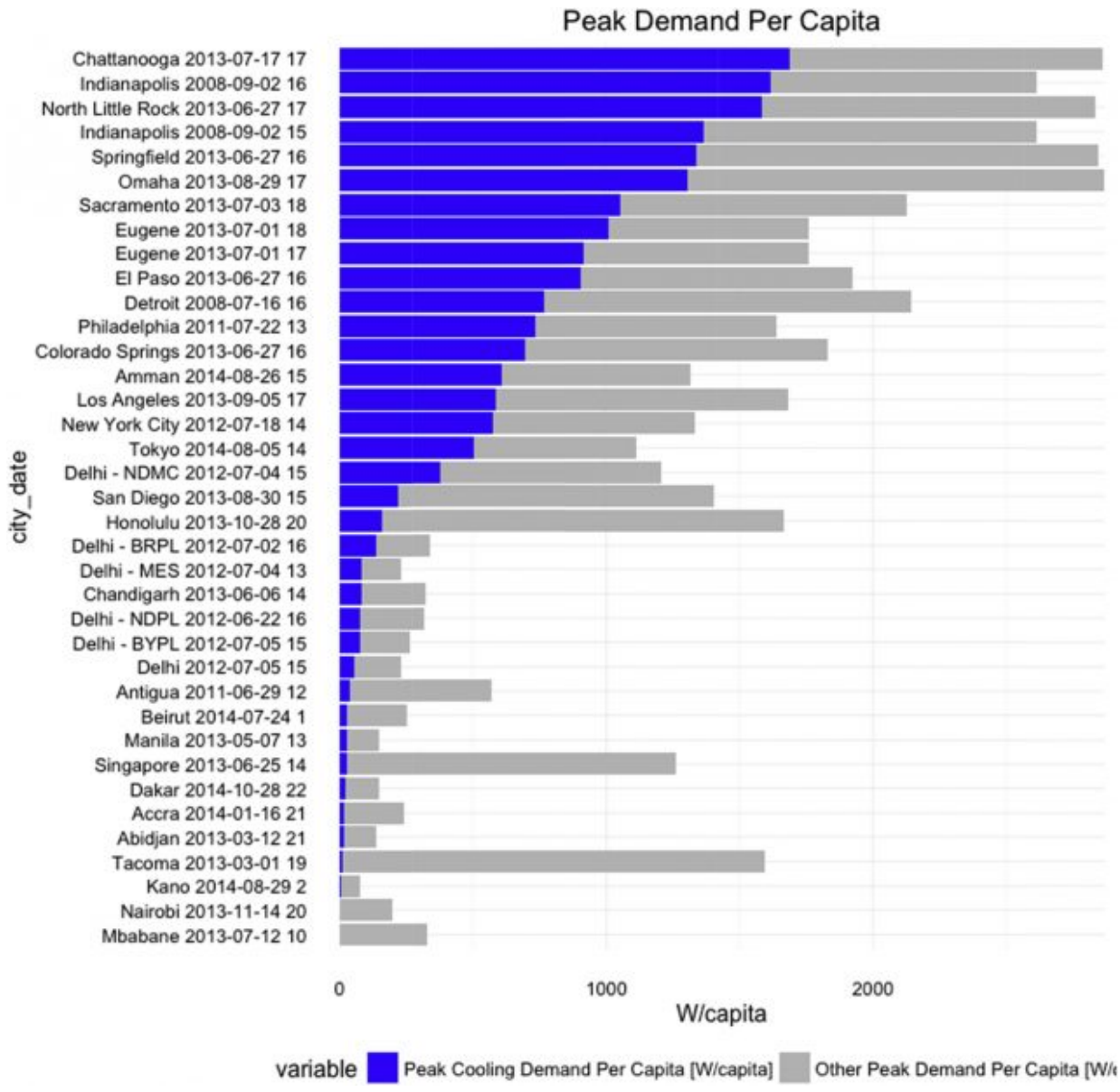
Is electricity use in the developing world about to skyrocket?

May 2 2017, by Lakis Polycarpou



Per capita peak electricity demand and estimated contribution from cooling. Credit: Michael Waite

Cities in the developing world may soon see dramatic spikes in electricity consumption for heating and cooling, according to a new study led by researchers from the Earth Institute's Quadracci Sustainable Engineering Lab.

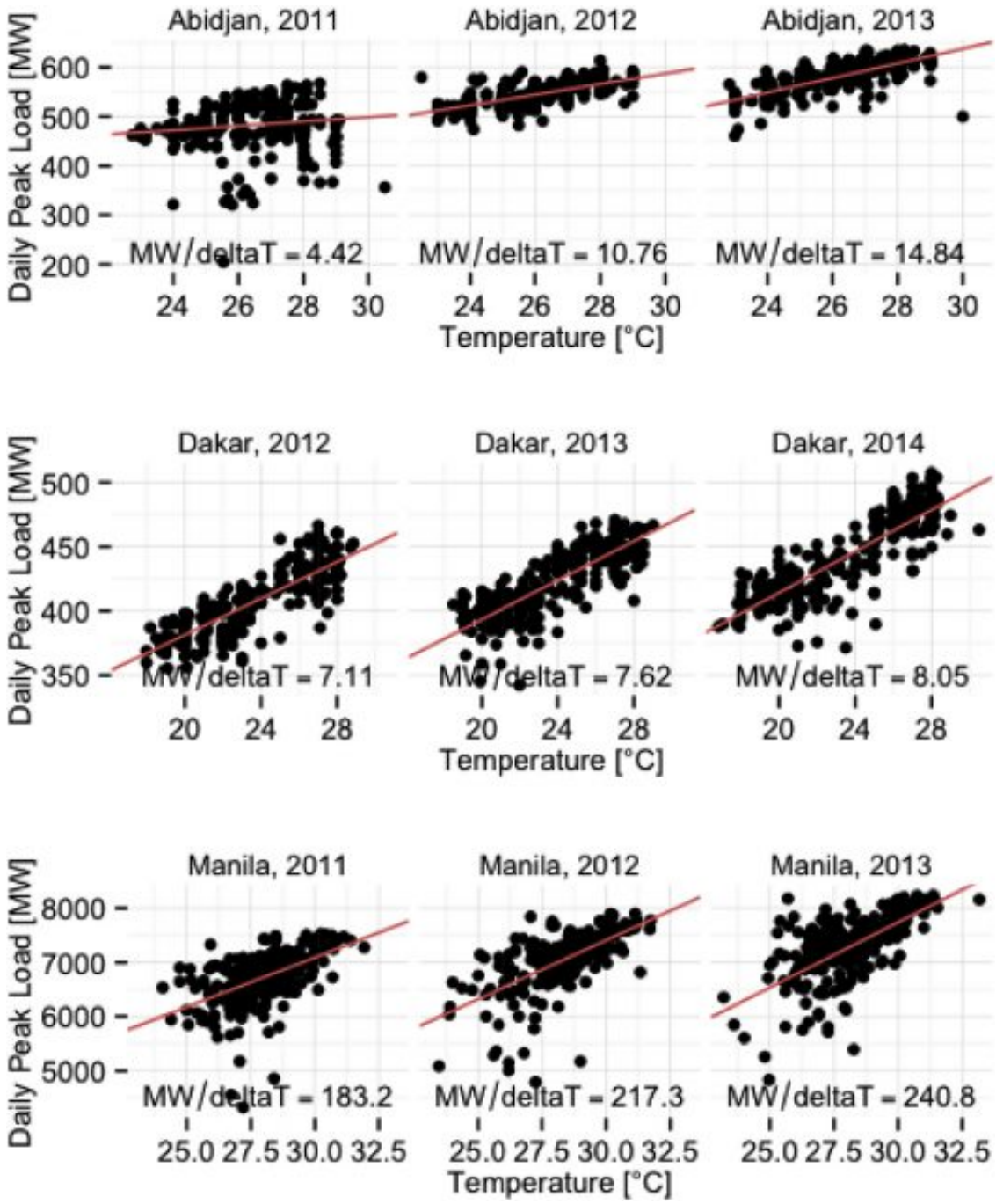
The study, which was published in the journal Energy, compared the hourly electricity profile of utilities serving 35 cities across the globe to identify the relationship between ambient temperature and electricity demand. Eighteen of the cities were in mature economies in the U.S. and Japan; the other 17 were in emerging market nations of South Asia, the Middle East and Africa. Building heating and cooling are the largest drivers of peak demand in dense urban areas and therefore are responsible for a large share of the overall energy footprint of cities.

The researchers found a significant "cooling signal" (an increase in electricity consumption on hotter days) in 33 of the 35 cities. The only exceptions were Mbabane, Swaziland, and Nairobi, Kenya, both of which are at high elevations and have cool nights much of the year. A similar "heating signal" for cold days was found in 21 of the 35 cities.

"Looking at electricity versus temperature behavior, we find a very distinct checkmark pattern," explained Michael Waite, the paper's lead author. "Below a certain temperature, there's an increase in electricity demand with a decrease in temperature, reflecting additional electricity needs for heating. And there's a temperature above which use increases, reflecting electricity needs for cooling."

Waite, a postdoctoral researcher at the Sustainable Engineering Lab, has

been looking at the dynamics of electricity consumption in cities for some time, with much of his research focusing on how cities like New York can achieve deep reductions in greenhouse gas emissions and a much greater penetration of renewable energy use.



Observed growth in cooling electricity response in tropical/subtropical cities. Credit: Michael Waite

In their recent study, Waite and his fellow researchers focused on a broad selection of urban areas for which data was available. The study found that while emerging market cities currently use much less energy for heating and cooling than mature economies (2-9 watts per degree centigrade per capita above room temperature for cooling, versus 35-90), daily peak demand in those cities has been increasing year-on-year, with an "intensifying relationship" to outside temperature, suggesting that those cities have a significant unmet demand for air conditioning and heating.

"Already, even in the three-year span of the data we have available for some cities, we see the cooling response temperature creeping up. And these were statistically significant changes," says Waite. "That was really interesting to see. The thing that tends to happen is that once cooling starts to be adopted, it can tip. At that point, growth happens rapidly before it eventually plateaus and slows down."

Waite points out that even among developed world cities, consumption can vary substantially depending on climate and other factors, as well as from year-to-year. In addition, the emerging market cities in the study actually represent a wide range of development levels, from relatively low-consuming cities in sub-Saharan Africa to much higher consumers such as Delhi, India. Nevertheless, he says, "the general trend of increases is very clear."

That fact that growth in consumption primarily affects peak demand may have especially worrisome consequences from an emissions perspective. Electricity demand that is highly temperature-dependent

results in underutilized capacity for much of the year. The problem with that, says Waite, is that "the types of generators that are economically viable at very low capacity factors tend to be the least efficient, the highest carbon emitting, and frankly higher generators of things like nitrogen oxide emissions as well."

High and fluctuating peak loads can cause other problems. In August 2003, a high voltage wire touched a branch in Ohio, causing cascading failures that blacked out much of the northeastern United States and eastern Canada. According to a Department of Energy report, high peak loads, particularly air conditioning, contributed to the problem by straining local generation. In July 2012, India suffered the largest blackout in history, leaving 700 million people without power.

Coal-fired power plant. Credit: Pixabay

To make matters worse, cities of the "global south" such as New Delhi, India, tend to experience more days of extreme heat than those in northern mature economies. "Even though the slope of the electricity versus temperature line may be similar," says Waite, higher temperatures could end up meaning higher overall peak loads. "How are you going to generate that electricity to meet these demands?"

So where does this all end up? It depends, says Waite, in large part on how cities develop. Even in the United States, there are big differences in electricity consumption between relatively dense, older cities in the Northeast and the post-war sprawl of the Midwest.

As for solutions, Waite says that there are no silver bullets, although the study does point out that on the heating side, choosing to adopt efficient heat pumps instead of commonly used electric resistance heaters could help. "Especially at relatively high exterior temperatures—say the 45-50 degree range when you want some heating—heat-pumps can be much more efficient," than electric resistance heating, says Waite, and they can double as air conditioners as well.

On the cooling side, he says, some form of demand response—in which a signal is sent to increase the temperature set point among consumers—could help save significant energy. However, solutions will depend heavily on the climate of the area "as well as on the specific solar, wind, hydro resources near these cities," he says.

"Urban and building design that reduces the needs for air conditioning; looking for high-efficiency solutions when air conditioning is being adopted…it's that straightforward. We're hoping that by identifying

these trends and showing the differences among the [developing world] cities, that we can alert the research community about the range of potential behavior that might be seen in the future so that researchers, policymakers, and electricity grid operators start to consider these issues in long-term development planning.

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