ARC 4133 – 903: Applications in Sustainable Design - Spring 2008

Decision Support Tools for Carbon-Neutral Design

Hazem Rashed-Ali, Ph.D.

Class hours: TR 9:00 to 10:15 a.m.
Location: FS 2.508
Office hours: MWF 10:00 a.m. to 11:00 a.m. and 2:00 to 3:00 pm; or by previous appointment.
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> *"Although architects now generally acknowledge that sustainability is important, many see it as a technical solution without fully understanding the mechanics or worth of green technologies. As a result, the entire industry is abuzz with vague generalizations and valuable principles get reduced to marketing sound bites. …….We posit that sustainable design must put as much emphasis on design as it does on sustainability."*
>
> *AIA COTE: Ecology & Design, 2006.*

> *"[Sustainable design is] an approach that holistically and creatively addresses land use, site ecology, community design and connections, water use, energy performance, energy security, materials and construction, light and air, bioclimatic design, and issues of long life and loose fit."*
>
> *AIA COTE: Ecology & Design, 2006.*

> *"[Ecological design] is not about making greener widgets but how to make decent communities that fit their places with elegant frugality. The issue is whether the emerging field of ecological design will evolve as a set of design skills applied as patchwork solutions to a larger pattern of disorder or whether design will eventually help to transform the larger culture that is badly in need of reformation."*
>
> *David Orr: The Nature of Design, 2002.*

> *"Sustainable design is not limited to simply trying to be more efficient. A new approach offers a clear alternative: an ecologically intelligent framework in which the safe, regenerative productivity of nature provides models for wholly positive human designs . . . we can begin to redesign the very foundations of architecture and industry, creating systems that purify air, land, and water; use current solar income and generate no toxic waste; and use only safe, healthful, regenerative materials. The benefits would enhance all life.*
>
> *William McDonough: Teaching Design That Goes From Cradle to Cradle, 2004.*

COURSE CONTENT

This course is based on the premise that there is an increasing need to integrate environmental performance considerations in the form-making processes of architectural design. Such a need responds to and is motivated by the growing interest of the built environment professionals in achieving a more sustainable and environmentally conscious built environment. While this integration can be achieved through various methods which differ according to the stage of the design process they are intended for, all of these methods aim to inform design decisions by an assessment of the expected performance of the community, building, or building component in question, which is based on measurable criteria such as energy consumption, lighting levels, solar shading and solar access, harmful emissions, or other impacts. Integrating sustainability considerations in the early stages of the design is recognized to be particularly important because of the high impact that design decisions taken in these stages have over the subsequent performance of the building or community especially when aiming for carbon-neutral designs.

Carbon-neutral or 'zero-emissions' buildings or communities can be defined as **EMITTING NO NET CARBON INTO THE ATMOSPHERE THROUGH THEIR OPERATION.** Achieving this goal requires the utilization of both passive design strategies and state-of-the-art energy efficient technologies to design buildings and communities that use much less energy than current practice (up to 50%-80% reductions are possible), and then to incorporate renewable energy generation systems into the fabric of the architecture to cover the remaining demand. Achieving carbon-neutrality is fundamentally a design problem; one that must be solved by intelligent and informed design decisions at every phase of a project. For architectural education, the global imperative of addressing climate change demands a comprehensive response so that design intuition itself is reshaped to reflect this imperative and create hospitable human environments fundamentally through their refined relationship with the natural environment and its forces.

Carbon-neutral design standards represent the future of the building industry, as highlighted by the International Protocol on Climate Change (IPCC), which identifies integrated building design as a "key mitigation technology" that needs to be commercialized before 2030 if we are to avert global climate change. To this end, legislative standards for carbon-neutral buildings are already under development in California and other states, as well as at the Federal level[1].

This course will primarily focus on the application of a wide range of strategies, systems, and technologies typically associated with various aspects of sustainable design to achieve carbon-neutral buildings and communities. Several state-of-the-art design decision support and environmental performance simulation tools, currently used by practitioners and/or researchers, will be introduced as a means of informing sustainable and carbon-neutral designs. The course will provide opportunities for students to have hands-on experiences in using these tools, which they can then utilize in their future academic and professional design activities. These hands-on exercises will also be used to demonstrate how sustainable design practices can reduce the negative environmental impact of the built environment, while providing more comfortable, healthy and economical buildings and communities.

The course will cover a wide range of topics, related to achieving carbon-neutral buildings and communities, including the definition(s) of sustainability, sustainable design, and carbon neutrality; climate analysis and climatic design strategies; building envelopes and indoor thermal environment; human thermal comfort; passive and active design strategies for different climatic regions; shading amd solar access; passive and low-energy sustainable systems and technologies; daylighting; life-cycle analysis of sustainable building materials and systems; whole building energy use and building energy efficiency; ventilation and indoor and outdoor environmental quality; and sustainability assessment methods and frameworks.

THE CARBON-NEUTRAL STUDIO INITIATIVE

This course is being conducted as part of the "***Carbon-Neutral Studio Initiative***". This initiative is a collaborative research effort consisting of a network of more than 30 studio faculty from 26 North American schools of architecture who currently teach design studios or courses with carbon neutrality as a theme. The project involves conducting a survey of teaching methods of carbon-neutrality at different schools across north America to be presented at a research conference being planned by the group members for summer 2008 and to be eventually included in a book about the topic. Exemplary student work from all participating studios will have the opportunity of being presented in the national conference and to be included in any resulting publications.

As part of this initiative, this course investigates the teaching of carbon-neutrality in design studios through a studio-seminar model in which course participants will be teamed up with students in a concurrent design studio to form integrated design teams in which students from the course will perform the role of the environmental performance consultant. In this capacity, course students will be responsible for utilizing the tools presented in the course in performing all the necessary analysis, modeling, and simulation required to inform the design decisions of the team.

1 James Wasley, 2007, Carbon Neutral Studio Project Proposal, University of Wisconsin-Milwaukee.

COURSE STRUCTURE AND ACTIVITIES

This course will involve a variety of activities including readings, lectures, discussions, demonstrations and hands-on exercises of sustainable building design tools, a semester project, and a research paper. Readings are a major component of the course and relevant articles, reports, and/or book chapters will be assigned which will provide a background for the lectures and the related discussions sessions. A list of assigned readings will be provided and, as much as possible, these assigned readings will be made available in a digital format (PDF) on WebCT. Lectures and presentations will be conducted by the instructor to present the theory and principles behind the topics covered in the course as well as to demonstrate the capabilities of the modeling and simulation tools utilized in the class. Hands-on exercises in which students will utilize these tools will also be conducted and will form components of the semester project discussed below. A course website will be developed in which the resulting student work will be posted.

PROJECTS AND ASSIGNMENTS

READINGS & DISCUSSIONS:

Readings will be assigned on topics related to the objectives of the course. For each assigned reading topic, students will submit a brief review of the readings (no more than 250 words, or one page), which both summarizes their understanding of the material and presents their position with regard to the topic being discussed. The summary will be submitted before the beginning of each class having assigned readings using WebCT. Strong and effective participation in discussion sessions based on the readings is expected from all students and will be considered part of the course evaluation.

INTERIM EXERCISES AND SEMESTER PROJECT

During the course of the semester, several assignments and hands-on exercises will be conducted in which students will apply sustainable design principles and strategies to a specific design project through utilizing the variety of performance modeling and simulation tools addressed in the class, therefore gaining experience in using these tools. A written brief will be provided by the instructor for each of the assignments comprising this project as well as the requirements of the final submission. Due dates for the assignments are included in the course schedule. The design project forming the basis of these exercises will be selected following one of the three options described below. Each student will select one of the options and inform the instructor of their selections during the first week of the semester. The options are:

Option A: In this option, students will be teamed up with students in a concurrent design studio working on a national competition with carbon-neutrality as a design objective. While not being responsible for the quality of the resulting design, students from the course will play the role of the environmental performance consultant within the design team and will therefore be responsible for conducting the necessary analysis and simulation needed to inform the design tam members using the tools presented in the course. Students selecting this option will be eligible to participate in the carbon-neutral studio project.

Option B: This option is possible for students taking concurrent design studios. In it, student will adopt carbon neutrality as an additional objective for their studio design project (in addition to all other objectives that may be assigned to them by their studio instructors) and will utilize the tools presented in the course to conduct the analysis and simulation necessary to inform their design decisions. While the course tasks should not interfere with any other requirement of the design studio in this option, students are strongly encouraged to discuss this option with their studio instructors.

Option C: In this option, students will select one of their previous design projects which will serve as a vehicle for applying the concepts and methods presented in this course. Students will use the results of the different exercises performed during the semester to reconsider or modify their original design and achieve the goal of carbon-neutrality.

For each of the options listed above, the final outcome of this semester project, to be submitted at the end of the semester, will consist of:

1- A 24” x 36” board including a graphical representation of the results of the different exercises performed during the semester. The board should be designed as a part of the overall final presentation of the design project but should also have the possibility of being presented as a stand-alone project.

2- A report which includes a description of the design project (in both written and graphic forms), results of each of the assignments and the design recommendations and/or modifications performed based on each of them, and finally, a description of the final design and the resulting performance including documentation of the achievement of carbon-neutrality.

EVALUATION & GRADING POLICY

Evaluation in this course will involve a number of components including: reading summaries, course project (including assignments and hand-on exercises), research paper, attendance, and participation in discussions. Extra credit may be assigned during the semester. The breakdown of the course evaluation is as follows:

▪ Reading summaries:	10%
▪ Interim assignments and exercises	30%
▪ Final Semester Project	50%
▪ Attendance and participation:	10%
▪ Total:	100%

GRADING POLICY

The general meaning of the letter grades is presented below:

A (90-100) ***Excellent:***Exceeds minimum requirements and reaches a state of exceptional work produced. Exhibits strong initiative, attendance, participation, research and reading. Complete comprehension of course/project goals. Adds positively to the educational experience of the rest of the class. Projects, papers, and assignment are delivered by the due date and are of exceptional written and graphic quality.

B (80-89) ***Good:*** Often exceeds minimum requirements for work produced – for quality and quantity, attendance, research and reading. Participates regularly in class discussions. Solid comprehension and above average demonstration of course/ project goals. Projects, papers, and assignments are delivered by the due date and are of good written and graphic quality.

C (70-70) ***Average:*** Meets minimum requirements for work produced – for quality and quantity, attendance, research and reading. Little or no participation in class discussions. Projects, papers, and assignments are delivered by due date and are of average or acceptable informational and graphic quality.

D (60-69) ***Poor :*** Work produced is consistently weak with poor craft, absences, insufficient or no research, little or no reading, little or no participation. Demonstrates a weak comprehension of course/ project goals. Projects, papers, and assignments, if delivered by the due date, are of poor informational and graphic quality.

F (below 60) ***Unacceptable**:* Work, if any, produced is very weak with poor craft, 4 or more absences, little or no research, reading, and participation. Demonstrates that course/ project goals or test questions were misunderstood or ignored. Projects, papers, and assignments, if delivered by the due date, are of unacceptable written and graphic quality.

COURSE POLICIES

ATTENDANCE:

Course attendance is mandatory and is considered an integral component of the learning experience. Punctuality is required and considered an indication of professionalism and responsibility. A maximum of ONLY THREE UNEXCUSED ABSENCES are allowed during the semester without affecting the final course grade. The final grade will be reduced by a full letter grade for each additional day of unexcused absence. Excused absences must be arranged for beforehand with the instructor as much as possible (e-mail will be acceptable) and the required documentation should be provided as soon as possible afterwards; otherwise, they will count as unexcused absences.

LATE SUBMISSION:

Late submission of projects and assignments is not allowed. Students with excused absences, who will not be present to meat a submission deadline, should consult with the instructor beforehand to make alternative arrangements for submitting their work on time. No exceptions will be made. Late submittals of projects or assignments will result in a reduction in the grade of the assignment in question by 10% (or a full letter grade) for each CALENDAR DAY. No excuses will be accepted for late submissions. All submittals are due at the BEGINNING of class at the due date unless otherwise announced.

WEBCT:

All course material, including syllabus, class presentations, projects and assignment briefs, and other resources, will be made available on WebCT. WebCT mail will also be used by the instructor to communicate important information to students. Students are responsible to check their WebCT mail account regularly or forward it to a main e-mail account they do check regularly. Student grades will also be posted on WebCT as they become available.

COURSE TOOLS AND SOFTWARE

The course will introduce several state-of-the-art digital modeling and simulation tools being used by researchers and practitioners all over the world to inform their design processes. All efforts will be made to have all of these tools available on the computers in the architecture lab as soon as possible. Additionally, most of these tools are either freeware or shareware and can therefore be downloaded free of charge from the internet to be used on students' personal computers if needed and students are encouraged to take advantage of that as much as possible. Information about the sources of these tools and the download/installation procedures will be provided by the instructor during the semester.

The course will utilize one commercial tool, ECOTECT (http://squ1.com/ecotect), which represents the latest advances in building environmental performance modeling and simulation. Full versions of this tool WILL BE MADE AVAILABLE on the architecture lab computers as soon as possible. However, students also have the option of buying a student copy of the software for $90 to be installed on their personal computers. Fully functional demo versions of the software are also available free of charge but only allow for a maximum session length of 2 hours with no possibility of saving the outcomes. Interested students should contact the instructor for information about obtaining student copies.

BUILDING GREEN SUBSCRIPTION

As part of the carbon-neutral studio initiative, students in this course have the opportunity to get a one-year subscription to the BuildingGreen.com Suite at a reduced price of $39. This is a 60% reduction from the existing academic discount price of $99/year for the suit, and an %80 reduction from the full price of the suit.

The BuildingGreen.com Suit is an online resource featuring comprehensive, practical information on a wide range of topics related to sustainable building--from energy efficiency and recycled-content materials to land-use planning and indoor air quality. The suite integrates online versions of ***GreenSpec***, ***Environmental Building News***, and a database of more than 160 high-performance building case studies. Students interested in taking advantage of this offer should email the instructor for detailed subscription instructions.

RECOMMENDED TEXTS

There are NO REQUIRED TEXTS for this course. Assigned readings, if not available on-line or through the library, will be made available in PDF format on WebCT. However, the following is a recommended general reading list that can provide you with a more in-depth understanding of the topics covered in the course.

Ander, G. 1995. *Daylighting Performance and Design*. New York, NY: Van Nostrand Reinhold.

Baker, N. and Steemers, K. 2000. *Energy an Environment in Architecture*. London, UK: E & FN Spon.

Brown, D.; fox, M.; and Pelletier, M. (eds.) 2005. *Sustainable architecture White papers*. New York, NY: Earth Pledge.

Brown, G. and Dekay, M. 2002. *Sun, Wind, and Light, 2nd edition.* New York, NY: John Wiley & Sons.

Buchanan, B. 2006. *Ten Shades of Green*. The Architecture League of New York. Available Electronically at: http://www.archleague.org/tenshadesofgreen/10shades.html

Stein, B. and Reynolds, J. 2005. *Mechanical and Electrical Equipment for Buildings, 10th edition*. New York, NY: John Wiley & Sons.

Guzowski, M. 2000. *Daylighting for Sustainable Design*. New York, NY: McGraw Hill Inc.

Harvey, L. D. 2006*. A Handbook on Low-Energy Building and District Energy systems*. London, UK: Earthscan.

Kwok, A. and Grondzik, W. 2007. *Green Studio Handbook, Environmental Strategies for Schematic Design.* Oxford, UK: Architectural Press.

McDonough, W. and Braungart, M. 2002. *Cradle to cradle: Remaking the Way We Make things*. New York, NY: North Point Press.

Orr, D. 2002. *The Nature of Design: Ecology, Culture, and Human Intention*. New York, NY: Oxford University Press.

The European Commission. 1999. *A Green Vitruvius: Principles and Practice of Sustainable Architectural Design.* London, UK: Earthscan Publications.

Yeang, K. 1995. *Designing with Nature: The Ecological Basis for Architectural Design.* New York, NY*:* McGraw Hill Inc.

ON-LINE RESOURCES

AIA Committee on the Environment (COTE): http://www.aia.org/cote_default
American Sola Energy Society (ASES): http://www.ases.org/
Building Energy Software Tools Directory: http://www.eere.energy.gov/buildings/tools_directory/
Building Environmental Quality Evaluation for Sustainability through Time (BEQUEST): http://research.scpm.salford.ac.uk/bqtoolkit/index2.htm
Center for Alternative technology (CAT): http://www.cat.org.uk/
Center for Maximum Potential Building Systems: http://www.cmpbs.org/
Development Center for Appropriate technology: http://www.dcat.net/
DOE2: http://www.doe2.com/
Energy Design Resources: http://www.energydesignresources.com/index.php
Energy Information Administration (EIA): http://www.eia.doe.gov/
Energy Star Program: http://www.energystar.gov/

Environmental Building News:	http://www.buildinggreen.com/
Green Builder:	http://www.greenbuilder.com/
Green Building Materials:	http://oikos.com/green_products/index.php
International Code Council (ICC):	http://www.iccsafe.org/
Lawrence Berkeley National Laboratory (LBNL) Windows and Daylghting Group:	
	http://windows.lbl.gov/
Metropolitan Partnership for Energy:	http://www.mp4e.nfo
Rocky Mountain Institute (RMI):	http://www.rmi.org/
San Antonio Sustainable Building Coalition:	http://www.buildsagreen.org
Solar Decatholon:	http://www.eere.energy.gov/solar_decathlon/
Smart Communities Network:	http://www.smartcommunities.ncat.org/
Smart Growth Network:	http://www.smartgrowth.org/Default.asp?res=1280
Square one:	http://www.squ1.com/
Sustainable Buildings Sourcebook:	http://www.austinenergy.com/Energy%20Efficiency/Programs/Green%20Building/Sourcebook/index.htm
Sustainable Communities Network:	http://www.sustainable.org/
Sustainable Habitat Design Advisor (SHADA):	http://www.sustainable-buildings.org/
US Green Building Council (LEED):	http://www.usgbc.org/
US Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE):	
	http://www.eere.energy.gov/
Whole Building Design Guide	http://www.wbdg.org/

SCHOLASTIC DISHONESTY

Scholastic dishonesty or plagiarism *WILL NOT BE TOLERATED* in this class. Any such incident will result in automatic failure in the project or assignment involved. Any and all incidents of plagiarism and academic dishonesty will be reported to the Office of Student Life. For more details, please refer to the Scholastic Dishonesty Policy as stated in the current University Catalogue.

STUDENTS WITH DISABILITIES

The Americans with Disabilities Act (ADA) is a federal anti-discrimination status that provides comprehensive protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you need accommodation related to a disability, please make an appointment to discuss your needs.

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Assignment 1: Climate Analysis

Date issued: Thursday 1/24/2007

Date Due: Thursday 1/31/2007

The purpose of this assignment is to conduct an analysis of the local climate in the city/area in which your selected design project is located. The analysis should be conducted using one of the two climate analysis software presented in class: UCLA's *"Climate Consultant 3"* or Square One's "*The Weather Tool".* The analysis should include the following:

1. Identification of your selected project site (city), the corresponding weather station, and the corresponding climate region from the Lechner climate classification (see Lechner:, heating, Cooling, Lighting, design methods for architects)
2. A description of the climate parameters listed below with regard to your selected location. This description MUST BE supported by graphs generated, from either of the climate analysis tools, that sufficiently describe these parameters especially their seasonal variations (In the case of the weather tool, use the print-screen command to capture the graphs in question).
   a) Air temperatures.
   b) Relative humidity levels.
   c) Precipitation.
   d) Snow fall.
   e) Solar geometry
   f) Availability of solar radiation.
   g) Cloud cover.
3. A summary and discussion, based on the previous analysis, of the climate in your location with regard to the need for heating/cooling, the availability of natural resources (e.g. solar energy, rain, etc.), as well as any other conclusions you deem relevant.
4. An analysis of the climatic design strategies (or combination of strategies) recommended for your site for each season (winter, summer, spring/fall) and for the year as a whole. This analysis must also be supported by graphs from either of the tools.
5. A comparison between the design strategies suggested by your climate analysis and those recommended by Lechner for the climate region in which your selected city is located.

The assignment will be submitted in the form of a report on 8.5" x 11" paper. As this assignment will form part of the final report of the project, careful consideration of the layout and the graphic design of the report in this stage will make it easier to produce the final report at the end of the semester.

Students selecting project option 1 will be assigned project locations/cities based on their corresponding design team.

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Assignment 2: Assessment of Conceptual Design Ideas using ECOTECT.

Date issued: Tuesday 3/4/2008

Date Due: Thursday 3/13/2007

In this assignment, students are asked to utilize the solar, shading, and thermal analysis functions of ECOTECT to identify the available natural resources for their project site (solar, wind, etc.), determine how to best take advantage of these resources, and then evaluate the conceptual design ideas and preliminary forms of the project.

Assignment Tasks:

The tasks required for this assignment include the following:

1. Building a model of the project site in ECOTECT. The model should include all nearby buildings, which can reduce solar access to the site (or at least the surfaces of these buildings that can result in that).
2. Identifying the requirements of your site/climate in terms of solar resources (i.e. is there more need for summer shading, winter solar access, or both). Perform the appropriate analysis to determine the parts of your site which provide the most potential for that (taking into consideration site characteristics and surrounding buildings).
3. Using the passive design strategies recommendations developed in the climate analysis assignment, as well as all other design objectives for your project, develop AT LEAST three design alternatives for the projects. The alternatives can differ in terms of form, orientation, height, utilization of site, etc.). All alternatives must achieve the design objectives of the project except for environmental performance).
4. Building thermal models in ECOTECT for each of your alternatives. The zoning of these models should be simplified as much as possible, meaning that only major differences in use should be accounted for. Default values for occupancy and schedules should be consistently utilized as much as possible.
5. Conducting a parametric (comparative) analysis of the thermal performance of each alternative using ECOTECT. Use either the monthly heating/cooling loads parameter (for air-conditioned buildings) or the percent of discomfort hours parameter (for passive ones).
6. Using the results of the thermal analysis to compare/contrast your design alternatives and to identify the future direction for your design. The selected alternative can either be one of the alternatives initially being evaluated or it can be a combination of two or more of those alternatives.
7. Conducting an analysis of the solar shading/solar access potential of your selected alternative. Suggest modifications if necessary.

Submission Requirements:

The assignment submission will be in the form of a report (letter size) integrating both graphics and text. BOTH a digital AND a hard copy submission of the assignment are required. The report will consist at least of the following:

1. A description of the design project, space program, project site, and design objectives. The description should be supported by images as much as possible.
2. An analysis of the natural resources potential of your site (solar, wind, water, vegetation, etc.). Analysis of the solar resources must be supported by the results of the ECOTECT site solar access analysis in both graphics and text format.
3. A description of the design alternatives being evaluated, and the major difference between them (at least three alternatives are needed).
4. The results of the ECOTECT parametric thermal l analysis supported by both excel graphs of the changes in monthly loads/discomfort hours as well as by images extracted from ECOTECT.
5. A description of the selected alternative (or combination of design alternatives), its thermal performance, and shading/solar access potential.
6. Summary and conclusions.

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Assignment 3: Daylighting Analysis.

Date issued: Tuesday 4/1/2008

Date Due: Tuesday 4/8/2007

In this assignment, students are asked to utilize the daylighting analysis functions of ECOTECT to identify and optimize the daylighting design of one of the major spaces in their project.

Assignment Tasks:

The tasks required for this assignment include the following:

1. Identify either "one" major space or one "typical" space in your project in which daylighting is both desirable and possible.
   - Major spaces can include, but are not limited to, large meeting rooms, lecture rooms, atria, ..etc.
   - Typical spaces are a space type size which is exists in your project in large number. Examples include, but are not limited to, an office space in a high-rise building, a living room in a multiunit residence; etc.
2. Develop a daylighting design solution for your space. Only one space is needed if the typical space option is used. Use either: 1) side lighting, 2) top lighting, or 3) a combination of the two (depending on the location, orientation, and size of your selected space. Use daylighting design guidelines and rules of thumb as a starting point.
3. Use the daylighting analysis functions in ECOTECT to optimize the daylighting solution. Your optimum solution should achieve the following:
   - A minimum daylight factor of 2.
   - An average daylight factor of 4.
   - A maximum ratio or 3:1 between area of maximum daylight and area of minimum daylight (expressed in either DF or lux).
4. If the orientation of your spaces would result in sun penetration, demonstrate that your daylighting solution will be successful in providing solar control in the overheated period of the year in predominantly hot climate and/or will allow solar penetration in the under-heated period of the year in predominantly cold climates. Refer to your climate analysis to identify the overheated and under-heated periods.

1. FOR EXTRA CREDIT:
   Generate a Radiance rendering of your space at a suitable day/time to illustrate the effectiveness of your daylight solution.

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Assignment 4: Overall Energy Use and PV System Sizing.

Date issued: Tuesday 4/8/2008

Date Due: Tuesday 4/22/2007

The objective of this assignment is to utilize the whole building energy simulation software eQUEST in identifying the total energy use of the semester project, and then to determine the required size of the renewable energy system needed to meet this demand.

Assignment Tasks:

The tasks required for this assignment include the following:

1. Build a model of your semester project in eQUEST. The model should be developed using the "design development" wizard. As much as possible, you should select from the available default values within eQUEST for building types, zone patterns, space types, typical loads, etc. The default values will vary according to your selected building and space type.

   Since eQUEST also simulates the performance of HVAC and DHW systems, make sure to select the appropriate values for both from the wizard. Again, use the default values as much as possible.

   For projects with multiple buildings, start by creating one building and make sure to input the "exact site coordinates". Then use the "create new shell" function in the wizard to add the other buildings and use the exact coordinate to determine its location. Make sure to create a new HVAC system and assign it to your new shell.

2. Simulate the whole year energy usage of your project. Extract the "*Monthly energy consumption by end use*" and "*annual energy consumption by end use*" summary report.
3. Calculate the Energy Use Intensity (EUI) for your project in kWh/ft^2 or in Btu/ft^2 if you have both gas and electric systems.
4. Discuss the different end uses of energy in your project. What can be done to reduce them?
5. Using the EPA "target finder" tool (available on-line on: http://www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder), identify the site & source energy use intensity for your project as well as the projected CO_2 emissions from the project. Use a target rating of "50" to get the average EUI for a similar project and location. Note that Target Finder results are based on the EIA's 2003 Commercial Buildings Energy Consumption Survey (CBECS) database.
6. Discuss the energy use intensity of your project and how it compares with conventional buildings of similar type and location as well as with high performance buildings (top 10%) as defined in the target finder tool.

7. Use the "my solar estimator" tool on the "http://findsolar.com " website to estimate the required size of the photovoltaic system needed to meet the electricity demand of your project.
8. Identify on your project the location of the surfaces on which the needed PV system can be installed. Take into consideration the optimum orientation and tilt for the PV system in your location as well as the fact that PV systems should be shaded at any time of the year.
9. For extra credit:
   a) Use ECOTECT to verify that your selected location for the PV system is not shaded by any other parts of your project.
   b) Use either of the two PV analysis tools discussed in class (HOMER or RETScreen) for a more detailed sizing/analysis of your PV system.

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Assignment 5: Life Cycle Assessment of Building Materials and Systems.

Date issued: Tuesday 4/24/2008

Date Due: No separate submission required, but must be included in final report.

The purpose of this assignment is to conduct an assessment of your materials and systems selections as well as the overall life cycle environmental impact of your whole building(s) using the two life cycle analysis (LCA) tools discussed in class: BEES (Building for Environmental and Economic Sustainability), and the ATHENA EcoCalculator, and following the methodology described in the manuals of the two tools as well as the lectures covering the topic.

The objective of this assignment is for you to understand the basic principles and procedures involved in comparing alternatives for materials and systems and making these selections based on "life-cycle" considerations as well as to become familiar with one of the tools used for that purpose.

The assignment will involve the following tasks:

1. Download the two required software from the two following web sites:
   a. For BEES version 4.0: http://www.bfrl.nist.gov/oae/software/bees.html .
   b. For ATHENA EcoCalculator: http://www.athenasmi.ca/tools/ecoCalculator/index.html Make sure to download the appropriate spreadsheet for your project location and building height (low-rise or high-rise).

   Both tools are freely available to download and use although registration may be required.
2. Install the tools to your computer (BEES 4.0 will also be available on the computers in the architecture lab)
   a. For BEES 4.0, extract the executable file to a folder on your desktop (or in any other location you prefer), and run the "setup.exe" file. Accept the default installation instructions.
   b. For EcoCalculator, the tool is in the form of an Excel file which can be used without installation.
3. Comparison and selection of materials on LCA basis using BEES:
   a. Identify at least 3 (three) building elements you intend to evaluate and the design alternatives you wish to evaluate for each element. Keep in mind that BEES can only compare alternatives of the same building element. Your selection of elements and alternatives should be based on both your original design decisions, i.e. materials you had already identified for your initial design, as well as on available building elements and alternatives in BEES.
   b. Conduct a life cycle analysis "LCA" (both environmental and economic) for each of your element selections. For each elements try to select "at least" 3 design alternatives if possible and appropriate. Assume the following parameters:

- A 50%/50% weighting for environmental and economic performance.
- The EPA Scientific Advisory Board method for environmental impact category weights.
- A discount rate of 10% (use the same discount rate for all evaluations).
- The same transportation distance unless more detailed information exists.

c. Extract the following tables/graphs from your BEES results for each building element being evaluated:

- Summary table.
- Overall performance graph.
- Environmental performance graph.
- Embodied energy by fuel renew ability graph.

d. Comment on the result you reach from the following points of view:

- First, based on BEES LCA results, which alternatives for each design elements would you select and why?
- Second, what changes in your original material selections (if any) do you now think are appropriate (based on your analysis), and what are their design implications?
- For only one of your selected building elements, preferably one in which a decision based solely on economic performance would be different than one based solely on environmental performance), repeat the evaluation using different weights for the environmental and economic performances (for example: 20% economic & 80% environmental, vs. 20% environmental and 80% economic). Comment in any changes in your selection of alternative based on this sensitivity analysis.

4. Evaluation of the combined environmental impact of the whole building using ATHENA EcoCalculator:

a. Using the most appropriate EcoCalculator spreadsheet for your location and building height, input the amount of materials your building is consuming into each of the six categories in the spreadsheet: columns and beams, intermediate floors, exterior walls, windows, interior walls, and roofs.

b. Extract the resulting environmental impact of your building in the categories calculated by the tool: primary energy use, global warming potential, resource use, air pollution, and water pollution. A description of the meaning of each performance indicator is included in the first worksheet of the tool title welcome and how-to.

c. Discuss the significance of each of the previous environmental performance indicator to your project. Certain [project locations/types may well increase/decrease the significance of some of these indicators compared to the others. On these basis, identify up to two indicators that you consider especially significant for your project and explain why.

d. Based on your previous discussion, identify at least three design decisions that will result in decreases the environmental impact of your building in general and the indicators you have identified in particular. Decisions may include replacement of materials or systems OR changes in the percentage of use of these materials or systems.

e. Using EcoCalculator, determine the percentage of reduction in the environmental impact of your building due to your design decisions.

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Exercise 1: Personal Carbon Footprint

Date issued: Tuesday 1/17/2007

Date Due: Monday 1/22/2007

The purpose of this exercise is for you to evaluate your personal annual personal carbon footprint. A personal footprint is the equivalent amount of carbon dioxide produced by an individual or a family during their everyday activities including household energy use, transportation, air travel, and consumption of food and other goods. Personal carbon footprints vary considerably depending of our everyday habits and patterns of use of different equipment and technologies.

A number of online personal footprint calculators are available including:

www.http://www.carbonfootprint.com/calculator.aspx

http://www.climatecrisis.net/takeaction/carboncalculator/

http://www.nature.org/initiatives/climatechange/calculator/

http://www.epa.gov/climatechange/emissions/ind_calculator.html

These calculators vary with regard to their accuracy and the amount of input they require. For the purpose of this exercise, we will use the calculator in www.carbonfootprint.com . Using this website, you need to perform the following tasks:

1. Estimate your personal annual carbon footprint for the year 2007. You will need the following information to perform the evaluation:
    a. Annual 2008 energy consumption in your household for each type of energy you use (electricity, natural gas, heating oil, etc.) either in dollars or in units of energy. Divide the annual consumption by the number of people in your household to get your personal contribution.
    b. Annual 2007 air travel (starting point & destination).
    c. Annual 2007 car travel (miles per year & car year make and model). If you use two cars, you need to estimate the miles driven by each car as car efficiencies vary considerably.
    d. Annual 2007 bus & rail travel (if any).

2. Compare your annual footprint to the US per capita average (around 20 tons of CO_2 per year), as well as the world average (approximately 2 tons of CO_2 per year)
3. Identify a reduction goal for your print in 2008. Your reduction goal should not be less than 20%.
4. Identify the measures you will perform to achieve these reductions in your footprint. These can include changes in personal behavior (for example driving less, riding public transportation more), or using more efficient technologies (e.g. a more efficient car), or a combination of the two. The website also includes options for carbon offsetting measures (such as planting trees), which you can include.

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Exercise 2: Modeling with ECOTECT

Date issued: Tuesday 2/12/2007

Date Due: Tuesday 2/19/2007

The purpose of this exercise is to build a model of the Monterrey Annex building using ECOTECT. The model will be based on a CAD geometry file of the building (available on WebCT). The model will achieve the following:

1. The building will be divided into the appropriate zones based on the loads and variances in patterns of use. Spaces with a similar function/pattern of use should be combined in one zone.
2. The correct geometry will be used for all building components (walls, roofs, floor, windows, doors, etc.)
3. Appropriate materials will be applied to all created surfaces. New ECOTECT materials can be created if needed; however, students should make sure not to overwrite existing library materials.
4. Occupancy and internal gains schedules will be created for all zones (Sample maximum occupancies and profiles for different space types will be posted on WebCT, which students can use to generate the appropriate schedules).
5. Appropriate lights will be created in all zones.
6. Appliances will be added where appropriate (e.g. computer lab).

Two models of the building should be created as described below. The two model can either occupy the same space (using the show/hide zone function), or they can be created completely separately. These models are:

A- A thermal analysis model:

This model requires a much higher precision in terms or zonal adjacencies but can have a lower level of geometry detail. For example, wall thicknesses can be ignored and all windows in the same zone can be grouped in one window with the combined area of all existing windows. All zones in this model must of thermal zones.

B – A solar/shading/lighting analysis model:

This model can have a lower level of precision with regard to zonal adjacencies but should have a higher level of detail in terms of geometry. For example, wall thicknesses should be accounted for and all opening should be modeled as built. All zones in this model must be non-thermal zones.

The exercise submission will consist of the ECOTECT digital input file as well as any supporting file created during the modeling (such as schedule files). All files should be uploaded to WebCT by the deadline.

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Exercise 3: Shading, Solar, & Thermal Analysis with ECOTECT

Date issued: Thursday 2/28/2007

Date Due: Thursday 3/6/2007

The purpose of this exercise is to examine the solar, shading, and thermal analysis functions in ECOTECT, which will for the basis for selecting and applying the appropriate functions to your projects. The exercise will be based on the THERMAL MODEL of the annex building prepared by the instructor and posted on WebCT. This exercise includes the following tasks:

1- <u>Shadow Range Analysis:</u>

Use the shadow range function (in the shadow settings panel) to generate a shadow range for the annex buildings from 8 am to 5 pm in the following two days: June 21st & December 21st.

Extract images from ECOTECT showing the two cases. The images should preferably be in plan view and from the visualization tab.

Identify areas north of the building which receive shading for most of the year and would therefore be suitable for outside student activities.

2- <u>Design of Shading Devices:</u>

Design a shading system for the south facing windows of the annex building. The shading device should prevent solar penetration from the windows during the working day (8 am to 5 pm) in the period from April 11th to August 30th.

You should use the shading design wizard to generate an optimum shading device for one of the windows then use the resulting device as a basis for generating a more comprehensive shading system for the whole elevation. Keep in mind that all external shading devices must be placed on a separate NON-THERMAL zone.

Generate and extract images from the visualization tab (in perspective view) that show the solar penetration through one of the south windows on each of the following dates: June 21st , April 11th , August 30th , and December 21st .

Comment on the performance of your shading system.

3- <u>Shading Masks:</u>

a. For one of the south-facing window:

Turn off the layer with your shading devices, and then use the “sun-path diagram tool” to generate a shading mask for one of your south windows. Use the “calculate shading” tab with default settings. Extract an image of the shading mask.

Turn your shading system back on then, repeat the process and generate another shading mask of the performance of the shading system.

b. *For the whole south-facing wall:*

Repeat the same process for the whole southern wall of the building and generate a shading mask to show the impact of your shading system on shading the wall.

Comment on the performance of your shading system.

4- Solar access analysis:

a. *For the south-facing wall:*

Use the "surface subdivision" tool to generate an analysis grid for the south-facing wall. Set the size of the tiles as 3' x 3', limit them to the boundaries of the wall, and offset them by 1" or 2" from its surface.

Use the "Solar access analysis" wizard to calculate the "shading, overshadowing, and sunlight hours" for the analysis grid throughout the year. Use "cumulative values" and "for selected objects only" options.

Use the display attributes part of the display settings panel to generate a colored scale showing the "percentage of shaded hours" for the south-facing wall. Generate an image (in elevation) for the results of your analysis.

Comment on the performance of your shading system

b. *For the roof:*

Repeat the same process for the building's roof. Use a 3' x 3' subdivision grid. Generate an image of the "percentage of sunlight hours" for the roof.

Based on the results of the analysis, and assuming that we are planning to install a PV system on the roof and knowing that a PV system performs best when it is not overshadowed, identify the area on the roof which such a system could occupy.

5- Thermal Analysis:

a. *Perform an Inter-Zonal Adjacency test:*

Uncheck the "calculate overshadowing" for faster calculations but MAKE SURE TO CHECK IT BACK AGIN afterwards otherwise the thermal calculations will not be accurate.

b. *Turn off the layer with the shading devices*

c. *Base-line temperature and discomfort hours analysis – passive building:*

Change the HVAC system selection for all "THERMAL" zones to "Natural Ventilation".

Use the thermal analysis wizard to perform a thermal analysis of internal temperatures. Use the annual temperature distribution option.

Extract a graph showing temperature distribution from the thermal analysis tab.

Repeat the process to calculate the hours of discomfort for the users in all visible thermal zones. Use the "adaptive – free run" option.

Generate a graph of the "percentage" of time in which users are not comfortable.

d. *Base-line building with HVAC:*

Change all thermal zones back to "full air conditioning".

Repeat the thermal analysis to calculate the monthly heating/cooling loads for all thermal zones.

Extract a graph showing the loads.

Extract the tabular data to excel and save as "base line case".

e. *Parametric analysis of possible design modification:*

Perform the following design modifications to your design and repeat the two previous processes for each:

- The building with the shading devices turned on.
- Change all windows to double-glazing-low e – timber frame but with no shading devices. Use the "select by element type" command.
- Increased wall and roof insulation. Increase thickness of existing insulation in wall/roof materials OR create new materials. Document the resulting R-value.
- *For extra credit,* identify one possible additional measure that would improve the performance of the building.
- A combination of all these measures.

For each case, generate a graph for the passive-running mode, and another one for the fully air-conditioned mode. Also extract tabular hourly loads data for the loads in the fully air-conditioned mode.

Using excel, generate a graph for the heating load changes and another graph for the cooling load changes resulting from the design modifications compared to the base-line case.

f. Using both extracted images and the excel graph, comment on the relative impact of each design modification, and make recommendations.

<u>Submission Requirements:</u>

The required submission for the exercise will include:

1- A report including the images extracted from ECOTECT for the various tasks requested as well as comments and analysis on the results when necessary.

2- The ECOTECT model files (*.eco , *.adj , and *.shd files

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Exercise 4: Lighting Analysis

Date issued: Tuesday 3/25/2007

Date Due: Tuesday 4/1/2007

The purpose of this exercise is to examine the daylighting and electric lighting analysis functions in ECOTECT, which will for the basis for selecting and applying the appropriate functions to your projects. This exercise includes the following tasks:

1- <u>Daylighting analysis in ECOTECT:</u>
For this task, use the Annex lighting model posted on WebCT, and conduct the analysis for the "north-east" corner studio. Perform the following:

a. Generate an analysis grid for the studio (use the analysis grid side tab and select the floor of the studio then click "display analysis grid"). Make sure your grid DOES NOT TOUCH OR EXCEED any of the model walls.

b. Using the lighting analysis wizard (from the calculate menu), conduct a daylighting analysis of the DAYLIGHT FACTOR over the analysis grid. Set your grid to working plane height (2' 6"). Use medium to low precision, and calculate the design sky illuminance for your site.

c. Conduct this analysis for both overcast (worst-case) and uniform sky conditions.

d. Adjust the scale to best illustrate your results (use the same scale in both cases). Use either 2D or 3D views for the grid. Export your results as images and comment on the availability of daylight in the studio.

e. Suggest any design modifications you feel are necessary.

<u>For Extra Credit:</u> Model your suggested design modifications and perform the analysis for the modified case. Comment on the improvements if any.

2- <u>Daylight and electric light analysis in ECOTECT:</u>
For this task, use the Annex lighting model posted on WebCT, and conduct the analysis for the "south-east" corner studio. Perform the following:

a. Generate an analysis grid for the studio (use the analysis grid side tab and select the floor of the studio then click "display analysis grid"). Make sure your grid DOES NOT TOUCH OR EXCEED any of the model walls. (You will need to draw a plane over the floor of your studio, and fit the grid to this plane, then delete the plane).

b. Using the lighting analysis wizard, conduct an overall daylight and electric light analysis over the analysis grid. Set your grid to working plane height (2' 6"). Use medium to low precision, and calculate the design sky illuminance for your site. Uncheck "assume compliant thermal model". Conduct the analysis for both overcast (worst-case) and uniform sky conditions.

c. Generate images for daylighting levels (lux), electric light levels (lux), and overall light levels (lux) for both scenarios. Adjust the scale to best illustrate your results (use the same scale in all cases). Use either 2 D or 3D views for the grid. Export your results as images and comment on the availability of daylight in the studio.

d. Suggest any design modifications you feel are necessary.

For Extra Credit: Model your suggested design modifications and perform the analysis for the modified case. Comment on the improvements if any.

WORKING WITH RADIANCE:

The use of Radiance allows for a more detailed calculation of daylighting levels in the space.

a. To perform this task, you need to have RADIANCE on your system. A RADIANCE version compiled for windows can be found in:

   http://www.arch.mcgill.ca/prof/reinhart/software/Radiance3P7forWindows.zip

   Download the zip file and extract it directly to you C:\ drive (extracting to any other subfolder will cause the software to not work properly).

b. Download and install the following material libraries:

   http://irc.nrc-cnrc.gc.ca/ie/lighting/daylight/daysim/docs/NRC_LightingLibrarySetup.exe

   http://www.arch.mcgill.ca/prof/reinhart/software/Kalwall_LightingLibrarySetup.exe

   Follow the default instructions. These libraries will add some RADIANCE material files to your ECOTECT folder.

c. You can find more detailed guidance on the download and the following RADIANCE related tasks in the following documents:

   http://www.arch.mcgill.ca/prof/reinhart/software/Radiance.htm

   http://www.arch.mcgill.ca/prof/reinhart/software/GettingStarted.pdf

   and the following ECOTECT tutorials:

   http://squ1.org/wiki/Radiance_Daylighting_Tutorial

   http://squ1.org/wiki/Radiance_Daylighting_Analysis_Tutorial

   http://squ1.org/wiki/Import_Radiance_Calculations_Tutorial

d. To add custom RADIANCE materials to your rendered image, you need to have Radiance material files. The material libraries you have installed will add "some" Radiance files to your computer. These files will be located in the following path: C:\program files\square one\materials and will have the .RAD extension.

   To have these materials appear in your rendered image, you need to create new materials in your ECOTECT file with the EXACT name as the radiance material and assign this material to the surfaces you want.

The following tasks are required (These tasks WILL NOT include the simulation of electric lighting sources, and therefore, lighting levels may appear low).

3- <u>Generating rendered images of Daylighting Conditions using RADIANCE:</u>

For this task, use the Annex lighting model posted on WebCT, and conduct the analysis for the South-east corner studio.

First, generate an appropriate internal camera view in the desired space at eye-level (6 ft). Delete all other views in the Visualize tab (except the default model view).

This task will be conducted for two cases:

1- Without any Radiance materials attached.

2- With the following RADIANCE materials: "BrickWork" and "WoodGrain" for the wall, "WoodGrainFloor" for the floor, and "LinoliumBack" for the ceiling.

The following procedures should be followed in both cases:

a. From the lighting analysis wizard, select "export to Radiance". Generate a "Luminance" image.

b. Select "Open Radiance Control Panel" (you can also select "final Render" to bypass the panel although the panel gives you more control over the rendering parameters).

c. For the rest of the options, select "Intermediate Sky", 640 x 480 pixels images and use medium precision settings. Generate the image for the summer solstice at 12 noon (best case scenario).

d. If your computer does not automatically find the RADIANCE software, browse to the C:\Radiance folder and select any file in the bin sub-folder

e. In the final screen, select the destination folder for your images, MAKE SURE OT CHECK THE "check for materials.rad files" option; and to set indirect reflections to 5 at least (higher values will give better results but take more time).

f. In the RCP, review your selections to make sure they are appropriate, then click "Render"

g. Following the end of the calculations (which may take long depending on your settings), an image browser will open with the rendered image. Adjust the exposure of the image for best viewing and save the image as JPG.

h. Generate a false color image of the luminance, adjust the exposure and the scale for best viewing, Save the mage.

i. Comment on the availability of daylight in the studio and suggest any design modifications you feel are necessary.

<u>For Extra Credit:</u> Model your suggested design modifications and perform the analysis for the modified case. Comment on the improvements if any.

4- <u>Importing RADIANCE calculation data into ECOETCT:</u>

Use the Annex lighting model posted on WebCT, and conduct the analysis for the north-east corner studio.

a. Generate an analysis grid for the studio similar to task one.

b. From the lighting analysis wizard, select "export to radiance" . Select "Daylight Factors" and "Final Render". IN the final screen, check "generate point data" for the existing grid.

c. Run the analysis, when the calculations are done, you will be prompted to load your results in ECOTECT. This will load the DF values calculated from RADIANCE into the analysis grid in ECOTECT. (For best results, view your model in plan view before exporting)

d. Export the DF image for the space and compare to the results generated from ECOTECT. Comment on the differences.

5- FOR EXTRA CREDIT:

Using the "Getting Started" tutorial listed above, conduct a "useful daylight index" and "daylight autonomy" analysis of either of the two studios.

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Final Report and Board

Date Due: Monday May 5th at 12 noon.

Semester Project Option 1 only: Final Presentation of Competition Boards in on May 6th (attendance recommended).

The final report and board represent the culmination of your work this semester and are therefore meant to illustrate both the breadth and the depth of the different phases of design optimization work that was conducted throughout the semester including the objectives, tools, and results of each phase.

You are required to submit your work in two formats, a professional report describing and detailing your work throughout the semester, and a 24' x 36' board offering a graphical representation of that work. Being aimed at different audiences, these two formats, while complementing each other, should each be designed to independently and sufficiently illustrate your work. Additionally, your board should be designed to be part of the overall design project presentation, while in the same times having the possibility of being viewed as a complete piece of work in itself.

The following section describe the minimum requirements for both the report and the board, however, students are strongly encouraged use their creativity in both formats to go beyond these minimum requirements.

<u>THE FINAL REPORT</u>

The final report is meant to fully illustrate your semester work using both text and graphics in an integrated layout/graphical design. The report MUST BE ON LETTER SIZE paper and must include at least the following sections:

1. ***Cover Page.***
2. ***Executive Summary:***

   The executive summary should offer a reader with no time to read the full report a full and comprehensive overview of the entire report. The summary should not exceed 2-3 pages (at the most) and should include both text and graphics. In many cases, important sentences/paragraphs from the text are also used in the executive summary.

3. ***Table of Contents.***
4. ***List of Figures***
5. ***Background and Objectives:***

   This section should BREIFLY discuss the background for this design optimization exercise and the performance objectives that you were aiming to meet. Objectives will vary from one project to another and may range from simply reducing the environmental impact of the building, to making it a net zero energy user or ultimately to making it a carbon-neutral building. *<u>The highest credit will be</u>*

given to projects aiming to design a carbon-neutral building and are successful in achieving this target. The section should also clarify which phase of a building's life cycle the different exercises are addressing (i.e. construction, use, demolition, embodied energy of material, etc.)

6. Design Project Problem Statement

This section should describe the problem statement of your design project, its location, immediate context, space program, and the design issues being explored/addressed in it.

7. Performance Assessment Methodology

Here you need to discuss the procedure you went through during the semester in the variety of performance optimization exercises that were conducted. This section should ONLY describe the procedures and NOT the results/conclusions of each phase. The discussion should list and describe all the design-decision support tools used in each of these phases.

8. Optimization Results

For each one of the design optimization phases conducted throughout the semester, you need to discuss the goals, results obtained, conclusions reached, and the design modifications that were performed on the basis of these conclusions. All sections MUST be supported by the appropriate graphics from your earlier assignments. The different phases are:

8.1. *Climate analysis*

Discuss the results of the climate analysis, the conclusions reached (i.e. optimum climate design strategies), and their impact on the design decision in the early stages of the design process.

8.2. *Solar access and shading analysis*

Discuss your assessment of the solar resources in the site, the shading/shadow impact both of your surrounding buildings (if any) as well as for your initial form options. Discuss the impact of the results reached in this phase on selecting and/or optimizing your design option.

8.3. *Thermal analysis*

Discuss the results of the thermal analysis performed for the various initial design options and the impact of the results reached in this phase on selecting and/or optimizing your design.

8.4. *Lighting analysis*

Discuss the potential for daylighting in your site/project and the results of the lighting analysis performed for your project. Describe the design decisions made/impacted by the results reached in this phase.

8.5. *Whole building energy use*

For your final design, discuss the results of the whole-building energy use simulation and compare that to conventional and high performance buildings of the same type and location. Discuss any final design modifications made on the bases of this analysis.

8.6. *Photovoltaic system sizing*

Determine the appropriate size of the photovoltaic system needed to meet the electrical demands of your building. Even if your final design project does not include a PV system, you report (and board) MUST illustrate the location on which such a system could be appropriately installed. The proposed location should meet the required orientation and tilt requirements of PV systems.

8.7. Overall carbon footprint of your project

Describe the overall annual carbon footprint of the project in tons of CO_2 both with and without a PV system. Compare that with similar conventional and high performance buildings.

8.8. Life-cycle assessment of materials

Discuss the results of your life cycle assessment exercise, and any design decisions made on the bases of these results. Describe the overall environmental impact of the materials used in your whole building using appropriate units.

9. Conclusions

Based on the previous analysis, the conclusions parts should cover the following:

9.1. Final design project

Graphically describe your final design project using graphics from your design project boards. These should include general representation of the project as well as graphics illustrating the impact of performance optimization exercise.

9.2. Comments on methodology

FROM YOUR POINT OF VIEW, comment on the various performance optimization exercises conducted during the semester, and their impact, if any, on your design process. This should include your overall evaluation of the process and its effectiveness, as well as an evaluation of the effectiveness of each of the tools you used during the semester in meeting your specific needs and set of skills. Be honest and straightforward in your evaluation. Students working with studio design teams are should also comment of their experiences in this regard (both positive and negative).

10. References

All references used during the semester must be listed, including software manuals.

11. Appendices

Appendices can and should be used to include any additional or supplementary material not included in the main body of the report.

Report Format and Graphical Design

The main body of the report (including all the main sections but EXCLUDING the executive summary, ToC, list of figures, references, and appendices) **MUST NOT EXCEED 30 LETTER SIZE PAGES**. To achieve this, your text should be very concise, while in the same time comprehensively covering the topic. You also need to be selective in the graphics you include in the main body of the report. Additional graphics and analysis results can and should be included in the appendices. There is not size limit of appendices.

The report must have a consistent layout and graphical design that integrate text and graphics, use a two or a three column format (both portrait and landscape orientation are acceptable). Larger graphics can cover the full page as long as you remain within the 30 page size limitation. Number your pages and your figures. Font size should not smaller than 10 points or larger than 12 points. Figure captions and appendices can use smaller font sizes but no text smaller than 8 points should be included anywhere in the report.

THE FINAL BOARD

You will also represent your semester work in a ***24" x 36"*** board. The board should graphically illustrate both the results of the performance optimization exercises (your process) as well as selected images of the final project and its overall performance (your product). Tables can be used to illustrate numerical results (such as your final carbon footprint). While the boards need to include some text, it should be used sparingly to describe the graphical content when needed.

The board should be designed as one of the boards of your design project boards and therefore should be consistent in layout and format to the rest of your boards, however, it should also be designed to be viewed separately and still be sufficient for a viewer to understand the performance optimization part of the work. Creativity in board graphical design is welcomed and encouraged.

Students working with design studio teams should coordinate the design of their boards with their team members. The level of coordination, or lack of it, will be one the evaluation criteria of the work.

The board should be digitally produced. However, you can select the tool you want to use for that purpose (Photoshop, Illustrator, etc.)

SUBMISSION REQUIREMENTS

Both the report and the board must be submitted in both a hard copy and a digital format by the stated deadline. Because of the need to submit the final grade by a specific deadline, late submission of either the report or the board, in addition to resulting in a reduction in the grade per the syllabus, may also result in a grade of "incomplete" being awarded temporarily.

The report must be professionally bound.

For the digital format submission, please save both the report (in PDF format) and board (either in PSD format or in JPG format combined with the source images) to a CD or a DVD and submitted along with the hard copies by the deadline.

Students working with design studio teams should also give a copy of their board to their team members to include in their final presentation on May 6th. Students are also strongly encourages to attend this presentation.