4.432/4.433 Modeling Urban Energy Flows: Towards Sustainable Cities and Neighborhoods

Department	School of Architecture and Planning (Course 4)
Time / Location	TR 9:30 -11:00, Room 1 -150 (Lecture) R 11:00 -12:00, Room 3-442 (Lab)
Instructor	Christoph Reinhart, Professor, Architecture (tito@mit.edu)
Teaching Assistant	Ali Irani, PhD Candidate, Architecture (airani@mit.edu)
Prerequisites	Previous exposure to building technology, design and/or urban planning is desirable but optional.

Fig 1: Visualization of the MIT Volpe Redevelopment Project by DesignDistil; Source: https://volpe.mit.edu

Course Description

In response to global environmental challenges, city governments world-wide have developed ambitious greenhouse gas (GHG) emission reduction targets which are typically based on projected savings in the building and local transportation sectors. Those goals can conflict with a city's other needs such as housing a growing population, providing healthy environments for all residents, and attracting new commerce. Similarly, while many people will agree that reducing carbon emissions is a societal imperative, very few individuals will move into a neighborhood solely because it consists of low energy buildings. More urgent selection criteria beyond safety include stimulating nearby jobs, good schools, healthy food options, a diversity of entertainment opportunities as well as attractive indoor and outdoor spaces (Fig 1). A balanced urban analysis framework is hence needed to support the design of vibrant mixed-use and pedestrian-friendly innovating districts that are also resource-efficient.

Fig 2: Boston Seaport District - Efficiency, resiliency & livability (2017; N Brown, M Giampieri, E Jungmin Han, NJ Namju Lee)

This hands-on survey course deals with the fundamentals and application of environmental performance simulations to urban design. Core topics include neighborhood walkability and outdoor thermal comfort, access to daylight, operational and embodied building energy use, locally grown food supply, electric vehicle charging and resource-efficient district energy systems. We will also be reviewing basic cash flow models to compare the economic viability of competing neighborhood proposals. Throughout the term, students will work in groups and apply the course content to develop a neighborhood proposal for select sites in Lisbon, Sandy Springs (GA) and Singapore. A third focus area of the class is the impact assessment of climate change and urban heat island effects on long-term building energy use and resident comfort. Previous course projects can be found at the MIT Sustainable Design Lab web site.

The class is open to all members of the MIT community. Previous exposure to building technology (through classes such as 4.401/4.464 and 4.421), design and/or urban planning is an asset since we will be working at the interface of these three fields. The instructor will ensure that all student groups are well balanced and have members representing all three disciplines.

Learning Objectives

At the end of this course, students will be able to:

- Understand the various physical effects that generate urban microclimates and their impact on building energy use, carbon emissions and thermal comfort in cities.
- Evaluate new and existing neighborhoods regarding key environmental performance indicators including energy, daylight, walkability, outdoor comfort and food supply.
- Run computer simulations for such metrics, using 3D models generated in Rhinoceros using MIT's Urban Modeling Interface.
- Conduct a series of design interventions to improve these performance indicators for a given neighborhood design.

Fig 3: Lisbon Alfacinha - Building integrated agriculture (2016; K Benis, S Tolgay and I Turan)

Course Format

The class format will consist of two weekly 90 minute lectures and a one hour lab session. Work for the class will be divided into a series of homework assignments that successively build up to a mixed-use neighborhood proposal. A key task for all groups will be the use of digital analysis methods to build a convincing argument as to why a particular proposal deserves to be called 'sustainable'.

For the first seven weeks, student groups will work on a street network and massing solution for their site that balances walkability, outdoor comfort, access to daylight and building energy use. During weeks 8 to 11, we will be exploring how the neighborhood may develop between now and 2050 considering climate change, dietary changes and the displacement of private parking with shared electric vehicles. During the final two weeks of class, we will be introducing an independent project period where students can either further explore a previously covered topic or work on a new urban analysis workflow. During that time, we will also offer a workshop on how to program new UMI plugins. The instructor and members of the Sustainable Design Lab will closely work with all student groups on defining overall project goals and specific deliverables. Possible design questions that students may choose to explore are:

- How much urban infill is needed to make a car centric downtown walkable and comfortable for pedestrians?
- What urban building massing solutions ideally balance access to daylight and annual building energy use?
- Will naturally ventilation still be an option for residential buildings in Lisbon in 50 years?
- How do density and urban form affect outdoor thermal comfort conditions?

Course Requirements

Attendance and active participation in all lectures and labs are mandatory. Timely completion of all assignments is also required. Assignment types, due dates and grading weights are listed below. Presentations for the semester long project will be graded based on the clarity of the project's objectives, originality and inner logic of the design, sophistication of analysis techniques used and comprehensiveness of the final design.

Assignment/Requirement	Due Date	Grade Weight
Active participation in class	-	10%
Ass 1 Project goals & accessibility	Feb 17	5%
Ass 2 Daylight & massing	Feb 24	5%
Ass 3 Outdoor comfort	Mar 3	5%
Ass 4 Operational energy now and in 2025	Mar 10	5%
1st Presentation Urban massing	Mar 17	10%
Ass 5 Resiliency	Apr 9	5%
Ass 6 Urban food supply	Apr 16	5%
Ass 7 District energy concept	Apr 21	5%
2nd Presentation Vision 2050	Apr 21	10%
Ass 8 Independent project	Apr 30	15%
Final Presentation Sustainable neighborhood concept	May 7	20%

Software and Tools

Throughout the course, we will be using a Rhinoceros/Grasshopper-based urban modeling environment called UMI as well as a series of compatible, third party Grasshopper components. Detailed software installation instructions and support will be provided in class and during lab time. Additional custom tools will be prepared when required during the course depending on student needs for the semester projects. The specific programs used are:

- Rhinoceros 7.0 (http://www.rhino3d.com/)
- UMI (http://www.urbanmodeling.net)
- ClimateStudio (http://solemma.com)

Academic Integrity

As in any other MIT course and especially in a research context, plagiarism and cheating are not acceptable. Never turn in an assignment that is not your own work, or products that do not include your own work as part of team assignment. If required, please re familiarize yourself with the MIT Academic Integrity Handbook that can be downloaded from http://web.mit.edu/academicintegrity/.

wk		Tuesday Lecture for 4.432/4.433 9.30 – 11.00, Room1-150	Thursday Lecture for 4.432/4.433 9.30 – 11.00, Room1-150	Thursday Lab: 11.00 – 12.00, Room 3-442	Reading	Assignment (due date)
1	Urban Massing	**Feb 1** L01 Course introduction	**Feb 3** L02 Previous and this year's projects	**Feb 3** Software session; UMI site metrics and FAR	UMI paper	**Ass 0** Tool setup & form groups
2		**Feb 8** L03 Walkability, bikability and parking (Sevtsuk & Reinhart)	**Feb 10** L04 Urban Network Analysis (Sevtsuk & Reinhart)	**Feb 10** Urban Network Analysis + UMI walkability		**Ass 1** Project goals & Accessibility (Feb 17)
3		**Feb 15** L05 Daylighting, urban daylight calculations, view, value of daylight, outside glare	**Feb 17** L06 Jobs, rent and cash flow	**Feb 20** UMI daylighting module	Urban daylight; Value of daylight & view	**Ass 2** Daylighting & massing (Feb 24)
4		**Feb 22** No class, Monday schedule due to Presidents' Day	**Feb 24** L07 Outdoor Thermal Comfort (Mokhtar & Reinhart)	**Feb 24** UTCI script		**Ass 3** Outdoor comfort (Mar 3)
5		**Mar 1** L08 Building energy modeling: Methods, metrics and templates	**Mar 3** L09 Urban Building Energy Modeling I: Simulation approaches	**Mar 3** UMI energy module & template editing	BEM chapter 1; UBEM chapter	**Ass 4** Operational energy now and in 2025 (Mar 10)
6		**Mar 8** L10 Urban Building Energy Modeling II: Applications	**Mar 10** L11 Carbon reduction pathways for cities	**Mar 10** Template updates & carbon savings		
7		**Mar 15** L12 Materials and LCA + UMI embodied energy module	**Mar 17** Student Presentations I – Urban massing	**Mar 17** Presentations continued		
		Mar 21 – 25 MIT Spring Break				
8	Vision 2050	**Mar 29** L13 Climate change; future weather & morphing	**Mar 31** L14 Urban Heat Island (UHI) effect & urban weather generator	**Mar 31** Modified weather files	Morphing paper; UWG	**Ass 5** Resiliency (Apr 9)
9		**Apr 5** L15 Building integrated agriculture: Urban Footprints (Benis TBC)	**Apr 7** L16 Building integrated agriculture: UMI Harvest module (Benis TBC)	**Apr 9** UMI Harvest module (Benis + Reinhart)		**Ass 6** Urban food supply (Apr 16)
10		**Apr 12** L17 On site renewables, EV charging; Street lighting	**Apr 14** L18 Urban energy supply systems	**Apr 16** UMI district energy module		**Ass 7** District Energy (Apr 23)
11		**Apr 19** Individual meetings with groups	**Apr 21** Student Presentations II – Vision 2050	**Apr 23** Presentations continued		
12		**Apr 26** Workshop: Developing Umi plugins I (Rose TBC)	**Apr 28** Workshop: Developing UMI plugins II (Rose TBC)	**Apr 28** Workshop continued		**Ass 8** Independent project (May 10)
13		**May 3** Presenting urban datasets	**May 5** Student Presentations III	**May 7** Presentations continued		
14		**May 10** Post mortem & the future				