Cities WITHOUT

Modeling Zero-Carbon Cities (Kendall Square as a Case Study)

A City Science Workshop (MAS 552 / 4.557)

Instructors: Kent Larson & Luis Alonso (with City Science Researchers & Guest Lecturers)

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Time: Wednesdays 2-5pm (1st class meets on September 8)

Location: Silverman Room, 6th Floor, MIT Media Lab, E14 SS-648

Summary: This workshop will be a rapid-fire, high-level exploration of how to model urban interventions that could enable low-carbon (ultimately zero-carbon) cities, using the MIT-Kendall Square district as the case study. We will focus on two questions:

- What would be required for MIT-Kendall Square to achieve zero-carbon in 20 years?
- Can social performance be simultaneously increased to create a model entrepreneurship community?

Motivation: Climate change presents an existential threat to human civilization, and the IPCC report of August 2021 sounds "a death knell for coal and fossil fuels before they destroy our planet." With cities generating more than 70% of current global CO_2 emissions, and with 90% of future population growth occurring in urban areas, it is a societal imperative that cities rapidly transition to a low-carbon future.

Assumptions: (for the purpose of the workshop)

- Solutions are unconstrained by zoning regulations, legacy systems, and current development plans.
- We can anticipate the successful commercialization of selected technology.

Prerequisites: Permission of Instructor, Units (3-0-9), Fall 2021

Objective: To explore key challenges and opportunities related to:

- **Current Performance:** calculating the environmental and social performance of the district, with an emphasis on CO_2 emissions of people who live and work in the district.
- **Urban Interventions:** modeling the impact of interventions that may dramatically reduce energy consumption and CO_2 emissions.
- **Renewable Energy:** modeling the deployment of non-fossil fuel energy sources from solar to future fusion
- **Urban Performance:** estimating the resulting impact of proposed solutions on the environmental and social performance of the district.

Experience: Students will gain hands-on experience with the collection and analysis of data, basic python scripts, and simulation tools. Students will have an opportunity to evaluate the potential of a range of current and emerging urban interventions in order to establish priorities for bottom-up action by cities and their communities.

Enrollment: This class seeks highly motivated students with a background in data analytics, engineering, architecture, urban planning, public policy, business, and entrepreneurship. Programming experience is useful but not required (small-team assignments may pair, for example, a designer with a programmer).

Structure: Typically, each 3-hour session will begin with a 30 to 45-minute lecture plus Q&A. Students will then be given a 2-hour in-class assignment, with results documented on the class website and/or GitHub.

Final Project: Students will select a module to develop that could later be integrated into an urban simulation platform such as CityScope. See:
https://cityscope.media.mit.edu/
https://www.media.mit.edu/projects/cityscope/overview/

Weekly Schedule

Week 1 (9/08) - Hyper-LOCAL solutions to GLOBAL problems

Class introduction: Kent Larson
Class overview:

- Summary of goals and the material that will be explored in the class
- Syllabus
- Class methodology
- Sources and materials

Students and class mentor introductions
Q&A

Week 2 (9/15) - Learning from Masdar City
Lecture: Anthony Mallows, Architect and former Executive Director of Masdar City.
Masdar City, designed by Foster and Partners in 2007-2008, was to be the world's first zero-carbon city for life beyond oil. The city was designed to encourage walking and to operate without fossil-fueled vehicles at street level. The land surrounding the city was to contain wind and photovoltaic farms, research fields and plantations, allowing the community to be entirely energy self-sufficient. But the city was never built as planned. Which of the goals and strategies are still relevant today? What can we learn from this ambitious project? How has design and technology progressed in the past 15 years?

Tutorial: Ronan Doorley
Introduction to data analytics and python scripting, establishing the boundaries of the district, and an overview of a process to evaluate social and environmental performance.

Assignment: Begin the analysis of Kendall Square using the tools presented in the tutorial.

Week 3 (9/22) - Mobility without Cars (or net-zero commuting and ultra-lightweight community-scale autonomous mobility)
Lecture: Alex Berke
Making use of the MIT Transportation Survey, the National Household Travel Survey, and other datasets to understand commuting and live-work patterns.

Lecture: Naroa Sanchez
Developing new community scale mobility modes and simulating their impact.

Assignment: Using the resources identified, students will approximate transportation-related emissions and approximate the impact of new mobility modes.

Week 4 (9/29) - Harmony without Zoning (or dynamic systems to encourage low-carbon development)

Lecture: Kent Larson
Dynamic algorithmic zoning to create incentives for property owners, real estate developers, and infrastructure companies to deploy pro-social, low-carbon solutions.

Lecture: Markus ElKatsha
ESG Metrics and live-work symmetry / local access to resources.

Assignment: Using the resources identified, approximate CO_2 reductions from new approaches to urban planning and land use regulations and a reduction of commuting and the use of mechanized mobility.

Week 5 (10/06) – City Science Summit
Students will participate in at least one online workshop. See the agenda at:
https://citysciencenetwork.org/

Week 6 (10/13) - Housing WITHOUT Rooms (or high-performance building and hyper-efficient transformable architecture)
Lecture: Luis Alonso & Markus ElKatsha
How high-performance buildings can reduce CO_2 emissions, including the retrofit of existing buildings. New model for housing with the following components:

- Dynamically Transformable Apartments: Using architectural robotics to enable ½ the space of conventional apartments to function as if 2X larger – resulting in +/- ½ of the embodied energy and electric energy for cooling, appliances, lighting etc. per person.
- Diverse Housing: Modular design to optimize apartments for a diverse population: students, young professionals, families, mid-career, independent elderly, and assisted living.
- Carbon-positive Chassis. Deploying cross-laminated timber (CLT) building structures and other possibilities.
- Modeling and Simulation: How to estimate the impact of increased diversity and density of the residential population and the innovation potential of the community.

Assignment: Using resources provided, students will be challenged to approximate:

- C02 emissions from buildings
- Reduction of emissions from the retrofit of existing buildings
- Reduction of emissions from compact high-performance apartments (per capita)

Week 7 (10/20) Power WITHOUT Carbon: Solar (or distributed community and building-scale photovoltaic electricity)
Lecture: Luis Alonso
Solar energy is an important component of a zero-carbon future, but the potential to produce electricity within the district is limited to the area it can be deployed and the solar energy reaching these surfaces.

Assignment: Approximate the maximum percentage of energy demand that could be produced from photovoltaics within the case study district.

Week 8 (10/27) Power WITHOUT Carbon: High Density (or distributed community-scale zero-carbon power)
Lecture: Guadaloupe Babio
High density cities will require high density baseload power. We will survey existing and emerging high-density power sources including natural gas with carbon capture, small and micro modular fission reactors, and fission reactors that may be commercialized within the next 15 to 25 years.

Assignment: Analyze the required land, energy output, estimated cost, and pros/cons of high-density power sources.

Week 9 (11/3) Cities WITHOUT Infrastructure (or transitioning from centralized Infrastructure to lightweight distributed systems)
Cambridge has a good centralized infrastructure, but many cities – particularly in the developing world – do not. This session will look at emerging technology for:

- Food WITHOUT Soil. Food production near the point of consumption using industrial-scale hydroponics and aeroponics.
- Water WITHOUT Pipes. Water purification, at the community or building scale.
- Sanitation WITHOUT Sewers. Sanitation at the scale of the community, building, and toilet.

Lecture: Luis Alonso and Maitane Iruretagoyena

Assignment: Using the resources identified, students will approximate CO_2 reductions from local production of resources and their potential for both developed and developing nations.

Week 10 (11/10) Social Performance
Lecture: Ronan Doorley and Cristian Jara Figueroa
How to quantify the current social performance (innovation potential, health and wellness, safety and security, resilience) and how to estimate the impact of proposed interventions

Tutorial: How to build a full python module for CityScope using BRIX: Ronan Doorley and Cristian Jara Figueroa

Assignment: identify a module to develop for the final project and outline the functionality of the module and the process for implementation.

Week 11 (11/17) Presentation of Module Proposal
Students will make a 5-minute presentation to propose an analysis or simulation model to develop for their final project.

Assignment: Students will focus on the development of their module with help from the class mentors.

Week 12 (11/24) CityScope Overview
Lecture: Ariel Noyman
The open source CityScope platform will be presented including the frontend, online and tangible interfaces, current simulations modules, and the backend.

Assignment: continue to develop the module with guidance and input from the class mentors.

Week 13 (12/1) Module Development
Assignment: continue to develop the module with guidance and input from the class mentors, and document all work on the class GitHub.

Week 14 (12/8) Final Presentation
Presentation of final projects accompanied by a 2 to 3-page paper.