4.432/433 People, Planet, Property: How to drive climate action in buildings worldwide

Department	School of Architecture and Planning (Course 4)
Time / Location	TR 9:30 - 11:00, Room 2-139 (Lecture + Lab)
Instructors	Christoph Reinhart, Professor, Architecture (tito@mit.edu) Nada Tarkhan, Architecture (ntarkhan@mit.edu)
Teaching Assistant	Sam Wolk (szvsw@mit.edu)
Prerequisites	Previous exposure to building technology, design and/or urban planning is desirable but optional.

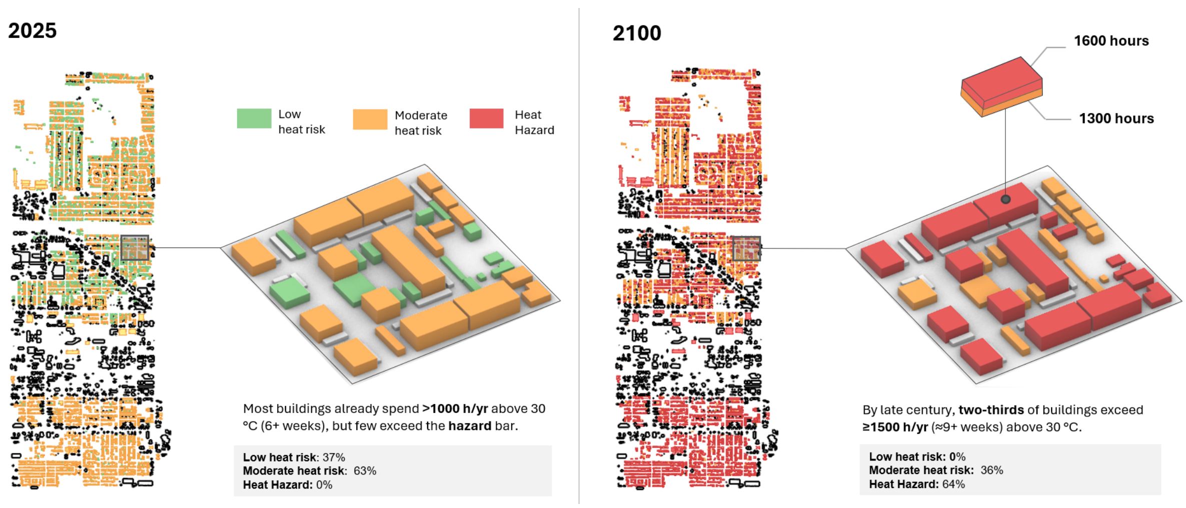

Fig 1: Overheating propensity map for a zip code in Phoenix, AZ, showing heat exposure in 2025 vs. 2100

Given their outsized contribution to anthropogenic greenhouse gas emissions and unique ability to provide shelter to occupants, buildings are a key lever for both climate mitigation and adaptation. As weather events become more extreme, many buildings will fail to protect human health and provide economic security, causing an estimated 14.5 million premature deaths and US$12.5 trillion in losses by 2050. While the stakes could not be higher, we have surprisingly limited *climate-actionable* information on individual buildings worldwide. Within the context of this class, climate-actionable information cover three topic areas: The ability of a building to protect its occupants' health during extreme heat waves or cold spells, its potential to be upgraded to reduce operations-related carbon emissions and costs and its capacity to contribute to owners' and occupants' long-term livelihood.

This hands-on survey course teaches students how to derive this information for thousands of existing and new buildings across multiple case study regions, formulate long-term health, environmental and economic policy goals and work with local policymakers on realistic implementation strategies. Students will be working in small teams on one of several case study regions for which local stakeholders and required urban data sets have already been secured. We are open to also consider other regions which meet these requirements.

Starting at the scale of individual households, students will learn how to use physics-based *building energy models* (BEM) to evaluate the performance of individual apartments along our three criteria with a specific focus on evaluating occupant indoor health. This Initial analysis will be conducted via the ClimateStudio environmental analysis plugin for Rhinoceros 3D using both current and future climates. Once 'as is' conditions for a typical apartment in a case study region have been determined, we will explore upgrade packages ranging from wearables to apartment, building and neighborhood-level interventions. Example strategies include painting rooftops white, combining rooftop photovoltaics with low-energy active cooling systems and adding vegetation and shading. For carbon reduction strategies, investigated upgrades measures may range from added insulation to electrifying heating and rooftop photovoltaics.

During the next phase of the class, we will scale the analysis to a full census tract (~1000 buildings) within each study region. To do so, students will learn about the evolving science of bottom-up building stock or *urban building energy modeling* (UBEM). We will cover a variety of UBEM use cases spanning policymaking, portfolio owner advice and building grid interactions. Using MIT's new Global Building Inventory (GloBI) suite of simulations tools, students will explore how a stock-level wide adoption of the earlier developed upgrade packages would impact their study area. These findings will be shared during the mid-term presentations.

After spring break, we will switch from a technical potential analysis to also address socioeconomic barriers to upgrade implementation. To understand which households may be willing to upgrade their homes and when, we will use occupant demographics-based willingness-to-pay and technology adoption models. The models will be used to test different incentive structures and align long-term impact predictions with policy goals. We will complement these modeling efforts with focused discussions on environmental justice and policies that demonstrably help vulnerable populations to improve their living conditions. We will also address the necessity to train a green workforce to continuously balance labor supply with demand.

During the third course section, we will explore simulation uncertainty and the emergence of potential tipping points, i.e. moments when a region crosses from manageable conditions into regimes where current climatization strategies will no longer keep residents safe. These explorations will lead us to the evolving concept of climate frontiers and trigger debates on how to deal with multiple plausible futures. For this part of the class, we will be using MIT's new *Heat-alert* Grasshopper plugin. *Heat-alert* empowers students to identify impending risk thresholds (for example, overheating propensity levels that meaningfully change resident exposure) and to communicate how soon a place may reach their tipping point.

Finally, the course will close the loop between academic work and governance by bringing in regional stakeholders to vet suggested upgrade policies. These stakeholders will clarify what outcomes matter to them, what tradeoffs are acceptable, and what kind of evidence moves decisionmakers.

About the class

Given the rapid proliferation of building stock modeling in recent years, the scope and focus of this version of the class have significantly changed. Nevertheless, 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 instructors 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:

- Assess the ability of any building to protect its occupants' long-term health, potential to reduce its carbon emissions and costs and its capacity to contribute to resident livelihood,
- develop economically and environmentally viable upgrade strategies,
- scale their strategies to the neighborhood or regional level,
- consider resident demographics to evaluate when and where suggested upgrades might realistically happen and
- propose a set of policies to meet equity, emission and prosperity targets for a region.

Course Format

The class format will consist of two weekly 90-minute lectures with a lab component on most Thursdays. Work for the class will be divided into a series of homework assignments that successively build up to an overall policy concept for buildings in that region. A key task for all groups will be the use of digital analysis methods to build a convincing argument as to why a particular policy has potential. The instructors and select members of the Sustainable Design Lab will work closely with all student groups on defining overall project goals and specific deliverables.

Course Requirements

Attendance and active participation in all lectures 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 Climate analysis and visualization	Feb 19	5%
Ass 2 Project goals and metrics	Feb 26	5%
Ass 3 Revised metrics and results to stakeholders	Mar 5	10%
Ass 4 Identify archetypes + upgrade packages	Mar 12	5%
1st Presentation Midterm Presentation	Mar 19	20%
Ass 5 Prepare epengine format and runs	Mar 19	5%
Ass 6 Share presentation with your stakeholder	Apr 2	5%
Ass 7 Analyze upgrade potential	Apr 9	5%
Ass 8 Generate overheating propensity map	Apr 16	5%
Ass 9 Prepare dry run slides	Apr 30	5%
2nd Presentation- Final Presentation to Stakeholders	May 7	20%

Software and Tools

Throughout the course, we will be using a Rhinoceros/Grasshopper-based environmental analysis software ClimateStudio for building level analytics, GloBI tools for stock level analytics and heat-alert to explore multiple climate futures. 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.

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, Room 2-139	Thursday Lecture for 4.432/4.433 9.30 – 11.00, Room 2-139	Reading/Resources	Assignment (due date)
1	Generate building data	**Feb 3** L01 Course introduction People, Planet, Property	**Feb 5** L02 Project introduction and software overview (Ahmedabad, Everett, Phoenix, Seattle)	ClimateStudio installer	**Ass 0** Form groups and install course software (Feb 12)
2		**Feb 10** L03 Climate futures I: Weather files and urban heat island	**Feb 12** L04 Climate futures II: Climate emulators; Lab on climate analysis and data visualization (P Giani MIT-EAPS)	Papers RMY + FRMY (Tarkhan); *Colab notebook with RMY + UWG + FRMY*	**Ass 1** Climate analysis and visualization (Feb 19)
3		**Feb 17** No class, Monday schedule due to Presidents' Day	**Feb 19** L05 Modeling overheating risk: Fundamentals and simulation approaches		**Ass 2** Project goals and metrics; Baseline residential model + upgrades in ClimateStudio (Mar 5)
4		**Feb 24** L06 Overheating as a public health concern; Critical cooling as a human right (T. Giannini Harvard Law)	**Feb 26** L07 Climate extremes and economic impact; Lab on sourcing GIS data	Paper: Critical cooling (Tarkhan); *Colab notebook- set up data for Case Study*	
5		**Mar 3** L08 Urban Building Energy Modeling I: Fundamentals	**Mar 5** Lab: Introduction to GloBI Toolkits	Papers: UBEM overview and Auto-calibration	**Ass 3** Prepare GloBI input files (Mar 10)
6		**Mar 10** L10 Urban Building Energy Modeling II: Applications + SBEM	**Mar 12** L09 Urban Building Energy Modeling III: Model calibration; Lab: Launch your GloBI project	Papers: UBEM Applications, UBEM 8 cities and SBEM	
7		**Mar 17** L12 Heat Resiliency; Lab on GloBI results analysis (CR on juror duty)	**Mar 19** Midterm presentations – Project goals and technical potential of suggested building upgrades		**Ass 4** Implement review feedback and share presentation with your stakeholder (Apr 2)
		Mar 23 – 27 MIT Spring Break			
8	Drive Action	**Mar 31** L13 Environmental justice and incentive policies (M. Arcaya)	**Apr 2** L14 Willingness-to-pay and + technology adoption models; Lab on modeling technology uptake	Paper: Willingness-to-pay and Notions of fairness (de Simone); *Colab notebook Willingness to pay*	**Ass 5** Analyze likelihood of upgrade adoption (Apr 9)
9		**Apr 7** L15 Navigating uncertainty from climate predictions	**Apr 9** Lab: Climate frontiers exercise	Heat-Alert Grasshopper plugin	**Ass 8** Generate overheating propensity map for your site (Apr 16)
10		**Apr 14** Gensler climate advisors (Mallory Taub TBC)	**Apr 16** Desk crits		
11		**Apr 21** Climate Walk at Mount Auburn Cemetery (A. Chokhachian)	**Apr 23** Outdoor comfort analytics (A. Chokhachian)		**Ass 9:** Prepare dry run slides (Apr 30)
12		**Apr 28** Case Study/ Guest lecture (TBD MA)	**Apr 30** Dry run presentations		
13		**May 5** Desk crits	**May 7** Final class presentation with stakeholders		
14		**May 12** Postmortem			