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**1.0 INTRODUCTION**

A building is an intervention in a continuous environment. It creates space, it is a visual object, it imposes an idea on (or responds to) the world around it. It affects the occupant mentally and physically; indeed it is the shelter for the occupant, and as such fulfills needs which are considerably older than recorded history. It responds to natural forces around it (whether well or badly) and even effects the ecology as a whole.

This course deals with the thermal and environmental processes which effect buildings, and how the designer responds to or manipulates the thermal environment. It is necessary for the architect to understand those processes, human response to them, and the materials and tools with which we may work.

**2.0 OUTLINE**

The building envelope, or "skin," consists of structural materials and finishes that enclose space, separating inside from outside. This includes walls, windows, doors, roofs, and floor surfaces. The envelope must balance requirements for ventilation and daylight while providing thermal and moisture protection appropriate to the climatic conditions of the site. Envelope design is a major factor in determining the amount of energy a building will use in its operation. Optimal envelope designs such as climate windows are also studied.

In keeping with the whole building approach, the entire design must integrate design of the envelope with other design elements including material selection; daylighting and other passive solar design strategies; heating, ventilating, and air-conditioning (HVAC) and electrical strategies; and project performance goals. One of the most important factors affecting envelope design is climate. Hot/dry, hot/moist, temperate, or cold climates will suggest different design strategies. Specific designs and materials can take advantage of or provide solutions for the given climate.

A second important factor in envelope design is what occurs inside the building. If the activity and equipment inside the building generate a significant amount of heat, the thermal loads may be primarily internal (from people and equipment) rather than external (from the sun). This affects the rate at which a building gains or loses heat.

The indoor thermal environmental criteria selection process must be sensitive to the type of building being designed as well as the activities expected within these spaces. Buildings which are designed to house athletic activities often require different occupant expectations than those of sedentary workers in typical office spaces, who often have higher sensitivity to drafts and local discomfort. Accordingly, the criteria level selection process must be sensitive to the space use within the bounds of the building type. Buildings which have naturally ventilated spaces may consider using the alternate comfort criteria. Therefore the type of conditioning system must be specifically designed for each unique solution.

**3.0 HOLISTIC BUILDING DESIGNS**

*Understanding the principles of sustainability in making architecture and urban design decisions that conserve natural and built resources, including culturally important buildings and sites and the criterion in the creation of healthful buildings and communities.*

**3.1 BUILDING CONFIGURATION AND PLACEMENT**

Orienting the building on an east-west axis will increase the potential use of daylighting. An elongated building that has its major axis running east-west will allow for capturing winter solar gain and reducing
unwanted summer sun that strikes the east- and west-facing surfaces. Exposed east- and west-facing glass should be avoided wherever possible because it will cause excessive summer cooling loads. South glass should incorporate properly sized overhangs that limit radiation in warmer months.

The most compact orthogonal building would then be a cube. This configuration, however, may place a large portion of the floor area far from perimeter daylighting. Contrary to this, a building massing that optimizes daylighting and ventilation would be elongated so that more of the building area is closer to the perimeter. While this may appear to compromise the thermal performance of the building, the electrical load and cooling load savings achieved by a well-designed daylighting system will more than compensate for the increased skin losses.

3.2 CLIMATE CONSIDERATIONS

Assess the local climate (using typical meteorological-year data) to determine appropriate envelope materials and building designs. The following considerations should be taken into account, depending on the climate type.

3.2.1 HOT/DRY CLIMATES

Use materials with high thermal mass. Buildings in hot/dry climates with significant diurnal temperature swings have traditionally employed thick walls constructed from envelope materials with high mass, such as adobe and masonry. Openings on the north and west facades are limited and large southern openings are detailed to exclude direct sun in the summer and admit it in winter.

A building material with high thermal mass and adequate thickness will lessen and delay the impact of temperature variations from the outside wall on the wall's interior. The material's high thermal capacity allows heat to penetrate slowly through the wall or roof. Because the temperature in hot/dry climates tends to fall considerably after sunset, the result is a thermal flywheel effect—the building interior is cooler than the exterior during the day and warmer than the exterior at night.
3.2.2 HOT/MOIST CLIMATES
Use materials with low thermal capacity. In hot/moist climates, where nighttime temperatures do not drop considerably below daytime highs, light materials with little thermal capacity are preferred. In some hot/moist climates, materials such as masonry, which functions as a desiccant, are common. Roofs and walls should be protected by plant materials or overhangs. Large openings protected from the summer sun should be located primarily on the north and south sides of the envelope to catch breezes or encourage stack ventilation.

3.2.3 TEMPERATE CLIMATES
Select materials based on location and the heating/cooling strategy to be used. Determine the thermal capacity of materials for buildings in temperate climates based upon the specific locale and the heating/cooling strategy employed. Walls should be well insulated. Openings in the skin should be shaded during hot times of the year and unshaded during cool months. This can be accomplished by roof overhangs sized to respond to solar geometries at the site or by the use of awnings.

3.2.4 COLD CLIMATES
Design wind-tight and well-insulated building envelopes. The thermal capacity of materials used in colder climates will depend upon the use of the building and the heating strategy employed. A building that is conventionally heated and occupied intermittently should not be constructed with high mass materials because they will lengthen the time required to reheat the space to a comfortable temperature. A solar heating strategy will necessitate the incorporation of massive materials, if not in the envelope, in other building elements. Where solar gain is not used for heating, the floor plan should be as compact as possible to minimize the area of building skin.

3.2.5 DOORS, WINDOWS, AND OPENINGS
Size and position doors, windows, and vents in the envelope based on careful consideration of daylighting, heating, and ventilating strategies.

The form, size, and location of openings may vary depending on how they affect the building envelope. A window that provides a view need not open, yet a window intended for ventilation must do so. High windows for daylighting are preferable because, if properly designed, they bring light deeper into the interior and eliminate glare.

Shade openings in the envelope during hot weather to reduce the penetration of direct sunlight to the interior of the building.

The use of overhangs or deciduous plant materials on southern orientations to shade exterior walls during warmer seasons. Be aware, however, that deciduous plants can cut solar gains in the winter by 20 percent. Shade window openings or use light shelves at work areas at any time of year to minimize thermal discomfort from direct radiation and visual discomfort from glare.

Shading coefficient is a ratio used to simplify comparisons among different types of heat reducing glass. The shading coefficient of clear double-strength glass is 1.0. Glass with a shading coefficient of 0.5 transmits one-half of the solar energy that would be transmitted by clear double-strength glass. One with a shading coefficient of 0.75 transmits three-quarters.

4.0 PASSIVE SOLAR DESIGN
Passive solar systems make use of natural energy flows as the primary means of harvesting solar energy. Passive solar systems can provide space heating, cooling load avoidance, natural ventilation, water heating, and daylighting. This section focuses on passive solar heating, but the other strategies also need to be integrated and coordinated into a whole-building design. Passive solar design is an approach that integrates building components—exterior walls, windows, and building materials—to
provide solar collection, heat storage, and heat distribution. Passive solar heating systems are typically categorized as sun-tempered, direct-gain, sunspaces, and thermal storage walls (Trombe walls).

Passive solar design considers the synergy of different building components and systems. For example:

- Can natural daylighting reduce the need for electric light?
- If less electric light generates less heat, will there be a lower cooling load?
- If the cooling load is lower, can the fans be smaller?
- Will natural ventilation allow fans and other cooling equipment to be turned off at times?

### 4.1 Passive Solar Heating

- Analyze building thermal-load patterns. An important concept of passive solar design is to match the time when the sun can provide daylighting and heat to a building with those when the building needs heat. This will determine which passive solar design strategies are most effective. Commercial buildings have complicated demands for heating, cooling, and lighting; therefore their design strategies require computer analysis by an architect or engineer.
- Integrate passive solar heating with daylighting design. A passive solar building that makes use of sunlight as a heating source should also be designed to take advantage of sunlight as a lighting source. However, each use has different design requirements that need to be addressed. In general, passive solar heating benefits from beam sunlight directly striking dark-colored surfaces. Daylighting, on the other hand, benefits from the gentle diffusion of sunlight over large areas of light-colored surfaces. Integrating the two approaches requires an understanding and coordination of daylighting, passive design, electric lighting, and mechanical heating systems and controls.

### 4.2 Passive Solar Cooling

Design buildings for cooling load avoidance. Minimization of cooling loads should be carefully addressed for both solar building and conventional energy-efficient building design. Design strategies that minimize the need for mechanical cooling systems include proper window placement and daylighting design, selection of appropriate glazing’s for windows and skylights, proper shading of glass when heat gains are not desired, use of light-colored materials for the building envelope and roof, careful siting and orientation decisions, and good landscaping design.

### 4.3 Other Cooling Strategies

- Design the building to take advantage of natural ventilation. Natural ventilation uses the passive stack effect and pressure differentials to bring fresh, cooling air through a building without mechanical systems. This process cools the occupants and provides comfort even in humid climates. Buildings using this design will incorporate operable windows or other means of outdoor air intakes. Wingwalls are sometimes used to increase the convective airflow. Other features include fresh air inlets located near floor level, use of ceiling fans, and the use of atriums and stairwell towers to enhance the stack effect. Caution should be used not to increase the latent load (i.e., the increased cooling load resulting from condensation) by bringing in moist outside air.
5.0 BUILDING ENVELOPE SYSTEMS

Understanding of the basic principles and appropriate application and performance of building envelope materials and assemblies.

The building envelope is a critical component of any facility since it both protects the building occupants and plays a major role in regulating the indoor environment. Consisting of the building's roof, walls, windows, and doors, the envelope controls the flow of energy between the interior and exterior of the building. The building envelope can be considered the selective pathway for a building to work with the climate-responding to heating, cooling, ventilating, and natural lighting needs.

The building envelope, or "skin," consists of structural materials and finishes that enclose space, separating inside from outside. This includes walls, windows, doors, roofs, and floor surfaces. The envelope must balance requirements for ventilation and daylight while providing thermal and moisture protection appropriate to the climatic conditions of the site. Envelope design is a major factor in determining the amount of energy a building will use in its operation. Also, the overall environmental life-cycle impacts and energy costs associated with the production and transportation of different envelope materials vary greatly.

5.1 WINDOWS

Glazing systems have a huge impact on energy consumption, and glazing modifications often present an excellent opportunity for energy improvements in a building. Appropriate glazing choices vary greatly, depending on the location of the facility, the uses of the building, and (in some cases) even the glazing's placement on the building. In hot climates, the primary strategy is to control heat gain by keeping solar energy from entering the interior space while allowing reasonable visible light transmittance for views and daylighting. Solar screens that intercept solar radiation, or films that prevent infrared and ultraviolet transmission while allowing good visibility, are useful retrofits for hot climates. In colder climates, the focus shifts from keeping solar energy out of the space to reducing heat loss to the outdoors and (in some cases) allowing desirable solar radiation to enter. Windows with two or three glazing layers that utilize low-emissivity coatings will minimize conductive energy transmission. Filling the spaces between the glazing layers with an inert low-conductivity gas, such as argon, will further reduce heat flow. Much heat is also lost through a window's frame. For optimal energy performance, specify a low-conductivity frame material, such as wood or vinyl. If metal frames are used, make sure the frame has thermal breaks. In addition to reducing heat loss, a good window frame will help prevent condensation—even high-performance glazing's may result in condensation problems if those glazing's are mounted in inappropriate frames or window sashes.

6.0 BUILDING SERVICES SYSTEMS.

Understanding of the basic principles and appropriate application and performance of plumbing, electrical, vertical transportation, communication, security and fire protection systems.

The systems that have found application in commercial office buildings have evolved over the past decades in response to the changes in the perceived goals of the entity that is constructing the building, the expanding needs of the potential occupants be they a corporate end user or a leasing party, and the concerns of the owner with the availability and the cost of energy and the resultant expenditures necessary to operate the building. More recently, the import of environmental concerns, including indoor air quality and the growing challenge to provide safer buildings, has further influenced the approach that is taken in the system selected for a modern commercial building.

To meet the challenge of providing systems that address these major issues, the commercially available equipment and the deployment of that equipment have also gone through a period of modification in
some design details over the recent past. This process of evolution will undoubtedly continue in the future but the basic general system categories that are available today will undoubtedly continue to find wide usage in the commercial building. It is the technical details of the system design that have been and will be subjected to ongoing modification.

6.1 AIR CONDITIONING SYSTEM ALTERNATIVES

There are a number of alternative systems that have found application in commercial office buildings. While the precise configurations of the systems are subject to the experience and imagination of the designing HVAC engineer, the systems that have primarily been utilized are variations of generic all-air systems and air-water systems.

Unitary refrigerant-based systems such as through-the-wall units have found application in conjunction with all-air systems providing conditioned ventilation air from the interior zone, but this combined solution has been limited to the retrofit of older buildings that were not air conditioned at the time of their construction and smaller low-rise projects. They are infrequently used in first-class commercial buildings due to the several inherent shortcomings of this type of solution. These shortcomings include a probability of higher energy use, the need for routine filter change at each unit and periodic cleaning of the cooling and condenser coils to maintain system capacity, the relatively short equipment life, the inability to cope with stack effect and the outside air flow through the unit, the generation of higher noise levels than are acceptable for first-class office space, and the failure to be able to respond to environmental concerns due to inadequate filtration, poor ventilation air control, and unacceptable space temperature variation as a result of the on-off nature of the compressor control.

7.0 HEATING AND COOLING SYSTEMS

HVAC (heating, ventilating, and air-conditioning) refers to the equipment, distribution network, and terminals that provide either collectively or individually the heating, ventilating, or air-conditioning processes to a building.

HVAC systems provide

- Heating
- Cooling
- Air Handling, Ventilation, and Air Quality

HVAC accounts for 40% to 60% of the energy used in U.S. commercial and residential buildings. This represents an opportunity for energy savings using proven technologies and design concepts.

HVAC systems have a significant effect on the health, comfort, and productivity of occupants. Issues like user discomfort, improper ventilation, and poor indoor air quality are linked to HVAC system design and operation and can be improved by better mechanical and ventilation systems. In existing buildings, envelope upgrades are often necessary to maximize comfort and energy efficiency, such as reducing envelope leakage.

8.0 BUILDING SYSTEMS INTEGRATION

Ability to assess, select and conceptually integrate structural systems, building envelope systems, environmental systems, life safety systems and building service systems into building design.
Integrated building design is a process of design in which multiple disciplines and seemingly unrelated aspects of design are integrated in a manner that permits synergistic benefits to be realized. The goal is to achieve high performance and multiple benefits at a lower cost than the total for all the components combined. This process often includes integrating green design strategies into conventional design criteria for building form, function, performance, and cost. A key to successful integrated building design is the participation of people from different specialties of design: general architecture, HVAC, lighting and electrical, interior design, and landscape design. By working together at key points in the design process, these participants can often identify highly attractive solutions to design needs that would otherwise not be found. In an integrated design approach, the mechanical engineer will calculate energy use and cost very early in the design, informing designers of the energy-use implications of building orientation, configuration, fenestration, mechanical systems, and lighting options.

Consider integrated building design strategies for all aspects of green design: improving energy efficiency, planning a sustainable site, safeguarding water, creating healthy indoor environments, and using environmentally preferable materials. Major design issues should be considered by all members of the design team—from civil engineers to interior designers—who have common goals that were set in the building program. The procurement of A&E services should stress a team-building approach, and provisions for integrated design should be clearly presented in the statement of work (SOW). For example, the SOW should stipulate frequent meetings and a significant level of effort from mechanical engineers to evaluate design options.

The design and analysis process for developing integrated building designs includes:

- Establishing a base case—for example, a performance profile showing energy use and costs for a typical facility that complies with code and other measures for the project type, location, size, etc.
- Identifying a range of solutions—all those that appear to have potential for the specific project.
- Evaluating the performance of individual strategies—one by one through sensitivity analysis or a process of elimination parametrics
- Grouping strategies that are high performers into different combinations to evaluate performance.
- Selecting strategies, refining the design, and reiterating the analysis throughout the process.

9.0 COURSE LOGISTICS

The course consists of three parts. The first and largest part deals with the basic physics and concepts which are the core of environmental controls and thermal processes. We will cover the numerical information and tools required to design a reasonable building anywhere in the world, including a numerical understanding of how loads are calculated. Anyone who finds physics and nature to be disagreeable will have difficulty with this part. Please expend the necessary mental effort to understand the material if you don't already know it.

The second part of the course deals with historical design strategies and prototypes that respond to environmental issues. Passive solar strategies, active solar panels, wind energy and photovoltaics will be covered.

The third part deals with unusual or recently developed systems and strategies or issues which are being addressed by society at large. This will include community solutions, sustainability issues and the professional knowledge required of an architect currently in practice in the state of California, and dealing with consultants in Heating, Ventilating and Air Conditioning.
9.1 **REQUIRED “TEXT”:**


c. Arch 215 Class Handouts

The required texts are *Mechanical and Electrical Equipment for Buildings* (MEEB) and the class handout. The readings from MEEB will be assigned weekly to correspond with the Lecture. MEEB is expensive but will be used as a reference and a backup for this class and in the following semester for Arch 315: Design of the Luminous and Sonic Environment. It is also an excellent reference for now, and for the remainder of your career. *How Buildings Work* is useful, especially if you have trouble with the class. It explains concepts with many graphic illustrations. The class handout is a large collection of tables and useful graphs and information. The handouts should always be brought to class, preferably kept in a notebook along with your notes. You will need information from the handouts and notebook for exams, and even for unannounced pop quizzes.

There will be homework throughout the semester. Material on quizzes, prelims and the final will be heavily related to the homework. Thus, though the homework is not required, it is generally advisable to do them. All exams will be open book, but limited in time. This means that books and notes may be brought into the exam, **but previous exams, quizzes or web pages are not allowed.** You may bring a homework which you have worked out, **but not a homework answer sheet from the web.** Possession of a previous exam, quiz or any webpage while taking an exam will disqualify the exam. Too many students have counted on these materials in the past, instead of doing the homework, and the result has been a drop in the average grades! (You are encouraged to study using these materials before the exams, but you may not bring them into the exam with you. If you find that you have such materials among your notes, you must immediately take them out and place them upside down on the floor in front of you for the duration of the exam.)

The grade for the semester will be based on the following percentages:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>3 Pop quizzes @ 10% each</td>
<td>30%</td>
</tr>
<tr>
<td>1 Design Analysis @ 20%</td>
<td>20%</td>
</tr>
<tr>
<td>1 Midterm @ 20%</td>
<td>20%</td>
</tr>
<tr>
<td>1 Final @ 30%</td>
<td>30%</td>
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9.2 **DISABILITIES**

Over the years we have had many students in the course with various disabilities and have had excellent experiences thus far. Any Student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to Prof. Schiller as early in the semester as early as possible. DSP is located in STU 301 and is open 8:30 a.m. - 5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

9.3 **CRITICAL DATES AND RELIGIOUS OBSERVANCES:**

The university recognizes the diversity of our community and the potential for conflicts involving academic activities and personal religious observation. The university provides a guide to such observances for reference and suggests that any concerns about lack of attendance or inability to participate fully in the course activity be fully aired at the start of the term. As a general principle students should be excused from class for these events if properly documented and if provisions can be made to accommodate the
absence and make up the lost work. Constraints on participation that conflict with adequate participation in the course and cannot be resolved to the satisfaction of the faculty and the student need to be identified prior to the drop add date for registration. After the drop out date the University and the School of Architecture shall be the sole arbiter of what constitutes appropriate attendance and participation in a given course.

9.4 **Disruptive Behavior**
Behavior that persistently or grossly interferes with classroom activities is considered disruptive behavior and may be subject to disciplinary action. Such behavior inhibits other students’ ability to learn and an instructor’s ability to teach. A student responsible for disruptive behavior may be required to leave class pending discussion and resolution of the problem and may be reported to the Office of Student Judicial Affairs for disciplinary action.

9.5 **Professional Degree:**
The USC School of Architecture’s five year BARCH degree is an accredited professional architectural degree program. All students can access and review the NAAB Conditions of Accreditation (including the Student Performance Criteria) on the NAAB Website, http://www.naab.org/accreditation/2004_Conditions.aspx.

9.6 **Attendance**
Attending classes is a basic responsibility of every USC student who is enrolled in courses at the School of Architecture. Regular and punctual class attendance is considered an essential part of satisfying the NAAB accreditation requirements therefore attendance will be taken at every class session. A student may miss up to two class sessions without directly affecting their grade and ability to complete the course if they provide an excused absence for any confirmed personal illness/family emergency/religious observance. *For each absence over that allowed number, the student’s letter grade is in danger of being lowered up to one full letter grade.* Any student not in class within the first 10 minutes is considered tardy, and any student absent for more than 1/3 of the class time can be considered fully absent. If arriving late, a student must be respectful of a class in session and do everything possible to minimize the disruption caused by a late arrival. It is always the student’s responsibility to seek means to make up work missed due to absences. *Being absent on the day of a quiz or exam can lead to an “F” for that quiz or exam.*

9.7 **2010 Imperative Statement:**
The Architecture Faculty have voted to accept the 2010 Imperative-- to improvement of ecological literacy among the students and faculty and to achieve a carbon-neutral design school campus by 2010. To that end, this class will address issues of carbon neutrality and supports the following goal for all designs produced in the USC School of Architecture:

> “The design should engage the environment in a way that dramatically reduces or eliminates the need for fossil fuel.”

This does not mean that no other issues are to be addressed. Precisely to the contrary, all design issues are fair game, but in the background, all will be considered within the generalized goal of reducing or eliminating the need for fossil fuel.
10.0 COURSE OUTLINE

Part I:

1. Logistics and Handout, Basic Physics of Heat Transfer I & II

2. Human Comfort
   Metabolic mechanisms and resultant Human Comfort ranges, Relative Humidity, Mechanisms of
   comfort, Fanger, angle factors, ASHRAE Comfort Tool

3. Adaptive Comfort
   Natural Ventilation, mean monthly temperatures, operative temperature, applications of adaptive
   comfort

4. Climate, and Building as Organisms
   Climate zones,

5. Solar Position
   altitude, azimuth, declination, shading masks.

6. Solar Design I
   fin and overhang shadows, profile angle.

7. 

8. 

9. Demonstrate of a complete building in HEED.

10. Energy Codes
    Title 24, ASHRAE 90.1, ASHRAE 189.1

11. Pop Quiz
    (given at an earlier date, unannounced)

12. MIDTERM (well before design studio reviews)

Part II:

13. Site Planning & Regional Vernacular I
    Cold & Temperate climate strategies

14. Site Planning & Regional Vernacular II
    Hot Arid & Hot Humid climate strategies
15. Sustainability
   Reduce, Reuse, Recycle, Operational Energy, Embodied Energy, Renewable Energy, other resources, LEED

16. Active Solar Thermal
   Collector types, Domestic Hot Water, Space Heating

17. More Active Systems
   photovoltaics, BIPV, principles and examples

18. Wind Systems and Community Scale Solar Systems
   wind generation: individual scale and community scale, Solar One, cogeneration

19. Planning & Zoning
   Shadow plots, Solar access, solar envelopes, Ralph Knowles

20. Alternate Architecture and Lifestyles
   Earthship, Arc and Nader Khalili

21. Global Warming

22. Pop Quiz
   (given at an earlier date, unannounced)

23. DESIGN ANALYSIS

24. Part III:

25. HVAC I
   Building Services systems

26. HVAC II
   Building Systems Integration

27. HVAC III
   Building Systems Integration- examples.

28. Pop Quiz
   (given at an earlier date, unannounced)

29. Final Examination: see online schedule
2010 Imperative at the
University of Southern California School of Architecture

Whereas: It is clear to all that global warming is occurring.
Whereas: It is clear that human generated CO\textsubscript{2} is a greenhouse gas and contributes to that warming.
Whereas: It is clear that buildings create a large portion of the CO\textsubscript{2} on the planet and have a long lifespan, drastically increasing the impact of each building.
Whereas: We are now at a critical stage requiring ALL of society’s response, including our own.

Be it resolved that:
The School of Architecture of the University of Southern California will add the following statement to every design studio syllabus.

| This design should engage the environment in a way that dramatically reduces or eliminates the need for fossil fuel. |

By 2010, achieve complete ecological literacy in design education, including:

- design / studio
- history / theory
- materials / technology
- structures / construction
- professional practice / ethics

By 2010, achieve a carbon-neutral design school campus by:

- implementing sustainable design strategies
- generating on-site renewable power
- purchasing green renewable energy and/or certified renewable energy credits.