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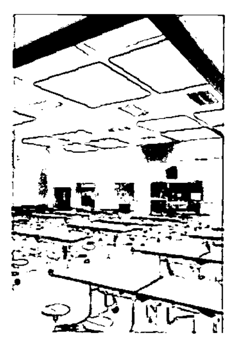
ABSTRACT

This guide offers a detailed listing of the key practices and technologies that can help create a sustainable school. The document includes hundreds of cost-effective recommendations that can improve the energy performance and environmental quality of school designs. Each design and construction phase is addressed, from site selection through commissioning. Each phase is further divided into some or all of the following fourteen areas, which apply to each phase: general considerations; site planning and landscape design; daylighting; energy efficient building shells; 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 ecological education. (GR)

Texas Initiative on Sustainable Schools

Texas Sustainable School Design Guideline

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

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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. Sustainable design is a holistic effort and as such, these guidelines would not have been possible without the dedication and energy of the below list of team members.

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Table of Contents

This document, *Texas Sustainable School Design Guideline*, is organized by the Design and Construction Phases listed above in the table of contents (Site Selection through Commissioning). Each of these phases are further divided into some or all of the following fourteen areas that apply to each phase.

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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 *Texas Sustainable School Design Guideline* was 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. The schools we design and build should make a strong statement that saving energy and protecting our environment is important.

During the past two decades Texas has moved from a period of abundant, inexpensive energy and 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. This guideline, which embraces a philosophy of long-term thinking, is important because it points out numerous options that can drastically reduce these unnecessary costs. The guideline is significant because it is now apparent that the way we design our schools strongly impacts both the health and productivity of students and teachers. In schools, the use of natural daylighting in place of electrical lighting (one of the sustainable design strategies featured throughout this guideline) has been shown in studies in North Carolina and later in California, Colorado, and Washington to greatly increase student performance. The use of daylighting is a win-win opportunity because it also can cut energy bills as well as reduce initial construction costs.

This *Texas Sustainable School Design Guideline* offers 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 that others working to create such facilities will find this guide useful.

Key Components of Sustainable School Design

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.

1 Site Planning and Landscape Design

- Develop the site in an environmentally sensitive manner.
- Understand and maximize natural site conditions.
- Design the site for easy pedestrian, bicycle, mass transit, and handicap accessibility.

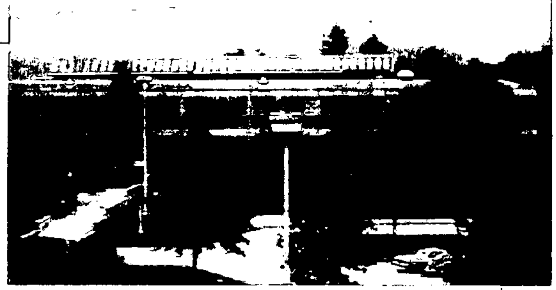
2 Daylighting

- Incorporate daylighting as a significant lighting strategy for all main teaching and learning spaces.
- Orient buildings to maximize southern exposure and minimize east-west walls.
- Reduce cost by integrating daylighting components into overall design.
- Account for benefits of daylighting by reducing cooling equipment and electrical lighting.

3 Energy Efficient Building Shell

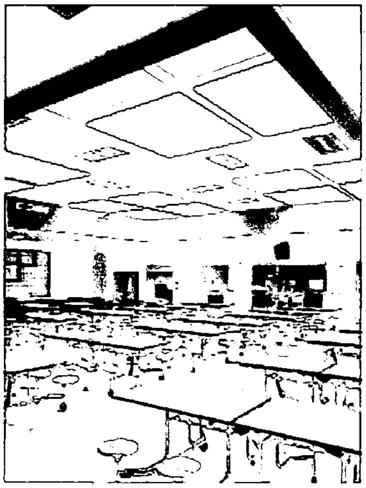
- Design shell to address all radiant energy flows as well as conductive heat gain and loss.
- Select the optimum glazing for each location on the building.
- Provide proper window treatments to maximize winter solar gain and minimize summer overheating.

4 Solar Systems



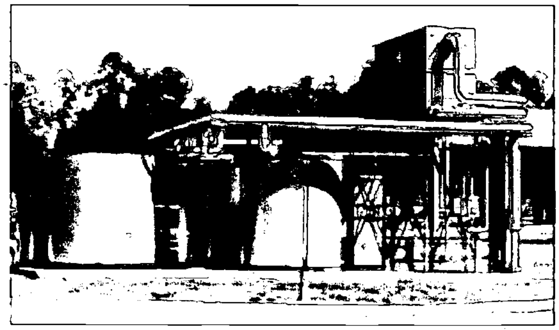
- Consider wide range of viable solar technologies including daylighting, passive heating, domestic hot water and space heating, absorption cooling, building integrated photovoltaics, and exterior photovoltaic lighting systems.
- Reduce the net cost of solar systems by integrating them into overall design elements.
- Employ solar technologies as integral parts of the school's eco educational programs.

5 Energy Efficient Lighting and Electrical Systems



- Employ lighting systems that are compatible with the daylighting strategy and use full-spectrum lighting in well-utilized, non-daylit spaces.
- Utilize controls that reduce lighting levels in stages according to the amount of natural daylight in each space.
- Specify high-efficiency products that require low maintenance.
- Control key components of lighting, mechanical, and electrical systems with energy management system.

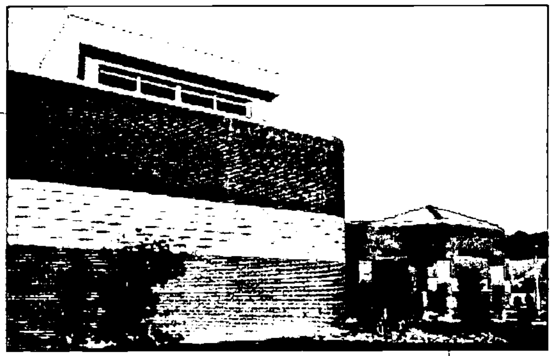
6 Energy Efficient Mechanical and Ventilation Systems



- Employ energy efficient mechanical system.
- Avoid oversizing equipment.
- Utilize waste heat wherever possible.
- Use energy efficient strategies to insure good indoor air quality.

7 Environmentally Sensitive Building Products and Systems

- Consider the life-cycle energy and environmental impacts of products, materials, and processes.



- Specify products that are made from recycled materials.
- Prefer local products, materials, and services.
- Consider the impact the product has on the building operation and maintenance.
- Specify products that do not pollute.

8 Indoor Air Quality

- Consider physical, biological, and chemical sources of potentially harmful contaminants and select environmentally friendly alternatives.
- Consider material placement, encapsulation, and the incorporation of barriers as means to insure good indoor air quality.

- Incorporate ASHRAE standards for air ventilation strategies and rates.
- Implement pollutant sensors and air quality monitoring equipment that controls fresh air make-up.
- Use natural ventilation strategies where practical.

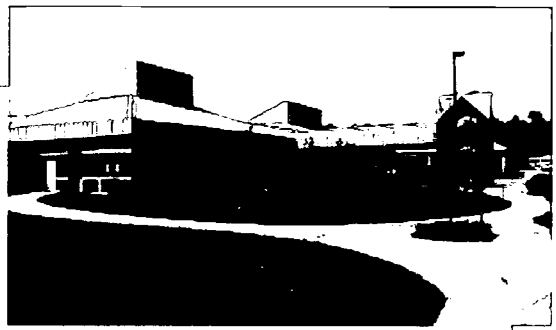
9 Water Conservation

- Harvest rainwater from the building roof and site for irrigation and toilet flushing.
- Avoid unnecessary water waste by incorporating low-flow and water conserving fixtures.
- Minimize water consumption for irrigation through the use of native plants and xeriscape principles.

10 Recycling Systems and Waste Management

- Encourage contractors to recycle waste materials during construction.
- Design school to facilitate recycling by students and staff.

11 Transportation



- Use alternative fuel and solar electric service vehicles and buses.
- Discourage single car travel by providing convenient connections to mass transit, safe bicycle paths, and pedestrian friendly walkways.

12 Commissioning and Maintenance

- Develop and implement an effective commissioning process that will help insure proper operation of mechanical, electrical, and solar systems.
- Recognize the needs for on-going efforts.

13 Eco Education

- Through the design of the building, send a clear message that sustainability matters.
- Design the school as a teaching tool for sustainability.

1. SITE SELECTION

1. SITE SELECTION

■ 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.

■ Site Planning and Landscape Design

- Consider rehabilitation of existing site or urban infill area versus use of undisturbed site.
- Avoid sensitive ecosystems, such as wildlife habitats and wetlands.
- Select site that can maximize orientation for solar access and daylighting.
- Consider geological, micro-ecological, and micro-climatic conditions.
- Determine existing air and water quality and impact that school will have on these conditions.
- Evaluate noise levels typically experienced at site.
- Evaluate flooding and site water issues.
- Determine presence of historic landmarks and/or archeological features on site.
- Conduct assessment of impact school will have on wetlands, wildlife habitats, and other sensitive ecosystems.
- Evaluate the impact the school will have on local environment.
- Consider protection and retention of existing landscaping.
- Evaluate potential for utilizing existing vegetation for shading.

■ Daylighting

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

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

■ Solar Systems

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

■ Indoor Air Quality

- Consider outdoor air conditions and physical relationships to industries or utilities which pollute air.

■ Recycling Systems and Waste Management

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

■ Transportation

- Consider mass transit accessibility to site.

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

2. SELECTION OF ARCHITECTURAL & ENGINEERING DESIGN TEAM

2. SELECTION OF ARCHITECTURAL & ENGINEERING DESIGN TEAM

■ General

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

- Request for qualifications and proposals should include questions regarding:

    1. site landscape considerations;
    2. daylighting;
    3. building shell design;
    4. solar design;
    5. energy-efficient systems (mechanical, electrical, ventilation);
    6. environmentally sensitive building products and systems;
    7. indoor air quality;
    8. water conservation; and
    9. recycling systems and waste management.

- 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 sustainability.

3. PROGRAMMING AND GOAL SETTING

3. PROGRAMMING AND GOAL SETTING

■ 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.

- Design element is determined to be cost effective based upon:

    1. a life-cycle cost analysis using a projected life of the facility;
    2. a simple payback with a time frame that reflects a balance between the overall budget and a life-cycle cost approach; or
    3. another criteria.

- Design element cannot be justified economically but it:

    1. is environmentally preferable and costs no more than 15% more than typically utilized elements;
    2. demonstrates an environmentally sound technology that will produce educational benefits;
    3. should be incorporated because it will become an integral part of the educational program (e.g., greenhouse for growing plants and creating space heating advantages);
    4. will provide productivity, psychological, and/or health benefits (e.g., a product substitution that will eliminate outgassing of volatile organic compounds);
    5. will result in significantly greater benefit to the local economy (e.g. locally manufactured product or locally available materials);
    6. replaces an element with a high negative environmental impact; and/or
    7. addresses an increasingly problematic environmental issue (e.g. water conservation).

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

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

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

- 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;

        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 regarding the number of students that access the school by foot, bicycle, bus, or mass transit.

- 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.

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

■ Site Planning and Landscape Design

- Establish objectives regarding:

    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 (coupled with a minimization of east-west exposure);
    3. protection of wetlands, 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 cntributing to heat islands;
    7. protection of the regional and global environment; and
    8. use of vegetation for shading.

■ Daylighting

- Establish objectives regarding:

    1. inclusion of natural daylighting in typically occupied spaces;
    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.

■ **Energy-Efficient Building Shell**

- 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 and south-facing glass for passive heating benefit (building orientation);
  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;
  6. use of one-story strategies to maximize daylighting potential; and
  7. use of light colored roofing materials.

■ **Solar Systems**

- Establish objectives regarding:

  1. the use of solar, including daylighting, passive heating, 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.

■ **Energy-Efficient Lighting and Electrical Systems**

- 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.

■ **Energy-Efficient Mechanical Ventilation Systems**

- 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.

■ **Environmentally Sensitive Building Products and Systems**

- 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;

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.

■ Indoor Air Quality

- 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.

■ Recycling Systems and Waste Management

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

- Determine local options for collecting waste materials for recycling.

- 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 selection of waste materials from construction that will require recycling by contractor; and

5. the collection, sorting, and appropriate disposal (including recycling and composting) of waste materials generated on site.

■ Water Conservation

- Gather information on water, including:

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

  2. quality and cost of municipal water; and

  3. quality of local rainwater and potential for uses.

- Gather information on sewage treatment and costs.

- Establish objective regarding:

  1. rainwater harvesting and use;

  2. graywater usage; and

  3. water conservation.

■ Transportation

- Evaluate locally available transportation options.

- 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.

■ **Commissioning and Maintenance**

- 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 (e.g., fluorescent lamps);

     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., lease of carpets); and

     j. minimizing personal travel associated with maintenance activities.

■ Eco Education

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

  5. 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;

  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.

4. SCHEMATIC DESIGN

4. SCHEMATIC DESIGN

■ General

- Conduct energy simulations of the entire school to determine interrelationships of key energy-saving measures being considered under the subcategories listed below.

- Conduct life-cycle cost analysis (or other agreed upon evaluation procedure) 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.

- Develop a breakdown of anticipated energy requirements listing major categories of use.

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

- Compare this to typical school consumption patterns and compare overall projected consumption to energy budget and goal.

■ Site Planning and Landscape Design

- Visit site and evaluate existing conditions carefully.
- Establish building orientation on east-west axis to maximize solar access.
- Employ one-story design to maximize daylighting.
- Protect and retain existing landscaping and natural features.
- Siting should protect or restore ecosystems, wildlife habitats, and wetlands.
- Consider erosion control and storm water management issues.
- Utilize earth-berming where possible.

- Utilize existing trees to protect against winter winds and to provide shading in the cooling season.

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

- Minimize impervious surface area on site.

- Consider wind patterns during site design to maximize positive benefits of natural ventilation in swing months and minimize negative impacts of cold winter winds.

- Identify area for stockpiling mulched vegetation and existing topsoil removed from the building area during excavation so that it can be reapplied as ground cover.

■ Daylighting

- 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.

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

- Conduct daylighting simulation of representative major spaces (e.g., classroom, gym, cafeteria, media center) and incorporate into full building energy analysis to determine overall effectiveness of design.

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

■ Energy-Efficient Building Shell

- 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);

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

6. internal mass to stabilize temperature fluctuation;

7. light colored roofing materials; and

8. overhangs and exterior shading.

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

- 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.

Solar Systems

- 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

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

- 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;

  5. solar electric charging stations for electric vehicles; and

  6. wind generators located on site.

■ Energy-Efficient Lighting and Electrical Systems

- 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 highest energy efficiency, state-of-the-art lighting strategies.

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

- 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.

- 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.

■ Energy-Efficient Mechanical and Ventilation Systems

- During schematic design, life-cycle cost analysis should be conducted on the comparison of various heating, cooling and ventilation systems appropriate for the area (and taking into account the daylighting, shell and electrical measures being considered).

- This evaluation should consider various options for mechanical systems including:

1. geothermal heat pumps;
2. air-to-air heat pumps;
3. central gas boiler with centrifugal chillers, with four-pipe chilled and hot water loops; and
4. solar assisted absorption cooling with gas backup.

- Different strategies to ensure adequate fresh air should be evaluated including:

  1. photocatalytic oxidation air treatment;
  2. economizer cycles;
  3. heat exchanger options, including those with enthalpy wheels;
  4. low-grade solar air heating options; and
  5. inclusion of pollutant sensors with above options.

- Thermal Energy Storage systems should be considered when there are:

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

Environmentally Sensitive Building Products and Systems

- 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 exterior wall construction or internal 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.

■ Indoor Air Quality

- 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.

■ Water Conservation

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

  1. the design and use of roof assemblies to capture rainwater for storage and later use for irrigation and/or toilet flushing;
  2. the incorporation of storage areas if rainwater or graywater is to be utilized; and
  3. the use of alternative fixtures, such as composting toilets, that have different space considerations.

Recycling Systems and Waste Management

- 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;
    3. space allocated for yard waste and/or composting; and
    4. collection chutes in multi-story facilities.

Transportation

- 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.

Commissioning and Maintenance

- 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.

Eco Education

- 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 and providing passive heating benefits;
  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;
  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 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.

5. DESIGN DEVELOPMENT

5. DESIGN DEVELOPMENT

■ General

- Verify that energy strategies chosen in schematic design meet the energy budget goals.

    1. If the energy analysis completed in schematic design reflects a projected energy consumption that meets energy budget goals, 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 goals, establish a list of secondary energy saving measures which will enable the goals to be met.

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

- 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.

- 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

- 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.

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

Site Planning and Landscape Design

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

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

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

    1. trees and landscaping to protect against winter winds as well as traffic noise;
    2. trees to provide shading in cooling season;
    3. earth-berming to earth-temper the walls or provide against winter winds;
    4. contours to better define floor levels and minimize grading; and
    5. site features to enhance eco-educational programs.

- 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 parking lots); and
    3. the use of rainwater catchment devices as design elements.

- 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.

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

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

- The degree of site disturbance should be re-assessed and areas should be clearly defined for temporary stockpiling of mulched vegetation and existing topsoil. This material will be removed from the building area during excavation and reused after grading is completed.

■ Daylighting

- 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.

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

- 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. South facing, vertical glazing is typically better in areas where there is a significant heating load (even if this load is typically met by artificial lighting) because roof overhangs can be designed to effectively admit low-angle winter radiation for daylighting and passive heating while excluding higher angle sunlight, experienced only in the summer months. North glazing is second best in that it doesn't create overheating problems in the summer but it also doesn't provide any passive heating benefits.

- 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.

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

- 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).

- 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;
    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. consider fiber optic task lighting with a daylighting source; and
    10. use photocell controls to turn off exterior lights during daylight hours.

- Vertical windows, located below lightshelves, should be controlled independently of those above the lightselves. 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.

- 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).

- 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.

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

  1. employ baffles within the lightwells 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.

Energy-Efficient Building Shell

- 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.

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

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

- 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 choice is typically tinted, low-e or low-e with argon;

    2. if windows are well shaded by the building elements or vegetation, tinting would not be advised;

    3. if windows are physically located close to the floor level (where comfort is a primary concern) and utilized for 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.

- Consider the possibilities for implementing natural ventilation strategies.

- 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.

- 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.

- 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.

■ Solar Systems

- 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.

- The best possible design data should be gathered regarding solar radiation and typical wind speeds at the site.

- 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.

- 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.

- 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
  3. passive heating systems including greenhouses.

- 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;
  3. solar electric charging stations for electric vehicles; and
  4. wind generators located on site.

  Small hydro systems could be a viable option if site conditions permit.

- 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.).

■ Energy-Efficient Lighting and Electrical Systems

- 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.

- 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;

    3. reduces the use of incandescent fixtures; and

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

- 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 where a low, uniform, low-glare light is most desirable.

- Check the lighting requirement associated with the specific task. Overlighting 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.

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

- Infrared or ultrasonic motion detectors (occupancy sensors) should be incorporated in all major spaces to turn off lights when the space is not occupied.

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

- 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.

- 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.

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

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

- 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.

- 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.

- 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.

- 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).

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

- 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.

- 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.

- 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.

- 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.

Energy-Efficient Mechanical and Ventilation Systems

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

- Optimize the mechanical system as a complete entity in order to allow for the interactions between the system components. For example, optimize the geothermal well field, piping, loop pumps and classroom units together to achieve a good overall system performance.

- Accurately size and select system components by using superior design tools. Computer based design tools should include capability to do an annual simulation for reliable results.

- 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.

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

- 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 radiated noise.

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

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

- 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.

- 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.

- 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.

- 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.

- 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.

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

- 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.

- Select plumbing fixtures and appliances that conserve water.

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

- 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.

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

    1. increasing insulation,
    2. using anti-convection valves, and
    3. using heat traps.

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

■ Environmentally Sensitive Building Products and Systems

- 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.

- By the design development phase a listing of locally produced materials and products should be assembled by the design team. 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.

- 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.

- 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;
  3. landscaping designs that rely on native planting materials; and
  4. the inclusion of rainwater catchment and its positive impact on site drainage issues.

- 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.

- 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 properly designed roof drainage system may enhance or hurt the potential for rainwater catchment; and/or

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

Indoor Air Quality

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

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

- 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.).

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

- Consider natural ventilation strategies in appropriate spaces.

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

- 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.

- Incorporate interior planting strategies.

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

- Design outside spaces that can be utilized for:

    1. teaching,

    2. breaks and lunch, and

    3. recreation.

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

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

- 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.

- 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.

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

- Develop an indoor pollutant source assessment and control plan.

- 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.

■ Water Conservation

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

- Calculate the typical rainfall on the site as well as projected roof areas.

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

- Waterless urinals should be considered as an alternative to conventional urinals.

- If rainwater is adequate and determined to be a viable option, rainwater catchment elements should be designed that make for:

    1. easy collection (slope roof or insulation to collection points);

    2. visually pleasing storage; and

    3. economical distribution to points of use (locate storage close to fixtures served or areas to be irrigated).

■ Recycling Systems and Waste Management

- Verify that consideration has been given to:

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

    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.

- 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.

■ Transportation

- 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.

■ Commissioning and Maintenance

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

- 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,

7. All approvals, non-compliance, and cost-tracking forms; and complete and detailed operational and maintenance manuals; and

8. All photography, video and other documentation of verification work.

Post Occupancy

- 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.
- 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.
- 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.
- 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.
- Photographs and video taken during the commissioning effort can be used to enhance the eco educational efforts.

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. rainwater collection and distrubution systems.

■ Eco Education

- 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 and providing passive heating benefits;

    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;

    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.

6. CONSTRUCTION DOCUMENTS

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■ General

- Verify that energy strategies developed in Design Development are consistent with the energy budget goals. At 50% completion of construction documents a 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 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 improvement can still be made.

        a. heating
        b. cooling
        c. lighting
        d. ventilation
        e. hot water
        f. miscellaneous electrical

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

- 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.

- 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.

■ Site Planning and Landscape Design

- Protect the existing environment.

    1. Specify the manner in which significant trees, natural features, ecosystems, wetlands, 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.

- Incorporate environmentally-friendly design solutions.

    1. Minimize impervious surfacing materials, allowing rainwater to soak into the ground.

    2. Eliminate heat island effects from parking lots by saving or planting trees that shade the area.

    3. Employ environmentally-sound erosion control and storm water retention.

    4. Stockpile existing topsoil, rock, and mulched vegetation from site for later use as ground cover.

    5. Use organic fertilizers in lieu of petroleum-based products.

    6. Use photovoltaic lighting for parking areas and exterior walkways.

    7. Distinguish between light, heavy and pedestrian traffic when designing paving thickness and stone base requirements.

    8. Aggregate location of utility piping and conduits servicing building to minimize site disturbance.

- Utilize native planting materials and xeriscape principles to minimize need for site irrigation.

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

  2. In the Dallas/McKinney area, select native canopy trees including:

     a. Bur Oak,
     b. Cedar Elm,
     c. Chinquapin Oak,
     d. Shumard Red Oak,
     e. Texas Ash, and
     f. Ashe Juniper.

  3. In the Dallas/McKinney area, select native understory trees including:

     <u>Flowering</u>

     a. Eve's Necklace,
     b. Rusty Blackhaw,
     c. Mexican Plum,
     d. Mexican Buckeye,
     e. Scarlet Buckeye, and
     f. Wafer Ash.

     <u>Bird Friendly</u>

     a. Common Perimmon,
     b. Carolina Buckthorn, and
     c. Roughleaf Dogwood.

  4. In the Dallas/McKinney area, select native ground covers including:

     a. Cedar Sedge,
     b. Golden Groundsel,
     c. Lyreleaf Sage,
     d. Missouri Violet,
     e. Violet Ruellia, and
     f. White Troutlily.

  5. In the Dallas/McKinney area, select native wildflowers including:

     a. Bluebonnet,
     b. Cutleaf Daisy,
     c. Wild Foxglove,

d. Greenthread,
e. Indian Blanket, and
f. Standing Cypress.

6. In the Dallas/McKinney area, select native ornamental accent plants and trees including:

   a. Prarie Edge,
   b. Possumhaw,
   c. Prairie Flameleaf,
   d. Purple Coneflower,
   e. Yucca,
   f. Black Dalea,
   g. Maximilian Sunflower, and
   h. Sideoats.

7. Where appropriate, use native, drought resistant turf grass (such as Buffalo Grass in Dallas/McKinney area).

- Develop landscaping designs that minimize potable water use including:

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

  2. use of soaker hoses that minimize evaporative losses and concentrate water on plants; and

  3. capture of rainwater from roof areas for use in irrigation and toilet flushing.

- Understand and maximize natural conditions at the site.

  1. Retain or plant vegetation that will protect against winter winds but, when possible, allow for natural ventilation in swing months.

  2. Maximize site features that could be utilized in eco educational programs.

  3. Provide or retain tree and landscaping buffers to protect against traffic noise.

  4. Finalize grading plan that will maximize natural drainage systems.

  5. Verify that the locations of any wind energy systems are not adversely affected by building design or landscaping (planned or existing).

  6. Verify that the locations of solar systems are not shaded by buildings or landscaping (planned or existing).

- 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.

Daylighting

- 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 or trees 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 refections and glare inside the classroom.

- 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 resistent. 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.

    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 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.

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

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 a 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.

- Make sure that 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. This improvement is due to the fact that the light is reflected deeper into the space. The color of these walls, immediately inside the window, should be light in order to enhance this reflectance.

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

- 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).

■ Energy-Efficient Building Shell

- 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;
  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.

- 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
	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

Solar Systems

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

- Integrated solar systems reduce cost by saving materials and labor. Detail integration so as 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. integrate the system into the overall design to improve the aesthetics.

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

- 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.

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

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

- 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 uninterruptable power supply) security lighting.

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

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

■ Energy-Efficient Lighting and Electrical Systems

- 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.

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

Lighting

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

    1. utilizes a relative 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. employs lighting solutions that minimize glare.

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

    1. incorporates full-spectrum lamps;
    2. consists of high-efficiency lamps, fixtures, and electronic ballasts;
    3. reduces the use of incandescent fixtures; and
    4. incorporates reflectors within the light fixtures to maximize lumens per watt.

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

1. T8 fluorescent lamps,
2. compact fluorescent lamps,
3. lower-wattage, high-color rendering HID lamps,
4. compact reflector HID lamps, and

5. halogen lamps with infrared reflectors.

- Specify nominal 4 foot, T8 fluorescent lamps with a minimum color rendering index (CRI) of 80.

- In selecting lamps, consider:

  a. the environmental impact associated with lamp disposal and

  b. the maintenance associated with each option.

- 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.

- 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 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.

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

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

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

- 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.

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

Lighting Controls

- Specify appropriate occupancy sensors.

  1. 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.).

  2. 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.

  3. 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 small motion sensing.

- 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.

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

- 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.

- 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.

- Specify that exterior lighting be controlled on astronomical clocks that are 365 days programmable.

Energy-Efficient Equipment

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

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

- 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.

Energy-Efficient Mechanical and Ventilation Systems

Mechanical

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

- 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.)

- 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.

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

- 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.

- 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.

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

- Consider the use of building pressurization in warm, humid climates to limit the infiltration of moist, hot outside air into the building interior. This will reduce the exposure of interior materials and finishes to moisture, inhibiting growth of molds and fungi on their surfaces.

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

- 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.

- 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.

- 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).

- 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.

- Incorporate variable speed, energy efficient pumps and motors.

- 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.

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

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

- Include in specifications expectations that the mechanical contractor will participate in training of staff and providing detailed information on all systems' and sub-systems' operational procedures and required maintenance.

- Consider off-peak thermal storage systems for chilled and hot water.

- Utilize waste heat from mechanical processes.

- Consider low-grade solar thermal systems for fresh air preheat and building-integrated PV/thermal preheat systems.

Ground Source Heat Pumps

- When designing ground source heat pumps consider the following suggestions.

  1. Conduct a survey at the site before the ground loop is designed.

  2. Specify thermally fused, high-density polyethene (HDPE) for all in ground piping.

  3. Avoid the use of low thermally conductive grout. Do not grout the entire bore. Grouting the upper portion of the bore provides more than adequate ground water protection.

  4. Consult with an experienced ground-loop contractor. Good contractors have perfected methods of installing 4-tubes and piping in-ground headers that are reliable, effective, and easily purged of air, dirt, and debris. This avoids assembling a large field-fabricated reverse-return header in a deep, muddy trench.

  5. Conduct a thorough study of heat gain and heat loss. Oversizing the system costs the owner much more in up-front construction costs.

  6. Separate vertical bores to minimize long-term heat storage effects that must be offset with longer loops. Twenty feet is the minimium recommended separation.

  7. Specify high-efficiency, single stage heat pumps with a minimum ARI-330 energy efficiency ratio (EER) of 13.0 Btu/w.h. (COP = 4.0). The economy of scale normally associated with larger units are not realized with GSHP systems. Water-to-air heat pumps larger than 6 tons (21 kW) typically have two compressors with individual refrigeration circuits. Minimal savings are realized compared to two smaller units. This discrepancy often becomes apparent when the added costs of central duct work and the equipment room space (required for larger units) are included. Also, be careful when using two-speed units in cooling-mode-dominated applications. While they appear to have a high rated EER, closer examination is normally necessary. Compare the high-speed cooling EER (with acceptable latent capacity) with the EER of a single-speed unit.

  8. Avoid using a highly sophisticated and complex controls.

  9. Avoid pumping too much water with too great a pump head. A well designed system should only require 5 to 7.5 pump horsepower per 100 tons of cooling (11 to 16 pump watts per kilowatt of cooling capacity). These guidelines can be met by circulating 2.5 to 3 gpm per ton of peak block load.

10. Use a single pump control with a minimum number of control valves. A single variable-speed pump with a differential pressure server across the building supply and return headers (at a location near the end of the piping) is adequate to control the system. Diverting the flow around the ground loop pays little dividend since a balanced heat load on the water loop rarely occurs.

11. Avoid using excessive amounts of antifreeze solution. Most ground loops require little or no antifreeze since schools typically have greater cooling loads than heating loads and water-to-air heat pumps reject almost twice the amount of heat they absorb.

Energy-Management Systems and Controls

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

    1. comfort control (temperature & humidity);
    2. scheduled operation (time-of-use, holiday & seasonal variations);
    3. sequence mode-of-operation (optimum start-up);
    4. alarms and system reporting;
    5. lighting and daylighting integration (including the elimination of at least the final stage of lighting during peak load conditions);
    6. maintenance management;
    7. indoor air quality reporting (and control of the increase in outdoor air if quality is low);
    8. remote monitoring and adjustment potential; and
    9. commissioning flexibility.

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

    1. maximize use of economizer cycles;
    2. minimize operating time of all mechanical, electrical and solar systems;
    3. control programmed start and stop times;
    4. control chilled and hot water temperatures;

5. 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;

6. control general outdoor and interior lighting; and

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

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

Ventilation

- 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.

- Verify the design of the HVAC system to provide 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.

- 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.

- 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.

- 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.

- 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.

- Incorporate ventilation air cleaning with high-efficiency filtration.

- 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.

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

- 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.

Plumbing and Water Heating

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

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

- 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.

- 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.

- 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.

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

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

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

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

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

- Consider specifying water fountain in lieu of an electric drinking fountain.

- 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.

- Implement rainwater catchment systems that filter and use water for toilet flushing, irrigation, and cooling tower make-up.

- Review local the plumbing code to determine minimum water requirements for each fixture. Where code allows, specify water-efficient,

  1. tank type and flush valve toilets that do not exceed 1.6 gallons per flush;

  2. shower heads that do not exceed 2.5 gallons per minute;

  3. faucets that do not exceed 2.2 gallons per minute; and

  4. urinals that do not exceed 1 gallon per flush.

■ Environmentally Sensitive Building Products and Systems

- 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.

- 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.

- 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 client 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."

General Materials Selection Guidelines

- Consider the impacts of manufacturing processes and:

  1. optimize the use of materials to avoid consuming more resources than necessary;

  2. utilize products made with low-polluting processes or solar energy;

3. avoid using materials that are made from highly energy intensive processes;

4. use products, processes, or materials with low embodied energy;

5. select products made from raw materials without severe mining or harvesting; impacts;

6. avoid wood from old-growth forests unless wood is salvaged from a previous use;

7. specify products and materials that are made from recycled material; and

8. specify products or materials that are recyclable.

■ Prefer products and materials that:

1. are made from readily available resources;

2. support the local economy by utilizing locally produced products;

3. minimize transportation impacts by choosing locally available materials; and

4. enhance the connection to place by using indigenous materials.

■ Consider the impact on building operation by:

1. considering the environmental life-cycle impacts;

2. designing systems to take advantage of renewable energy sources; and

3. designing for water collection and efficient water use.

■ Do not include products that will pollute the building. This can be accomplished by:

1. not specifying products that emit excessive amounts of volatile organic compounds (VOCs) often found in carpets, carpet backing, adhesives, sealants, and paints;

2. not specifying products or materials that release particulates;

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

4. utilizing the least toxic termite control.

- Minimize pollution associated with maintenance by:

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

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

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

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

<u>Suggested Products and Practices by Division</u>

Division 2 Sitework

- Use natural fiber erosion control mats instead of synthetic mats to encourage living vegetation to take over erosion control function.

- 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.

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

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

- 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.

- Use only drought resistant, native grasses for lawn areas to reduce watering requirements and avoid introducing potentially invasive non-native species.

Division 3 Concrete

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

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

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

- 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.

Division 4 Unit Masonry

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

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

Division 5 Metals

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

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

Division 6 Wood and Plastics

- 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.

- 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.

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

Division 7 Thermal and Moisture Protection

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

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

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

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

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

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

Division 8 Doors and Windows

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

Division 9 Finishes

- 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.

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

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

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

- Use 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.

Division 10 Specialties

- Use restroom partitions with recycled content.

- Use recycling receptacles and carts with recycled content.

Division 11 Equipment

- All electrical equipment should be as energy-efficient as possible to minimize the greenhouse gas emissions from fossil-fuel powered electricity generation.
- All equipment should be designed for ease of maintenance to avoid efficiency degradation from ill-maintained equipment.
- Refrigeration equipment should be designed to minimize possibility of leakage of ozone-depleting refrigerant.
- Use natural gas or LP gas fired kilns.

Division 12 Furnishings

- Protect indoor air quality by avoiding furnishings made with urea-formaldehyde-based particleboard.
- Use refurbished office furniture where practical to minimize environmental impacts of manufacturing new furniture.
- Use anti-fatigue mats made of recycled rubber. These are a useful end-use for rubber from tires, which are a nationwide disposal problem.

Division 13 Special Construction

- Design graphic displays providing real-time feedback on the school's overall energy usage and the contribution from each renewable source.
- Provide replaceable nameplates for each bicycle parking space to encourage usage.

Division 15 Mechanical

- 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.
- Plumbing fixtures should be designed to minimize water use.
- Ozone-depleting refrigerants should be avoided to protect the stratospheric ozone layer.

- Avoid battery-powered flush valves and faucet controls to prevent toxic-waste disposal of used batteries.

Division 16 Electrical

- 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.
- Use low-mercury fluorescent lamps to reduce risk of mercury contamination from lamp breakage and reduce liability during recycling of used lamps.
- Specify that fluorescent lamps are always recycled upon removal to prevent toxic mercury from escaping into the environment.

■ Indoor Air Quality

- 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.

- Consider factors individually and collectively including those:

    1. physical,
    2. biological, and
    3. chemical.

- 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.

- Incorporate ASHRAE standards (62-1989 and 55-1992) for air ventilation rates.
- Consider design alternatives to achieving good indoor air quality including:
  1. material placement,
  2. encapsulation, and
  3. creating barriers.
- 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.
- Implement radon mitigation strategies, if necessary.
- Analyze the air circulation pattern to maintain proper air pressure relationship.
- 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.
- Consider the inclusion of photocatalytic oxidation as a means purifying air and reducing energy consumption.
- Insist that building ventilation system is 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.

- Specify that no-smoking be allowed inside the building from the commencement of construction through the life of the building.

- Specify easy-to-maintain building materials and system.

- 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.

- Specify/select low-VOC emitting, environmentally-friendly cleaning agents for use in for cleaning of work performed during construction.

- Prepare project specifications with appropriate warranties and, where appropriate, with extended maintenance contracts.

- Verify locations of (separate) ventilation air intakes and exhaust fans to avoid air quality problems.

- Eliminate or minimize building materials and furnishings containing toxics.

- Use air and vapor retarders in the building envelope to control unwanted air movement through walls.

- Limit the use of exposed, fibrous materials (microbial contamination).

- Create landscape buffers between high traffic areas and building air intakes or natural ventilation openings.

- 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.

■ Water Conservation

- Avoid unnecessary water waste in the school by:

  1. insulating piping and locating water heaters to help reduce hot water waste;
  2. incorporating waterless urinals; and
  3. using low-flow and water conserving fixtures.

- Specifications for systems that include water collection must spell out for the contractor the planned uses for the stored water to ensure that the collection devices are installed appropriately. For example, toxic sealants and epoxies should be avoided inside storage tanks.

- Specifications for graywater systems must include details about the proposed uses for the reused water.

- Any graywater systems or devices must be accompanied by detailed maintenance instructions to insure safe operation.

- Use plumbing fixtures that utilize the least possible amount of water.

- 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).

- When specifying unusual systems, ensure that all relevant costs and benefits are identified. For example, with waterless urinals the cost of providing water supply lines to the urinals is avoided.

- 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.

- Harvest water from the building and site and utilize for site irrigation of landscaping and toilet flushing.

- Provide separate plumbing for rainwater and/or graywater.

- Specifications should clarify the importance of conserving water during construction and disincentives should be developed that will discourage wasteful water use.

- Specify that the contractor is responsible for water cost during construction.

- Minimize water consumption for irrigation by:

  1. utilizing graywater for site irrigation;

  2. using native plants and xeriscape principles to minimize irrigation requirements; and

  3. using soaker hoses with rain water sensor overrides.

■ Recycling Systems and Waste Management

Recycling from School Activities

- Design school to facilitate:

  1. student, teacher and visitor placement of waste in localized bins throughout school;

  2. transfer of waste to central containers (mostly by students); and

  3. city or agency pick-up from central containers.

- Provide separate collection bins for paper, glass, aluminum, plastics.

- Provide central points within building for cardboard collection.

- Consider anaerobic digestion (methane) process using yard waste from school and other facilities.

- Provide recycling chutes for multi-story buildings.

- Consider composting of organic waste to produce nutrient-rich soil.

- Identify on the furniture plan provided to owner all built-in storage facilities, interim collection points, and central location from which materials can be collected by outside contractors for recycling.

Recycling During Construction

- 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.

- Overall goals and requirements should be described in Division 1 of Specifications, along with guidance for contractors on how to meet the recycling mandates.

- Include a list of materials that should be recycled. Materials that are typically recycled from job sites include:

  1. corrugated cardboard,
  2. all metals (i.e., copper piping, wire, etc.),
  3. clean wood waste,
  4. beverage containers, and
  5. clean fill materials (concrete, bricks).

- Include a list of local facilities that can take waste materials.
- 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.
- 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.
- Mulch vegetation and save rock in area of site to be disturbed, for use as ground cover after final grading
- Evaluate and control use and storage of hazardous waste products (oil, paint, thinner, cleaners, lighting lamps, etc.).
- Verify product and material substitutions during construction to ensure that substitutes contain the same level of recycled material.
- Ensure proper material handling and storage by contractor to minimize waste.
- Require that packaging of products, materials, and equipment delivered to site be made from recyclable or reuseable materials and discourage unnecessary packaging.

Transportation

- Ensure that pedestrian friendly site access to community sidewalks and public transit is provided.
- Design easy site access and convenient racks for bicycles.

- If electric service vehicles and buses are intended, design solar electric charging station.

- Design shower facilities for staff who choose to bicycle.

- Provide photovoltaic powered caution and school zone flashing signs.

Commissioning and Maintenance

- 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.

- 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. rainwater collection and distribution systems.

- The commissioning process should be clarified in the specifications.

■ Eco Education

- Design school as a teaching tool for sustainability.
- Send a clear message on sustainability by designing school to make a statement about the need to help protect our environment.
- Incorporate teaching/learning greenhouses for growing plants as well as providing passive heating benefits.
- Integrate photovoltaic systems that could serve to educate students about the concepts of solar energy and the conversion of sunlight into electricity.
- Provide visual display panel for students that indicates real-time energy consumption and the contribution that is being provided by each renewable energy system.
- Design daylighting strategies that could be enhanced through student participation.
- Use recycling systems within the school in which the students can participate.
- Develop interpretive nature trails through preserved wildlife habitats and ecosystems.
- Design the sustainable building components so as to make their purpose and function obvious to students.
- Incorporate artwork and graphics in the building design which would help to educate students about sustainability.
- Use outside teaching courtyards and spaces to allow for grouping plants, viewing habitat, and understanding eco-cycles.
- Provide for a means by which students can monitor and interact with the rainwater catchment and distribution systems such as water garden areas.
- Include educational signage about bicycle and other pedestrian-friendly transportation options for getting to and from the school.
- Provide interactive play equipment with environmental message.
- Provide interpretive displays showing total energy use at the school and the percentage of energy being provided by renewable sources.

7. BIDDING AND NEGOTIATIONS

7. BIDDING AND NEGOTIATIONS

■ General

Qualifications and Experience of Bidders

- Contractors, and subcontractors, experience in projects emphasizing sustainability should be considered in selection process.

- Contractors and subcontractors with poor track records in valuing sustainability related objectives should be eliminated from consideration.

Communicating Sustainability Goals

- All bidders should be notified within the specifications and at pre-bid meetings about the energy and environmental objectives of the project.

- Reference should be made to language in construction documents referring to the contractors, and subcontractors, responsibility regarding:

    1. energy and water conservation at the construction site;
    2. construction material recycling;
    3. safe storage and handling of toxics during construction;
    4. construction procedures that will will protect workers from contaminants; and
    5. protection of existing vegetation, wildlife habitats, and streams during construction.

Review Process During Bid Phase

- 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:

    1. energy consumption or peak demand;
    2. natural environment;
    3. level of pollutants or indoor air quality;

4. water consumption;

5. recyclability or recycled content of items;

6. environmental soundness of transportation options to site;

7. eco educational intent; or

8. the likelihood the items could be purchased locally.

- 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 ensure that substitutions will not result on an unintended negative consequences.

- 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.

■ Potential Pitfalls of the Bid Phase

- Site Planning and Landscape Design

  1. Trees and vegetation may be changed or modified as a budget saving measure, affecting the assumed shading value.

  2. Trees may be substituted with others that grow to greater heights, potentially affecting a solar system or daylighting system.

  3. Vegetation that requires considerably more irrigation may be substituted for the specified plants.

- 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.

- 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 visable light transmission may be altered, thus reducing potential benefits or creating significant additional thermal loads.

- Solar Systems

  1. Collectors (or systems) may be substituted that do not meet same standards, in turn affecting performance and/or durability.

- 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.

- Energy-Efficient Mechanical Ventilation Systems

  1. Air conditioning equipment could be substituted that does not match the load as well as the orginally 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.

- Environmentally Sensitive Building Products and Systems

  1. Functionally equivalent, but less environmentally friendly, products could be substituted.

- 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.

- 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.

- 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.

- Transportation

  1. Alternates should be evaluated in their relation to their effect on pedestrian access, public transit, and site accessibility.

- 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.

- 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.

8. CONSTRUCTION ADMINISTRATION

8. CONSTRUCTION ADMINISTRATION

■ General

- Communicate with local officials and inspectors regarding any non-standard practices and/or technologies employed in the project.

- 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.

- The design team, owner, and contractors (including subcontractors) should collectively develop a staging area (or areas) that:

  1. protect the existing trees 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.

- Shop drawings should be reviewed carefully to ensure that details do not undermine sustainability objectives.

- Create a pre-commissioning punchlist to clarify the necessity of testing and balancing and to establish the timing.

- Document any changes to the plans that affect the issues of sustainability, to ensure that "as-built" drawings are accurate and complete.

- 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.

- Identify a safe holding area for hazardous materials.

■ Site Planning and Landscape Design

- 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.

- Carefully mark all important trees 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.

- Determine where and how topsoil will the stockpiled on site for reuse. Implement measures to minimize loss to erosion and wind.

- Implement measures to prevent erosion of any exposed soils during and immediately after construction, until ground cover is established. Where necessary to adequately protect from run-off, implement a on-site retention pond that captures and slowly releases surface water.

- Minimize dust to reduce disturbance to nearby people, animals and plants.

- Minimize unnecessary noise from construction processes to reduce disruption to people and animals.

- Protect water sources from contamination during construction.

■ Daylighting

- Verify that key window characteristics (transmission, tinting, and low-e) are those specified.

- Confirm that the interior surface colors (walls, floors, and ceiling) are those specified. Darker colors will negatively impact the daylighting.

- Make sure that specified lighting controls are installed and that they are properly set to the desired light levels.

- Verify the geometry of the overhangs and the dimensions and spacing of the baffles (if employed).

■ Energy-Efficient Building Shell

- Verify that the color of exterior finish materials are close to those anticipated, particularly the roof color, which will have the biggest impact.
- Confirm that insulation levels are not reduced and the insulation is installed according to good practice.
- Confirm that the radiant, infiltration, and moisture barriers have been installed correctly.
- Care should be taken in accepting substitutes for radiant barriers because many less expensive options degrade over time.
- Verify that key window characteristics (transmission, tinting, low-e coatings, and thermal breaks) are those specified.
- Confirm that construction details have not been changed in a manner negatively affecting the thermal bridging.

■ Solar Systems

- Verify that solar thermal collectors and/or photovoltaic panels are not shaded.
- Verify that batteries associated with wind or photovoltaic systems are vented and battery case is adequately sealed.

■ Energy-Efficient Lighting and Electrical Systems

- Ensure that reflector design and reflectivity of reflectors in light fixtures are similar to those specified.
- Verify that dimmable or staged lighting control sensors are placed correctly, accurately reading light levels at the work plane.
- Check lamps for specified wattage.
- Verify that full spectrum fixtures are used in specified areas.
- Verify that occupancy and motion sensors are working properly.
- Check programmable controls for exterior lighting.
- Verify that equipment being supplied by owner matches that previously supplied to architect and/or engineer.

■ Energy-Efficient Mechanical and Ventilation Systems

Mechanical

- Ensure that mechanical equipment substitution does not result in oversizing units.
- Conduct duck leakage tests if workmanship does not meet SMACNA standards.
- Test for proper air balancing.
- Check insulation within ductwork and air handling units to ensure that any fibrous material is encapsulated.
- Complete operation and maintenance manuals should be supplied to owner and design team.

Energy-Management Systems and Controls

- Check capabilities of energy management system to verify compliance with specifications.

Ventilation

- Check to verify that ventilation air rate is not reduced.
- Test set temperatures and humidity level controls.

Plumbing and Water Heating

- Check hot water pipe and tank insulation levels.
- Verify time-of-day controls on hot water heater.

■ Environmentally Sensitive Building Products and Systems

- Review submittals and any substitutions to verify that the original considerations regarding sustainability are maintained.

■ Indoor Air Quality

- 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.

- 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.

- 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 there 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.

- Inspect and test contamination-mitigation strategies for effectiveness and make necessary adjustments to IAQ plan if pollutant levels are not acceptable.

- 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.

- Install localized air filtration systems when it is not possible to employ construction ventilation strategies.

- Ensure that ductwork and mechanical equipment is thoroughly cleaned with nontoxic cleaning agents before it is connected and operated, and again just before occupancy.

- 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.

- Carefully collect and label all equipment manuals and guides, and provide additional guidance as needed to ensure that healthy conditions will not be compromised.

- Check to ensure that all condensate pans drain properly, and no moisture will be trapped elsewhere in the mechanical system.

- 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.

■ Water Conservation

- Notify contractor of responsibility for paying for water used during construction.

- Verify that low-flow fixtures as specified (or better) are installed.

- Verify that pipe insulation is installed according to specifications.

- Review landscaping materials for substitutes that may not be native to local area and require more water.

Recycling Systems and Waste Management

- 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.

- 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.

- 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.

Transportation

- Encourage carpooling of workers to site.

Commissioning and Maintenance

- Coordinate between contractor, sub-contractors, the design team and owner on commissioning process and timing.

- Conduct a pre-commissioning meeting to ensure that all commissioning issues will be adequately addressed.

- 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.

- Establish timing for training of personnel so as to ensure attendance by future building operators, the principal, and maintenance staff.

■ Eco Education

- Take photographs during construction to assist in eco educational efforts and commissioning training.

- Encourage articles by the media explaining the unique sustainability aspects of what is being employed in the school construction.

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9. COMMISSIONING

9. COMMISSIONING

■ 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.

- 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. rainwater collection and distribution systems.

- The individuals who will actually participate in the commissioning should include a the architect, engineers, contractor, appropriate subcontractors, equipment suppliers, and the building owner and staff.

Construction Documents

- 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.

- Additionally, the architect should describe the commissioning process at any pre-bid, pre-construction, or pre-commissioning meetings.

Construction Administration

- As required in the specifications, the contractor and subcontractors shall:

    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.

- 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.

- 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.)

- 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.

- When the commissioning process is complete, the commissioning team (agent) should issue a report to the owner including:

    1. Building description, including size, location and use;

    2. Team members and their responsibilities;

    3. The final project construction documents, specifications, changes, and as-builts;

    4. A written description or schematic description of all key elements on the commissioning list;

    5. A summary of the evaluated system performance relative to the design intent;

    6. The completed "pre-functional" checklist;

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