MIT researchers create citywide building energy model for Boston

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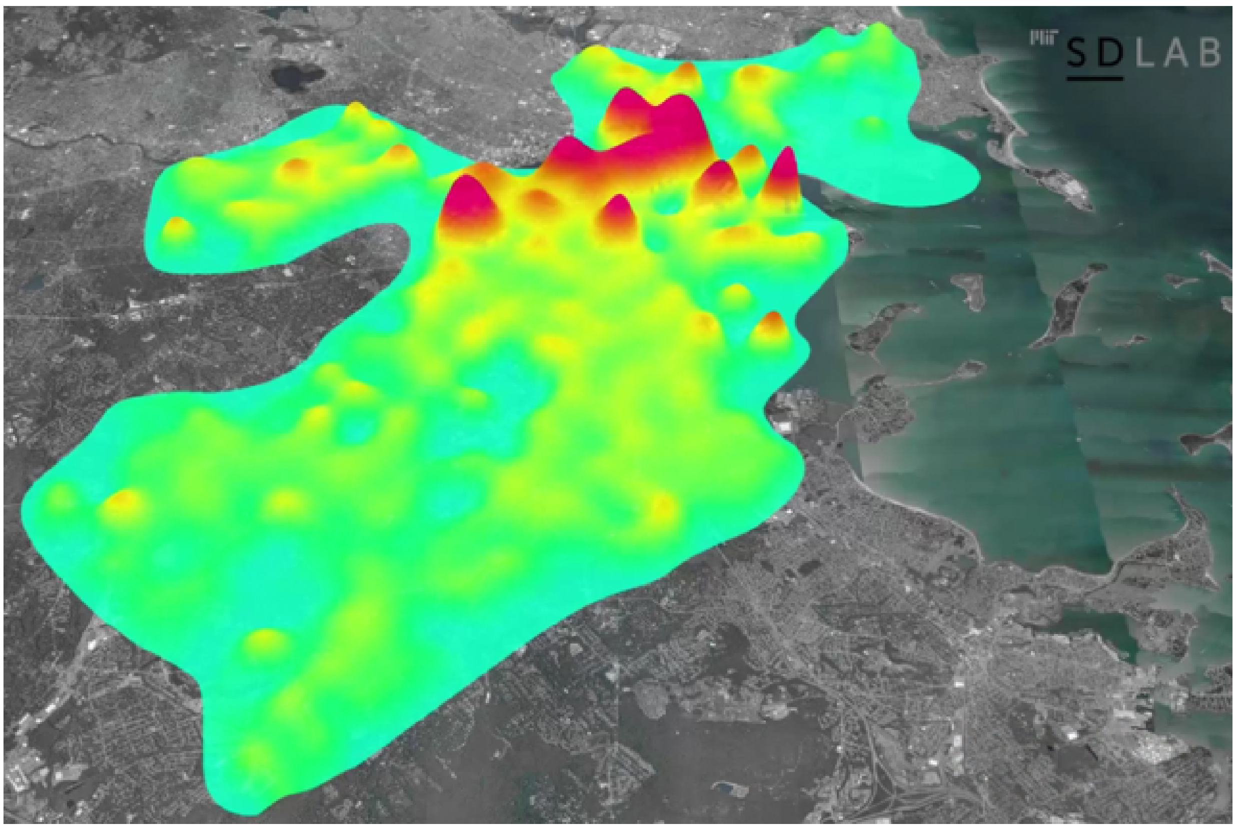

Boston Citywide Energy Model simulated energy use in a 200-by-200-meter grid for the City of Boston. Credit: Carlos Cerezo, Jamie Bemis, Tarek Rakha, and Christoph Reinhart/MIT Sustainable Design Lab

City governments in the age of climate change often find themselves in a predicament: It's hard to create a more energy-efficient city without detailed information about how—and when—buildings consume electricity and heating fuel.

The City of Boston now has a powerful new tool for planning its energy future, thanks to pioneering work done by researchers at the MIT Sustainable Design Lab (SDL) and the MIT Lincoln Laboratory, in collaboration with the Boston Redevelopment Authority (BRA).

Christoph Reinhart, associate professor of architecture, and Carlos Cerezo, a PhD student in the Building Technology Program, together with their SDL colleagues, have developed a citywide urban building energy model of unprecedented scale and spatio-temporal detail. The model estimates the gas and electricity demand of every building in Boston—nearly 100,000 total—for every hour of every day of the year. "Nobody has ever modeled a city the size of Boston at this level of detail," Reinhart says. "It's also the first time that these data are being used by a city to guide energy policy decisions."

The model was announced this month by the City of Boston and the BRA as an integral part of the Boston Community Energy Study, commissioned by the city to help Boston stakeholders better understand the potential for community energy solutions and to identify specific project opportunities that could lower costs, reduce greenhouse gas emissions, and make Boston's energy system more resilient.

"Community energy solutions such as targeted energy efficiency, district energy, microgrids, local energy generation, and energy storage represent an opportunity to fundamentally change the way our energy system works," says Austin Blackmon, chief of energy, environment, and open space for Boston, "but to get there we need a better understanding of the existing system and a way to identify the most promising solutions."

"Every city has long-term goals," Cerezo says. "But nobody knows exactly how to plan for and measure them. With this model, the city has a map to help them target and reach those goals."

Merging supply and demand

Cities—as well as energy companies, businesses, and community groups—can reduce energy use at the building level through efficiency measures such as retrofits or installing rooftop photovoltaics. But in order to identify more holistic solutions, such as combined heat and power (CHP) systems that service multiple buildings, building demand predictions have to be linked to energy supply models.

For the Boston model, SDL partnered with Eric Morgan of the Energy Systems Group at MIT Lincoln Laboratory. Morgan and fellow Lincoln Laboratory researchers identified dozens of suitable sites across Boston where a combination of CHP, photovoltaic, battery storage, and ground source heat pumps could reduce greenhouse gas emissions and offer lower-cost alternatives to current centralized energy supply scenarios.

"If you have a building consuming a lot of electricity at certain hours, you need buildings around them that can use that waste heat," Cerezo says. "Our model is built for figuring out where those things happen."

The havoc wreaked by Hurricane Sandy on New York's power grid in 2012 heightened awareness of the need to develop urban energy systems that can withstand extreme weather events, Morgan says. Microgrids—localized power grids that can function autonomously when disconnected from the larger grid—are another option that city officials are looking at closely as a way to adapt to the changing climate.

A library to build on

Processing the data wasn't so straightforward. The city made available its comprehensive geographic information systems dataset, which includes information on building geometry, the various uses of parcels, and property tax assessment records.

The team spent many hours sorting all 92,000 buildings into 48 different "archetypes," and 12 different use categories (e.g., residential or office). They then assigned various characteristics to each archetype, accounting for heating and cooling systems, electricity use, thermostat settings, time occupancy, wall and roof structure, and so on.

But, Cerezo notes, the data were not gathered with energy planning in mind, so they had to do some sleuthing and computational legwork to make it usable for their model. "You develop tricks and algorithms to work with existing incomplete datasets," Reinhart says. "That took us the most time. A lot of work went into the description of the building stock."

Thanks to all that work, the resulting tool can simply be adapted, rather than reinvented, by others interested in performing similar analyses across the Northeast.

"We only had to do that data gathering once," Reinhart says. "Boston and cities with comparable building practices such as Providence will be able to work for a long time with our building stock library."

The Boston project represents the latest SDL effort to turn large amounts of complex information into practical decision-making tools at the urban scale. The lab collaborated with the City of Cambridge in 2013 to create an interactive solar map of the city, helping residents understand the potential power output and cost savings from installing rooftop photovoltaic panels.

The Boston Community Energy Study received funding and technical support from the Massachusetts Clean Energy Center and funding from the Barr Foundation, the U.S. Department of Energy, and the U.S. Department of Homeland Security.

A toolkit for targeted, energy-smart planning

Reinhart and Cerezo say their new model is designed to help policymakers and planners focus on problem areas—for instance, buildings responsible for driving peak electricity demand on a hot summer afternoon—and, conversely, on where the best opportunities for energy savings might be found.

Another immediate outcome of their work is concrete guidance for city officials on how to document buildings and collect detailed data, relevant to energy planning, going forward.

Reinhart sees a bright future for these urban building energy models, as both an avenue of continued academic research and a vital resource for those trying to meet climate targets well beyond Boston's boundaries. The SDL has now developed templates for Boston and Kuwait and is working on new models of Lisbon, Portugal; and Riyadh, Saudi Arabia. The group hopes that the emerging field of urban building energy models will come to a consensus on how to sort and classify city building data across different regions and climate zones.

To be sure, challenges remain: Right now the team is in the process of validating the Boston model, comparing the results of the simulation to actual energy consumption data. "We'll do this using any building-level energy dataset that we can get our hands on, so the models become more and more accurate," Reinhart pledges. "Ultimately, our goal is for every city in the world to rely on a citywide energy model to meaningfully manage its future energy supply and carbon emissions."

More information: Boston Community Energy Study, www.bostonredevelopmentauthori … mmunity-energy-study

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