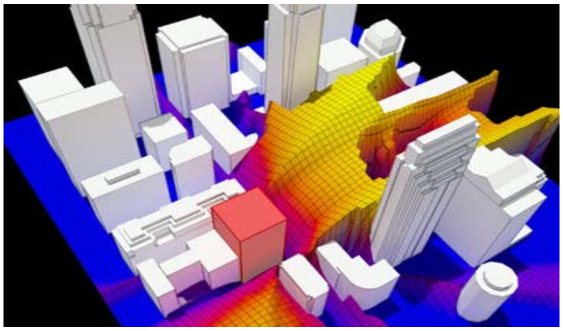
ARCH 5550: Whole Building Analysis

Envisioning the Sustainable Campus

Integrating carbon, energy, and water management strategies toward zero- and net-positive design



Each building is a unique ecosystem within the larger ecosystems of landscape and region… Ecologically designed buildings and institutions afford a chance to make such relationships explicit, thereby becoming part of the educational process and research agenda organized around the study of local resource flows, energy use, and environmental opportunities.
- *David Orr, The Chronicle of Higher Education*

Instructor

Loren Abraham, AIA, LEED AP, Adjunct Assistant Professor
Phone: 651.480.2237; E-mail: abrah221@umn.edu
Class Hours: Tuesday and Thursday, Time TBD
Office hours: Friday, 12:00-1:00 p.m. or by appointment, location TBD

If you cannot make these office hours please see the instructors after class to make an appointment. Office hours can be used to discuss course work, review work in-process, get additional readings, or to talk about the subject matter in relation to your special interests.

Course Description

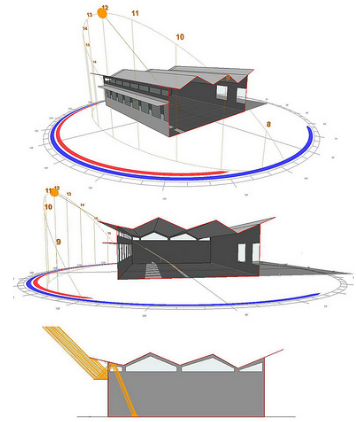
3 Credits; 15 week Seminar
This course will provide opportunities to learn about energy use and energy conservation measures employed in buildings; gain experience with methods for evaluating ecological performance of buildings including energy demand, thermal loads and the process for achieving optimal integrated design solutions. In addition students will become able to perform daylighting and energy simulation and performance assessment of simple buildings; understand the main principles of the thermal envelope, materials and construction incuding living walls and roof systems, internal gains, operation controls, weather, HVAC systems, zoning and become familiar with the process of Building Life-cycle Cost Analysis. The deliverables will be project based and student teams will work directly for an actual “client” on planned building projects for the University of Minnesota Campus.

Parallel Course

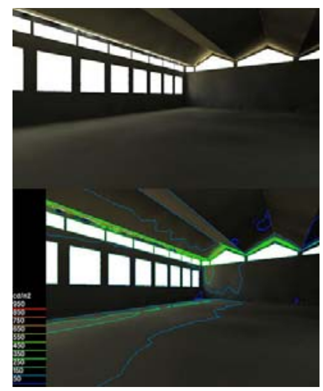
This course will be run in parallel with a similarly constructed Landscape Architecture course where the performance criteria and metrics will be related in part to landscape elements that can impact building performance and to the application of vegetated “living” systems for roof and building skins. The students in these two classes will have certain lectures and collaboration times scheduled concurrently creating opportunities for iterdisciplinary study and work. It is intended that the final presentations will be attended by both classes.

Course Focus & Objectives

The primary goal of this course is to explore an integrated approach to analyzing and optimizing *building performance in order to move toward the next generation of zero-energy and zero-emissions holistic design thinking.*

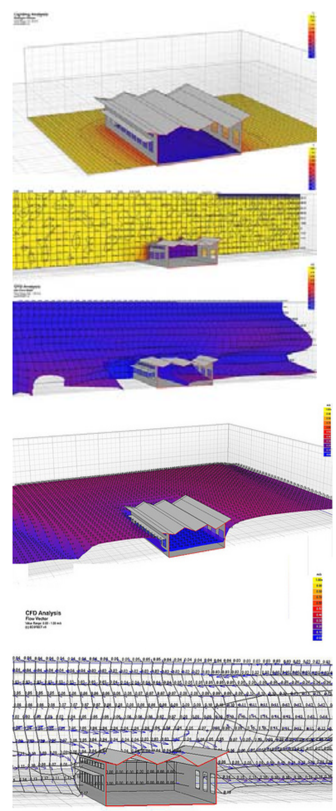


The course is formulated around the principal that lessons learned and knowledge gained by a course in Building Performance Modeling is best applied not only through application assignments but also a semester project that deals with using the selected energy design tools and preferred methods. The intent is to demonstrate the use of these tools and methods to model a proposed building design, compare the results with measured building data and perform the analysis for various design options to optimize the overall performance of the building.



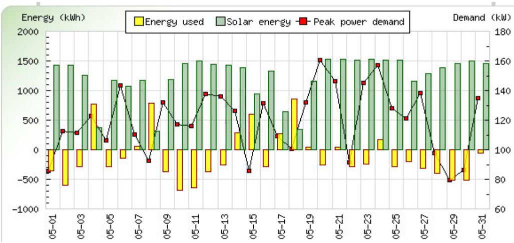
Key Questions:
The course will explore these fundamental questions related to modeling and improving building performance:

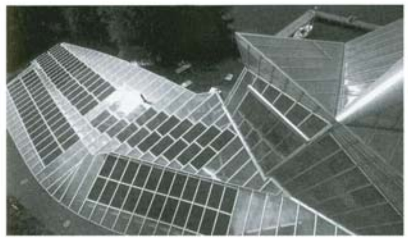
a) What are the performance criteria and metrics that can be assessed relating to energy and environmental performance?
b) What are the preferred tools and methods for assessing building performance and how can we best use them to inform the design process?
c) How do we select from the myriad of technologies, materials and strategies available that if optimally exploited could move toward synergetic "zero energy" performance.
d) How can we provide designers, owners and facilities managers comparative life-cycle cost data that will help in the decision-making process?

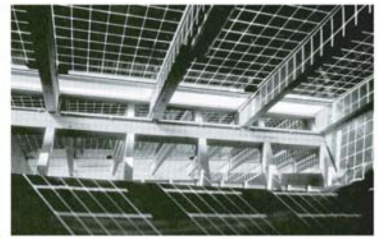


The objectives of the course:

1. Introduce students to a method for holistic building performance assessment for the purpose of achieving cost-effective Zero Energy Design.
2. Provide hands-on experience with design tools and analysis methods for achieving zero carbon emissions and zero energy performance goals.
3. Provide experience working for a real client on real planned projects where proposed solutions will have future potential value.
4. Enable students to develop an effective design process and methodology based on empirical (simulated) performance and comparative life-cycle cost data.







Course Framework

The course will introduce students to Energy 10, an energy design tool developed by the National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Laboratory (LBNL), the Sustainable Buildings Industries Council (SBIC), and the Berkeley Solar Group under the direction of the Department of Energy. Other tools that will be employed include *Ecotect, Radiance, DAYSIM and the EnergyPlus* plugin for *Sketchup*.

The students will take on the role of a consultant and will meet with the "client" (Capital Planning and Project Management) to determine the scope and specific requirements for a modestly-scaled and locally-based building project. They will develop several potential scenarios or discrete bundles of energy conservation measures intended to achieve an incremental level of performance with the Zero Energy Design solution as the penultimate scenario, environmental strategies and renewable energy systems to be modeled and compared.

They will complete a "shoebox" model energy simulation, run parametric studies related to envelope and fenestration configuration in order to determine optimal design specifications and they will use their results and findings to inform their proposed design solution and continue to make incremental design improvements based on assigned exercises.

For example, they will perform a variety of daylighting performance studies using advanced daylighting metrics for their analysis and they will evaluate their proposed performance "bundles." Explorations will include iterative studies using computer analysis tools and other quantitative investigations. Exercises will be used to integrate various ecological design considerations such as vegetated building skins and green roofs, landscape elements, super insulated envelopes, passive strategies and renewable energy systems.

The course will include: 1) informal design critiques, 2) in-class presentations of issues and exemplars, 3) discussion of readings and case studies, and 4) hands-on experience generating quantitative assessment of daylighting performance, thermal comfort, loads, energy demand and use, carbon emissions and life-cycle cost analysis.

Assignments

Working with a "real" client, CPPM and an actual planned building project, students will investigate a set of ecological, energy and resource issues and building operation objectives. Exercises will be assigned centered around 7 key topic areas with the client project as the vehicle for study. As a result the students' proposed project design solutions will develop incrementally over the 15 week period based on the following tentative course topics with a final presentation to the "client."

Course Structure

Tentative topics and weighting:

"Shoebox" Analysis - Calculating Loads and Energy Use	*10%*
Optimizing the Envelope - Parametric Studies	*10%*
Optimizing Windows and Shading - Parametric Studies	*10%*
Evaluating daylighting performance using Radiance and DAYSIM	*10%*
Analyzing the Impact of Shading and Living Envelopes on HVAC Loads	*10%*
Advanced Building and Landscape Modeling Strategies	*10%*
Building Life-cycle Cost Analysis	*10%*
Final Integrated Design	*30%*
Total	*100%*

Eligibility

This course is open to all M. Arch. and M.S. in Sustainable Design Students. A maximum of 30 student participants has been set as the course enrollment.

Prerequisites

Students should have taken Arch 5516 previous to taking this course and will need design and analysis skills. Some knowledge of computer building performance analysis is required (e.g., Ecotect, Energy 10, IES VE Ware, BIM, etc.)

Teaching Format

The 15-week, 3-credit course will meet in class for 3 hours per week, including the following: 1) one 1.5 hour lecture session per week, 2) one -1.5 hour computer lab per week. Students will work individually on various exercises and assignments and collaboratively in teams on projects.

Grading Standards

University of Minnesota Grading Standards:

A Achievement that is outstanding relative to the level necessary to meet course requirements
B Achievement that is significantly above the level necessary to meet course requirements
C Achievement that meets the course requirements in every respect
D Achievement that is worthy of credit even though it fails to meet fully the course requirements
SAchievement that is satisfactory, which is equivalent to a C- or better
F (or N) Represents failure (or no credit) and signifies that the work was either: 1) completed but at a level of achievement that is not worthy of credit or 2) was not completed and there was no agreement between the instructor and the student that the student would be awarded an incomplete.
I (Incomplete) Assigned at the discretion of the instructor when, due to extraordinary circumstance, e.g., hospitalization, a student Is prevented from completing the work of the course on time. Requires a written agreement between instructor and student.

Academic Dishonesty

Academic dishonesty in any portion of the academic work for a course shall be grounds for awarding a grade of F or N for the entire course.

Workload

One credit is defined as equivalent to an average of three hours of learning effort per week (*over a full semester*) necessary for an *average student* to achieve an *average grade* in the course. For example, a student taking a three-credit course that meets for three hours a week should expect to spend an additional six hours a week on coursework outside the classroom (over a semester) to receive an *average grade*.

Schedule and Attendance

The course meets daily on Tuesday and Thursday mornings in a room or computer lab (time and locations to be announced). Attendance is required. It is critical that you fully participate and attend all activities (lectures, discussions, labs and presentations). Please make every effort to be on time.

Reading

Specific readings will be assigned with the individual course assignments in one week blocks. Selected readings will be provided through e-reserve and will include Software Tutorials, Project Case Studies and examples of Whole Building Analysis Reports and Daylighting Studies authored by the Instructor and other consultant groups and research organizations, Renewable Energy Post Occupancy Studies prepared by NREL, etc. In addition the following readings will be required:

- Abraham, Loren E. et al, Designing Low-Energy Buildings with ENERGY-10 Software, FEMP, SBIC, 1996, v.1.8 rel. 2008
- Abraham, Loren E. et al, Whole Building Analysis Reader

POLICY STATEMENTS

Subject to Change

With the exception of the grade and attendance policies, parts of this syllabus are subject to change with advance notice, as deemed appropriate by the instructors.

Students with Disabilities

This syllabus can be made available in alternative formats upon request.
Contact the School of Architecture 612.624.7866. Students with Disabilities that affect their ability to participate fully in class or meet all course requirements are encouraged to bring this to the attention of the instructor so that appropriate accommodations can be arranged. Further information is available from Disability Services (16 Johnson Hall).

Scholastic Conduct

All students are responsible for conduct in conformance with the University of Minnesota Student Conduct Code which, among other provisions, broadly defines scholastic misconduct as "any act that violates the rights of another student in academic work or that involves misrepresentation of your own work."

Intellectual Property

The College of Design has the right to retain any student project whether it be for display, accreditation, archive, documentation or any other educational or legal purpose. In addition, the College reserves the right to reproduce and publish images of any such student work in collegiate publications, printed or electronic, for the purposes of research, scholarship, teaching, publicity and outreach, giving publication credit to the creator/student.

Academic Policies

Academic policies for this course (including but not limited to: accommodations for students with disabilities, statements on classroom conduct, and statements regarding sexual harassment, and academic integrity) can be can be found in the University's website at http://www1.umn.edu/usenate/usen/usenpol.html . Classroom misconduct, violation of academic integrity, sexual harassment and issues concerning

Tentative Course Schedule

Part One - Building Performance Modeling - the Shoebox Approach

Session	Date	Class Type	Description
1	6-Sep	General	Class Overview and Course Syllabus - Initial Meeting with Client
2	8-Sep	Lecture 1	Introduction to Thermal Envelope Analysis Tools and Methods
		Computer Lab 1	Getting Started with Ecotect, Energy 10, EnergyPlus Plugin to Sketchup
3	13-Sep	Lecture 2	The process of Building Performance Modeling
		Lecture 3	Establishing a Baseline, Shoebox Analysis, Optimizing Building Loads
4	15-Sep	Computer Lab 2	Creating a Shoebox Analysis with Enregy 10
5	20-Sep	Lecture 5	Optimizing the Thermal Envelope - Walls and Roof
6	22-Sep	Computer Lab 3	Parametric Envelope Studies
7	27-Sep	Lecture 6	Optimizing the Envelope - Windows and Shading
8	29-Sep	Computer Lab 4	Parametric Fenestration Studies
9	4-Oct	Presentations	In-Class Presentations By Students
10	6-Oct	Presentations	In-Class Presentations By Students

Part Two - Optimizing Design through iterative analysis and incremental improvement

11	11-Oct	Lecture 8	How the Shoebox Analysis informs Building Design
		Lecture 9	Refining the Energy 10 model - Introduction to Modeling with Ecotect
12	13-Oct	Computer Lab 5	Energy 10 model refinement and Creating a thermal model in Ecotect
13	18-Oct	Lecture 10	Advanced Daylighting analysis methods using Radiance and Daysim
		Lecture 11	Balancing Daylighting goals and thermal loads
14	20-Oct	Computer Lab 6	Daylighting analysis with Ecotect/Radiance/Daysim and thermal loads
15	25-Oct	Lecture 12	Peak Load conditions - Load shifting strategies
16	27-Oct	Computer Lab 7	Integrated Systems Strategies - HVAC/Shading and Living Envelopes
17	1-Nov	Lecture 13	Integrating Renewable Energy Systems
18	3-Nov	Computer Lab 8	Sizing and modeling Renewable Energy Systems
19	8-Nov	Presentations	In-Class Presentations By Students
20	10-Nov	Presentations	In-Class Presentations By Students

Part Three - Getting to the bottom line - Integrated Financial Life-cycle Cost Analysis

21	15-Nov	Lecture 14	Optimizing the ROI - Integrating Building and Landscape
22	17-Nov	Computer Lab 9	Advanced Building and Landscape Modeling Strategies
23	22-Nov	Lecture 15	Bundling Strategies for Cost Benefit Analysis and getting to ZED
24	24-Nov	Computer Lab 10	Creating and modeling bundles with Energy/Ecotect
25	29-Nov	Lecture 16	Financial Analysis and Model Refinement
26	1-Dec	Computer Lab 11	Performing Financial Analysis and Model Refinement
27	6-Dec	Computer Lab 12	Students Work on Projects in Class
28	8-Dec	Computer Lab 13	Students Work on Projects in Class
29	13-Dec	Presentations	Final Presentations By Students
30	15-Dec	Presentations	Final Presentations By Students