4.401/4.464 Environmental Technologies in Buildings – Syllabus

Term: Fall 2018

Department: Architecture

Instructor: Christoph Reinhart (creinhart@mit.edu)

Teaching Assistants: Alpha (aarsano@mit.edu)
Hellen Rose Anyango Awino (awino@mit.edu)

Time & Location: Lecture - Mondays 11.00 - 12:30, Room 9-354
Lecture - Wednesdays 11.00 - 12:30, Room 9-354
Lab - Fridays, 11:00 - 12.00, Room 1-150

Course Description

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 second 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 9. During the game, students will compete in groups who develops the building with the lowest energy use within a given cost budget. 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.
☐ 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 building. More details will be provided later in the term. Final presentations for 4.401 will be on Nov 30. Presentations for 4.464 will be during Exam Week.
☐ Preparation of 15 minute in–class group presentations on one of the AIA Cote Top Ten Projects for the current year (http://www.aiatop10.org/). Dates are set to Nov 19 (4.401) and Nov 28 (4.464). Presentations should have the following format:
  - Overview of the main environmental features of the building
  - Discussion of predicted energy use (Note: You do not have to explicitly model the building for energy use. You should rather review the predicted and actual energy use for the building – this is published for most of the AIA awarded buildings – and assess how they compare; also compare the data to typical buildings of the same type. CBECS has data on energy usage for various building types in different parts of the country. How much better is your building than the average? What design strategies contribute the most to the savings?)
  - Daylighting analysis of the building (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 light is being distributed in the space.
  - Discuss what you like and/or dislike about the building and its environmental concept.
☐ Active participation in class discussions.

Methods of Assessment:

Grades will be determined based on:

☐ Quality and timely submission of completed assignments (45%).
☐ Course project presentation (30%)
☐ AIA case study presentation (15%).
☐ 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 DIVA 4 only runs under Windows.

- **Rhinoceros** forms the CAD backbone of all environmental analysis tools that we will be using in this class. Students should therefore ideally have working version of Rhinoceros 5 or 6 installed on their laptops or workstations. You can install a 90 day demo version of Rhino 6 from [http://www.rhino3d.com](http://www.rhino3d.com).

- **DIVA-for-Rhino** is a daylighting and energy modeling plug-in for Rhino ([http://diva4rhino.com](http://diva4rhino.com)). We will be using DIVA for assignments on solar radiation and daylighting and energy simulation. Students may request free licenses for their laptops from the DIVA-for-Rhino web. DIVA will also be installed on select cron computers.

- **Climate Consultant** is an easy to use, graphic-based computer program to visualize and interpret annual climate files. The tool can be downloaded free-of-charge from [http://www.energy-design-tools.aud.ucla.edu/climate-consultant/request-climate-consultant.php](http://www.energy-design-tools.aud.ucla.edu/climate-consultant/request-climate-consultant.php). During class we will also be introducing MIT’s new CLIMA+ tool that has comparable functionality to Climate Consultant.

Bibliography

- Information required for completing the assignments will be provided through the lecture notes, selected online materials as well as the Daylighting Handbook Volume 1 which can be purchased directly from the course instructor for $20 or on Amazon for $38. The second volume of the Handbook will be released on October 23 in New York City.
<table>
<thead>
<tr>
<th>Week</th>
<th>Monday Lecture for 4.401/4.464 11:00 – 12:30, Room 9-354</th>
<th>Wednesday Lecture for 4.401/4.464 11:00 – 12:30, Room 9-354</th>
<th>Weekly Reading*</th>
<th>Friday Lab for 4.401/4.464 : 11:00 – 12:00, Room 1-150</th>
<th>Assignment (due date)</th>
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<tr>
<td>1</td>
<td>Sep 5 L01 Course Introduction</td>
<td>Energy Use in Society</td>
<td>Sep 7 Software Overview and Installation [Arsano, Awino, Reinhart]</td>
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<td>Ass 1 – My Energy Essay (Sep 14)</td>
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<td>2</td>
<td>Sep 10 L02 Energy Use in Buildings</td>
<td>Sep 12 L03 Understanding Climate – Solar Radiation</td>
<td>Sep 21 No Lab (Student Holiday due to Career Fair)</td>
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<td>Ass 2 – Direct Shading + Sun Path Diagrams (Sep 21)</td>
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<td>3</td>
<td>Sep 17 L04 Understanding Climate – Wind, Temperature and Rel. Humidity</td>
<td>Sep 19 L05 Thermal Comfort + CBE Comfort Tool + Case Studies</td>
<td>Sep 21 No Lab (Student Holiday due to Career Fair)</td>
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<td>Ass 3 – Visual + Thermal Comfort (Sep 28)</td>
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<td>4</td>
<td>Sep 24 L06 Active Solar</td>
<td>Sep 26 L07 Light and Human Vision + Photometry</td>
<td>DH9, DH4</td>
<td>Sep 28 DIVA Radiation Maps</td>
<td>ArchSim PV Simulations (DIVA-GH)</td>
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<td>Oct 1 L08 Daylighting Design Principles</td>
<td>Oct 3 L11 L09 Daylight Simulations + Characterizing Material + Daylight Availability Metrics</td>
<td>DH2, DH5, DH10, DH11, DH12</td>
<td>Oct 5 DIVA Photography + Daylight Availability Calculations (DIVA-GH1, DIVA-GH2)</td>
<td>[Arsano, Awino, Reinhart]</td>
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<td>10</td>
<td>Nov 5 Manual Load Calculations + Energy Simulations</td>
<td>Nov 7 L18 Simulation Game</td>
<td>Nov 9 Simulation Game Presentations (separate from 4.401 and 4.464)</td>
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<td>Ass 9 – Simulation Game Presentation (Nov 9)</td>
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<td>11</td>
<td>Nov 12 No Class (Veteran’s Day)</td>
<td>Nov 14 HVAC for Small Buildings</td>
<td>Nov 16 No Lab (Instructor at Greenbuild)</td>
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<td>Nov 19 AIA student presentations 4.401</td>
<td>Nov 21 HVAC for Large Buildings [Nagpal TBC]</td>
<td>Nov 23 No Lab (Thanksgiving)</td>
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<td>Nov 26 Meetings with 4.401 Groups</td>
<td>Nov 28 AIA student presentations 4.464</td>
<td>Nov 30 Final Project Presentations for 4.401</td>
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<td>14</td>
<td>Dec 3 L22 Acoustics I [Markham]</td>
<td>Dec 5 L23 Acoustics II [Markham]</td>
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<td>MIT HVAC tour [Norford TBC]</td>
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<td>Dec 10 No Class</td>
<td>Dec 13 Individual Meetings with 4.464 Groups</td>
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<td>16</td>
<td>Dec 17 -21 Exam Week Final Project Presentations for 4.464</td>
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