Study shows cities can consider race and income in household energy efficiency programs

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Researchers surveyed energy use in Tallahassee, Fla., and St. Paul, Minn. Shown are utility workers in Tallahassee's REACH program. Credit: City of Tallahassee Utilities

Climate change and social inequality are two pressing issues that often

overlap. A new study led by Princeton researchers offers a roadmap for cities to address inequalities in energy use by providing fine-grained methods for measuring both income and racial disparities in energy use intensity. Energy use intensity, the amount of energy used per unit floor area, is often used as a proxy for assessing the efficiency of buildings and the upgrades they receive over time. The work could guide the equitable distribution of rebates and other measures that decrease energy costs and increase efficiency.

Examining inequality in cities has been hampered by a lack of energy use data at fine spatial scales within cities. Until now, only Los Angeles has been able to use a data-driven approach to shine a light on where energy use inequalities exist, focusing specifically on the effect of income disparities. But according to new results reported in *Proceedings of the National Academy of Sciences*, to truly understand and fully address energy use inequality, cities must take an even more nuanced approach—one that unpacks race-related disparities from income. As the authors report, examining the issue solely through the lens of income risks missing significant race-related inequalities that exist beyond income effects.

"Often, in discussions about social justice, people sometimes ask, 'Oh, how do you know it's a race effect and not 'just' an income effect?'" said co-author Anu Ramaswami, a professor of civil and environmental engineering and the High Meadows Environmental Institute at Princeton University. "This paper actually shows you the data, that there's a structurally linked income-race effect, and an additional race effect even within the same income group."

Ramaswami and her colleagues arrived at their findings by studying two cities, Tallahassee, Florida, and St. Paul, Minnesota. The findings showed that when evaluating annual energy use, homes in the lowest income neighborhoods on average used 25-60% higher energy use per

square foot compared to the highest income neighborhoods. What was more surprising was that within the income groups, predominantly non-white neighborhoods had higher energy use intensity compared to predominantly white neighborhoods.

"We were struck when we first saw these patterns," said Ramaswami, who also is Princeton's Sanjay Swani '87 Professor of India Studies and director of the Chadha Center for Global India.

The results were even starker considering seasonal energy use in summer and winter. Focusing on seasonal energy use intensity, the study uncovered disparities by income, and disparities by race within the lowest-income group, that can be greater than 150%, which are five times larger than the 25% disparity previously known in U.S. cities, based on the limited data availability in prior studies. The study found that households in low-income non-white neighborhoods report higher energy use intensity, reflective of lower energy efficiency of the buildings, as well as lower participation in rebate programs.

The method she and her colleagues developed can be applied in other cities and utility sectors (mobility, water, etc.) and is available now for adoption by cities interested in addressing racial inequalities. "We don't think it's only these two cities," Ramaswami said. "These effects are probably happening everywhere."

Inequalities surrounding income and race in the U.S. tend to be conflated because lower income communities often have higher non-white populations, while higher income areas tend to be predominantly white. To untangle these variables, Ramaswami and her co-authors worked with city officials and utility companies to obtain detailed energy use data.

"Part of the problem is that race and income are so intertwined, you need fine-scale data to actually unpack inequality," Ramaswami said.

"Typically, cities get energy use data at the zip code level, which is very coarse, but we got data at the level of census blocks through a unique collaboration with our partner cities and utilities, who are committed to understanding baseline inequalities in their neighborhoods."

In total, the researchers obtained anonymized and aggregated data from utilities covering all 90,000 households in Tallahassee, and all 110,000 in St. Paul. They divided total household energy use in a neighborhood by the total square footage of the dwellings to compute the average energy use intensity for that neighborhood. They then compared energy use intensity across different neighborhood groups partitioned into five income brackets, and further by the racial composition of the neighborhoods within each income bracket.

The results revealed a number of surprises. In St. Paul, for example, the lowest income group had a 27% higher annual energy use intensity (use per square foot) compared to the highest income group. St Paul's result is comparable to the 25% disparity by income seen in Los Angeles. However, Tallahassee's disparity in annual electricity use intensity by income was found to be more than double at 66%. Furthermore, when the researchers further partitioned the income groups by racial composition of the census block groups, they found substantial additional disparities by race even within the same income groups. For example, in St. Paul, the poorest predominantly non-white neighborhoods had a 40% higher energy use intensity compared to poorest predominantly white neighborhoods. Such racial disparity was seen within all income brackets except for the very wealthiest block groups, which were majority white to begin with.

When the team took a closer look at seasonal energy use—i.e. energy used for heating and cooling in winter and summer—they found an up to 167% disparity in electricity use intensity between the lowest- and highest-earning households in St. Paul, with the lowest-earning

households footing that outsized energy burden. In Tallahassee, seasonal energy use showed large racial disparities within the lowest income group of the order of 156%.

"To my knowledge, this is the first study to show inequalities in urban energy use by race, and to show that it's different from energy use inequality by income," says Karen Seto, the Frederick C. Hixon Professor of Geography and Urbanization Science at Yale University, who was not involved in the research. "The study corroborates other studies that show significant within-city inequalities" by both race and income, she said, "whether it's exposure to heat or green space."

The researchers also examined household participation in several types of rebate programs designed to increase energy use efficiency and decrease costs. They found that homes in wealthier predominantly white neighborhoods were more likely to participate in rebate programs, while poorer predominantly non-white ones tended to slip through the cracks.

"Making this type of data visible is helpful for making people understand that infrastructure-related racial disparities are not just some abstract thing—it's real and you can see it in the data," Ramaswami said. "We all say we want social justice, but to get to that, it helps to be quantitative."

Ramaswami and her colleagues hope that cities across the country adopt their method to better understand their own energy equity dynamic. They are already working with officials in Austin, Texas, to apply this new approach.

Ultimately, they also hope to follow up on their findings to determine what is actually driving disparities in energy use intensity and rebate participation, so cities can use that information to further close the gap on inequalities.

"The new understanding gained from this study is already quite a lot," said Kangkang Tong, first author of the study and a postdoctoral researcher in civil and environmental engineering at Princeton University. "But it will take another several studies to really understand the reasons behind our findings, to help communities improve their energy use efficiency."

The study also addresses fundamental questions about the geographical scale researchers can use to measure social inequality in urban areas. The researchers found that choosing to study social inequality across city blocks as the unit of analysis provides different results than studying inequality across larger block groups or even larger census tracts. This is part of a fundamental question that scholars from many disciplines—including geography, public health, computer science, mathematics, and political science—are grappling with, called the modifiable areal unit problem. The problem is that measures of dispersion and inequality change as the spatial unit area of observation is modified—whether it is a city block, block group, census tract, or zip code. Ramaswami said the *PNAS* paper is the first to characterize the modifiable areal unit problem for the issue of energy use inequality in cities by exploring multiple metrics for energy use inequality across a range of scales. These findings are highly policy relevant because it means measuring disparity ratios from data aggregated at the block-level could give very different results from computing them from block-group or census tract-level data.

"This is also another area for further research, wherein policy-relevant questions can trigger fundamental scientific discoveries." Tong said.

More information: Kangkang Tong el al., "Measuring social equity in urban energy use and interventions using fine-scale data," *PNAS* (2021). www.pnas.org/cgi/doi/10.1073/pnas.2023554118

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