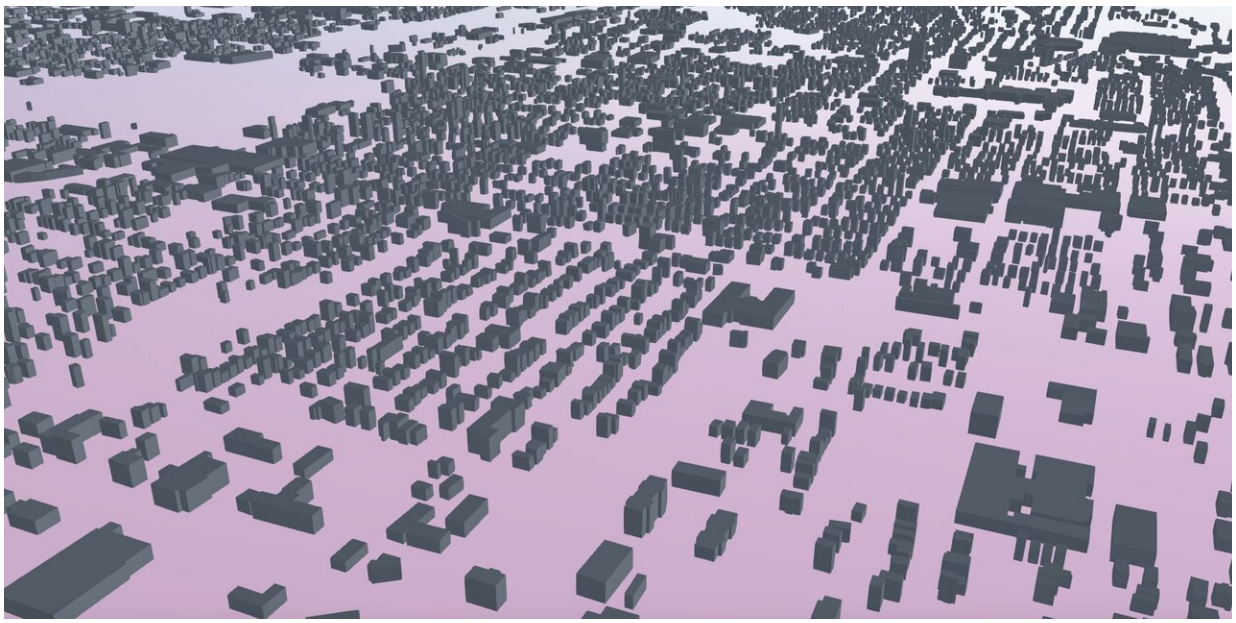
Modeling every building in America starts with Chattanooga

November 14 2019, by Rachel Harken



ORNL-created Chattanooga Building Energy Models. Credit: Joshua New, ORNL

Buildings use 40 percent of America's primary energy and 75 percent of its electricity, which can jump to 80 percent when a majority of the population is at home using heating or cooling systems and the seasons reach their extremes.

The US Department of Energy's (DOE)'s Building Technologies Office

(BTO), one of eight technology offices within DOE's Office of Energy Efficiency and Renewable Energy, aims to reduce the energy consumption per square foot of American buildings by 30 percent from 2010 to 2030—a massive challenge considering that America is home to 124 million building structures.

At the same time, DOE's Office of Electricity (OE) supports research for a more efficient, secure, and modern power grid, including research on ways to control electricity demand to keep the grid balanced and more resilient to disruption.

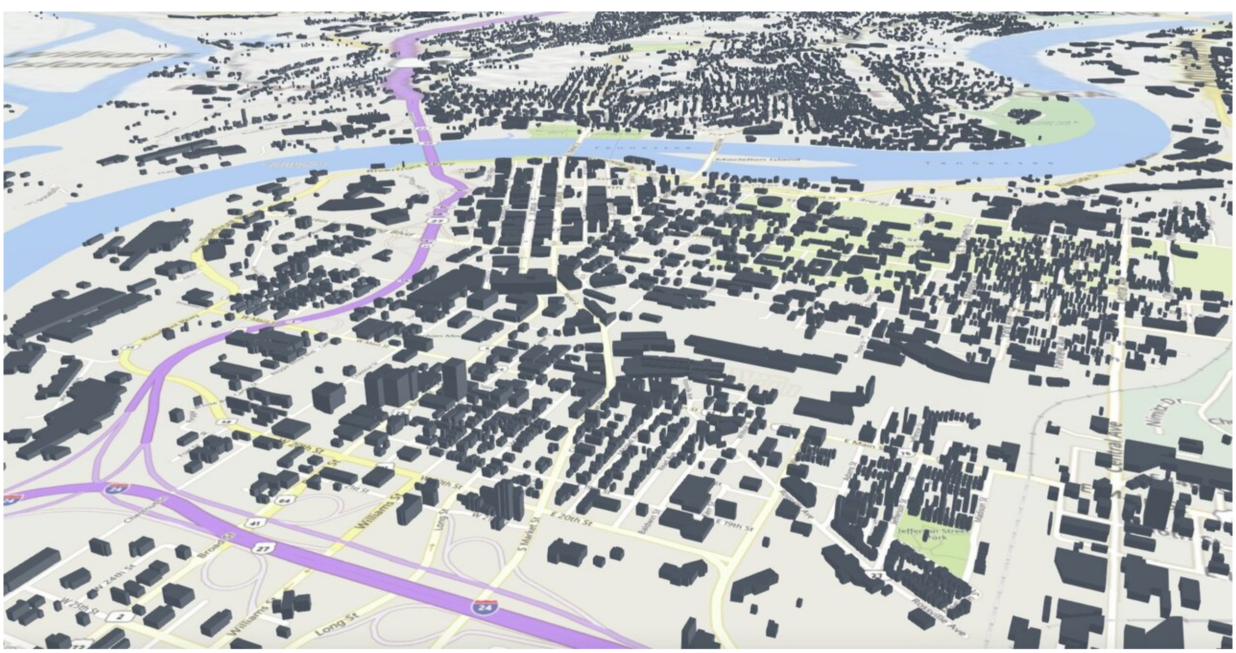
Building energy modeling—computer simulation of building energy use given a description of the building, its systems, use patterns, and prevailing weather conditions—is an analytical tool that can be used to identify cost-effective energy efficiency opportunities in existing and new buildings. Today, collecting and organizing the data required to put together an energy model are largely manual processes. As a result, modeling is used in only a fraction of new construction and retrofit projects.

A team led by research and development senior staff member Joshua New at DOE's Oak Ridge National Laboratory (ORNL) is looking to change that, and specifically to make it possible to cost-effectively create a building energy model for every building in America. The ORNL approach relies on automated extraction of high-level building parameters such as floor area and orientation from publicly available data sources like satellite images and automated calibration—the use of multiple simulations to find the combination of unknown building parameters that most closely matches measured energy use. To demonstrate their approach, the team recently used the Oak Ridge Leadership Computing Facility's (OLCF's) Cray XK7 Titan supercomputer to model every building serviced by the Electric Power Board (EPB) of Chattanooga—all 178,368 of them—and discovered through more than 2 million simulations that EPB could potentially save $11-$35 million per year by adjusting electricity usage during peak critical times.

"This kind of modeling is really the next level of intelligence in energy-saving policies and technologies," New said.

In the EPB project, funded by both BTO and OE, the models can be used to suggest retrofits or other solutions to save energy, thereby helping lower electricity demand during peak critical hours and better balance power grid operations. The simulations could also indicate where EPB might consider adding distributed energy resources known as microgrids—locally sited power generation such as solar, along with energy storage—to further improve grid resilience.

New and his colleagues intend to make the models openly available to help reduce energy, demand, emissions, and costs for America's homes and businesses.



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Supercomputing for energy solutions

EPB's 9,000-mile fiber optics network serves as the backbone for its Smart Grid, one of the nation's most advanced electric distribution systems. EPB records utility data every 15 minutes for every building in its service territory. The EPB-ORNL partnership allows ORNL researchers to rapidly and accurately compare and validate building models with this real-world data. The simulations also help ORNL improve EnergyPlus, DOE's flagship whole-building simulation product, in partnership with other national laboratories and various contractors.

The recent project developed out of EPB's eagerness to understand the energy usage and demand for the buildings in its territory.

"EPB wanted to see how much money they could save their customers by taking steps to lower energy demand during peak critical hours," New said.

Switching to natural gas, sealing buildings properly, bringing insulation levels up to code, and using smart thermostats to preheat or precool homes are some ways of lowering the energy demand during times of maximal use. Quantifying the energy savings on a per-building level and scaling that up to nearly 179,000 buildings, however, is a challenge that requires high-performance computing resources such as the ones at the OLCF, a DOE Office of Science User Facility located at ORNL.

"EPB has 178,368 buildings, and each building model requires around

3,000 inputs," New said. "If we wanted to include a 15-minute lighting schedule, we would have 35,040 numbers just to tell us if the lights are on or off—and that's only one input."

At these numbers, simulating one building on a desktop computer takes between 2 and 10 minutes. Simulating multiple scenarios for hundreds of thousands of buildings requires a supercomputer.

The ORNL team earned time on the recently decommissioned Titan supercomputer through the OLCF's Director's Discretionary allocation program and ran simulations of all the buildings in EPB's territory. The team ran nine different monetization scenarios, with each set of simulations lasting 6.5 hours on Titan, to analyze which building variables affect electrical use and thereby cost to EPB. The team wanted to know what would happen if infiltration, lighting, or insulation was upgraded for each building.

By comparing the results to the 15-minute utility data, the team verified the accuracy of the measurements of energy saved and spent.

"We're not just creating these models and doing what-if analyses in the blind," New said. "We have an error rate for every building on how closely we're matching that 15-minute energy use."

Better for business

In 2020 EPB plans to install smart thermostats in some 200 buildings to validate the team's simulation estimates. One strategy that needs to be validated, New said, is the use of buildings as "thermal batteries."

"When you pump energy into a building, you can coast through the critical hour rather than turning on your air conditioning during the peak critical times," New said. "That lowers the demand significantly and could keep a utility company from having to build a new multimillion-dollar substation."

Lowering energy usage and demand is an important goal for the researchers and for utilities. The thermostat installation could be the first step to a full program rollout, New said.

"At the end of the day, utilities want energy to be an economic productivity factor," New said. "Our models are helping them achieve that goal."

More information: E. Garrison, J. R. New, and M. Adams, "Accuracy of a Crude Approach to Urban Multi-Scale Building Energy Models Compared to 15-min. Electricity Use." Best PhD Student Paper award in Proceedings of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Winter Conference, Atlanta, GA, January 12–16, 2019.

Garrison, J. R. New, and M. Adams, "Buildings as Thermal Batteries: Peak-Shaving Potential of Smart Thermostats and Varying Thermal Capacitance." Proceedings of the International Building Performance Simulation Association (IBPSA) Building Simulation Conference, Rome, Italy, September 2–4, 2019.

R. New, M. Adams, E. Garrison, W. Copeland, B. Smith, and A. Campbell, "Nailing the Peak: City-Scale, Building-Specific Load Factor and Contribution to a Utility's Hour of Critical Generation." Proceedings of the International Building Performance Simulation Association (IBPSA) Building Simulation Conference, Rome, Italy, September 2–4, 2019.

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