4.401/4.464 Environmental Technologies in Buildings – Syllabus

Term:	Fall 2024
Department:	Architecture
Instructor:	Christoph Reinhart (creinhart@mit.edu)
Teaching Assistants:	4.401 Ali Irani (airani@mit.edu) 4.464 Ben Taube (taube@mit.edu)
Time & Location:	Lecture - Mondays 11.00 - 12:30, Room 9-354 Lecture - Wednesdays 11.00 - 12:30, Room 9-354 Lab - Fridays, 10:00 - 11.00, Room 1-134 Lab - Fridays, 11:00 - noon, Room 3-442

Course Description

Welcome to 4.401/4.464! The primary focus of this course is the study of the thermal, luminous and acoustical behavior of buildings. The course examines the basic scientific principles underlying these phenomena and introduces students to a range of technologies and analysis techniques for designing comfortable indoor environments. Students will be challenged to apply these techniques and explore the role energy, light and sound can play in shaping architecture.

Following a review of how to analyze a site's climate and local energy mix, the course will introduce students to the art and science of lighting buildings along with rules of thumb and computer-based methods for analyzing daylight within and around buildings. The third part of the course is dedicated to the principles of heat storage and heat flow into and out of buildings. Basic manual and computer-based methods to predict the energy use of buildings will also be discussed. In order to introduce students to the effective use of computer simulations during design, a *Building Optimization Game* that mimics a sustainable design charrette will be organized on Nov 15. During the game, student groups will compete who develops the building with the lowest energy use within a given cost budget and for a given climate. Your group will need a Windows laptop for the day. Check with STOA if you need to borrow one. The last part of the course provides an overview of building acoustics and sound attenuation.

The course format consists of semiweekly lectures and weekly labs. Individual and group assignments as well as in-class presentations and exercises will help students to study the use of environmental technologies in contemporary buildings.

Learning Objectives

The course aims to help students to:

- understand and apply the scientific principles underlying the thermal, luminous and acoustical behavior of buildings,
- learn to evaluate the pros and cons of a range of technologies for creating comfortable indoor environments,
- conduct a series of design analysis workflows regarding climate, building energy use and daylighting and
- acquire the knowledge required to critically discuss/present the environmental concept of a building.

Requirements

The following deliverables will be required to pass this class:

- Attendance of semiweekly lectures and Friday Labs. Up to two unexcused absences per term.
- Timely completion of assignments. Late assignments will not be accepted.
- Completion of a group course project. The course project will be to develop and present an environmental concept for a small office or multi-unit residential building. More details will be provided later in the term. Final presentations for 4.401 will be on Dec 6. Presentations for 4.464 will be scheduled during Exam Week (Dec 18 to 20).
- Preparation of in–class group presentations on one of the AIA Cote Top Ten Projects for the current year (http://www.aiatopten.org/). Presentations will be timed and should have the following content:
  - Overview of the main environmental features of the building (3/15 points)
  - Discussion of predicted energy use. Review predicted and actual energy use for the building according to the AIA website and assess how both compare to the LBNL Building Performance Database (https://bpd.lbl.gov/explore). How much better is the AIA building than the average? What design strategies contribute the most to the savings? (5/15 points)
  - Daylighting performance. Construct a simple 3D model of the whole or key spaces within the building. The model does not have to be very detailed, but should include the major façade openings and elements so that you can evaluate how daylight is being distributed and controlled throughout the building. (5/15 points)
  - Discuss what you like and/or dislike about the building and its environmental concept. (2/15 points)
- Active participation in class discussions.

Methods of Assessment

Grades will be determined based on:

- Quality and timely submission of completed assignments (60%)
- Final course project (20%)
- AIA case study presentation (10%)
- Participation in class discussions (10%)

Please familiarize yourself with MIT's Academic Integrity Expectations at http://web.mit.edu/academicintegrity/.

Software

Throughout the course we will be using the following software packages. You will be needing a Windows computer since ClimateStudio only runs under Windows.

- Rhinoceros forms the CAD backbone of all environmental analysis tools that we will be using in this class. Students should have a working version of Rhinoceros 6, 7 or 8 installed on their laptops or workstations. The Department of Architecture provides free Rhino access to all students.
- ClimateStudio is a highly optimized daylighting and energy modeling plug-in for Rhino. We will be using ClimateStudio for assignments on solar radiation, daylighting and energy simulations. Students can download a Windows installer from https://www.solemma.com/cs-installers. An educational license code for ClimateStudio will be provided during the first week of class.

Bibliography

Information required for completing all assignments will be provided through the lecture notes, selected online materials as well as the *Daylighting Handbook Volumes I + II* which can be purchased on Amazon for $38 per volume or during in class for $20 per volume. A draft version of the upcoming Climate Driven Design I book will be available by signing up for a free account on https://buildingtechnologypress.com/.

Wk	Monday Lecture for 4.401/4.464 11.00 – 12.30, Room 9-354	Wednesday Lecture for 4.401/4.464 11.00 – 12.30, Room 9-354	Weekly Reading*	Material to review before Friday lab	Friday Lab 4.464 10.00 – 11.00, Room 1-134 4.401 11.00 – noon, Room 3-442	Assignment (individual | group, due date)
1		**Sep 4** L01 Course Introduction; Climate Change and the Building Sector		• Go through CANVAS - Course software steps	**Sep 6** Lab: Review course software; finish introductions	**Ass 1** Essay (individual, Sep 13)
2	**Sep 9** L02 Energy Use in Buildings	**Sep 11** L03 High Performance Buildings	CDD1, CCD2	• Introduction CS GUI (video) • Building Performance Database (web site)	**Sep 13** Lab: Benchmarking; form groups	**Ass 2** Personal Benchmarking (individual, Sep 20)
3	**Sep 16** L04 Understanding Climate – Solar Radiation	**Sep 18** L05 Understanding Climate – Wind, Temp. and Rel. Humidity	DH3, DH6 CDD3	• Direct Shading Study (video)	**Sep 20** No labs (student holiday)	**Ass 3** Direct Shading Study (individual. Sep 27)
4	**Sep 23** L06 Thermal Comfort + Climate File Quiz	**Sep 25** L07 Active Solar; Introduction to Course Project	DH9, CDD4,	▪ CBE Thermal Comfort Tool (video) ▪ Solar Radiation Analysis (video) ▪ Sizing a PV System (video)	**Sep 27** Lab: Net Zero Feasibility Study; Thermal comfort study	**Ass 4** Net Zero Feasibility Study (group, Oct 4) **Ass 5** Thermal Comfort Study (individual, Oct 11)
5	**Sep 30** L08 Light and Human Vision	**Oct 2** L09 Daylighting Design Principles	DH1, DH2, DH4, DH5		**Oct 4** Lab: Photometry	**Ass 6** Daylit Precedence & Massing (group, Oct 11)
6	**Oct 7** L10 Daylight Simulations + Daylight Availability Metrics	**Oct 9** L11 Visual Comfort	DH10, DH11, DH13	• CS GUI for Daylighting (video) • LEED Daylight Credit (video)	**Oct 11** Lab: Daylight availability simulations	**Ass 7** Daylight Availability Study (group, Oct 18)
7	**Oct 14** No class (Indigenous Peoples Day)	**Oct 16** L12 Electric Lighting + Controls + Occupant Behavior	DH14, DH15	▪ Annual Glare Study (video) ▪ Electric Lighting (video)	**Oct 18** Lab: Glare & Electric Lighting	**Ass 8** Visual Comfort + Electric Lighting (group, Oct 25)
8	**Oct 21** L13 Load Calcs & Internal Gains	**Oct 23** L14 Thermal Mass + Heat Flow	CDD5, CDD6	▪ Tutorial: Thermal Model Setup (video)	**Oct 25** Lab: Building a thermal baseline model	**Ass 9** Thermal Model Setup (group, Nov 1)
9	**Oct 28** L15 Insulation Materials + Window Technologies	**Oct 30** L16 Shading + Integrated Façade Design	CDD7, DH16	▪ Internal loads & envelope upgrades (video)	**Nov 1** Lab: EUI study for internal loads and envelope properties	**Ass 10** EUI Study (group, Nov 8)
10	**Nov 4** L17 Indoor Air Quality + Fresh air requirements; HVAC benchmark quiz	**Nov 6** L18 Ventilation		• Bring a working energy model of your building.	**Nov 8** Lab: Intro to simulation game and ventilation requirements	**Ass 11** Ventilation section (group, Nov 15)
11	**Nov 11** No class (Veterans Day)	**Nov 13** L19 HVAC for Small Buildings		• Practice running the simulation game Grasshopper definition.	**Nov 15** Simulation Game (students must join both labs)	**Simulation Game** submission (during lab time)
12	**Nov 18** L20 HVAC for Large Buildings	**Nov 20** AIA student presentations I			**Nov 22** Lab 09 HVAC Exercise [Ali Irani]	**Ass 12** P9 HVAC System Selection (group, Dec 6)
13	**Nov 25** AIA student presentations II	**Nov 27** AIA student presentations III			**Oct 29** No Lab (Thanksgiving)	
14	**Dec 2** L19 Acoustics I [Guest lecture: Ben Markham]	**Dec 4 L20** MIT Acoustics II [Guest lecture: Ben Markham] HVAC quiz			**Dec 6** Final Project Presentations for 4.401	
15	**Dec 9** No Class (Core I review)	**Dec 11** No class				
16	**Dec 16 - 20 Exam Week** Final Project Presentations for 4.464					

*) DH = Daylighting Handbooks; CDD = Climate Driven Design

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