
Spring 2011

Department: Architecture & Urban Planning and Design

Instructors: Christoph Reinhart
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Tarek Rakha (TA)

Time & Location: Tu & Th 11:30 - 13:00, 42 Kirkland Street Seminar Room G

Prerequisites: GSD6205 or instructor’s permission
Good working knowledge of Rhinoceros.
A newer laptop with Rhino V4.0 SR8 or higher*
Some grasshopper and Python scripting skills are desirable.

“In 2008, the world reached an invisible but momentous milestone: For the first time in history, more than half its human population [...] was living in urban areas. By 2030, this is expected to swell to almost 5 billion. Many of the new urbanites will be poor. Their future, the future of cities in developing countries, the future of humanity itself, all depend very much on decisions made now in preparation for this growth.”
United Nations Population Fund

“In the US, the building sector alone accounts for some 40% of the country’s carbon emissions.”
US Energy Information Administration

“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 ...”
The Instructors

Course Description

The primary focus of this course is the study of energy flows in and around groups of buildings. The investigated scales will range from individual buildings to urban 'proto blocks' (around twenty buildings) and complete neighborhoods that include hundreds of buildings. Students will learn about and practice the use of emerging digital techniques that allow them to analyze and influence building energy use as well as occupant health and comfort at these three scales through deliberate design interventions. An initial learning objective is for students to appreciate that in dense urban settings buildings strongly interact with each other and thus create urban microclimates that significantly alter their energy use from what it would be if they were placed sufficiently far away from each other. These microclimatic effects include shading of neighboring buildings, urban heat island effects and localized

* Throughout the course we will be using a series of Rhino plug-ins that only work with Rhinoceros V4.0 SR9 or higher.
wind patterns. Predicted climate change projections from the Intergovernmental Panel on Climate Change (IPCC) over the coming 90 years will be used in simulations, and student projects will be evaluated in current and future climate scenarios.

Throughout the course, students will work in groups on the design of a 'sustainable' mixed use urban neighborhood that makes effective use of the above mentioned physical effects to the benefit of residents and the environment. To this end, the course is organized into four phases.

During the first phase, students will learn how to model thermal/energy performance of individual buildings using the US-Department of Energy's EnergyPlus simulation engine combined with the DesignBuilder interface. During this first phase students will learn the basic assumptions underlying the simulation program and practice its use through a series of simulation exercises. Modeling concepts for naturally ventilated and air conditioned buildings will be covered. At the end of this phase all groups are expected to have developed base designs for a residential and commercial building that will later function as building blocks for an entire neighborhood.

During the second phase, students will learn how to translate these energy plus models into a Rhinoceros-based urban modeling platform that is currently under development at the GSD in collaboration with the School of Public Health and Penn State with funding from the National Science Foundation. The platform will allow students to automatically run energy simulations of urban scale massing models built in Rhino.

During phase three, students will learn about various attempts to model urban microclimatic effects. During this stage they will start to work with small urban proto blocks consisting of arrangements of about twenty of the base buildings that were developed during phase one. Students will be allowed to modify their base designs throughout the course. The purpose of the proto blocks is to break up the problem of designing urban neighborhoods into smaller entities of buildings so that different design variants can be quickly explored. At this stage the use of Grasshopper combined with the earlier mentioned Rhino plug-in may be useful but will be optional.

Finally, during phase four, we will be exploring complete neighborhoods including their boundaries to other neighborhoods. At this point the discussion will start focusing on what suitable criteria and techniques are to visualize the environmental performance of neighborhoods. The final course deliverable will be student presentations that make convincing arguments as to why the neighborhoods that they designed deserve to be called 'sustainable'.

The class format will consist of lectures, software tutorials and discussions. A series of homework assignments and group projects will further deepen the content of what has been covered in class. A number of guest speakers will be joining us throughout the term.

**Learning Objectives**

At the end of this course students will ...
- understand the various physical effects that generate urban microclimates,
- be able to estimate and or model the magnitude of these effects for their particular projects and
- have explored a series of design interventions to reduce energy use and improve occupant comfort in dense urban settings.
<table>
<thead>
<tr>
<th>Week</th>
<th>Tuesday Lecture (11.30 – 13.00, 42 Kirkland G)</th>
<th>Thursday Lecture (11.30 – 13.00, 2 Kirkland G)</th>
<th>Reading/Event</th>
<th>Assignment (always due the following Thursday at 11.30)</th>
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<tbody>
<tr>
<td>1</td>
<td>1 Sep: Introduction to thermal modeling, goal setting and student projects</td>
<td>Reading: Original E+ paper</td>
<td>Ass 1: Work through ‘Getting Started with DesignBuilder EnergyPlus’</td>
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<td>2</td>
<td>2 Sep: Manual Methods, peak load calculations</td>
<td>3 Sep: Natural ventilation and benchmarking</td>
<td>Sept 15/16 GSD conference: A Roadmap to Sustainable Infrastructure</td>
<td>Ass 3: Work through ‘Construction Assemblies, Load Reduction &amp; Shading’</td>
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<td>3</td>
<td>4 Sep: Simulation Strategies</td>
<td>5 Sep: Student Presentations – Prototype Buildings</td>
<td>Sep 20: GSD Lecture: Transportation Futures</td>
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<td>4</td>
<td>6 Sep: DesignBuilder/ EnergyPlus, the “four ugles”</td>
<td>7 Sep: Building Simulation Game</td>
<td>Averaging schedules, IDF file editor -&gt; Rhino; setting up an E+ simulation in Rhino</td>
<td>Ass 4: Compare prototype results in DB and Rhino</td>
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<td>6</td>
<td>10 Oct: Modeling Urban Heat Island Effect</td>
<td>11 Oct: Climate Change and Health (Spengler School of Public Health)</td>
<td>Ass 6: Design study - Windows and shading</td>
<td>Ass 7: Climate Change and the proto block</td>
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<td>7</td>
<td>12 Oct: Morphing and Future Climate Files</td>
<td>13 Oct: Urban Wind Analysis (Les Norford MIT)</td>
<td>Student Presentations – Proto Block Design</td>
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<td>8</td>
<td>14 Nov: Data Visualization (Pfister Engineering and Applied Sciences)</td>
<td>15 Nov: Transportation: Predicting Traffic Use Urban Transportation: Zofnass Street Emission Calculator</td>
<td>Nov 3: Walk score ratings</td>
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<td>10</td>
<td>18 Nov: CR, AJ &amp; DI traveling (no class)</td>
<td>19 Nov: Modeling PV and solar hot water</td>
<td>Nov 24: Thanksgiving (no class)</td>
<td>Reading: PV in E+ paper</td>
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<td>11</td>
<td>20 Nov: Solar potential study for the City of Cambridge</td>
<td>21 Dec: A vision for urban modeling</td>
<td>Dec 1: Urban Energy Modeling (Robinson, University of Nottingham)</td>
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<td>12</td>
<td>22 Dec: Project Presentations</td>
<td>23 Dec:</td>
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**Course Requirements**

Attendance of and active participation in all lectures and workshops is mandatory. More than two unexcused absences will lead to a failing grade. Timely completion of a series of individual and group assignments to practice what has been covered in class. All assignments have to be submitted online and in time, usually on Wednesday evening. Students are expected to prepare three group presentations on:
- 2 Prototype Buildings (Sep 22)
- 3 Proto-Block Designs (Oct 27) and
- 3 Sustainable Neighbourhood Concepts (some time in Dec).

**Methods of Assessment**

Grades will be determined based on the quality of the completed assignments (49%), class participation (11%) and the three group presentations (40%). The presentations will be graded based on the:
- clarity of the project’s design objectives,
- originality and inner logic of the design techniques used,
- comprehensiveness of the final design solution,
- overall quality of the presentation.

**Software**

Detailed software installation instructions and support will be provided in class.

- Rhinoceros 4.0 SR9 or higher
- DesignBuilder Software version 2.4 (can be downloaded from the icourse web site and is installed in the 5th floor computer lab).
- EnergyPlus version 6.0 (can be downloaded from the icourse website)
- Diva for Rhino 2.0 (can be downloaded from the icourse website)

**Bibliography**

- Robinson D, Computer Modelling for Sustainable Urban Design, Earthscan, 2011 ([www.earthscan.co.uk/?TabId=102499&v=512641](http://www.earthscan.co.uk/?TabId=102499&v=512641))