4.s42 Carbon Reduction Pathways for the MIT Campus

Department	School of Architecture and Planning (Course 4)
Time / Location	R 9:00 – 12:00 lecture in 26-142
Instructor	Christoph Reinhart, Professor, Architecture (tito@mit.edu)
Teaching Team	TA Kiley Feickert, PhD Candidate, Architecture (feickert@mit.edu)
Prerequisites	Permission of instructor

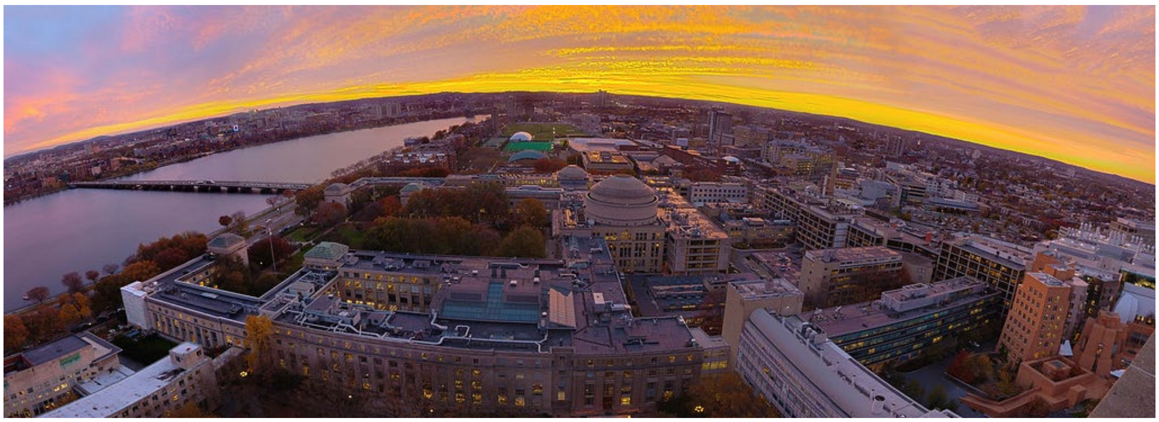

Figure 1: MIT's campus consists of 190 buildings including 5,551 labs and1,329 classrooms spread over 168 acres.

Context

Members of the MIT community have long worked on a broad set of technical, economic and policy solutions to address the climate crisis. Still, the urgency to do more reverberates across campus and – as our *Fast Forward: Climate Action Plan for the Decade* affirms – "we must go as far as we can, as fast as we can, with the tools and methods we have *now*."[1] In addition to a wide ranging list of research, educational and outreach initiatives, the plan states that MIT aims "to eliminate all direct campus emissions by 2050, recognizing that making this happen will depend on significant advances in carbon-reducing technologies and a decarbonized electrical grid in New England." Practically, this goal necessitates that the use of *all* fossil fuels to operate our campus buildings and vehicles – with the exception of some very limited local carbon capture offsets[2] – must be ended.

This research seminar will contribute to the effort of MIT's *Campus Decarbonization Working Group* to develop a technology roadmap for the campus. Specifically, we will develop an integrated decarbonization analysis framework to evaluate technoeconomic pathways towards a net zero campus by 2050. Starting with

[1] Fast Forward: MIT's Climate Action Plan for the Decade A commitment to leadership in solving the climate crisis May 2021 https://climate.mit.edu/sites/default/files/2021-05/FastFoward-ClimateActionPlan_3.pdf

[2] In this context "local" means that these offsets need to be realized within the Boston Metropolitan Area.

Figure 2: The lion's share of or electricity and space-conditioning needs is met by MIT's Central Utility Plant on Vassar Street (Photo: B Babakinejad)

the status quo, we will explore the potential impact of ten interventions to our campus including technology implementations, evolving energy policies and electric grid supply changes throughout New England. Some of these technologies exist today, others may become available over the coming decades. The ten interventions are:

- Building retrofits
- Low temperature district systems with electrified heating and onsite renewables
- High-resolution building controls
- Energy-efficient labs
- Financial and reputational risk of inaction
- Future New England electric grid emissions and capacity forecast
- Deep geothermal
- Micro-reactors
- Energy storage including electric vehicles
- Local carbon capture

Course Description

This hands-on course will be joined by students and researchers from across MIT with technical expertise in the above listed topics. A series of introductory lectures from subject matter experts will introduce the different interventions including technical maturity, ease of implementation over time, costs and how to model their impact on campus. Seminar participants will collaborate on a set of key performance indicators (KPIs)[3] and develop an integrated modeling framework that includes all ten interventions (Figure 3)[4]. We will then break up into ten groups, each of which will evaluate one

[3] A preliminary list is provided at the end of this document.
[4] S, J Hanson, C Reinhart, 2019, A framework for using calibrated campus-wide building energy models for continuous planning and greenhouse gas emissions reduction tracking, *Applied Energy*, 241, pp. 82-97

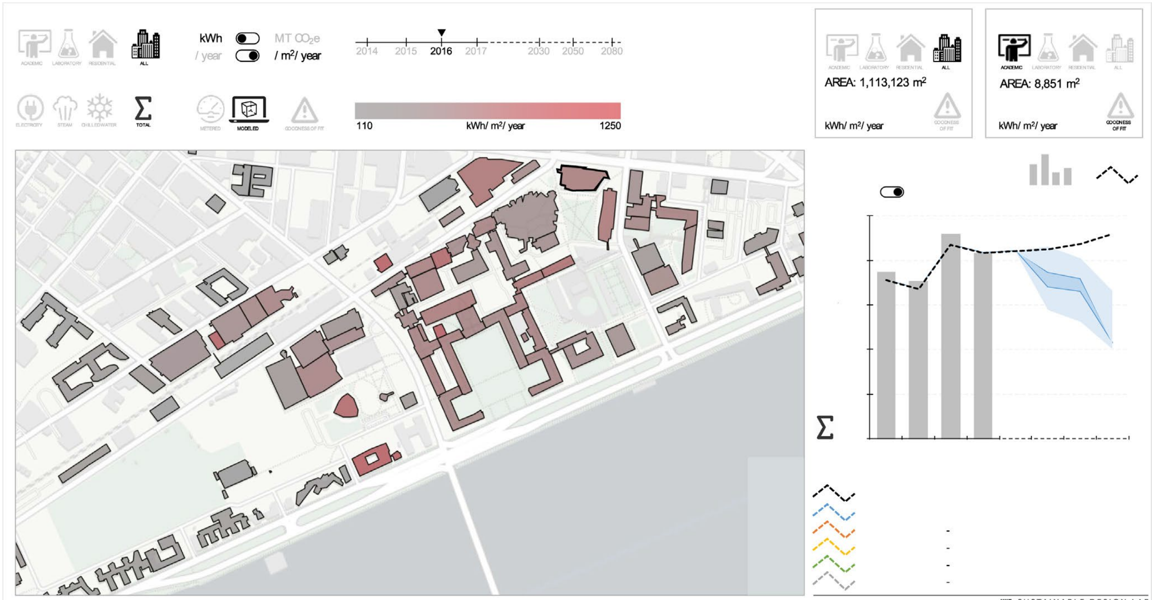

Figure 3: Screenshot of user interface mock-up showing the campus overview (left), and building specific trends (right)

intervention according to these KPIs. Throughout the term, these groups will work towards an expert review on May 2 and an executive summary on May 9. During the former, students will present their technology evaluation to a group of experts and discuss their findings. For the latter, the group will present a high level summary of their findings including recommendations to MIT leadership and members of the Climate Nucleus. The educational goal is to practice presenting technical findings in a manner that is accessible to a general audience.

Learning Objectives

- Learn how to holistically evaluate a set of interrelated technology strategies
- Experience how to effectively work in a multidisciplinary team
- Practice how to present research results to different groups of stakeholders

Course Format

Seminar participants will meet once a week for a three-hour session. Sessions will consist of technical background lectures; case studies of how other universities aim to decarbonize their campuses and lab sessions. Work for the seminar will consist of implementing an intervention model within a larger simulation, documenting assumptions, developing an implementation strategy, presenting findings, and providing recommendations.

Course Requirements

Attendance and active participation in weekly sessions and group work.

Assignment/Requirement	Due Date
Active participation in class	-
Ass 1 Technology evaluation plan (one pager)	Feb 29
Ass 2 Presentation of the evaluation plan	Mar 7
Ass 3 Technology model overview (one pager)	Mar 21
Ass 4 Presentation Initial results	Apr 11
Ass 5 Draft Technology report	Apr 18
Ass 6 Expert review	May 2
Ass 7 Executive summary presentation	May 9
Ass 8 Technology evaluation report (5 pager)	May 17

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/.

Week	Date	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	Assignment
1	Feb 8	**Lecture** Course introduction; A decarbonization strategy for MIT						**Lab** Develop evaluation framework and KPIs; form groups						
2	Feb 15	Stand up	**Lecture** Future New England electric grid emissions and capacity forecast (Andy Sun Sloan)				**Lab** Modeling workshop							
3	Feb 22	Stand up	Visit Campus Utility Plant (J Sepich)							**Lecture** What is MIT doing? (J Newman & J Higgins Facilities)				
4	Feb 29	Stand up	Buildings Retrofits				Lab: MIT Campus UBEM & on-site renewables							**Ass 1** Technology evaluation plan (1 pager)
5	Mar 7	**Lecture** High resolution building controls (J Paradiso Media Lab, L Norford Architecture)					1st Review (Critic T Auer TU Munich)							**Ass 2** Presentation Technology evaluation plan
6	Mar 14	Stand up	**Lecture** Financial and reputational risk of inaction (S Zheng Real Estate)				**Lecture** Energy Efficient Labs (B Olsen Chemical Engineering)				Case study Harvard (Henriksen TBD)			
7	Mar 21	Stand up	**Lecture** Low temperature district systems with electrified heating (P Martinez MITEI)				**Lab** Data visualization (N Tarkhan Architecture)				Case study Middlebury (Z Berzolla TBD)			**Ass 3** Technology model overview (1 pager)
8	Mar 28	Spring break												
9	Apr 4	Stand up	**Lecture** Deep geothermal (D White Nuclear)				**Lab** Modeling workshop				Case study Cornell (TBD)			
10	Apr 11	Stand up	**Lecture** Micro-reactors (J Buongiorno Nuclear)				2nd Review (Critic M Schuler Transsolar)							**Ass 4** Presentation Initial results and assumptions
11	Apr 18	Stand up	**Lecture** Energy storage incl. EV (F Angizeh Trancik Lab IDSS)				**Lab** Modeling workshop				Case study Berkeley (TBD)			**Ass 5** Draft Technology report
12	Apr 25	Stand up	**Lecture** Local Carbon Capture (B Galant MechE)				**Lab** Modeling workshop				Case study Stanford (TBD)			
13	May 2	Presentation to Decarbonization staff and research leads												**Ass 6** Expert review
14	May 9	Presentation to leadership (MIT Nucleus)								Post-mortem meeting				**Ass 7** Executive summary presentation
	May 17													**Ass 8** Technology report (5 pager)

Preliminary Key Performance Indicators

We will evaluate all above-mentioned technologies based on a version of the following criteria which were developed by MIT Campus Decarbonization Working Group.

Feasibility

- ❑ Provides the campus with a safe system for the operators and community.
- ❑ Compliant with local, state, and federal laws and regulations.
- ❑ Comports with Institute resource commitments (staff time, funding, communications, etc.).
- ❑ Provides infrastructure modernization and renewal.
- ❑ The technology is acceptable to the MIT community.
- ❑ The technology is acceptable to neighboring communities.
- ❑ The technology has no known negative knock-on effects.

Technical compatibility

- ❑ Preserves future flexibility for emerging or near-term solutions.
- ❑ Generation equipment is capable of integrating within the existing distribution network or new distribution network, and existing electrical system but require minor modification of the building MEP infrastructure.
- ❑ During implementation of a pathway, the individual system can be part of the phased solution and allow continuous campus operation.
- ❑ System technologies will help decarbonize campus and are consistent with the anticipated decarbonization of the MA and/or ISO NE Grid, based on current state regulations.

Relevance

- ❑ Has the potential to reduce campus emissions in significant ways
- ❑ Mitigates the utility-system associated effects of climate change on campus.
- ❑ Life cycle costs of technology are favorable with respect to low-carbon alternatives, independently, or when combined with overall pathway strategies.
- ❑ The technology is socially acceptable to society.
- ❑ The technology can be widely adopted if proven successful at MIT.
- ❑ Even if not today, the technology has the potential to become financially sustainable over time.
- ❑ The technology complements existing policies.
- ❑ The technology has environmental or financial co-benefits to neighboring communities.

Risk assessment/Resiliency

- ❑ Ensures that delivered heating, cooling, and power is at least as reliable as the current N+1 firm heating, cooling, and power capacity.
- ❑ Data for analysis, implementation, and LCCA are known current day.
- ❑ The potential environmental and financial rewards to technical risk ratio for MIT to adopt this technology is high.