Syllabus Spring 2016 (01/10/2016)

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) F 11:00 -12:00, Room 1 -150 (Lab)
Instructors	**Christoph Reinhart**, Professor, Department of Architecture **Carlos Cerezo**, PhD Candidate, Department of Architecture TBA, Teaching Assistant
Prerequisites	4.401/4.464 or Permission of instructors Basic knowledge of Rhino / Grasshopper

Cerezo, Reinhart, Bemis (2015): Boston energy study.

"Our task is to house 1.5 billion new city dwellers in 15 years. That's a city of two million every week."

"This is a research course with the word 'research' being used not as in 'fact finding' but as in trying to do something that nobody has done before."

Course Description

The United Nations estimates that the number of city-dwellers worldwide will grow until 2030 at a net rate of about two million per week. In parallel, greenhouse gas emissions are at an all-time high. Unless we dramatically reduce current emission rates, we will experience an increase of more than 2°C in global mean temperature along with unmanageable sea level rises. In response to those global challenges, city governments world-wide have developed ambitious long-term GHG emission reduction targets such as 60% by 2025 (San Francisco) or 80% by 2050 (New York City and Boston). In addition, resiliency measures are being put in place to face extreme storm, flood and heat wave events, which largely affect urban decision making.

With buildings being responsible for 40% or more of most countries' GHG emissions, city planners and municipal governments worldwide are working on strategies for energy efficiency and more sustainable urban developments and redevelopments. Apart from being resource efficient, next-generation sustainable neighborhoods need to provide their residents with indoor and outdoor comfort conditions including access to daylight, feature high-quality public spaces and streetscapes as well as support human-powered transportation. How can architects, urban designers and planners account for these diverse issues in their proposals?

The primary focus of this subject is the study and simulation of energy and material flows in and around groups of buildings for a specific climate, and their impact on urban design and planning. Students will learn about emerging digital techniques for environmental simulations, and develop skills for their application in decision making. Such techniques will allow them to analyze, quantify and influence multiple environmental aspects of the built environment, including operational building energy use and carbon emissions, embodied energy use, access to daylight as well as walkability and outdoor comfort at the neighborhood scale. All metrics will be applied in specific design interventions with the investigated scales ranging from individual buildings to neighborhoods that include hundreds of buildings. Students will work in groups on sustainability concepts for three neighborhoods located in Boston, Lisbon and Kuwait City described at the end of this document.

A fundamental focus of the course, addressed throughout the semester, is the impact of the urban microclimates on the built environment. Students will learn to appreciate, as a main learning objective, that in dense urban settings buildings strongly interact with each other, thus creating microclimates that significantly alter their energy use and comfort from what it would be if they were placed sufficiently far away from each other. Microclimatic effects, which students will learn how to model, include shading from neighboring buildings, localized wind patterns, and urban overheating or "urban heat island effect". Furthermore, predicted climate change projections from the Intergovernmental Panel on Climate Change (IPCC) over the coming 70 years will be simulated as well, enabling students to evaluate their projects under current and future climate scenarios.

If you are an architect or planner and have sometimes wondered how to introduce energy efficiency, daylight access, and thermal comfort in your urban designs or planning proposals, this is the right course for you. It mainly is oriented to students who have already taken some class in building environmental technology (Such as 4.401, 4.464, 4.42J, 2.66J, 4.424J or 2.52J) and especially to those with interests and skills in urban design and planning. However, a basic introduction will be provided to most topics and ideally groups will have students with both technical and design skills, so the class is open to the whole institute. Prospective students who have not taken 4.401/4.464 should contact the instructors before the beginning of class and join us for the first lecture.

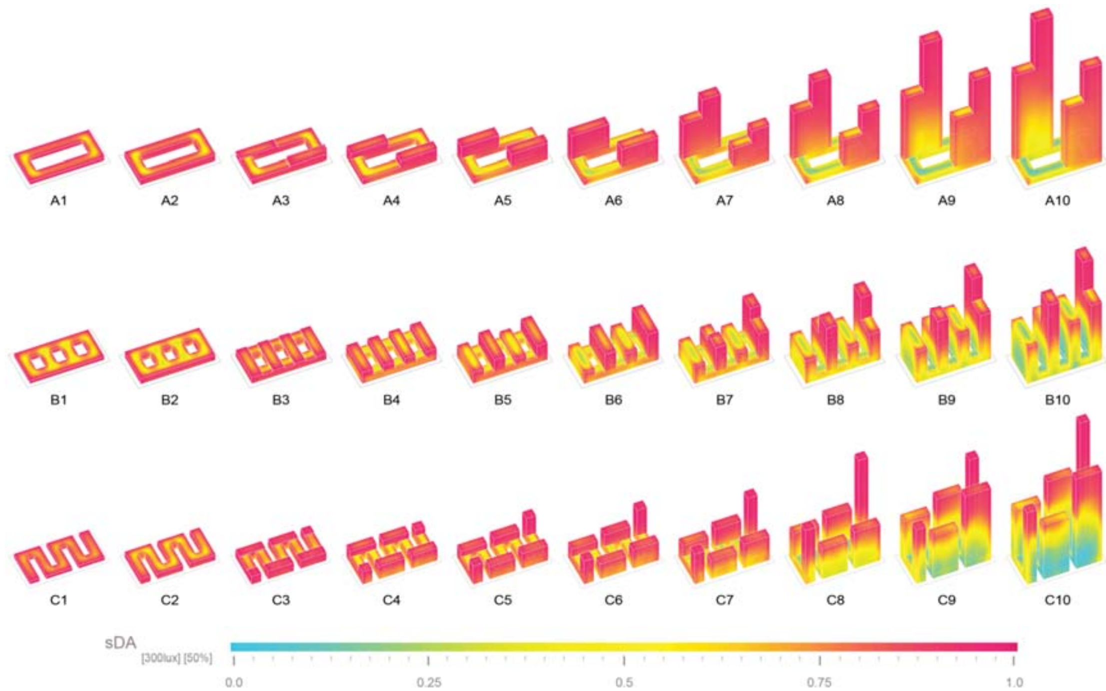
Learning Objectives

At the end of this course, students will have acquired the fundamental knowledge, skills and tools required to be able to:

- Understand the various physical effects that generate urban microclimates and their impact in the energy use, carbon emissions and thermal/luminous comfort in cities.
- Evaluate new and existing neighborhoods regarding key environmental performance indicators including energy consumption, material consumption, daylight hours, outdoor comfort and walkability/bikability indexes.
- Run computer simulations for such metrics, using 3D models generated in Rhinoceros using MIT's Urban Modeling Interface (http://urbanmodellinginterface.ning.com/).
- Explore and understand a series of design interventions to improve these performance indicators for a given neighborhood, and introduce these metrics into the design of urban planning spatial regulations and proposals.

Course Format

The class format will consist of two lectures, and a lab session every week. Work for the class will be divided into a series of homework assignments and a semester long group project. Assignments will further develop the content covered in class and give students the opportunity to apply it to small design problems.



Saratsis, Dogan, Reinhart (2015): Daylight density.

For the main urban planning and design project, students will work in groups of 3 to 4 on one of three ongoing neighborhood case studies in **Boston, Lisbon and Kuwait City**. Each case study area consists of around 2000 residential and commercial buildings and is linked to ongoing projects at the MIT Sustainable Design Lab. For each site, students will develop an **urban proposal for a mixed use new neighborhood**, informed by the techniques introduced in the class. A key task for all groups will be the use of these digital analysis methods to build a **convincing argument supported by quantifiable metrics** as to why a particular proposal deserves to be called 'sustainable'. The instructors will closely work with all student groups on defining overall project goals and specific deliverables. In addition each case study will have access to an expert student or "champion" currently researching the site. Example projects from previous cases can be found on the Sustainable Design Lab's web site (http://mit.edu/sustainabledesignlab/projects/UMIverse/UMIverse.html#). Some of the design questions you will be able to explore are:

- What urban building massing effectively takes advantage of (or avoids) solar radiation and how does that translate into electricity or gas saved per year?
- Which planning and design regulations will maximize access to daylight in buildings, and how does that impact energy spent on cooling loads?
- How do density and urban form affect outdoor comfort conditions at a site?
- Can MIT create a net zero energy community for our campus over the coming 30 years?
- Can Middle Eastern countries design neighborhoods that are resource efficient and walkable for most of the year?
- Will naturally ventilation still be an option for residential buildings in Lisbon in 50 years?

Course Requirements

Attendance and active participation in all lectures and labs is mandatory. Timely completion of a series of individual and group assignments to practice what has been covered in class 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, analysis techniques used, and comprehensiveness of the final design solution as well as overall quality of the work. Final presentations will have guest reviewers, recognized experts both within the US and abroad.

Assignment/Requirement	Due Date	Grade Weight
Active participation in class	-	15%
Ass 0 Tool setup / Pick a project	Feb 11	0%
Ass 1 Essay on project goals	Feb 18	5%
Ass 2 Block concept (Energy)	Mar 1	5%
Ass 3 Block concept (Daylight)	Mar 3	5%
First Presentation	Mar 10	15%
Ass 4 Thermal comfort	Mar 17	5%
Ass 5 Umi lifecycle	Apr 5	5%
Second Presentation	Apr 6	15%
Ass 6 Umi mobility	Apr 14	5%
Ass 7 Data visualization	Apr 21	0%
Final Review Presentation	May 6	25%

Software and Tools

Throughout the course, we will be using a Rhinoceros/Grasshopper-based urban modeling environment called ***umi*** (http://urbanmodellinginterface.ning.com/) that is currently under development by the Sustainable Design Lab at MIT as well as a series of compatible, third party Grasshopper components. The ***umi*** tool enables urban designers to model new and/or existing neighborhoods regarding operational energy, embodied energy, daylight, thermal comfort and walkability/bikability. Selected ***umi*** modules can be used in Grasshopper for parametric urban design analysis and optimization. Detailed software installation instructions and support will be provided in class and during labs, and 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 5.0 (http://www.rhino3d.com/)
- Grasshopper 3d (http://www.grasshopper3d.com/)
- UMI 2.0 beta (Will be provided via the course website)
- ArchSim (Will be provided via the course website)
- Diva for Rhino 3.0 (http://diva4rhino.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/.

Instructors Team

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References

[Will be provided during the first day of class]

Schedule Spring 2016 (01/10/2016)
4.433 Modeling Urban Energy Flows: Towards Sustainable Cities and Neighborhoods

WEEK	DATE	LECTURE TOPIC	ASSIGNMENT DUE*	READINGS
1 T	2 Feb	Introduction: Goals, modelling, project		[TBD]
R	4 Feb	Previous Projects (Tom, Julia, Dan, etc.)		
F	5 Feb	Lab1 Introduction to umi		
2 T	9 Feb	Energy use: Heat, targets, strategies, BEM	Ass 0 Tool Setup	[TBD]
R	11 Feb	Energy use: UBEM, archetypes, templates		
F	12 Feb	Lab 2 Umi energy and templates		
3 T	16 Feb	*NO CLASS (Presidents' Day)*	Ass 1 Project goals	[TBD]
R	18 Feb	Shading, radiation maps and PV		
F	19 Feb	Lab 3 Rooftop PV simulation		
4 T	23 Feb	Daylighting: Metrics, rules for massing	Ass 2 Block concept (energy)	[TBD]
R	25 Feb	Daylighting: Simulation, urban application		
F	26 Feb	Lab 4 Urban daylight		
5 T	1 Mar	Indoor thermal comfort, natural ventilation	Ass 3 Block concept (daylight)	[TBD]
R	3 Mar	Urban Heat Island (UHI) effect		
F	4 Mar	Lab 5 UWG + Natural ventilation		
6 T	8 Mar	Climate change: Future weather, morphing		[TBD]
R	10 mar	PRESENTATION 1: Block prototype		
F	11 Mar	Lab 6 Urban metrics discussion		
7 T	15 Mar	Outdoor comfort / Wind modelling (Norford)		[TBD]
R	17 Mar	Financing developments (Chegut)		
F	18 Mar	Lab 7 Outdoor comfort		
		Spring Break 2016		
8 T	29 Mar	Materials and LCA (Cerezo, Turan)	Ass 4 Comfort	[TBD]
R	31 Mar	Urban data / Urban energy supply (LL)		
F	1 Apr	Lab 8 Umi embodied energy and finance		
9 T	5 Apr	Urban guidelines (Cerezo)	Ass 5 Umi lifecycle	[TBD]
R	7 Apr	Walkable & bikable city		
F	8 Apr	Lab 9 Umi mobility		
10 T	12 Apr	Agent based modelling (Gonzales)		
R	14 Apr	PRESENTATION 2: Urban guidelines		
11 T	19 Apr	*NO CLASS (Patriots' Day)*		
R	21 Apr	Incorporating parking (Eran Ben Joseph)	Ass 6 Umi mobility	
12 T	26 Apr	Group meetings with instructors	Ass 7 Data visualization	
R	28 Apr	Data visualization (Strobelt)		
13 T	3 May	FINAL PRESENTATIONS		
R	5 May	FINAL PRESENTATIONS		
14 T	10 May	Post mortem		
R	12 May	FIELD TRIP (TBC)		

* Unless otherwise noted, Assignments are due on Stella before 9.30AM on Thursdays