New modeling techniques deliver county-level charging data to inform future power system upgrades

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Newly published NREL research is informing how electric grid stakeholders and planners can prepare for the future influx of electric vehicles and their potential impact. Credit: Werner Slocum, NREL

Electric vehicle (EV) adoption is moving forward at a rapid rate. However, the plan for supporting infrastructure—where, when, and how to deploy EV chargers and upgrade the power grid—is a complex and moving target.

The National Renewable Energy Laboratory (NREL) is working to pin down that moving target with first-of-its-kind data and modeling that enable the codesign of transportation and electricity systems, detailed in the newly published report, "Highly Resolved Projections of Passenger EV Charging Loads for the Contiguous United States."

Arthur Yip, lead NREL research engineer on the project, said the study showcases some critical results and insights from the Transportation Energy & Mobility Pathway Options (TEMPO) model.

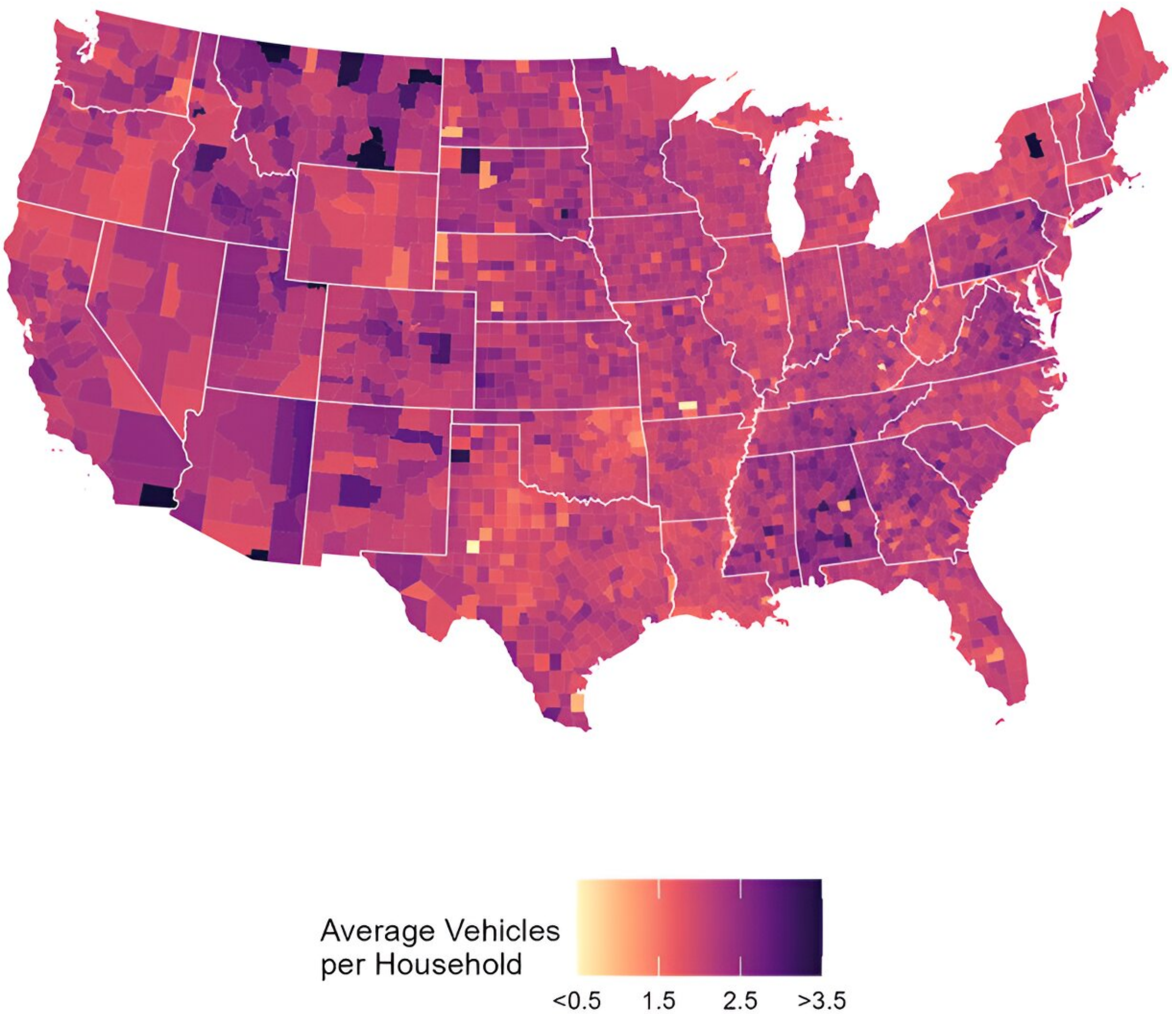
Yip and his colleagues at NREL used TEMPO to produce three projections of spatially and temporally differentiated EV charging loads through 2050 for the contiguous United States. The results could help inform future power grid infrastructure planning. Especially exciting to grid modelers and researchers is that this study reports, for the first time, county-level results for the entire nation.

The data set is important for power grid simulation efforts as well as energy demand estimates and decarbonization analyses. It complements other comprehensive NREL data sets such as the buildings sector end-use load profiles, enabling detailed analysis of economy-wide decarbonization.

"EVs are the largest driver of electricity growth. Now TEMPO can help power-grid modelers understand how much EV charging load could show up, when, and where," Yip said.

TEMPO results are already being applied

NREL Senior Research Engineer Elaine Hale, who co-authored the report, is an interdisciplinary systems scientist working to understand how new technologies might interact with future electricity systems.



An example of a simple, yet sometimes overlooked, factor in EV charging load is vehicle ownership, which varies across the nation, as shown in this map from the report. Credit: Figure from Yip et al. (2023) Highly Resolved Projections of Passenger EV Charging Loads for the Contiguous United States.

"The new county-level hourly profiles provide the specificity needed to understand potential EV loads in different utility territories, which differ in EV adoption rates, prevalent vehicle types, driving patterns, and weather," Hale said.

She said her colleagues have already tapped into the information for other research endeavors.

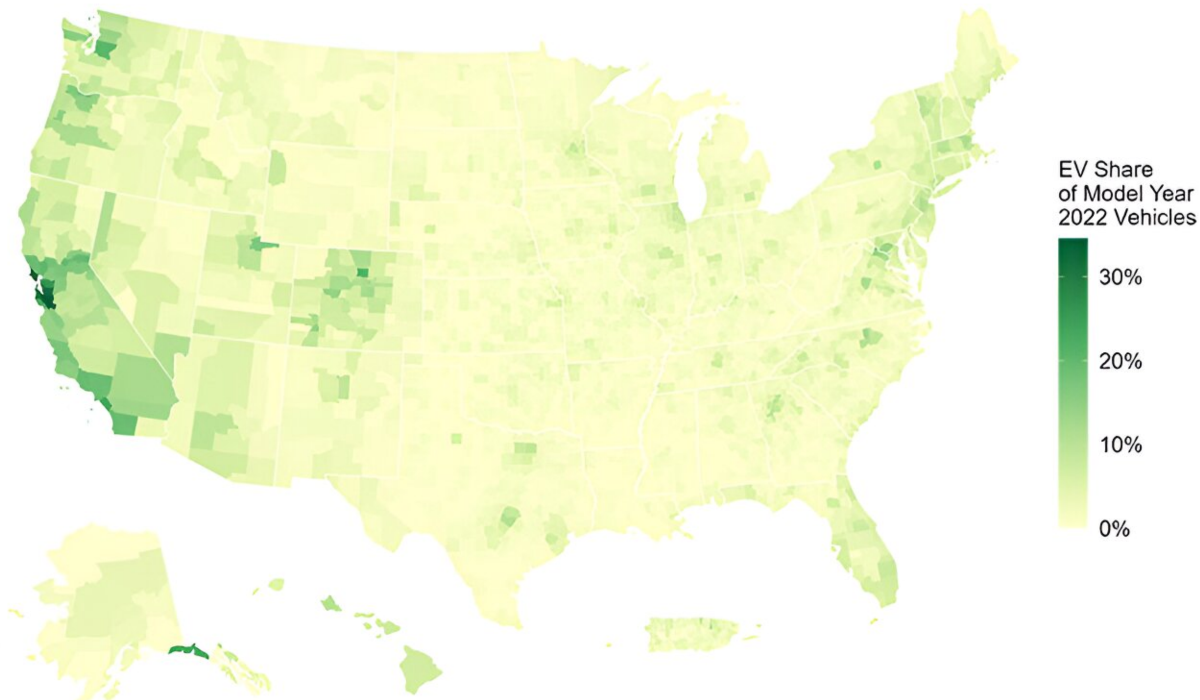
"We applied the new county-level TEMPO data to represent EV managed charging in a 2038 New England power system," she said. "We're currently combining county-level TEMPO data with other data sets using NREL's Demand-Side Grid Toolkit to create more realistic, highly resolved descriptions of future electricity loads for use in national, regional, and local planning activities."

How does the model work?

TEMPO was built primarily as a tool to explore the long-term transformation of the transportation sector and its synergies with energy supply and electricity systems.

Paige Jadun, a senior researcher at NREL who coordinates TEMPO efforts, said at its core the tool applies mobility demand data from the National Household Travel Survey and the Freight Analysis Framework, represented by the trips that move people and goods. Then, it simulates the many available traveler options and choices, such as modes of travel (for example, walk, car, ride hail, bus, or air) and technologies (including EVs, conventional engine vehicles, or hydrogen fuel cell vehicles).

Specific enhancements made to TEMPO for this study involve the analysis and incorporation of data from the American Community Survey Public Use Microdata Sample and from S&P (formerly Polk) and Experian about passenger vehicle registrations, allowing the modeling of spatial and temporal differences in EV ownership and EV charging options.



The sales share of EVs currently varies significantly across the country, as shown in this map from the report. Credit: Figure from Yip et al. (2023) Highly Resolved Projections of Passenger EV Charging Loads for the Contiguous United States.

"By incorporating the diversity of households, vehicles, locations, behaviors, and scenarios into the model, TEMPO results reflect a comprehensive and differentiated view of the EV load shape for every county in the United States," Yip said.

Featured in the adoption scenario section of the TEMPO report is a quote from science-fiction writer William Gibson, who once said, "The future is already here; it's just not very evenly distributed."

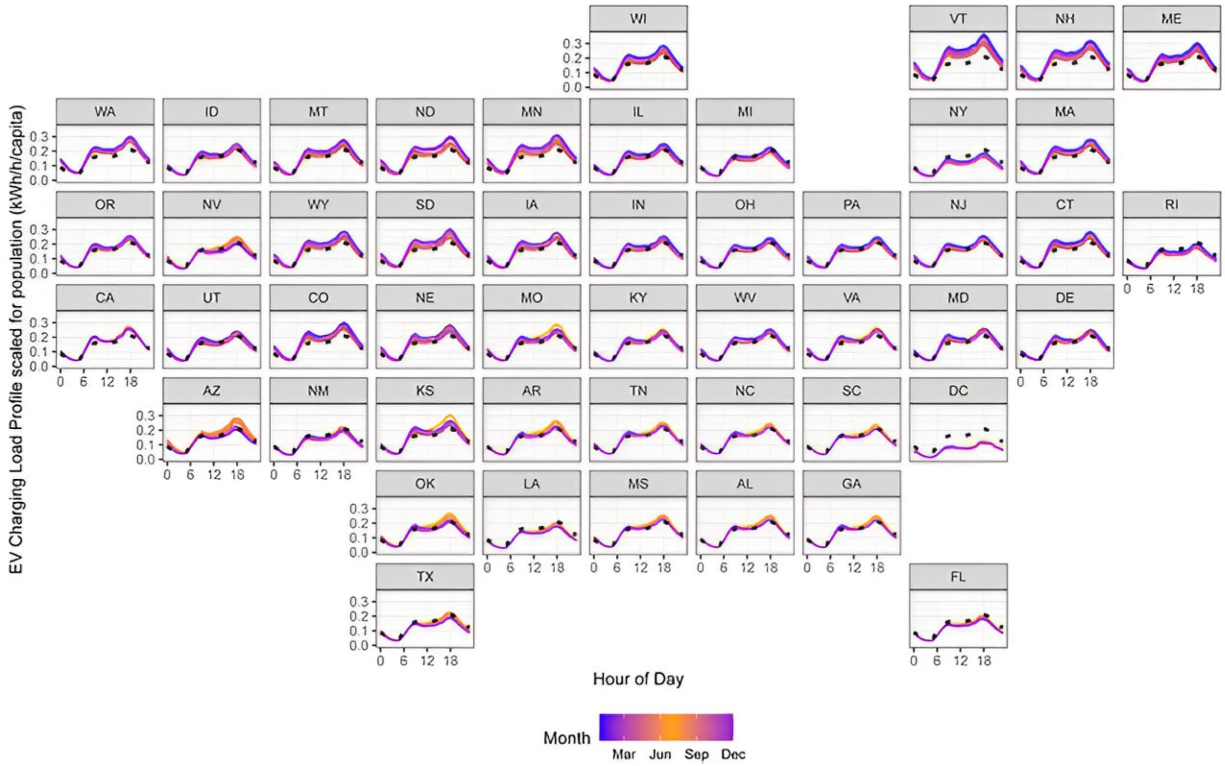
What this means, Yip said, is that some parts of the United States already offer a glimpse into the potential future of EV adoption. While it remains to be seen how quickly other communities may follow, NREL tools like TEMPO can help inform expectations and planning decisions around charging stations and the power grid.

What do we learn from TEMPO?

With these new capabilities, stakeholders can use the TEMPO model to explore long-term EV adoption and charging scenarios nationwide. The model is structured to work with other energy systems models, including those at NREL, so they can incorporate the fast-growing impacts and potential benefits of integrating EVs and the power grid—such as the value of managed EV charging and its ability to reduce electricity costs and improve resiliency.

In alignment with NREL's forward-looking grid modeling, this study provides different scenarios for EV adoption and load, projecting to the year 2050. The resulting data reveal strategic transportation-energy-environment objectives and synergies in relation to how they affect power grids locally and nationally.

"What we see is that the electric load from EVs is projected to grow substantially," Yip said, "which will require grid transformation, but this impact will be different in different regions."



The electrical load from EVs is expected to vary by shape and magnitude across the United States, as shown in this map from the report. Credit: Figure from Yip et al. (2023) Highly Resolved Projections of Passenger EV Charging Loads for the Contiguous United States.

Moreover, the study captures the impact of ambient temperature on EV power needs, showing critical seasonal and regional differences.

"For example, in Arizona, there is noticeable seasonal variation. When it's hot in the summer, EV charging loads are higher to replenish the energy used by air conditioning during hot afternoon trips. In North Dakota, EV charging loads increase substantially due to battery and cabin heating in cold weather," Yip said.

The charging load variations are also affected by how some areas have more EV adoption, or larger-sized vehicles using more energy, or populations that drive more or simply own fewer cars, like in New York City or Washington, D.C.

"Our modeling also reveals equity implications," Yip said. "We explore where people are driving more, have more energy cost and air quality burdens, or are adopting fewer or more EVs, which has implications on where to encourage EV adoption, where to provide more and cleaner electricity, and where to build more charging stations. Modelers and policymakers need these data to enable and support a clean transportation future for all."

What is next for TEMPO?

Understanding charging needs for passenger EVs is extremely timely and valuable, said Matteo Muratori, one of the architects of TEMPO and manager of the Transportation Energy Transition Analysis group at NREL.

"But there is more," he said. "We are using TEMPO to include other vehicle types like delivery vans, heavy trucks, trains, and other vehicles used at ports and airports and off-road. Electrification will quickly expand to those applications, and it will be critically important to understand charging needs and opportunities for effective grid integration of these new loads."

In the future, TEMPO will also be used to simulate new technologies and business models, including managed and optimized EV charging and EVs as distributed energy resources, which will help inform the transition of the energy system to meet mobility needs while driving transportation decarbonization.

More information: Report: www.nrel.gov/docs/fy23osti/83916.pdf

Provided by National Renewable Energy Laboratory