New global model uses 40 years of meteorological data to map energy demand at multiple spatial scales

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A model to map energy demand down to street level shows cooling demand in London grew by 5% per year between 1980 and 2022 as summers heat up.

The Demand.ninja model, created by researchers at Imperial College London and TU Delft, was designed to show how the weather influences hourly energy consumption in buildings. It can also account for changes in demand as the climate changes, including the increase in cooling demand in the summer as heat waves become more common and more intense.

Countries like the U.K. are traditionally unprepared for extreme heat. Events like 2022's 40°C heat wave caused sales of air conditioning (AC) units to skyrocket—a trend that is likely to accelerate as heat waves become more frequent. Rising demand for cooling is a lose-lose for homeowners and the climate as ACs increase electricity consumption leading to higher energy bills and greater emissions.

The U.S., which has much hotter summers and more widespread AC infrastructure, is now consuming an additional 66 TWh of electricity per year for air conditioning than it did just a generation ago due to rising summer temperatures—more than the entire electricity demand of Switzerland.

Security, affordability, climate

The model can also show the potential of behavior change to reduce energy consumption. For example, if every building in Europe turned their thermostat down by 1°C, the continent would save 240 TWh of natural gas per year, approximately a sixth of historical imports from Russia. This benefits both energy security and the climate: carbon emissions savings would be equivalent to taking Europe's two largest coal power plants offline.

Nathan Johnson, from the Center for Environmental Policy at Imperial, said, "Since Russia's invasion of Ukraine, Europe has been racing to reduce gas consumption to avoid shortages and lower consumers' bills. If all buildings across Europe lowered their temperature by 1°C, this would cut the cost of imports by €22 billion per year and cut CO_2 emissions by nearly 50 million metric tons per year: a win-win-win for energy security , affordability and the climate."

The model uses 40 years of meteorological data from NASA on local air temperature, humidity, solar radiation and wind speed to estimate the temperature that occupants feel when inside a building. This "feels like" temperature is then used to predict energy demand by training the model using measurements of energy demand at the national, regional and individual building level.

The result is a model that can predict hourly energy demand with high fidelity at any spatial scale. The details of the model are published in the journal *Nature Energy*.

Keeping the world comfortable

High-resolution data on energy demand can help energy system planners model future scenarios with the adoption of new technologies and user behaviors, and plan infrastructure upgrades at a scale ranging from individual streets to entire countries, such as the impact of the addition of heat pumps and electric vehicles to the grid.

It can also help in answering global questions, such as how much energy the world needs for everyone to be comfortable—to be warm enough in winter and cool enough in summer. More than five million deaths per year (nearly 10% of global mortality) are associated with excess cold (4.6 million) and heat (0.5 million).

For example, heat-related fatalities start to rise when temperatures reach a daily average of 27°C, and the model can show how often and where this has occurred over the past 40 years to help understand where interventions to prevent this tragic loss of life are best targeted.

Lead researcher Dr. Iain Staffell, from the Center for Environmental Policy at Imperial, said, "Accurate modeling of the impacts of weather on energy supply and demand is critical to decarbonizing power systems. We are making the Demand.ninja open for anybody to use, which we hope will open up new possibilities for researchers, for example when looking at how to operate 100% renewable grids, or the impact of heat waves and heat pumps on peak electricity demand.

"This isn't just about energy, it's a major global health issue. More than five billion people experience over 100 additional cooling degree days per year compared to a generation ago. A successful global energy transition will depend in part on understanding where, when and how much energy is required to close the gap in heating and cooling."

More information: A Global Model of Hourly Space Heating and Cooling Demand at Multiple Spatial Scales, *Nature Energy* (2023). DOI: 10.1038/s41560-023-01341-5 , www.nature.com/articles/s41560-023-01341-5

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