor should include the requirement that the proposed substitute be equal or better to the specified product in environmental attributes.

6.8.3 In some cases only one or two vendors may be identified that can provide a particular product. In such cases, the rationale and benefits of selecting this alternate should be provided to the Clark County Schools with all pertinent information in making the selection. If bidding requirements prevent the use of sole-source specifications, these products may need to be included in the specifications as "recommended alternates."

6.8.4 General Materials Selection Guidelines

1. Consider the impacts of manufacturing processes and:
   a. optimize the use of materials to avoid consuming more resources than necessary;
   b. utilize products made with low-polluting processes or solar energy;
   c. avoid using materials that are made from highly energy intensive processes;
   d. use products, processes, or materials with low embodied energy;
   e. select products made from raw materials without severe mining or harvesting; impacts;
   f. avoid wood from old-growth forests unless wood is salvaged from a previous use;
   g. specify products and materials that are made from recycled material; and
   h. specify products or materials that are recyclable.
2. Prefer products and materials that:
   a. are made from readily available resources;
   b. support the local economy by utilizing locally produced products;
   c. minimize transportation impacts by choosing locally available materials; and
   d. enhance the connection to place by using indigenous materials.
3. Consider the impact on building operation by:
   a. considering the environmental life-cycle impacts;
   b. designing systems to take advantage of renewable energy sources; and
   c. designing for graywater and efficient water use.
4. Do not include products that will pollute the building. This can be accomplished by:
   a. not specifying products that emit excessive amounts of volatile organic compounds (VOCs) often found in carpets, carpet backing, adhesives, sealants, and paints;

VOC Guideline for Paints

	flat (g/l)	non-flat (g/l)
Regulations		
United States (effective 9/13/99)		
Interior	250	380
Exterior	250	380
California South Coast Air Mgmt District		
	250 (1)	420 (2)
Voluntary Standards		
Green Seal Standards		
Interior	50	150
Exterior	100	200
Canadian Environmental Choice Program	200	200
European Eco-label	30	200

(1) Allowable levels scheduled to decrease to 100 g/l in 2001, and to 50 g/l in 2008
(2) Value based on resin type, non-flat category listed.

As seen in Energy Building News Magazine

b. not specifying products or materials that release particulates;

c. eliminating, reducing, or encapsulating formaldehyde in plywood, particleboard, composite doors, and cabinets; and

d. utilizing the least toxic termite control.

5. Minimize pollution associated with maintenance by:

a. avoiding products or materials which require maintenance with high environmental impact;

b. specifying products or materials that can be maintained in an environmentally sound way;

c. allowing for the outgassing of carpets containing VOCs prior to delivery to site; and

d. allowing adequate time between installation and occupancy for outgassing of materials.

6.8.5 Suggested Products and Practices by Division

1. Division 2 Sitework

a. Avoid wood treated with toxic metals (chromium, arsenic). Substitute wood treated with copper and ammonia, naturally rot resistant wood species (if available from sustainable sources), recycled plastic, and wood/plastic composites.

b. Use playground surfacing made from recycled rubber to utilize a recycled material and create a safe, attractive surface.

c. Use tire stops made from recycled plastic or old carpets to enhance durability, reduce use of concrete and utilize recycled materials.

d. Use outdoor furnishings made of recycled plastic or cast iron to utilize a durable, recycled material instead of less durable and/or toxic treated wood products.

e. Use drought resistant, native ground covers to reduce watering requirements and avoid introducing potentially invasive non-native species.

2. Division 3 Concrete

a. To reduce embodied energy and greenhouse gas emissions, minimize the amount of cement used by substituting flash or other pozzolanic material (per ASTM C 618).

b. Use recycled aggregate, if available, to reduce impacts of mining aggregate.

c. Use vegetable-oil-based form release agents to reduce toxic loading from petrochemicals and VOC emissions during construction.

d. Avoid formwork that is used once and wasted to reduce wood waste. Substitute with reusable forms, re-use of form materials in structure, or building systems in which the forms remain integral to the structure.

3. Division 4 Unit Masonry

a. Reduce embodied energy and greenhouse gas emissions by using CMUs with flash, replacing some of the cement.

b. Reduce energy use and greenhouse gas emissions from transportation by using clay brick from local sources.

4. Division 5 Metals

a. Reduce embodied energy and impacts of mining virgin ores by specifying that heavy-gauge steel products are made from at least 95% scrap.

b. Reduce embodied energy and impacts of mining virgin ores by specifying that aluminum products are made with at least 90% recycled content (except for aluminum in reflective coatings).

5. Division 6 Wood and Plastics

a. To avoid contributing to deforestation and habitat loss, all wood should be independently certified to the standards of the internationally recognized Forest Stewardship Council as coming from well-managed forests.

b. Avoid wood treated with toxic metals (chromium, arsenic). Substitute wood treated with copper and ammonia, naturally rot resistant wood species (if available from sustainable sources), recycled plastic and wood/plastic composites.

c. Avoid particleboard and other composites made with urea-formaldehyde to minimize formaldehyde emission in the school.

6. Division 7 Thermal and Moisture Protection

a. Prevent ongoing damage to the stratospheric ozone layer by avoiding insulation materials made with ozone-depleting substances.

b. Precautions should be established in specifications regarding the health related measures recommended for the installation of fiberglass insulation.

c. Avoid use of fibrous insulation materials inside ducts or in other locations where the fibers might enter into the occupied space.

d. Use radiant barriers in conjunction with other insulation materials to minimize radiant heat gain/loss.

e. Consider metal roofing, which is readily recycled and durable.

f. Minimize environmental loading of toxics and health risks to installers and school occupants by avoiding sealants containing methylene chloride or chlorinated hydrocarbons.

7. Division 8 Doors and Windows

a. Select windows for optimal balance of light transmission and thermal performance.

8. Division 9 Finishes

a. Consider impact-resistant gypsum board for interior walls. Gypsum board is relatively low in environmental impacts compared with other wall finishes. All gypsum should be made using recycled paper and recycled or synthetic gypsum should be used if possible.

b. Use ceramic tiles with recycled content for a highly durable, attractive recycled material.

Photo: Barry Halkin Photography, Philadelphia, PA

Recycled tile work

University City High School Cafeteria

School District of Philadelphia

c. Avoid carpet near entrances, in cafeterias, or in other potentially damp locations to reduce risk of microbial contamination from mold growth in the carpet.

d. Minimize environmental impacts associated with carpet manufacture by using modular carpet tiles with high-recycled content, refurbished tiles, or tiles made using renewable energy.

e. Use durable interior paints with the lowest possible VOC emissions (< 160 g/liter in high-wear areas, < 20 g/liter in less demanding locations) to minimize indoor air pollution.

9. Division 10 Specialties

a. Use restroom partitions with recycled content.

b. Use recycling receptacles and carts with recycled content.

10. Division 11 Equipment

a. All electrical equipment should be as energy-efficient as possible to minimize the greenhouse gas emissions from fossil-fuel powered electricity generation.

b. All equipment should be designed for ease of maintenance to avoid efficiency degradation from ill-maintained equipment.

c. Refrigeration equipment should be designed to minimize possibility of leakage of ozone-depleting refrigerant.

d. Use natural gas or LP gas fired kilns.

11. Division 12 Furnishings

a. Protect indoor air quality by avoiding furnishings made with urea-formaldehyde-based particleboard.

b. Use refurbished office furniture where practical to minimize environmental impacts of manufacturing new furniture.

c. Use anti-fatigue mats made of recycled rubber. These are a useful end-use for rubber from tires, which are a nationwide disposal problem.

12. Division 13 Special Construction

a. Design graphic displays providing real-time feedback on the school's overall energy usage and the contribution from each renewable source.

b. Provide replaceable nameplates for each bicycle parking space to encourage usage.

13. Division 15 Mechanical

a. Mechanical systems should be designed and installed for optimal long-term energy performance to minimize the greenhouse gas emissions from fossil-fuel powered, electricity generation.

b. Plumbing fixtures should be designed to minimize water use.

c. Ozone-depleting refrigerants should be avoided to protect the stratospheric ozone layer.

d. Avoid battery-powered flush valves and faucet controls to prevent toxic-waste disposal of used batteries.

14. Division 16 Electrical

    a. Lighting and other electrical systems should be designed for optimal long-term energy performance to minimize the greenhouse gas emissions from fossil-fuel powered electricity generation.

    b. Use low-mercury fluorescent lamps to reduce risk of mercury contamination from lamp breakage and reduce liability during recycling of used lamps.

    c. Specify that fluorescent lamps are always recycled upon removal to prevent toxic mercury from escaping into the environment.

6.9 Indoor Air Quality

6.9.1 Evaluate the HVAC system and design criteria in accordance with applicable codes and ASHRAE standards to:

1. provide adequate ventilation for the building occupants;
2. eliminate sources of microbial contamination; and
3. facilitate maintainability and cleanablity of the HVAC system.

6.9.2 Consider factors individually and collectively including those:

1. physical,
2. biological, and
3. chemical.

6.9.3 Implement strategies which address:

1. air intake locations,
2. air exhaust locations,
3. air filtration,
4. ventilation rates,
5. temperature,
6. humidity,
7. control systems,
8. exhaust systems, and
9. building commissioning.

6.9.4 Incorporate ASHRAE standards (62-1989R) for air ventilation rates.

6.9.5 Consider design alternatives to achieving good indoor air quality including:

1. material placement,
2. encapsulation, and
3. creating barriers.

6.9.6 When evaluating environmentally-friendly product alternatives to conventional options, consider:

1. equivalent products that are environmentally-safe,
2. products that are functionally equivalent but better environmentally,
3. products that have better component alternatives, and
4. options requiring less maintenance.

6.9.7 Implement radon mitigation strategies, if necessary.

6.9.8 Analyze the air circulation pattern to maintain proper air pressure relationship.

6.9.9 Consider the use of carbon dioxide (CO_2) and VOC sensors. The sensors should be linked to the building energy management system which can be used to regulate the quantity of the outside air needed to ventilate the building based on actual occupant-load and air quality conditions.

6.9.10 Consider the inclusion of photocatalytic oxidation as a means purifying air and reducing energy consumption.

6.9.11 Insist that building ventilation system be not operated during construction periods involving the application of VOC containing solvents or materials; painting, carpet installation. During these periods the spaces should be vented directly to the outdoors.

6.9.12 Specify that no-smoking be allowed inside the building from the commencement of construction through the life of the building.

6.9.13 Specify easy-to-maintain building materials and system.

6.9.14 Implement an integrated pest management program using only pre-authorized and non-hazardous chemicals that do not violate the integrity of the building indoor air quality.

6.9.15 Specify/select low-VOC emitting, environmentally-friendly cleaning agents for use in for cleaning of work performed during construction.

6.9.16 Prepare project specifications with appropriate warranties and, where appropriate, with extended maintenance contracts.

6.9.17 Verify locations of (separate) ventilation air intakes and exhaust fans to avoid air quality problems.

6.9.18 Eliminate or minimize building materials and furnishings containing toxics.

6.9.19 Use air and vapor retarders in the building envelope to control unwanted air movement through walls.

6.9.20 Limit the use of exposed, fibrous materials (microbial contamination).

6.9.21 Create landscape buffers between high traffic areas and building air intakes or natural ventilation openings.

6.9.22 Require contractors to:

1. minimize the use of toxic cleaners or chemicals;
2. safely store toxics and chemicals;
3. utilize construction procedures that will protect workers during installation of materials containing particulate matter, VOCs, or toxics;
4. utilize adequate ventilation during construction;
5. minimize open time of paint and thinner containers; and
6. utilize filters in ductwork and mechanical units during construction to minimize contaminants.

6.10 Water Conservation

6.10.1 To maximize water conservation, consider:

1. Avoid unnecessary water waste in the school by:
    a. insulating piping and locating water heaters to help reduce hot water waste; and
    b. using low-flow and water conserving fixtures.
2. Specifications for graywater systems must include details about the proposed uses for the reused water.
3. Any graywater systems or devices must be accompanied by detailed maintenance instructions to insure safe operation.
4. Use plumbing fixtures that utilize the least possible amount of water.
5. Specifications for water-conserving plumbing fixtures must include specific requirements regarding the amount of water those fixtures should use, and instruction as to how those requirements will be verified (whether by provision of documentation from the manufacturer, on-site testing, or otherwise).
6. When specifying unusual systems, ensure that all relevant costs and benefits are identified.
7. Any products that are not available from a sufficient number of competing manufacturers may need to be specified as "alternates". In such cases, the rationale and benefits of selecting this alternate should be noted to provide the client with all pertinent information in making the selection.
8. Utilize graywater from the building for site irrigation of landscaping.

9. Provide separate plumbing for graywater.

10. Specifications should clarify the importance of conserving water during construction and disincentives should be developed that will discourage wasteful water use.

11. Specify that the contractor is responsible for water cost during construction.

12. Minimize water consumption for irrigation by:

    a. utilizing graywater for site irrigation;

    b. using native plants and xeriscape principles to minimize irrigation requirements; and

    c. using soaker hoses and drip irrigation.

6.11 Recycling Systems and Waste Management

6.11.1 Recycling from School Activities:

1. Design school to facilitate:

    a. student, teacher and visitor placement of waste in localized bins throughout school;

    b. transfer of waste to central containers (mostly by students); and

    c. city or agency pick-up from central containers.

2. Provide separate collection bins for paper, glass, aluminum, plastics.

3. Provide central points within building for cardboard collection.

4. Consider anaerobic digestion (methane) process using yard waste from school and other facilities.

5. Provide recycling chutes for multi-story buildings.

6. Consider composting of organic waste to produce nutrient-rich soil.

7. Identify on the furniture plan provided to school system all built-in storage facilities, interim collection points, and central location from which materials can be collected by outside contractors for recycling.

6.11.2 Recycling During Construction:

1. Requirements for recycling of job-site waste during construction must be clearly spelled out in the specifications and reviewed by contractors and subcontractors before they bid on a job.

2. Overall goals and requirements should be described in Division 1 of Specifications, along with guidance for contractors on how to meet the recycling mandates.

3. Include a list of materials that should be recycled. Materials that are typically recycled from job sites include:

   a. corrugated cardboard,

   b. all metals (i.e., copper piping, wire, etc.),

   c. clean wood waste,

   d. beverage containers, and

   e. clean fill materials (concrete, bricks).

4. Include a list of local facilities that can take waste materials.

5. Construction documents should require that all bids are accompanied by a waste management plan, including estimates of the cost savings (or cost increase) of sorting and recycling waste.

6. Specific recycling language for each trade should also be included in each of the remaining 15 divisions. Subcontractors will need to know if the contractor is providing multiple bins for the sorting of materials, or if they are to be responsible for handling their own waste.

7. Save appropriate rock in area of site to be disturbed, for use as groundcover after final grading.

8. Evaluate and control use and storage of hazardous waste products (oil, paint, thinner, cleaners, lighting lamps, etc.).

9. Verify product and material substitutions during construction to ensure that substitutes contain the same level of recycled material.

10. Ensure proper material handling and storage by contractor to minimize waste.

11. Require that packaging of products, materials, and equipment delivered to site be made from recyclable or reusable materials and discourage unnecessary packaging.

6.12 Transportation

6.12.1 Ensure that pedestrian friendly site access to community sidewalks and public transits provided.

6.12.2 Design easy site access and convenient racks for bicycles.

6.12.3 If electric service vehicles and buses are intended, design solar electric charging station.

6.12.4 Design shower facilities for staff who choose to bicycle.

6.12.5 Provide photovoltaic powered caution and school zone flashing signs.

6.13 Commissioning and Maintenance

6.13.1 Include in specifications the requirement of subcontractors to:

1. provide adequate personnel during commissioning;
2. provide training of staff regarding all major equipment; and
3. provide the owner with operational/service manuals on all major equipment.

6.13.2 Major systems that require commissioning, training, and service manuals include:

1. water heating systems,
2. pumps,
3. cooling towers,
4. air handling systems,
5. refrigeration systems,
6. HVAC control systems,
7. energy management systems,
8. daylighting/lighting control systems,
9. emergency systems,
10. ventilation systems,
11. solar domestic hot water systems,
12. wind systems,
13. photovoltaic systems,
14. daylighting systems, and
15. graywater collection and distribution systems.

6.13.3 The commissioning process should be detailed in the specifications.

6.14 Eco Education

6.14.1 During the construction document phase, develop the integration of environmentally-sound and energy-efficient project components as identifiable, interactive educational tools.

1. Design school as a teaching tool for sustainability.
2. Send a clear message on sustainability by designing school to make a statement about

the need to help protect our environment.

3. Incorporate teaching/learning greenhouses for growing.

4. Integrate photovoltaic systems that could serve to educate students about the concepts of solar energy and the conversion of sunlight into electricity.

5. Provide visual display panel for students that indicates real-time energy consumption and the contribution that is being provided by each renewable energy system.

6. Design daylighting strategies that could be enhanced through student participation.

7. Use recycling systems within the school in which the students can participate.

8. Develop interpretive nature trails through preserved wildlife habitats and ecosystems.

9. Design the sustainable building components so as to make their purpose and function obvious to students.

10. Provide for a means by which students can monitor and interact with the sustainable building components.

11. Incorporate artwork and graphics in the building design which would help to educate students about sustainability.

12. Use outside teaching courtyards and spaces to allow for grouping plants, viewing habitat, and understanding eco-cycles.

Student planting beds within elementary school courtyard

13. Include educational signage about bicycle and other pedestrian-friendly transportation options for getting to and from the school.

14. Provide interactive play equipment with environmental message.

15. Provide interpretive displays showing total energy use at the school and the percentage of energy being provided by renewable sources.

ENERGY STATUS: CONSTRUCTION DOCUMENTS REPORTING FORM

Project .... **Project #**..................... **Date** ....

Submitted By..

Building Type	K-5 School	Middle School	High School ....
	Library	Gymnasium	Maintenance/Warehouse ....
	Horizon High Schools......................................		Other ....

Square Footage	Conditioned	Total	
Project Design Team	Architect	....	
	Lighting / Electrical Engineer	....	
	Mechanical Engineer	....	
Energy Consumption	Energy Budget	....	Btu/Square foot/Year
	Energy Goal	....	Btu/Square foot/Year
	Energy Projection	....	Btu/Square foot/Year

The analysis of energy consumption is based upon computer simulation of the school facility:

	% of Consumption	Btu/Square foot/Year
Heating	......................%	....
Cooling	......................%	....
Ventilation/O.A.*	......................%	....
Interior Lighting	......................%	....
Other Electrical	......................%	....
Hot Water	......................%	....
Other	......................%	....
Total Building	100 %	....

* Assume 15 CFM/person ventilation rate

Exterior Lighting and Other Loads: ....

Analysis Completed During Construction Documents

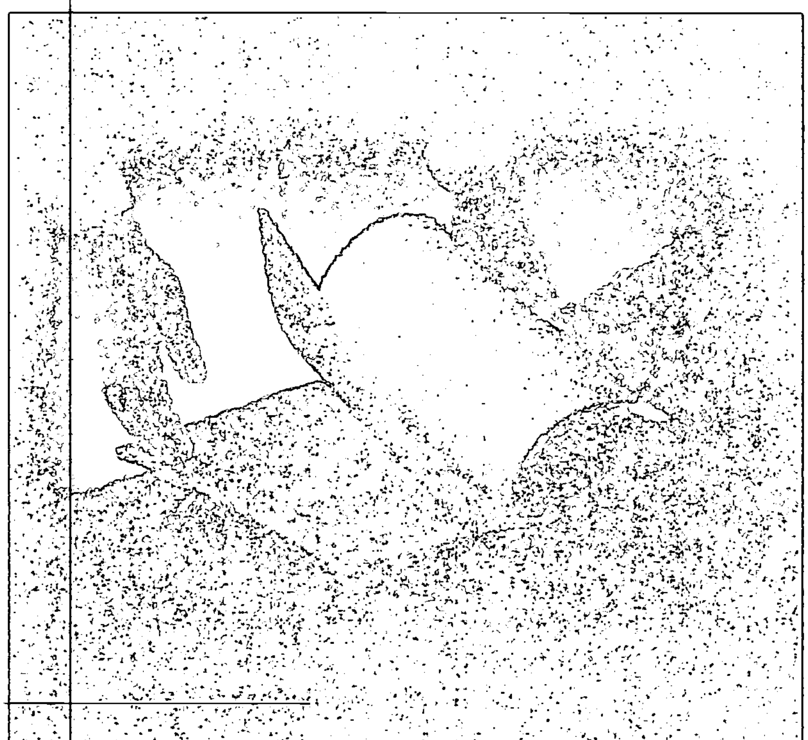
Please explain any variance from previous energy consumption projections.

Maintenance

Please explain the building maintenance ramifications of energy-saving features which require high maintenance

Section 7

BIDDING & NEGOTIATIONS



7. BIDDING AND NEGOTIATIONS

7.1 General

7.1.1 Qualifications and Experience of Bidders

1. Contractors, and subcontractors, experience in projects emphasizing sustainability should be considered in selection process.
2. Contractors and subcontractors with poor track records in valuing sustainability related objectives should be eliminated from consideration.

7.1.2 Communicating Sustainability Goals

1. All bidders should be notified within the specifications and at pre-bid meetings about the energy and environmental objectives of the project.
2. Reference should be made to language in construction documents referring to the contractors, and subcontractors, responsibility regarding:
   a. energy and water conservation at the construction site;
   b. construction material recycling;
   c. safe storage and handling of toxics during construction;
   d. construction procedures that will protect workers from contaminants; and
   e. protection of existing vegetation, wildlife habitats, and ecosystems during construction.

7.1.3 Review Process During Bid Phase

1. All alternatives or equals submitted by bidders should be evaluated as to whether or not the substitution affects the overall sustainability objectives. Specifically, products, materials, equipment, systems, or processes should not be replaced if the substitution results in a negative impact upon the:
   a. energy consumption or peak demand;
   b. natural environment;
   c. level of pollutants or indoor air quality;
   d. water consumption;
   e. recyclability or recycled content of items;
   f. environmental soundness of transportation options to site;

g. eco educational intent; or

h. the likelihood the items could be purchased locally.

2. Careful attention must be placed upon the interaction between building components and systems. Any substitution are alternate should be reviewed by representatives of the architect and engineers and, in appropriate cases, the landscape architect. This will help to ensure that substitutions will not result on unintended negative consequences.

3. Language relating to the submittal of substitutions by the contractor should include the requirement that the proposed substitute be equal to or better than to the specified product in environmental attributes.

7.2 Potential Pitfalls of the Bid Phase

7.2.1 Site Planning and Landscape Design

1. Shrubs and vegetation may be changed or modified as a budget saving measure, affecting the assumed solar access and/or shading values.

2. Vegetation that requires considerably more irrigation may be substituted for the specified plants.

7.2.2 Daylighting

1. Stepped daylighting controls may be substituted for continually dimming systems, greatly reducing the daylighting contribution.

2. Window transmission values or characteristics could be changed, which may negatively affect the energy performance.

3. Interior surface colors of walls, floors, ceilings, or furnishings may be changed, significantly affecting the daylighting contribution.

7.2.3 Energy Efficient Building Shell

1. A different color may be selected for the exterior building skin material, thereby affecting the thermal performance.

2. Insulation levels are sometimes reduced in order to save money, negatively affecting energy performance.

3. Substitutions regarding any components or wall or ceiling assemblies (e.g., insulation, vapor barrier, water barrier) may be modified, creating potential moisture problems.

4. Window substitutions can be made that disregard the benefits of the thermal breaks.

5. A cheaper radiant barrier may be substituted that is not properly protected from degradation, negatively affecting durability and, in turn, performance.

6. Glass transmission values, emissisivity, or types that were specifically selected to address orientation, comfort, glare, or desired visible light transmission may be altered, thus reducing potential benefits or creating significant additional thermal loads.

7.2.4 Solar Systems

1. Collectors (or systems) may be substituted that do not meet same standards, in turn affecting performance and/or durability.

7.2.5 Energy-Efficient Lighting and Electrical Systems

1. Substituted ballasts may conflict with daylighting controls.

2. Wattage of lighting fixtures might be modified, affecting cooling loads.

7.2.6 Energy-Efficient Mechanical Ventilation Systems

1. Air conditioning equipment could be substituted that does not match the load as well as the originally specified equipment, thus resulting in oversized equipment.

2. An energy management system could be substituted that doesn't have same capabilities to manage operations, thus reducing performance.

7.2.7 Environmentally Sensitive Building Products and Systems

1. Functionally equivalent, but less environmentally friendly, products could be substituted.

7.2.8 Indoor Air Quality

1. Substitute materials and products often contain different types and quantities of chemicals which may result in more pollution.

2. Alternate materials may require more environmentally harmful maintenance.

3. Care should be taken when substituting for materials that also serve as barriers or encapsulants of otherwise polluting sources.

7.2.9 Water Conservation

1. Alternate plumbing fixtures may consume greater levels of water.

2. Substitute planting may not be native to the region and may require additional irrigation.

7.2.10 Recycling Systems and Waste Management

1. Comparisons should be made regarding waste management plans submitted as a part of the bids.

2. Alternate recycling storage units/systems may be easier or more difficult to use. In analyzing alternates look at products from an ease-of-use perspective.

7.2.11 Transportation

1. Alternates should be evaluated in their relation to their effect on pedestrian access, public transit, and site accessibility.

7.2.12 Commissioning and Maintenance

1. If carpets or paints are substituted that release more VOCs, more time must be allowed between completion of installation and occupancy.

2. Alternates may have increased maintenance ramifications and should be analyzed carefully for life-cycle impacts.

3. The environmental impact of maintenance associated with alternates may not be obvious and should be considered.

7.2.13 Eco Education

1. Consider the educational aspect of alternates that were intended to serve as teaching aids as well as functional energy or environmental components of the design.

2. In evaluating cost saving strategies, items included that were more educational (and less integrally functional) may be viewed as items that could be eliminated. Special consideration should be placed on retaining these items, as they were already determined to be important instructional aids and teaching tools.

ENERGY STATUS: BIDDING PHASE REPORTING FORM

Project .... **Project #**..................... **Date** ....

Submitted by...

Building Type K-5 School .... Middle School .... High School ....
Library .... Gymnasium .... Maintenance/Warehouse ....
Horizon High Schools....................................... Other ....

Square Footage Conditioned: .... Total: ....

Project Design Team Architect ....
Lighting / Electrical Engineer ....
Mechanical Engineer ....

Energy Consumption

Energy Budget	....	Btu/Square foot/Year
Energy Goal	....	Btu/Square foot/Year
Energy Projection	....	Btu/Square foot/Year

The analysis of energy consumption is based upon computer simulation of the school facility:

	% of Consumption	Btu/Square foot/Year
Heating	......................%	....
Cooling	......................%	....
Ventilation/O.A.*	......................%	....
Interior Lighting	......................%	....
Other Electrical	......................%	....
Hot Water	......................%	....
Other	......................%	....
Total Building	100 %	....

* Assume 15 CFM/person ventilation rate

Exterior Lighting and Other Loads:	....
Total Facility (15CFM/person ventilation rate)	....

Status Report

Please explain any variance from previous energy consumption projections that may result from accepted alternates/change orders/modifications during construction

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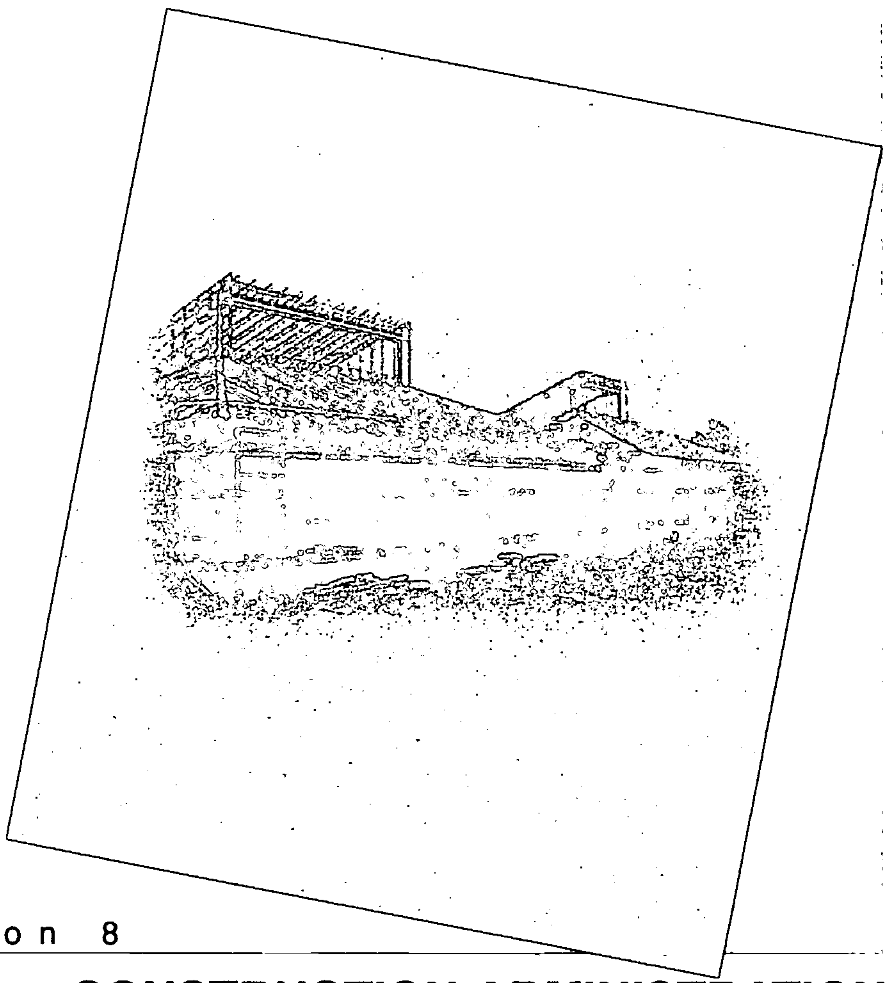


Section 8

CONSTRUCTION ADMINISTRATION

8. CONSTRUCTION ADMINISTRATION

8.1 General

8.1.1 Communicate with local officials and inspectors regarding any non-standard practices and/or technologies employed in the project.

8.1.2 Encourage all contractors, subcontractors, and workers to suggest ways to reduce the environmental impact of their work. Establish the individual(s) responsible for ensuring that these objectives are met.

8.1.3 The design team, owner, and contractors (including subcontractors) should collectively develop a staging area (or areas) that:

1. protect the existing shrubs and vegetation to be incorporated into the final design;
2. minimizes the chance for pollutants getting into any surface or ground water; and
3. facilitates recycling and waste removal.

8.1.4 Shop drawings should be reviewed carefully to ensure that details do not undermine sustainability objectives.

8.1.5 Create a pre-commissioning punchlist to clarify the necessity of testing and balancing and to establish the timing.

8.1.6 Document any changes to the plans that affect the issues of sustainability, to ensure that "as-built" drawings are accurate and complete.

8.1.7 Provide owner with maintenance/operational manuals and product information on all systems, products, and equipment that:

1. require specific maintenance to ensure sustained IAQ, environmental quality, and/or energy efficiency; or
2. detail means to maintain items in the most environmentally-sound manner.

8.1.8 Identify a safe holding area for hazardous materials.

8.2 Site Planning and Landscape Design

8.2.1 Establish and mark parking areas, travel routes, and staging areas, and discourage travel or parking outside these areas to protect the existing vegetation and the soil from compaction.

8.2.2 Carefully mark all important shrubs and vegetation areas for protection during construction. Consult with an arborist about how mature trees should be protected. Assign a value to any mature trees, and post it clearly, indicating that anyone who damages the tree will be charged that amount.

8.2.3 Implement measures to prevent erosion of any exposed soils during and immediately after construction, until planted vegetation is established.

8.2.4 Minimize dust to reduce disturbance to nearby people, animals and plants.

8.2.5 Minimize unnecessary noise from construction processes to reduce disruption to people and animals.

8.3 Daylighting

8.3.1 Verify that key window characteristics (transmission, tinting, and low-e) are those specified.

8.3.2 Confirm that the interior surface colors (walls, floors, and ceiling) are those specified. Darker colors will negatively impact the daylighting.

8.3.3 Make sure that specified lighting controls are installed and that they are properly set to the desired light levels.

8.3.4 Verify the geometry of the overhangs and the dimensions and spacing of the baffles (if employed).

8.4 Energy-Efficient Building Shell

8.4.1 Verify that the color of exterior finish materials are close to those anticipated, particularly the roof color, which will have the biggest impact.

8.4.2 Confirm that insulation levels are not reduced and the insulation is installed according to good practice.

8.4.3 Confirm that the radiant, infiltration, and moisture barriers have been installed correctly.

8.4.4 Care should be taken in accepting substitutes for radiant barriers because many less expensive options degrade over time.

8.4.5 Verify that key window characteristics (transmission, tinting, low-e coatings, and thermal breaks) are those specified.

8.4.6 Confirm that construction details have not been changed in a manner negatively affecting the thermal bridging.

8.5 Solar Systems

8.5.1 Verify that solar thermal collectors and/or photovoltaic panels are not shaded.

8.5.2 Verify that batteries associated with wind or photovoltaic systems are vented and battery case is adequately sealed.

8.6 Energy-Efficient Lighting and Electrical Systems

8.6.1 Ensure that reflector design and reflectivity of reflectors in light fixtures are similar to those specified.

8.6.2 Verify that dimmable or staged lighting control sensors are placed correctly, accurately reading light levels at the work plane.

8.6.3 Check lamps for specified wattage.

8.6.4 Verify that full spectrum fixtures are used in specified areas.

8.6.5 Verify that occupancy and motion sensors are working properly.

8.6.6 Check programmable controls for exterior lighting.

8.6.7 Verify that equipment being supplied by owner matches that previously supplied to architect and/or engineer.

8.7 Energy-Efficient Mechanical and Ventilation Systems

8.7.1 Mechanical

1. Ensure that mechanical equipment substitution does not result in oversizing units.
2. Conduct duct leakage tests if workmanship does not meet SMACNA standards.
3. Test for proper air balancing.
4. Check insulation within ductwork and air handling units to ensure that any fibrous material is encapsulated.
5. Complete operation and maintenance manuals should be supplied to owner and design team.

8.7.2 Energy-Management Systems and Controls

1. Check capabilities of energy management system to verify compliance with specifications.

8.7.3 Ventilation

1. Check to verify that ventilation air rate is not reduced.
2. Test set temperatures and humidity level controls.

8.7.4 Plumbing and Water Heating

1. Check hot water pipe and tank insulation levels.
2. Verify time-of-day controls on hot water heater.

8.8 Environmentally Sensitive Building Products and Systems

8.8.1 Review submittals and any substitutions to verify that the original considerations regarding sustainability are maintained.

8.9 Indoor Air Quality

8.9.1 Develop and implement an IAQ construction management plan that takes into account the unique aspects of each project, including:

1. whether portions of the building will be occupied while other areas are being completed;
2. project phasing; and
3. the possible impact on adjacent buildings.

8.9.2 Identify potential health and environmental hazards and take necessary steps to ensure good air quality for workers during construction as well as occupants after construction is completed.

1. Isolate areas under construction from occupied spaces. Use barriers to prevent the migration of airborne pollutants. Coordinate the location of these barriers with ventilation and mechanical systems so that the pollutants are not dispersed through the ventilation system.
2. Schedule hours of work involving significant use of VOCs and other pollutants during times when other trades are not in the affected area. Allow enough time to adequately flush out the building (and mechanical ductwork) prior to occupation by other workers.

8.9.3 Sequence construction phases to minimize the risk that building materials can become "sinks" for contaminants.

1. Wet construction processes such as painting, gluing or sealing often release their highest levels of VOCs during the curing process immediately after application. Certain construction materials such as fabrics, carpets, ceiling tiles, furniture, and movable partitions can often act as sinks for these pollutants, absorbing the contaminants and then slowly releasing them well after construction is completed.

8.9.4 Inspect and test contamination-mitigation strategies for effectiveness and make necessary adjustments to IAQ plan if pollutant levels are not acceptable.

8.9.5 Install temporary ventilation systems to exhaust specific construction areas when necessary to ensure good air quality and prevent pollutants from entering into the return air ductwork of the permanent mechanical system.

1. Ensure that effective, direct-to-outdoors ventilation is installed and working during application and curing of wet finishes and other products containing VOCs and urea-formaldehyde.
2. Ensure that ductwork and mechanical equipment is properly protected from dust and debris on site.
3. Implement methods to ventilate spaces during construction including using dedicated

exhaust systems (e.g., toilet, kitchen) that are not tied into the building's overall return air system; removing windows; and/or installing temporary fans in window openings.

8.9.6 Install localized air filtration systems when it is not possible to employ construction ventilation strategies.

8.9.7 Ensure that ductwork and mechanical equipment is thoroughly cleaned with nontoxic cleaning agents before it is connected and operated, and again just before occupancy.

8.9.8 Institute procedures to ensure that the site and building are maintained in a clean and orderly fashion. By frequently cleaning the construction and storage areas as well as disposing (in an environmentally sound manner) of non-recyclable site and building waste, the chance for contamination in the building is greatly reduced.

1. Special attention should be paid to traditional areas (e.g., mechanical rooms) where construction materials are often stored during the completion of a project.
2. Special care should be taken to ensure that all containers of substances containing VOCs, urea-formaldehyde, and other pollutants are closed when not being used.
3. Frequent cleaning with anti-dust sweeping compounds and the removal of waste materials should be normal practice.

8.9.9 Carefully collect and label all equipment manuals and guides, and provide additional guidance as needed to ensure that healthy conditions will not be compromised.

8.9.10 Check to ensure that all condensate pans drain properly, and no moisture will be trapped elsewhere in the mechanical system.

8.9.11 Check that any pesticide treatments are applied only as necessary, and not in such a way that a toxic residue might remain near student play areas or near building air inlets.

8.10 Water Conservation

8.10.1 Notify contractor of responsibility for paying for water used during construction.

8.10.2 Verify that low-flow fixtures as specified (or better) are installed.

8.10.3 Verify that pipe insulation is installed according to specifications.

8.10.4 Review landscaping materials for substitutes that may not be native to local area and require more water.

8.11 Recycling Systems and Waste Management

8.11.1 Review and enforce recycling and waste management objectives/requirements outlined in specifications, including:

1. recycling of job waste (corrugated cardboard, metals, clean wood waste, beverage containers, clean fill);

2. waste reduction through less packaging; and

3. use of recyclable or reusable packaging systems.

8.11.2 Make sure that the individual(s) in charge of implementing the waste management program, are clearly identified. This person or people should routinely monitor the effectiveness of the construction waste management program and modify it as necessary to meet the overall goals.

8.11.3 Contractor should track actual waste and recycled materials from construction site.

1. Tracking waste and recyclables can help ensure recycling bins are not contaminated and that pick-ups are timely.

2. Monitoring of the destinations of waste materials and recyclable materials also helps in evaluating cost-effectiveness.

8.12 Transportation

8.12.1 Encourage carpooling of workers to site.

8.13 Commissioning and Maintenance

8.13.1 Coordinate between contractor, sub-contractors, the design team and owner on commissioning process and timing.

8.13.2 Conduct a pre-commissioning meeting to ensure that all commissioning issues will be adequately addressed.

8.13.3 Contractor should start the operation of building systems and equipment so that they can be tested, inspected, adjusted, balanced, and corrected, if necessary. These procedures should be well integrated into the overall commissioning plan.

8.13.4 Establish timing for training of personnel so as to ensure attendance by future building operators, the principal, and maintenance staff.

8.14 Eco Education

8.14.1 Take photographs during construction to assist in eco educational efforts and commissioning training.

8.14.2 Encourage articles by the media explaining the unique sustainability aspects of what is being employed in the school construction.

ENERGY STATUS: CONSTRUCTION PHASE REPORTING FORM

Project .... **Project #**..................... **Date** ....

Submitted By...

Building Type K-5 School .... Middle School .... High School ....
Library .... Gymnasium .... Maintenance/Warehouse ....
Horizon High Schools....................................... Other ....

Square Footage Conditioned .... Total...

Project Design Team Architect ....
Lighting / Electrical Engineer ....
Mechanical Engineer ....

Energy Consumption

Energy Budget	....	Btu/Square foot/Year
Energy Goal	....	Btu/Square foot/Year
Energy Projection	....	Btu/Square foot/Year

The analysis of energy consumption is based upon computer simulation of the school facility:

	% of Consumption	Btu/Square foot/Year
Heating	......................%	....
Cooling	......................%	....
Ventilation/O.A.*	......................%	....
Interior Lighting	......................%	....
Other Electrical	......................%	....
Hot Water	......................%	....
Other	......................%	....
Total Building	100 %	....

* Assume 15 CFM/person ventilation rate

Exterior Lighting and Other Loads:	....
Total Facility (15CFM/person ventilation rate)	....

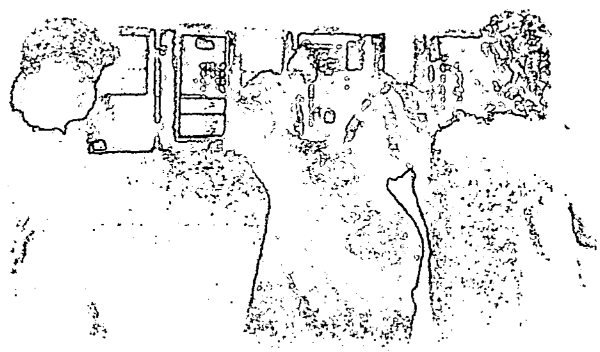
Status Report

Please explain any variance from previous energy consumption projections that may result from accepted alternates/change orders/modifications during construction

150

Section 9

COMMISSIONING



9. COMMISSIONING

9.1 General

Commissioning involves examining numerous building elements to verify that they are implemented in a manner consistent with design intent. A good commissioning process actually starts early in the design process with agreement on what items are to be included and how acceptable performance will be verified and documented from the end of construction through post-occupancy.

9.1.1 Major sustainable systems or building components that typically require commissioning include:

1. water heating systems,
2. pumps,
3. cooling towers,
4. air handling systems,
5. refrigeration systems,
6. HVAC control systems,
7. energy management systems,
8. daylighting/lighting control systems,
9. emergency systems,
10. ventilation systems,
11. solar domestic hot water systems,
12. wind systems,
13. photovoltaic systems,
14. daylighting systems,
15. graywater collection and distribution systems.

9.1.2 The individuals who will actually participate in the commissioning should include the architect, engineers, contractor, appropriate subcontractors, equipment suppliers, and the building owner and staff.

9.1.3 Develop and implement an air filter replacement schedule.

9.1.4 Construction Documents

1. During the construction documents phase, a detailed listing of items to be included and

the verification process shall be finalized for incorporation into the specifications.

2. Additionally, the architect should describe the commissioning process at any pre-bid, pre-construction, or pre-commissioning meetings.

9.1.5 Construction Administration

1. As required in the specifications, the contractor and subcontractors shall:

   a. provide adequate personnel during commissioning;

   b. provide training of staff regarding all major equipment; and

   c. provide the owner with operational/service manuals on all major equipment.

2. Use videotape and photographs taken during construction to help educate the building owner and staff. The commissioning process training could also be videotaped for training of future staff.

3. During appropriate times during construction, the systems and equipment shall be made operational, tested, adjusted, balanced, and/or deficiencies corrected. (See additional information listed under Construction Administration.)

4. Near the end of construction the performance will again be verified (if modifications were necessary); a training session will occur with representative of the owner and building maintenance staff present; and operational/service manuals distributed.

5. When the commissioning process is complete, the commissioning team (agent) should issue a report to the owner including:

   a. Building description, including size, location and use;

   b. Team members and their responsibilities;

   c. The final project construction documents, specifications, changes, and as-builts;

   d. A written description or schematic description of all key elements on the commissioning list;

   e. A summary of the evaluated system performance relative to the design intent;

   f. The completed "pre-functional" checklist;

   g. All approvals, non-compliance, and cost-tracking forms; and complete and detailed operational and maintenance manuals; and

   h. All photography, video and other documentation of verification work.

9.1.6 Post Occupancy

1. Conduct a fine-tuning of building systems after one year. This fine-tuning phase is an extremely important part of the commissioning effort and provides the opportunity to correct any problems identified and recorded by the owner.

2. During the first twelve months of operation the owner should record the conditions within the building during varying weather and load conditions. The owner should carry out normal procedures to adjust the systems to meet these varying conditions and record the response of the systems.

3. If the systems fail to respond to the varying weather and load conditions the owner should contact the contractor to fine-tune the malfunctioning system.

4. Every one-to-two years, throughout the life of the building, the system's performance should be re-evaluated and corrective action taken if there are any malfunctioning systems.

5. Photographs and video taken during the commissioning effort can be used to enhance the eco educational efforts.

Daylit library, Mt. Airy, NC, Courtesy of: The American Solar Energy Society

6. Conduct annual educational events with students, teachers and maintenance staff on sustainable features implemented into school.

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